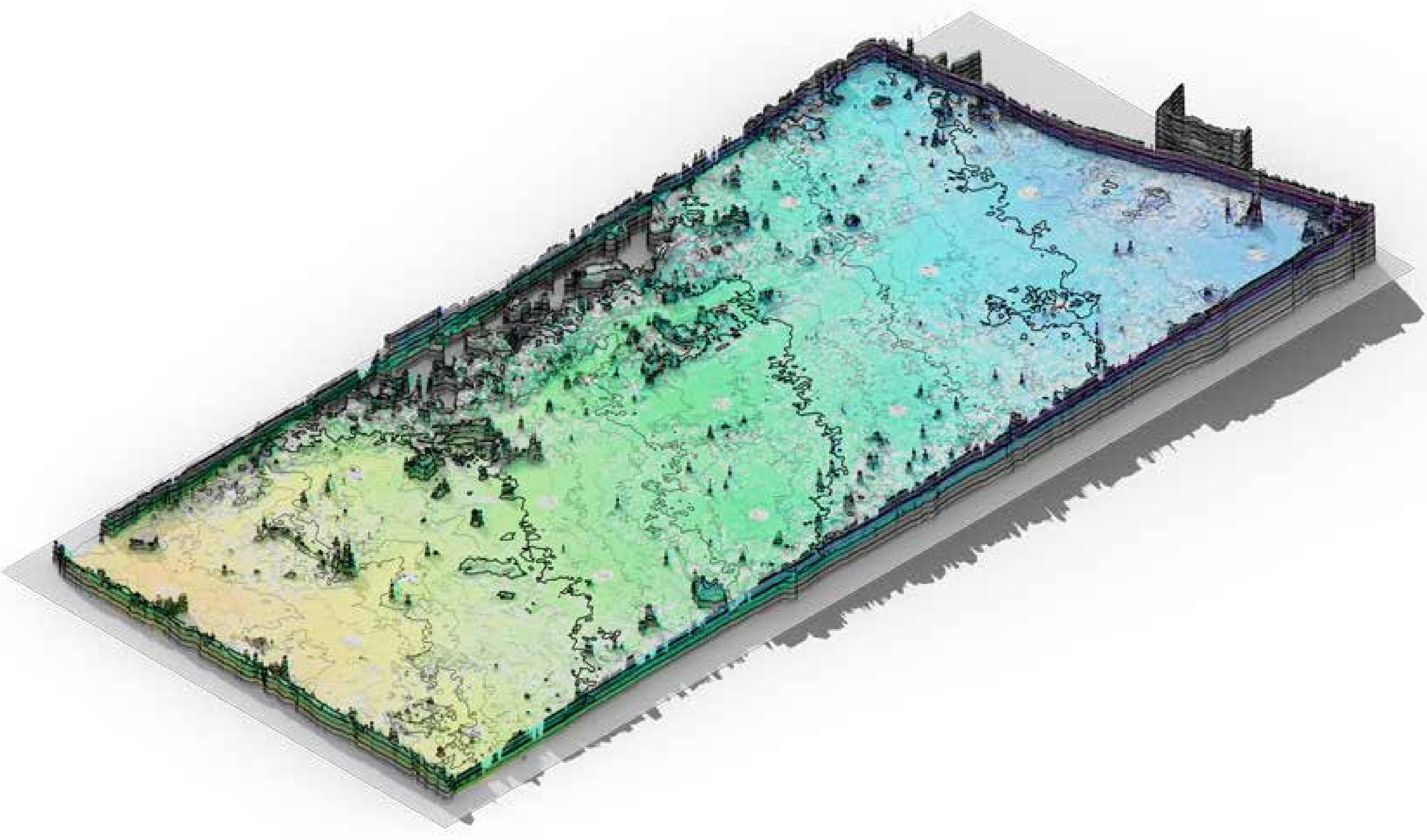
CENTER FOR HERITAGE CONSERVATION

TEXAS A&M UNIVERSITY College of Architecture

Terrestrial Laser Scanning Survey of Hockley Cemetery, San Antonio, Texas: Project Report I (CHC-2019-05-02)

Kevin Glowacki, Ben Baaske, & Andrew Billingsley



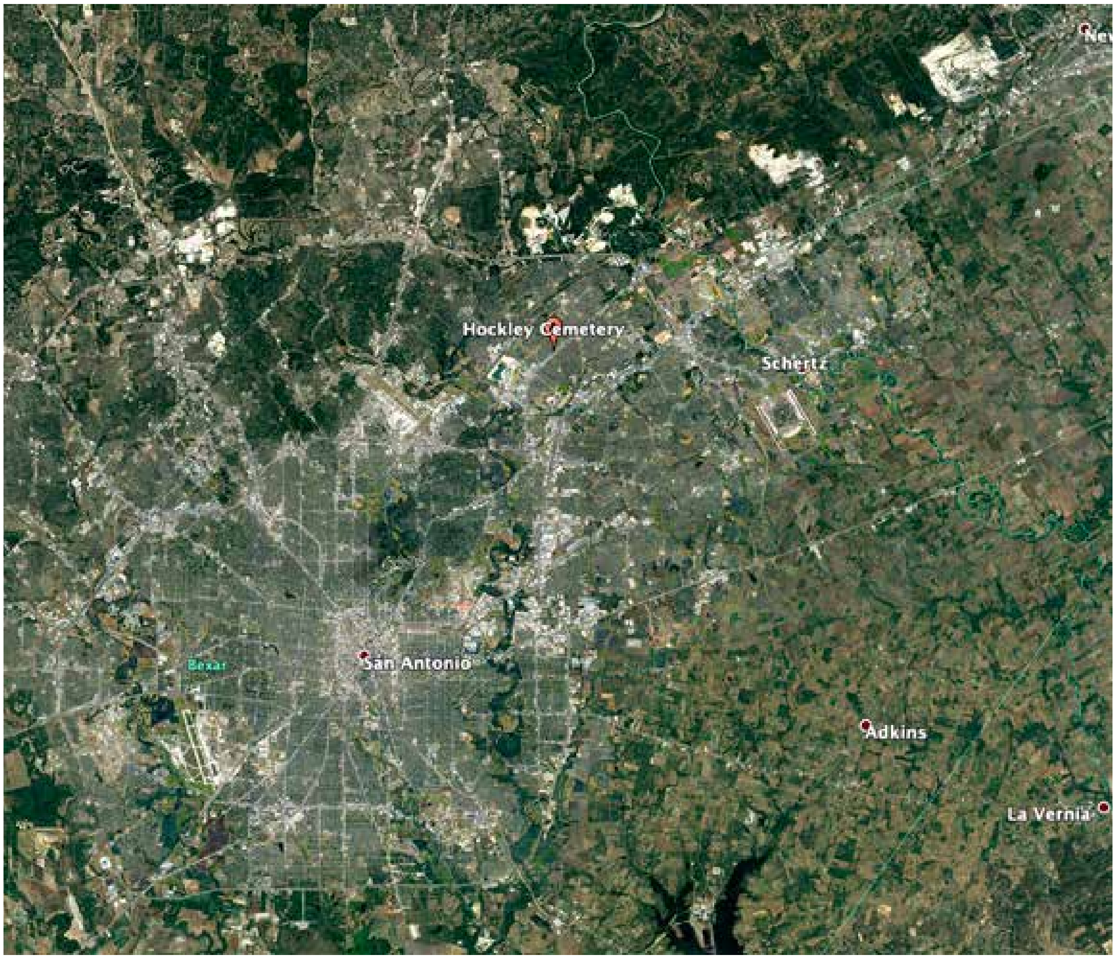


Figure 1: Aerial view showing location of Hockley Cemetery in northeast San Antonio, Bexar County, Texas. Google Earth (imagery date January 11, 2019).

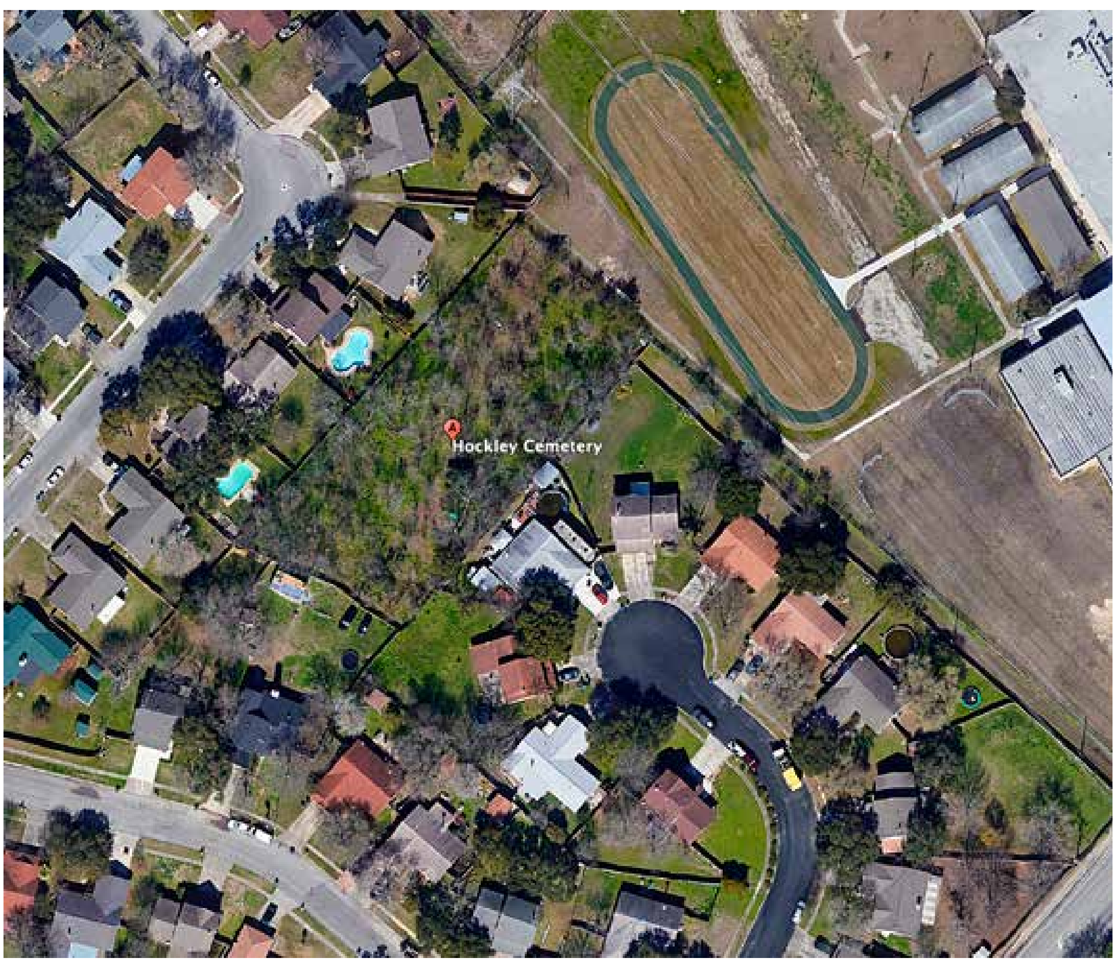


Figure 2: Aerial view of Hockley Cemetery. Google Earth (imagery date January 11, 2019).

Introduction

The following is a report on the terrestrial laser scanning survey of the Hockley Cemetery in San Antonio, Texas, conducted by the Center for Heritage Conservation at Texas A&M University on March 15th, 2019, for Everett Fly Associates.

The primary objectives were
1) to document the current condition of the historic cemetery;
2) to create a detailed plan and digital model of the surface terrain that might be useful in identifying mounds or depressions representing below ground features, such as burials;
3) to prepare a detailed plan and digital model that could be combined with data from future geophysical survey work, such as ground penetrating radar.

Figure 3 (above).Graduate student Andrew Bilingsley operating the FARO Focus s350 laser scanner.

Figure 4 (right). Graduate students Ben Baaske and Andrew Billingsley preparing to survey Hockley Cemetery.

