LiDAR Quality Assessment Report

The USGS National Geospatial Technical Operations Center, Data Operations Branch is responsible for conducting reviews of all Light Detection and Ranging (LiDAR) point-cloud data and derived products delivered by a data supplier before it is approved for inclusion in the National Elevation Dataset and the Center for LiDAR Information Coordination and Knowledge. The USGS recognizes the complexity of LiDAR collection and processing performed by the data suppliers and has developed this Quality Assessment (QA) procedure to accommodate USGS collection and processing specifications with flexibility. The goal of this process is to assure LiDAR data are of sufficient quality for database population and scientific analysis. Concerns regarding the assessment of these data should be directed to the Chief, Data Operations Branch, 1400 Independence Road, Rolla, Missouri 65401 or NGTOCoperations@usgs.gov.

Materials Received: 5/15/2012

Project Type: GPSC

Project ID: San Luis Valley LiDAR

Project Description: V13, 1.0 Meter NPS LiDAR

Project Alias(es):

Year of Collection: 2011

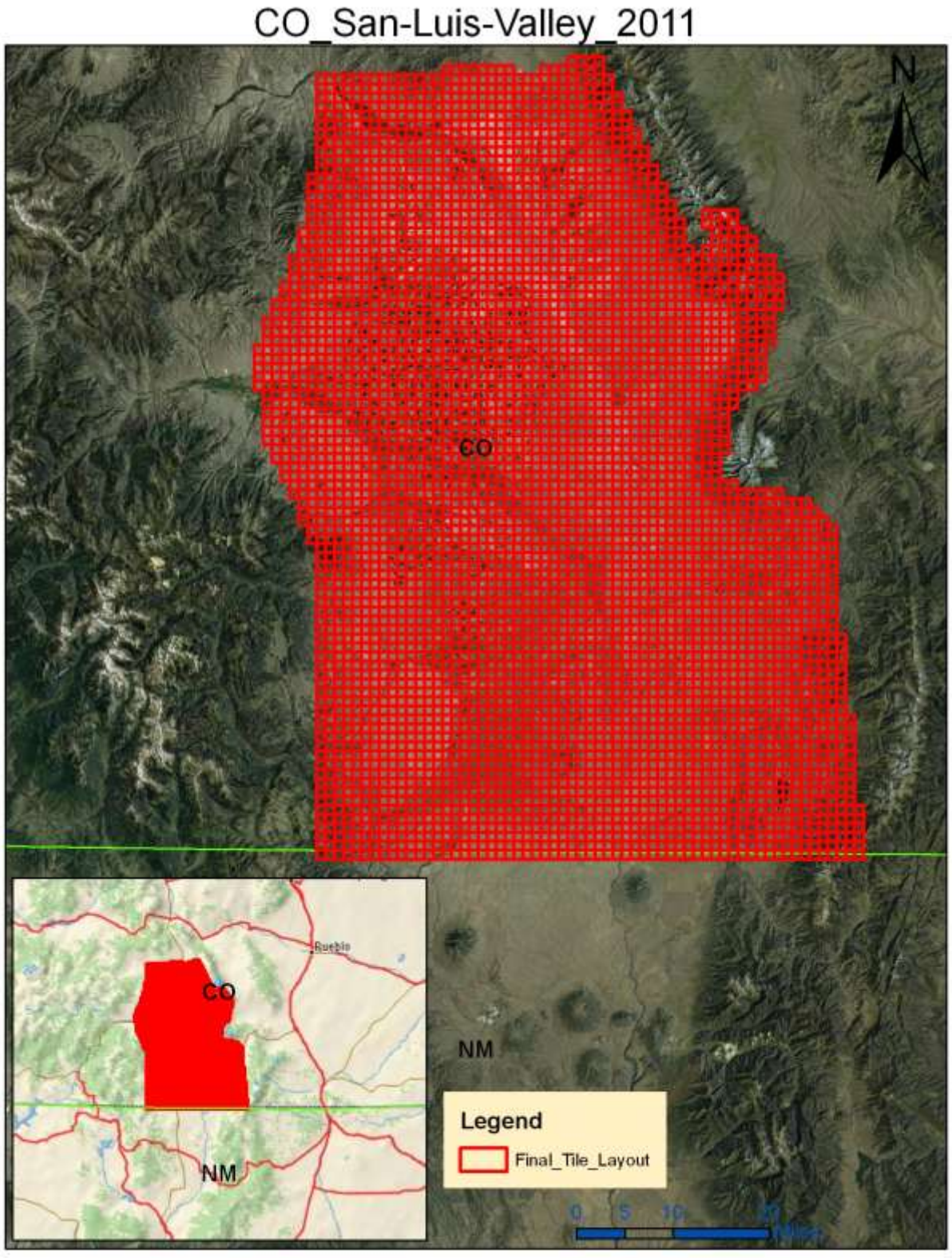
Lot 1&2 of 2 lots.

Project Extent:

☑ Project Extent image?

Project Tiling Scheme:

☑ Project Tiling Scheme image?



Contractor:

Applicable Specification:

Aerometric, Inc.	V13

Licensing Restrictions:

☐ Third Party Performed QA?

Project Points of Contact:

POC Name	Type	Primary Phone	E-Mail
Mike Duncan	CPT	573-308-3799	jduncan@usgs.gov

Project Deliverables

All project deliverables must be supplied according to collection and processing specifications. The USGS will postpone the QA process when any of the required deliverables are missing. When deliverables are missing, the Contracting Officer Technical Representative (COTR) will be contacted by the Elevation/Orthoimagery Section supervisor and informed of the problem. Processing will resume after the COTR has coordinated the deposition of remaining deliverables.

- [x] Collection Report
- [x] Survey Report
- [x] Processing Report
- [x] QA/QC Report
- [x] Control and Calibration Points
- [x] Project Shapefile/Geodatabase
- [x] Project Tiling Scheme Shapefile/Gdb
- [ ] Control Point Shapefile/Gdb
- [x] Breakline Shapefile/Gdb
- [x] Project XML Metadata

Multi-File Deliverables

File Type	Quantity
[x] Swath LAS Files [x] Required? [x] XML Metadata?	560
[x] Intensity Image Files [ ] Required?	4850
[x] Tiled LAS Files [x] Required? [x] XML Metadata?	4633
[x] Breakline Files [x] Required? [x] XML Metadata?	2
[x] Bare-Earth DEM Files [x] Required? [x] XML Metadata?	4633

Additional Deliverables

	Item
[x]	Intensity XML and HTML Metadata
[x]	20 FEMA Contour Shapefiles
[x]	19 FEMA area DEMs .img
[x]	3 FEMA Metadata.html (Contours, DEM, Shapefile).
[x]	3 FEMA Metadata .xml (Contours, DEM, Shapefile).
[x]	3 FEMA Shapefiles (Tile Layout; Limits; Water, streams, and breakline Breaklines)
[x]	FEMA Area Master Contours Shapefile

Errors, Anomalies, Other Issues to document? (•) Yes ( ) No

Final Control provided as txt files only. NGTOC used these to create a final control shapefile for vertical accuracy testing.

Project Geographic Information

Areal Extent:

3880.2

Sq Mi

Grid Size:

1.0

meters

Tile Size:

1500

meters

Nominal Pulse Spacing: 1.0 meters

Vertical Datum: NAVD88 meters

Horizontal Datum: NAD83 meters

Project Projection/Coordinate Reference System: UTM_Zone_13N meters.

This Projection Coordinate Reference System is consistent across the following deliverables:

- ☑ Project Shapefile/Geodatabase
- ☑ Project Tiling Scheme Shapefile/Gdb
- ☑ Checkpoints Shapefile/Geodatabase
- ☑ Project XML Metadata File
- ☑ Swath LAS XML Metadata File
- ☑ Classified LAS XML Metadata File
- ☑ Breaklines XML Metadata File
- ☑ Bare-Earth DEM XML Metadata File
- ☑ Swath LAS Files
- ☑ Classified LAS Files
- ☑ Breaklines Files
- ☑ Bare-Earth DEM Files

Review Cycle

This section documents who performed the QA Review on a project as well as when QA reviews were started, actions passed, received, and completed.

Review Start Date: 5/25/2012

Action to Contractor Date	Issue Description	Return Date
6/21/2012	Double Line Stream Flatten, Look at Marked Issues (issues fixed in redelivery)	7/19/2012

Review Complete: 8/2/2012

Metadata Review

Provided metadata files have been parsed using 'mp' metadata parser. Any errors generated by the parser are documented below for reference and/or corrective action.

The Project XML Metadata file parsed without errors.

The Swath LAS XML Metadata file parsed without errors.

The Classified LAS XML Metadata file parsed without errors.

The Breakline XML Metadata file parsed without errors.

The Bare-Earth DEM XML Metadata file parsed without errors.

