# EVALUATION OF REMOTELY SENSED HIGH RESOLUTION ELEVATION DATA IN TEXAS

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## ABSTRACT
There is high potential for increasing the quality, efficiency, and effectiveness in presentation and planning of many varied NRCS business activities including conservation practices utilizing spatial analysis processes with remotely sensed high resolution elevation data. Prior to implementation of elevation derivatives into production activities using GIS processes and models, how well the surface generated captures reality needs to be evaluated. Areas in 8 West Texas counties (Fig. 1) with a variety of landform and vegetation conditions were selected for the collection of elevation data using survey grade GPS systems. Point data were collected, processed, and used for the calculation of fundamental accuracy values for the different landform and vegetation conditions. Results of the evaluation identify some of the conditions that have higher uncertainty regarding the use of different elevation derivatives.

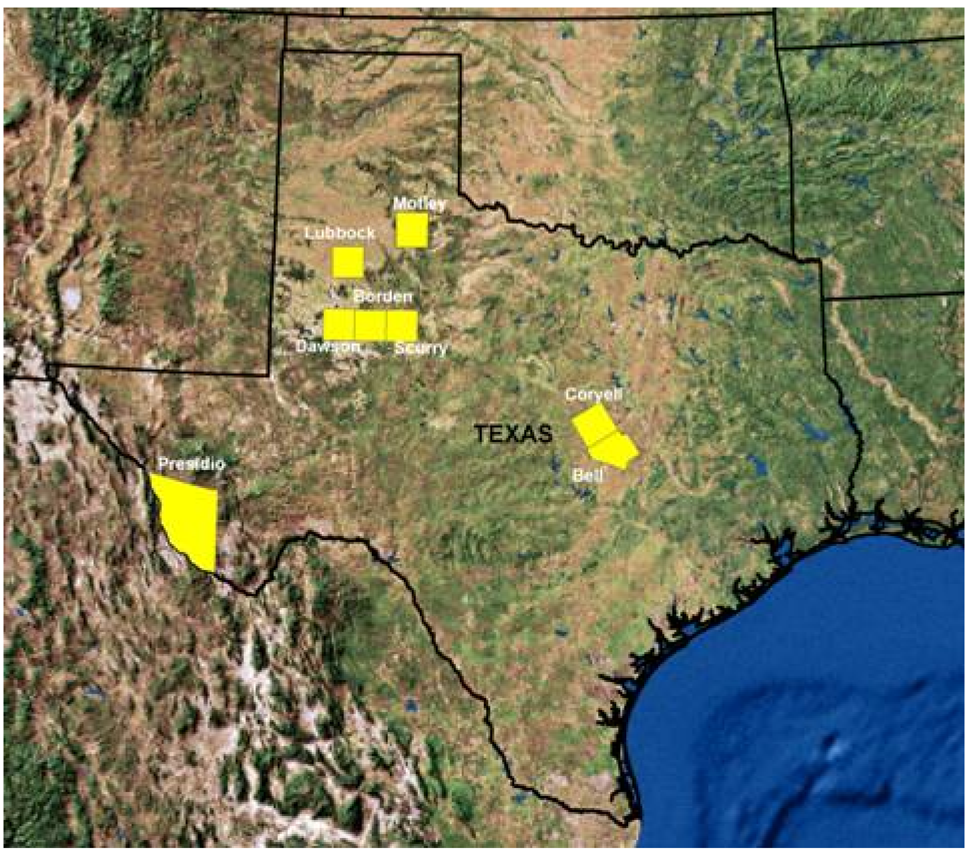



**Figure 1. Location of evaluation sites in Texas.**

## BACKGROUND
Elevation data has been used for terrain analysis to estimate slope gradient and determine overland water movement for soil conservation applications for many years. The

importance of elevation data was recognized in the past as shown by this quote from an early soil conservation handbook, *"The most desirable method of mapping slope would be to make a detailed topographic map having a contour interval of 1 foot or less."* (Norton, 1939) Albeit this not being feasible in many cases, elevation data has been captured on site or otherwise procured in order to meet the requirements as needed. Technology advances have introduced remotely sensed high resolution digital elevation data (HRDED) created with new methods, equipment, and data formats. Questions exist as to how well these new elevation products model the true surface for moderate to large scale mapping and planning applications. This paper summarizes the findings of several evaluations of HRDED in Texas.