[Photos: Matthew Busch with San Antonio Express News: https://www.expressnews.com/news/local/article/Texas-A-M-architectural-team-scans-for-burial-13694305.php#photo-17082727].

The Terrestrial Laser Scanning Survey

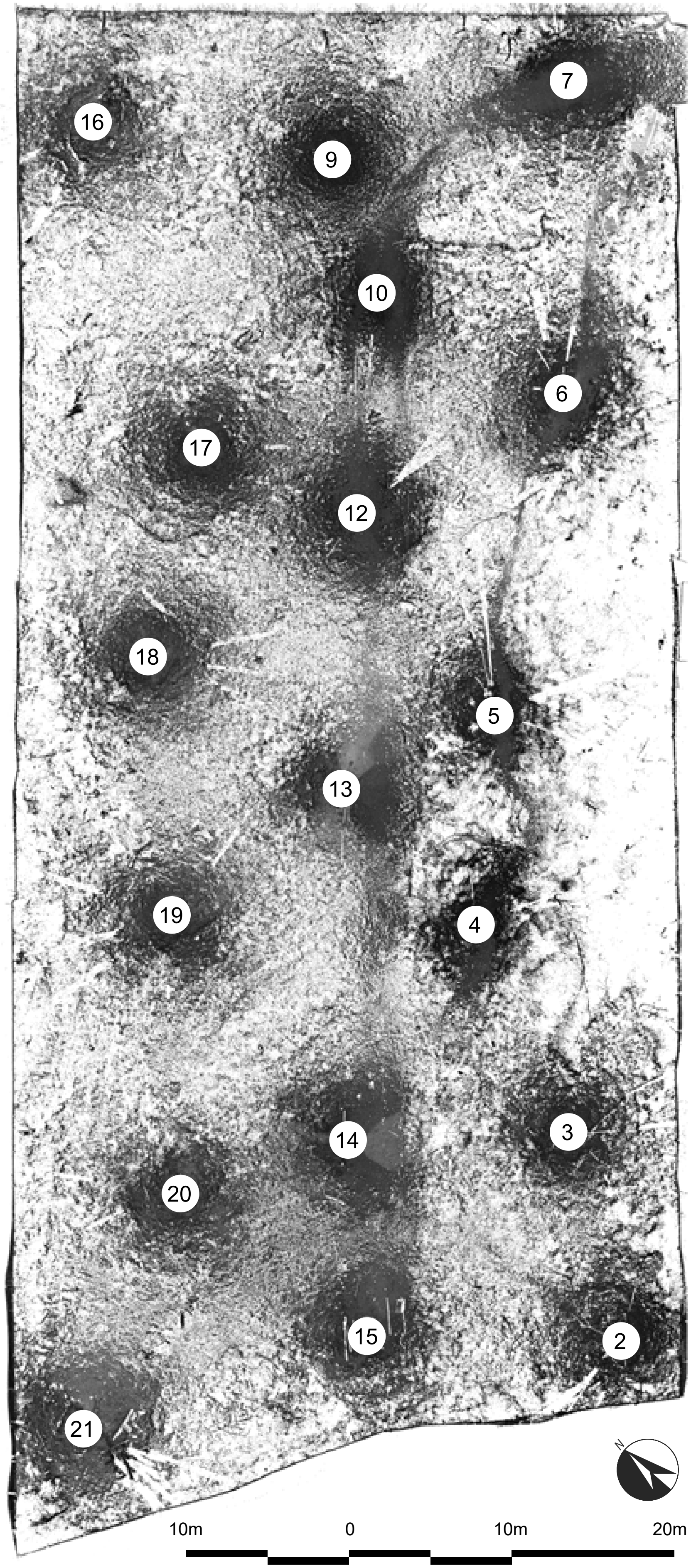
The Center for Heritage Conservation (CHC) at Texas A&M University (TAMU) documented the current condition of the Hockley Cemetery in San Antonio, Texas, using terrestrial laser scanning (TLS) technology on March 15, 2019. Temperatures during the site visit (ca. 11:30am to 6:45pm) ranged from 55-61 degrees Fahrenheit with winds from the NNE at 11-12 mph. The site was still in the process of being cleaned of vegetation, and several sections of tall grasses were still present, partially obscuring the perimeter and western side of the property.

The team utilized a FARO Focus s350, a phase-based laser scanning system. The scan data were initially processed with FARO Scene 2019.0 software. The team also recorded two previously established benchmarks (see survey by Gibbons Surveying & Mapping, Inc., January 30, 2019) and checkerboard registration targets with a Leica TPS1200 Series High Performance Total Station.

The scan project resulted in 18 usable scan positions, with each scan duration being around 8 minutes. A scan resolution of ¼ was set; this results in an average point spacing of 6mm at a distance of 10m. The scan quality was set to 3x; this number pertains to the number of measurements of a collected data point. A full 360-degree capture was obtained at each scan position, with a vertical declination range of -60-degree to 90-degrees. Light metering was set to even-weighted and the high dynamic range (HDR) setting was not used for images.

In order to optimize scan registration, checkerboard targets were placed on the inside of the Hockley Cemetery fence. These targets allow for common registration points between scan positions, both within themselves and when combined with survey points. A minimum of 3 targets are typically desired to be visible from each scan position. Once placed, these targets can then be shot in with a total station and recorded as points with local x-y-z coordinates.

Figure 5. Site Plan. Orthophoto of point cloud export from FARO Scene showing scan positions.



Processing & Registration

Despite the use of targets, top-view and cloud-to-cloud registration proved to be the most effective means of aligning adjacent scans correctly. However, once clusters were created with top-view and cloud-to-cloud registration, manual selection of targets and surface planes common between adjacent scans in each cluster was necessary for complete registration. Initial registration output yielded a mean point error of 8.9mm with a maximum point error of 16.5mm and a minimum overlap of 25.1%. Using the fine registration capabilities of Scene, scan point statistics were improved. The mean point error was reduced to 6.8mm with a maximum point error of 10.1mm and a minimum overlap of 26.2%.

Once sufficiently registered, the project point cloud was created; this allowed for export of orthophotos, the project point cloud itself (in various file formats), the generation of surface meshes and the rendered animations of the model. Overall, the Hockley Cemetery project point cloud consists of 190,476,603 data points.

Figure 6: Isometric view (from North looking South). Screenshot of color point cloud from FARO Scene: actual state on March 15, 2019.

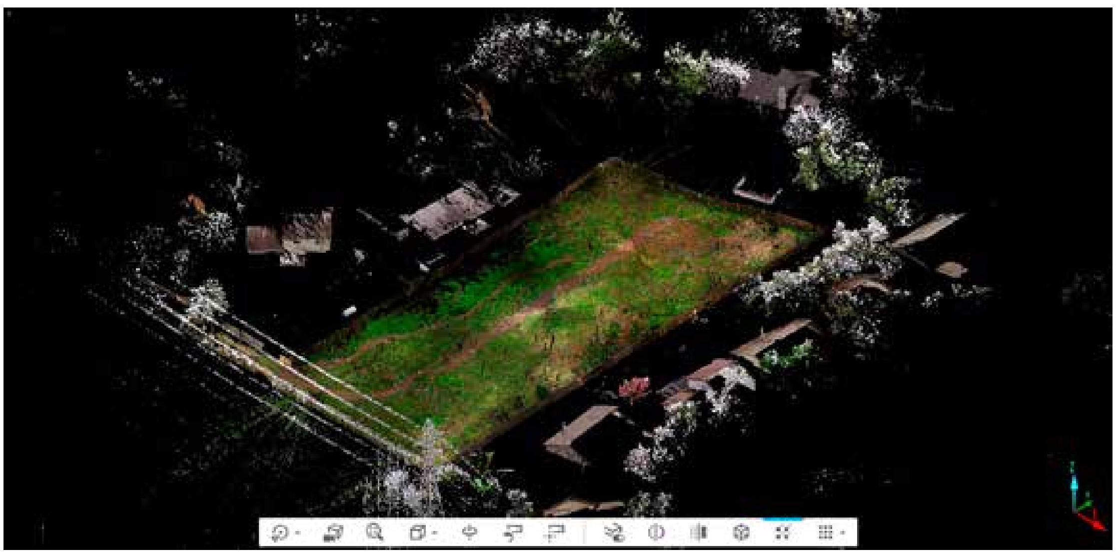


Figure 7: Isometric view (from North looking South). Screenshot of color point cloud from FARO Scene: trees digitally cropped.

Figure 8: Isometric view (from West looking East]. Screenshot of color point cloud from FARO Scene: trees digitally cropped.

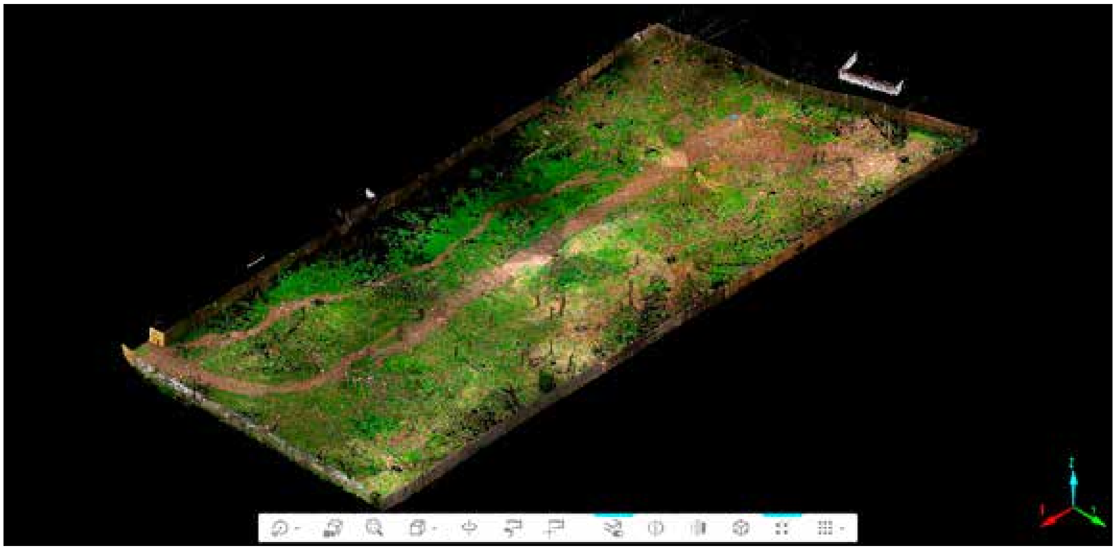


Figure 9: Isometric view (from North looking South). Screenshot of color point cloud from FARO Scene: trees and surrounding houses digitally cropped.

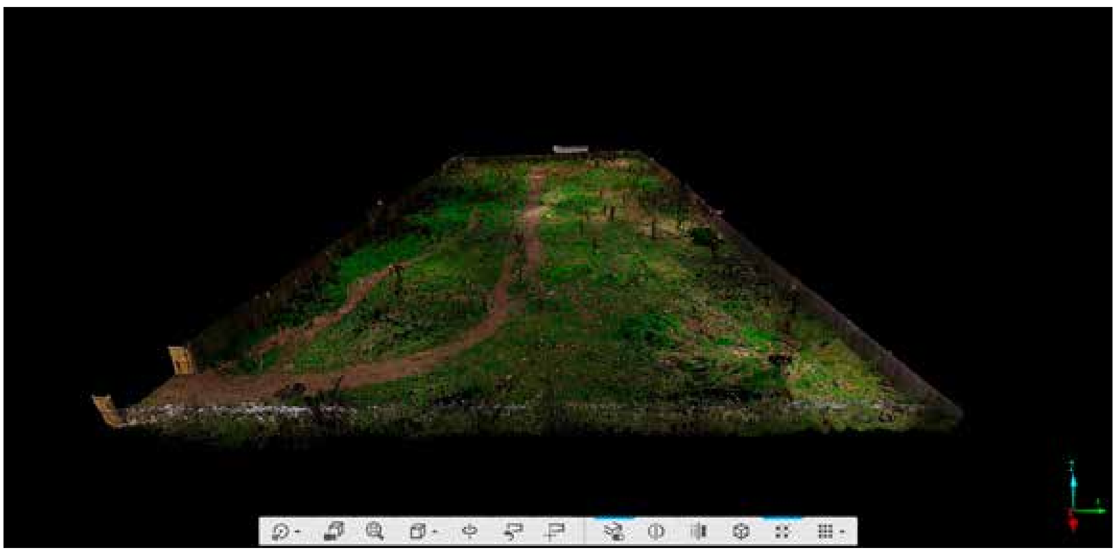


Figure 10: Perspective view (from Northeast looking Southwest). Screenshot of color point cloud from FARO Scene: trees and surrounding houses digitally cropped.

