

LiDAR and Its Use in the Identification of Faults, Fractures and Subsurface Structures in Drift Covered Areas*

Chuck Knox¹

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¹Knox Geological LLC, Fort Wayne, IN, USA (f4tknox@comcast.net)

Abstract

LiDAR (Light Detection and Ranging) is the scanning of the earth's surface with an airborne laser and the recording of the reflected scan. Individual laser pulses are projected upon the earth's surface with the individual pulse's reflection intensity, trajectory and corresponding GPS positioning digitally recorded. For the purpose of this report, we are only interested in the results of the bare earth or last return. LiDAR bare earth returns strip away all vegetation and culture to provide a stunningly clear digital image of the earth's surface and it is with these images of the surface we are able to locate buried faults, fractures and sub surface structures.

Very faint signatures of the upward propagation of geologic structures can be measured on the surface using LiDAR derived digital elevation models. Faults and fractures also have an upward propagation and a percentage can be traced on the surface using slope angle datasets. Slope angle terrain datasets are very precise and are proving to be an effective method of identifying sub surface faults and fractures on the surface of drift covered areas. We are seeing correlations between fracture-controlled Ordovician Trenton/Black-River oil and gas fields in Indiana and Michigan with higher slope angles. Albion-Scipio and the Adrian fields of Michigan have very distinct slope angle signatures. Differential compaction of formations above Devonian reefs in southwest Indiana in some cases can be modeled on the surface using LiDAR derived digital elevation models, with the Hulman oil field in Vigo County, Indiana being a prime example.

We are just beginning to integrate LiDAR data with other exploration methods such as magnetics, gravity, 2D and 3D seismic. The digital nature of LiDAR makes it a good fit with the other exploration methods used in the industry today. Current LiDAR technology is advancing rapidly, multispectral arrays, remote controlled drones and less expensive more powerful cameras will soon be the norm. In the very near future, LiDAR derived digital elevation models and terrain datasets will be important tools to be used by explorers looking for new oil and gas reserves.

References Cited

Keller, S.J., and T.F. Abdulkareem, 1980, Post-Knox unconformity - significance at Unionport gas-storage project and relationship to petroleum exploration in Indiana: Indiana Geological Survey Occasional Paper 31, 19 p.

Wickstrom, L.H., J.D. Gray, and R.D. Stieglitz, 1992, Stratigraphy, structure, and production history of the Trenton Limestone (Ordovician) and adjacent strata in northwestern Ohio: Ohio Division of Geological Survey, Report of Investigations No. 143, 78 p.

LiDAR and its Use in the Identification of Faults, Fractures and Sub Surface Structures in Drift Covered Areas

AAPG Eastern Section 9/22/15

Chuck Knox, Knox Geological LLC

Knox Geological LLC 6402 Old Trail Rd. Fort
Wayne, IN 46809 (260) 466-2422
f4tknox@comcast.net

LiDAR, which stands for *Light Detection and Ranging*, is a remote sensing method that uses light in the form of pulsed laser to measure ranges (variable distances) to the Earth. These light pulses-combined with other data recorded by the airborne system-generate precise, three-dimensional information about the shape of the Earth and its surface characteristics.

Noaa.gov/facts/lidar.html

Wrench Faulting Associated With
the Pokagon Line

Normal Faulting Associated
with the Fort Wayne Rift

LiDAR Derived DEM using Combined Hillshade and Raster of Flint Area Steuben County, Indiana



FIGURE 27.—Aerial photograph taken during drought of 1934 showing fault and fracture traces in the bed of the Maumee River along the Bowling Green Fault Zone. Southern edge of the France Stone Co. Waterville quarry is in upper right of photo. Forst Road bridge over the river is oriented N-S. Photo courtesy of the Ohio Historical Society.

Wickstrom,
Gray and
Stieglitz
1992

Aerial Photo of
the Maumee
River during the
drought of 1934
along the
Bowling Green
Fault Zone

Retreating Glaciers and the Signatures Left Behind

- Faults and Fractures at the Glacier/Bedrock Contact Influence the Melting of the Glacier
- Faults and Fractures in the Bedrock are Influenced by Daily Tidal Actions
- Heat From Friction and the Sub Surface Create Zones of Melting Above Faults and Fractures
- Kames and Eskars Develop Below Areas of Fractures in the Ice Leaving Geomorphic Signatures
- Early Drainage Patterns Follow Fractures in the Ice Which Correlate to Faults and Fractures in the Bedrock.
- Modern Drainage Patterns Follow the Early Glacial Drainage systems



Matanuska Glacier Palmer Alaska

Knox Geological LLC 6402 Old Trail Rd. Fort
Wayne, IN 46809 (260) 466-2422
f4tknox@comcast.net



Matanuska Glacier Palmer Alaska

Knox Geological LLC 6402 Old Trail Rd. Port
Wayne, IN 46809 (260) 466-2422
f4tknox@comcast.net



Matanuska Glacier Palmer Alaska

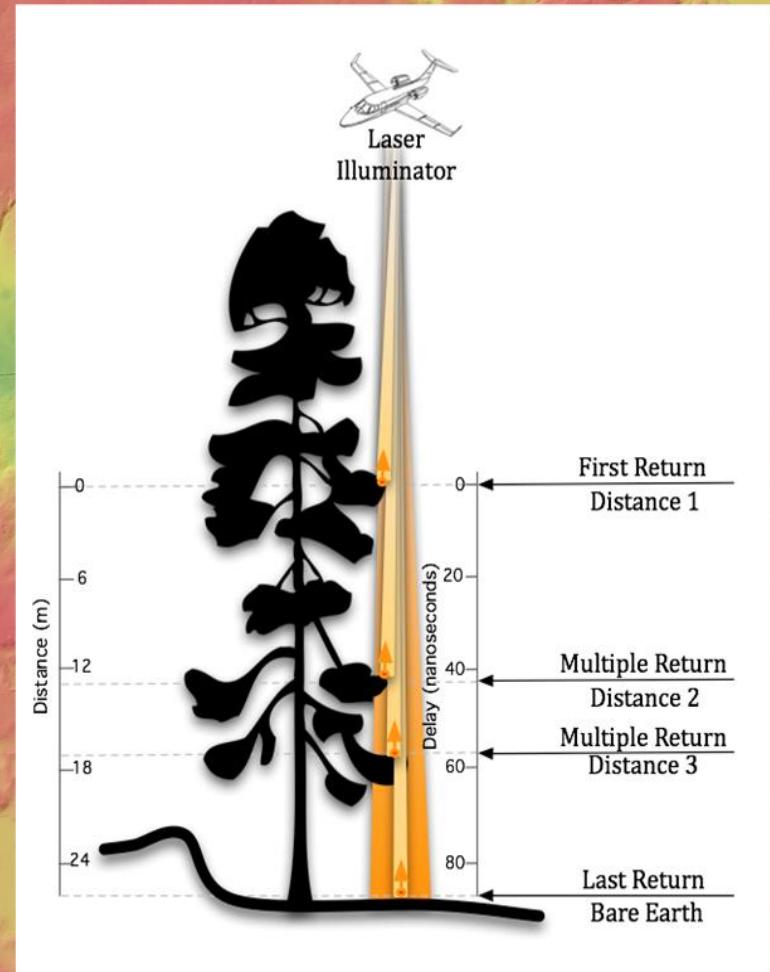
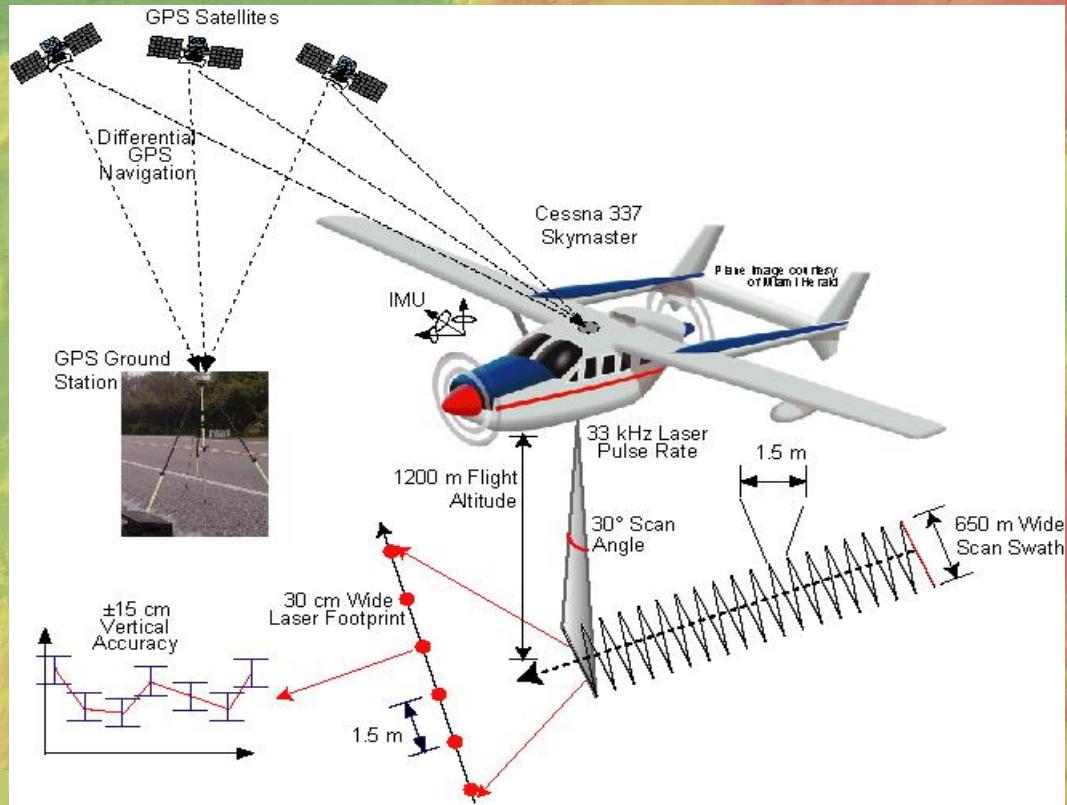
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Wayne, IN 46809 (260) 466-2422
f4tknox@comcast.net



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Knox Geological LLC 6402 Old Trail Rd. Fort
Wayne, IN 46809 (260) 466-2422
f4tknox@comcast.net

Collecting LiDAR Point Cloud Data



Working with Digital LiDAR Data

- Point Cloud Data is Stored as an LAS File
- Millions of Point Cloud Points Creates Computer Processing Issues
- Only Using Last or Bare Earth Returns Reduces the Amount of Data Needing to be Processed
- ArcGIS is a Good Program to Convert Point Cloud Data Into Useable Information
- Two Methods for the Reduction of Point Cloud Data in ArcGIS
 - LAS Data Sets
 - Terrain Data Sets

LAS Data Sets

- The Data is Stored Digitally and Can be Used in Queries
- In ArcGIS More Tools are Available for Modeling of the Surface
- Each Point of the Point Cloud is Used in Surface Modeling
- Takes a Stupendous Amount of Computer Storage
- Needs Powerful Computer Processing Ability to Reduce the Point Cloud into Useable Data
- Can Create 3D Images of the Bare Earth Returns

Terrain Data Sets

- Point Cloud Data is Reduced into a Pyramid System for Ease of Display
- Pyramid System Reduces the Amount of Computer Processing Power Needed to Create Visual Displays
- County Wide Point Cloud Data Can be Reduced With Minimal Processing Power
- Terrain Data Sets Cannot be Used in Queries
- Very Good Tool For Scalable Visualization of the Bare Earth surface

LiDAR Study of the Unionport Gas Storage Project, Randolph County, Indiana

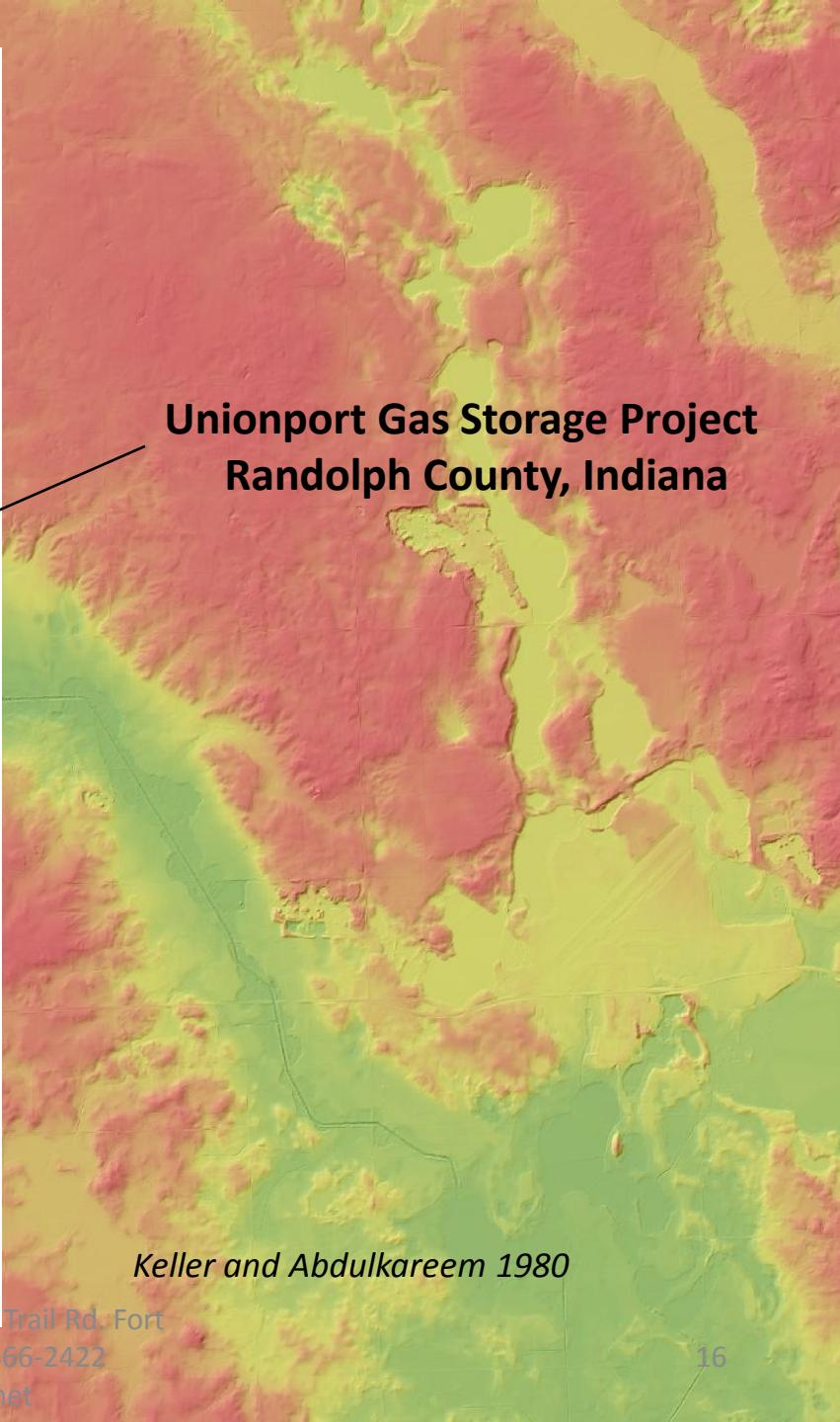
- “The Post Knox Unconformity provided the Principal Trapping Conditions for the Underground Gas Storage at Unionport”
- “Erosional Remnants of the Porous Knox Dolomite Protrude Upward into the Overlying Impermeable Black River Limestone”
- “Petroleum Has Been Produced in Indiana, Ohio, Kentucky and Southern Ontario from Knox Erosional Remnants”

Keller and Abdulkareem 1980

Unionport Gas Storage Project
Randolph County, Indiana



Figure 1. Map of Indiana showing counties, geologic provinces, and study area in Randolph County. Sellersburg, Unionport, and Redkey are features associated with the post-Knox unconformity. Modified from Carpenter, Dawson, and Keller, 1976, fig. 8.