## METHODOLOGY

### Description of Site Selection

Evaluation sites were selected by the NRCS field office staff in all locations. Sites were selected in order to obtain consolidated and relative vertical accuracy in the various terrain conditions. Sites were also selected to validate the elevation data in areas with steep slopes along escarpments and gullies that frequently occur in this area. Point data was collected at each site using High Accuracy GPS (HAGPS) system (TopCon HyperLite+) as shown in Figure 2. This point data was for comparison with the 5m digital bare earth terrain model. In many locations data was collected in a density to enable the creation of a comparison surface.

GPS data was collected on the base station at temporary bench marks at each site sufficient to submit to the National Geodetic Survey On-line Positioning User Service (OPUS). Data sheets were obtained for each of these locations based upon the National Spatial Reference System (NSRS). GPS elevation data collected for the comparison was adjusted based upon the UTM NAD83 and NAVD88 coordinates from the OPUS datasheets using the HAGPS software.

**Figure 2. High accuracy GPS base station and ATV mounted Rover antenna setup at the Borden County evaluation site.**

### GIS Processing

The ArcGIS Spatial Analyst extension SAMPLE function was used to intersect the HAGPS point shapefile with the HRDED terrain model. This function creates a table with an attribute containing each grid cell value that is nearest the location of each point feature (Childs, 2004). The table output from the SAMPLE function is joined in a one to one relationship to the elevation point shapefile using a sample_key attribute. Two additional attribute fields were created in the shapefile attribute table in order to calculate the statistical values for the evaluation:

1. A field named dtm_xxxx (xxxx denotes the type of GPS device used to obtain the high accuracy elevation value subtracted from the HRDED value.
2. A field named sq_err to contain the difference between the HAGPS and HRDED elevation squared.

The mean of the square error attribute was obtained by viewing the field statistics and is used to calculate the Root Mean Square Error (RMSE). The 95% accuracy is calculated with the equation:

95% accuracy = RMSE x 1.96

These calculations are based on the guidance provided in the <u>Guidelines for Digital Elevation Data</u> (ver. 1.0, 2004).

**GIS Analysis**

Surface comparisons were made between the 2 sources of elevation data. The surface generated from the HAGPS mass points was created with the ESRI ArcGIS 9.2 software. The Spatial Analyst extension function Natural Neighbor interpolation is used to create the surface. This surface is displayed in ArcScene with the DTM surface generated from the IFSAR elevation data along with the HAGPS point observations. A vertical exaggeration of 2x is usually applied to the ArcScene properties.

## RESULTS

### Conventional Test Areas

Over 20,000 HAGPS points were collected in the evaluation effort. Overall results of the evaluation were very good where the bare earth HRDED was compared with the HAGPS in conditions without trees, buildings, and unobstructed moderately sloped terrain. The 95% accuracy calculated for the areas that met these conditions was well within the specifications of the product. A sample of the results under these conditions is displayed in Figure 3. This area in Lubbock County is irrigated row crop land. The HAGPS data was collected on the south facing slope of a playa lake that is a common landscape feature on the High Plains. The points are symbolized with green indicating the difference or error calculated between the HAGPS and the HRDED is less than 25cm and the yellow indicating a range in difference of 25 to 50cm. The maximum and minimum difference in this set of 1,100 points was +/- 0.4m with an RMSE of 0.17.