Project QA/QC Report Review

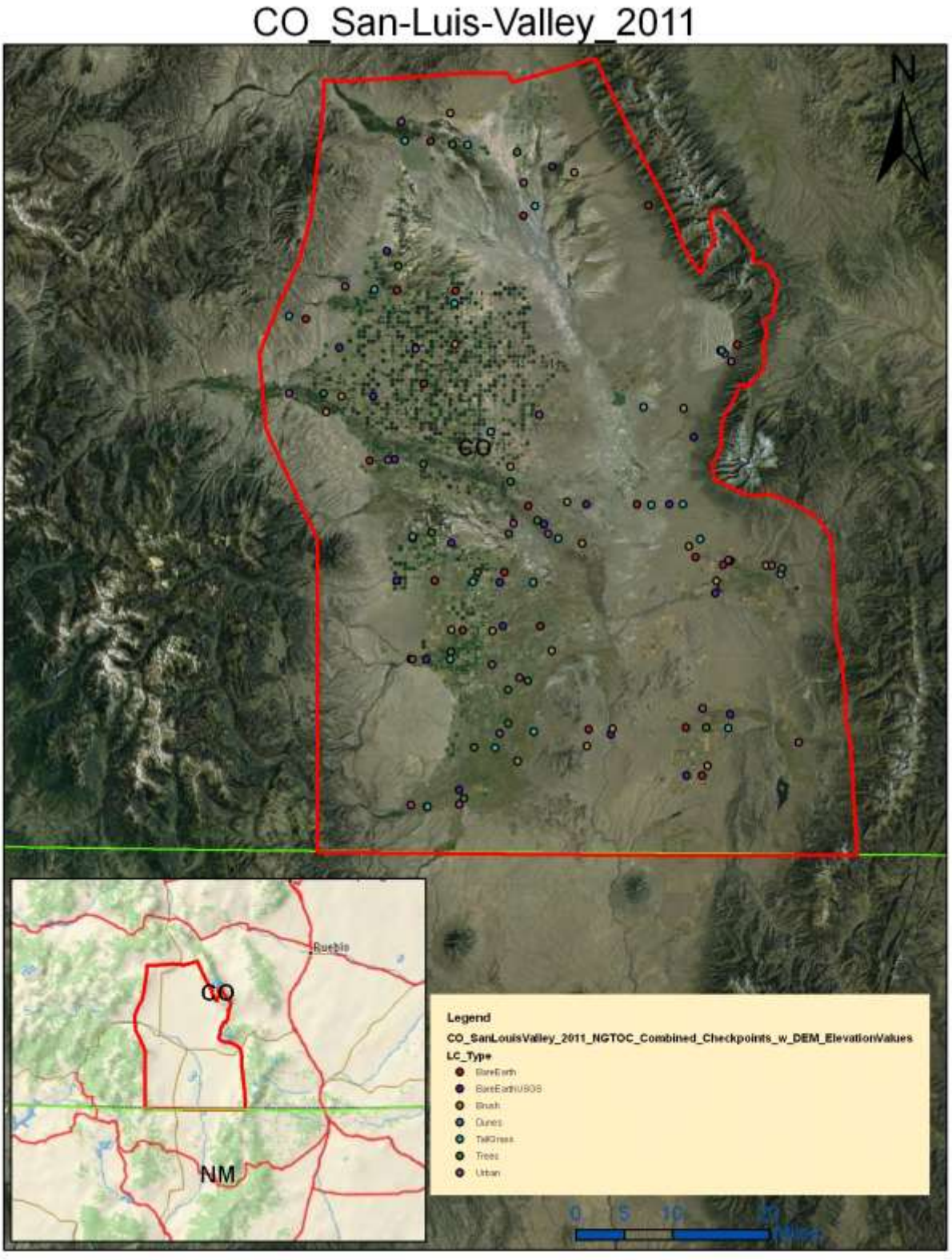
ASPRS recommends that checkpoint surveys be used to verify the vertical accuracy of LiDAR data sets. Checkpoints are to be collected by an independent survey firm licensed in the particular state(s) where the project is located. While subjective, checkpoints should be well distributed throughout the dataset. National Standards for Spatial Data Accuracy (NSSDA) guidance states that checkpoints may be distributed more densely in the vicinity of important features and more sparsely in areas that are of little or no interest. Checkpoints should be distributed so that points are spaced at intervals of at least ten percent of the diagonal distance across the dataset and at least twenty percent of the points are located in each quadrant of the dataset.

NSSDA and ASPRS require that a minimum of twenty checkpoints (thirty is preferred) are collected for each major land cover category represented in the LiDAR data. Checkpoints should be selected on flat terrain, or on uniformly sloping terrain in all directions from each checkpoint. They should not be selected near severe breaks in slope, such as bridge abutments, edges of roads, or near river bluffs. Checkpoints are an important component of the USGS QA process. There is the presumption that the checkpoint surveys are error free and the discrepancies are attributable to the LiDAR dataset supplied.

For this dataset, USGS checked the spatial distribution of checkpoints with an emphasis on the bare-earth (open terrain) points; the number of points per class; the methodology used to collect these points; and the relationship between the data supplier and checkpoint collector. When independent control data are available, USGS has incorporated this into the analysis.

Checkpoint Shapefile or Geodatabase:

☑ Checkpoint Distribution Image?



The following land cover classes are represented in this dataset (uncheck any that do not apply):

- [x] Bare Earth
- [x] Tall Weeds and Crops
- [x] Brush Lands and Low Trees
- [x] Forested Areas Fully Covered by Trees
- [x] Urban Areas with Dense Man-Made Structures

There are a minimum of 20 checkpoints for each land cover class represented. Points within each class are uniformly distributed throughout the dataset. USGS wasable to locate independent checkpoints for this analysis. USGS acceptsthe quality of the checkpoint data for these LiDAR datasets.

Errors, Anomalies, Other Issues to document? (•) Yes ( ) No

- [ ] Image?

Again, NGTOC had to compile a shapefile from the TXT checkpoints.

Accuracy values are reported in terms of Fundamental Vertical Accuracy (FVA), Supplemental Vertical Accuracy(s) (SVA), and Consolidated Vertical Accuracy (CVA).

Accuracy values are reported in: meters

Required FVA Value is 0.245 meters or less.
Target SVA Value is 0.363 meters or less.
Required CVA Value is 0.363 meters or less.

The reported FVA of the LAS Swath data is 0.12 meters.

The reported FVA of the Bare-Earth DEM data is 0.142 meters.

SVA are required for each land cover type present in the data set with the exception of bare-earth. SVA is calculated and reported as a 95th Percentile Error.

Land Cover Type	SVA Value	Units
Tall Weeds and Crops	.13	meters

Brush Lands and Low Trees	.21	meters
Forested Areas Fully Covered by Trees	.28	meters
Urban Areas with Dense Man-Made Structu...	.165	meters

The reported CVA of this data set is: .22 meters.

LAS Swath File Review

LAS swath files or raw unclassified LiDAR data are reviewed to assess the quality control used by the data supplier during collection. Furthermore, LAS swath data are checked for positional accuracy. The data supplier should have calculated the Fundamental Vertical Accuracy using ground control checkpoints measured in clear open terrain. The following was determined for LAS swath data for this project:

LAS Version

(•) LAS 1.2 ( ) LAS1.3 ( ) LAS 1.4

Swath File Characteristics

- [x] Separate folder for LAS swath files
- [ ] Each swath files <= 2GB
- [ ] *If specified, *.wdp files for full waveform have been provided

The reported FVA of the LAS swath data is 0.12 meters.

Based on this review, the USGS accepts the LAS swath file data.

Errors, Anomalies, Other Issues to document? (•) Yes ( ) No

- [ ] Image?

Swath LAS File 7075_B.las is larger than 2 GB [2.08 GB (2,240,863,517 bytes)].

LAS Tile File Review

Classified LAS tile files are used to build digital terrain models using the points classified as ground. Therefore, it is important that the classified LAS are of sufficient quality to ensure that the derivative product accurately represents the landscape that was measured. The following was determined for classified LAS files for this project:

Classified LAS Tile File Characteristics

- [x] Separate folder for Classified LAS tile files
- [ ] Classified LAS tile files conform to Project Tiling Scheme
- [x] Quantity of Classified LAS tile files conforms to Project Tiling Scheme
- [x] Classified LAS tile files do not overlap
- [x] Classified LAS tile files are uniform in size
- [x] Classified LAS tile files have no points classified as '12'

- [x] Point classifications are limited to the standard values listed below:

Code	Description
1	Processed, but unclassified
2	Bare-earth ground
7	Noise (low or high, manually identified, if needed)
9	Water
10	Ignored ground (breakline proximity)
11	Withheld (if the "Withheld" bit is not implemented in processing software)

- [ ] Buy up?

Based on this review, the USGS accepts the classified LAS tile file data.

Errors, Anomalies, Other Issues to document? (•) Yes ( ) No

- [ ] Image?

Tiling Scheme differs from that in the task order, but is still logical.

Breakline File Review

Breaklines are vector feature classes that are used to hydro-flatten the bare earth Digital Elevation Models.

Breakline File Characteristics

- [x] Separate folder for breakline files
- [x] All breaklines captured as PolylineZ or PolygonZ features
- [x] No missing or misplaced breaklines

Based on this review, the USGS accepts the breakline files.

Errors, Anomalies, Other Issues to document? (•) Yes ( ) No

- [ ] Image for error?