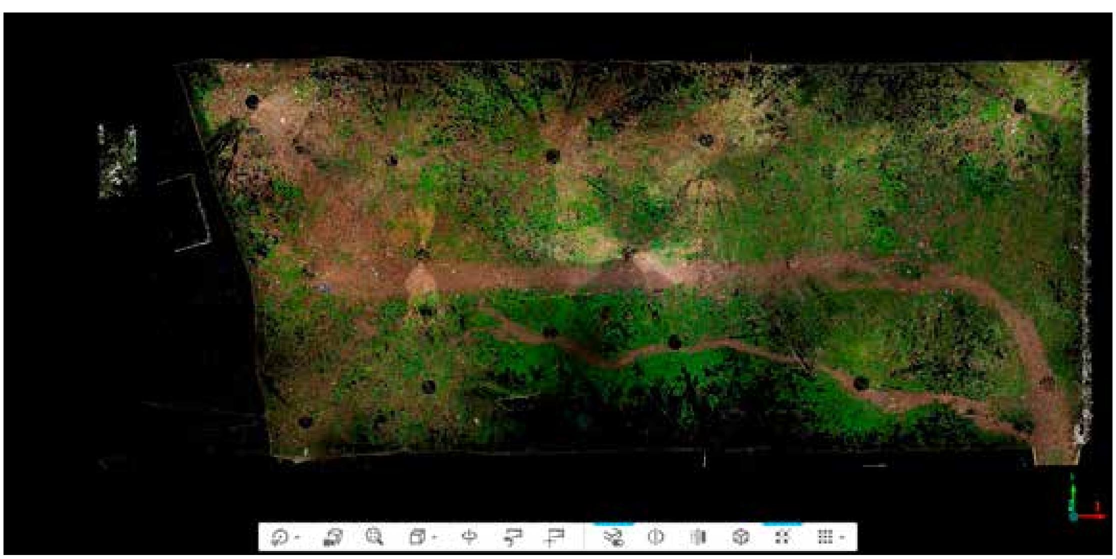
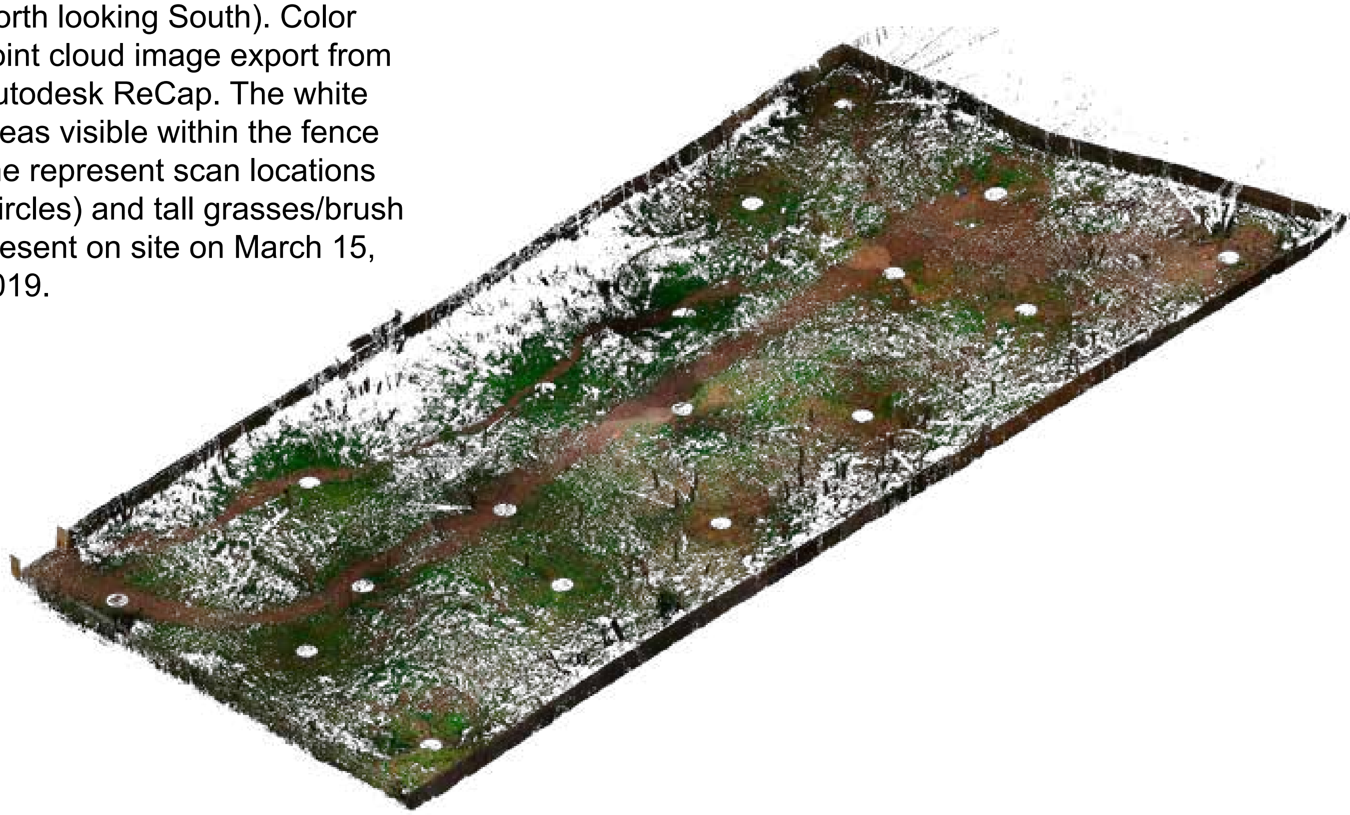


Figure 11: Site Plan. Screenshot of color point cloud from FARO Scene: trees and surrounding houses digitally cropped.

Table 1. Scan point statistics from FARO Scene registration report (after 4th fine registration).

Cluster/Scan	Connections	Max. Point Error [mm]	Mean Point Error [mm]	Min. Overlap
16	4	8.5	7.2	30.2%
2	4	7.4	5.7	38.2%
3	5	7.3	6.4	30.2%
4	5	9.7	7.3	41.0%
5	5	8.7	7.4	47.8%
6	5	7.1	5.5	26.2%
7	5	6.1	4.2	36.6%
9	5	8.9	5.6	36.7%
10	7	9.5	6.7	34.4%
12	4	9.2	7.7	62.3%
13	6	8.9	7.4	38.2%
14	6	8.8	7.3	48.7%
15	4	8.5	6.5	43.9%
17	4	7.0	6.6	43.9%
18	4	9.7	8.8	41.0%
19	5	8.3	7.3	44.5%
20	5	10.1	6.9	36.6%
21	4	10.1	8.6	26.2%

Figure 12. Isometric view (from North looking South). Color point cloud image export from Autodesk ReCap. The white areas visible within the fence line represent scan locations (circles) and tall grasses/brush present on site on March 15, 2019.



Cluster/ Scan 1	Cluster/ Scan 2	Mean [mm]	< 4 mm [%]	Overlap [%]	Used Points
21	20	10.125	26.2	40.5	3457
18	4	9.728	28.9	41.0	2597
21	10	9.5	25.9	34.4	3168
18	12	9.173	26.7	66.3	5415
21	9	8.913	30.2	36.7	3519
18	13	8.862	29.5	58.8	4422
13	14	8.791	25.6	60.8	6558
5	4	8.71	30.4	47.8	4057
15	16	8.497	32.6	62.7	6313
20	19	8.346	29.5	44.6	3862
5	12	7.607	34.1	67.9	6913
19	18	7.431	31.7	44.5	2873
14	2	7.389	36.1	48.7	3914
19	12	7.289	32.3	62.3	4818
13	3	7.251	35.8	75.7	9815
13	2	7.202	36.2	38.2	4506
5	6	7.108	36.9	54.3	4700
5	10	7.082	34.2	59.2	5224
15	14	7.06	33.2	75.2	9859
3	16	7.012	23.9	30.2	2771
17	15	6.982	37.3	43.9	3221
14	16	6.97	32.2	49.1	4111
19	10	6.949	32.1	61.3	5148
3	14	6.926	35.9	64.3	6220
13	17	6.849	34.7	47.9	3952
12	4	6.638	40.4	66.6	7293
17	14	6.586	37.9	62.8	6646
5	19	6.447	39.6	51.3	4712
10	6	6.377	36.1	79.7	10652
20	9	6.301	37.3	50.6	4507
17	16	6.144	31.6	46.6	4730
20	10	6.13	39.5	56.3	5194
7	10	6.071	32.0	50.5	7509
4	3	5.988	40.6	66.0	7373
21	6	5.836	39.7	26.2	2712
4	13	5.412	44.4	59.6	6505
3	2	5.043	43.9	44.4	4261
9	10	4.71	45.6	77.6	12571
9	6	4.514	47.0	70.5	10433
7	6	3.624	53.5	64.9	10262
7	9	3.605	52.5	56.6	8872
7	20	3.562	54.1	36.6	5864
15	2	3.262	53.3	62.4	7046

Table 2. Scan point tensions (registration statistics of two specific scan positions) from FARO Scene Scan Manager after 4th fine registration.