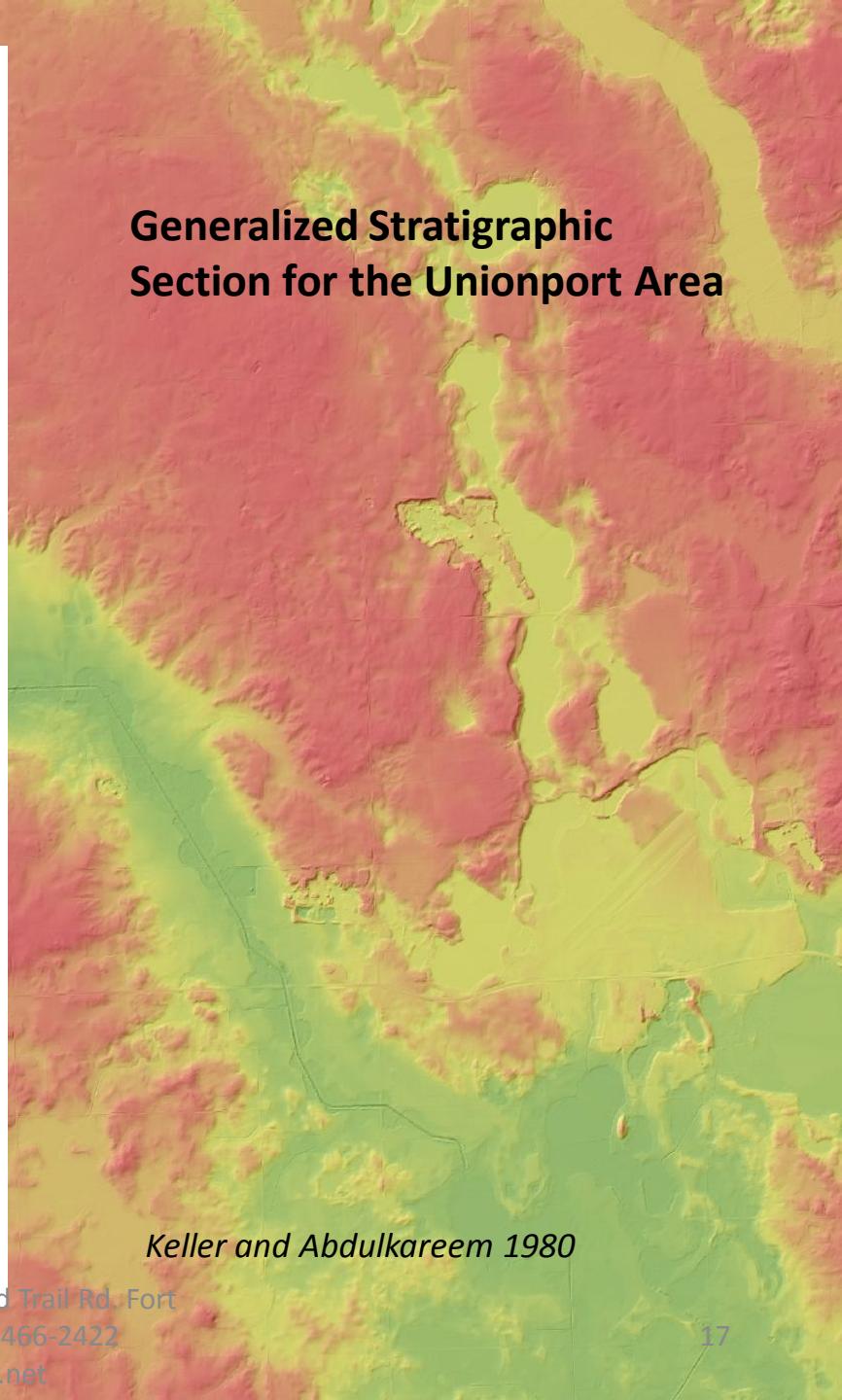


Keller and Abdulkareem 1980

SYSTEM	SERIES	FORMATION		THICKNESS (FT)	LITHOLOGY
ORDOVICIAN	CHAMPLAINIAN	Trenton Limestone		100 to 130	Limestone, tan, very finely to medium crystalline, dolomitic in upper part
				18	
		Black River Limestone		270 to 350	Limestone, tan to gray, micro-crystalline; some dolomitic limestone; trace of thin greenish bentonite (B)
	GLENWOODIAN	Glenwood Shale		0 to 60	Shale, greenish, and dolomite, tan, finely crystalline; quartz sand grains
CAMBRIAN	ST. CROIXIAN	Knox Dolomite		1000	Dolomite, tan, very finely to medium crystalline; abundant white chert; trace of pyrite and dark shale

Figure 2. Generalized stratigraphic section for the Unionport area.

Generalized Stratigraphic Section for the Unionport Area



Keller and Abdulkareem 1980

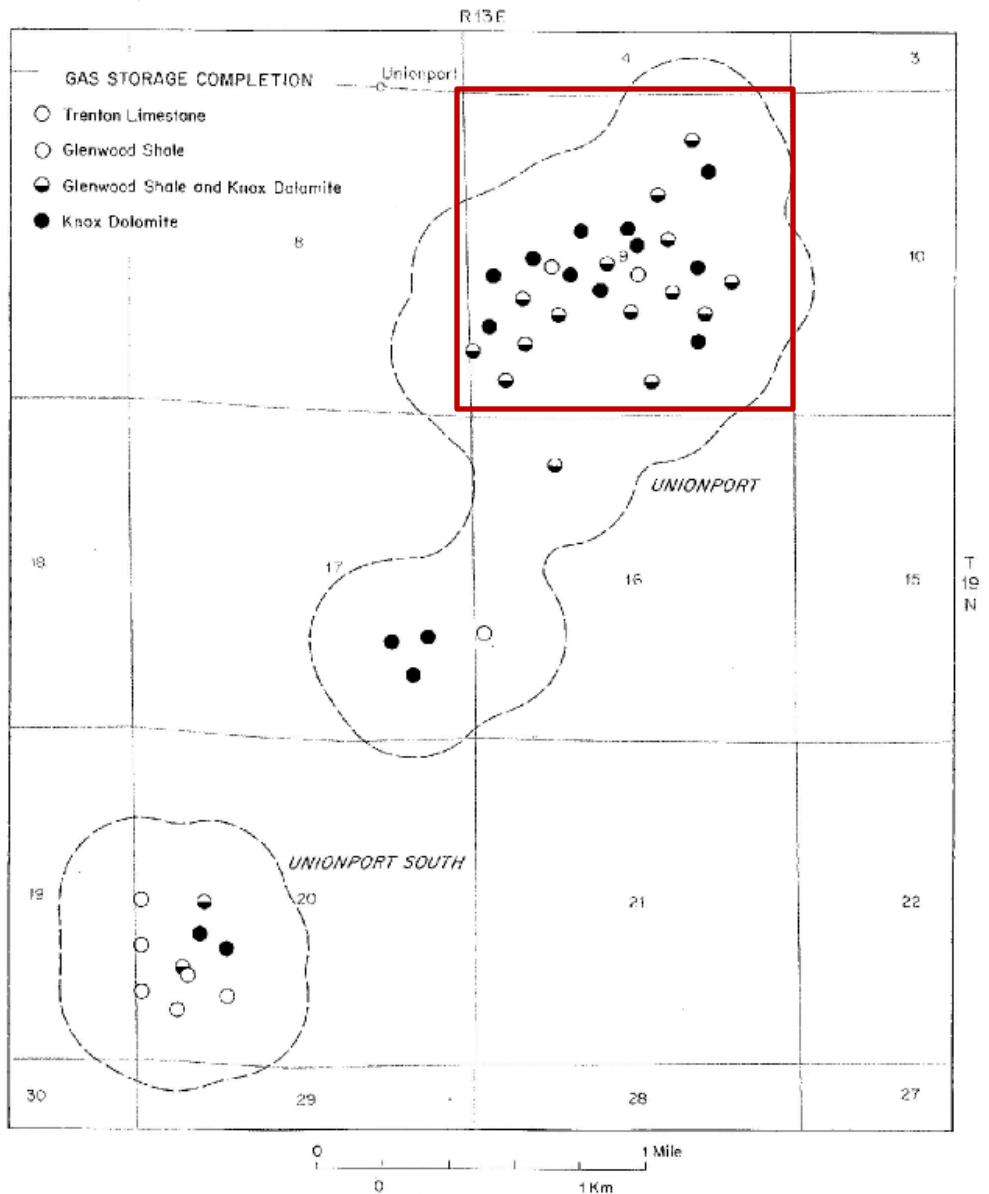
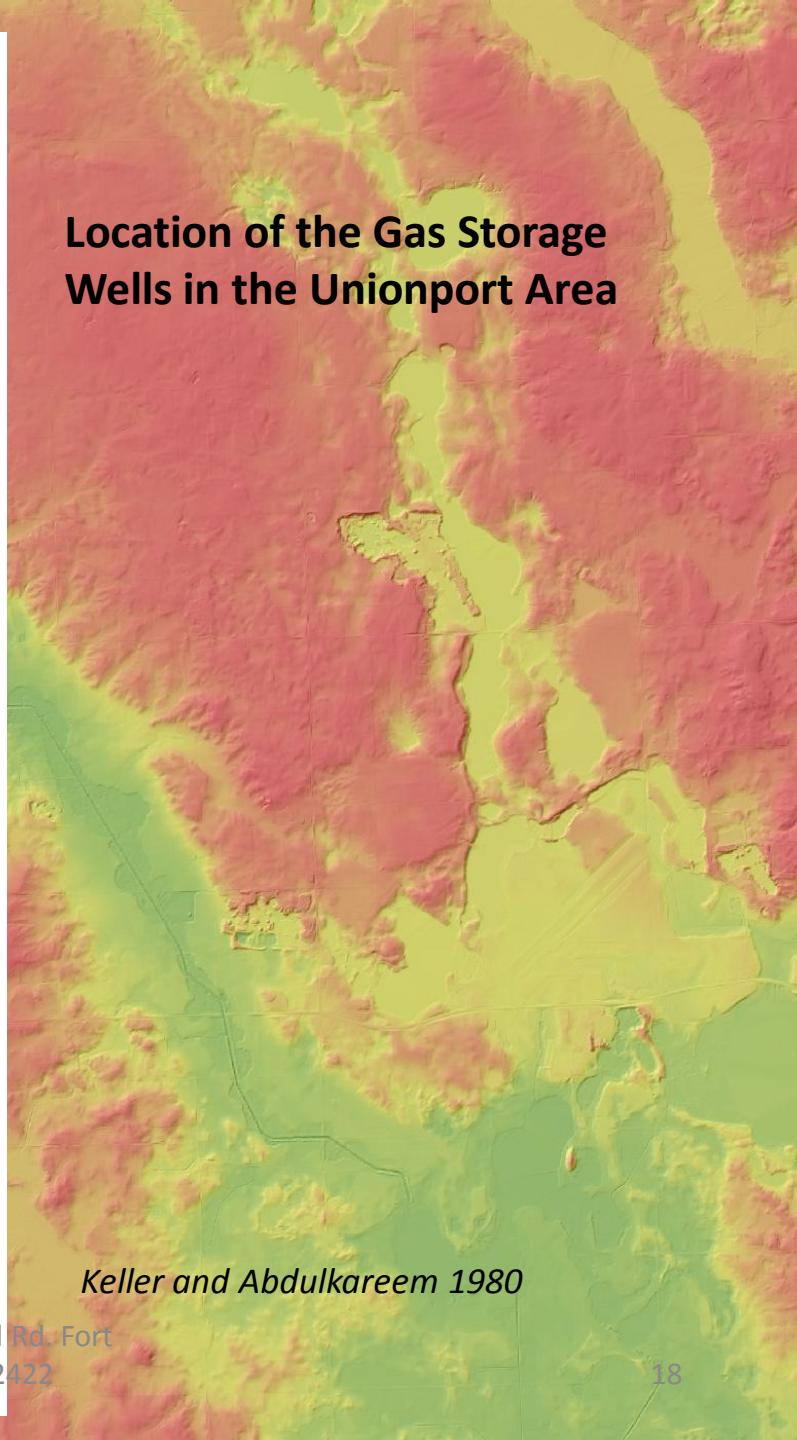


Figure 10. Map showing location of gas-storage wells in the Unionport gasstorage project.
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Wayne, IN 46809 (260) 466-2422
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Location of the Gas Storage Wells in the Unionport Area