* Redelivery corrected the issues below in both regualr and FEMA DEMs.
There are potential greater than 2 Acre Waterbodies missing from the breaklines and missing greater than 100ft nominal width double line streams missing as well.
See the DEM review section for more information.

Bare-Earth DEM Tile File Review

The derived bare-earth DEM file receives a review of the vertical accuracies provided by the data supplier, vertical accuracies calculated by USGS using supplied and independent checkpoints, and a manual check of the appearance of the DEM layer.

Bare-Earth DEM files provided in the following format: Erdas Imagine *.img

Bare-Earth DEM Tile File Characteristics

- [x] Separate folder for bare-earth DEM files
- [x] DEM files conform to Project Tiling Scheme

- [x] Quantity of DEM files conforms to Project Tiling Scheme
- [x] DEM files do not overlap
- [x] DEM files are uniform in size
- [x] DEM files properly edge match
- [x] Independent check points are well distributed

All accuracy values reported in meters.

Reported Accuracies

Land Cover Category	# of Points	Fundamental Vertical Accuracy @95% Confidence Interval ($Accuracy_z$) Required FVA = 0.245 or less.	Supplemental Vertical Accuracy @95th Percentile Error Target SVA = 0.363 or less.	Consolidated Vertical Accuracy @95th Percentile Error Required CVA = 0.363 or less.
Open Terrain	22	0.142		
Tall Weeds and Crops	21		0.13	
Brush Lands and Low Trees	21		0.21	
Forested Areas Fully Covered by Trees	22		.28	
Urban Areas with Dense Man-Made Structures	20		.165	
Consolidated	106			.22

- [x] QA performed Accuracy Calculations?

Calculated Accuracies

Land Cover Category	# of Points	Fundamental Vertical Accuracy @95% Confidence Interval ($Accuracy_z$) Required FVA = 0.245 or less.	Supplemental Vertical Accuracy @95th Percentile Error Target SVA = 0.363 or less.	Consolidated Vertical Accuracy @95th Percentile Error Required CVA = 0.363 or less.
Open Terrain	21	0.0997855817737		
Tall Weeds and Crops	21		0.132929995656	
Brush Lands and Low Trees	21		0.202992007136	
Forested Areas Fully	22		**0.36324400305**	

Covered by Trees				
Urban Areas with Dense Man-Made Structures	20		0.176411300898	
Consolidated	105			0.225935995579

Based on this review, the USGS recommends the bare-earth DEM files for inclusion in the 1/3 Arc-Second National Elevation Dataset.

Based on this review, the USGS accepts the bare-earth DEM files.

Bare-Earth DEM Anomalies, Errors, Other Issues

Errors, Anomalies, Other Issues to document? (•) Yes ( ) No

☐ Image?

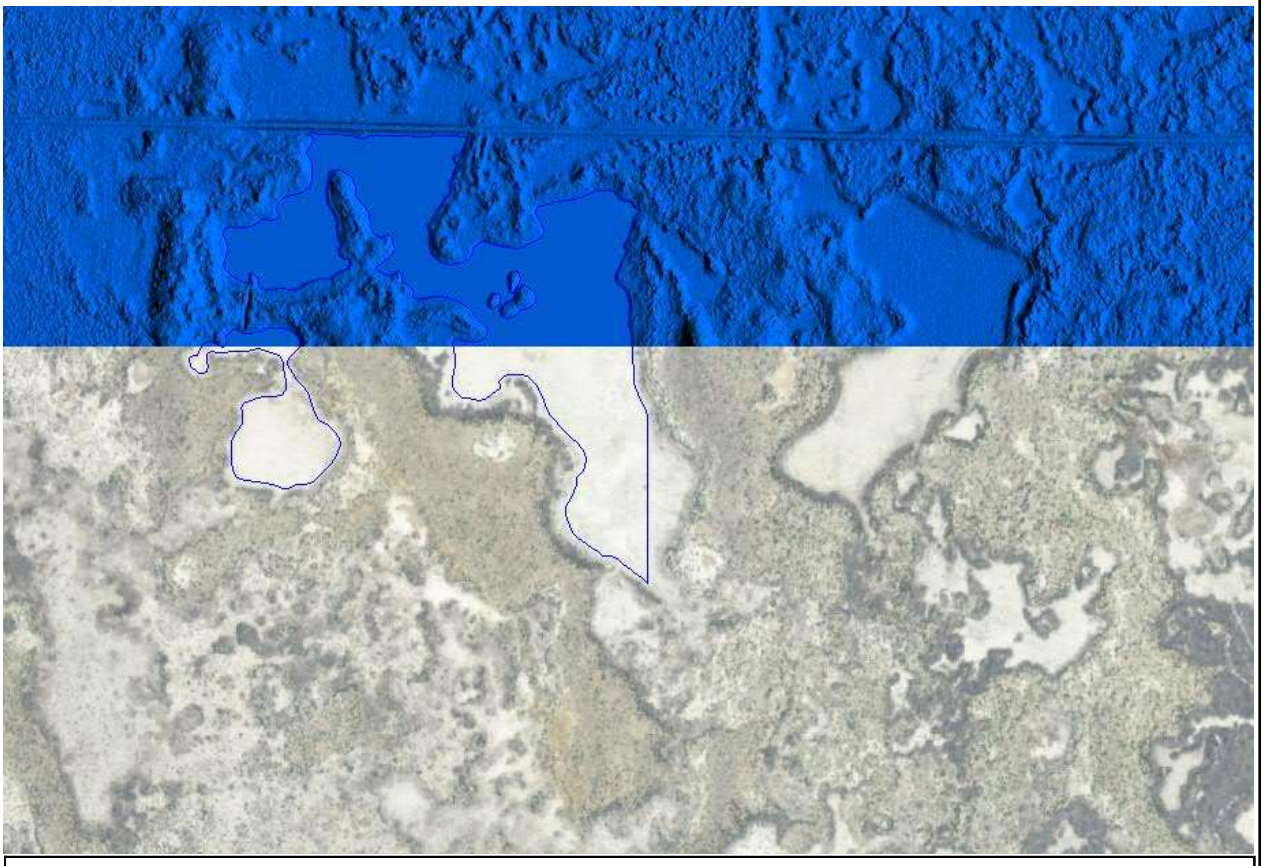
*Redelivered Data addressed the most prominent of these issues.
It should first be stated that this is a very large project covering very diverse landscapes and that overall the Bare Earth DEMs appear to be in very good order. Quantitatively the DEMs are in very good standing. The qualitative review found most of the data to be in good standing and will detail below issues and potential issues that were largely encountered in relation to the central valley, farmland, and treatment of the Rio Grande River. Unavoidably, some subjective calls had to be made for these areas and the following will attempt to characterize the issues present.

☑ Image?

OID	Type	N	Min	Max	Range	Mean	StdDev	Skew	Kurtosis	RMSE	NSSDA	Percen
0	BareEarth	22	-0.226936	0.078895	0.305831	-0.023941	0.068283	-1.06195	1.60411	0.070878	0.138922	0.11601
1	BareEarthUSGS	21	-0.120898	0.060965	0.181863	-0.018584	0.048568	-0.386634	-0.692466	0.050911	0.099786	0.103883
2	Brush	21	-0.202992	0.225936	0.428928	0.047204	0.116617	-0.462277	-0.593247	0.123207	0.241486	0.202992
3	Dunes	14	-0.255117	-0.004109	0.251008	-0.112793	0.079946	-0.12726	-1.27804	0.136591	0.267718	0.223847
4	TallGrass	21	-0.13509	0.13293	0.26802	0.013859	0.060589	-0.53581	0.436478	0.060732	0.119034	0.13293
5	Trees	22	-0.783906	0.251918	1.03582	-0.062525	0.225281	-1.39295	2.73275	0.22881	0.448468	0.363244
6	Urban	20	-0.184074	0.086074	0.270148	-0.027797	0.071733	-0.631459	-0.153498	0.07524	0.147469	0.176411
7	All Points	14	-0.783906	0.251918	1.03582	-0.022307	0.120037	-1.88541	10.7229	0.121673	0.238478	0.225936

Note that non-USGS BareEarth and Dunes SVA Categories were also tested (both passed) and were incorporated into the CVA result. See the DEM Vertical Accuracy Statistics Report for more information.

☑ Image?

