Exploration, Development, and Reclamation of Aggregate Resources

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Terracon

PRESENTATION OVERVIEW

Exploration, Development, and Reclamation of Aggregate Resources

- Aggregate Facts, Issues, and Uses
- Exploration, Inventorying, & Mapping
- Mine Development & Mining Techniques
- Opportunities / Sustainable Development
- Reclamation & Post-Mine Land-Use

AGGREGATE

- SAND & GRAVEL
- CRUSHED STONE

SAND & GRAVEL

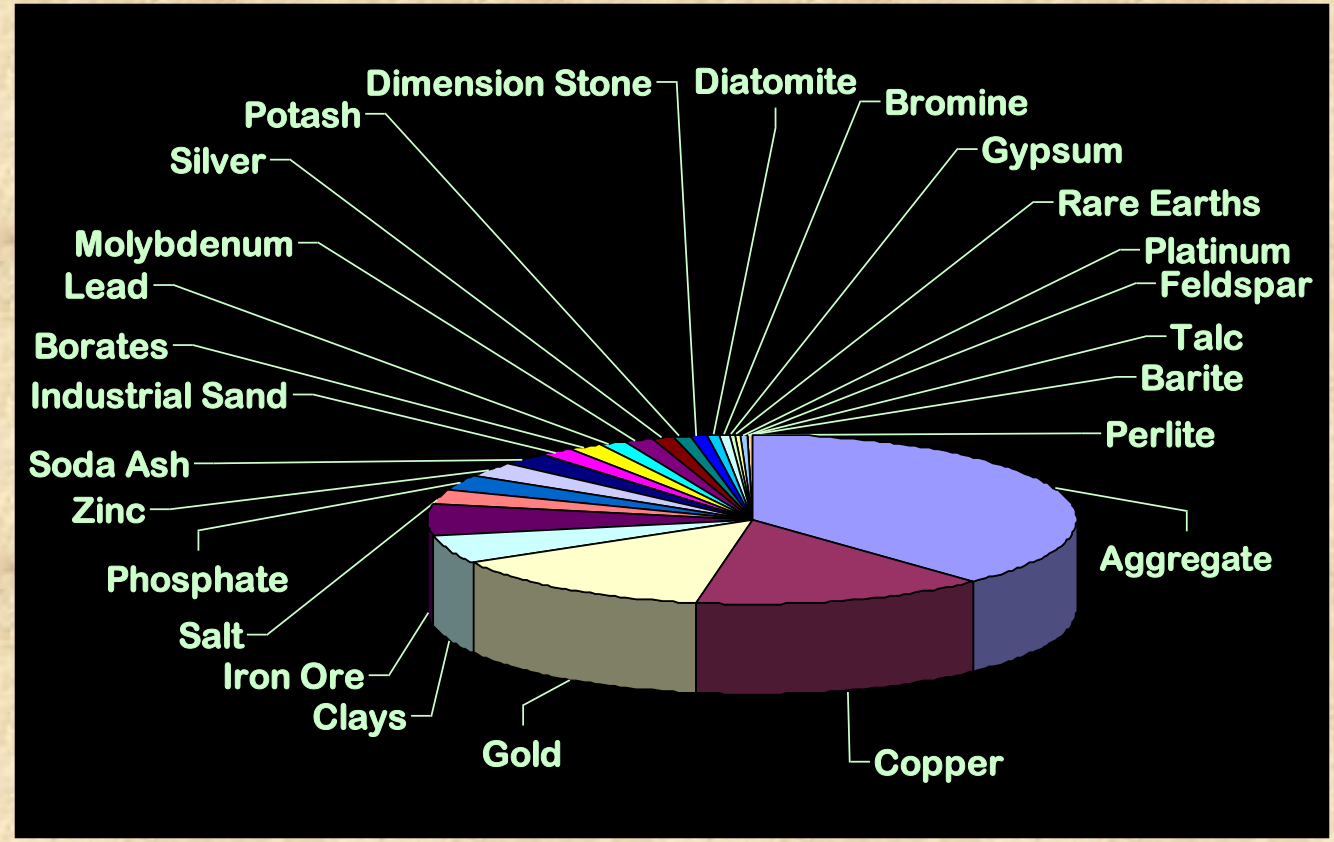
Glacial Outwash, Alluvium, etc…

CRUSHED STONE

Scoria, Limestone, Granite, Basalt…

AGGREGATE INDUSTRY:

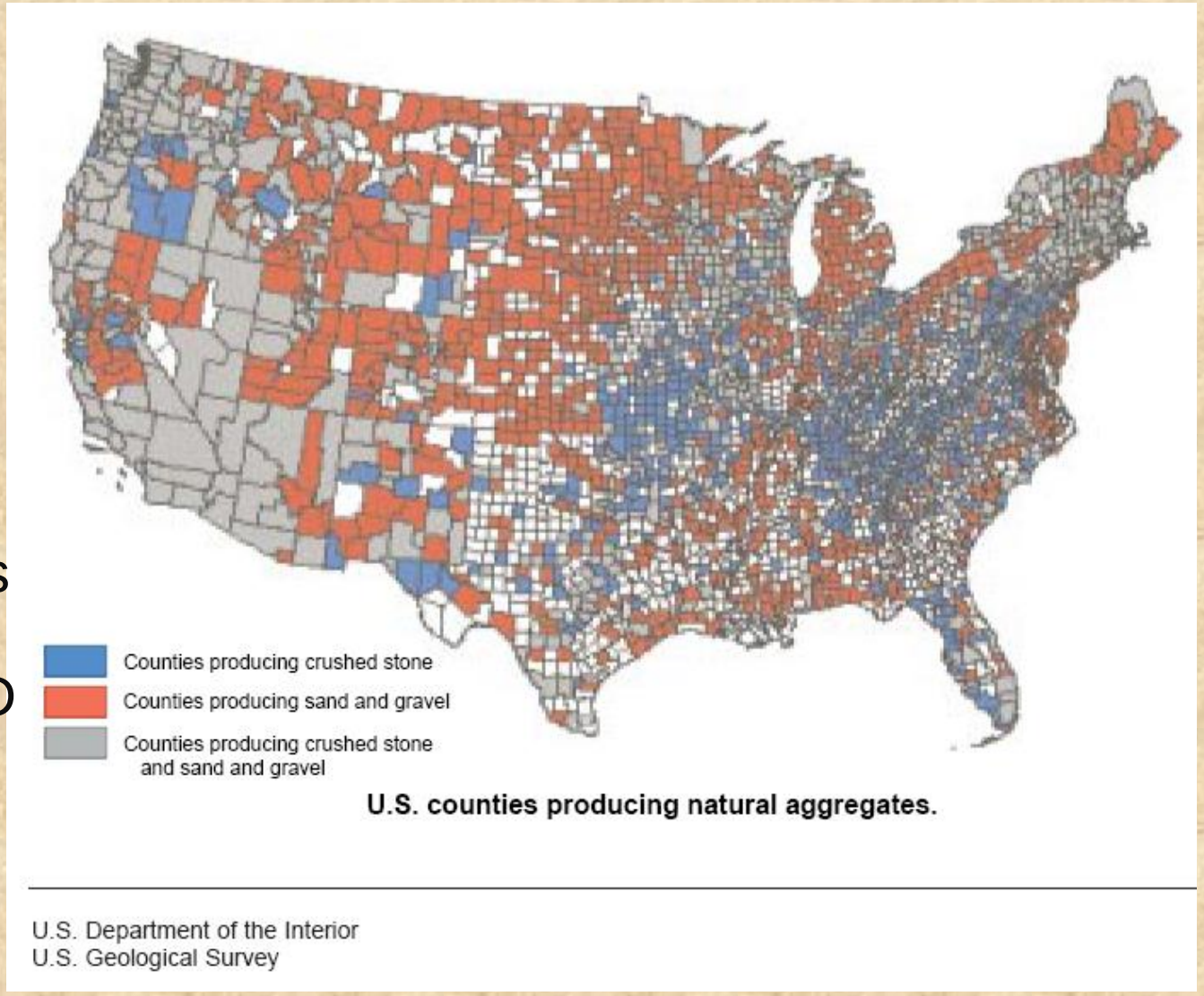
Largest Non-Fuel Minerals Industry in the World (Value and Volume)



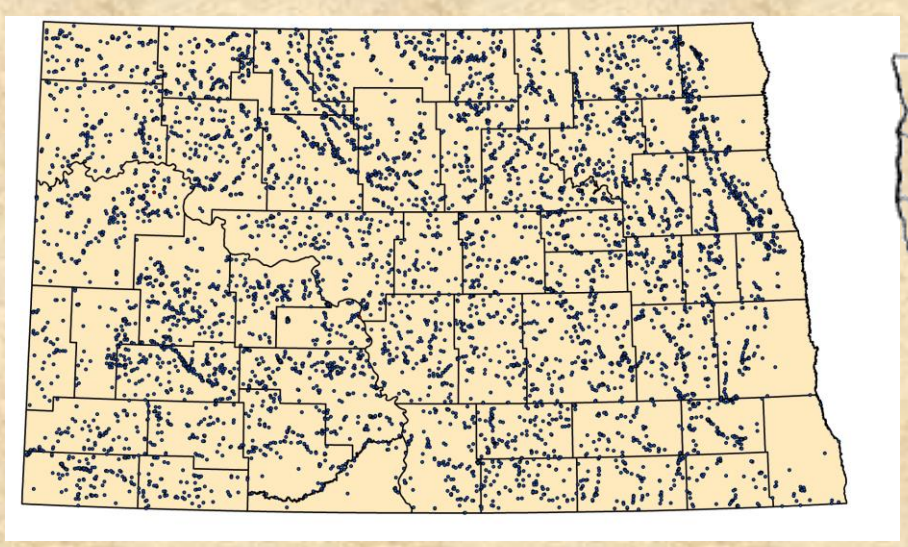
Reference : USGS – Miscellaneous Reports & Talks

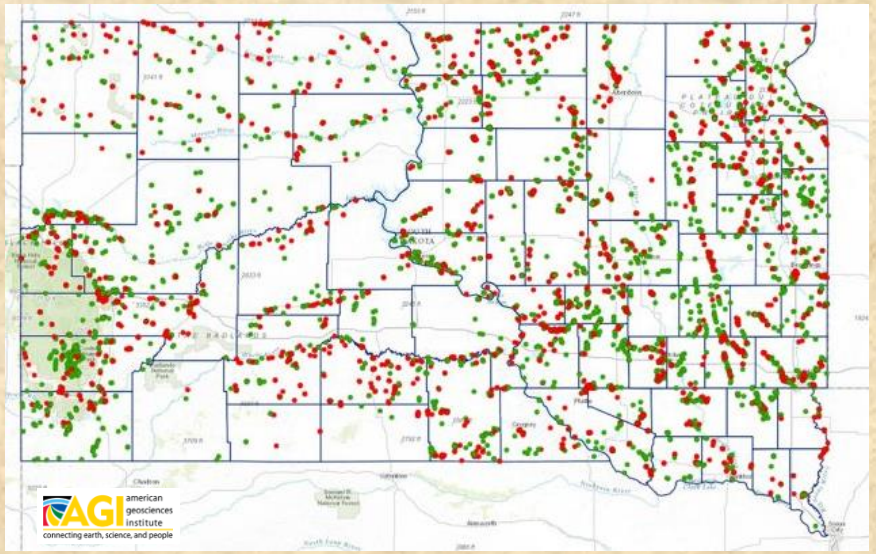
AGGREGATE INDUSTRY

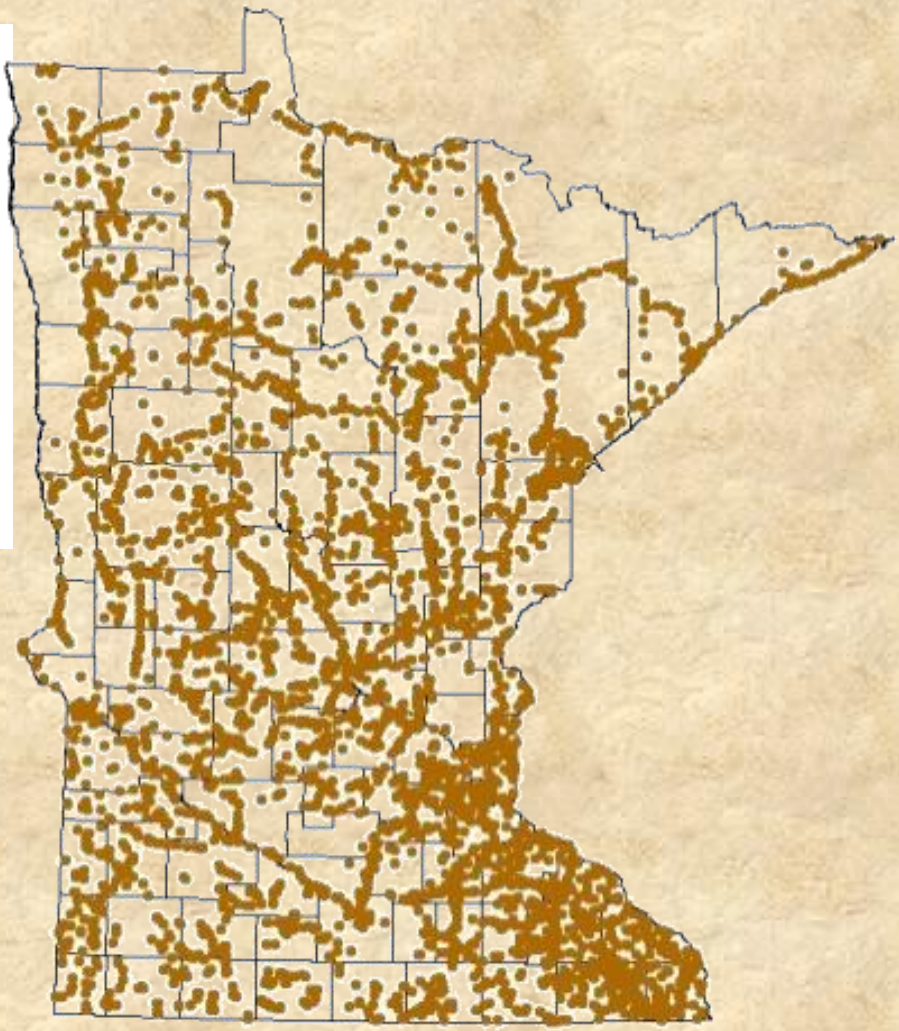
- Largest non-fuel minerals industry US
- Produced in all 50 States
- Produced in all 66 counties in SD, all 53 counties in ND and 87 Counties of Minnesota



DISTRIBUTION OF GRAVEL PITS

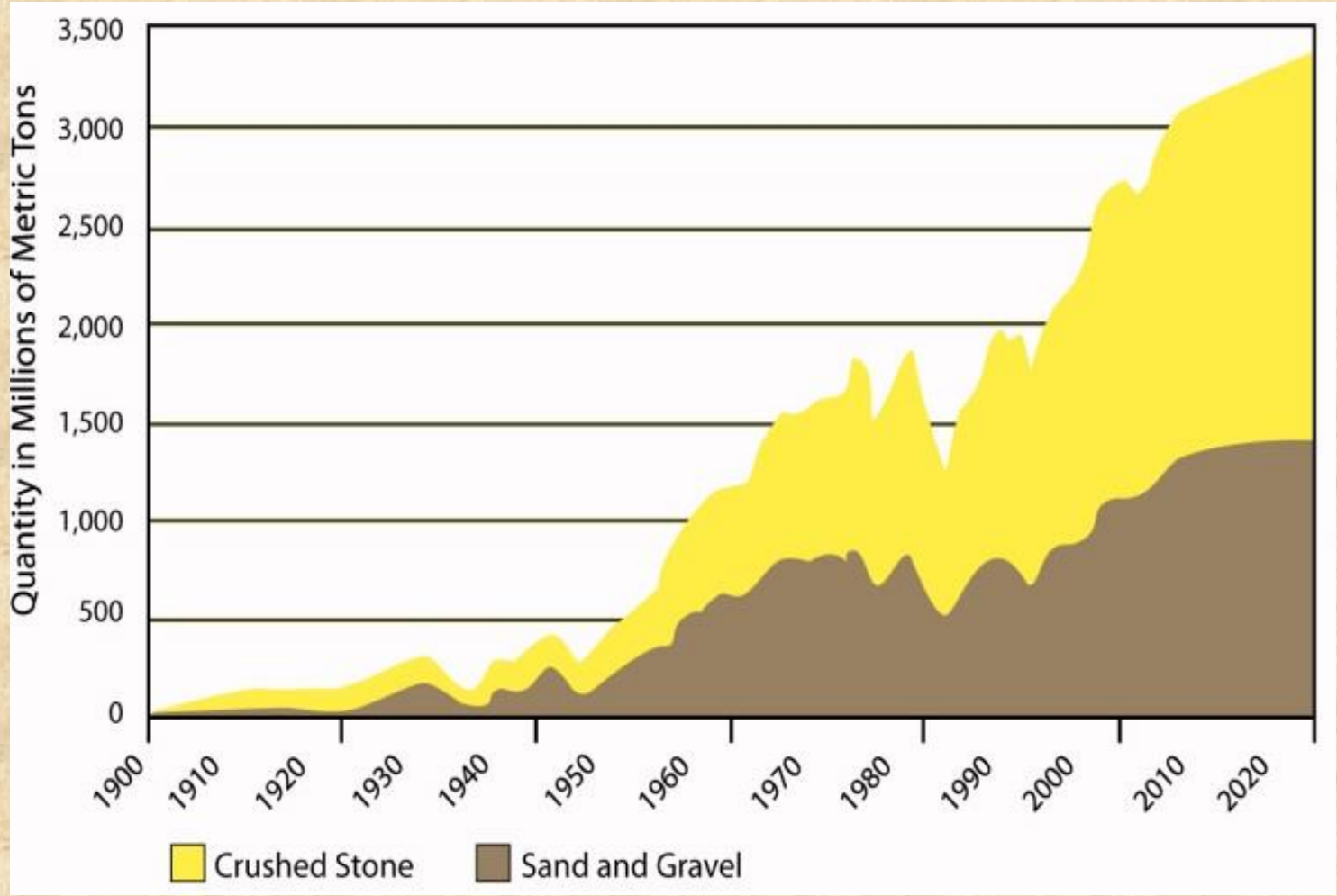






USGS-Landmarks-Gravel pits - http://gisdata.nd.gov/hubdata/NDGISHUB

TRENDS IN AGGREGATE RESOURCES



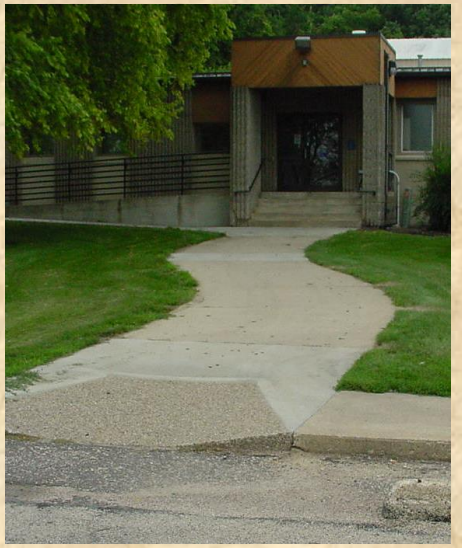
Aggregate production in the United States with projections to 2020, based on a growth rate of 1 percent for stone and 0.5 percent for sand and gravel. Data from the U.S. Geological Survey. (American Geosciences Institute, 2012).

USES OF AGGREGATE

USES OF AGGREGATE

- Sand and Gravel
  - Concrete Aggregates 45%
  - Road Base and Coverings 22%
  - Asphalt & Bituminous 13%
  - Construction Fill 13%
  - Concrete Products 2%
  - Plaster and Gunite 1%
  - Snow and Ice Control <1%
  - Railroad Ballast <1%
  - Roofing Granules <1%
  - Filtration <1%
  - Misc. Uses <1%
- Crushed Stone
  - Concrete Aggregates
  - Road Base and Coverings
  - Asphalt & Bituminous
  - Construction Fill
  - Railroad Ballast
  - Rip-Rap and Jetty Stone
  - Agricultural Limestone
  - Poultry Grit
  - Roofing Granules
  - Filtration
  - Misc. Uses

Concrete Aggregates - 45%



Concrete Aggregates - 45%

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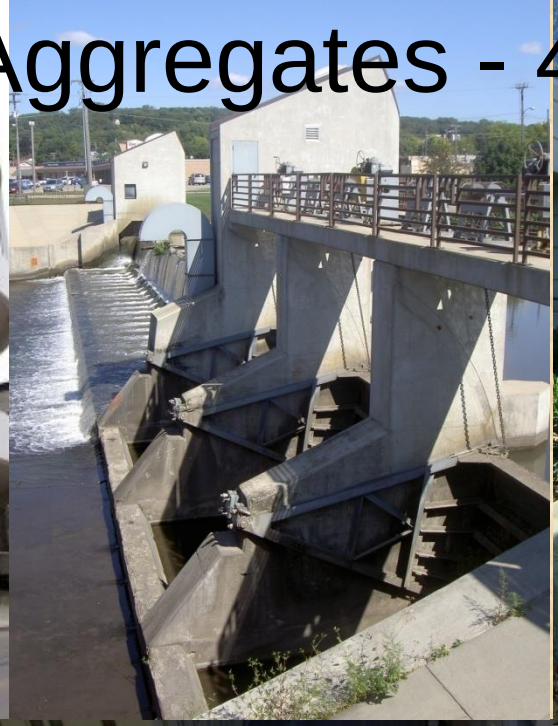
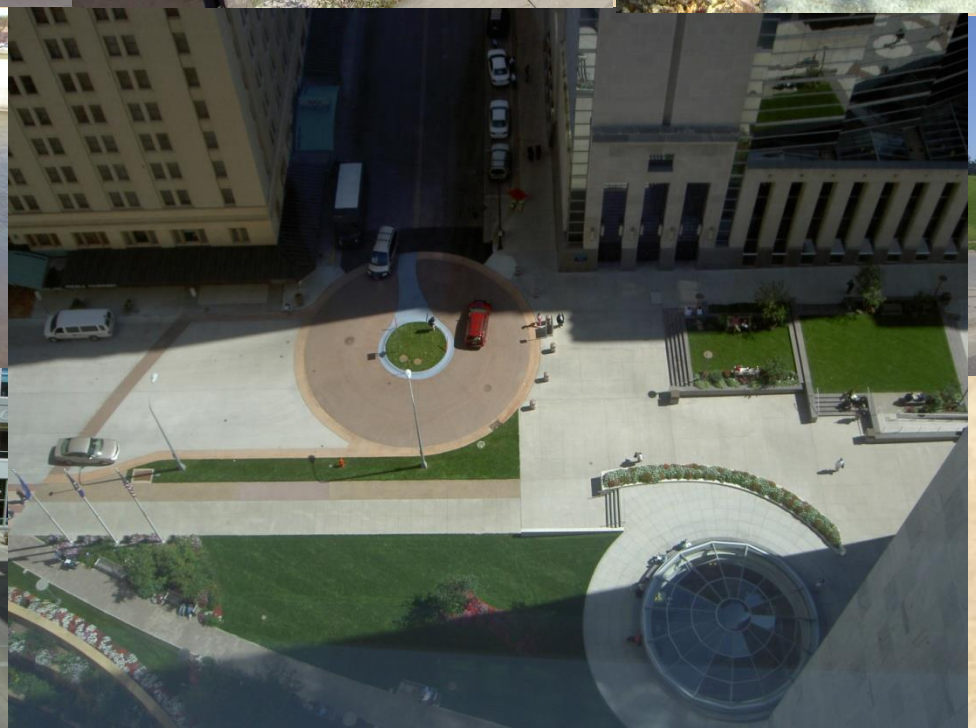
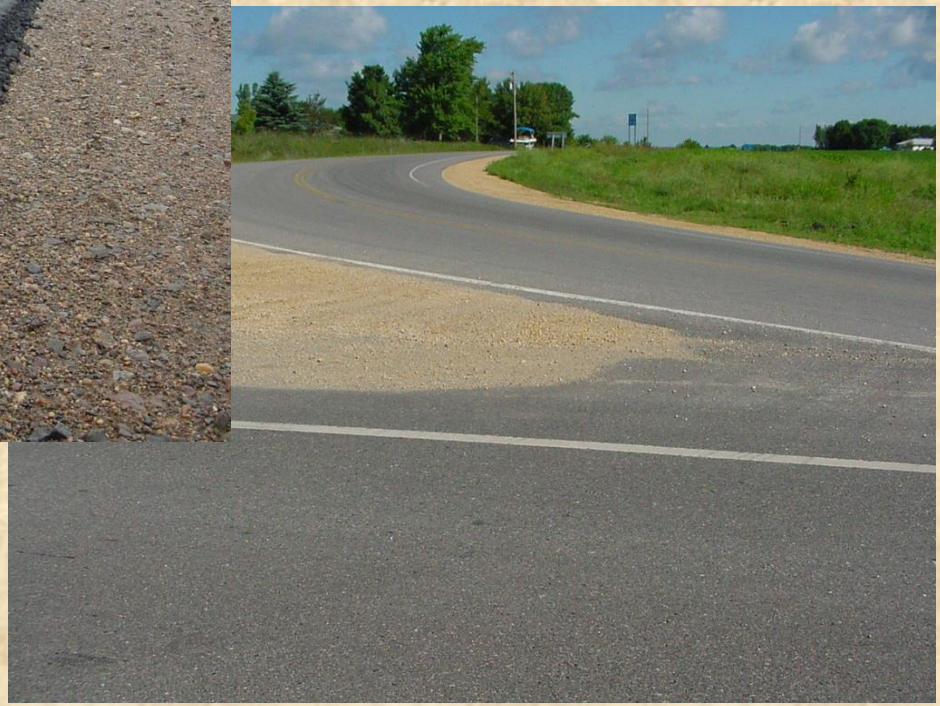
http://www.bismarckparkingauthority.com/