Keller and Abdulkareem 1980

POST-KNOX UNCONFORMITY

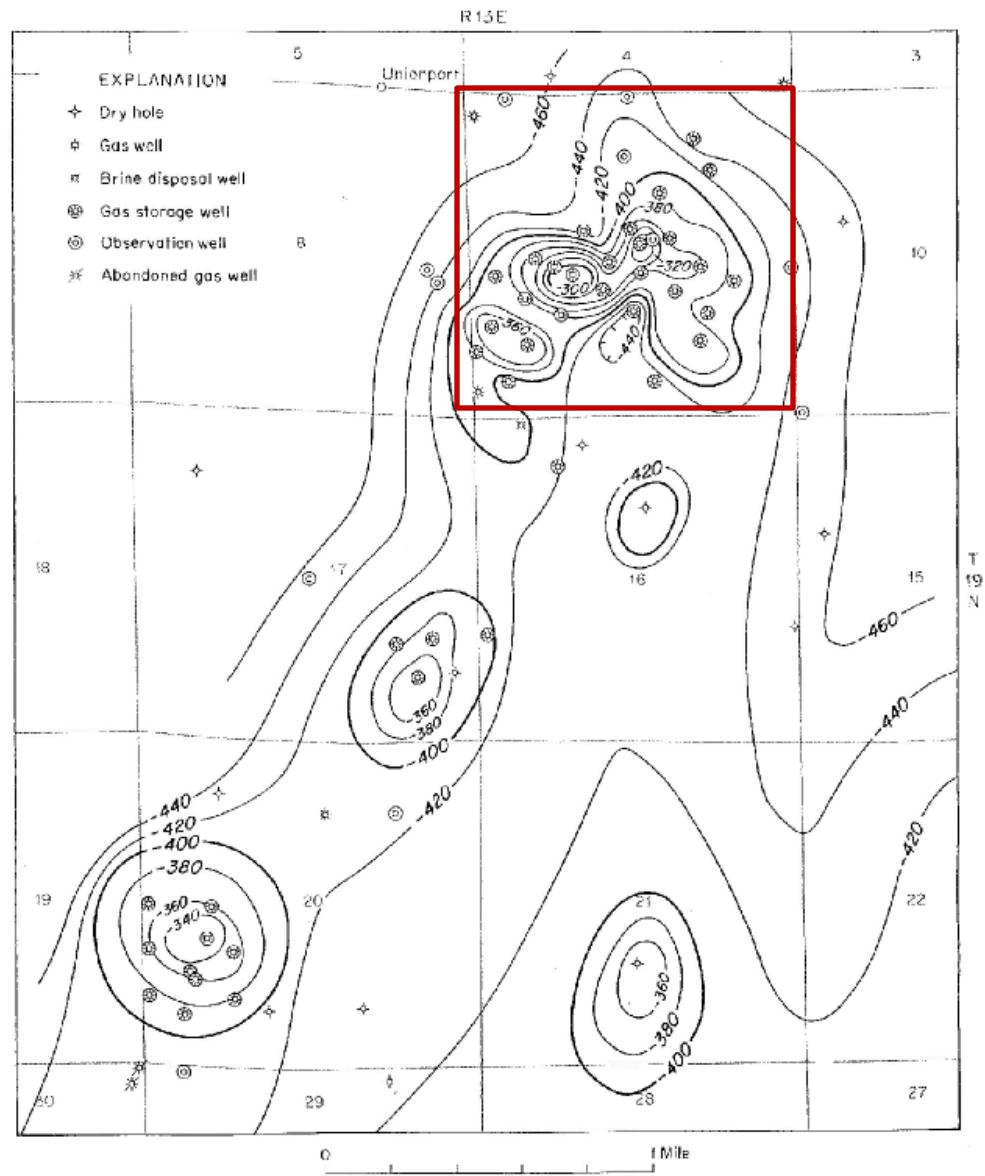
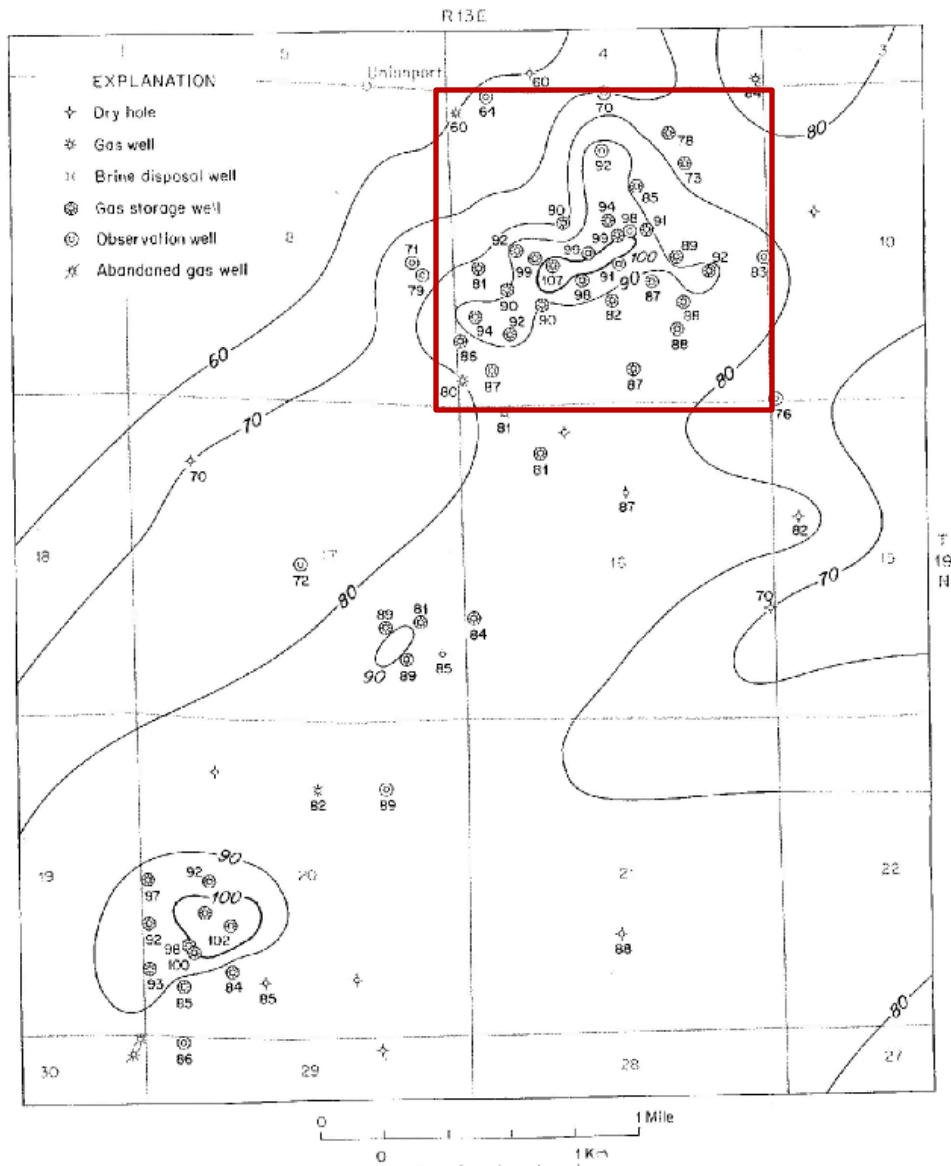


Figure 6. Map showing structure on top of the Knox Dolomite in the Unionport gas-storage project. Contour interval is 20 feet. Datum is mean sea level.
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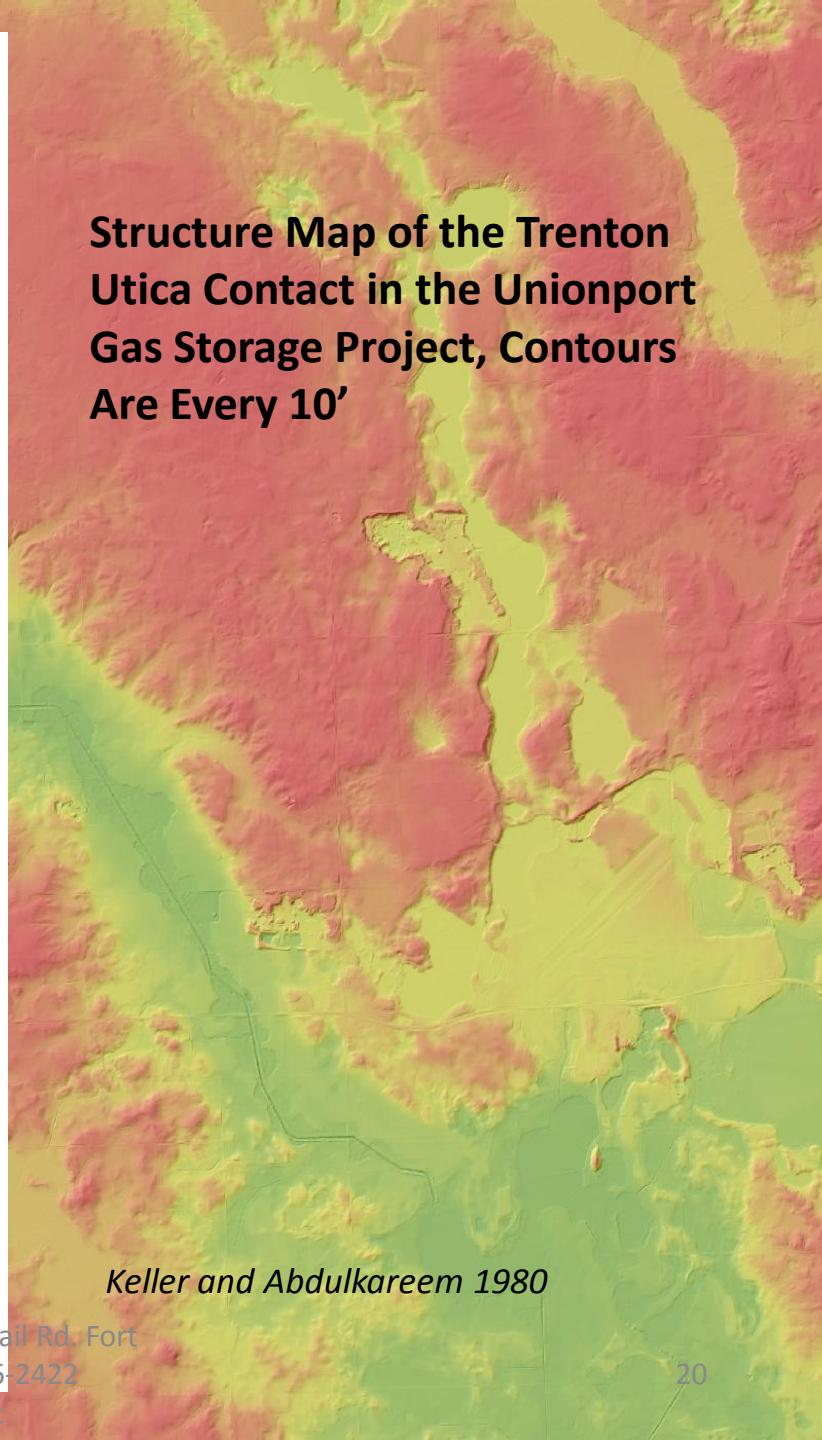
Structure Map on the Top of the Knox Dolomite in the Unionport Gas Storage Project, Contours Are Every 10'

Keller and Abdulkareem 1980

POST-KNOX UNCONFORMITY



Structure Map of the Trenton Utica Contact in the Unionport Gas Storage Project, Contours Are Every 10'



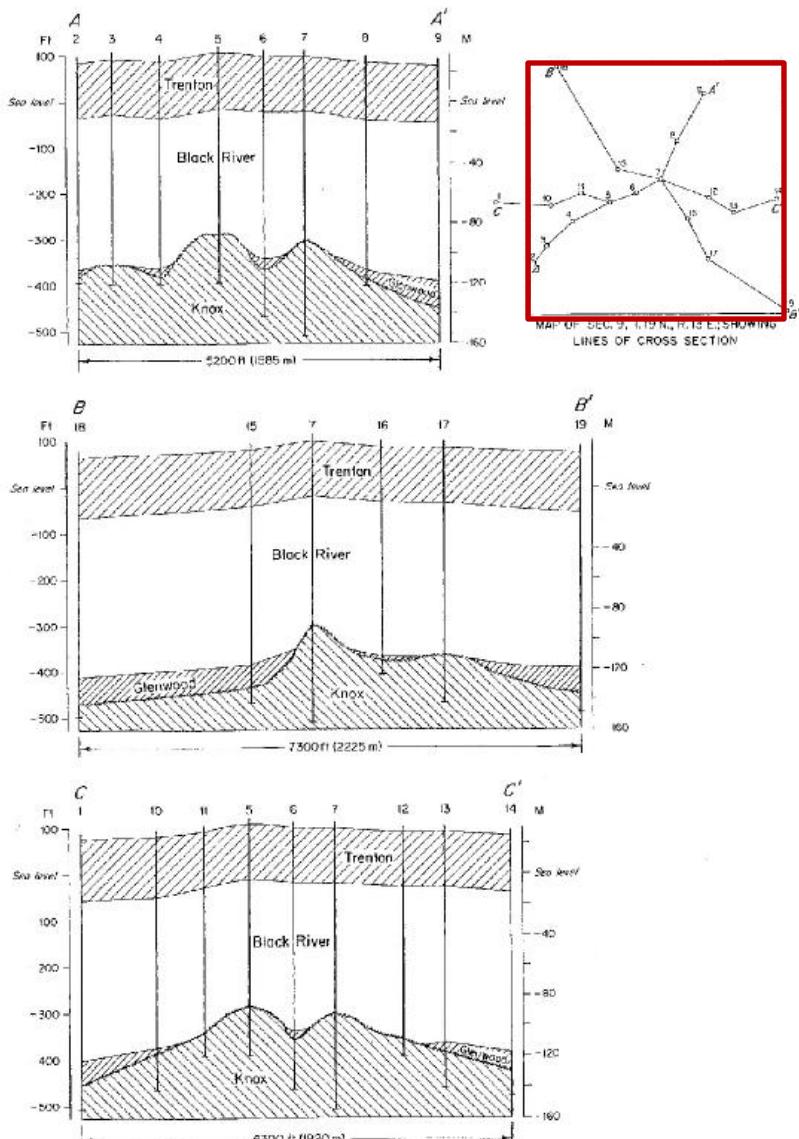
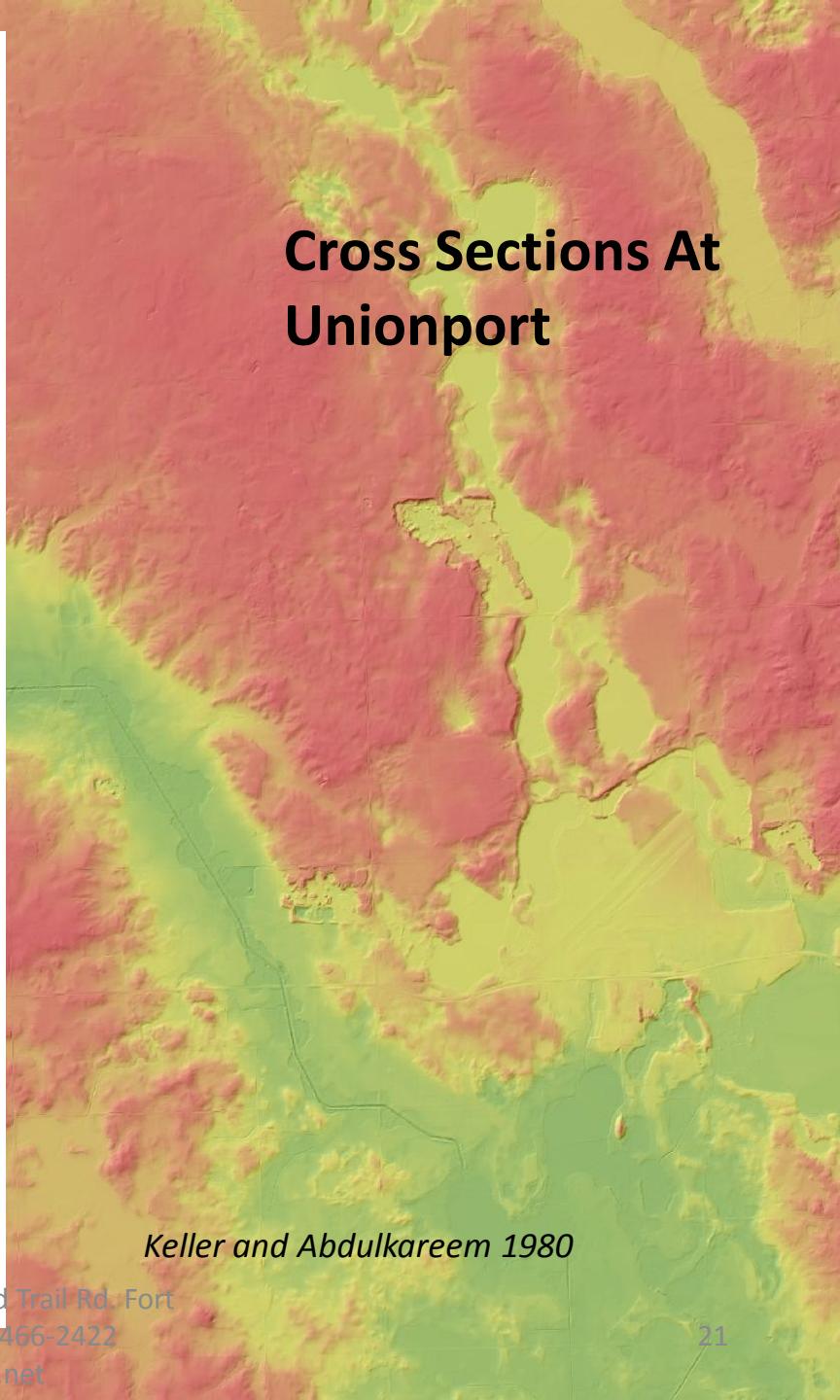


Figure 5. Structure cross sections A, B, and C showing the post-Knox unconformity in the Unionport gas-storage project. See appendix for wells used in cross sections. Vertical exaggeration is 6.6X.