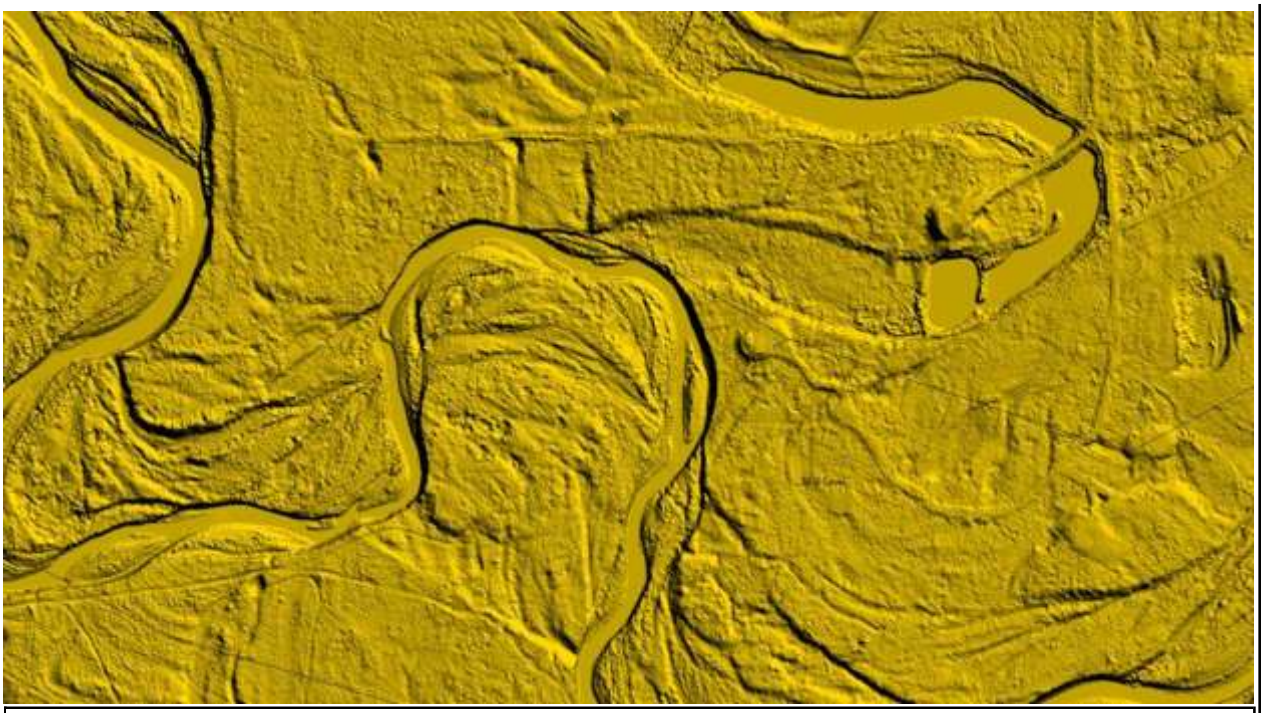


Above, we see we see an instance of waterbodies flattened and their respective breaklines. It is evident from the orthoimagery and DEM that there is a waterbody located to the right that was not flattened; however, there is sufficient density (lack of heavy tinning) within that waterbody to suggest that this feature was either dried up or very shallow at the time the LiDAR was flown. Some of these areas have been marked in the "DEM Error Tags" shapefile. However, unless there is heavy tinning, these areas are acceptable as is.

☑ Image?

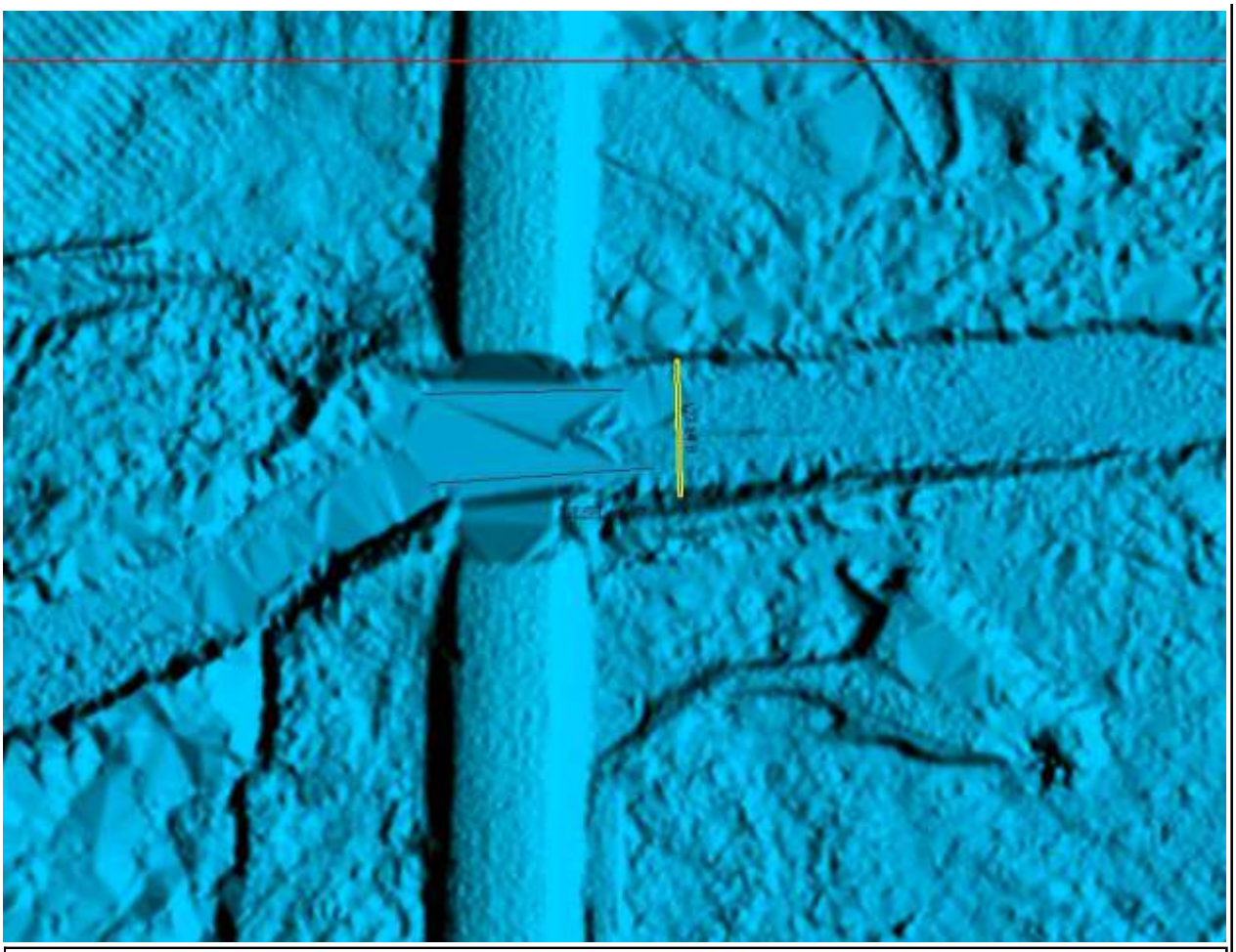
Pictured is a retention pond (there are numerous comparable features in this dataset) which were not flattened. Many are between 1 and 2 Acres, which technically do not require flattening; however a good number are greater than 2 Acers. Some of these ponds showcase clear tinning and should have been flattened; however, a good deal more show little tinning and are indicative of dry conditions or shallow water (the image above is a mixture of tinning and good point density). While some of these instances are marked in the "DEM Error Tags" Shapefile, not all instances have been marked. If ponds are greater than 2 Acers and exhibit tinning they should be flattened.

☑ Image?



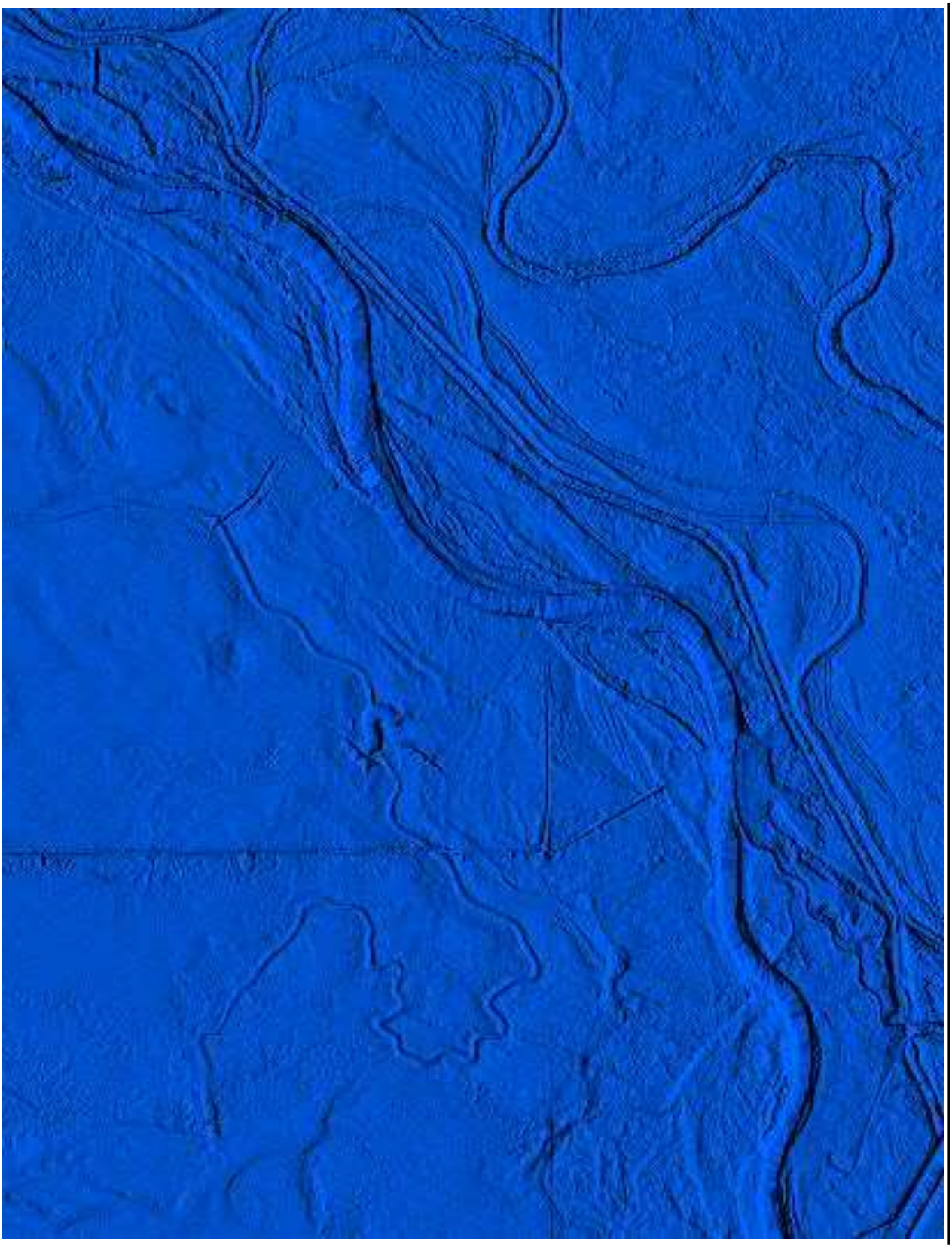
Pictured is an image or the Redelived Data, clearly the Rio Grande was hydro Flattened throughout the dataset and the issues below relating to double-line streams have been corrected.