Road Base and Coverings - 22%

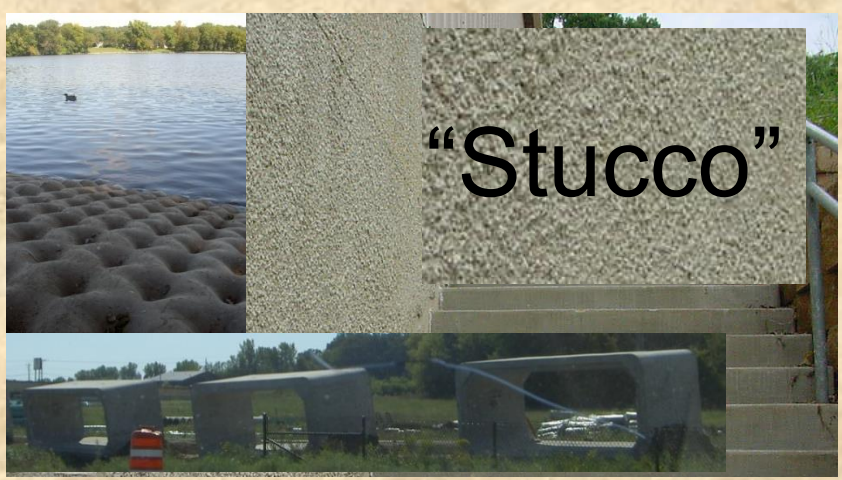


Asphalt / Bituminous - 13%

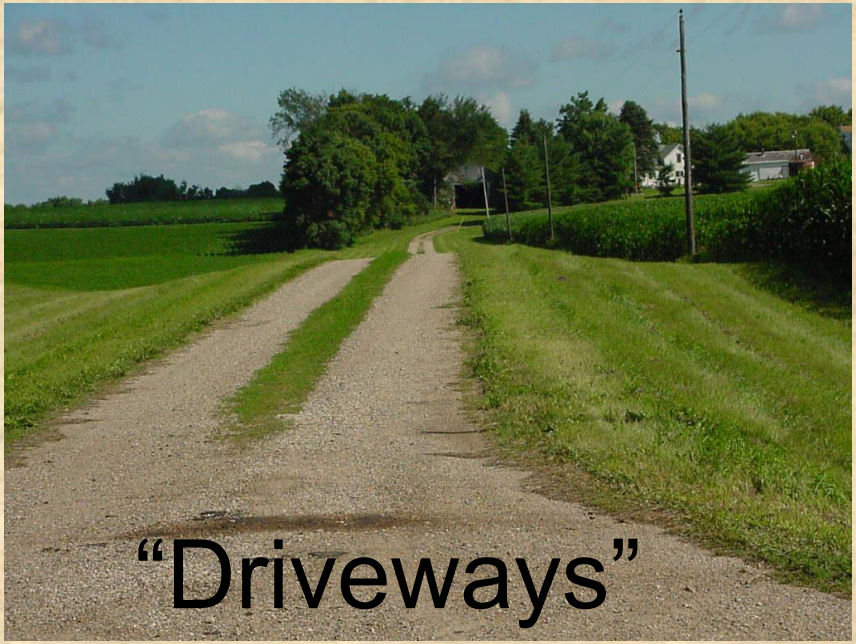
Asphalt / Bituminous - 13%

Construction Fill - 13%

Concrete Products-2%

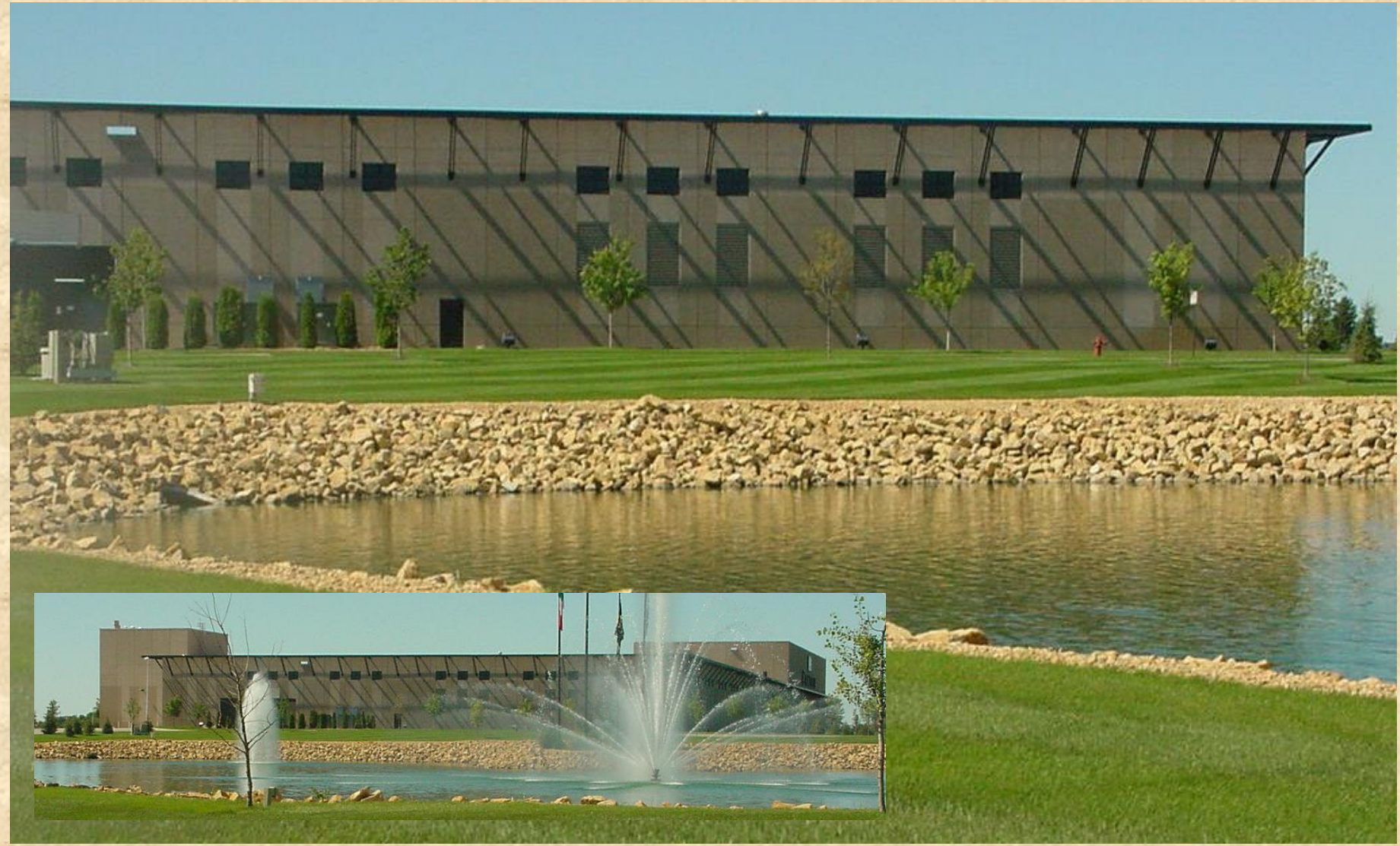



“Gravel Roads”

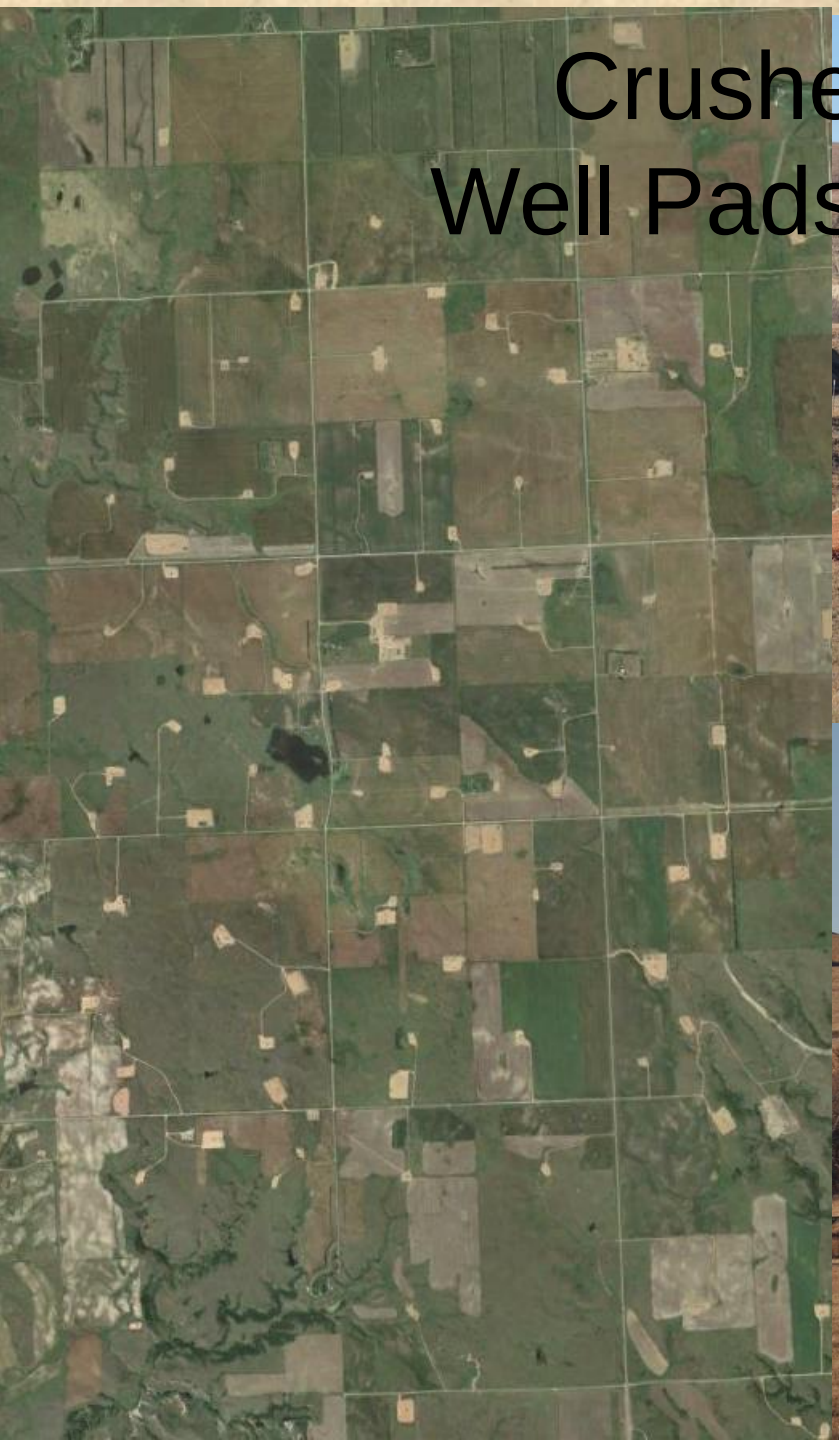

“Driveways”

Rail Road Ballast

Rip Rap and Jetty Stone



Crushed Stone Uses:
Well Pads & Access Roads



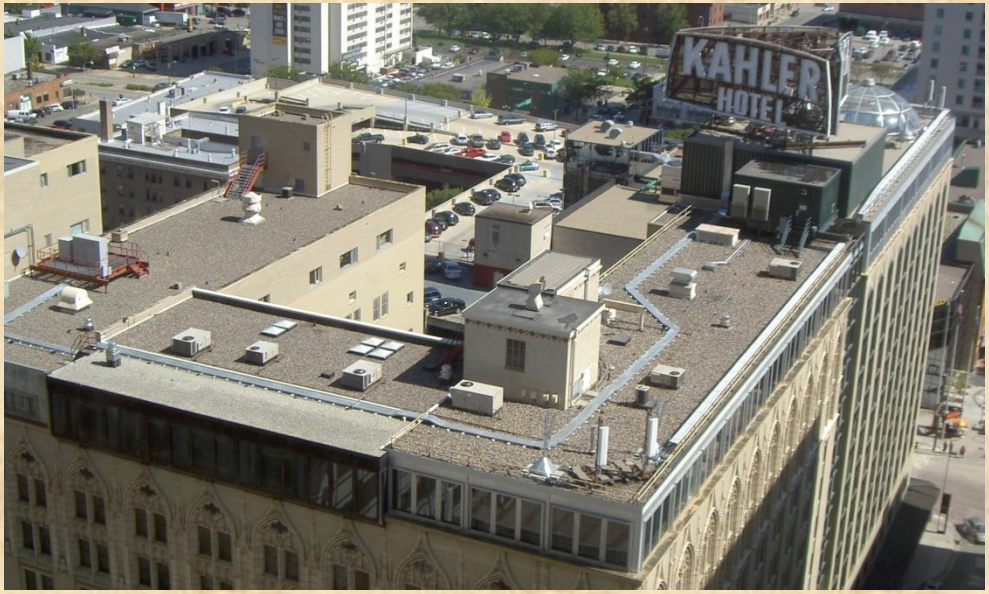
Miscellaneous Uses

Playgrounds, Pools, Benches, Fountains, Sidewalks, Posts, etc.

Miscellaneous Uses of Aggregate –

Beach Sand

Miscellaneous Uses of Aggregate




CLAIRMO CENTER
FOR PERFO MING ARTS

Quality of Deposit →Determines End-Use

AGGREGATE QUALITY

- Final end use is determined by the quality
  - Soundness / Durability / Textural Characteristics
  - Mechanical Properties
    - Strength of the Rock
    - Resists Abrasion
    - Resists Fracturing
  - Chemical Properties
    - Does not Decompose
    - Does not Swell / Shrink
    - Does not React Adversely with Cement or other Rock Types

- Textural Quality of Rock
  - Size of Material / Grains
  - Shape of Material / Grains
  - Textural Composition
    - Ex: Class 5 Material
    - Mixture of cs. and fines
    - Engineering Specifications
- High Quality Aggregate
  - Concrete and Asphalt
- Lower Quality Aggregate
  - Construction Fill & Base

AGGREGATE QUALITY

- Spall – Shale, Iron oxide, unsound chert, etc…
- LAR%, Mag %, Absorption, S.G., Litho-counts, etc…

- Iron oxide

Aggregate Quality

Where did the material come from?

Different glacial lobes deposited different material depending on location of lobe advancement.

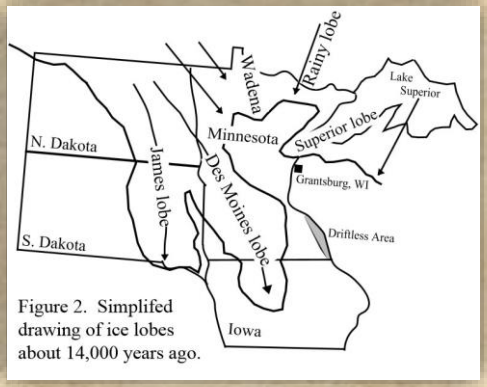
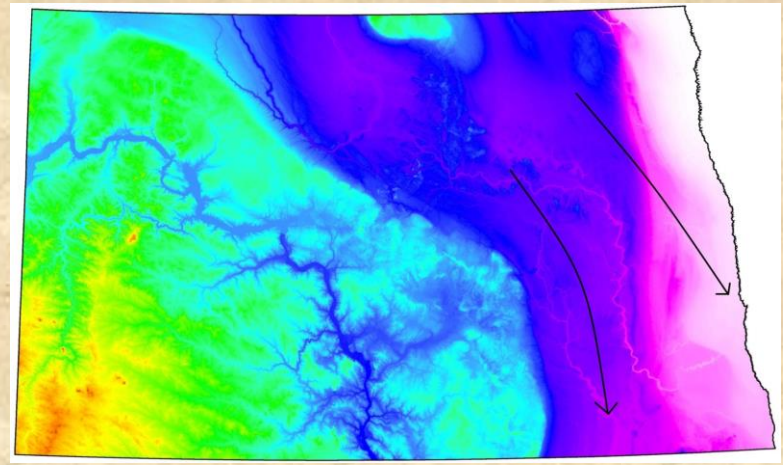
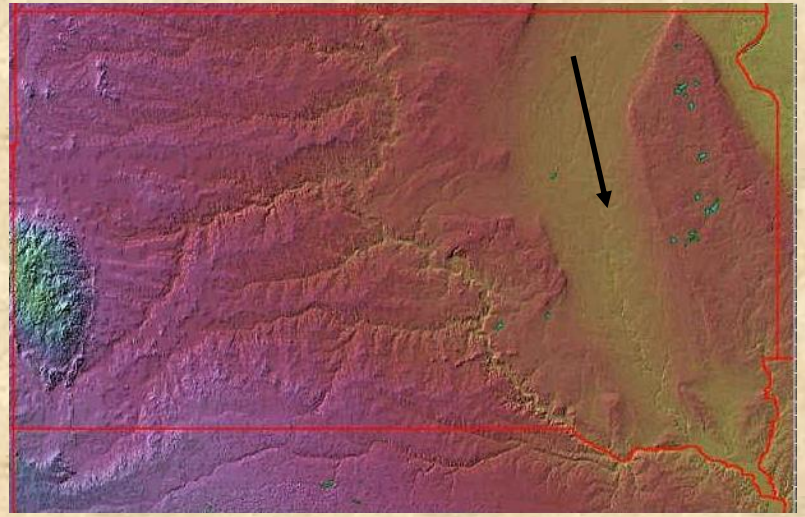
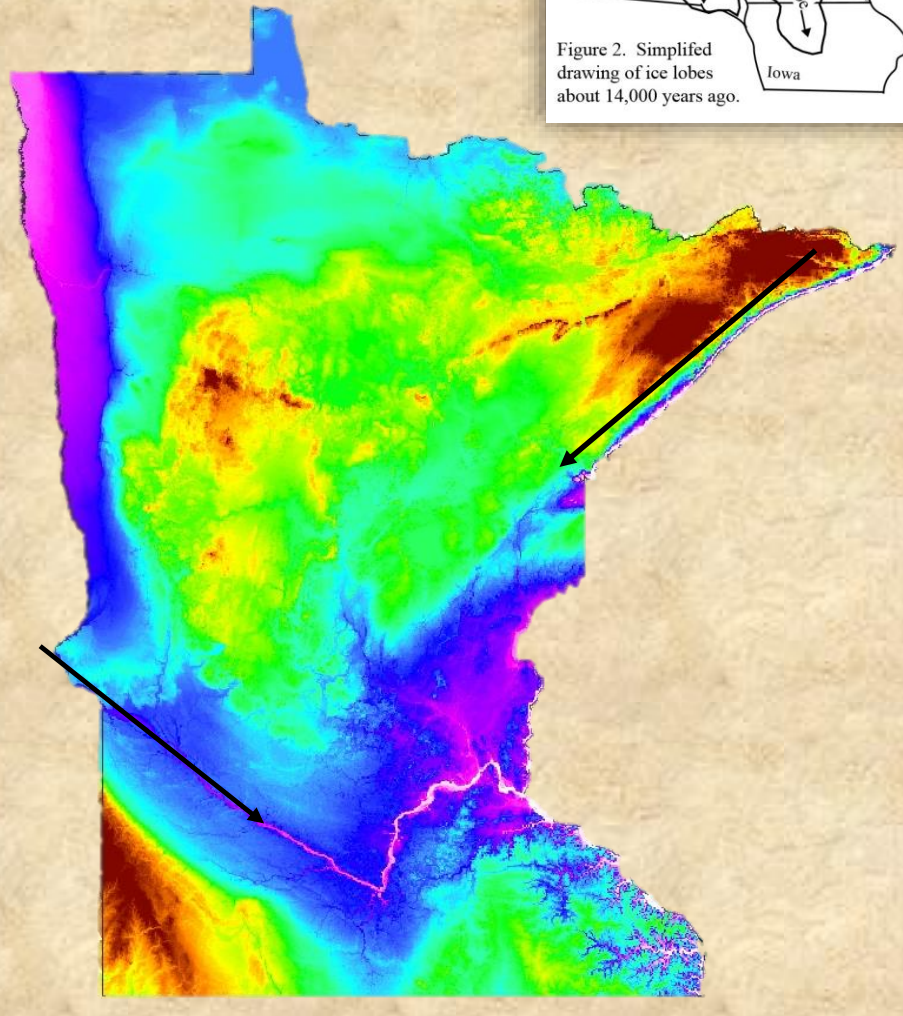


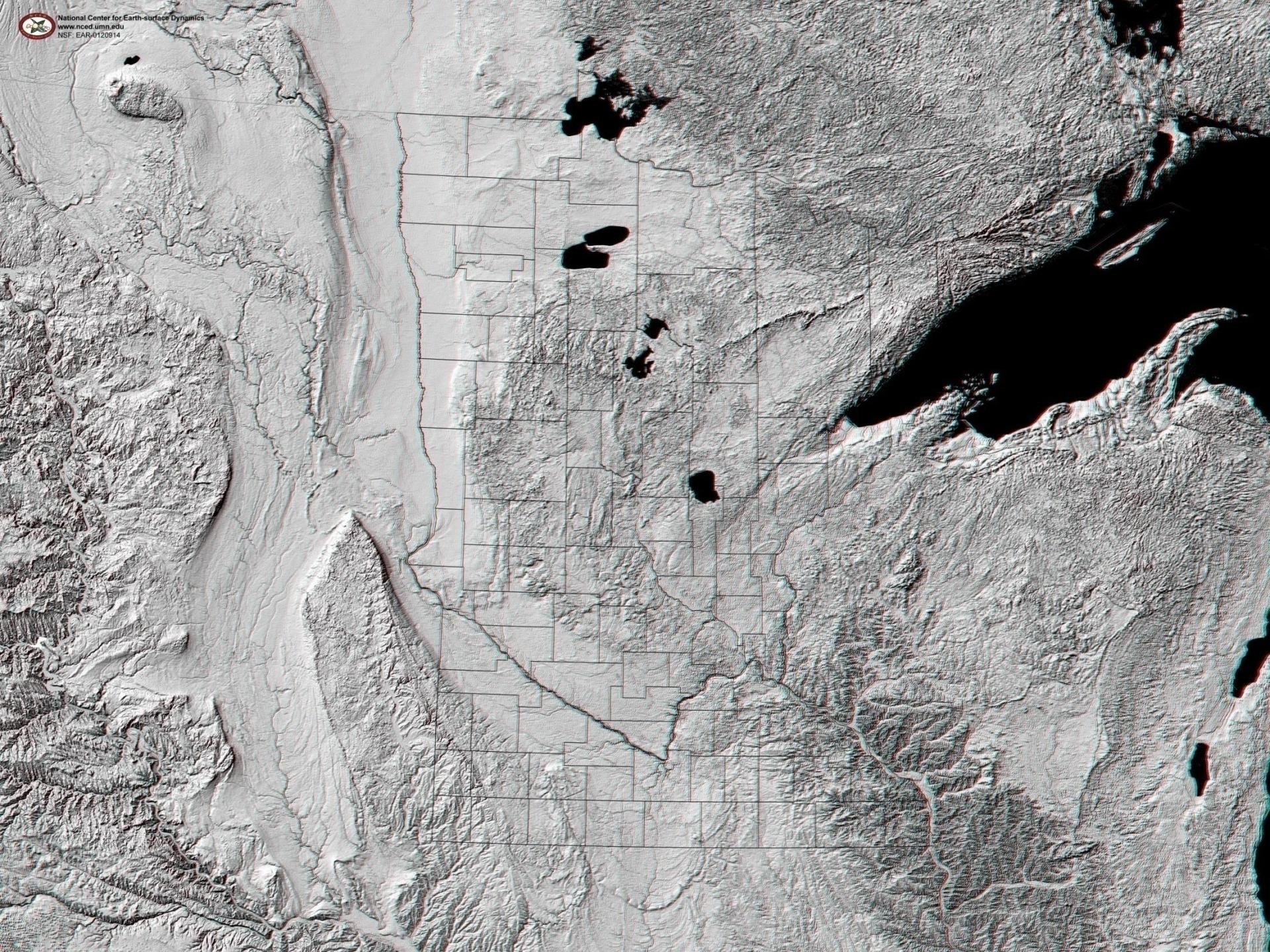
Figure 2. Simplifed drawing of ice lobes about 14,000 years ago.