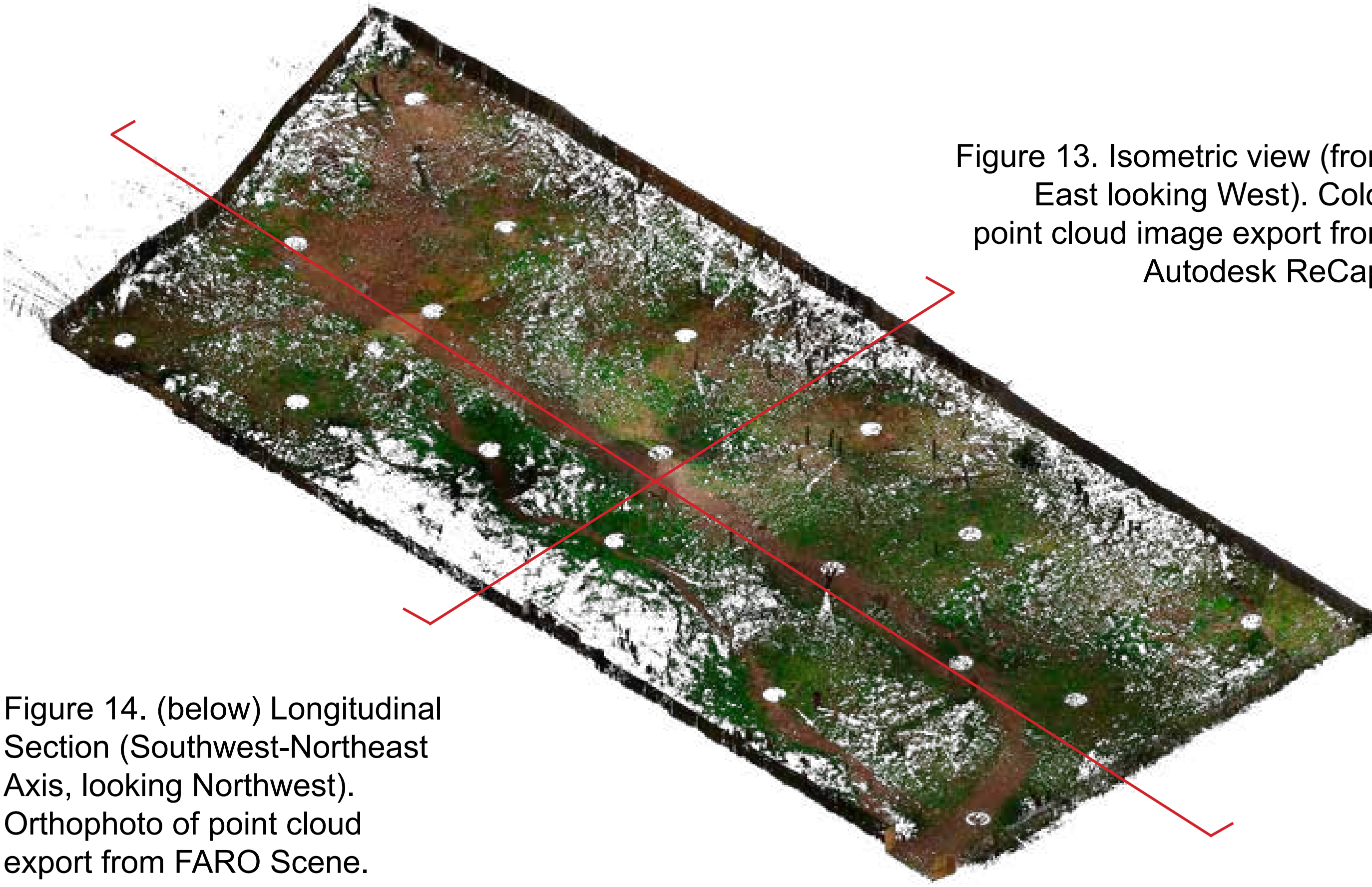
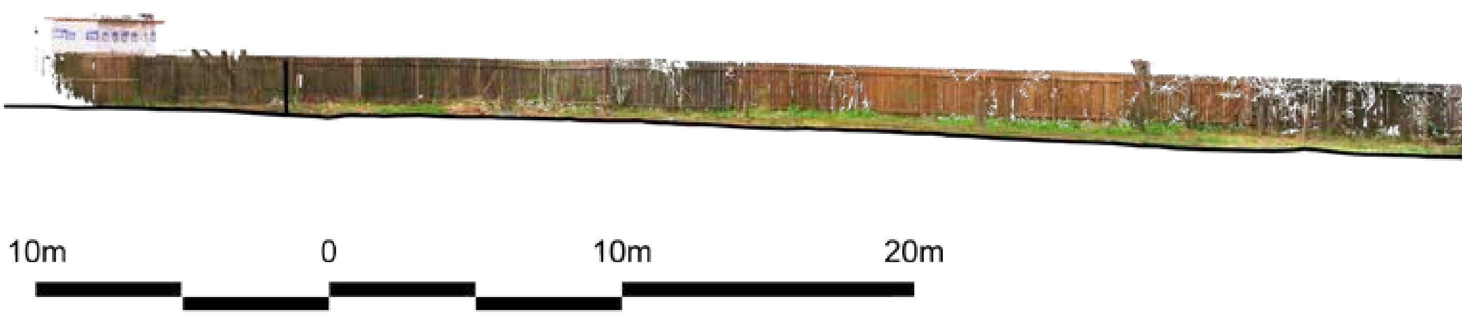
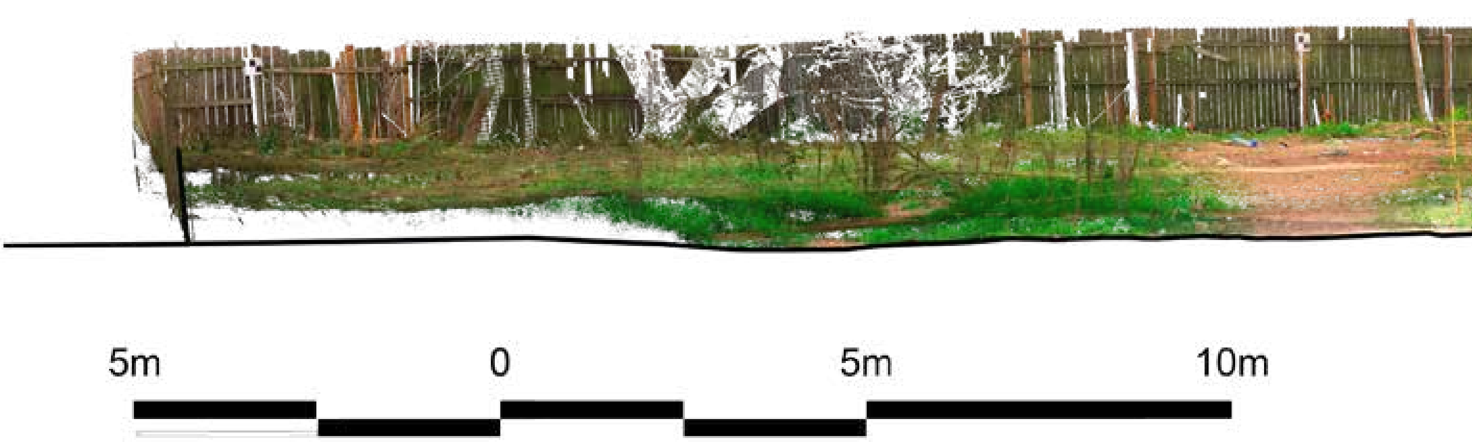


Figure 13. Isometric view (from East looking West). Color point cloud image export from Autodesk ReCap.

Figure 14. (below) Longitudinal Section (Southwest-Northeast Axis, looking Northwest). Orthophoto of point cloud export from FARO Scene.





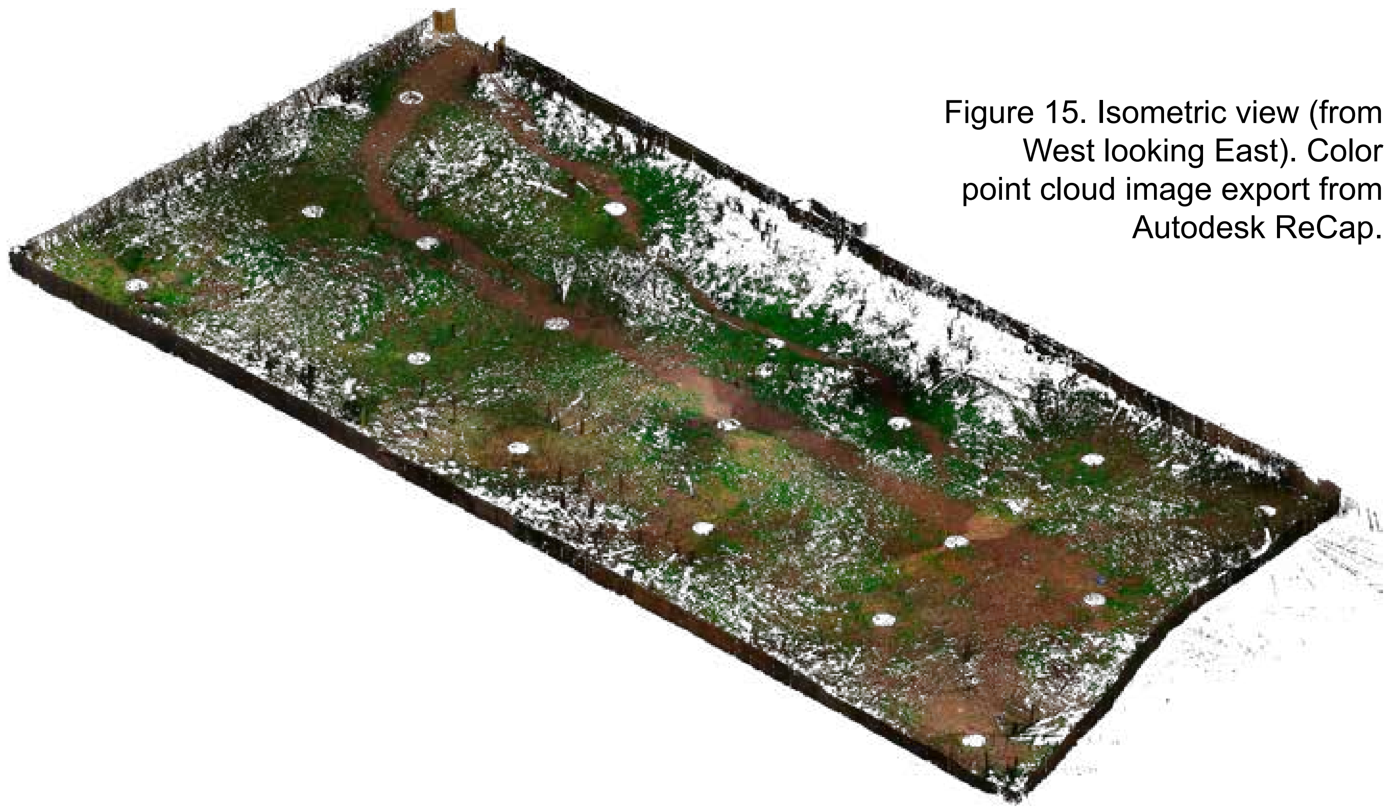


Figure 15. Isometric view (from West looking East). Color point cloud image export from Autodesk ReCap.

Figure 16. Transverse Section (Southeast-Northwest Axis, looking Southwest). Orthophoto of point cloud export from FARO Scene.

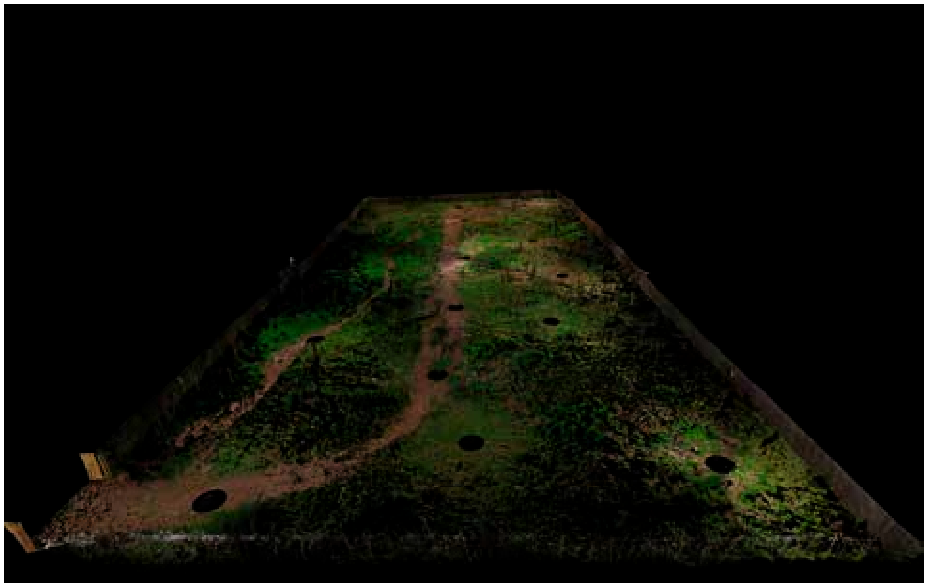


Figure 17. Perspective view (from Northeast looking Southwest). Color point cloud image export from Autodesk ReCap.The black areas visible within the fence line represent scan locations (circles) and tall grasses/brush present on site on March 15, 2019.