☑ Image?



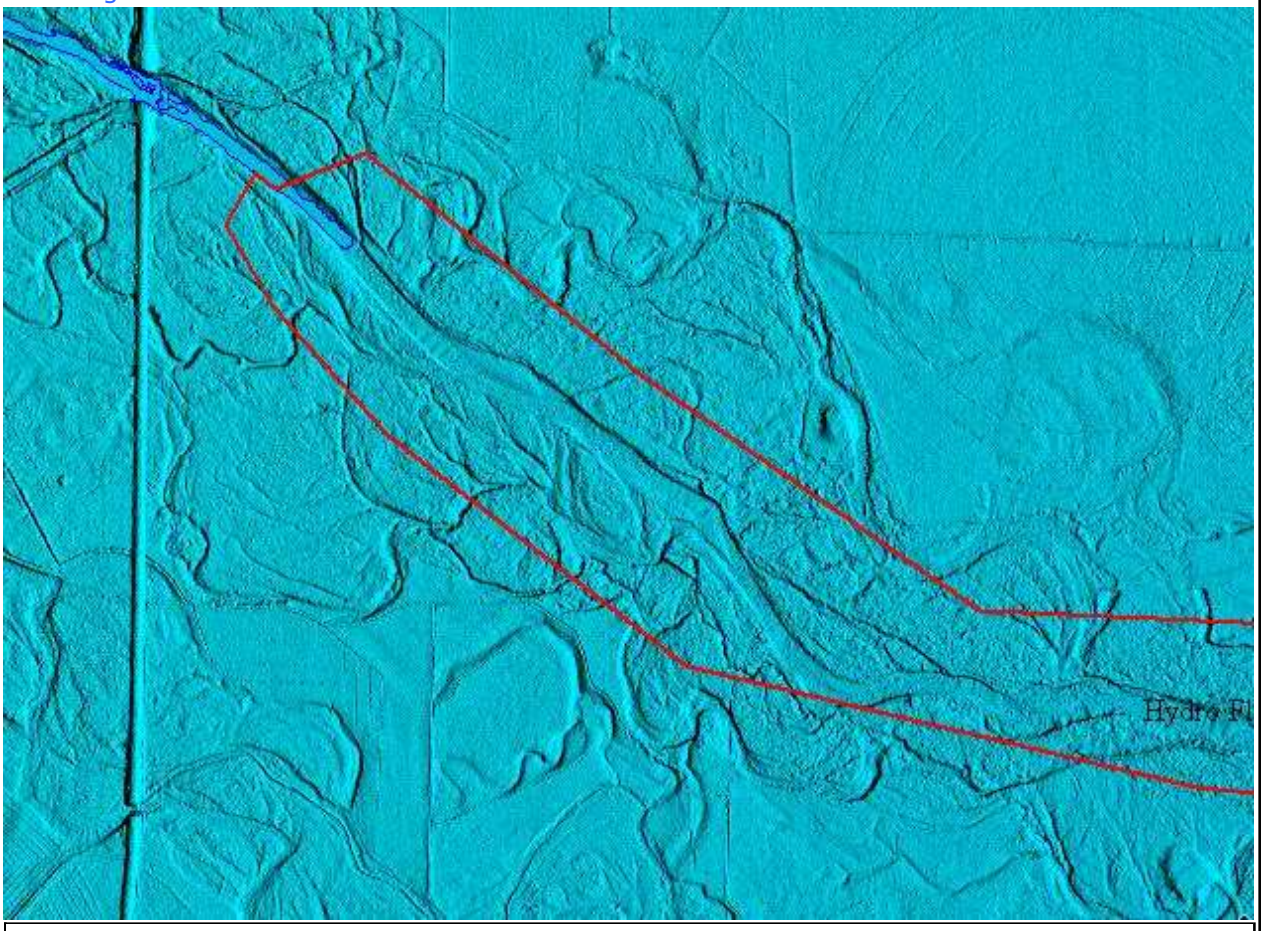
Pictured here is a portion of the Rio Grande River, a Double Line Stream (DLS), this particular section is greater than 100 Ft. across and should have been bank to bank hydro flattened with monotonic flow. The V13 LiDAR specification calls for flattening of streams 100ft across in diameter, even if portions of the stream go under that 100 Ft. metric at times ("100' nominal width: This should not unnecessarily break a stream or river into multiple segments. At times it may squeeze slightly below 100' for short segments.). Further, those portions going under 100 Ft. should still be hydro flattened. While a good portion of the Rio Grande and other rivers were hydro flattened there are still areas not flattened that exhibit heavy tinning. These areas have been marked, in part, in the "DEM Error Tags" Shapefile; however, only in sections to highlight the issue, this is not to say that only those sections need be fixed, the river as a whole needs to be treated.

☑ Image?



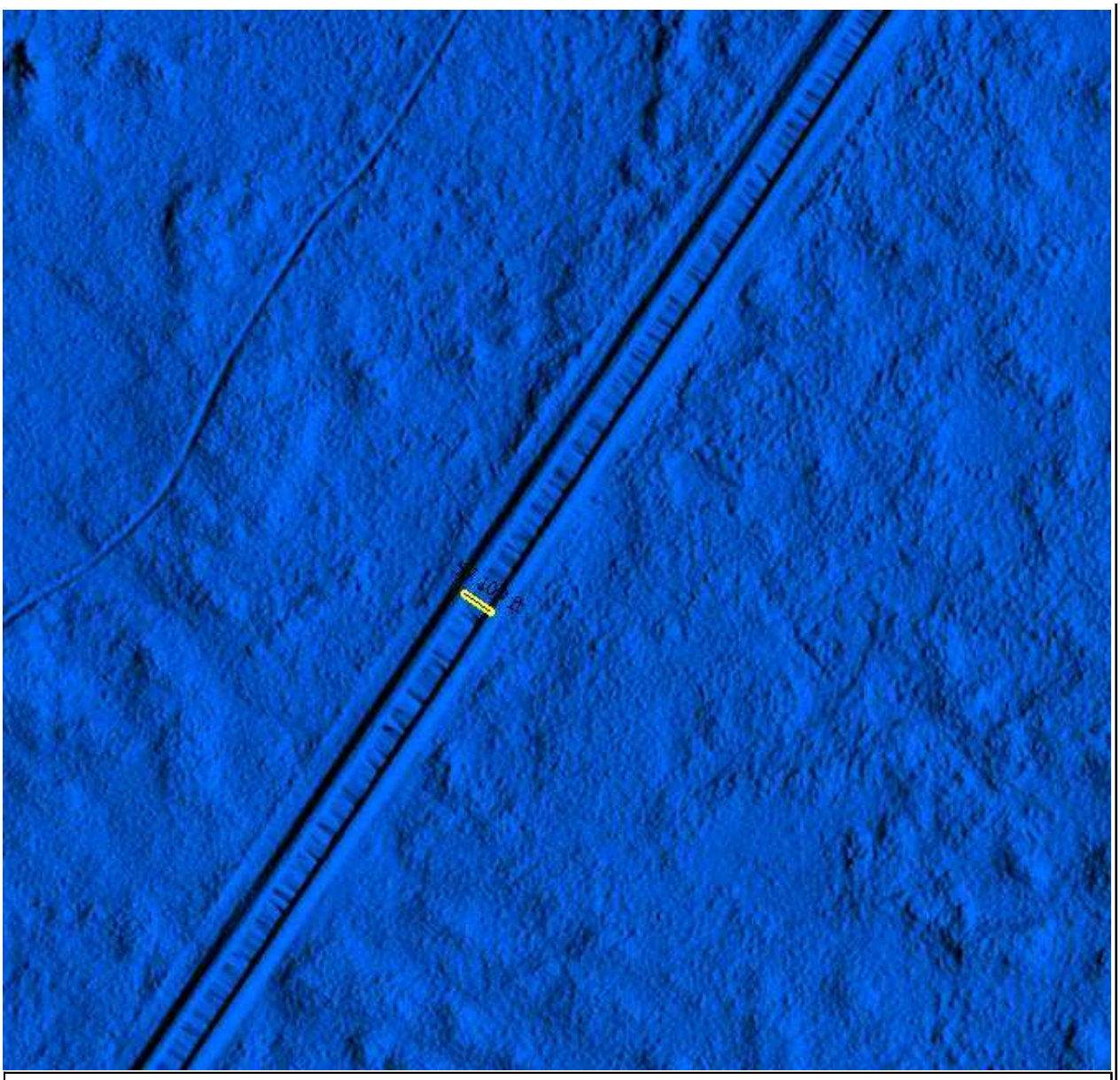
Here is another section of a DLS River that exhibits heaving tinning. In this instance the bank to bank distance is just under 100ft for some distance, but still connects to larger portions of the river further upstream and downstream.