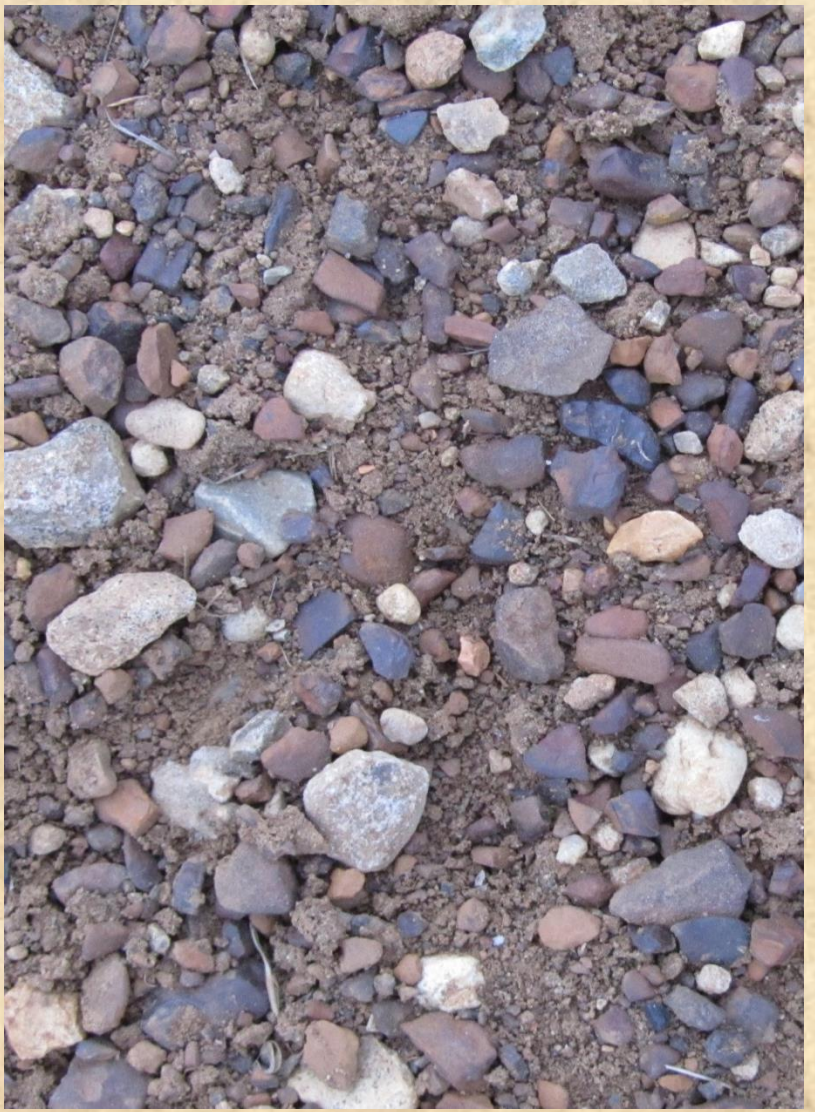




http://www.sdgs.usd.edu/publications/maps/reliefmap/reliefmap.htm


National Center for Earth-surface Dynamics
www.nced.umn.edu
NSF: EAR-0120914

Quality Issues in SW North Dakota



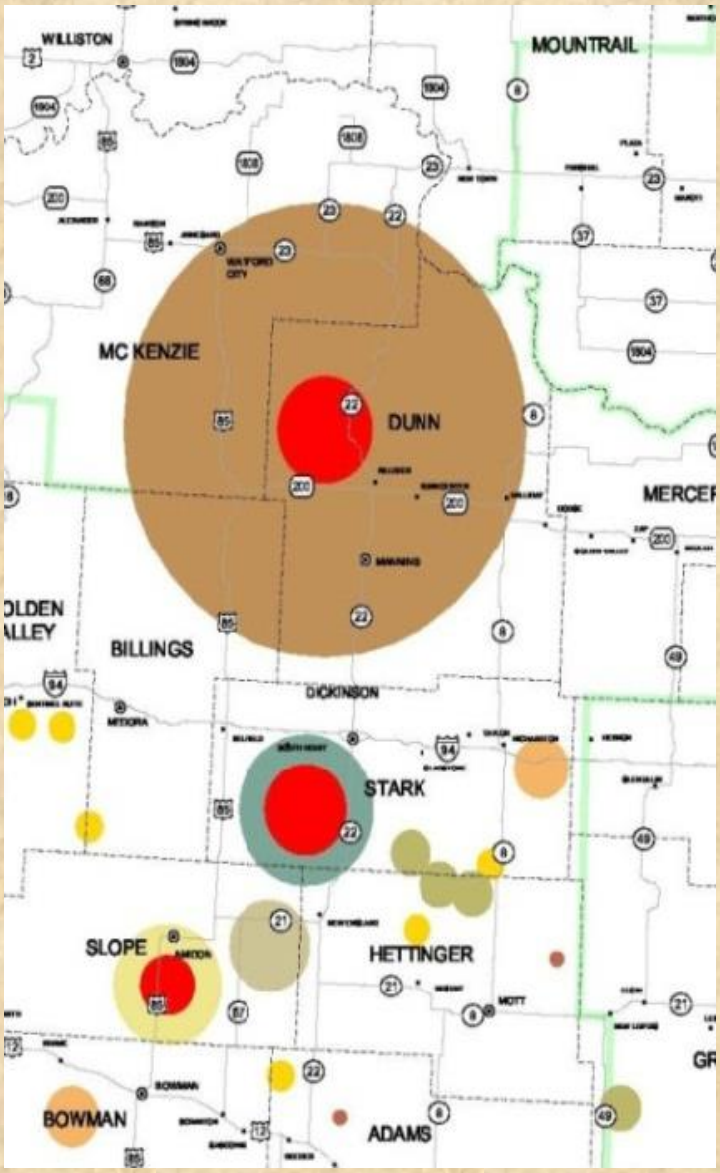
ERIONITE SAMPLING RADIUS

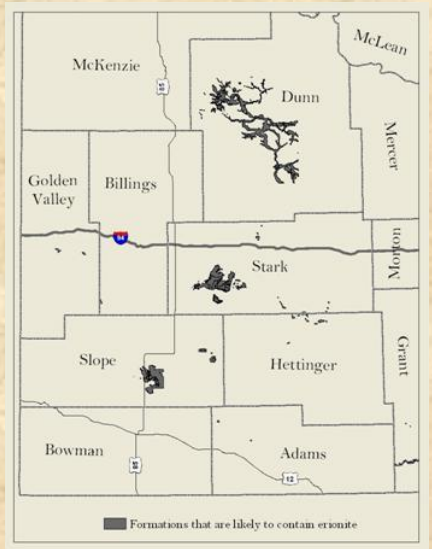
Pit Location Radius

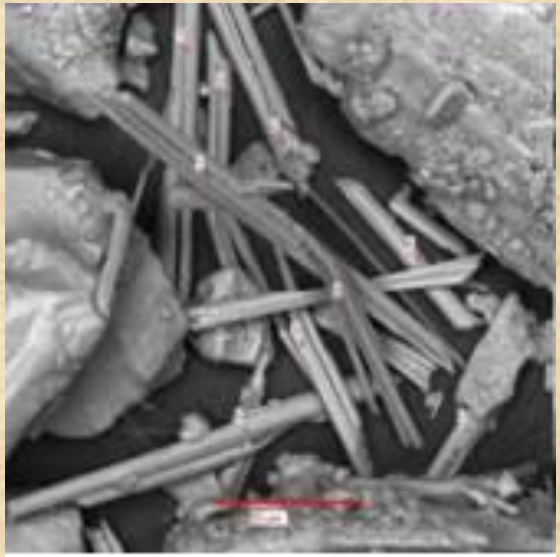
Restricted Locations

Radius in Miles

- 1 mile
- 2 mile
- 3 mile
- 4 mile
- 6 mile
- 7 mile
- 8 mile
- 10 mile
- 30 mile



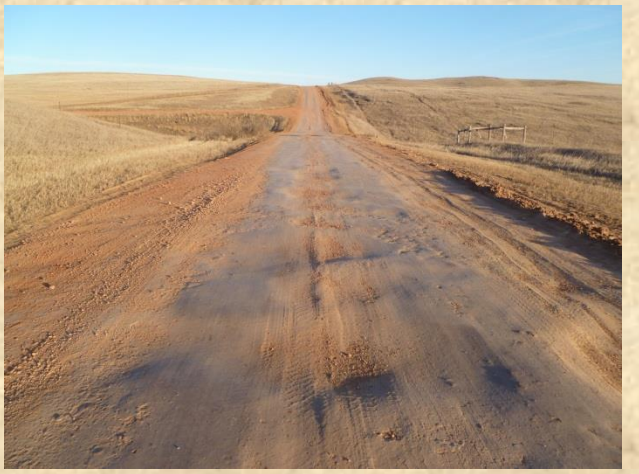




Erionite (500X magnification)

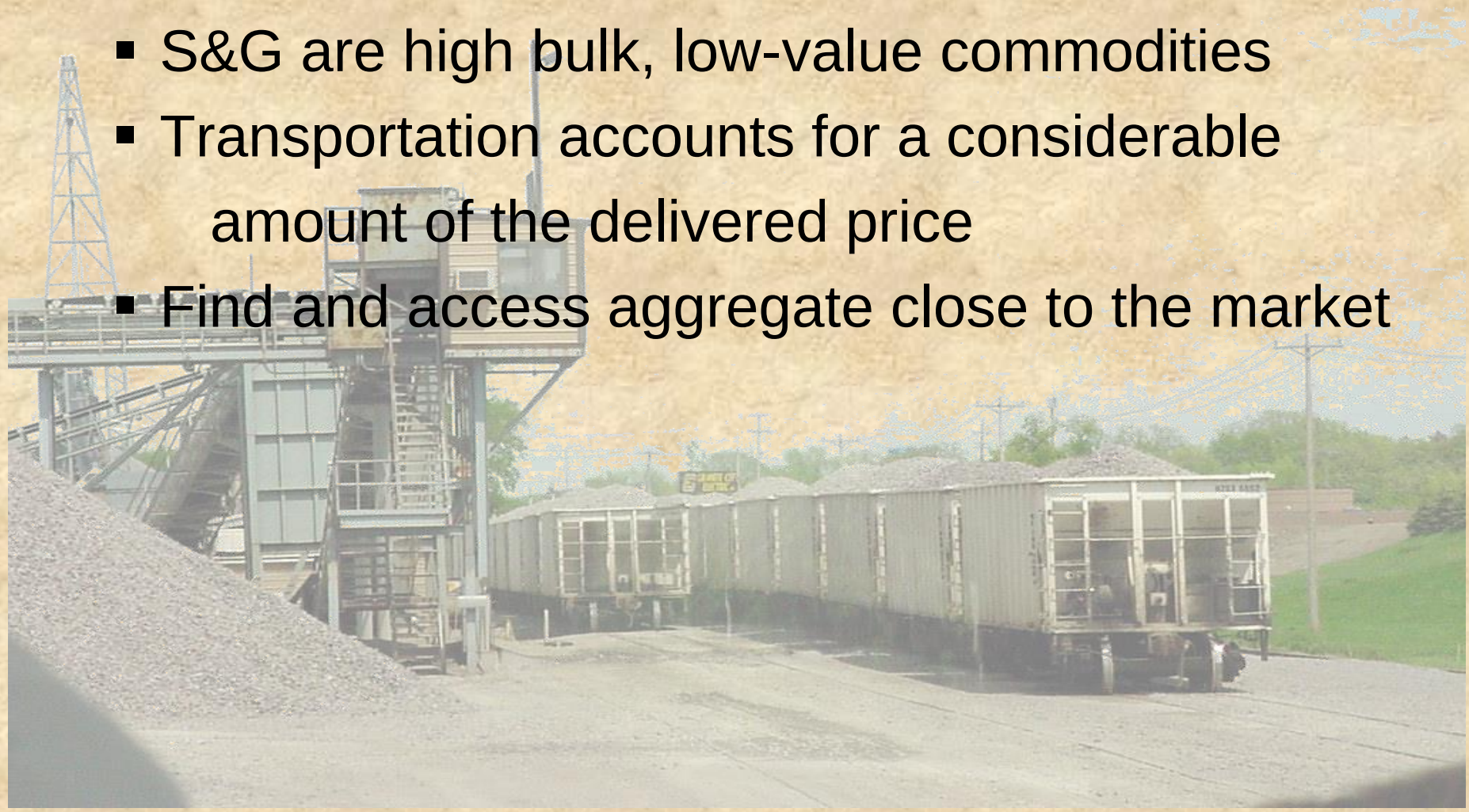
http://www.ndhealth.gov/EHS/erionite/

Scoria Roads – Degrade Very Quickly

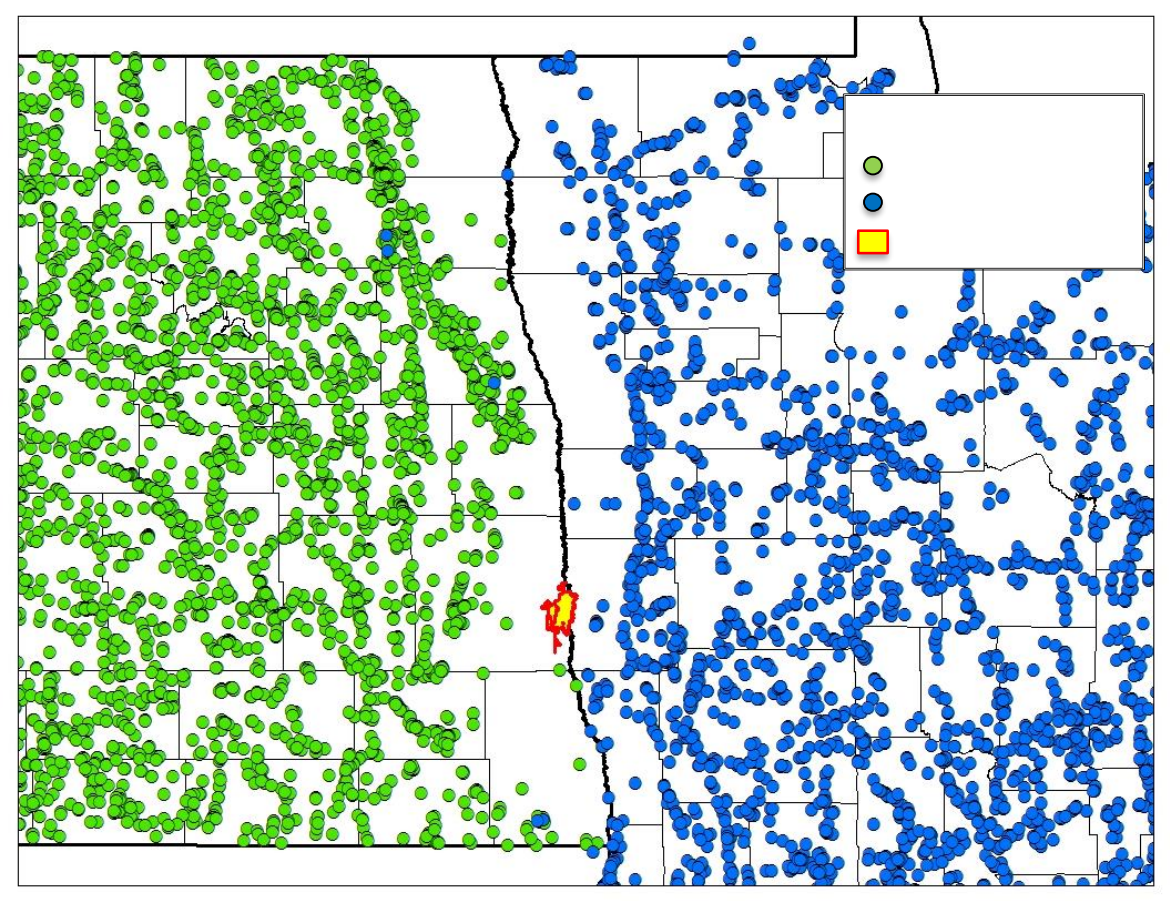


SUPPLY AND DEMAND

- Transportation
  - S&G are high bulk, low-value commodities
  - Transportation accounts for a considerable amount of the delivered price
  - Find and access aggregate close to the market



Supply & Demand



Red River Valley

- Limited sand & gravel resources

Reference: Reshaping The Tornado Belt – Red River Valley

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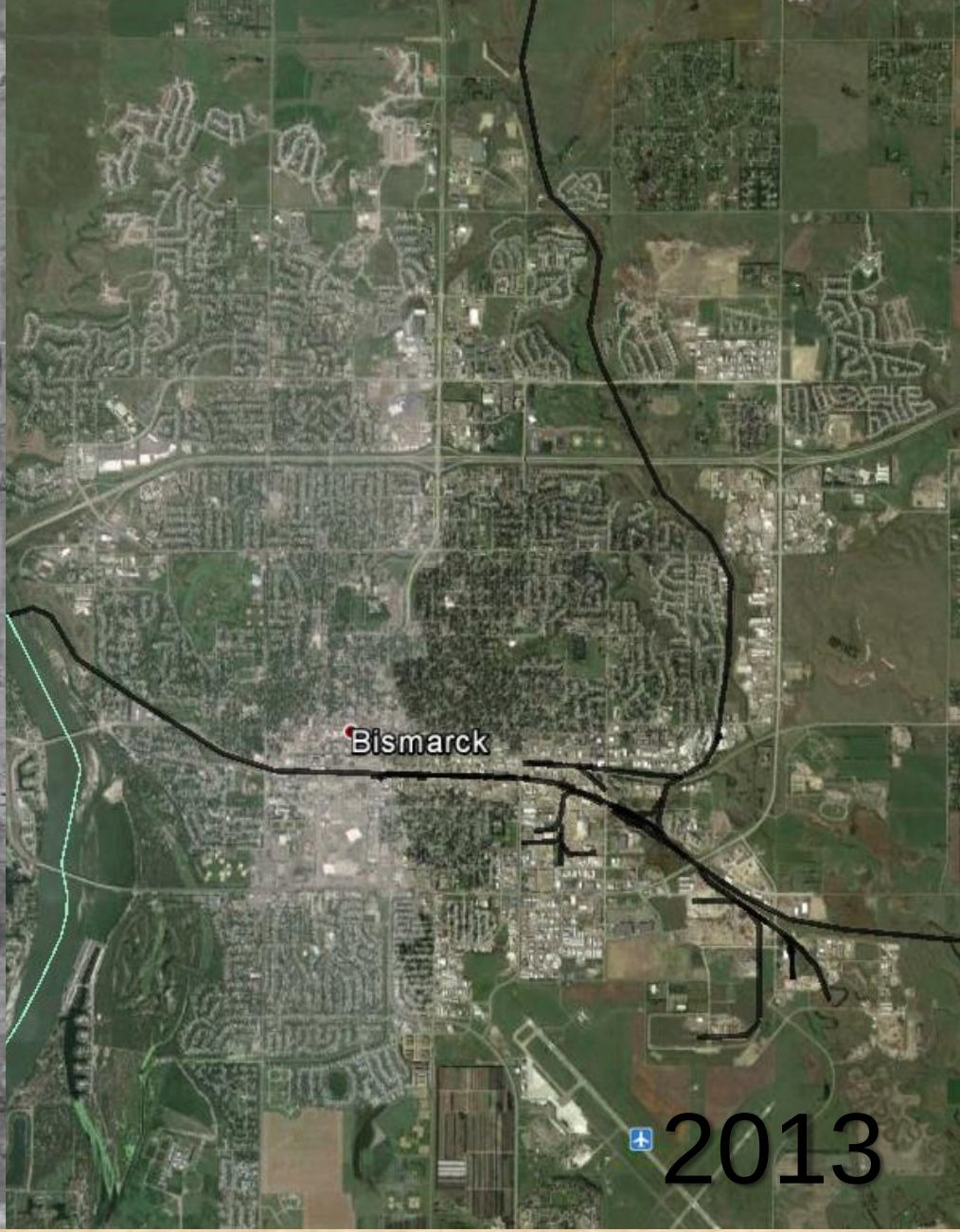
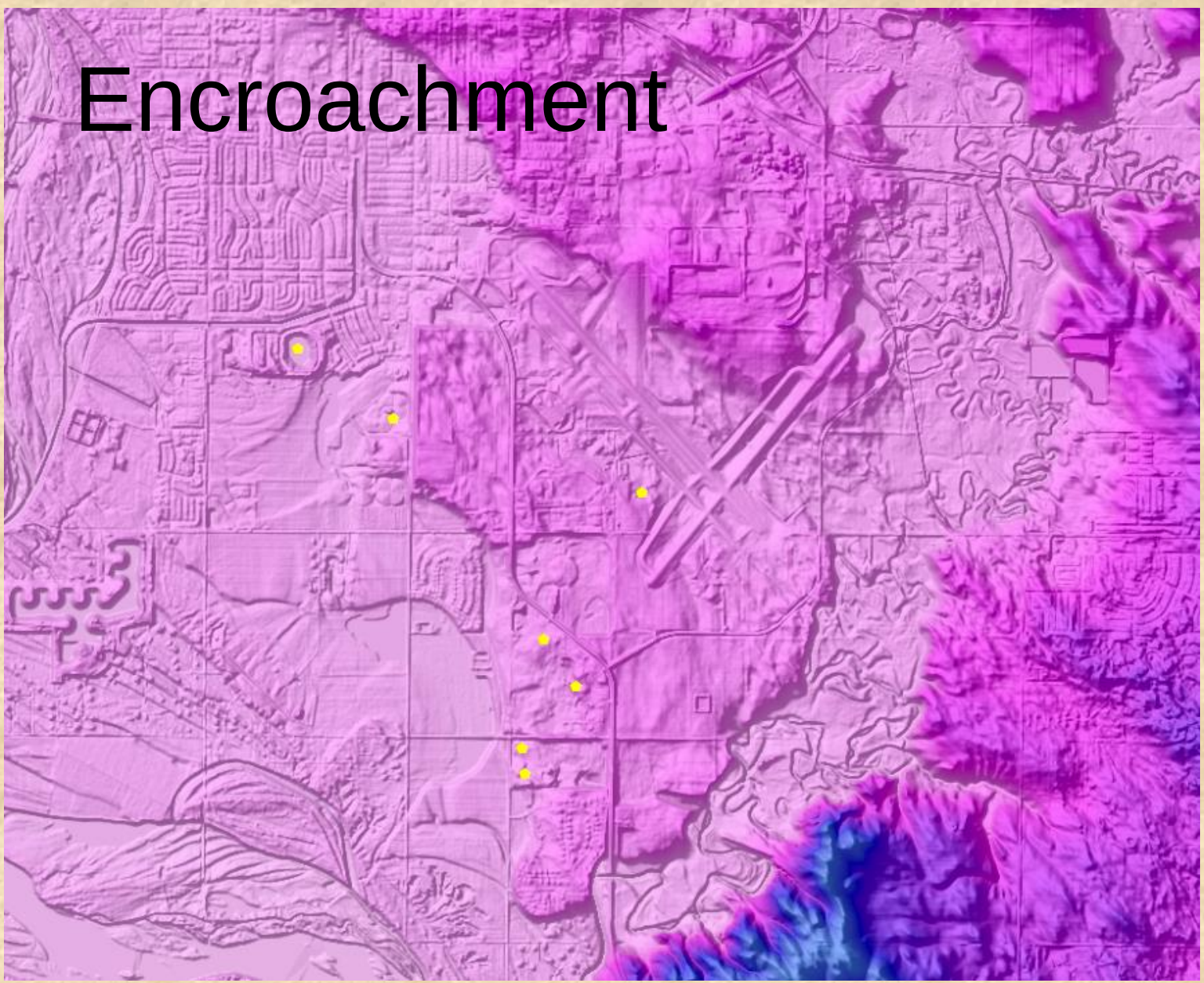
Encroachment

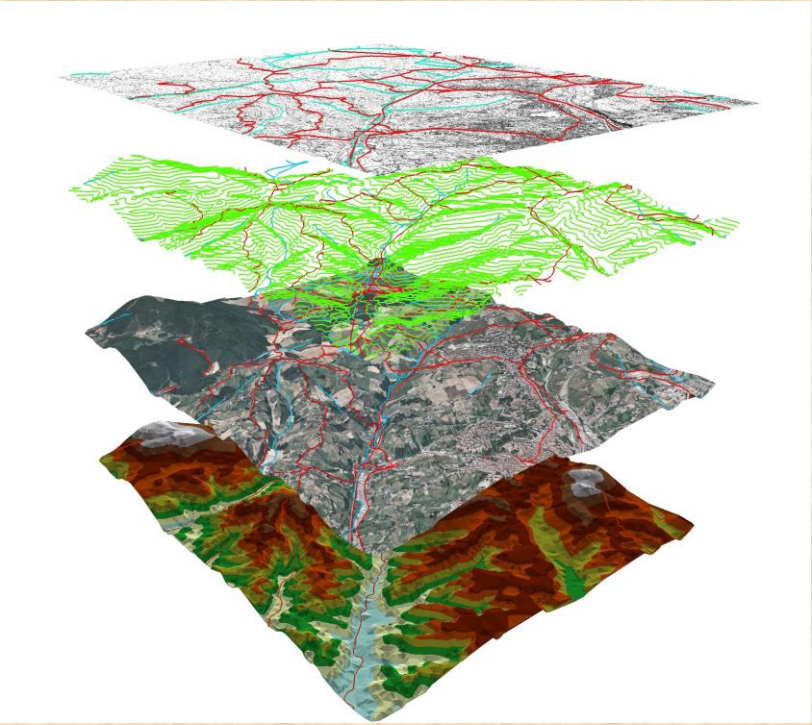


Encroachment



Traditional Sand & Gravel Mapping

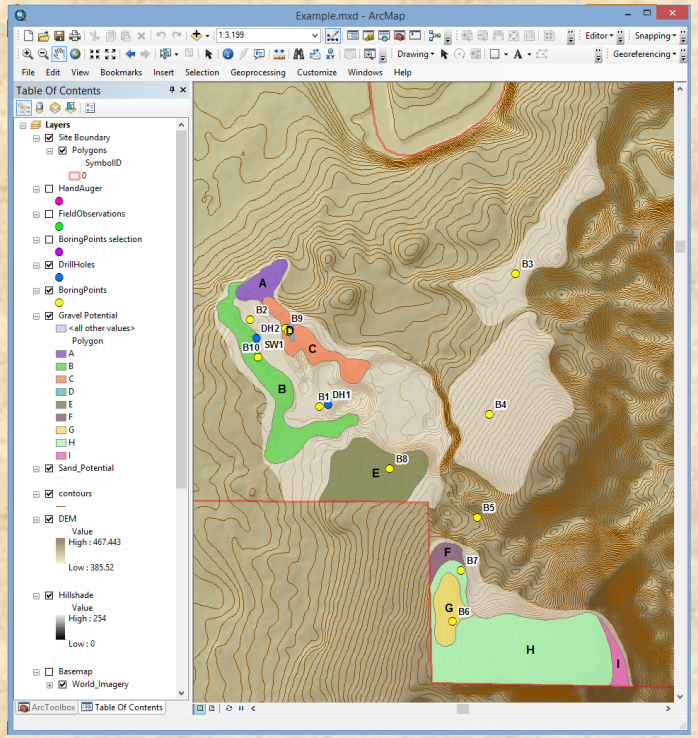
- Geographical Information Systems (GIS)
- Soils Maps
- Topographic Maps (Landform mapping)
- Aerial Photography
- Digital Elevation Models (DEMs)
- Water Well Data
- Vegetation / Land use
- Crop Production / Growth Patterns



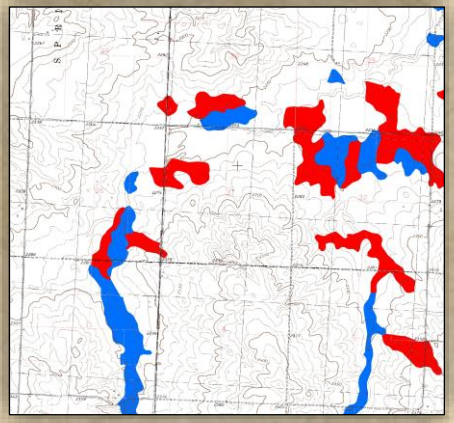
Reference: http://syntecx.com/gis-services/

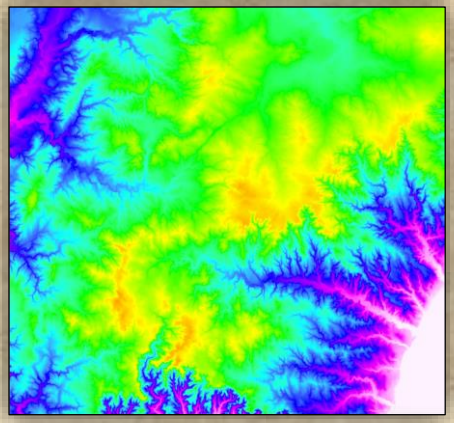
Traditional Sand & Gravel Mapping

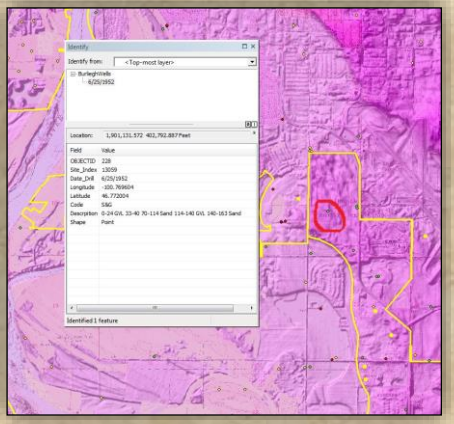
Geographical Information Systems (GIS) – ArcGIS (ArcMap)