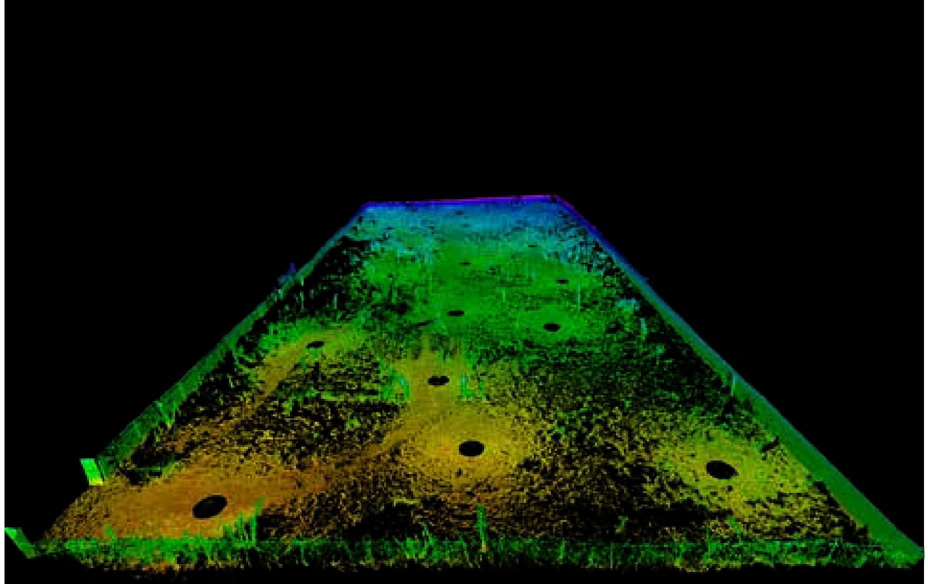


Figure 18. Perspective View (from Northeast looking Southwest). Color point cloud image export from Autodesk ReCap (“heat map” filter showing topographic elevations: high [violet/blue] to low [yellow/red] elevations).

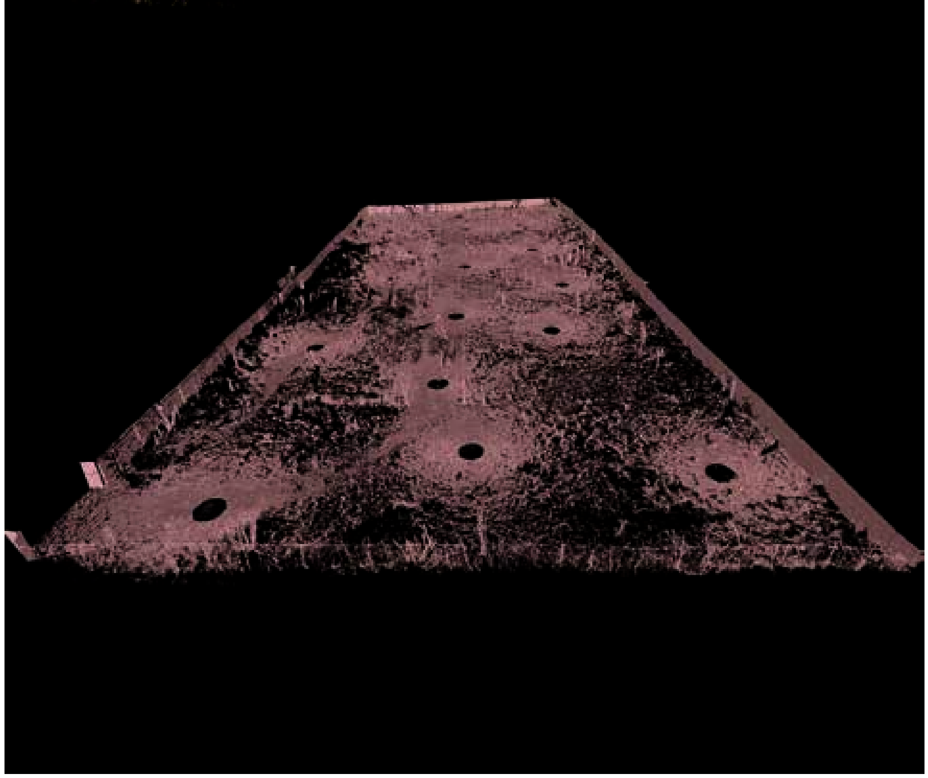


Figure 19. Perspective view (from Northeast looking Southwest). Point cloud image export from Autodesk ReCap (“scan location” filter, rendering all features similarly to observe surface resolution).

Post Processing & Modeling

Once sufficiently registered, the data was exported to various general formats and brought into secondary software for editing. The project point cloud was exported to E57 and PTS file formats, since either of these formats can be brought into a variety of useful secondary software (e.g., Autodesk ReCap Pro, CloudCompare, Rhinoceros 6, etc.). In the context of this project, the E57 file was imported into Autodesk ReCap Pro in order to take advantage of that software's "heat map" filter and preset isometric view settings (for image export). This ReCap point cloud can also be linked to AutoCAD and Revit for further modeling, if necessary.

FARO Scene also allows for surface meshing of the project point cloud. While relatively poor in the recent past, the meshing capabilities have improved considerably over the past few years. A mesh was created and exported to OBJ format and imported into Rhinoceros. Within Rhinoceros, the mesh was rendered monochromatic to examine surface features. Additionally, contour lines were created using the mesh at intervals of 10cm, 20cm, 50cm, and 1m. These renderings and contours were combined into composite drawings of the cemetery using Adobe Illustrator and Photoshop.

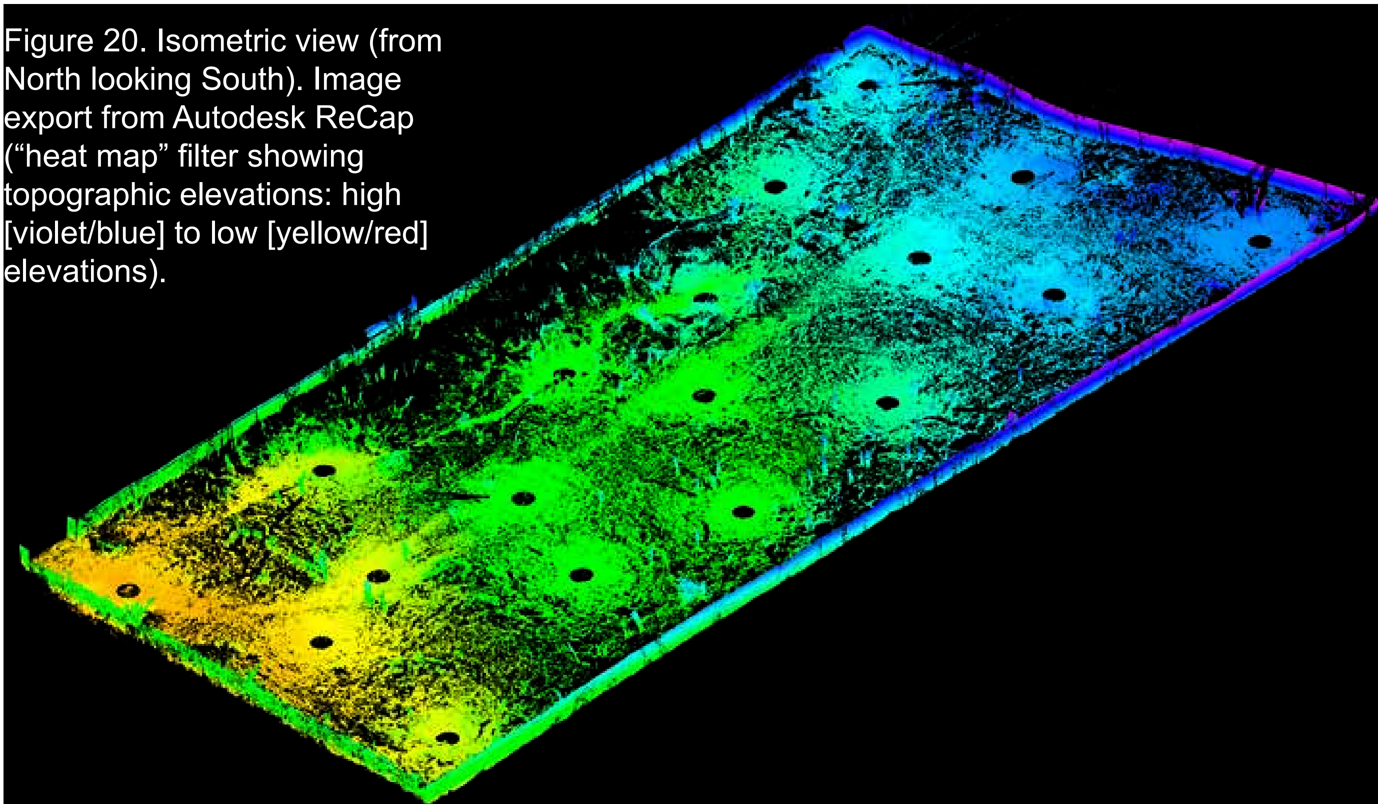


Figure 20. Isometric view (from North looking South). Image export from Autodesk ReCap ("heat map" filter showing topographic elevations: high [violet/blue] to low [yellow/red] elevations).

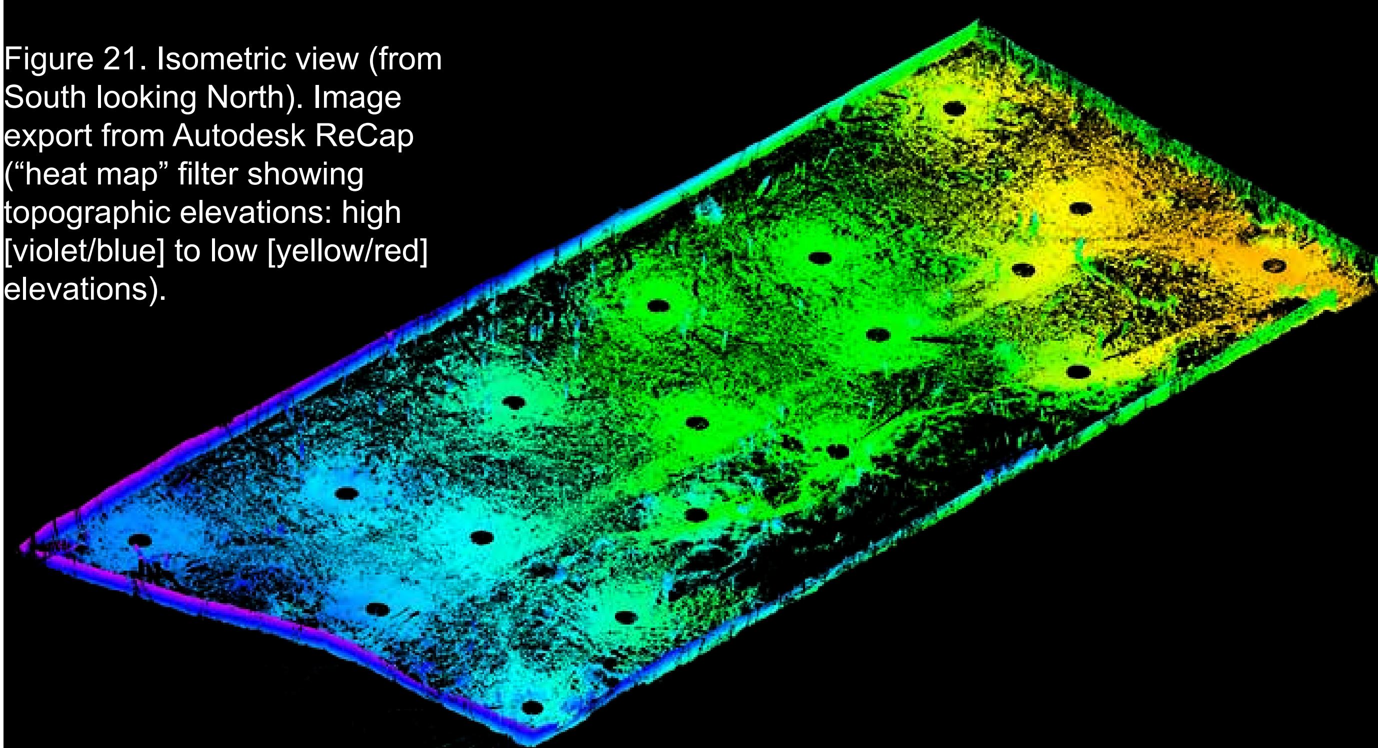


Figure 21. Isometric view (from South looking North). Image export from Autodesk ReCap ("heat map" filter showing topographic elevations: high [violet/blue] to low [yellow/red] elevations).