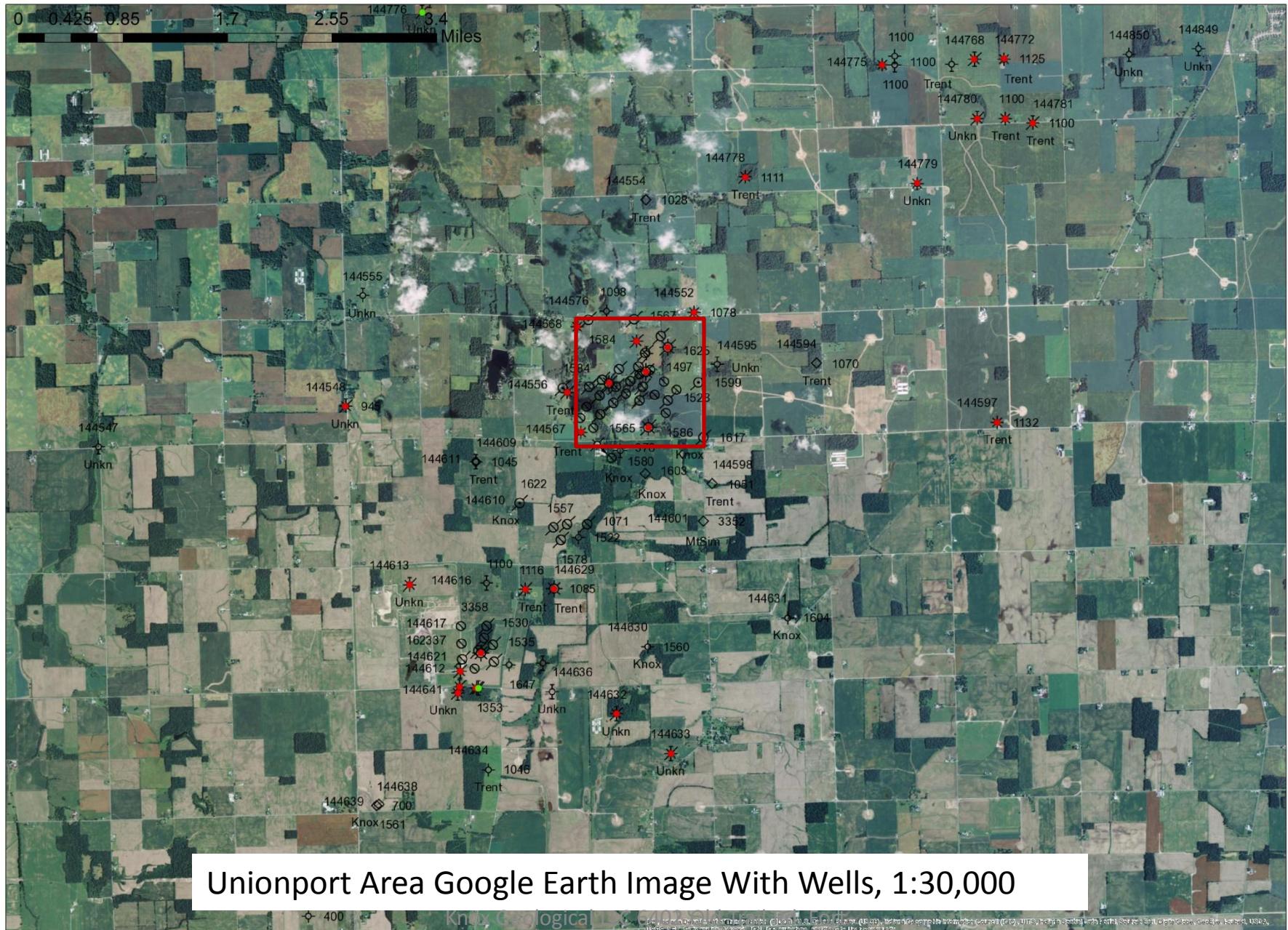


Cross Sections At Unionport

Keller and Abdulkareem 1980

The Unionport LiDAR Study

- Mosaic Tile LAS Data Set Compiled over the Unionport Gas Storage Complex
- Only Last or Bare Earth Returns Used in Data Set
- 3D Digital Elevation Model of Surface Built with Combined Hillshade and Transparent Red to Green Color Ramp Raster Image
- Terrain Data Set Also Created
- Elevation Contours, Slope Angles, Stream Flow and Aspect Maps Created from LAS Data Set
- Slope Angle Maps Created From Terrain Data Set

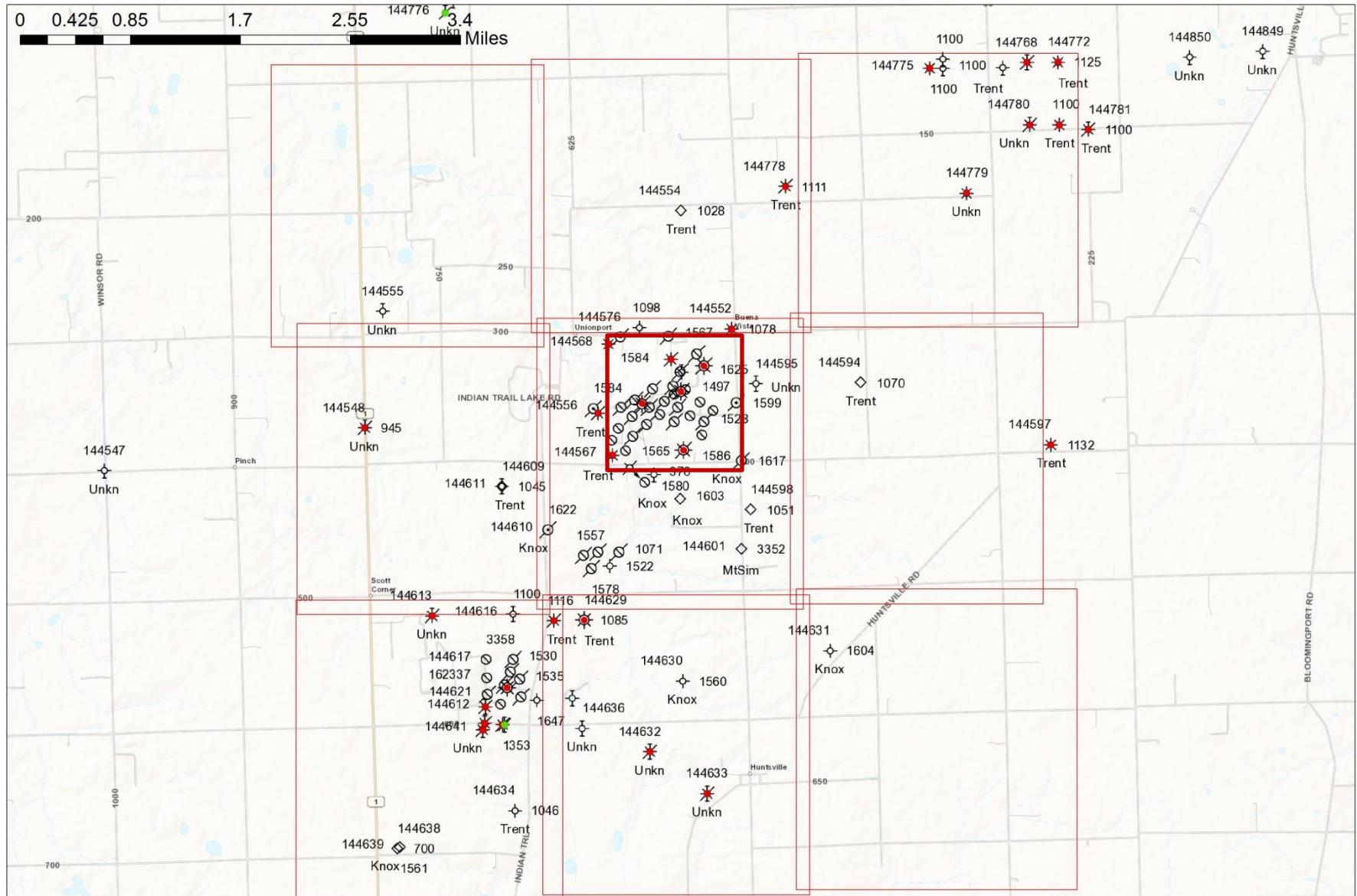


Unionport Area Google Earth Image With Wells, 1:30,000

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Wayne, IN 46809 (260) 466-2422

f4tknox@comcast.net



Unionport Gas Storage Project with 9 Mosaic Tile LAS Data Set, 1:30,000

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Knox Geological LLC 6402 Old Trail Rd. Fort

Wayne, IN 46809 (260) 466-2422

f4tknox@comcast.net

Rd. Fort 36 U.S. Census Bureau (USCB), Indiana Geographic Information Council (IGIC), MHTS, Indiana Spatial Data Portal



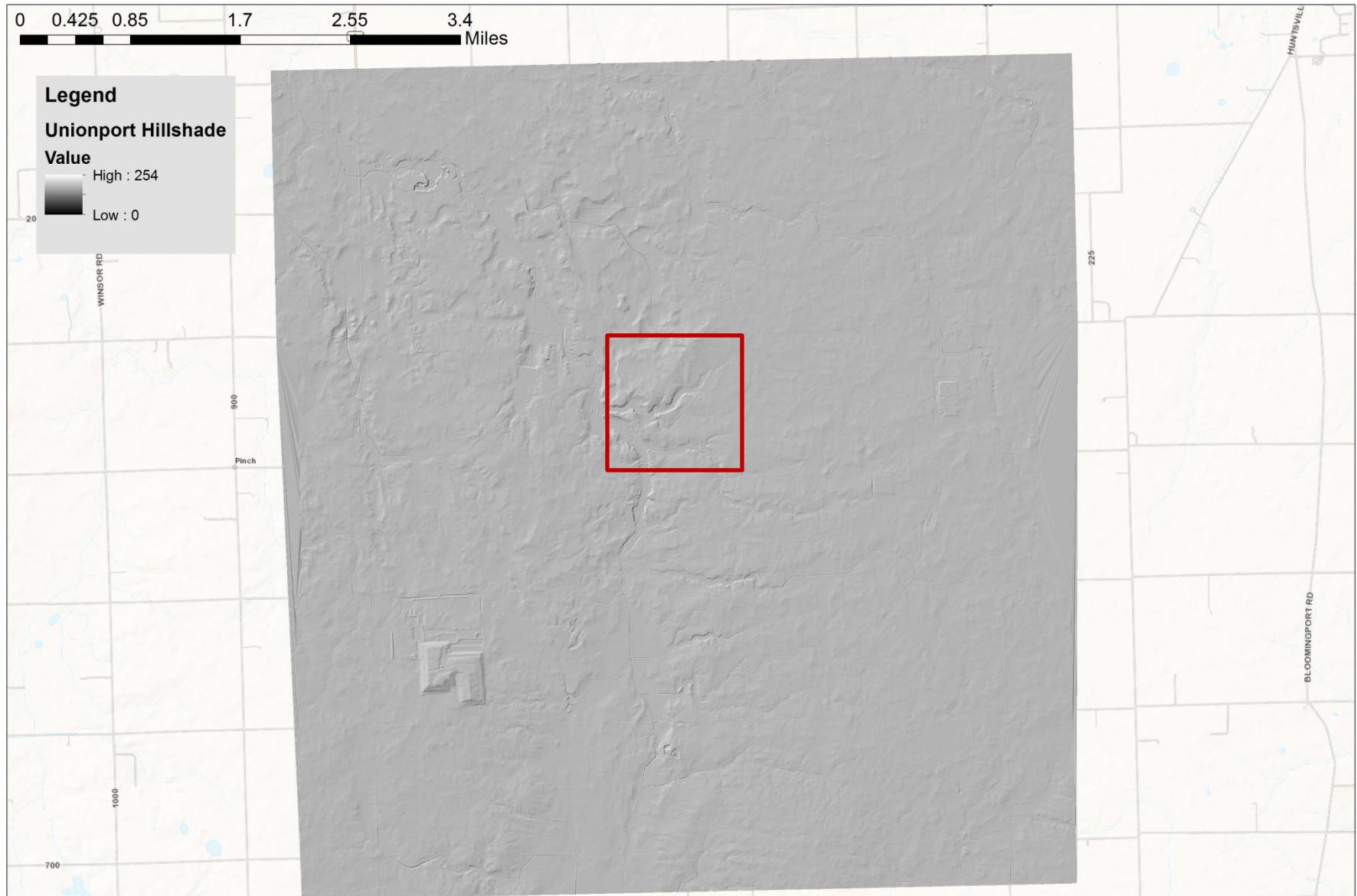
Unionport Gas Storage Project with Raster Image Derived from LAS Data Set

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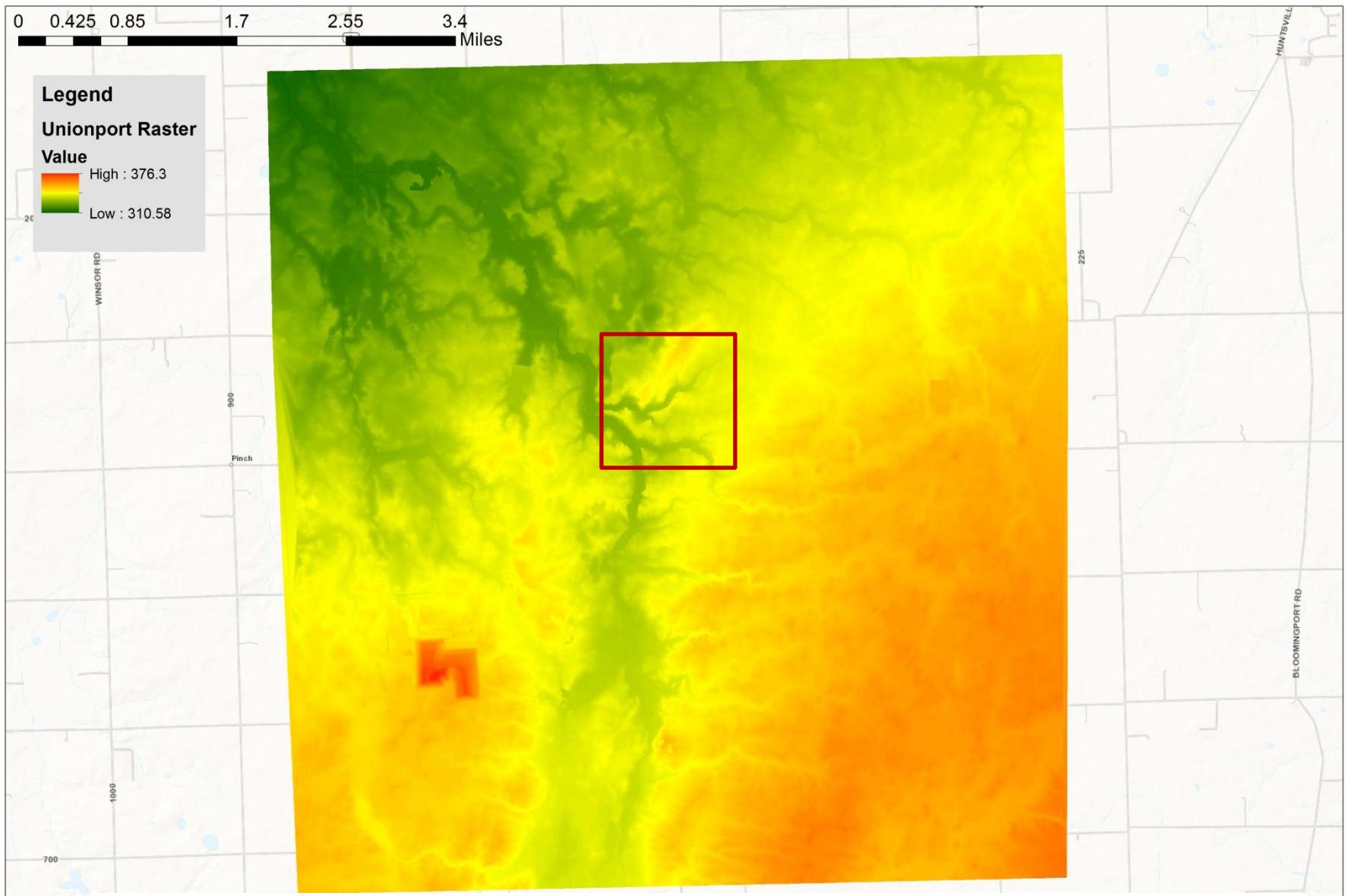
Unionport Gas Storage Project with Hillshaded Image Derived from LAS Data Set