**Figure 3. High accuracy GPS points collected using rover unit 4079 in a cotton field in Lubbock Co.**

### Unconventional or Challenging Test Areas

How the HRDED performed in areas that are not considered appropriate for testing was of interest in providing guidance to users on what can be expected from the product in different terrain and vegetation conditions. Some of these areas pose a formidable challenge to acquire an accurate elevation using any method available. The results of this part of the evaluation effort indicate that in areas with abrupt changes in the terrain, the bare earth terrain model deviates in a predictable manner. In areas with abrupt concave shape the terrain model is smoothed over or filled in compared to the actual terrain shape. Figures 4 to 6 display an area in Dawson County. Figure 4 displays the location of the HAGPS points collected in a tight series of profiles sufficient to create a surface area of an arroyo. The points are symbolized with green indicating the difference or error calculated between the HAGPS and the HRDED is less than 0.5m, the yellow indicating a range in difference of 0.5 to 1m, and the red indicating a difference greater than 1m. The maximum difference in this set of points ranged from -1.2 to 3 m.

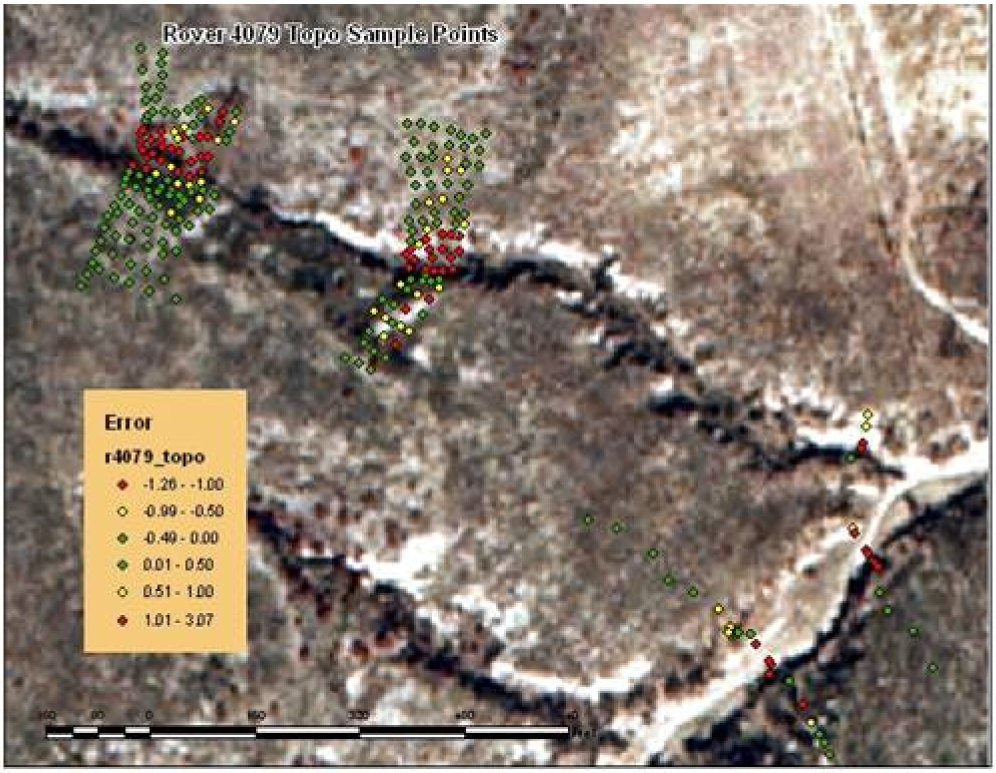



**Figure 4. High accuracy GPS points collected using rover unit 4079 across an arroyo in Dawson Co. TX.**

Figure 5 is a photograph taken of the area where HAGPS points were collected in a series of cross sections. The photograph is taken facing southeast on the south side of the arroyo displaying the steep rugged terrain in this area.

**Figure 5. Location of arroyo cross section in range pasture, Dawson Co.**

Figure 6 displays the HAGPS surface in a dark to light brown stretch, the HRDED bare earth surface is green, and the HAGPS points symbolized by the difference in the elevation values between the two datasets. The comparison of these surfaces displays the difference between the two representations in this abrupt concave part of the terrain.