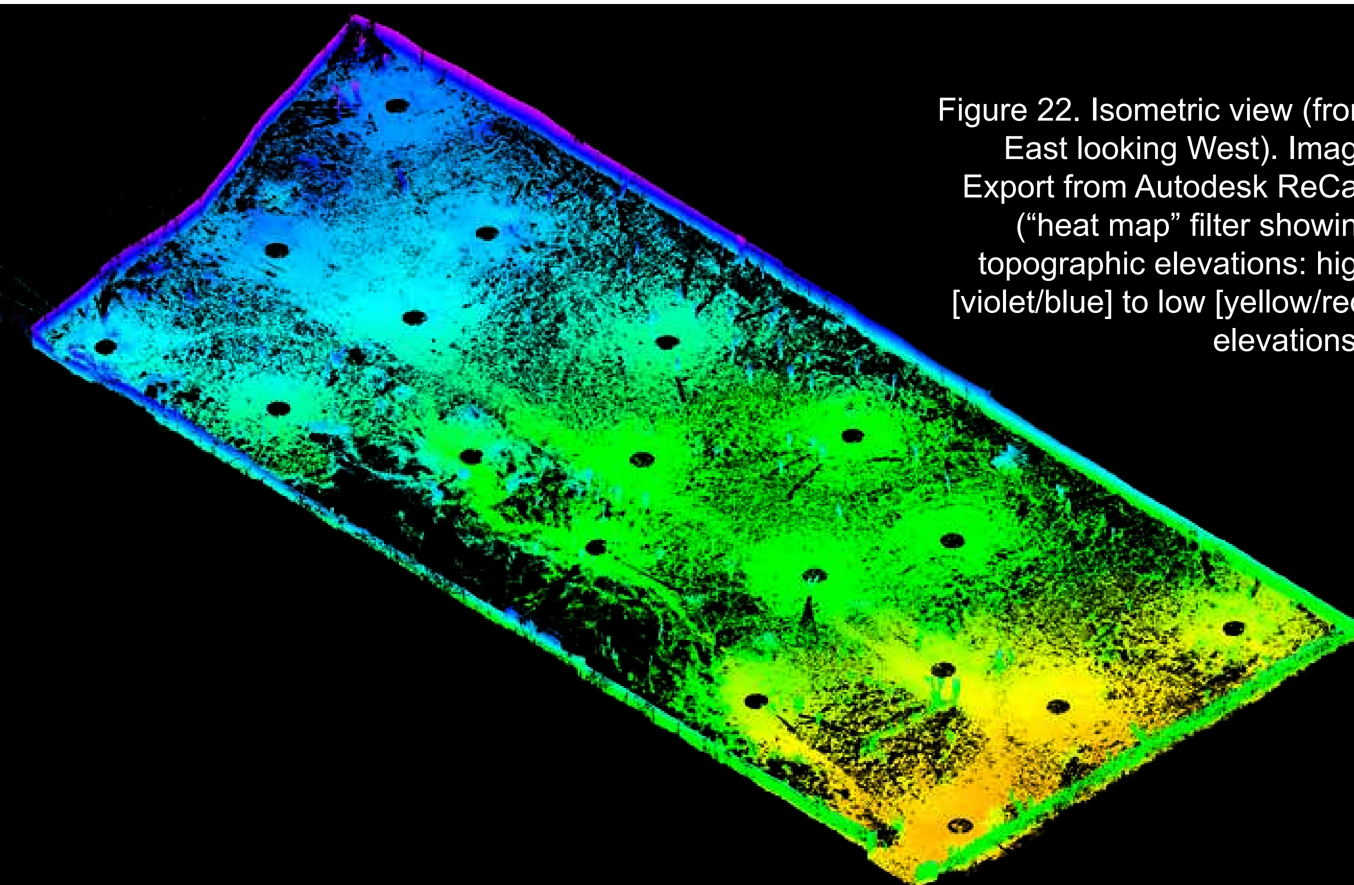


Figure 22. Isometric view (from East looking West). Image Export from Autodesk ReCap (“heat map” filter showing topographic elevations: high [violet/blue] to low [yellow/red] elevations).

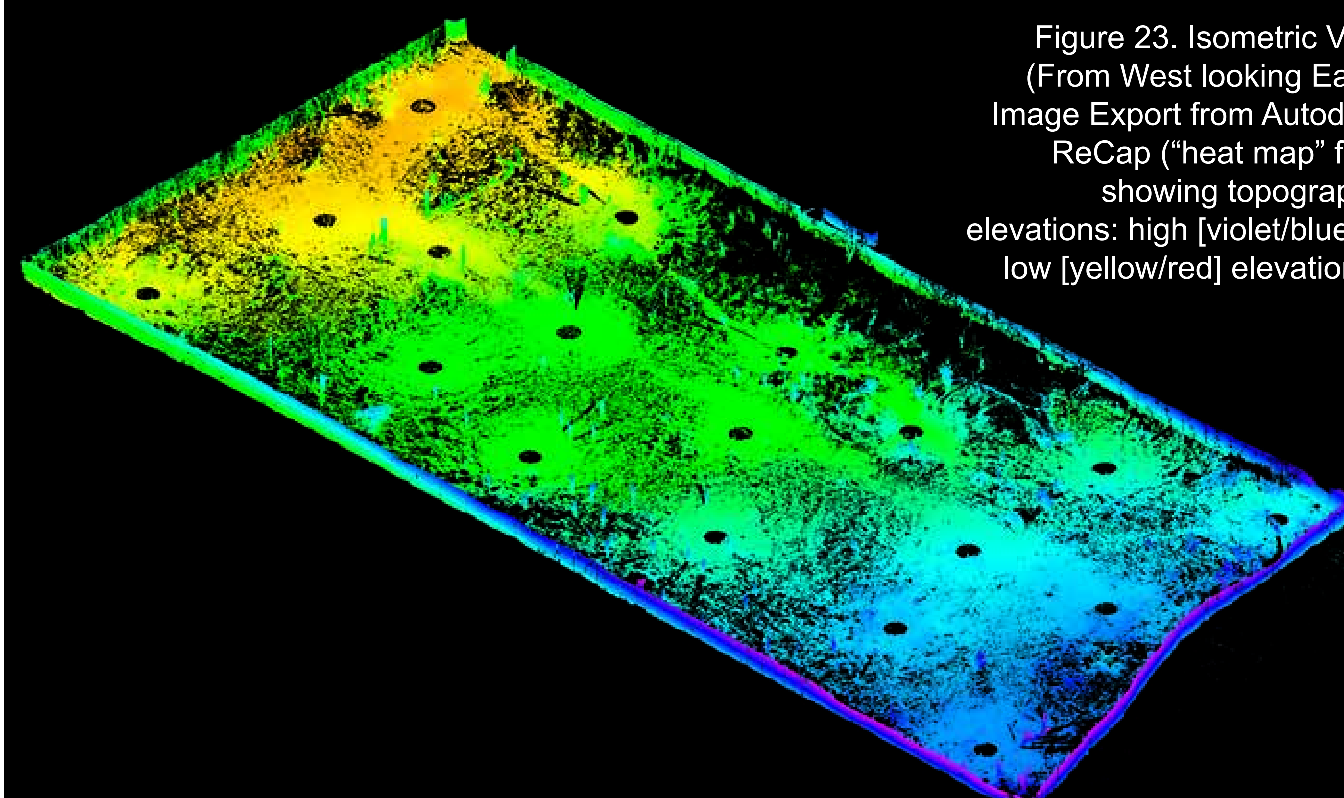


Figure 23. Isometric View (From West looking East]) Image Export from Autodesk ReCap (“heat map” filter showing topographic elevations: high [violet/blue] to low [yellow/red] elevations).

Figure 24. Isometric view (from North looking South). Mesh created in FARO Scene, rendering & contour lines from Rhino (1 meter intervals).

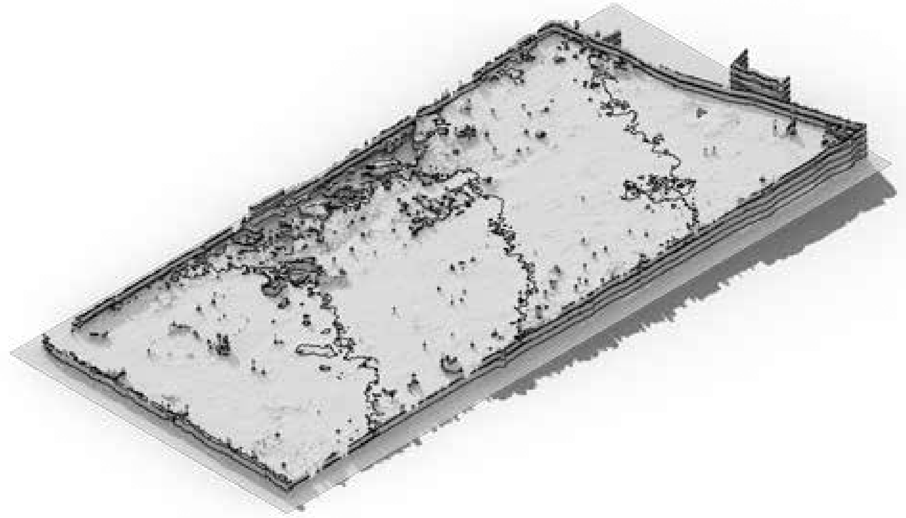


Figure 25. Isometric view (from North looking South). Mesh created in FARO Scene, rendering & contour lines from Rhino (.50 meter intervals).

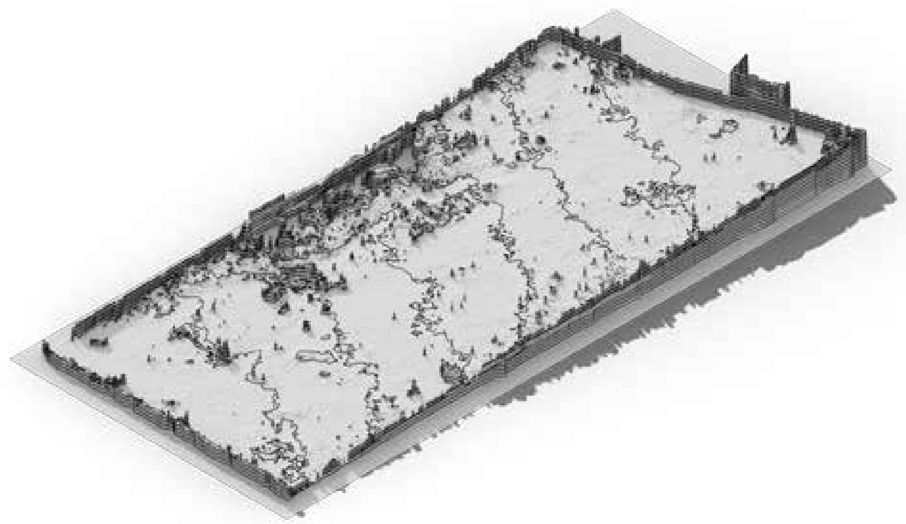
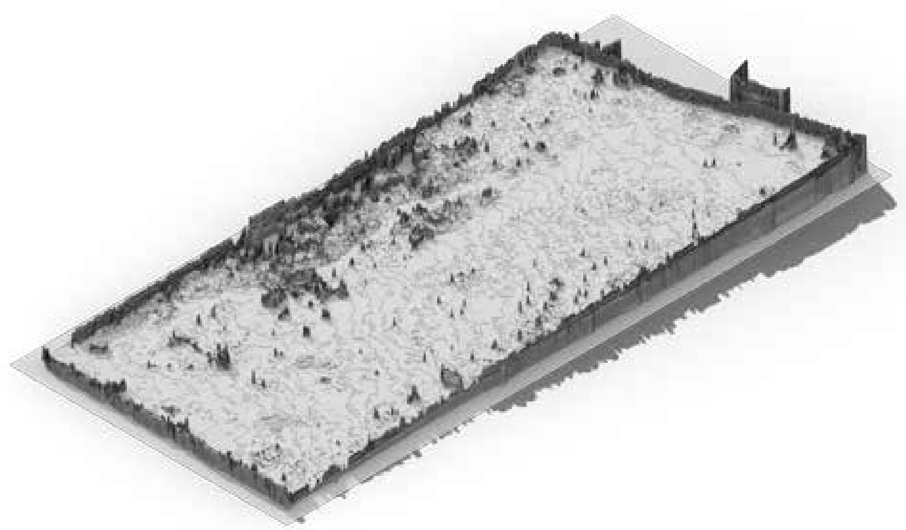


Figure 26. Isometric view (from North looking South). Mesh created in FARO Scene, rendering & contour lines from Rhino (.10 meter intervals).