- Maps & Information that can be added into ArcMap

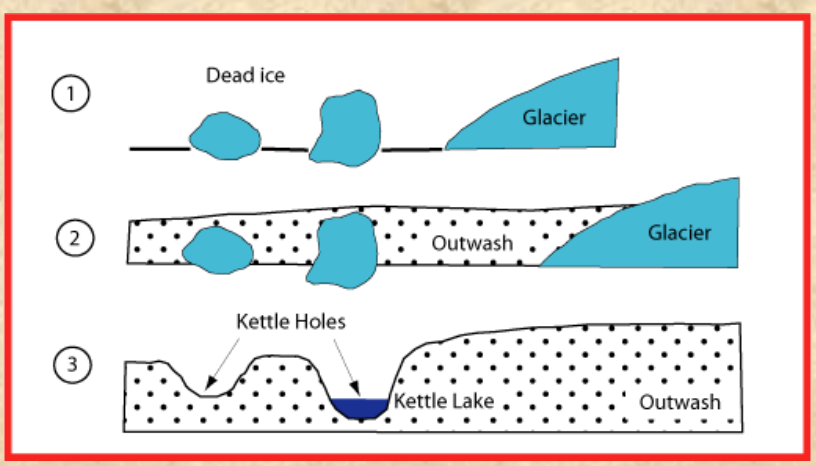




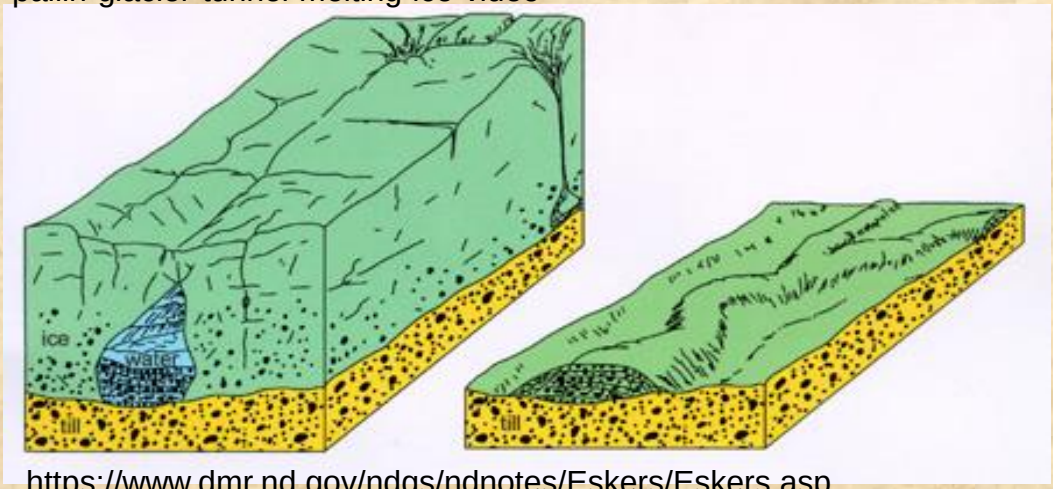


Landform Mapping - Glacial Deposits

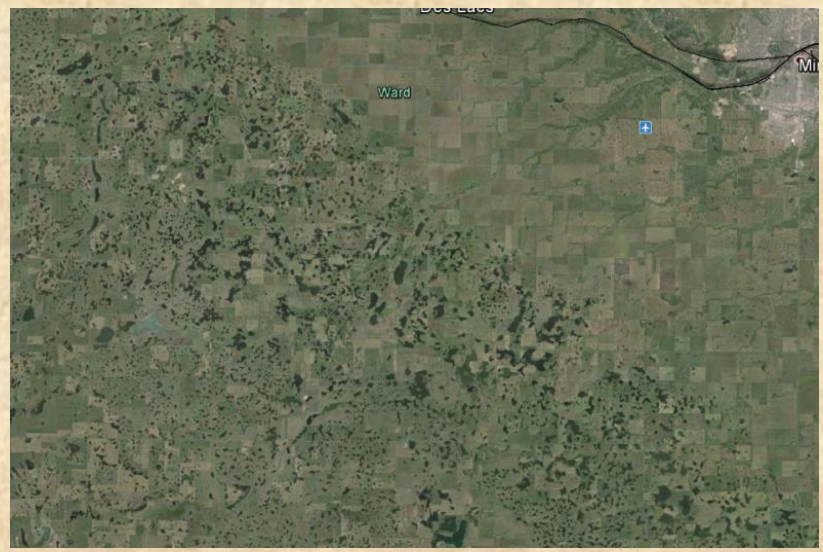
http://www.theguardian.com/environment/video/2013/oct/10/inside-pallin-glacier-tunnel-melting-ice-video



http://www.landforms.eu/cairngorms/kettle%20hole.htm

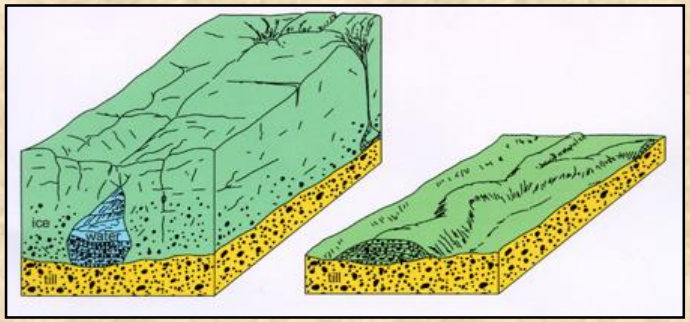


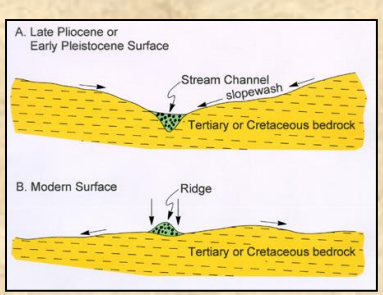
https://www.dmr.nd.gov/ndgs/ndnotes/Eskers/Eskers.asp



Landform Mapping – Glacial Deposits

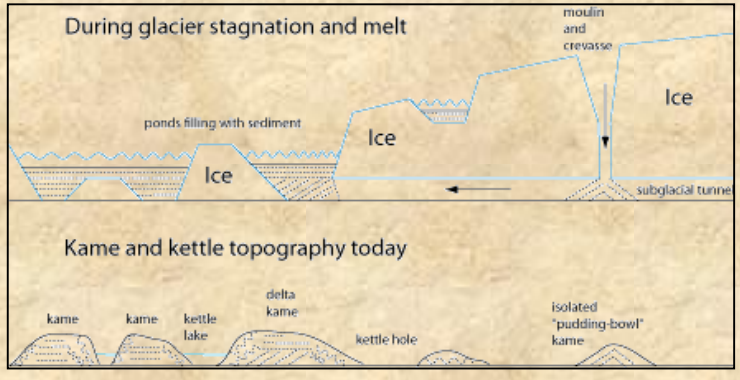
Esker – A long, narrow, winding ridge composed of stratified sand & gravel deposited by subglacial or englacial meltwater stream.





Reference: https://www.dmr.nd.gov/ndgs/ndnotes/Eskers/Eskers.asp

- Kames – A hill or hummock composed of stratified sand & gravel deposited by glacial meltwater.



Reference: http://landforms.eu/cairngorms/kame.htm

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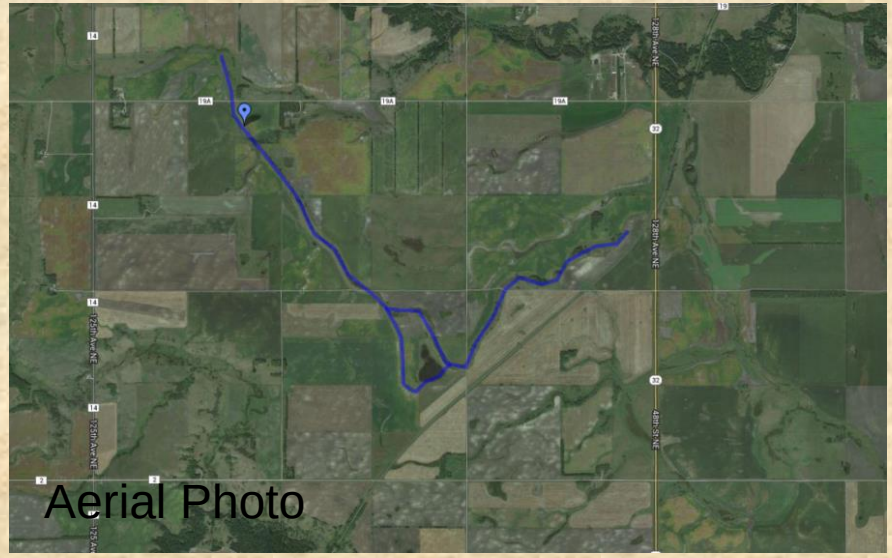
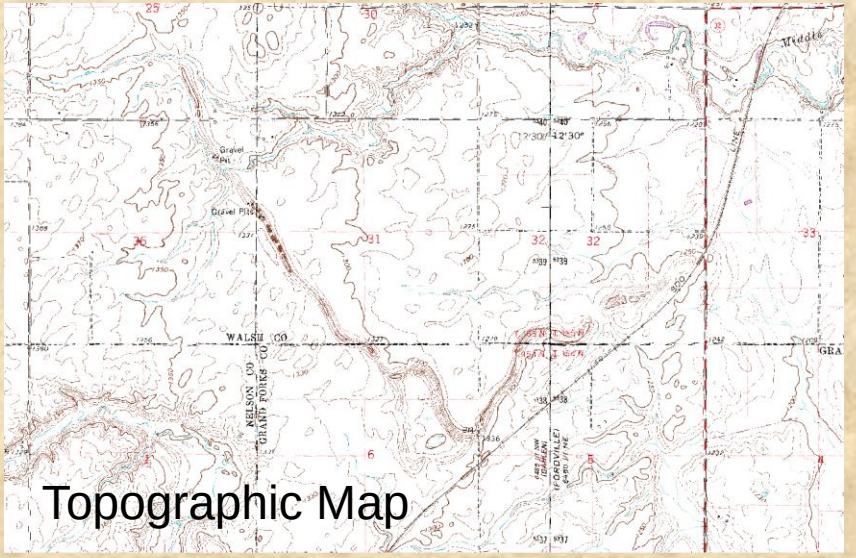
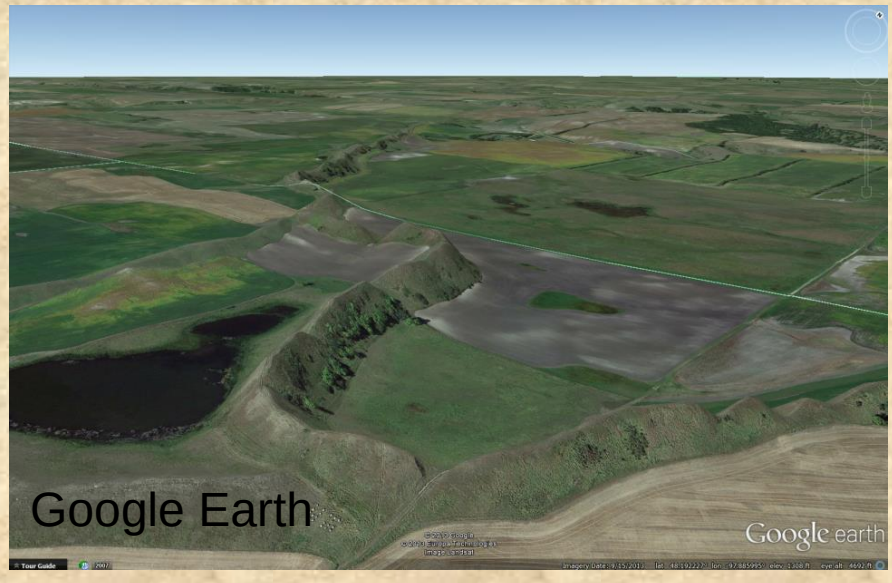
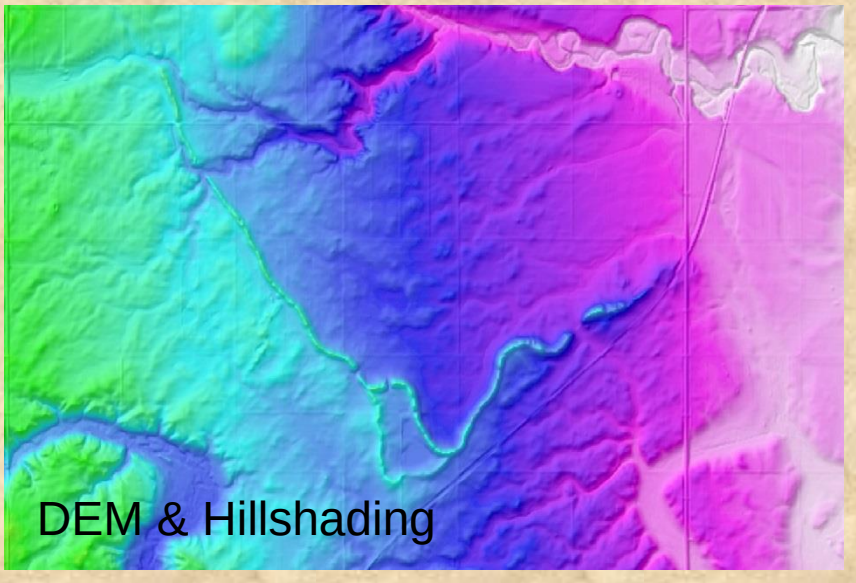
Glacial Mapping – The Dahlen Esker



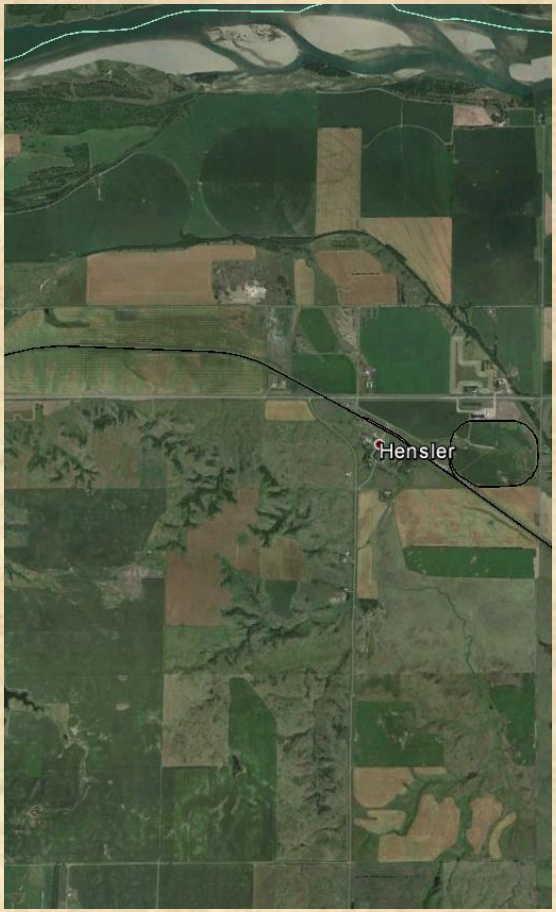




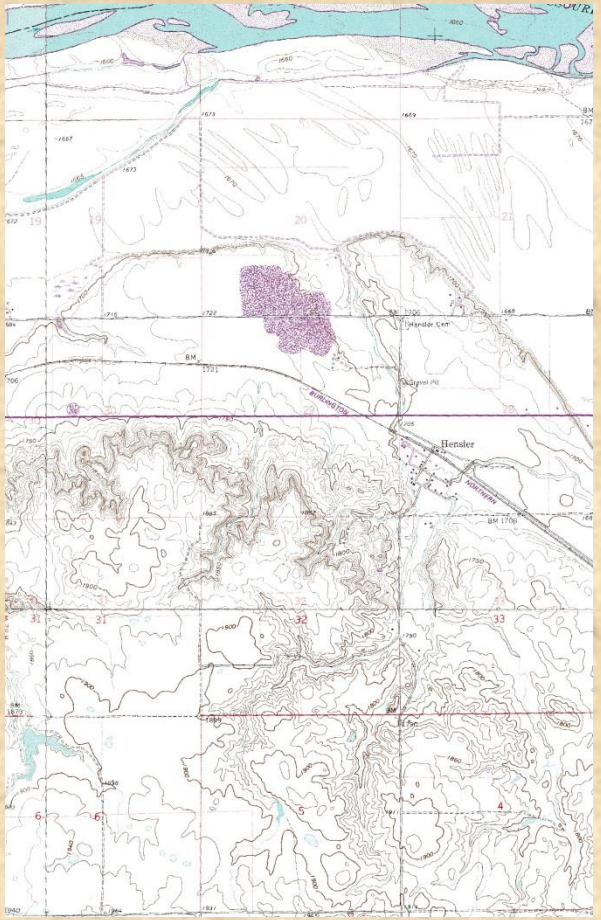


Landform Mapping - Fluvial Deposits

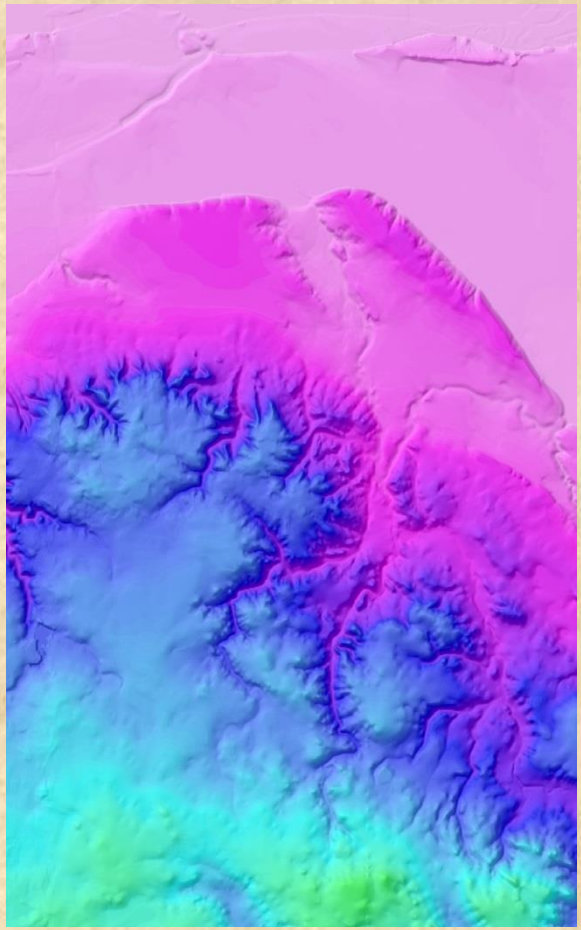
Aerial Image



Topographic Map

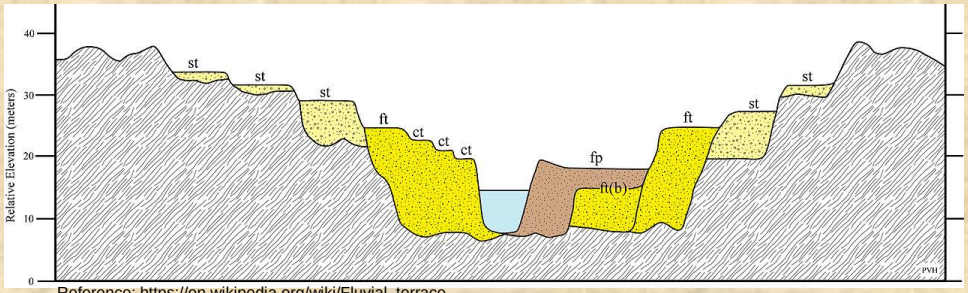


DEM/Hillshading



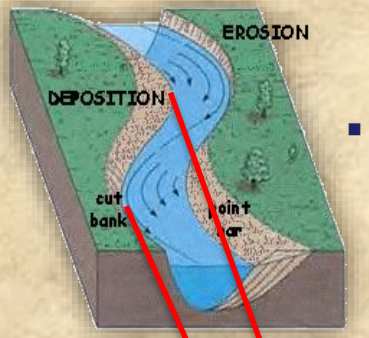
Landform Mapping – Fluvial Deposits

Terrace – Fluvial terraces are remnants of the former floodplain of a stream or river.



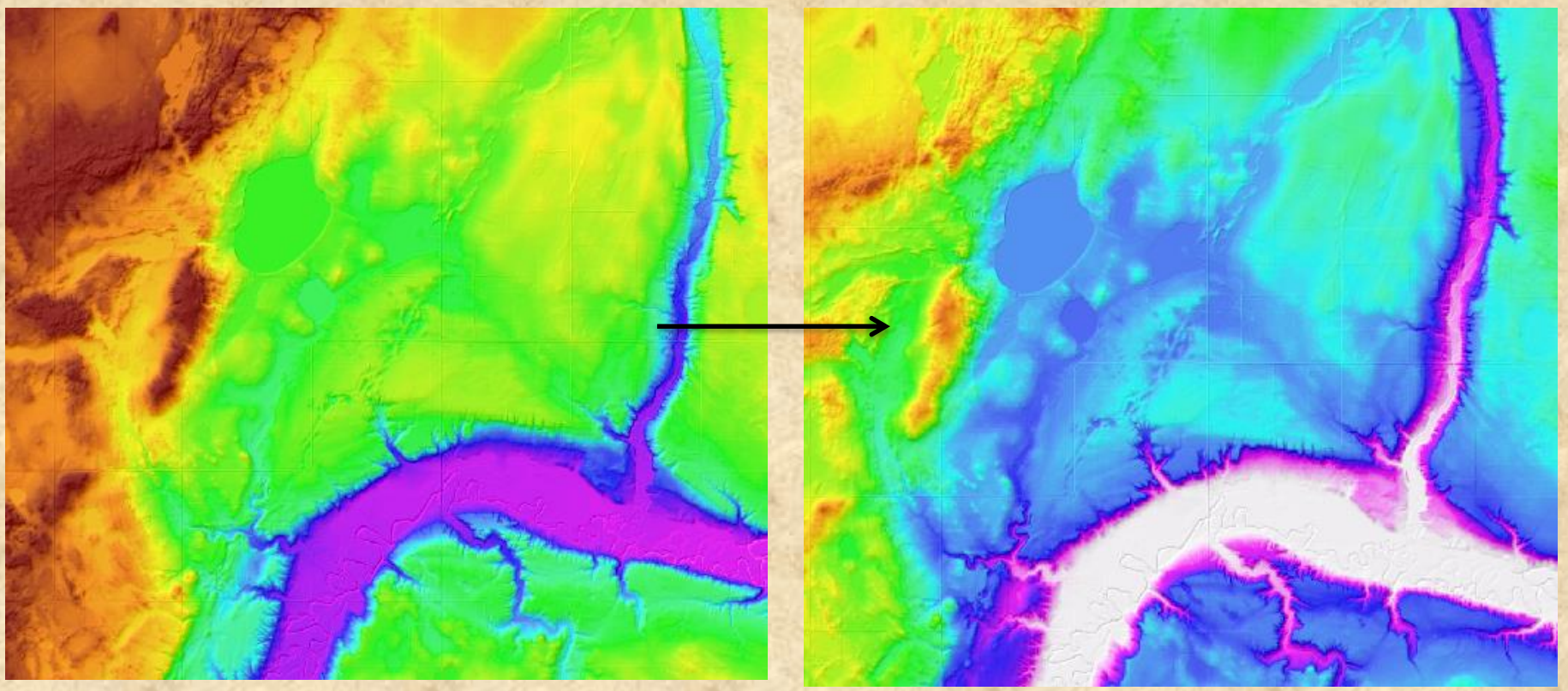
Reference: https://en.wikipedia.org/wiki/Fluvial_terrace

- Terrace

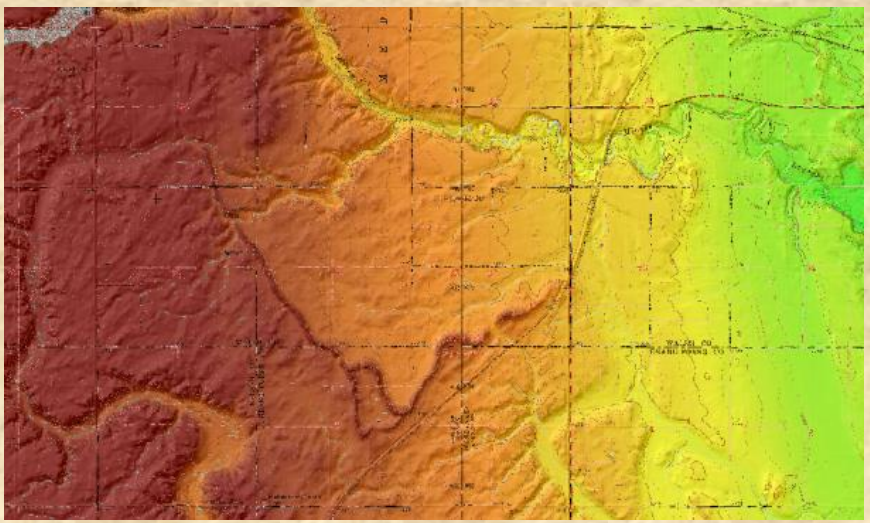


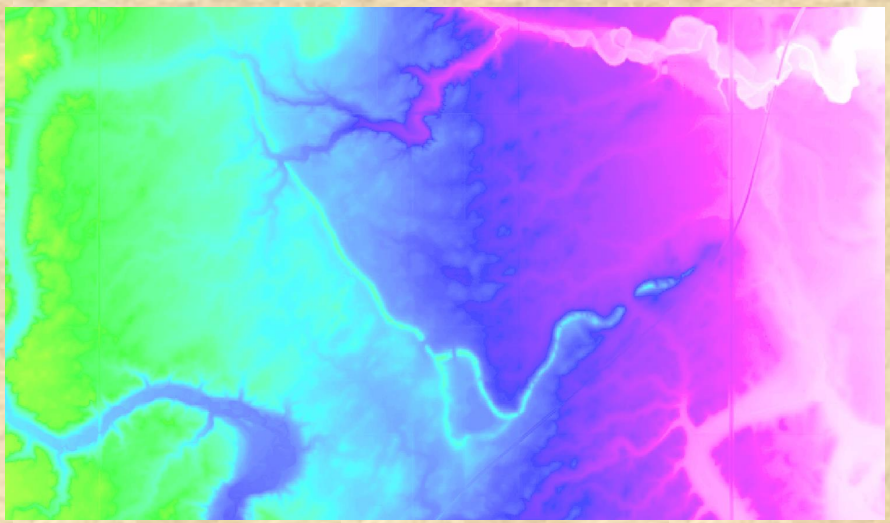
- How a river deposits sediment is based on velocity.