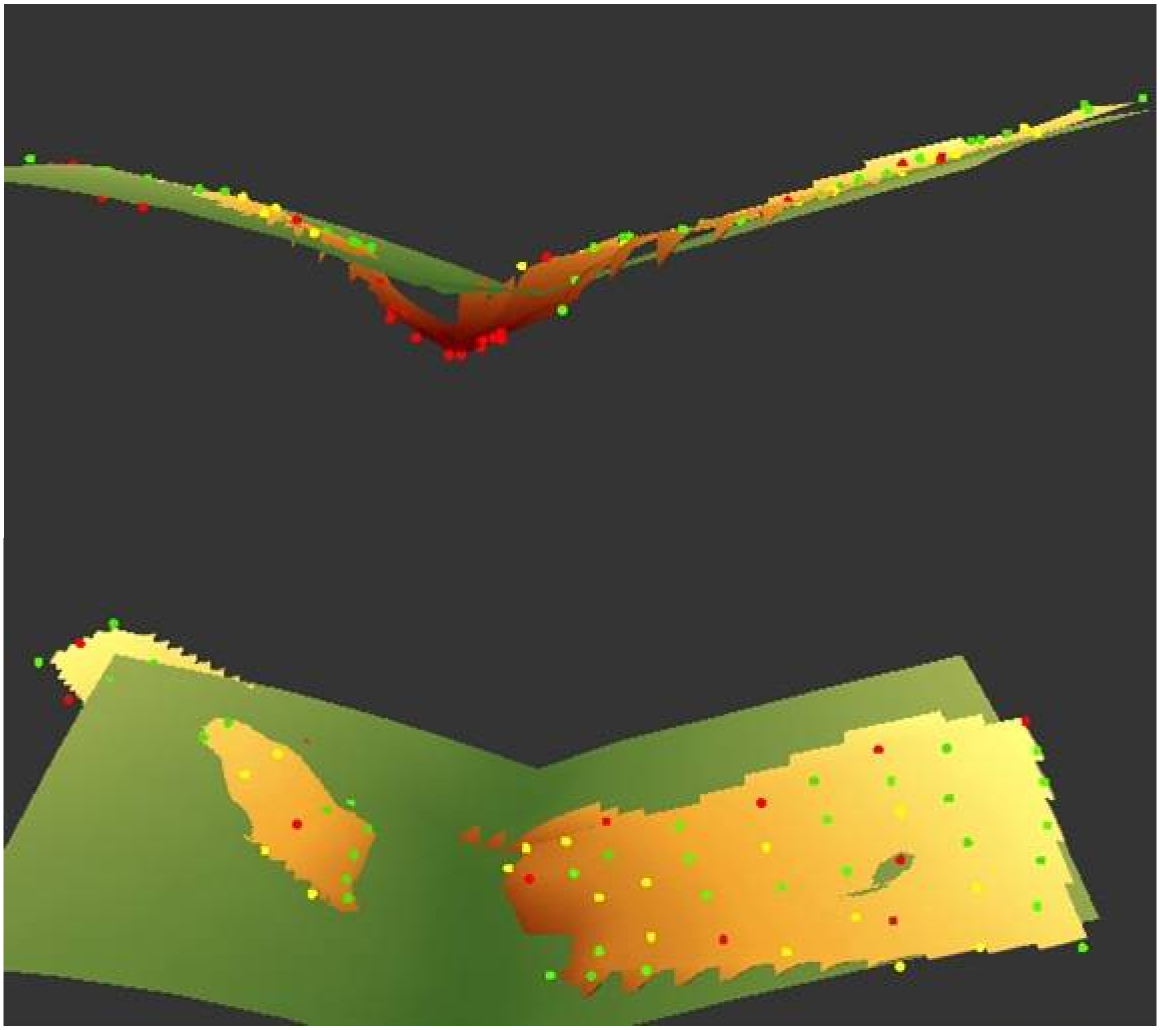