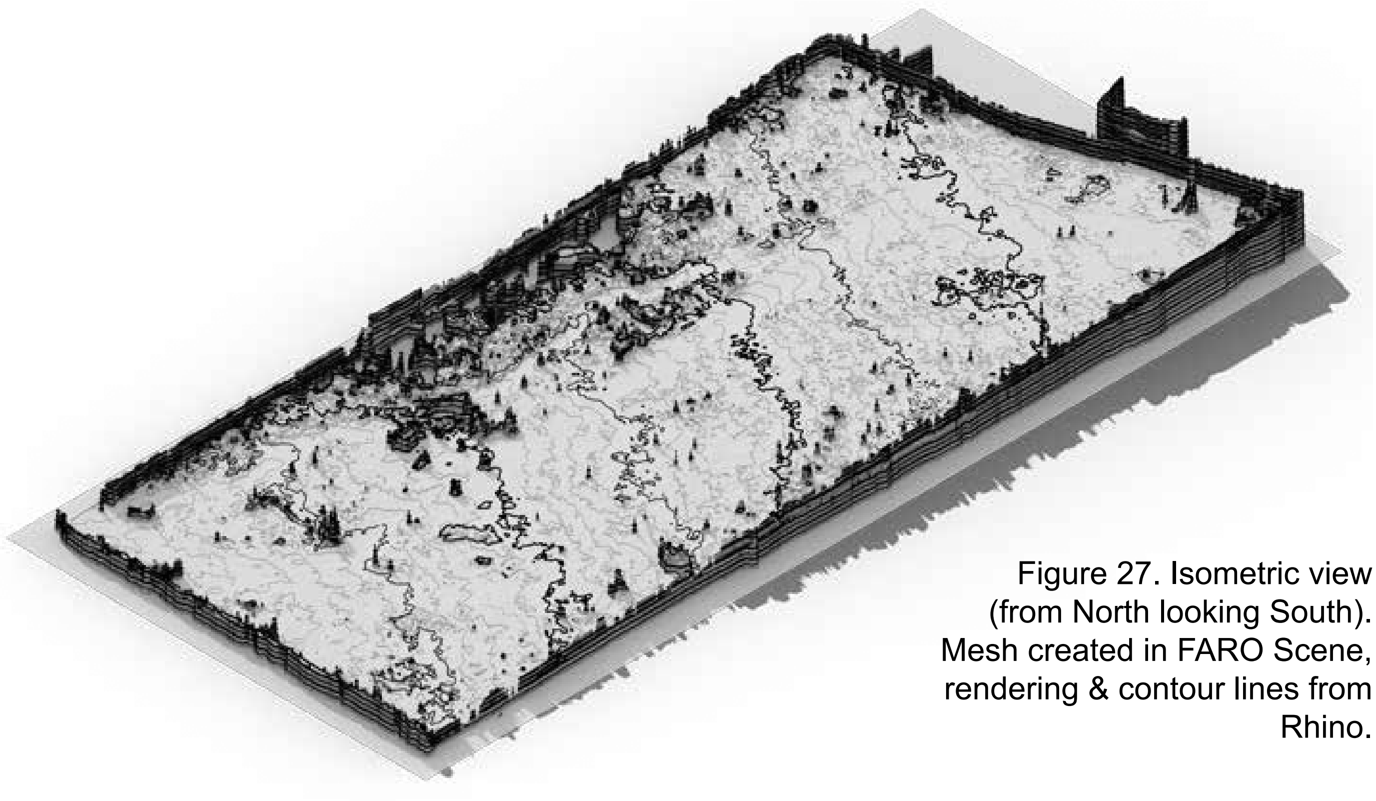


Figure 27. Isometric view (from North looking South). Mesh created in FARO Scene, rendering & contour lines from Rhino.

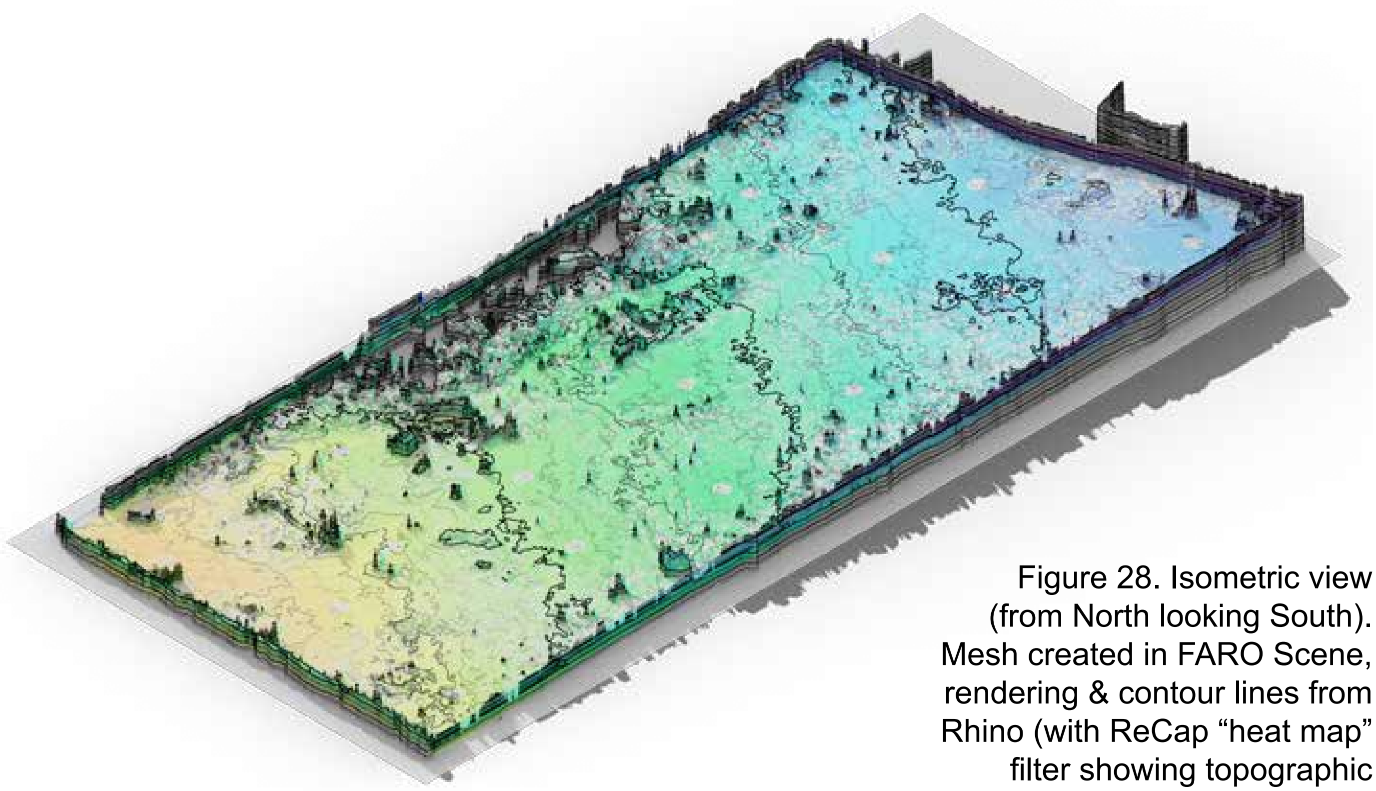


Figure 28. Isometric view (from North looking South). Mesh created in FARO Scene, rendering & contour lines from Rhino (with ReCap “heat map” filter showing topographic elevations: high [violet/blue] to low [yellow/red] elevations).

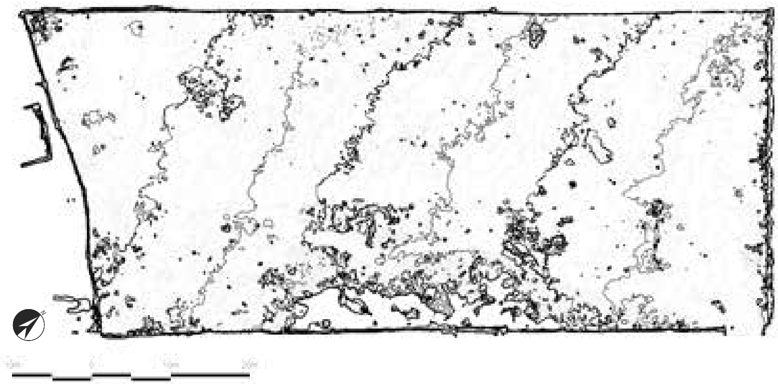


Figure 29. Site plan with contour lines from Rhino using the mesh created in FARO Scene.

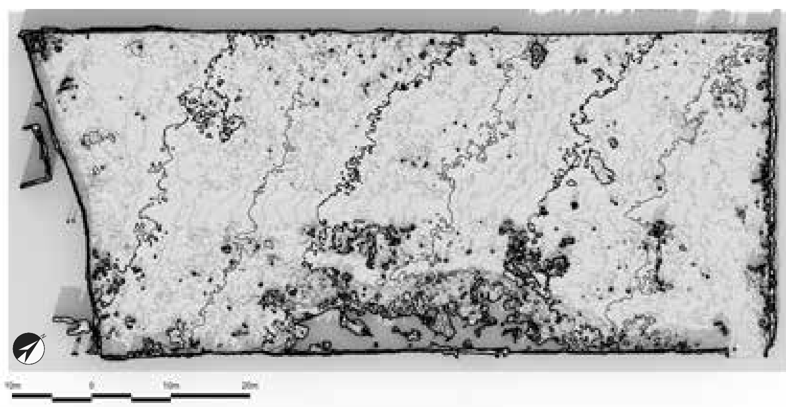


Figure 30. Site plan with mesh created in FARO Scene, rendering & contour lines from Rhino.

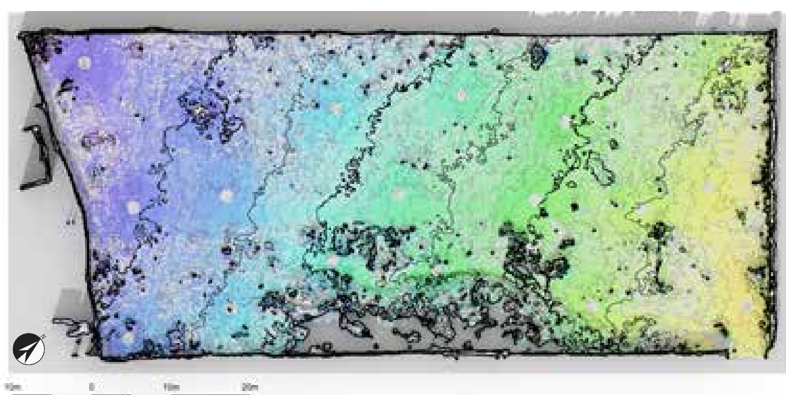


Figure 31. Site plan with mesh created in FARO Scene, rendering & contour lines from Rhino (with ReCap “heat map” filter showing topographic elevations: high [violet/blue] to low [yellow/red] elevations).