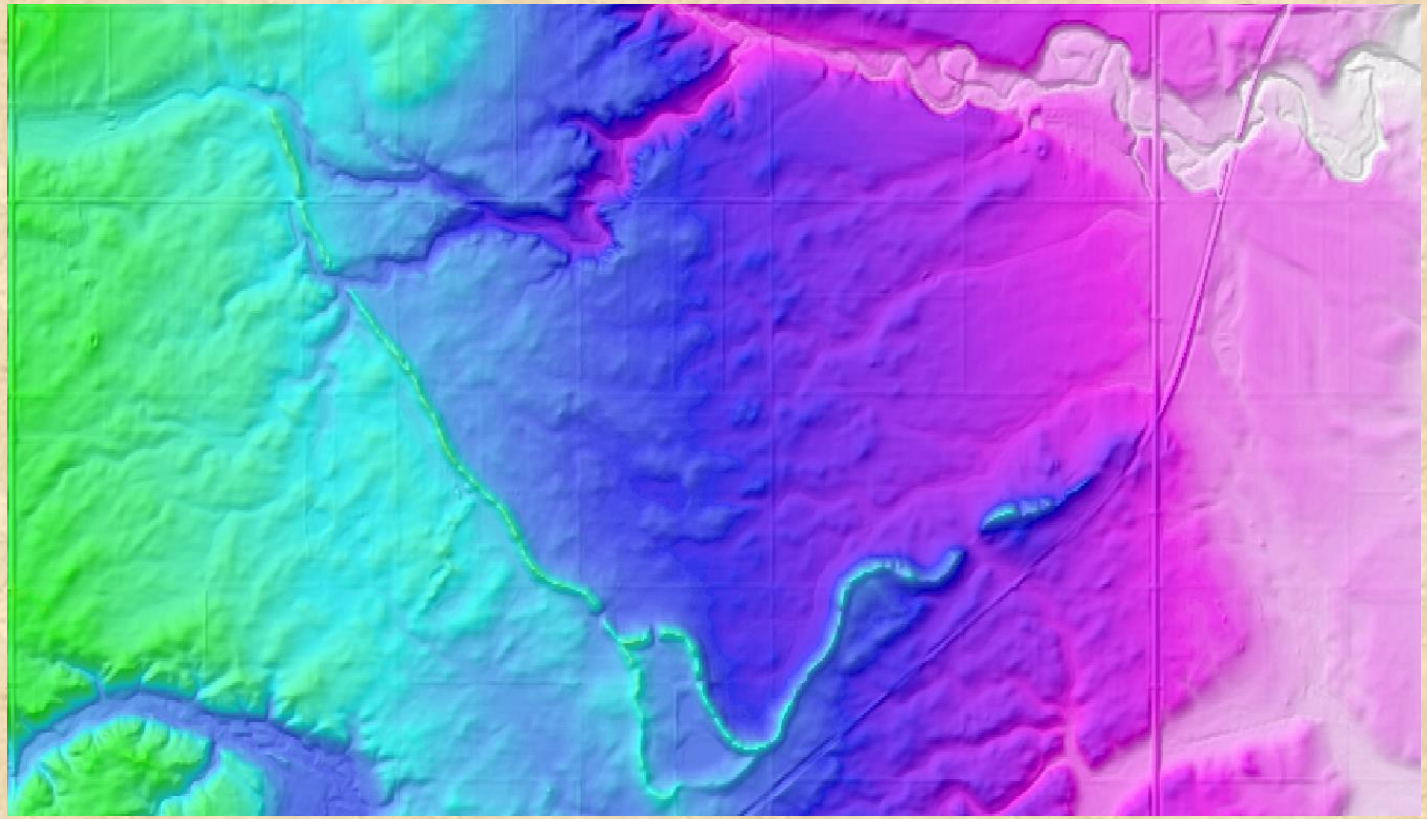
Reference: http://www.chartiersgreenway.net/hydrology.htm



Change the minimum & maximum elevation values to exaggerate features

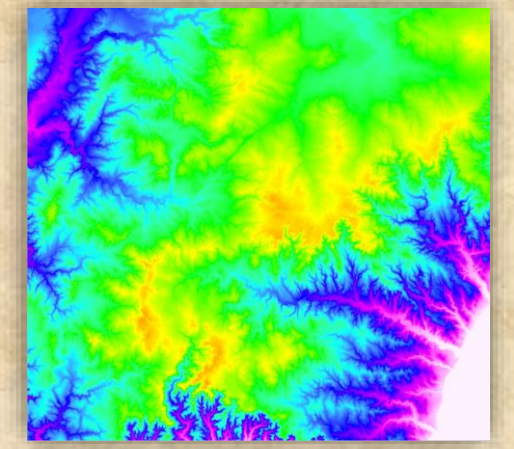




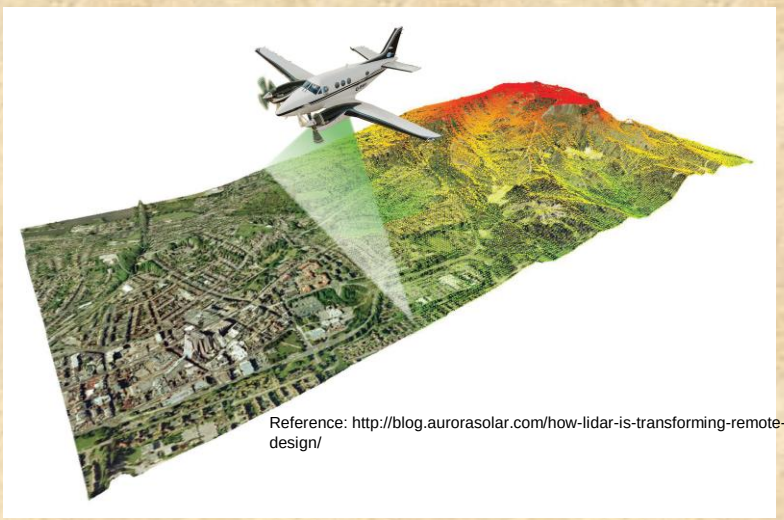


DEM vs. LiDAR

Digital Elevation Model (DEM)



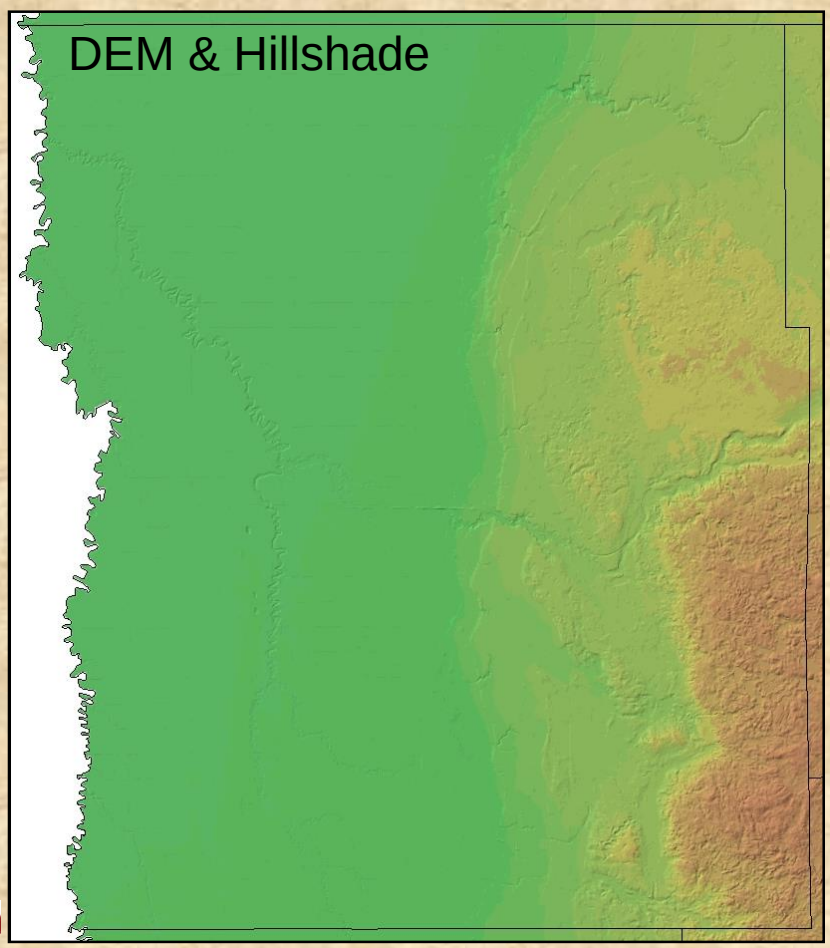
- Light Detection and Ranging (LiDAR)

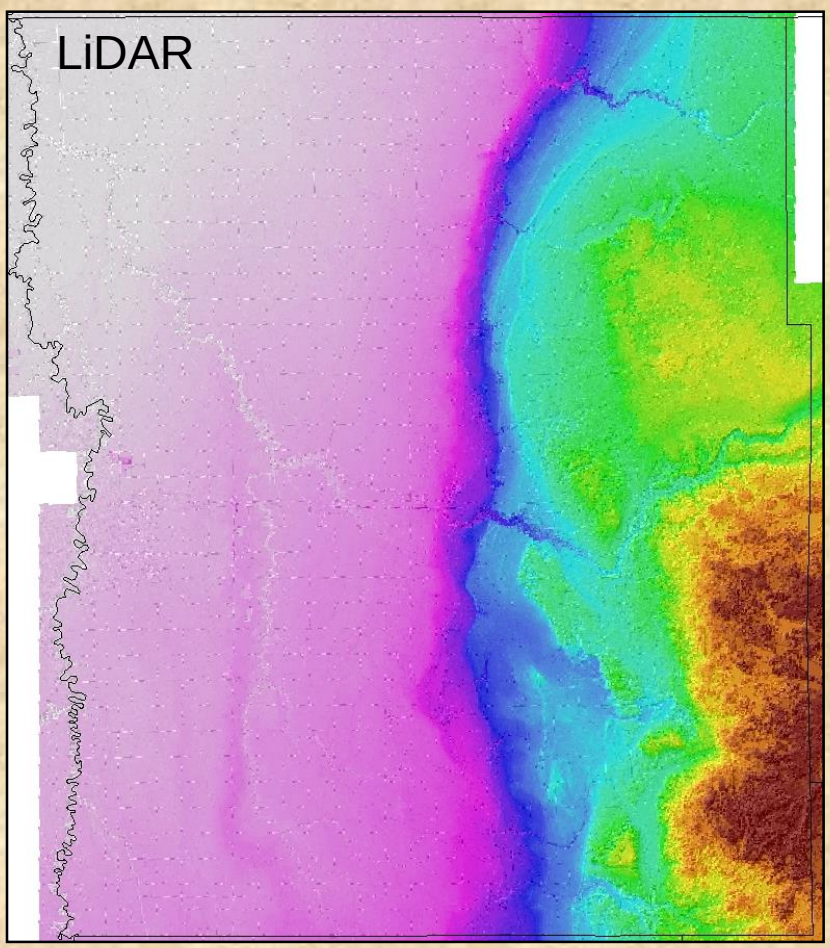


Reference: http://blog.aurorasolar.com/how-lidar-is-transforming-remote-solar-system-design/

- The USGS DEMs are raster images with digital value of the elevation at a given pixel and are generalized.
- LiDAR is developed scale independent with a grid of ground elevations giving very detailed data of the actual ground shape and greatly increases the horizontal and vertical accuracy.

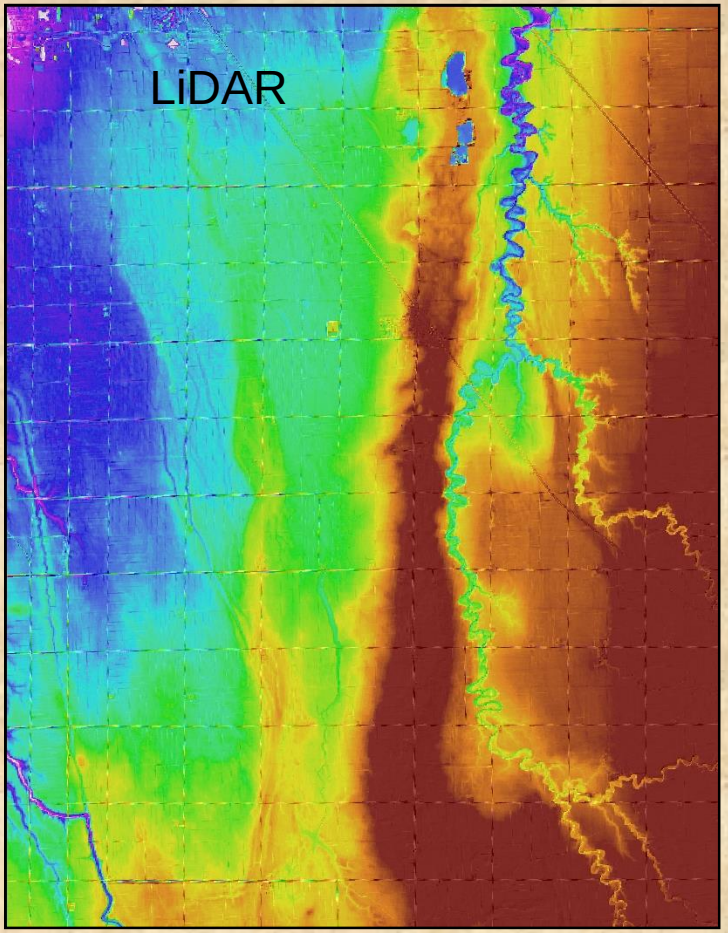
LiDAR Data – Red River Valley (Clay County)



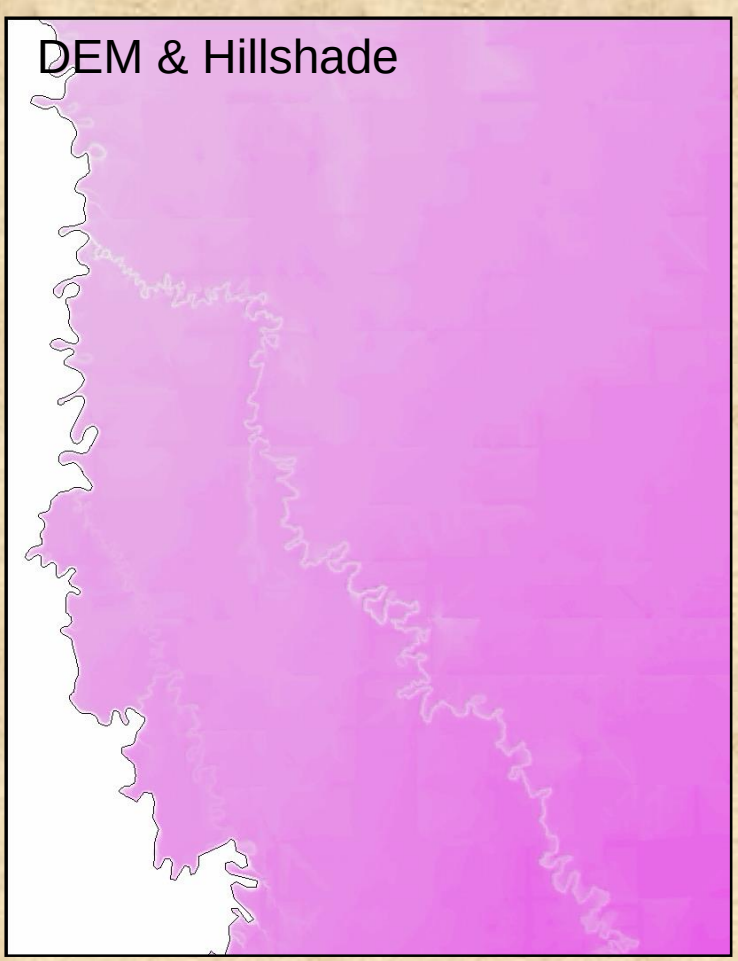


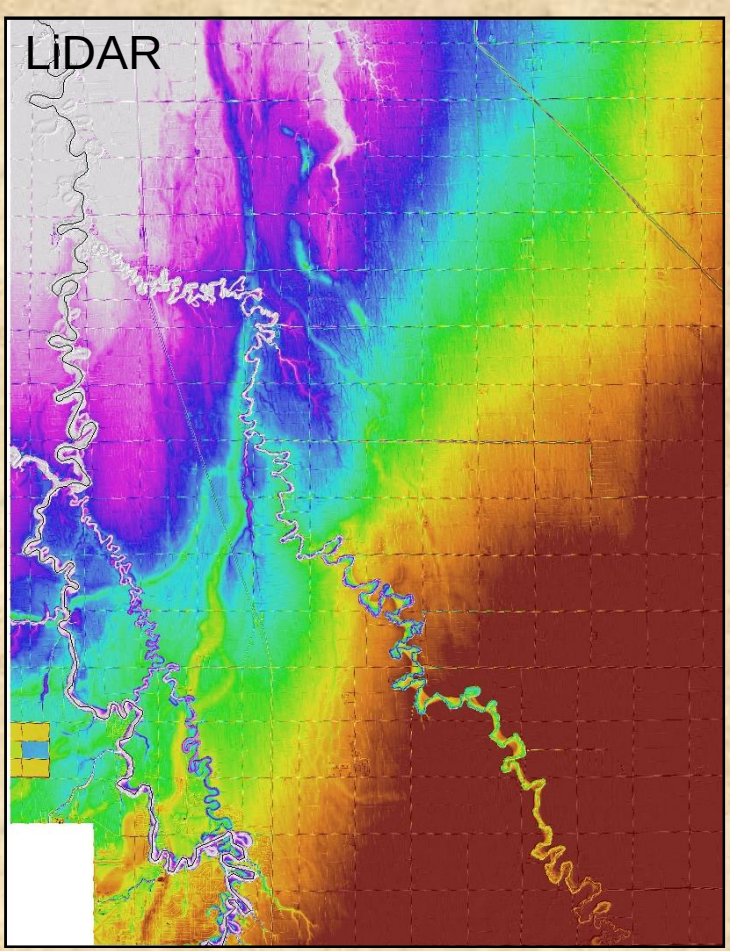
Terracon

LiDAR Data - Red River Valley (Clay County)

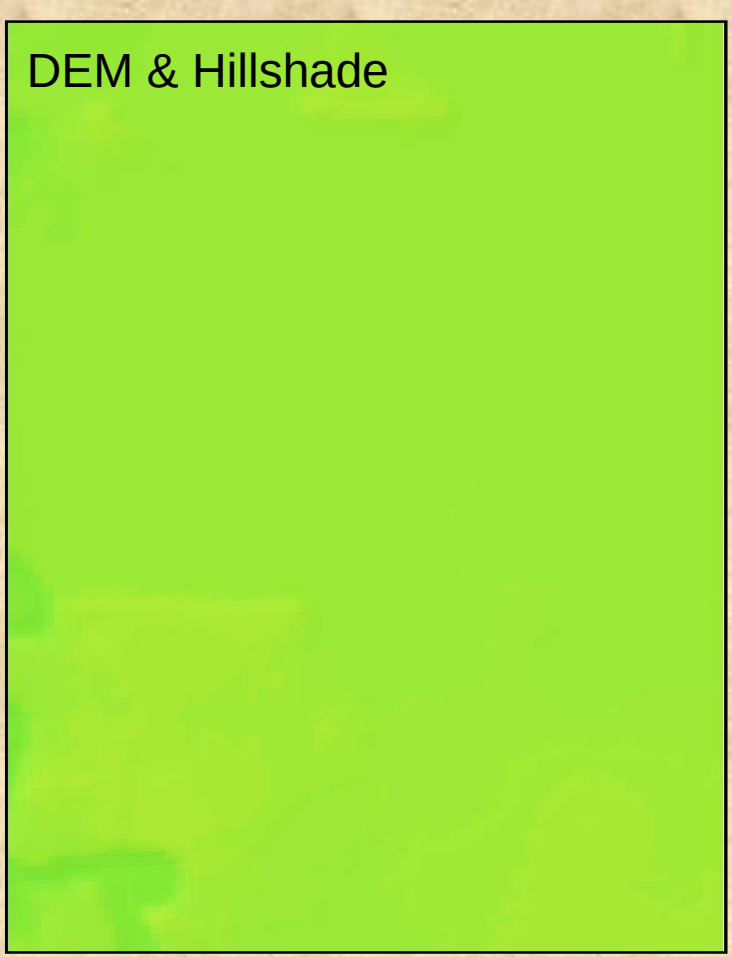


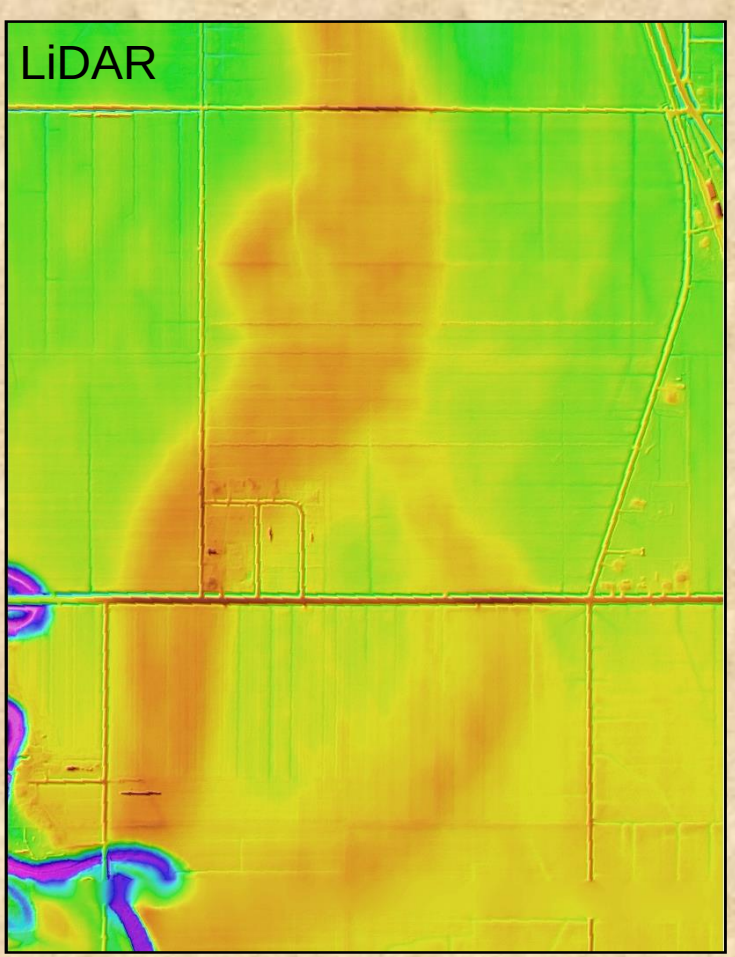
LiDAR Data - Red River Valley (Clay County)





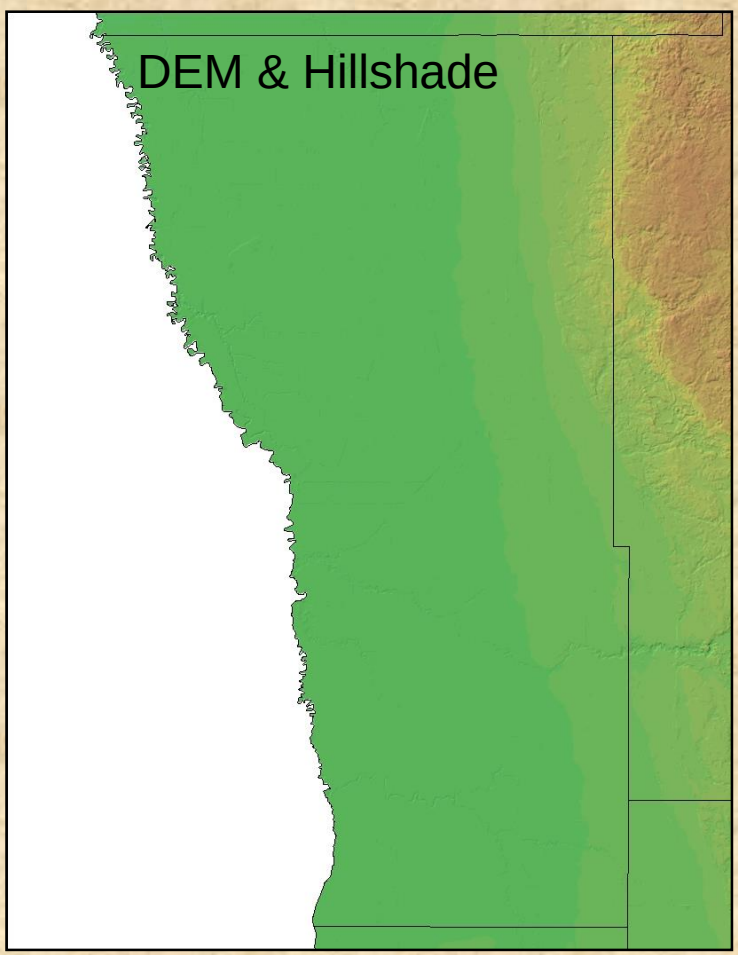
LiDAR Data - Red River Valley (Clay County)

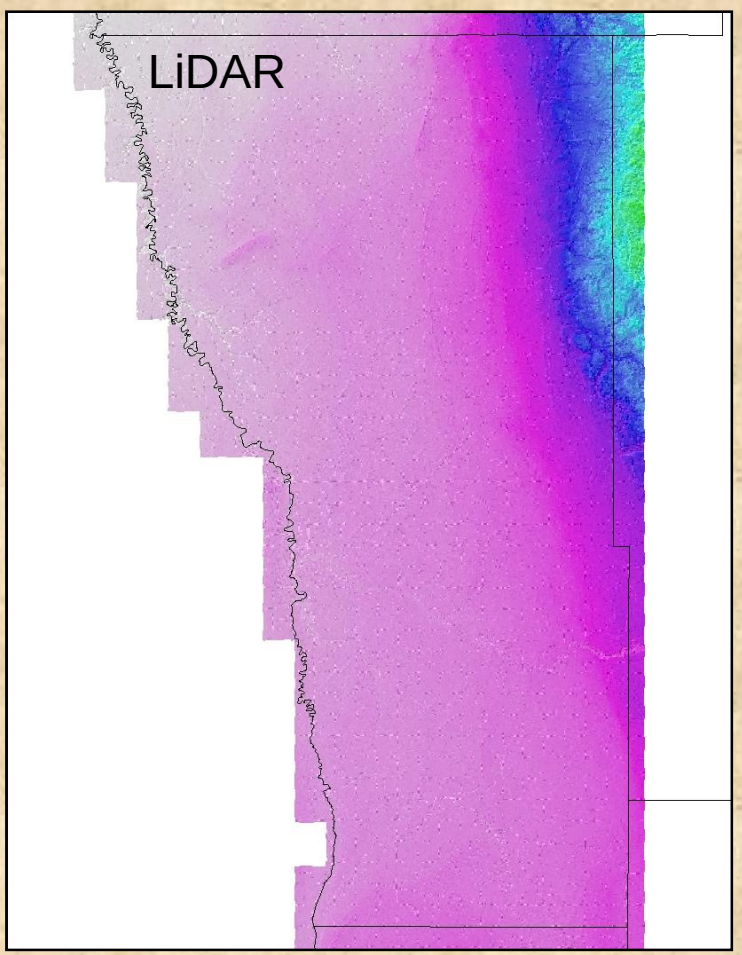




Terracon

LiDAR Data - Red River Valley (Wilkin County)