☑ Image?



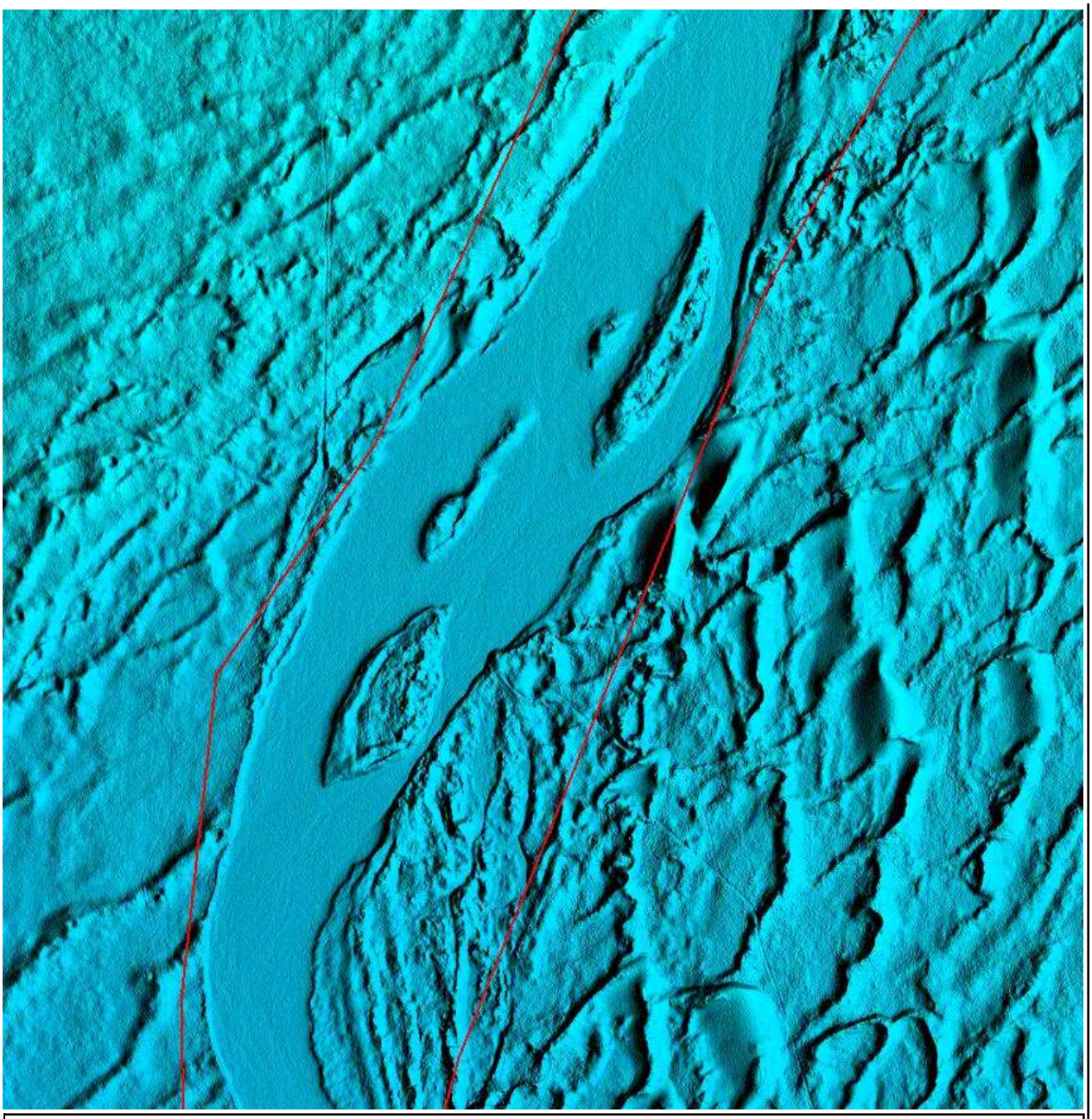
Here is an image showcasing inconsistent treatment of the DLS. The breakline and hydro flattening ends abruptly.

☑ Image?



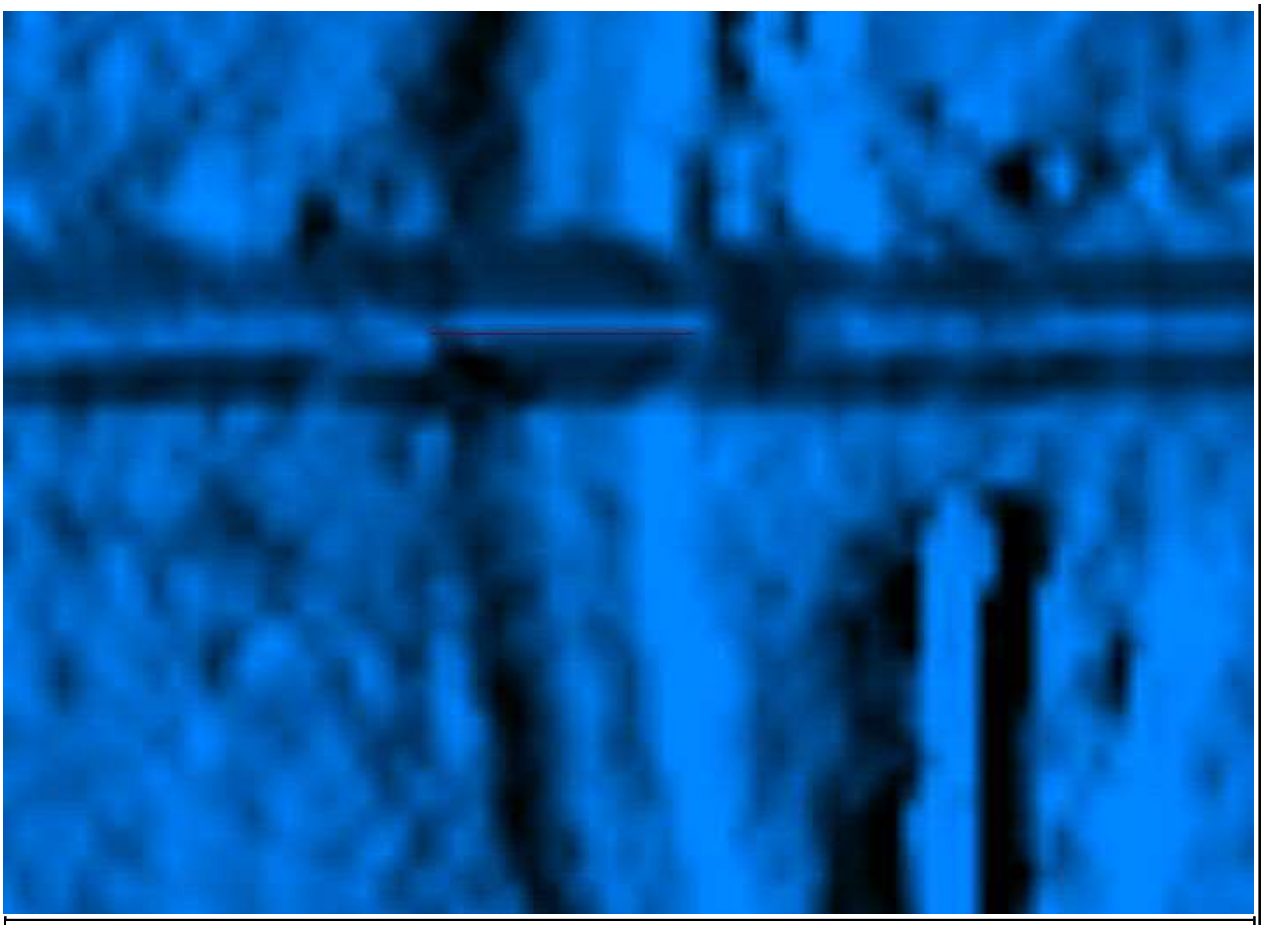
Pictured here is a less than 100ft nominal width Canal which exhibits heavy tinning and does not technically need to be "Hydro Flattened" because it does not grow greater than 100ft at any point.