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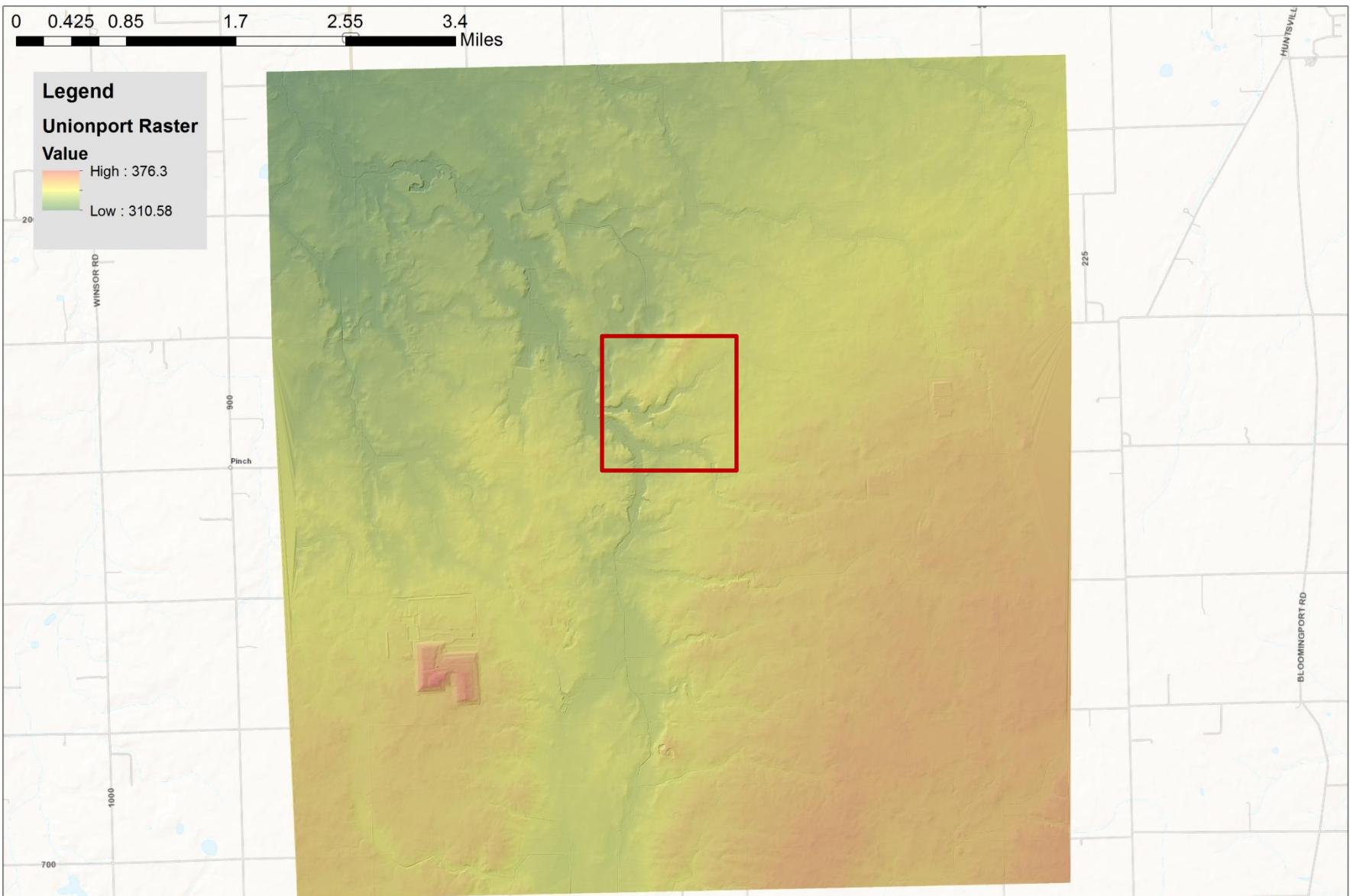
Unionport Raster Image with Red to Green Color Ramp from LAS Data Set

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Unionport With Combined Raster and Hillshade From 9 Tile LAS Data Set

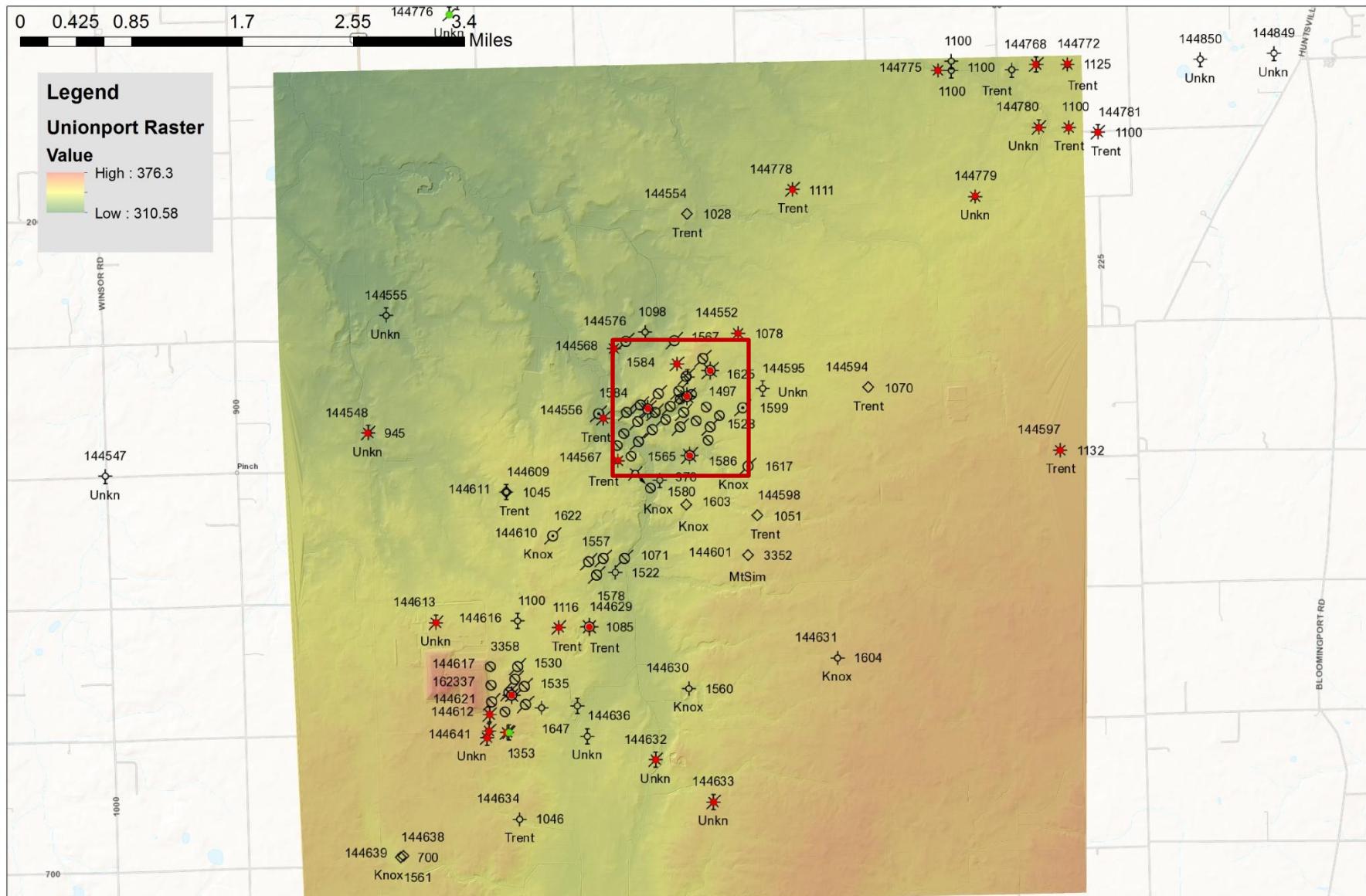
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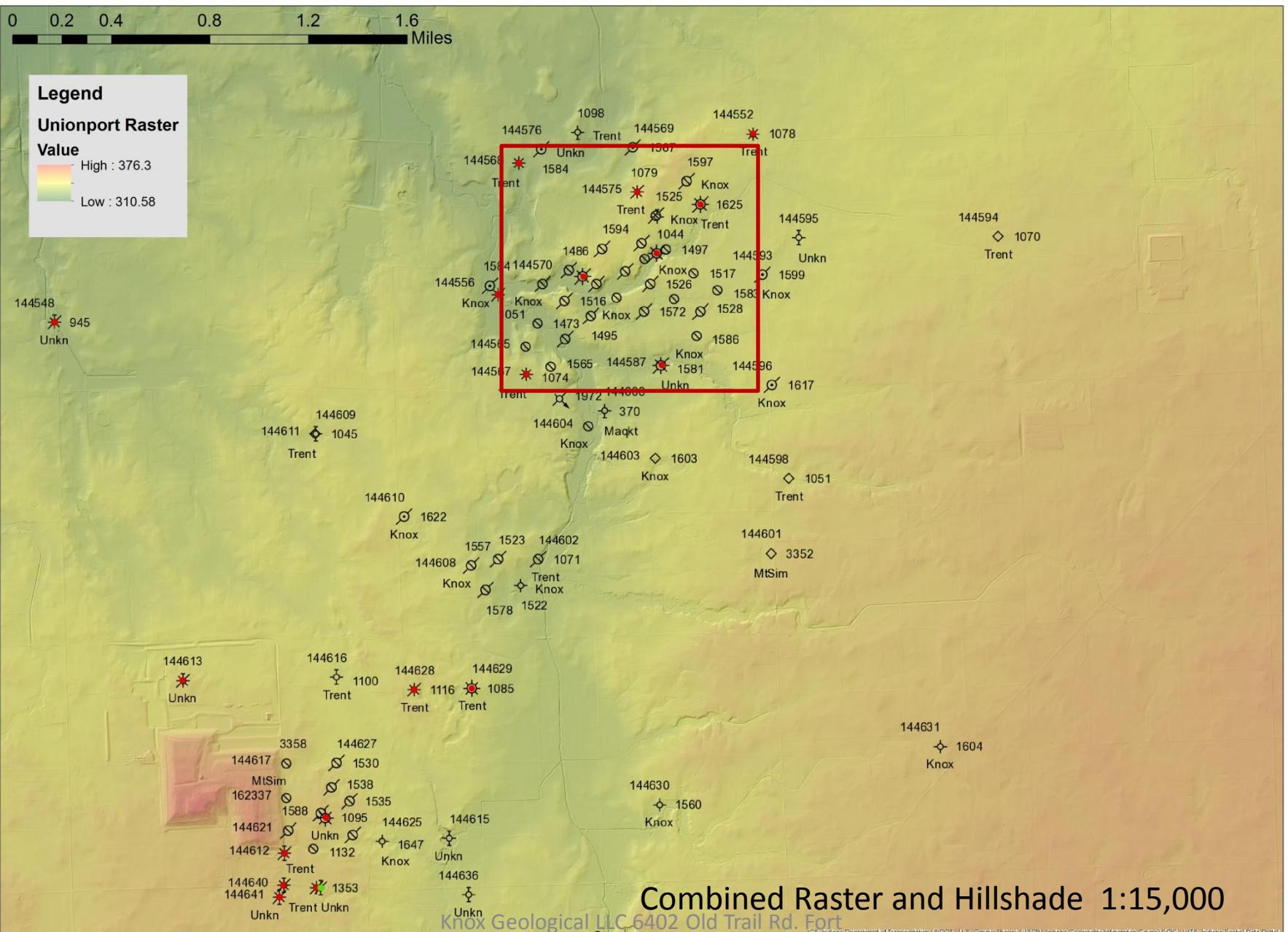
Unionport With Combined Raster and Hillshade With Wells