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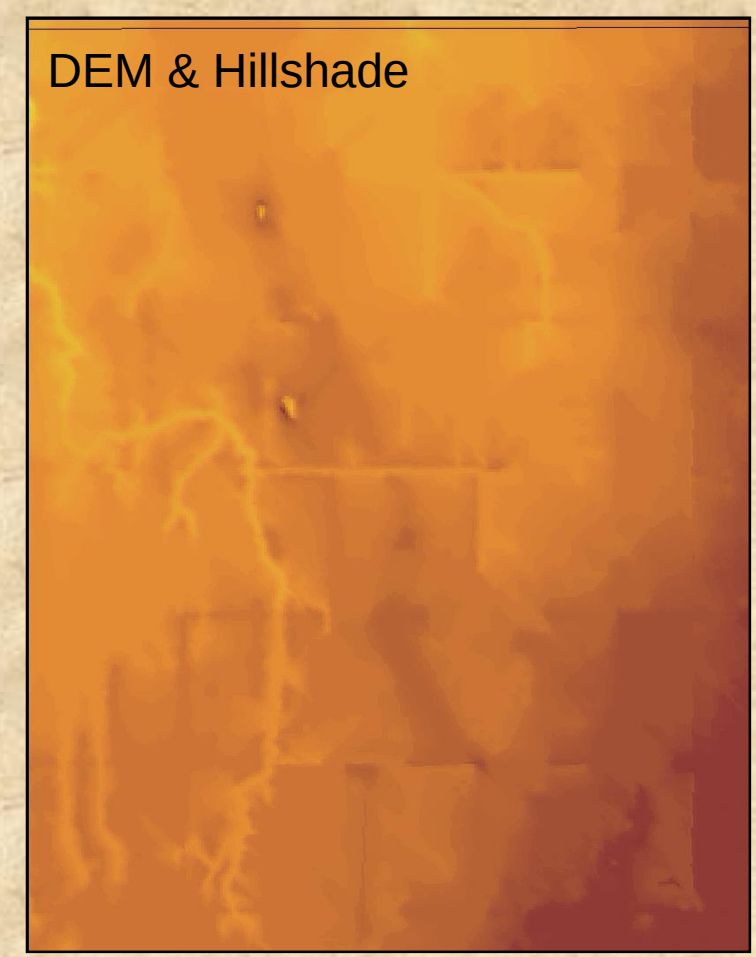

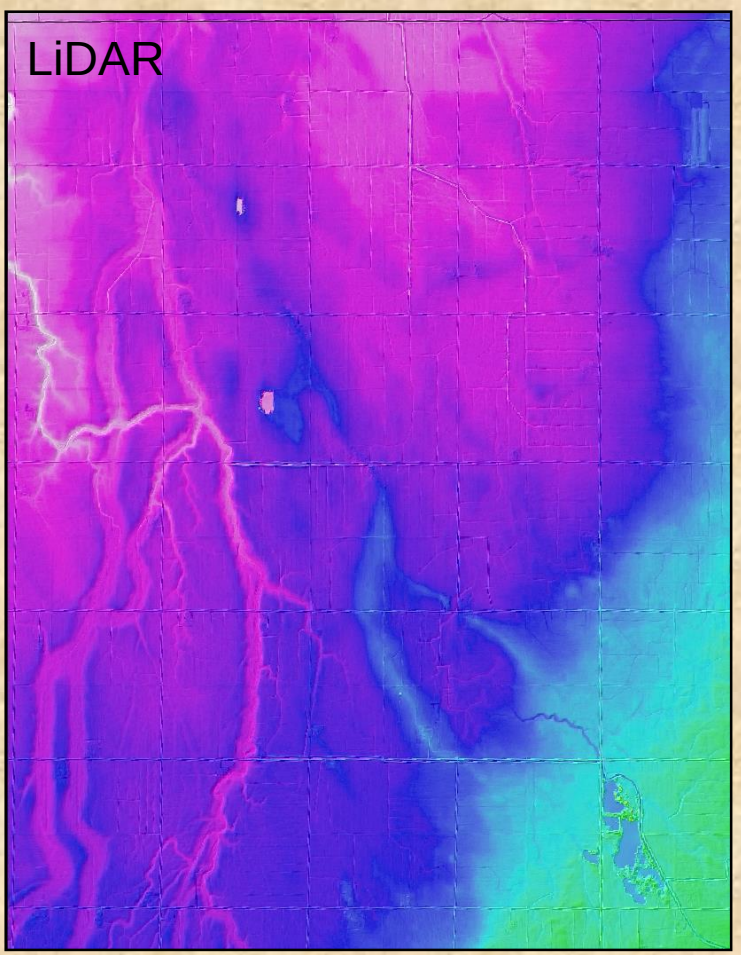

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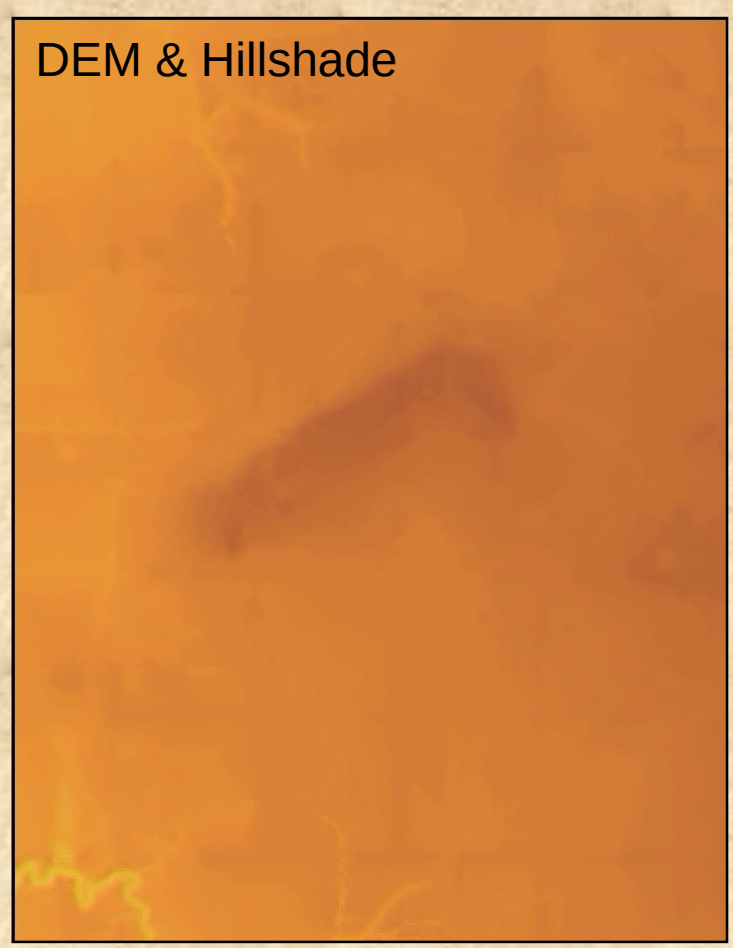
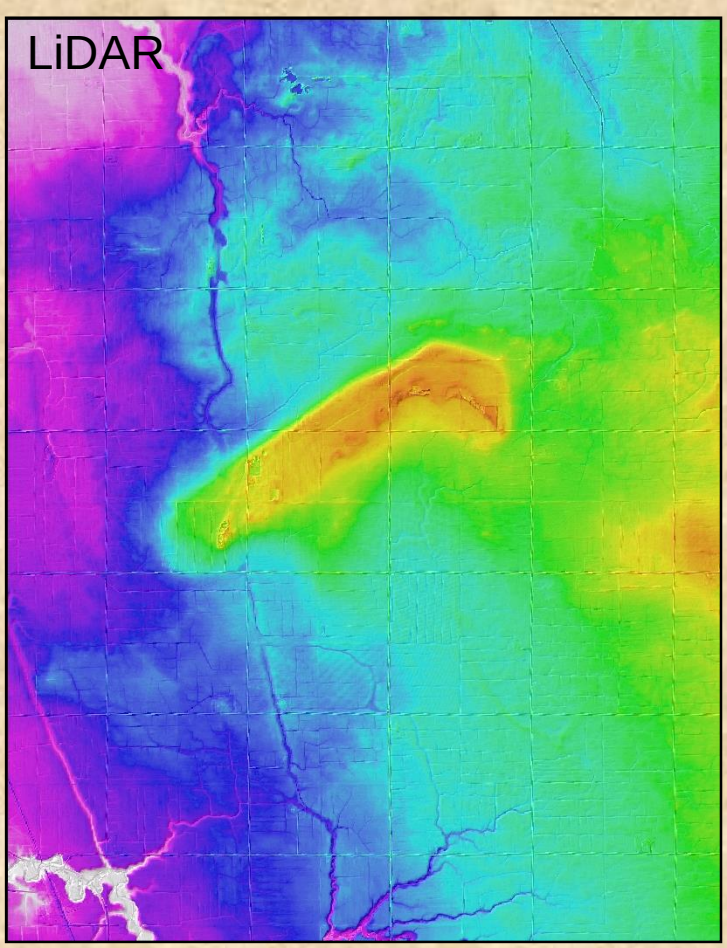
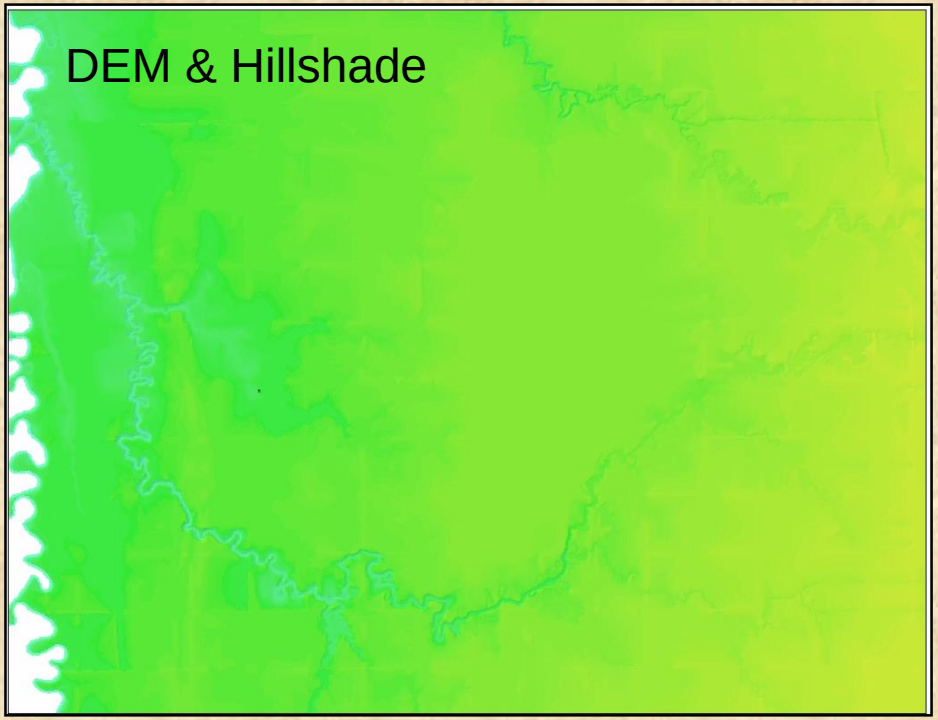
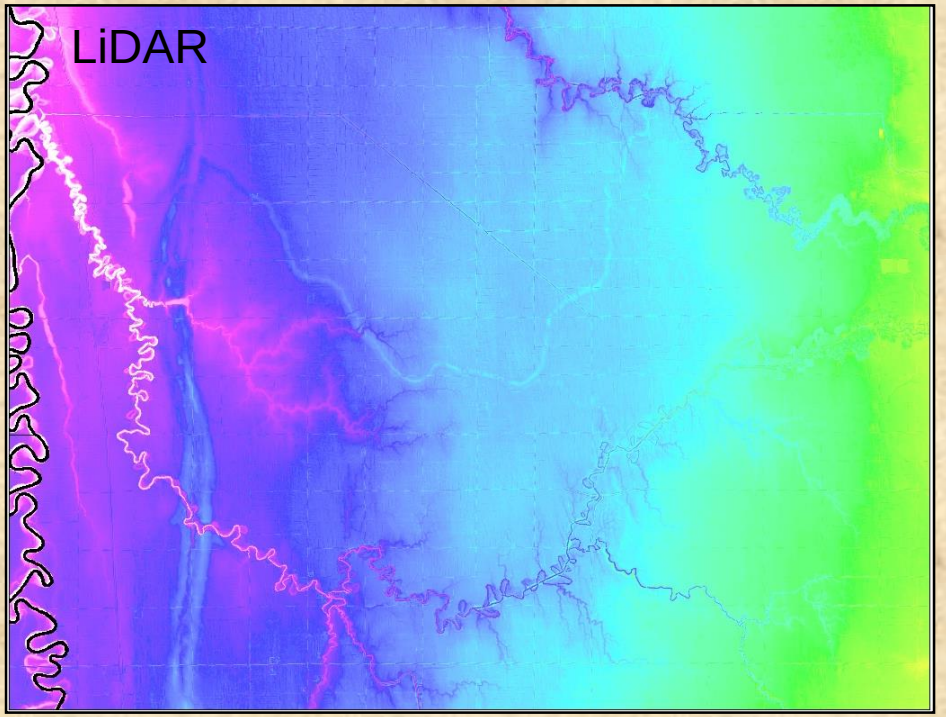




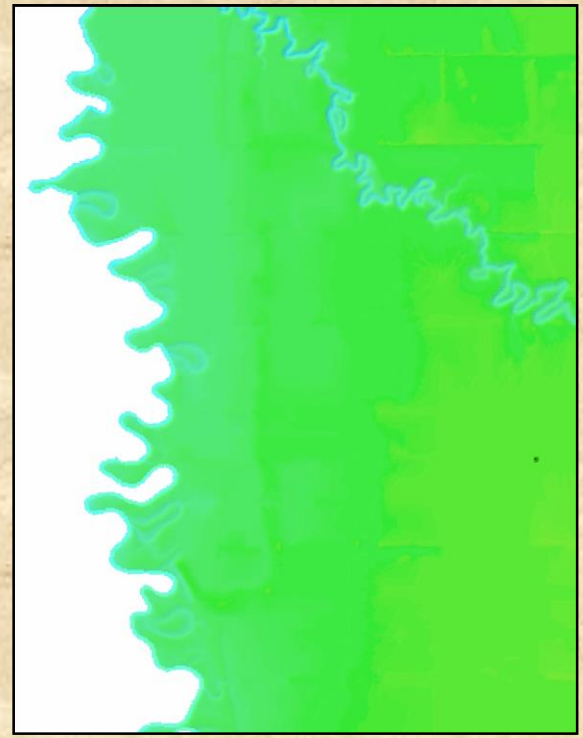
LiDAR Data - Red River Valley (Norman County)





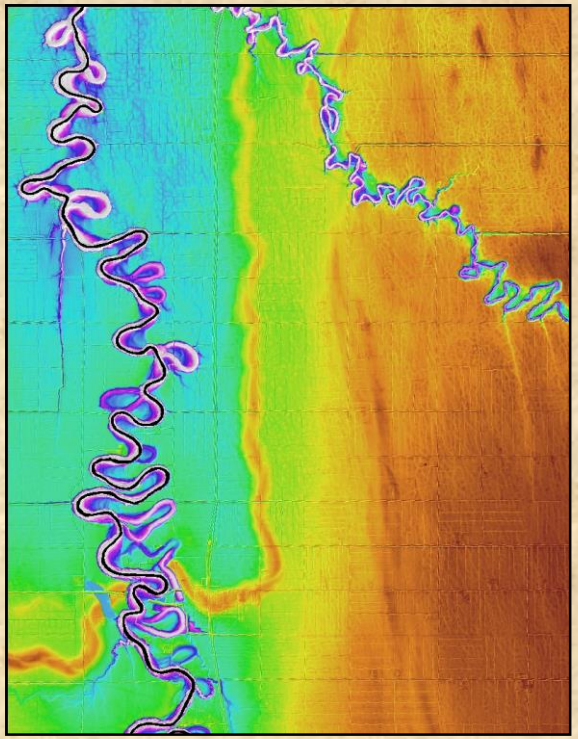
LiDAR Data - Red River Valley (Norman County)