☑ Image?



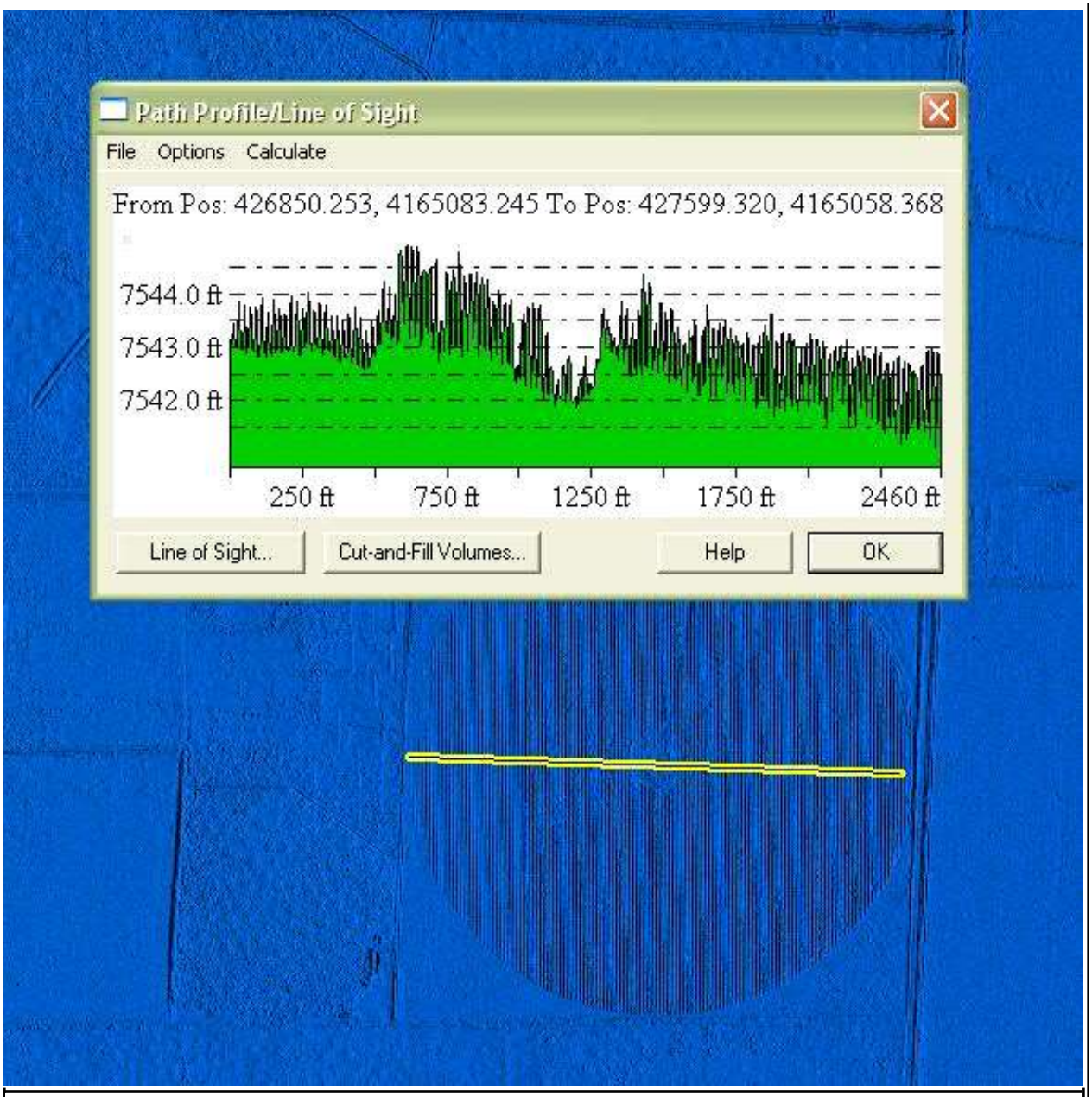
*Determined this is acceptable.
Above is a DLS which has a greater than 100ft nominal width (near the sand dunes), but was not flattened. As with many of the retention ponds and waterbodies, it exhibits higher point density and little tinning indication dry or shallow conditions and need not be flattened.

☑ Image?



Not an error, this image is to showcase the breaklines inserted at select bridges or culverts by the vendor(s) to allow for better drainage or hydro conditioning.

☑ Image?

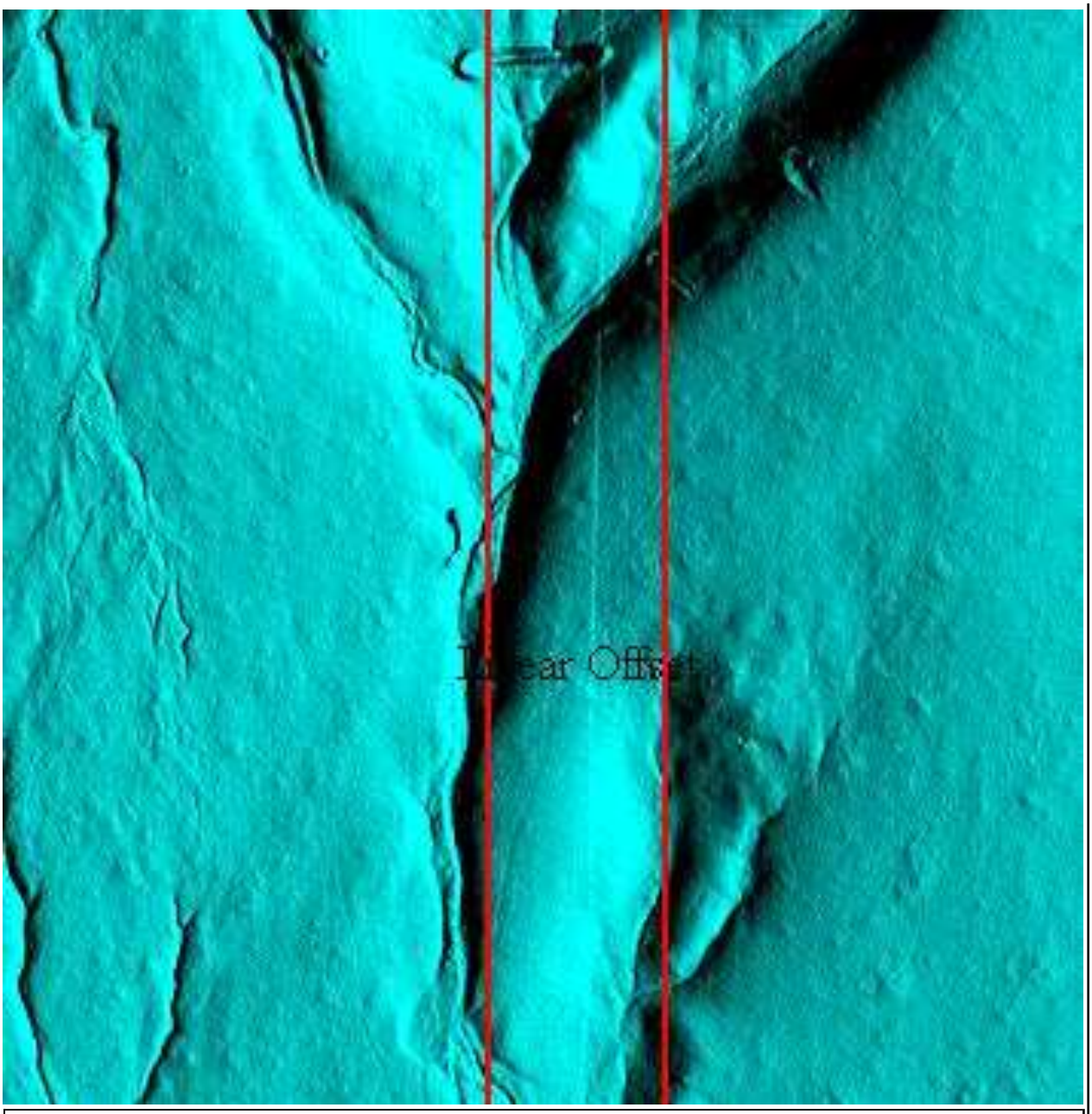


The Vendor provided the USGS with the statement that this project was flown over multiple dates and during crop harvest, leaving some strange patterns in many of the crop circles. Of concern however , is how well filtered the point cloud was in order to derive the Bare Earth in these areas, if only last returns and first and only returns were used, then there may be little the vendor could do to make the elevations more consistent as last returns and first and only returns will unavoidable not all penetrate to the actual ground. However, the profile graph pictured above does beg the question of if some more extensive manual editing could be performed to eliminate the spikes pictured above. Many, though by no means all of these are marked in the "DEM Error Tags" Shapefile.

☑ Image?

Also relating the harvest is the issue of suspected hay bales near many of the farms and highways. Several Ortho Images and profile graphs suggest the presence of hay bales in the DEMs. Feedback on the treatment of these features in this dataset would be welcome.

☑ Image?