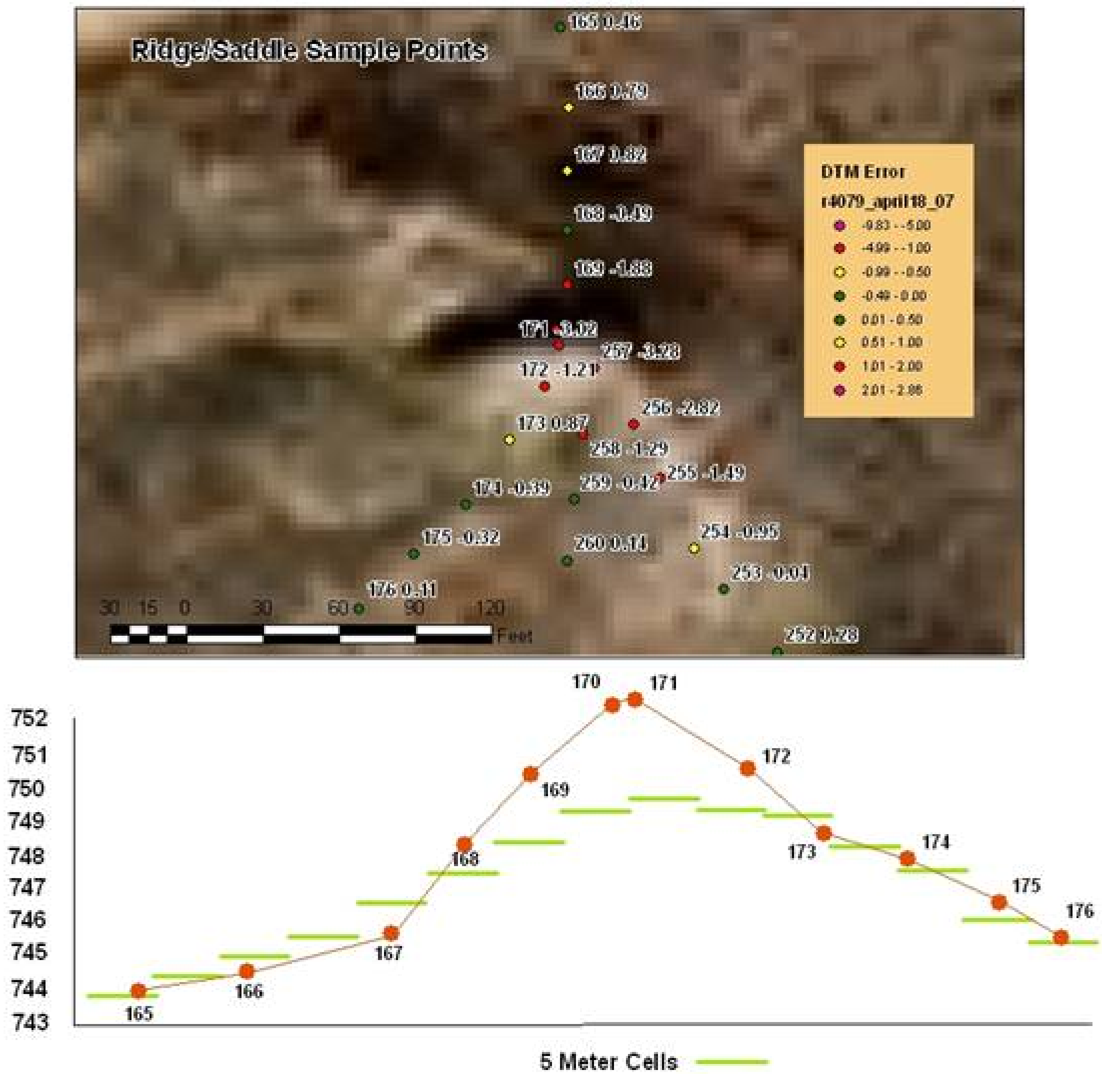