DEM & Hillshade

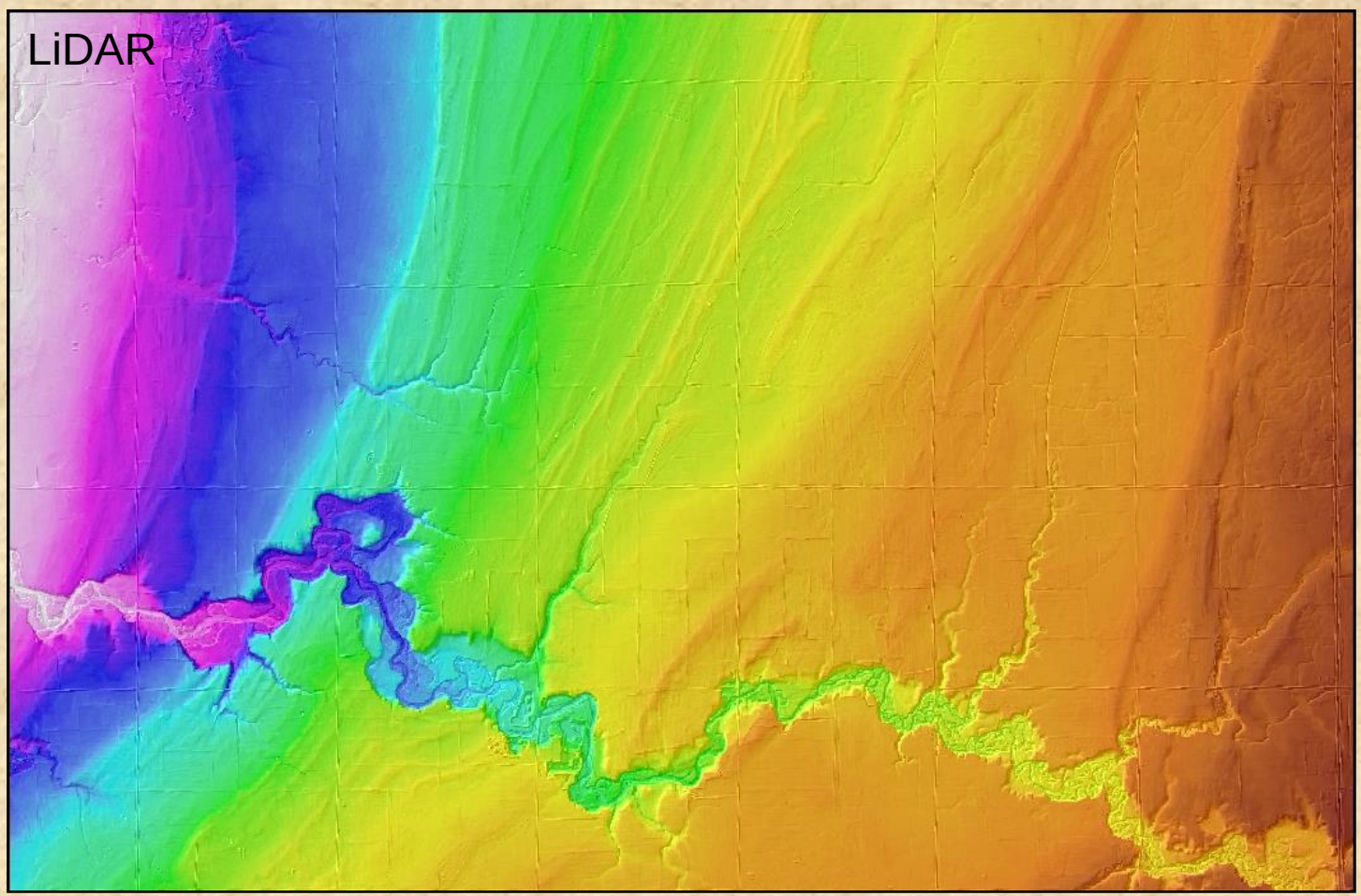


Aerial

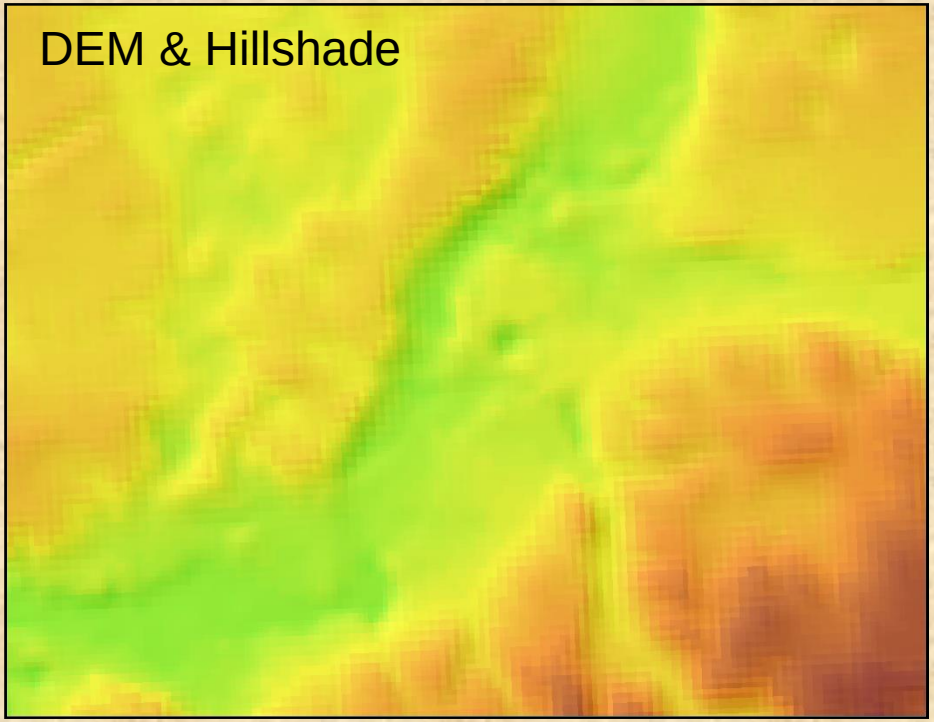
LiDAR

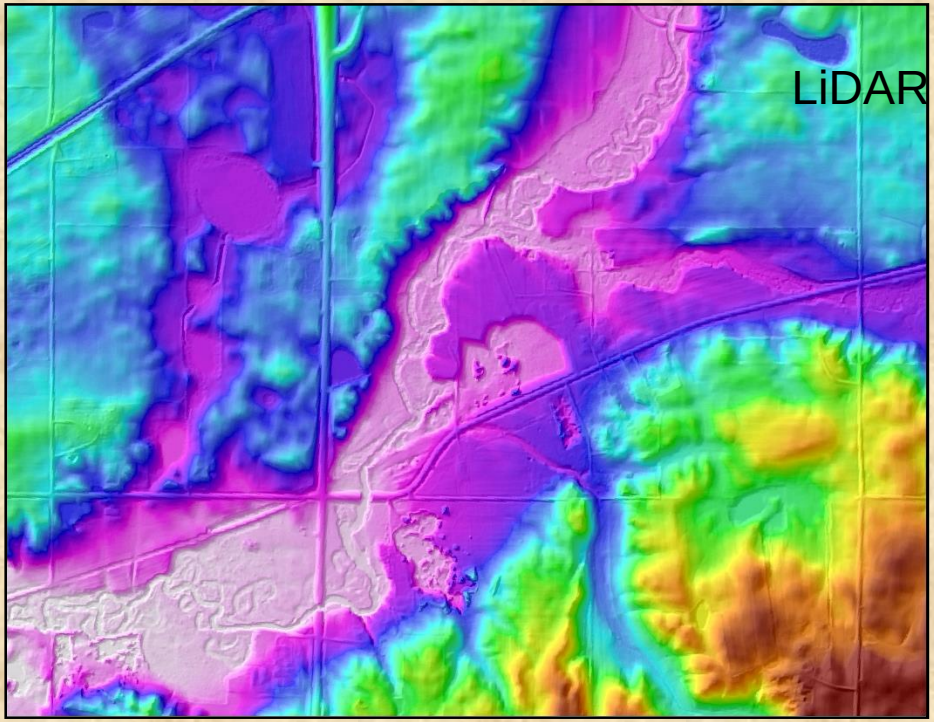


Beach Ridges – Clay County

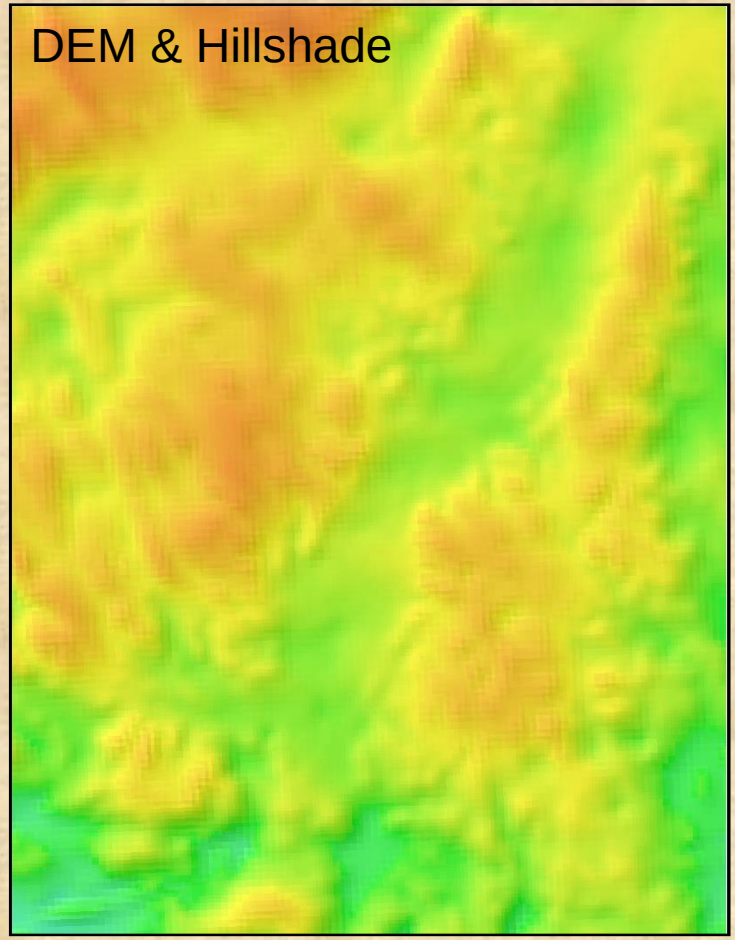


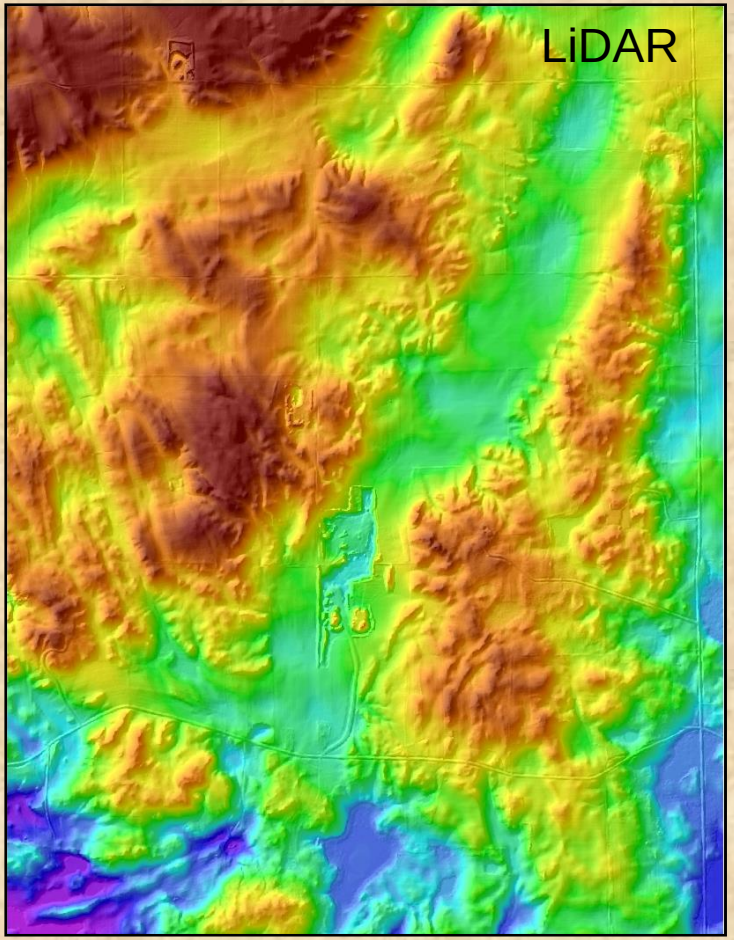
Terrace Deposits – Clay County



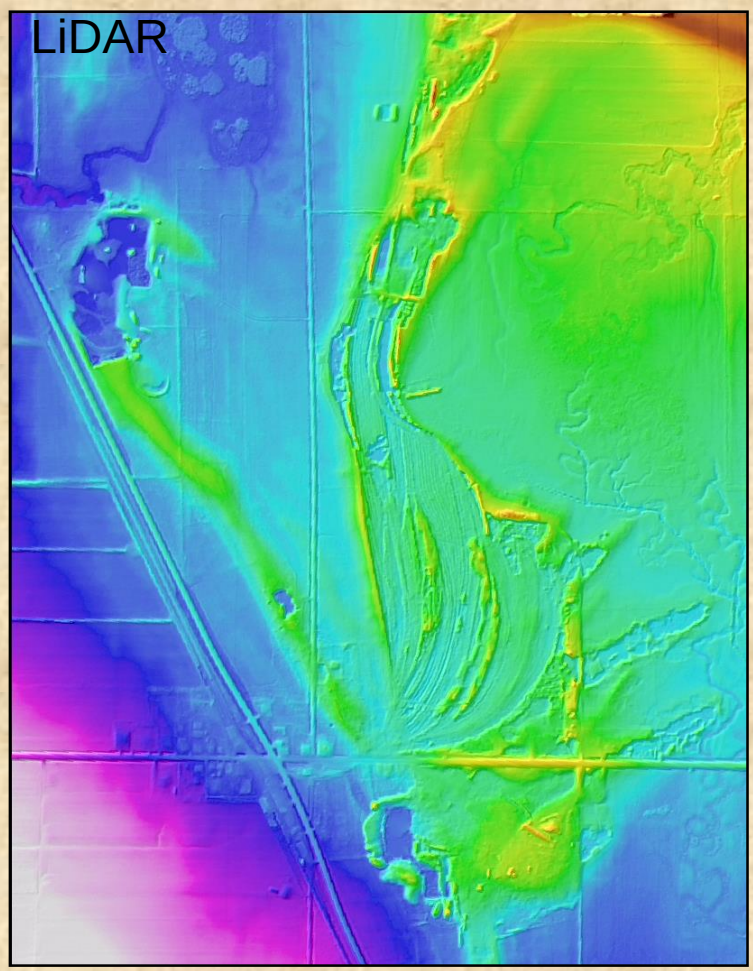


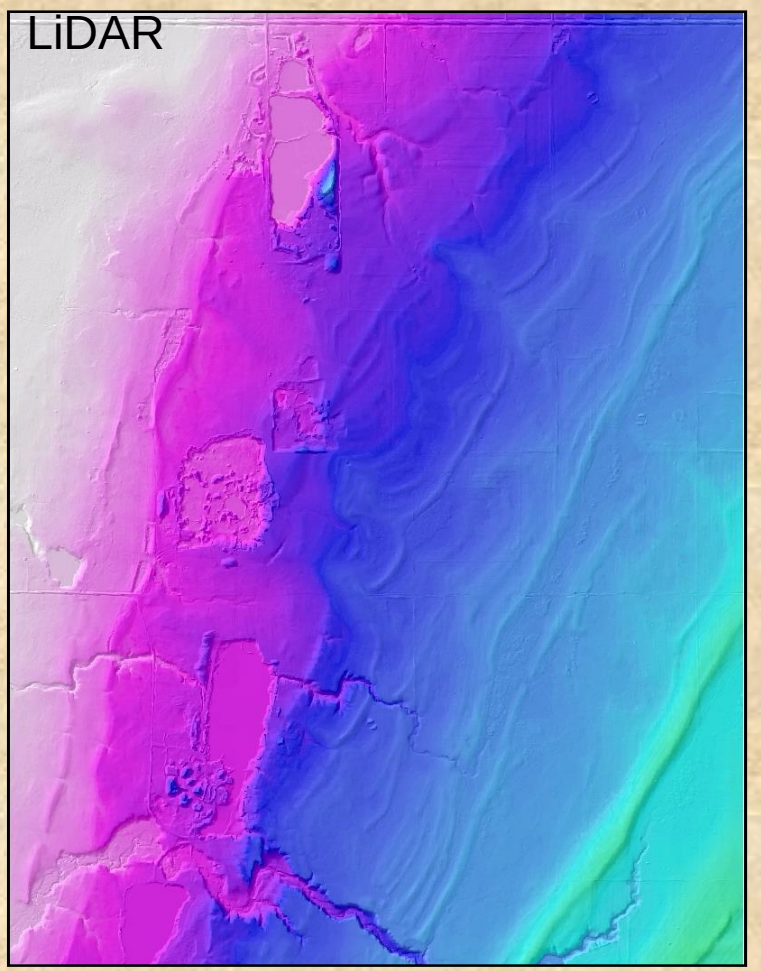
Outwash Channels – Clay County





Mined Area – Clay County





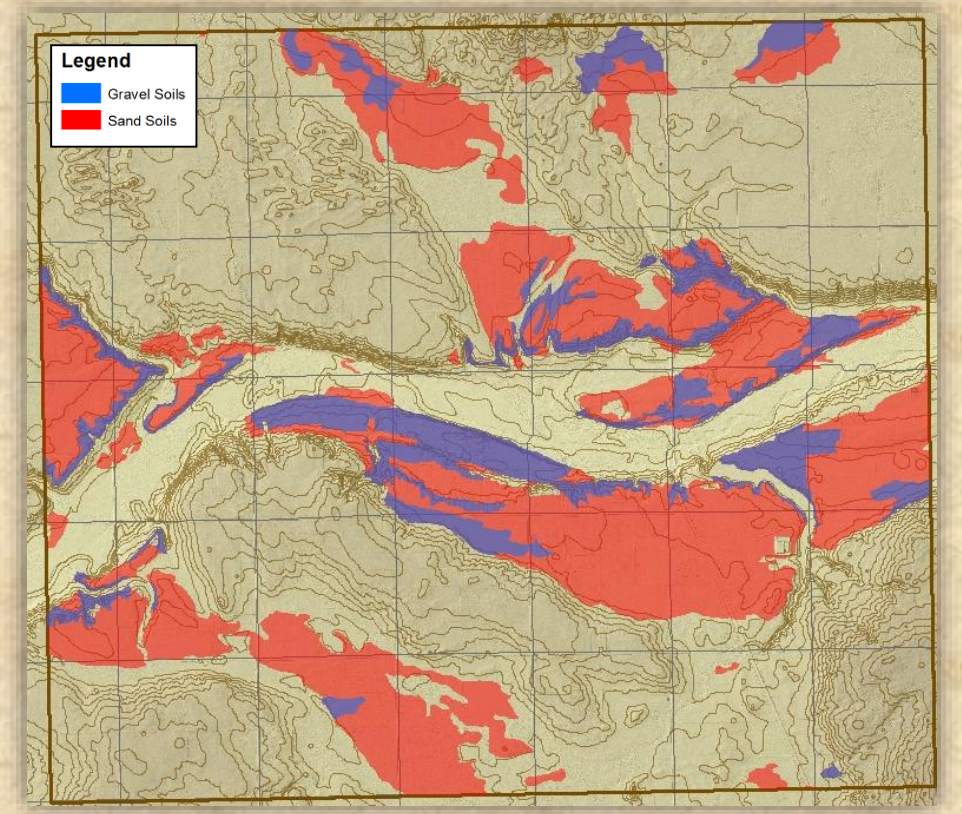
Aggregate Potential Mapping

Topographic Map

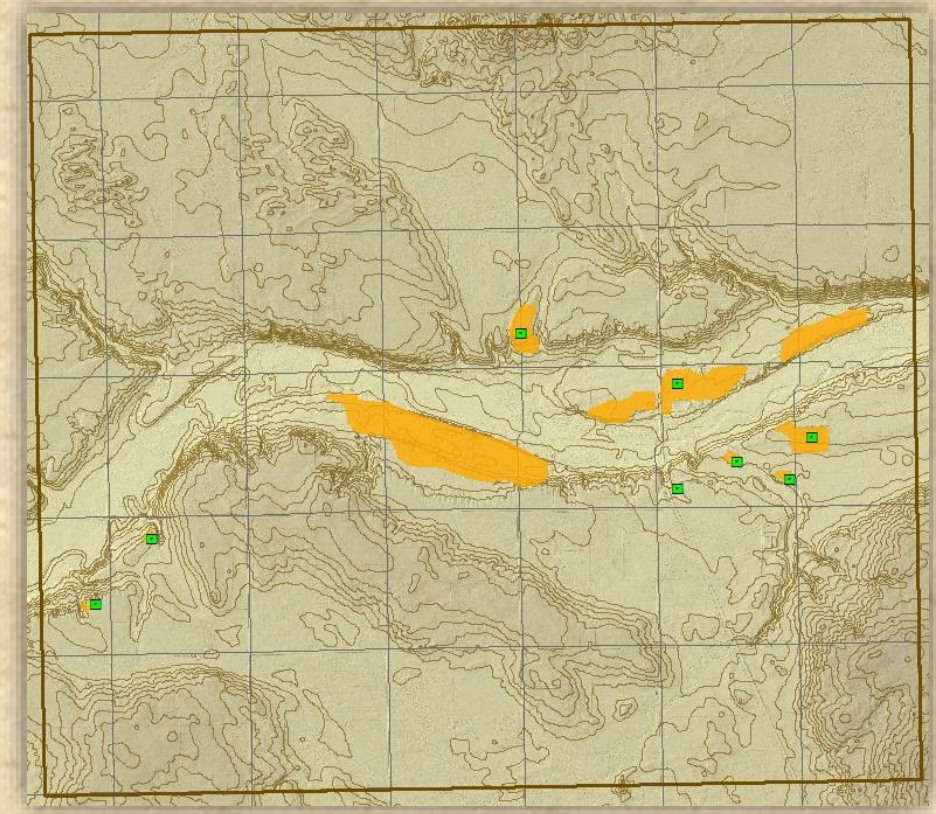
Aerial Photo

Aggregate Potential Mapping

Soils Data

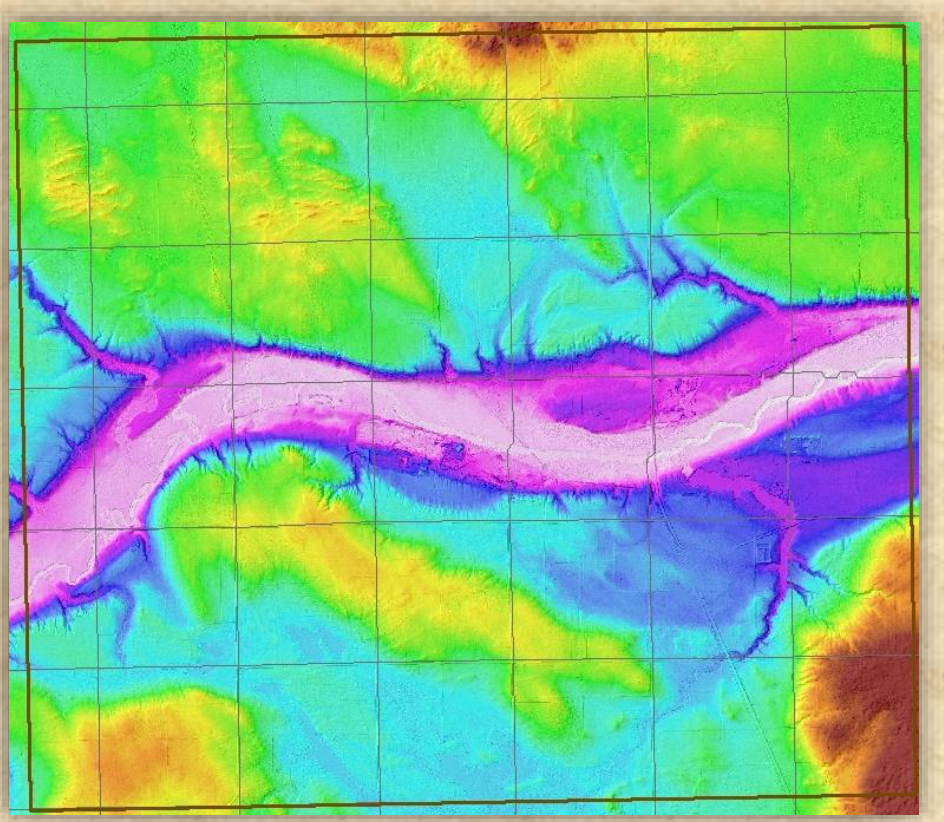


Current/Historical Pits



Aggregate Potential Mapping

LiDAR Data

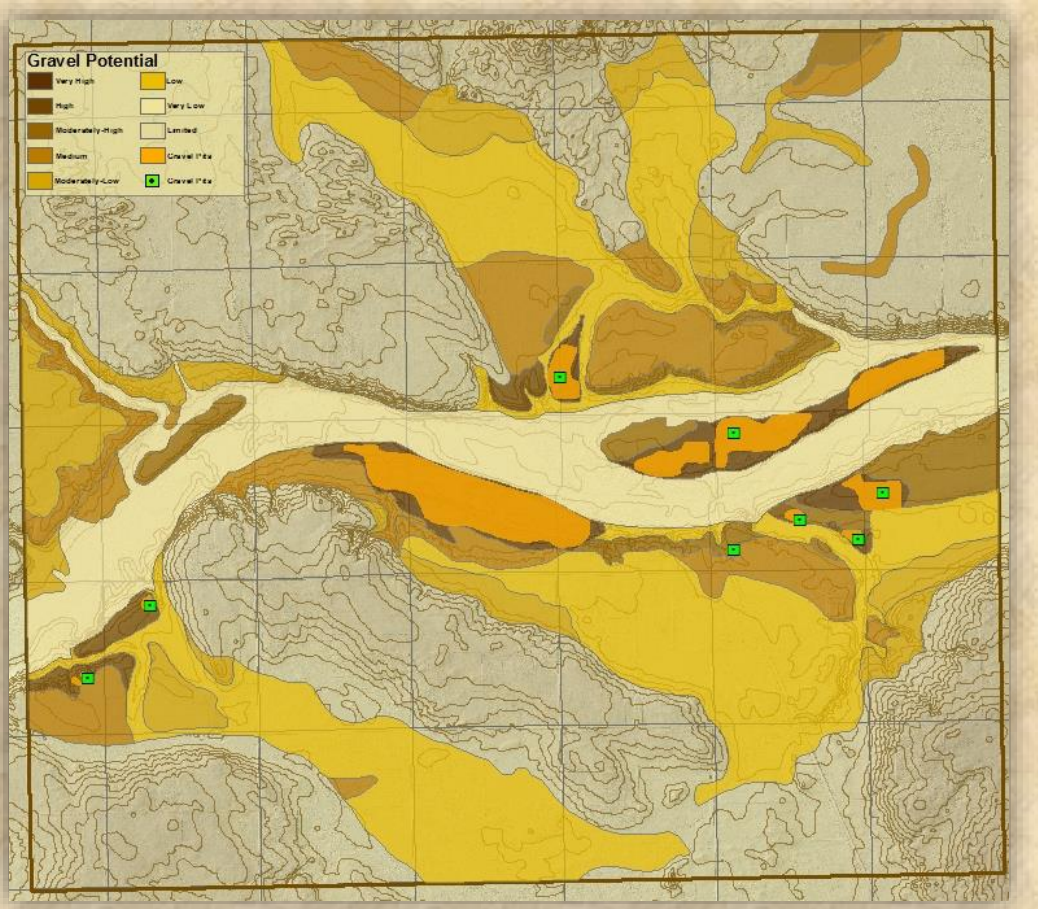


Google Earth

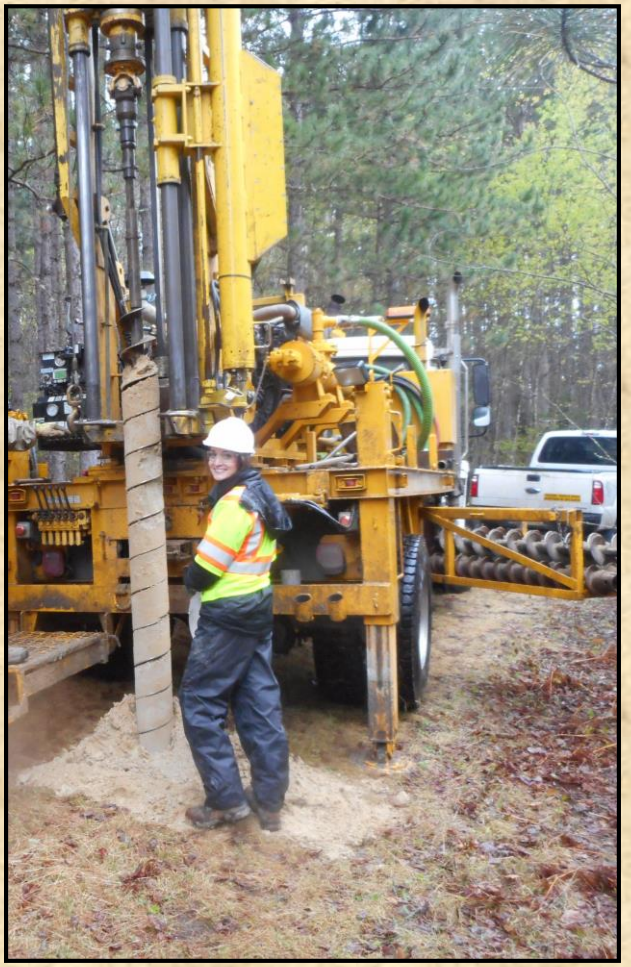
Aggregate Potential Mapping

Final Potential Map

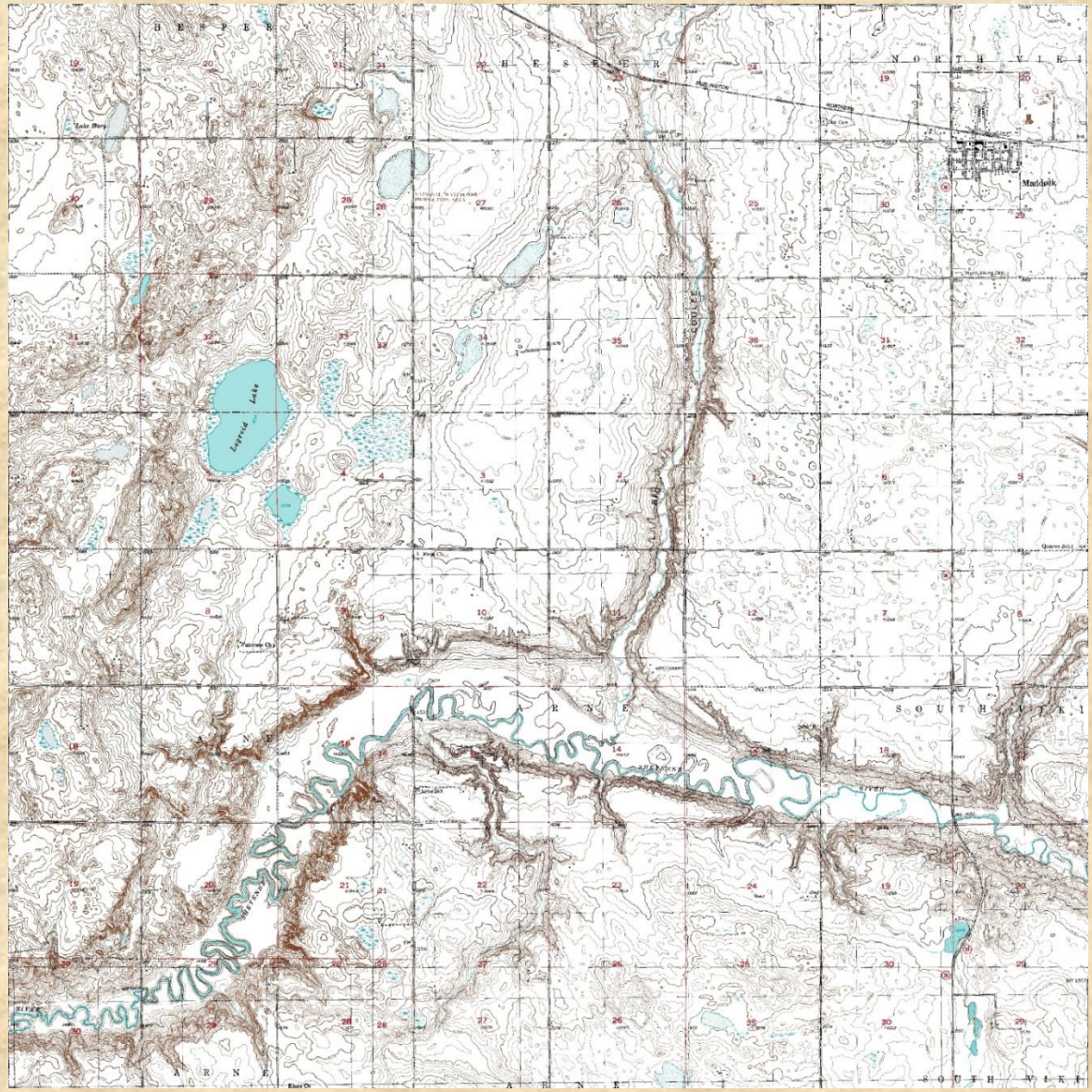
- Thickness
- Overburden
- Areal Extent
- Quality
- Texture
- Deposit type