Linear offsets such as the one pictured are rare in the dataset and do not significantly effect the elevations in the DEM. Moreover, it is not clear if this is caused by a genuine calibration/registration issue, natural fault, or software visualization, but the events have been noted and tagged.

☐ Image?

*Update FEMA areas were given full hydro enforcement via the use of additional breaklines and the issues in the images below have been largely corrected.
As for the FEMA Area DEMs, they were contracted as to be "Hydro Enforced", which implies heavy use of breaklines to achieve a surface well suited for hydrologic modeling of flow connectivity and flood risk assessment. For this reason, attention to use of breaklines in heavily tinned areas should be especially rigorous. There are quite a few tinned areas in these DEMs which should be appropriately leveled (Waterbodies and Double Line Streams). As well as a few culverts that should be removed. Please see the FEMA_DEM_Error_Tags Shapefile for more information and images below for more information.

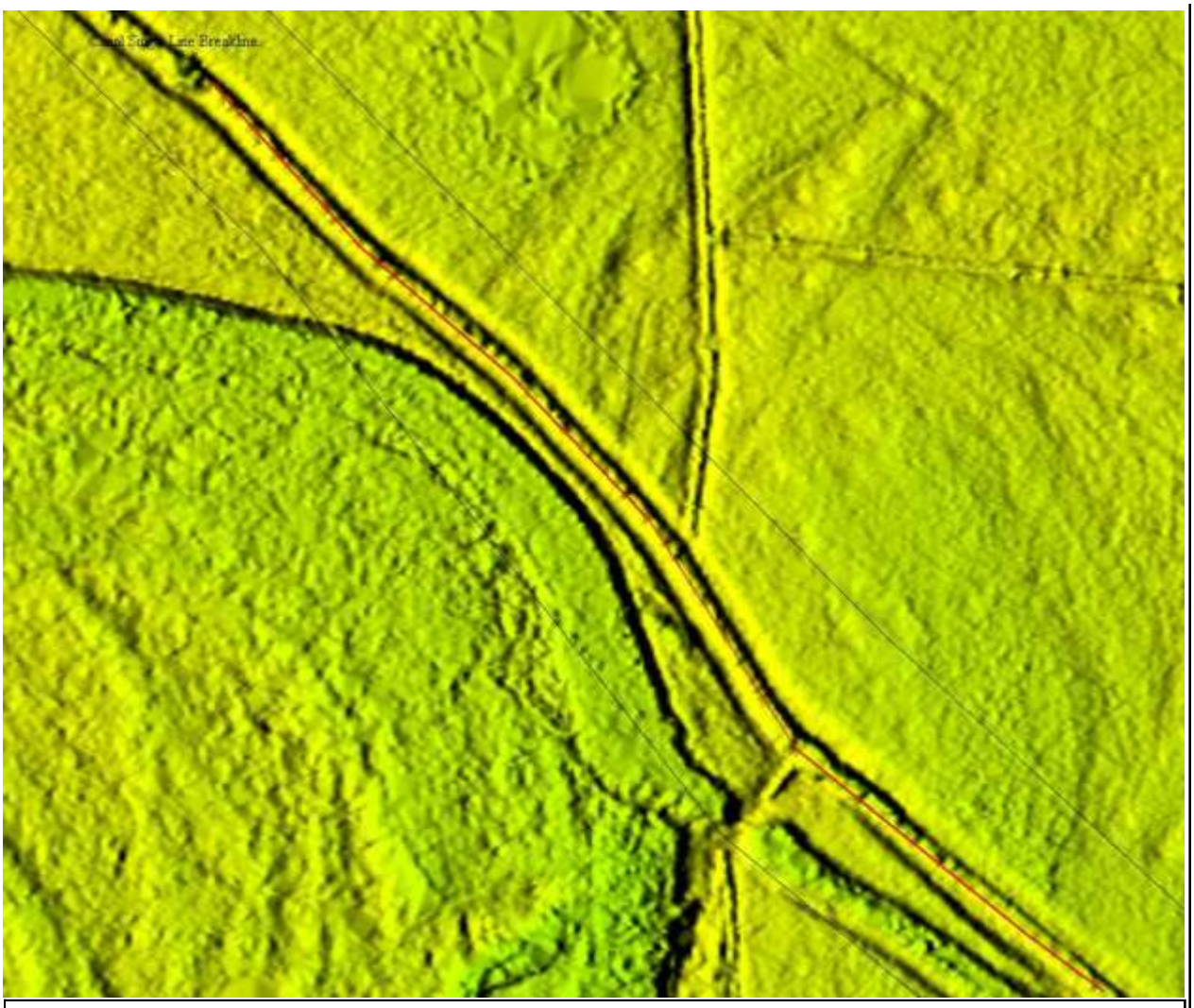
☑ Image?

Leveling of Waterbodies.

☑ Image?

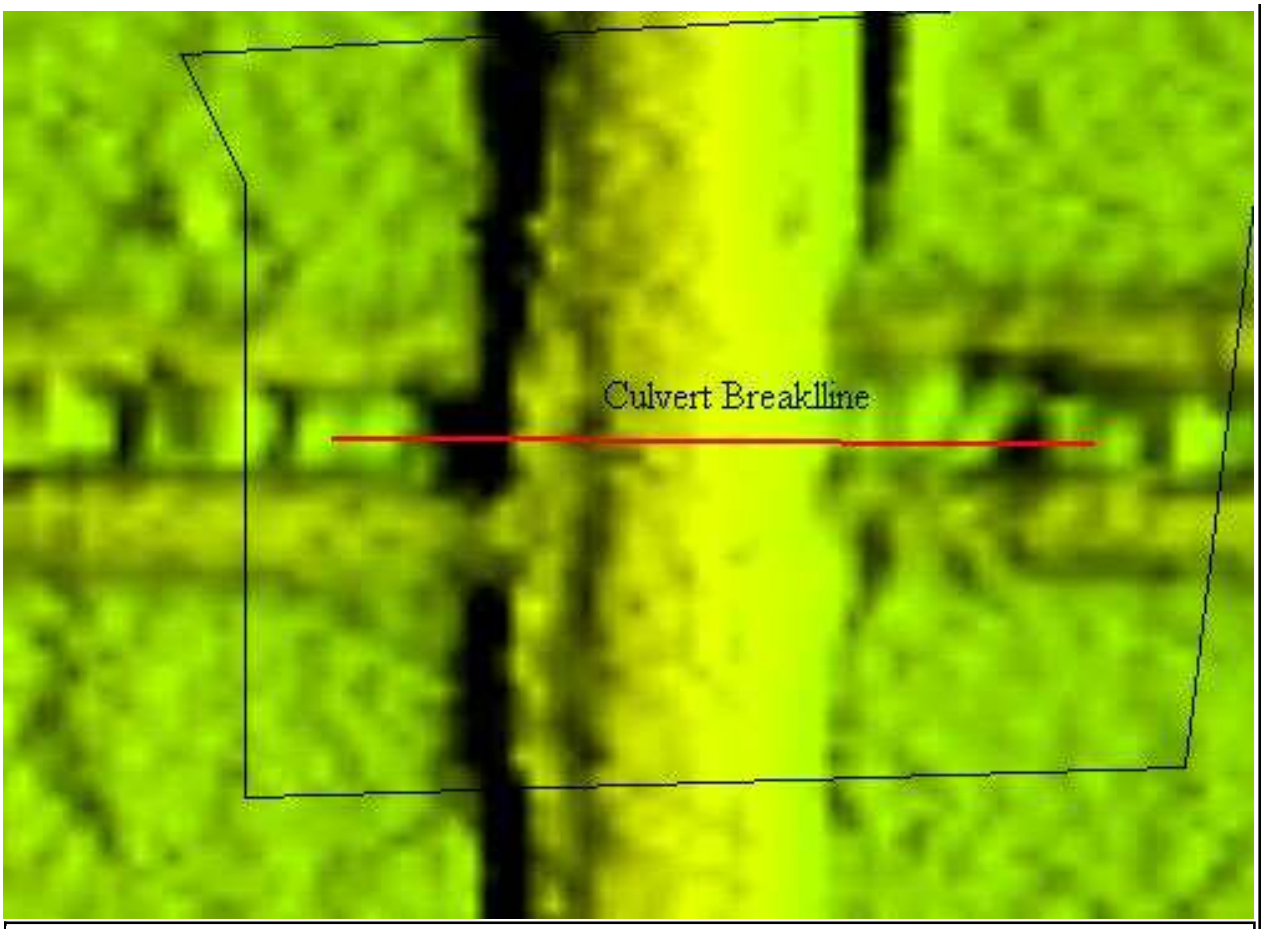
Leveling of Double Line Streams

☑ Image?



As I understand the term "Hydro Enforced" DEMs/DTMs should make use of single line breaklines to better model flow along narrow channels and canals.

☑ Image?



In accordance with the Previous Comment, "Hydro Enforced" models should have connectivity in through features like culverts, meaning the road would be removed at this location and the canal would continue through. In other words, a "Hydro Enforced" DEM depicts hydrographic connection over topographic features; whereas, a "Hydro Flattened" DEM places the onus on Topography over Hydrography.

This is the end of the report.