**Figure 6. Two oblique views of the HRDED and HAGPS surfaces in the arroyo.**

In areas with abrupt convex shape the terrain model is smoothed over and cut compared to the actual terrain shape. Figures 7 and 8 display two areas in Borden County that illustrate this feature of the HRDED model. Figure 7 displays a photograph of a narrow ridge in the landscape. A cross section profile of HAGPS points was collected in the area where the individual is walking along the crest of this ridge.

**Figure 7. Cross section location on narrow ridge in Borden County.**

The upper part of Figure 8 displays the aerial photograph and the locations of the HAGPS points collected across and along the crest of this ridge displayed in Figure 7. The feature identifying number (FID) of the individual points are displayed as labels along with the difference calculated between the HAGPS and the HRDED. The maximum error in this set of points is point 171 where the difference is -3.0 m located on the crest of the ridge. The lower part of Figure 8 displays an effort to graph the spatial relationship between the HAGPS points and the 5m cells of the HRDED horizontally in the x axis and the elevation in the y axis of the graph. Also displayed in the lower part of Figure 8 is a table of slope gradient values calculated using the HAGPS and HRDED data. This table shows there is an 8% difference in slope gradient between the 2 datasets in as a result of the smoothing effect in this abrupt convex shaped part of the terrain.




| FID | Distance | Slope% | IFSAR Slope% |
|---|---|---|---|
| 165 - 171 | 38.8 | 21 | 13 |
| 176 - 171 | 40.3 | 18 | 10 |

**Figure 8. HAGPS cross section points, graph of HAGPS and HRDED cells for narrow ridge in Borden County.**

Another example of how the HRDED models an area with abrupt convex shape in the terrain is displayed in Figures 9 and 10. This area of interest is a relatively small erosional remnant of the high plains escarpment in Borden County. This feature has a cone shaped appearance with very steep slope on a nearly level broad plain. Figure 9 displays the location of HAGPS points on an aerial photo base. The points are symbolized with green indicating the difference or error calculated between the HAGPS and the HRDED is less than 0.5m, the yellow indicating a range in difference of 0.5 to 1m, and the red indicating a difference of 1 to 5m. The purple indicates differences greater than 5m. The maximum difference in this set of points exceeded 9m at the summit of the erosional remnant.