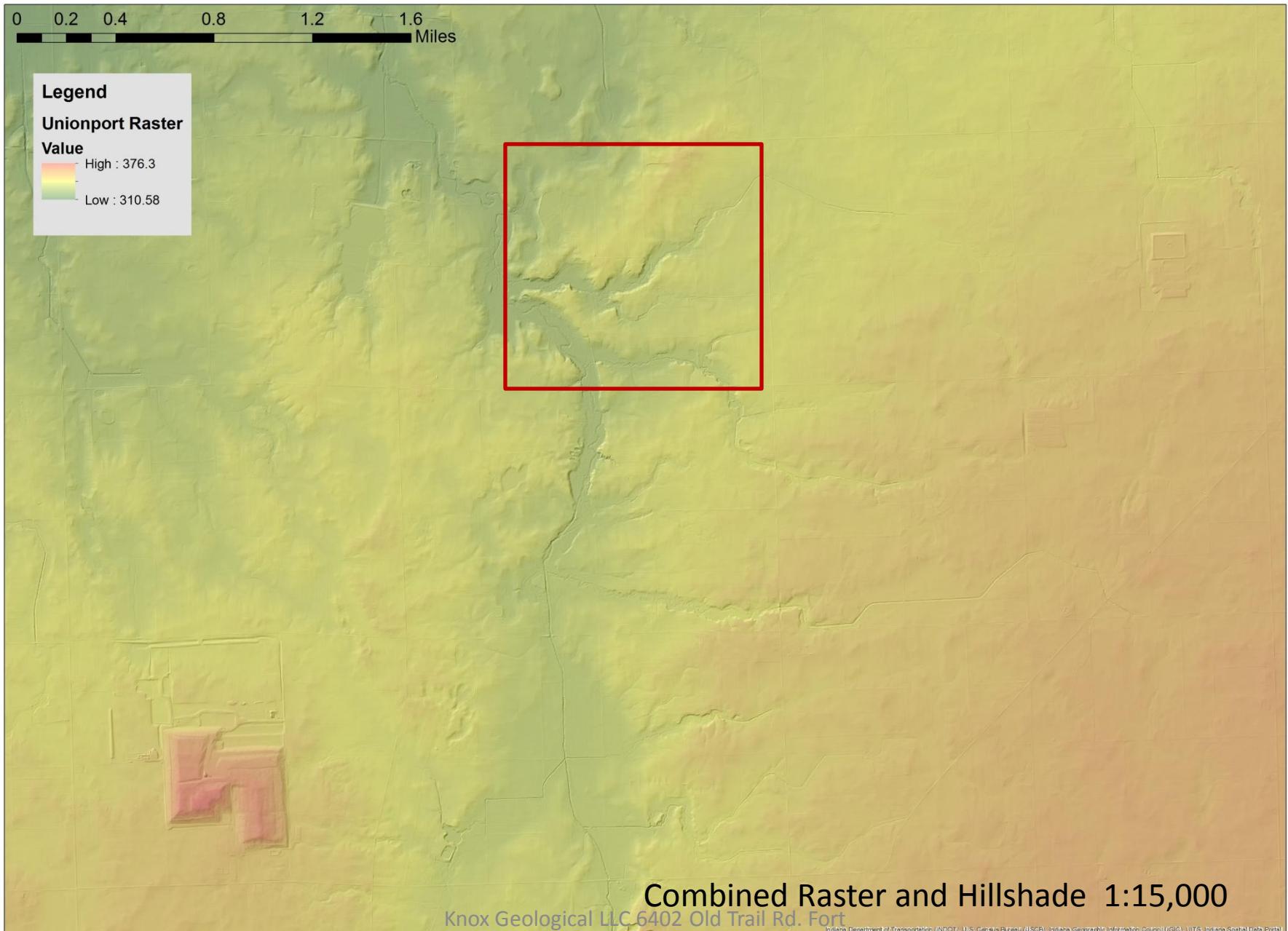
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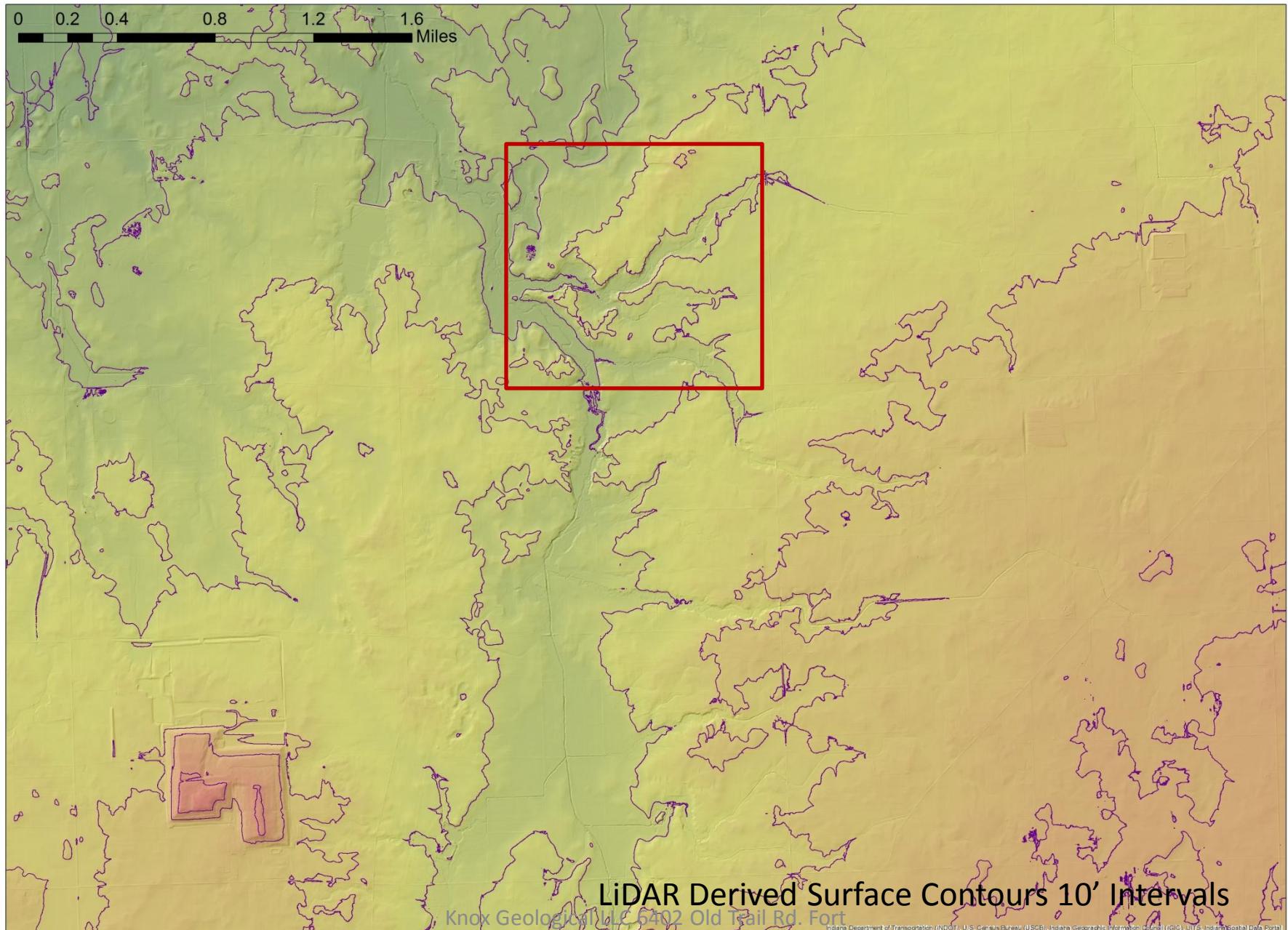
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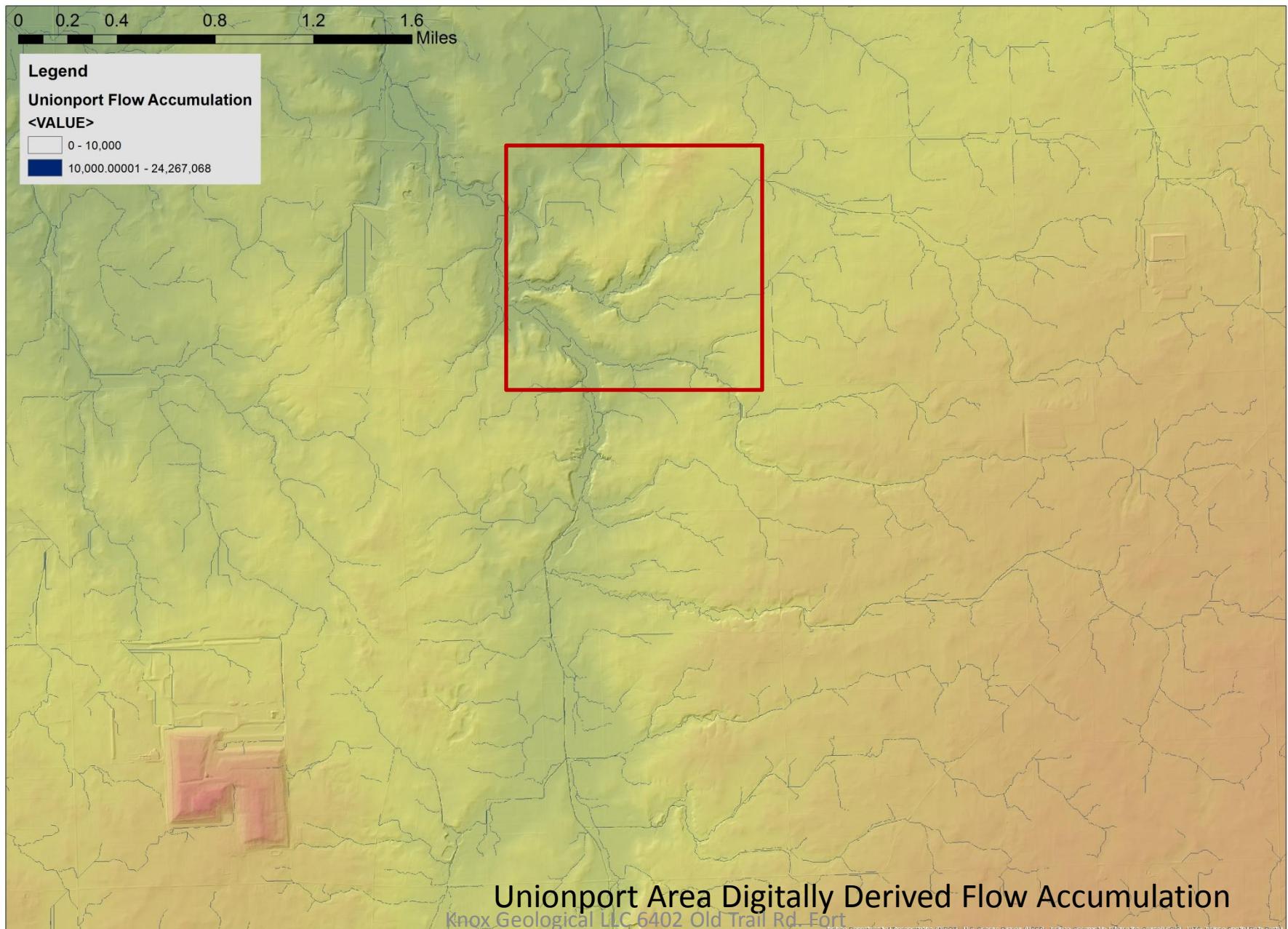