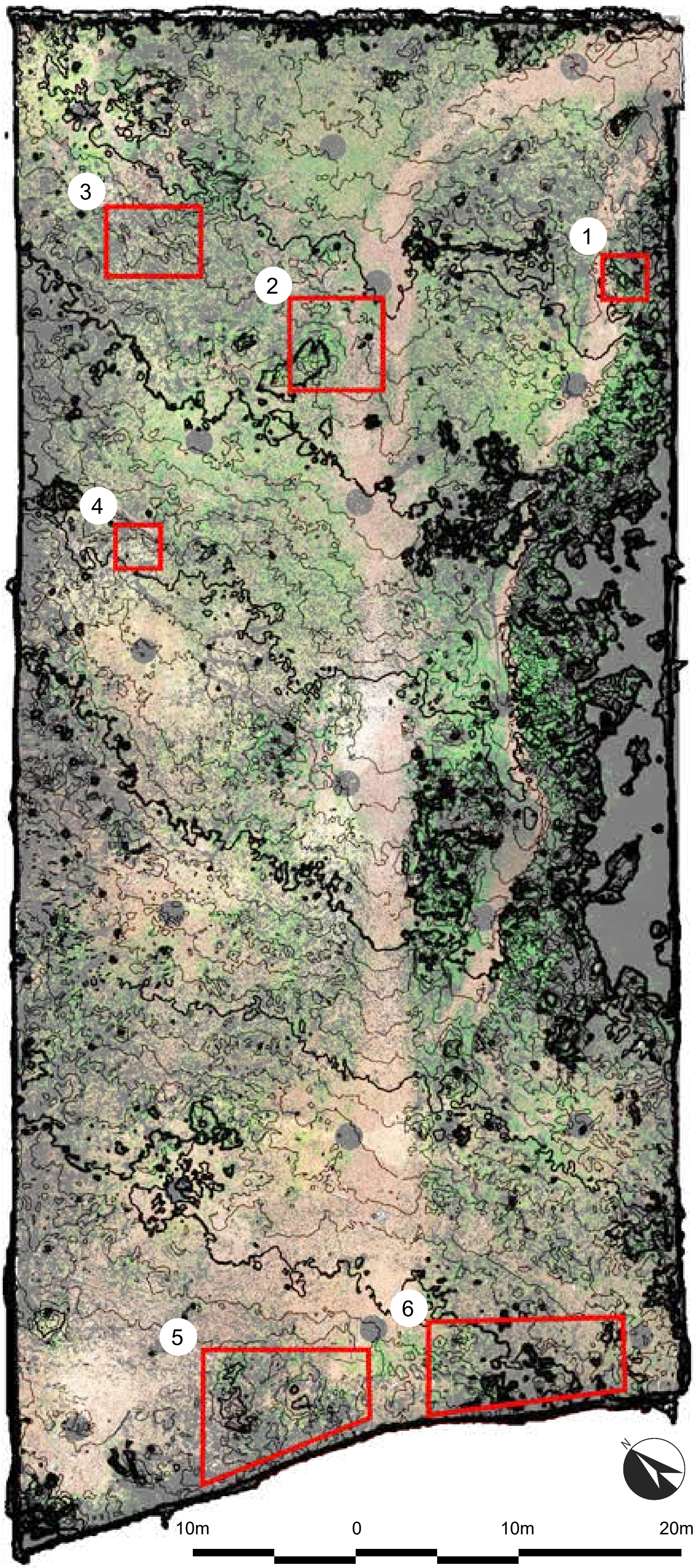
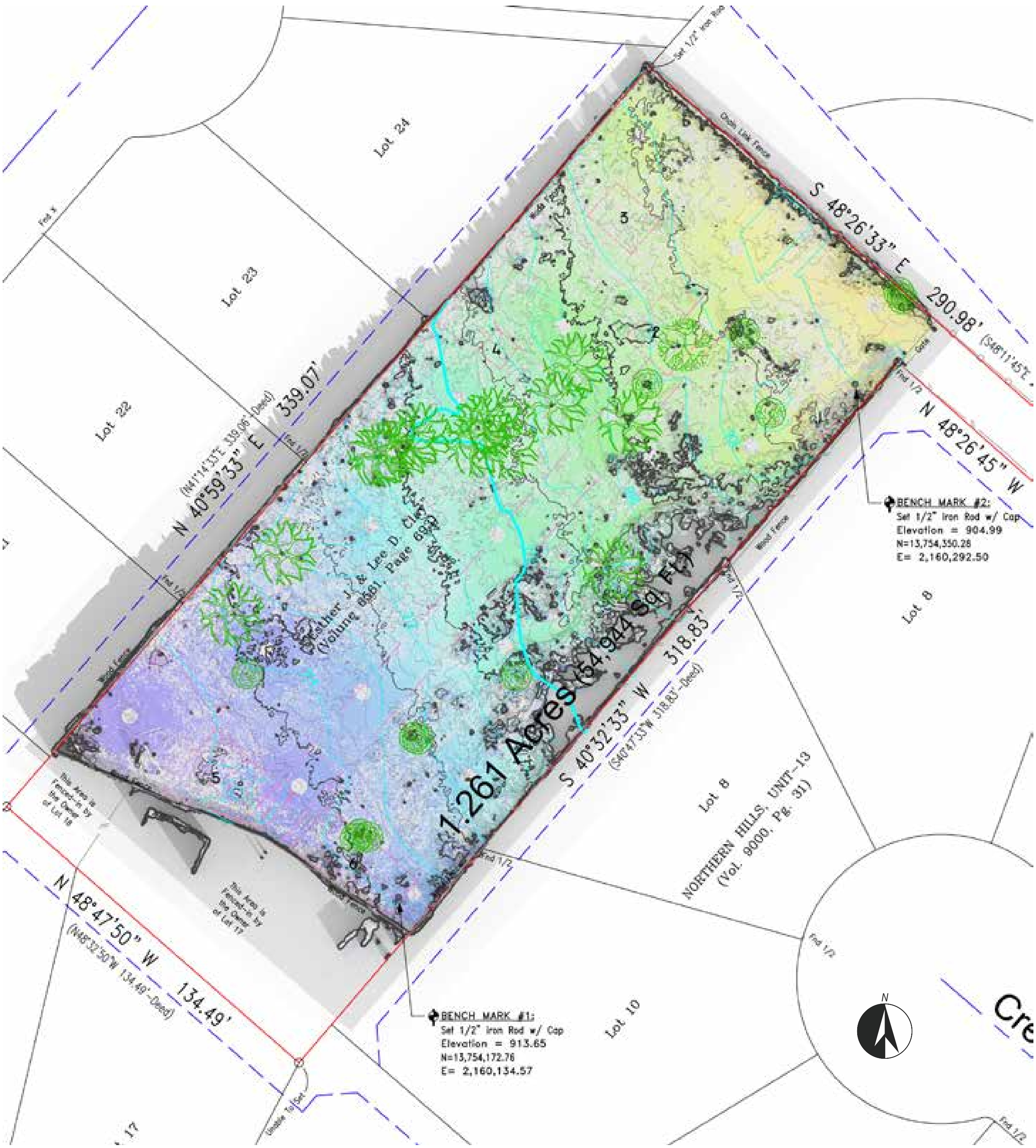


Figure 32. Site plan combining color point cloud image export from Autodesk ReCap, contour lines from Rhino, and potential archaeological features previously identified on the professional site survey. Gray areas visible within the fence line represent scan locations (circles) and tall grasses/brush present on site on March 15, 2019.

Figure 33. Site plan combining detail of previously surveyed site plan (Gibbons Surveying & Mapping, Inc., January 30, 2019) with underlay: mesh created in FARO Scene, rendering & contour lines (1 meter, .50 meter, and .10 meter intervals) from Rhino (with ReCap "heat map" filter showing topographic elevations: high [violet/blue] to low [yellow/red] elevations).



Site benchmarks established by Gibbons Surveying & Mapping, Inc., January 30, 2019.

Datum in ND ‘83
Texas State Plane, South Central Zone
State Plane Zone 4 Zone 5401 FIPS 4204 TX-S Central
State Plane Coordinate System (SPCS)

Bench Mark #1
N = 13,754,172.760 (US Survey feet)
E = 2,160,134.570 (US Survey feet)
Elevation = 913.65 (US Survey feet)
[= 278.481 meters]

Conversions to other systems
https://www.ngs.noaa.gov/NCAT/
Input Datum NAD83(2011); Output Datum (NAD82(2011)

UTM Zone 14
Northing 3,270,951.835; Easting 558,395.294

LAT-LON
29.5669388271, -98.3971452343
29°34’01.0”N 98°23’49.7”W

GOOGLE MAPS
https://www.google.com/maps/place/29%C2%B034’01.0%22N+98%C2%B023’49.7%22W/@29.5669498,-98.3977227,207m/

Bench Mark #2
N = 13,754,350.28 (US Survey feet)
E = 2,160,292.50 (US Survey feet)
Elevation 904.99 (US Survey feet)
[=275.842 meters]

Conversions to other systems
https://www.ngs.noaa.gov/NCAT/
Input Datum NAD83(2011); Output Datum (NAD82(2011)

UTM Zone 14
Northing 3,271,005.933; Easting 558,443.418

LATLONG
29.5674247857, -98.3966455371
29°34’02.7”N 98°23’47.9”W

GOOGLE MAPS
https://www.google.com/maps/place/29%C2%B034’02.7%22N+98%C2%B023’47.9%22W/@29.567426,-98.3971927,146m/

Analysis & Prospectus for Future Work

The terrestrial laser scanning (TLS) of Hockley Cemetery successfully produced a high resolution digital survey of the property as it existed on March 15, 2019. The project recorded over 190,000,000 data points with a mean point error of 6.8 mm and a maximum point error of 10.1 mm over an area of ca. 54,944 square feet (or 1.26 acres). Some loss of data and accuracy occurred along the perimeter and eastern edges of the property, where cleaning of tall grasses and brush had not yet been completed. As these taller grasses were frequently moved by the light but steady winds throughout the day, they were not recorded by the same number of overlapping points as other, more stationary, features, and so appear as white (e.g. Figures 5, 12-16) or black (e.g., Figures 6-11, 17-23) areas in the colorized point clouds.

The digital surface model (DSM) produced by the scanning represents both the "bare earth" ground surface (e.g., pathways and other areas cleared of brush), the projecting vegetation, and other natural and built features (trees, fences, posts, survey flags, stones, debris; for the purposes of this report, the trees within the property were digitally cropped to below the level of the surrounding fence line).

In an attempt to identify any potential surface anomalies (depressions, pits, mounds) that might represent below surface features, the CHC applied different filters in the Autodesk ReCap software (e.g., the "heat map" filter that provides a color-coded elevation map of the DSM; Figures 18, 20-23). We also created a closed surface "mesh" from the point cloud in FARO Scene; that model was then imported into another software program

(Rhinoceros), which allowed us adjust lighting conditions (i.e., to look for suggestive shadows by moving the angle of a light source; Figures 24-28) and to create extremely detailed contour lines reflecting the topography of the site (Figure 29). Overlapping the contour lines with the “heat map” (Figures 28 and 31), the top view orthophoto from the colorized point cloud (Figure 32), and an earlier site survey by Gibbons Surveying & Mapping (Figure 33) did not, unfortunately, clearly reveal any previously unrecognized features or series of anomalies in the digital surface model. It is possible, however, that the data can be refined further in the future by using other software, applying additional filters, and combining the results of geophysical or archaeological investigations after the site vegetation has been trimmed more thoroughly.

The logical next step in the analysis would be to incorporate data from the ground penetrating radar (GPR) survey conducted by Prof. Mark Everett and his students from Texas A&M on April 19, 2019, with the terrestrial laser scanning (TLS) survey conducted by the Center for Heritage Conservation. While TLS and GPR are both commonly used in the documentation of different types of historic sites and landscapes, there are, in fact, few scientific studies that attempt to combine both methods in the search for unmarked graves. In particular, it would be instructive to see how subsurface anomalies and features recorded by GPR relate to the detailed surface contours both in their two-dimensional and three-dimensional aspects. The combination of the results from the TLS and GPR surveys at Hockley Cemetery may help to refine the methodologies used analyze such digital data in the search for lost burials at other neglected cemeteries in San Antonio and elsewhere.