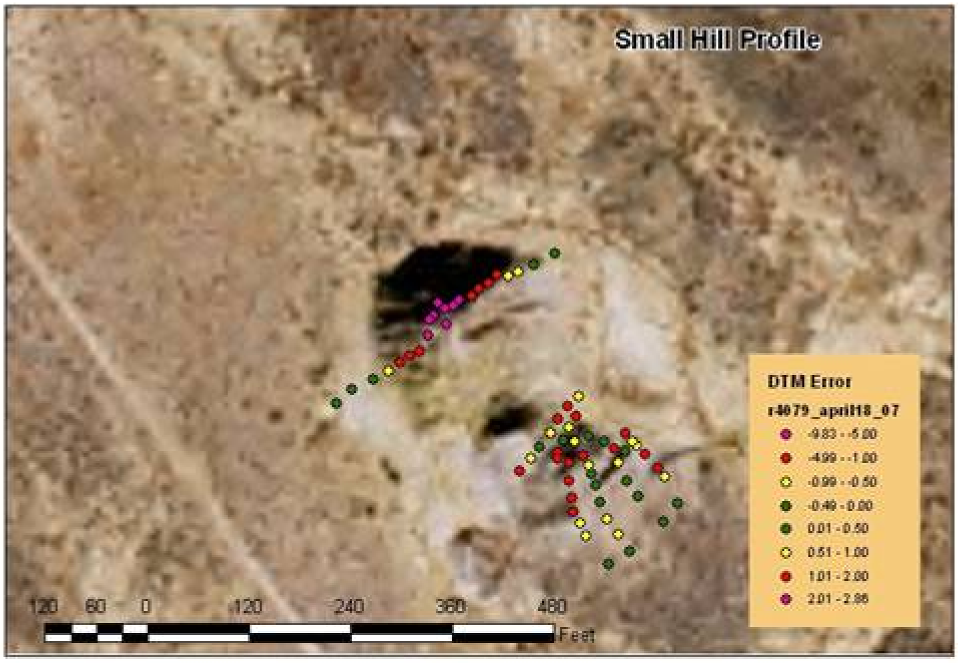



**Figure 9. HAGPS cross section points displayed on aerial photograph of the erosional remnant area in Borden County.**

Figure 10 is an oblique representation of this area with the aerial photograph image draped on the HRDED surface displayed concurrently with the HAGPS points. There is zero vertical exaggeration applied to this scene. This displays the smoothing effect present in the HRDED model of this abrupt change in the actual terrain surface.

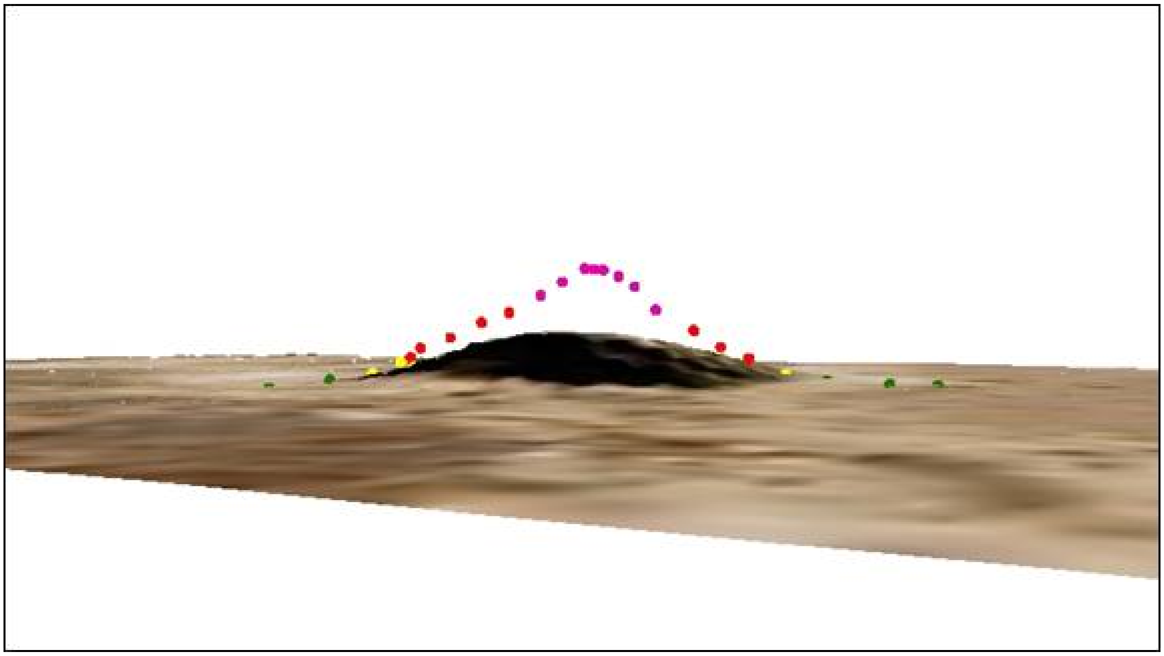


**Figure 10. Oblique view and 3D location of HAGPS points across the erosional remnant area in Borden County.**

## CONCLUSIONS

These findings support the premise that HRDED datasets and derived products should be tested empirically against on-site evaluation to determine appropriate use.
More evaluations need to be performed to further validate these results in different terrain and vegetation conditions. According to these areas examined, the accuracy of the HRDED is well within the specifications as described for the product. In areas of the terrain that have abrupt shape changes the HRDED surface is smoother than the shape of the terrain captured using HAGPS elevation data. Concave areas are filled and convex shaped areas are cut. This knowledge will provide users with a more thorough understanding of how the HRDED data can be used in terrain analysis applications.

## REFERENCES

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