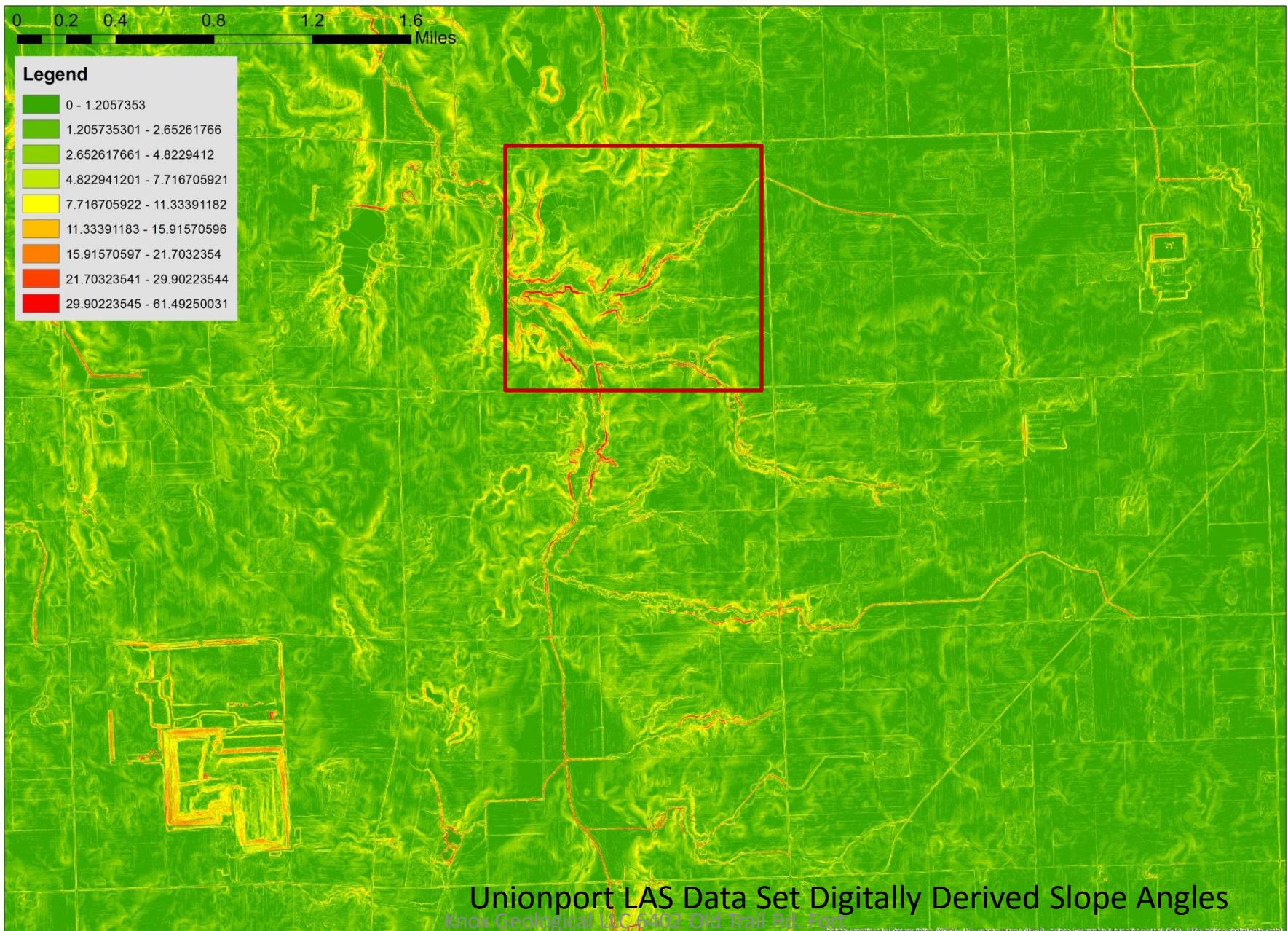


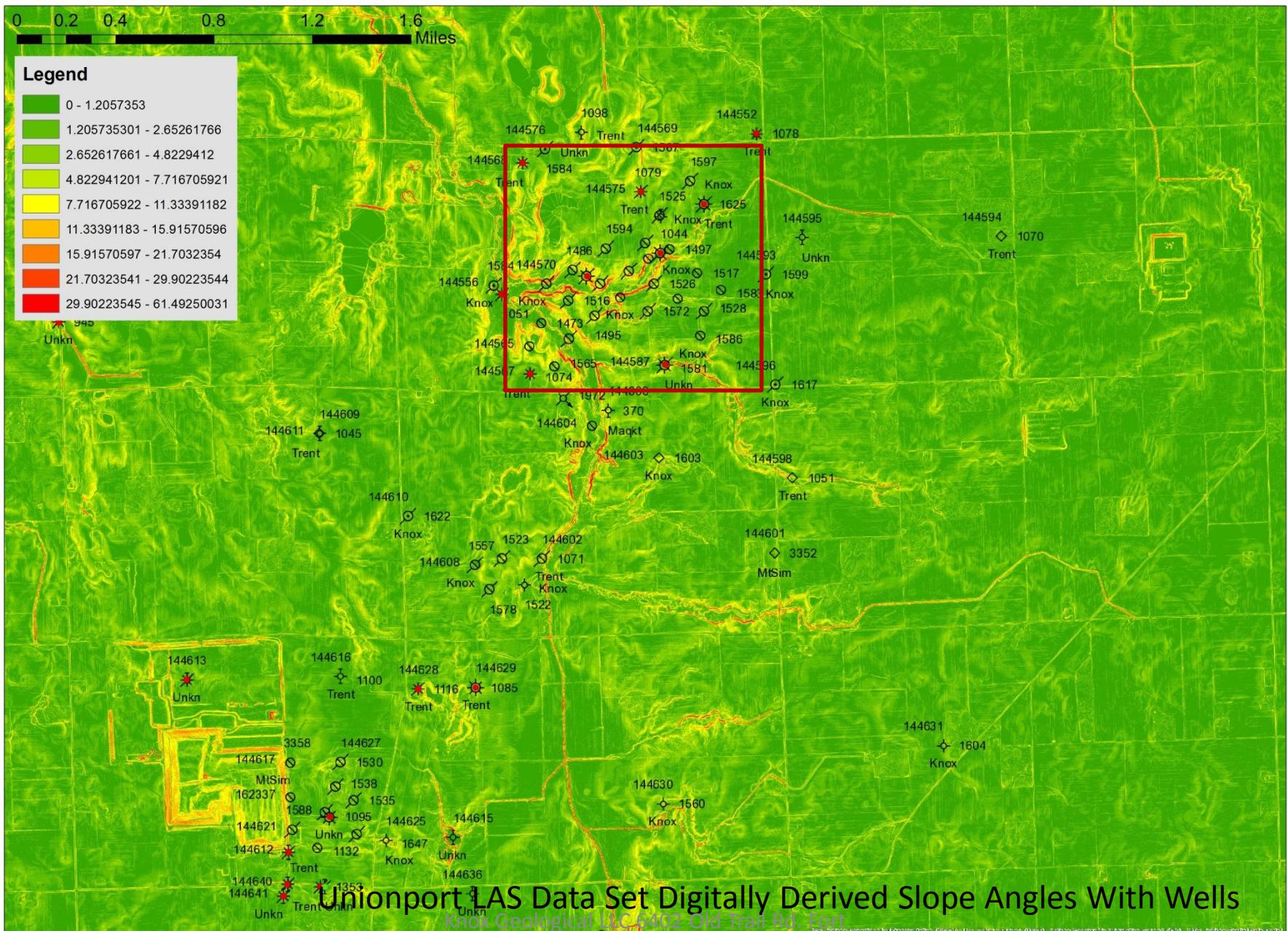


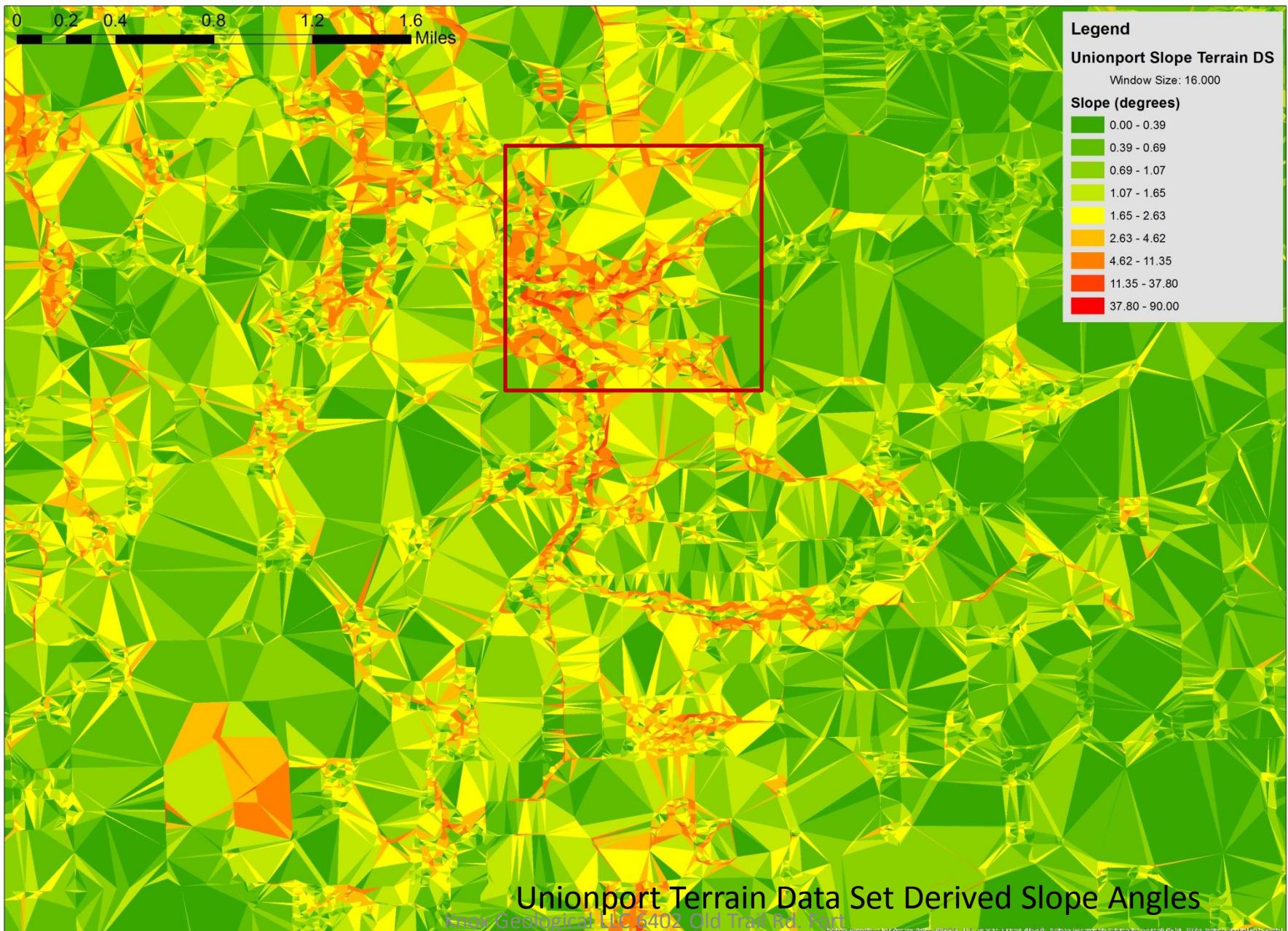
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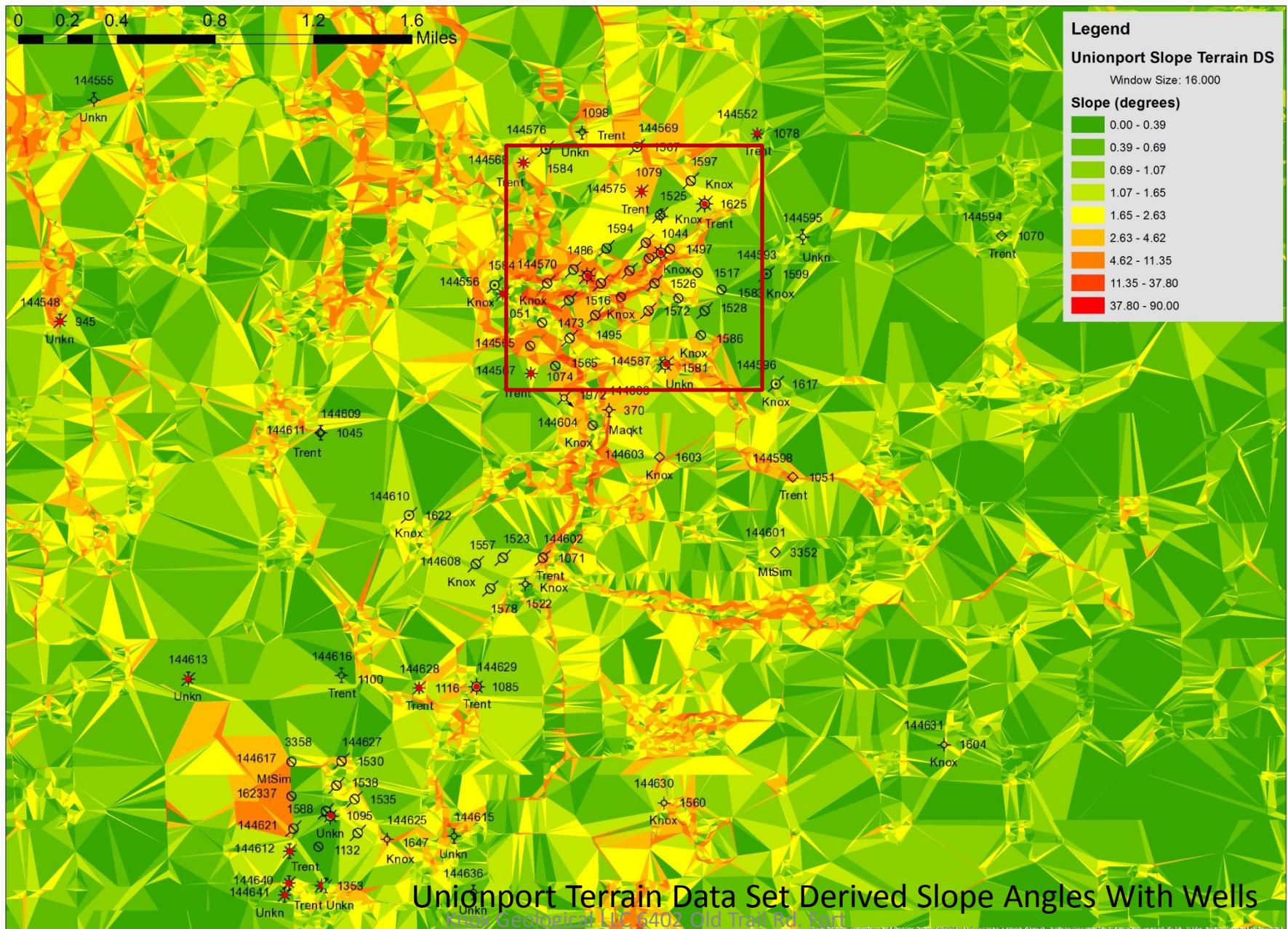
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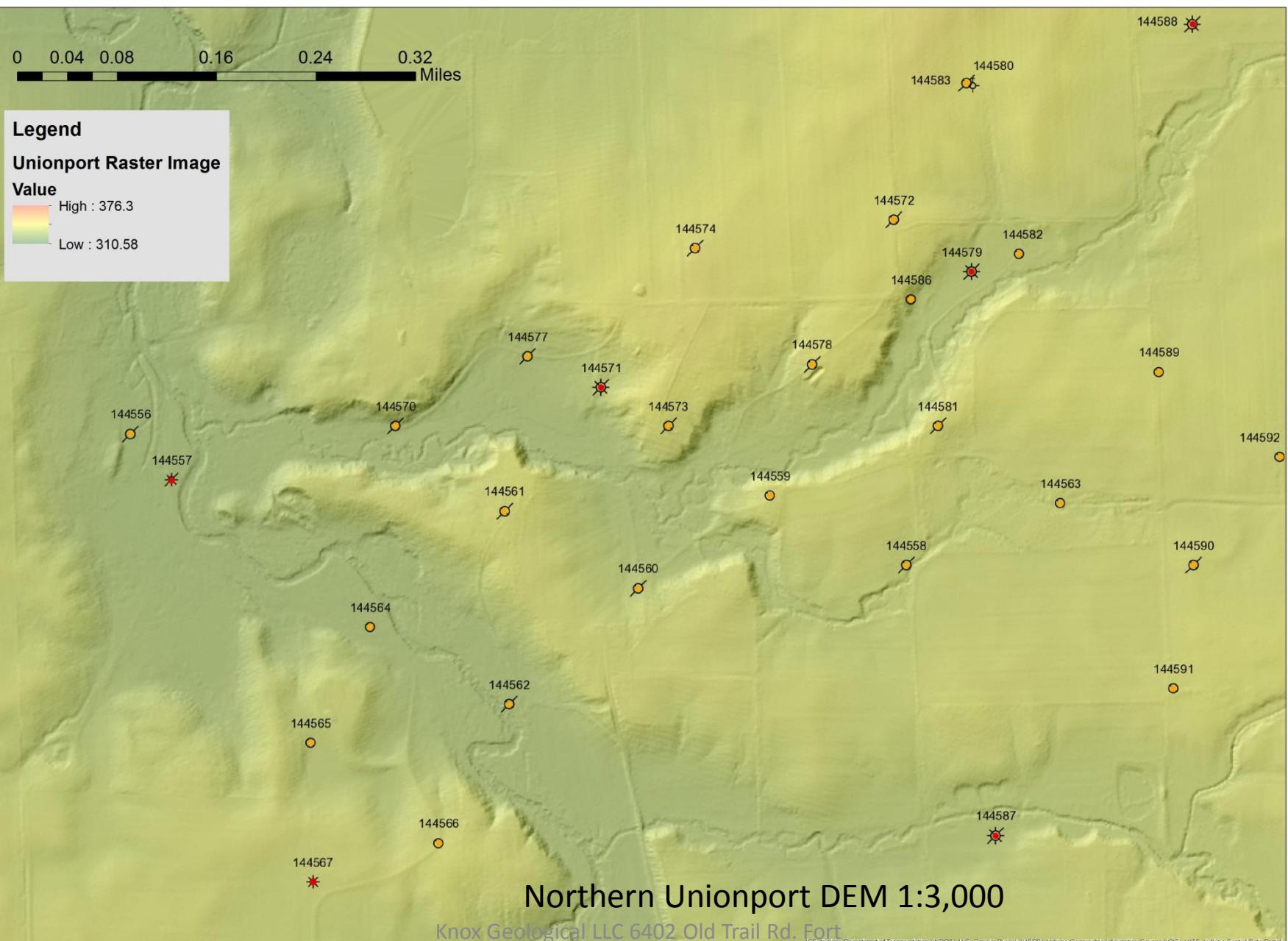


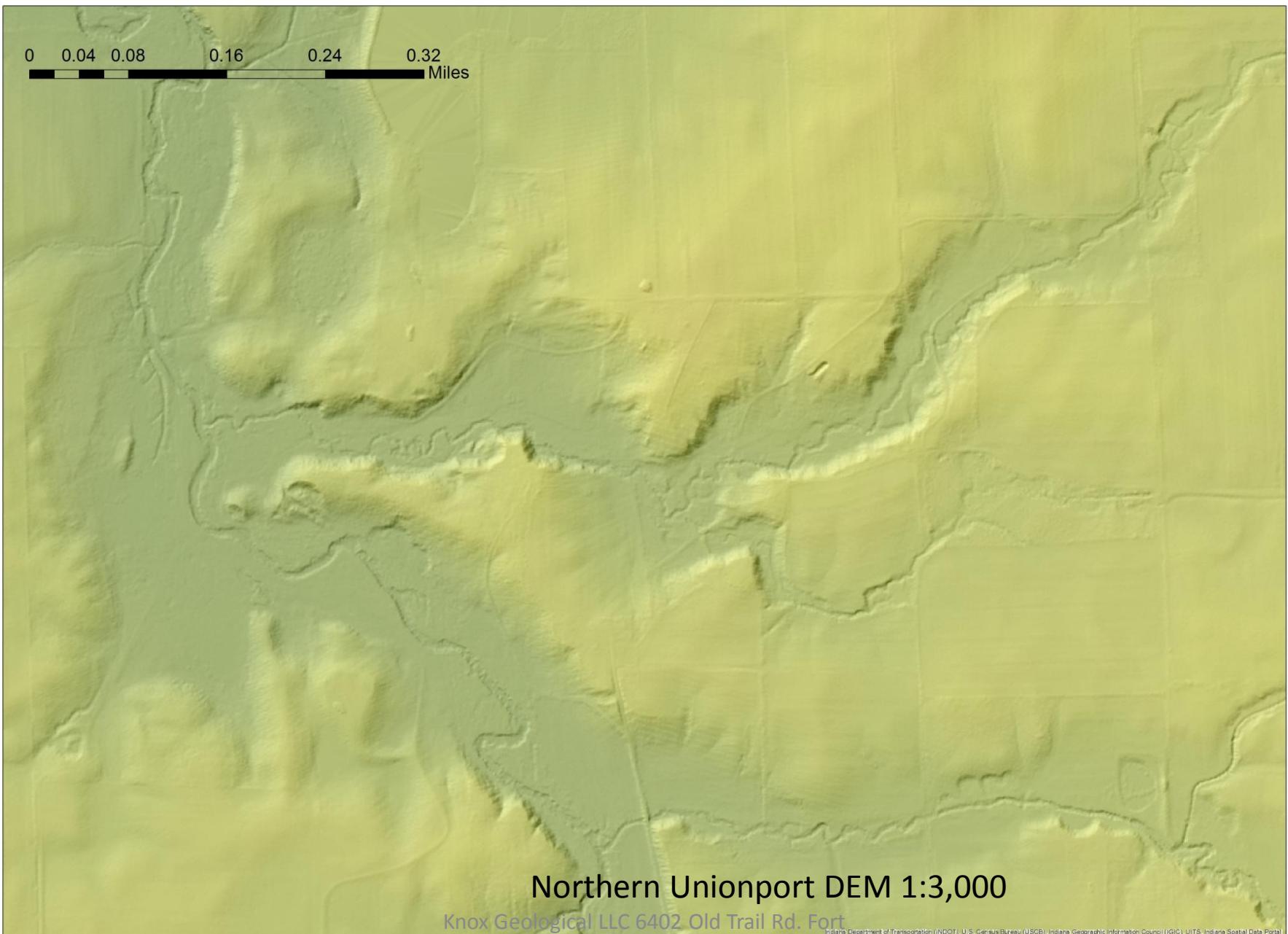


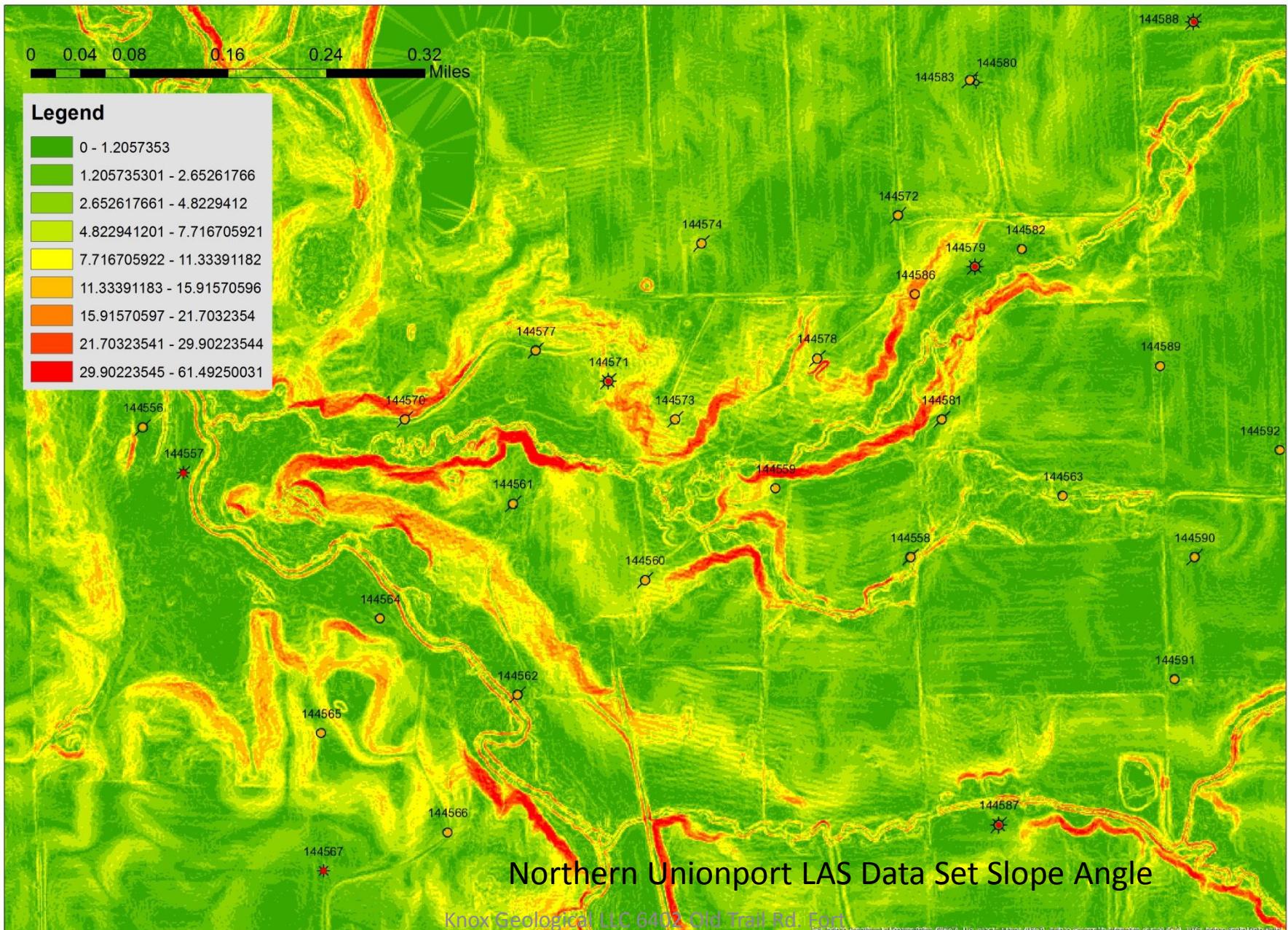


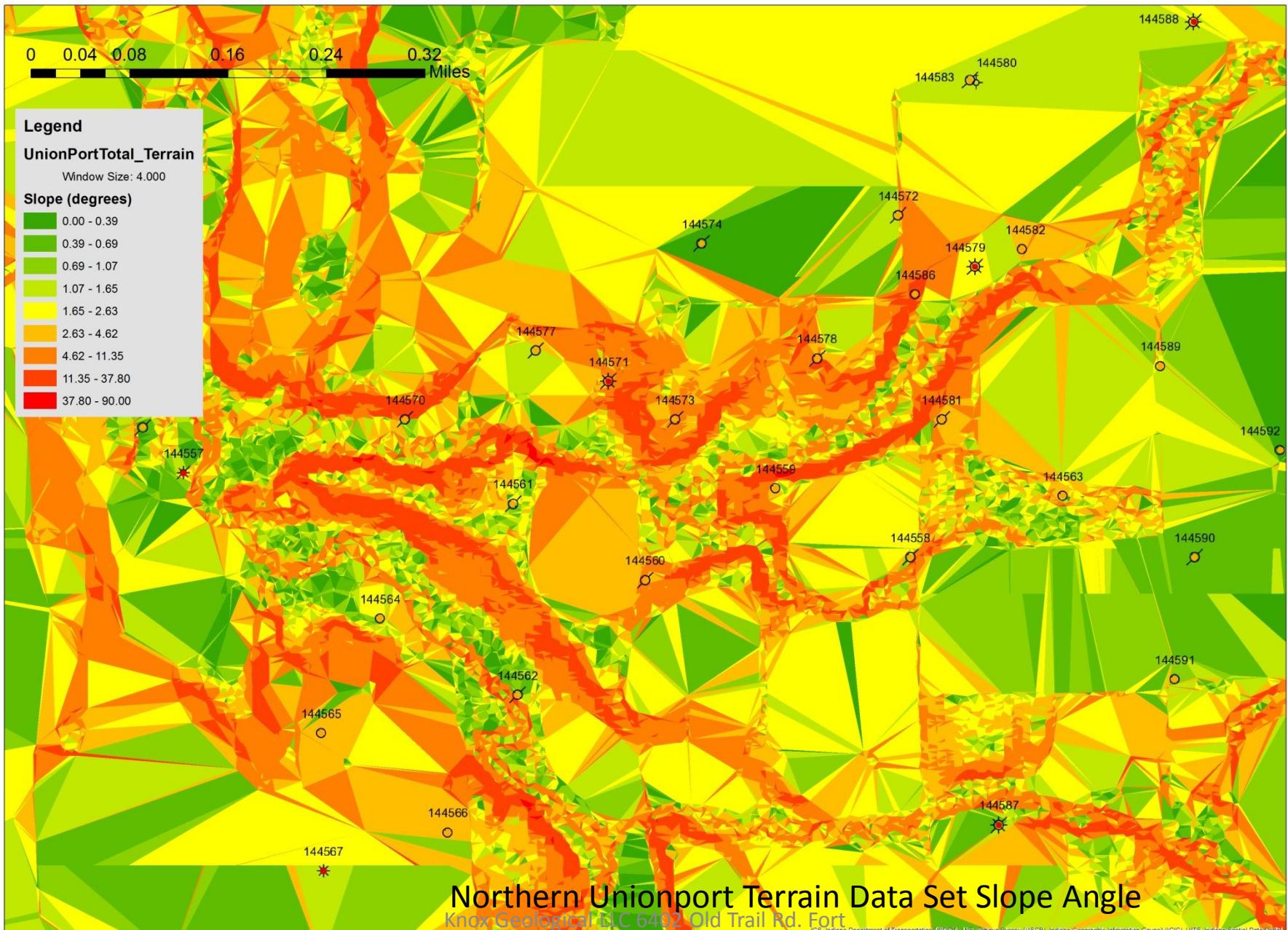


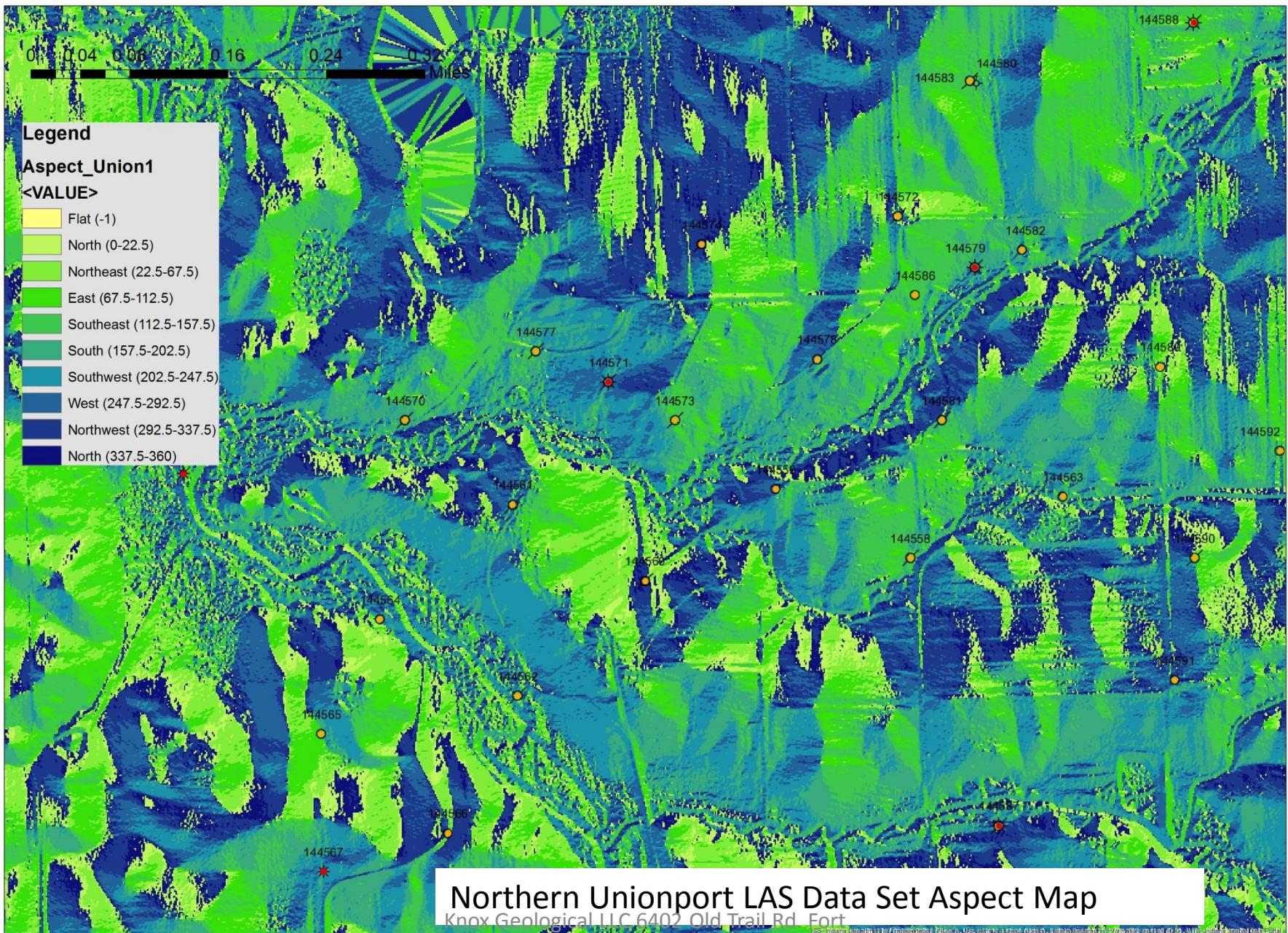










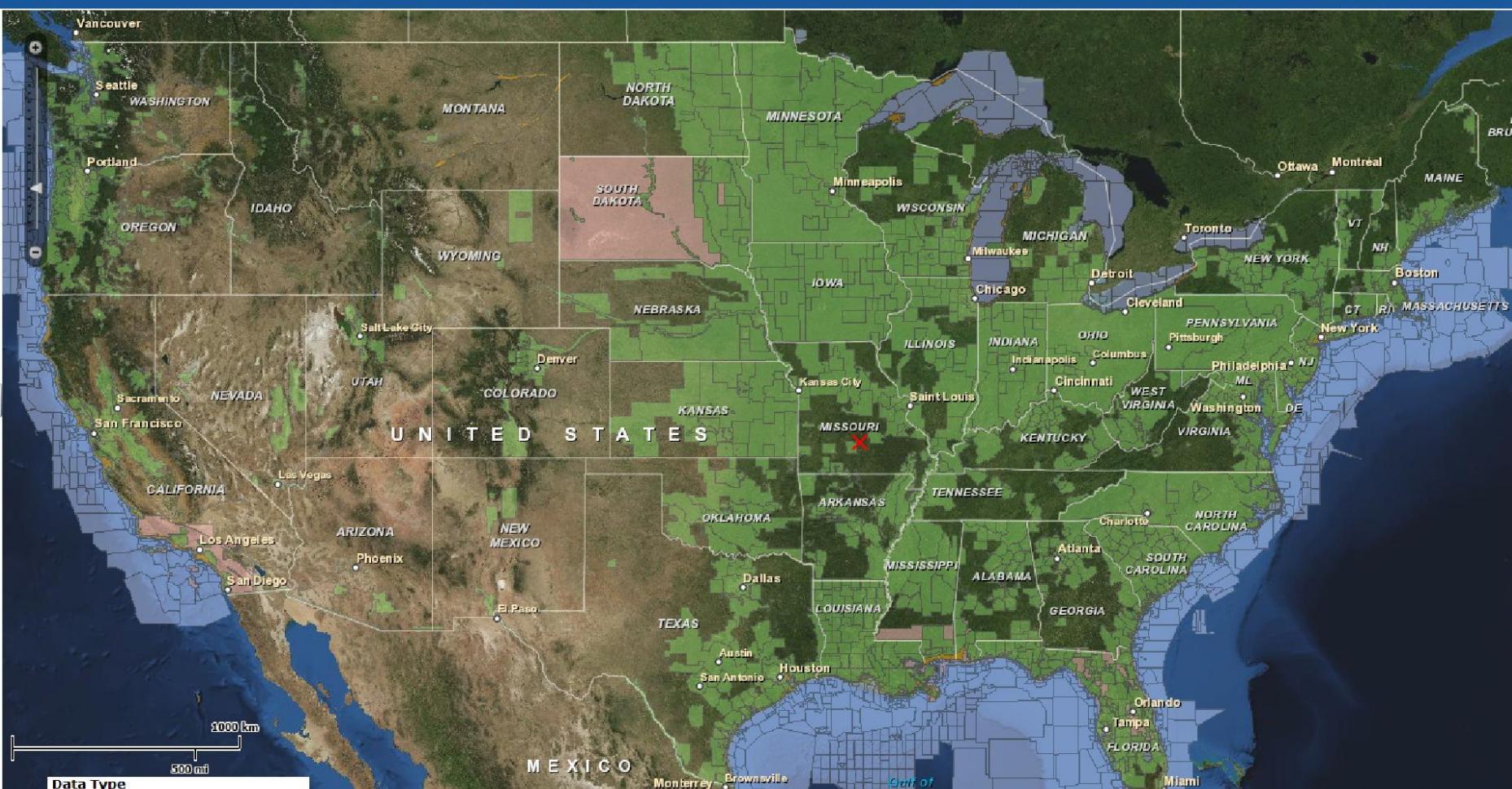


Results of The Unionport LiDAR Study

- Differential Compaction of the Trenton, Utica and Silurian Limes Over the Known Knox Erosional Remnants at Unionport Appears to Extend to the Surface
- LiDAR Derived Digital Elevation Models Show an Area of Higher Elevation Over the Known Knox Erosional Remnants
- LiDAR Derived Flow Accumulation Map Shows Stream Flow Radiating Away From Area Above Known Knox Erosional Remnants
- Slope Angle Maps, Both LAS Data Set and Terrain Data Set Show Higher Slope Angles Over the Known Knox Erosional Remnant

Conclusion of The Unionport LiDAR Study

- LiDAR Derived Digital Elevation Models with Flow Accumulation and Slope Angle Maps Can Be Used as a New Tool to Help Locate Knox Erosional Remnants in Drift Covered Areas



USGS LiDAR Availability Map of the Lower 48

Knox Geological LLC 6402 Old Trail Rd. Fort
Wayne, IN 46809 (260) 466-2422
f4tknox@comcast.net

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