Aggregate Exploration – Drilling

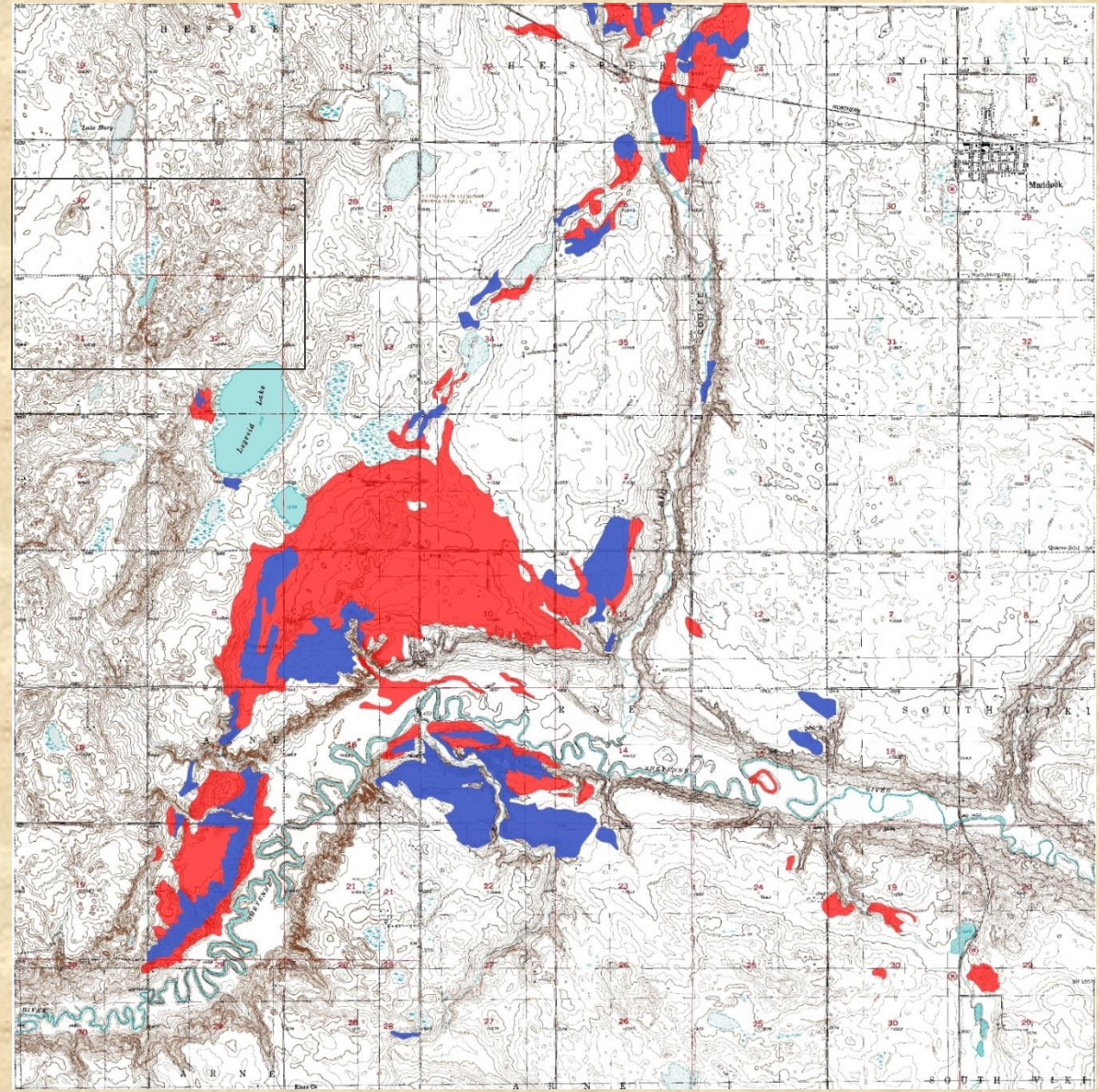


GRAVEL POTENTIAL MAPPING



Topographic Map

GRAVEL POTENTIAL MAPPING

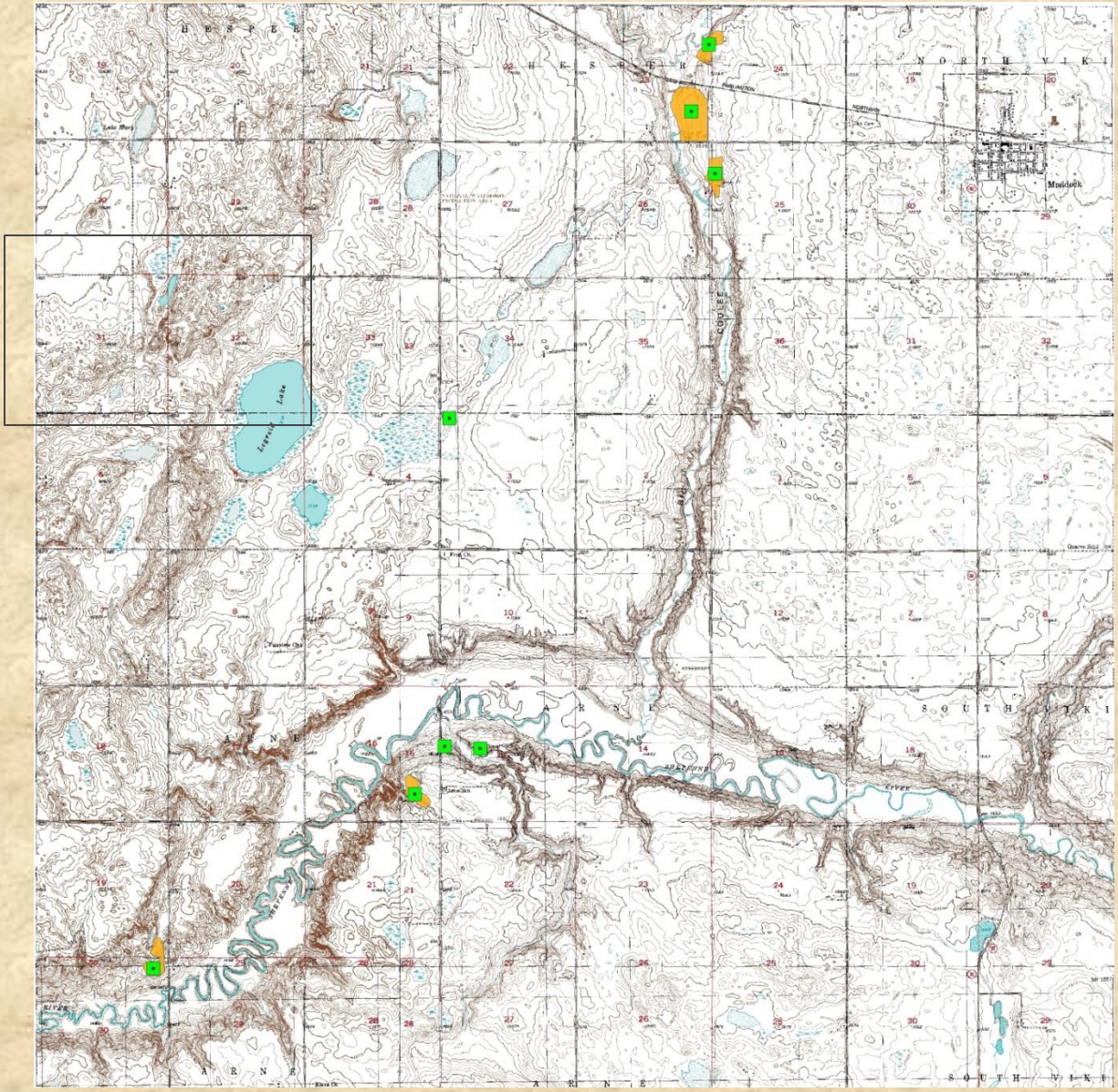


Soils Map

Legend

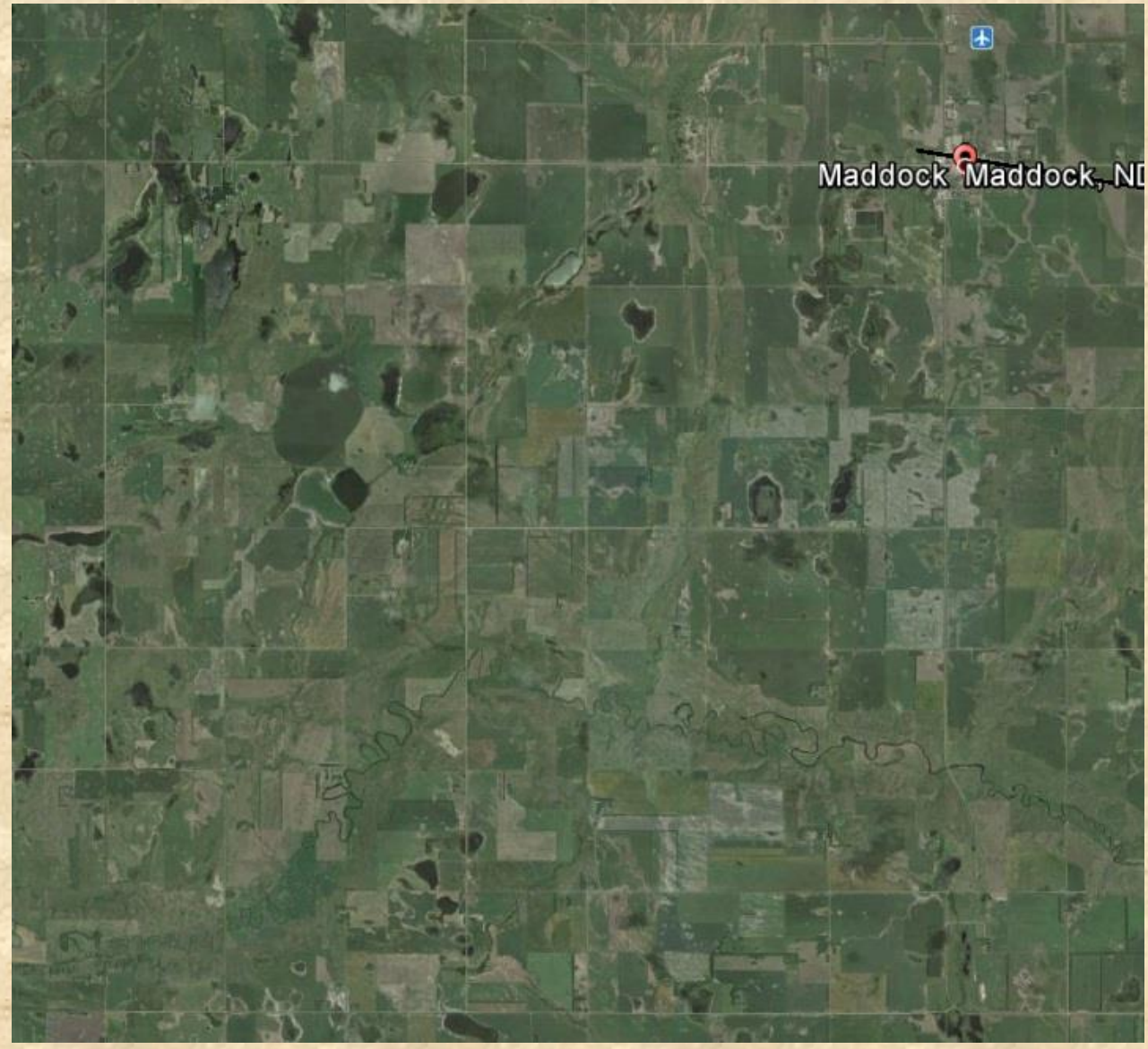
- Gravel_Soil
- Sand_Soil

GRAVEL POTENTIAL MAPPING



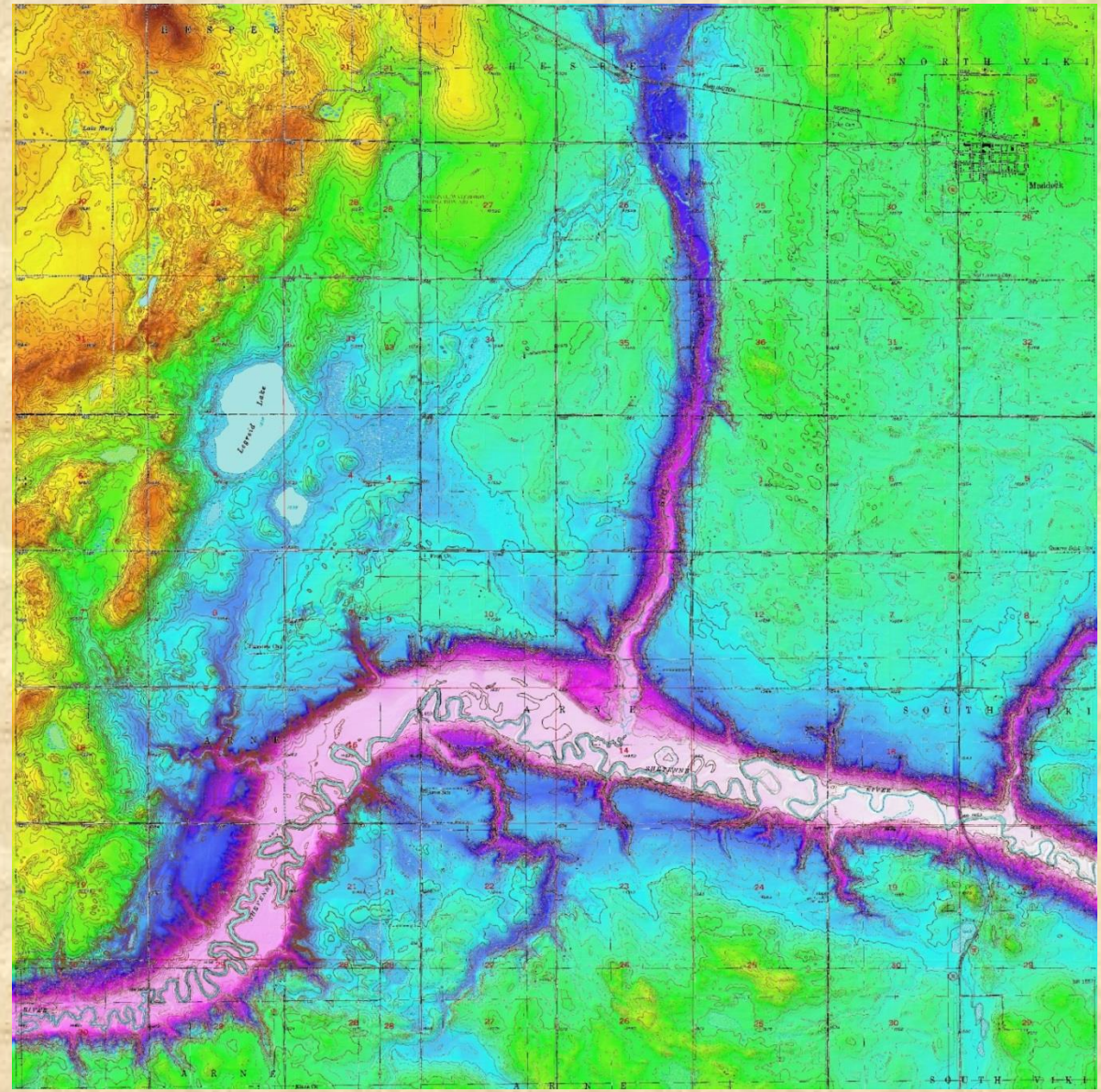
Active &
Inactive
Gravel Pits

GRAVEL POTENTIAL MAPPING



Aerial Photography

GRAVEL POTENTIAL MAPPING

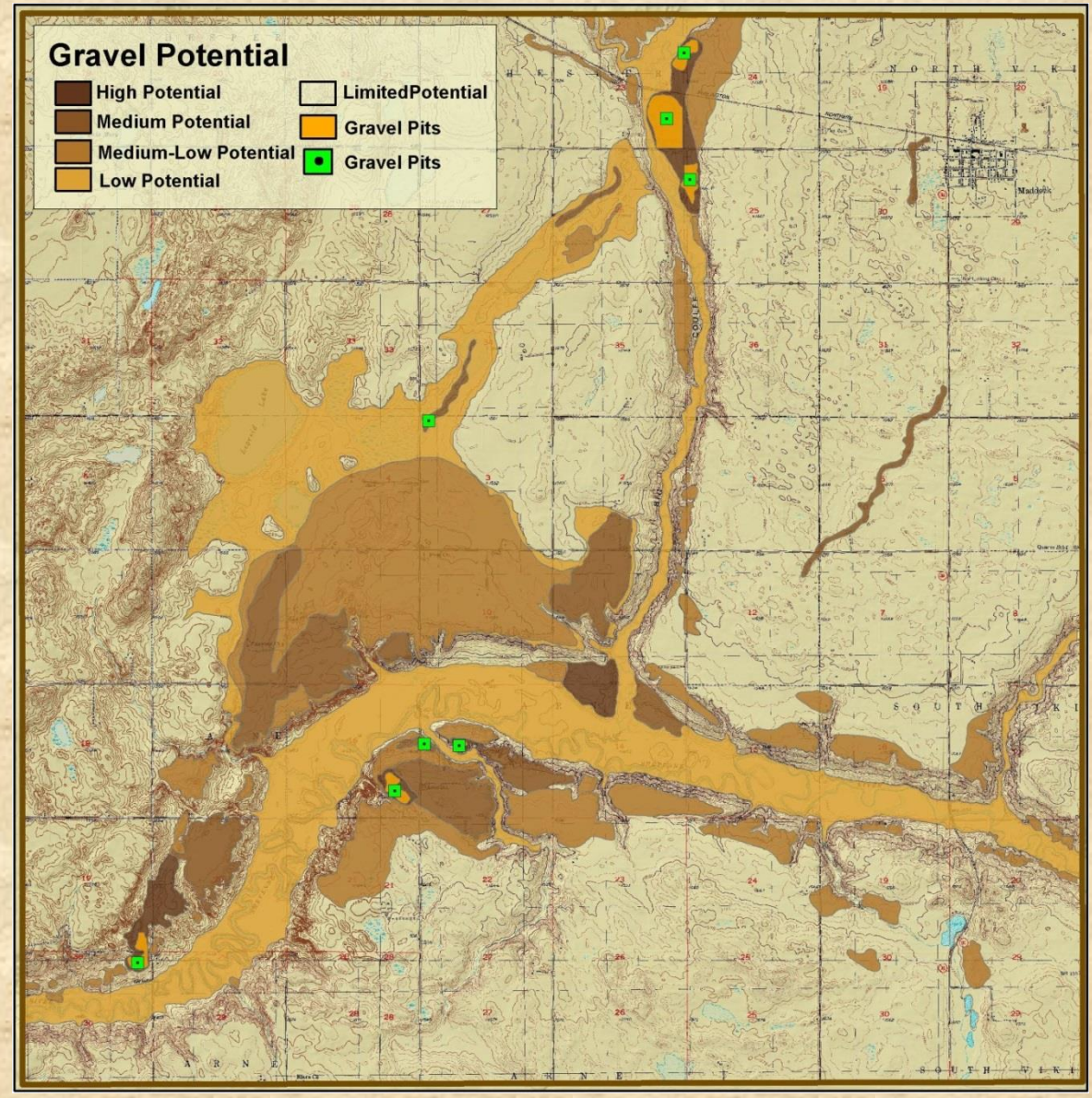


DEM &
Hillshading

GRAVEL POTENTIAL MAPPING

Google Earth

GRAVEL POTENTIAL MAPPING



Final Potential Map

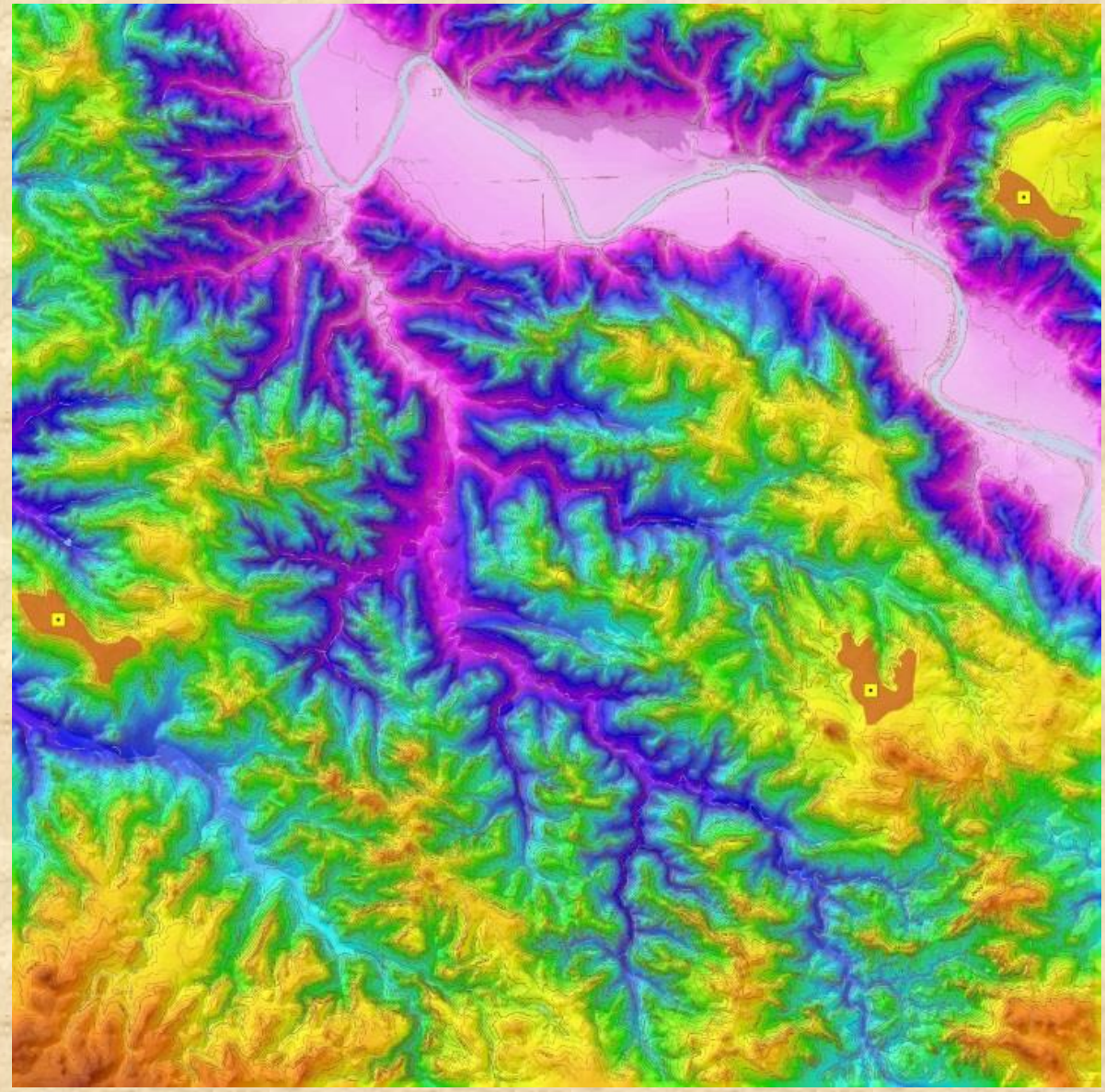
- Thickness
- Overburden
- Areal Extent
- Quality
- Texture
- Deposit Type

Clinker A.K.A. “Scoria”

- Clinker is a sedimentary rock that has been “baked” by burning coal seams beneath it
- It is considered a crushed stone and is mined for oil pads and access roads

Clinker (“scoria”) as Road Surfacing Material in Western North Dakota – Edward C. Murphy, NDGS

Scoria Potential Mapping

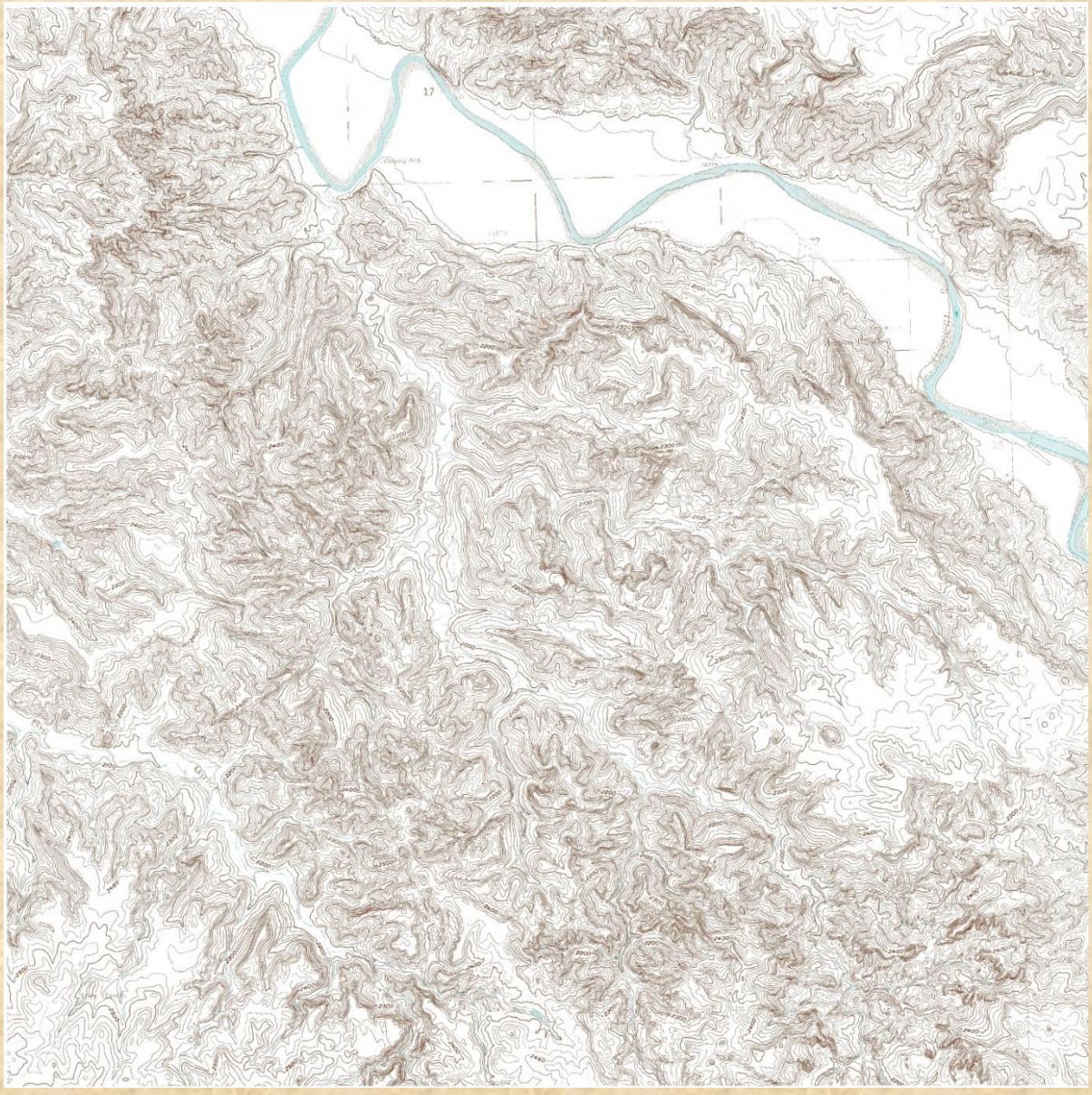


Active &
Inactive
Pits

Scoria Potential Mapping

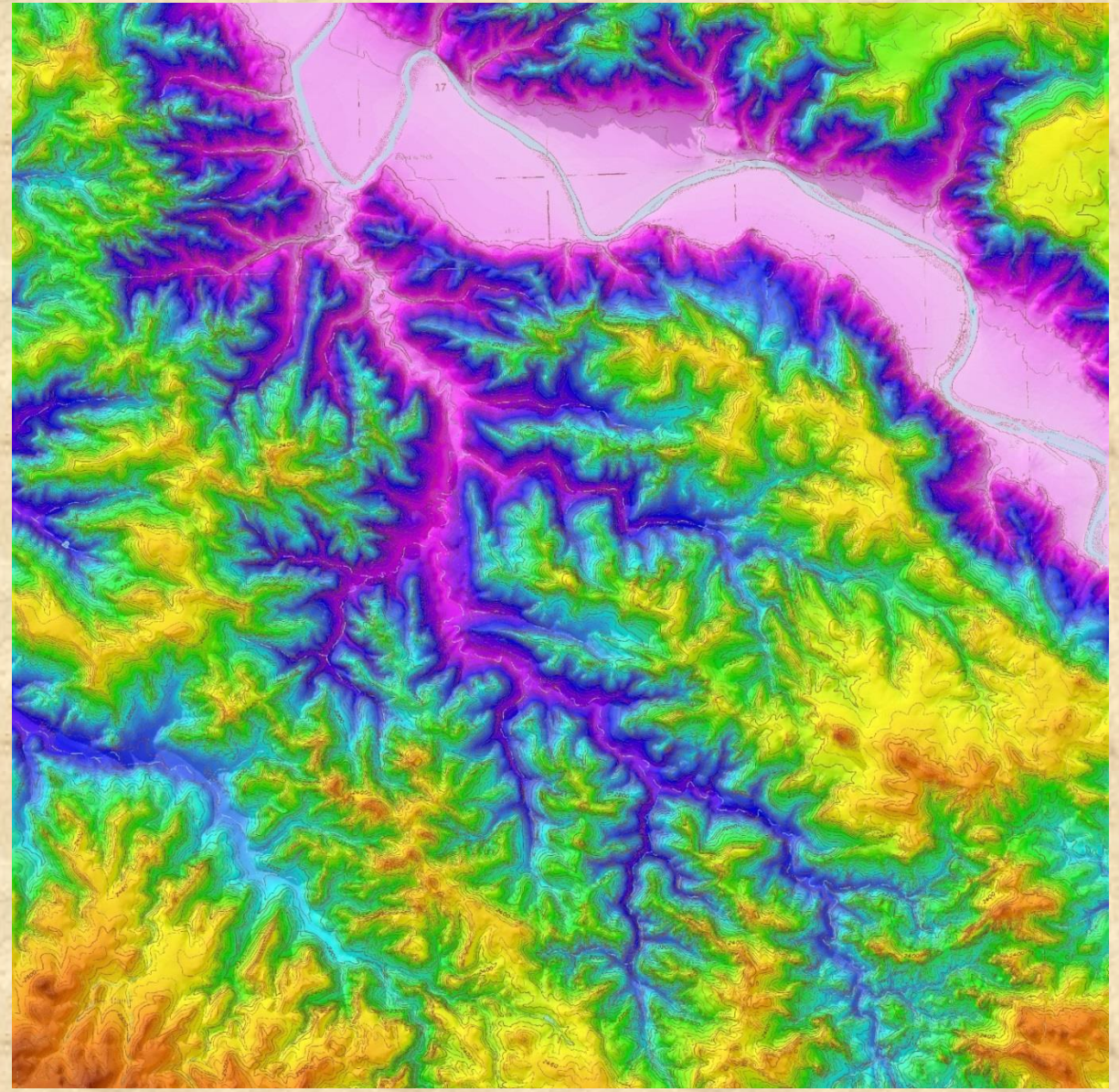
Aerial Photography & Google Earth

Scoria Potential Mapping



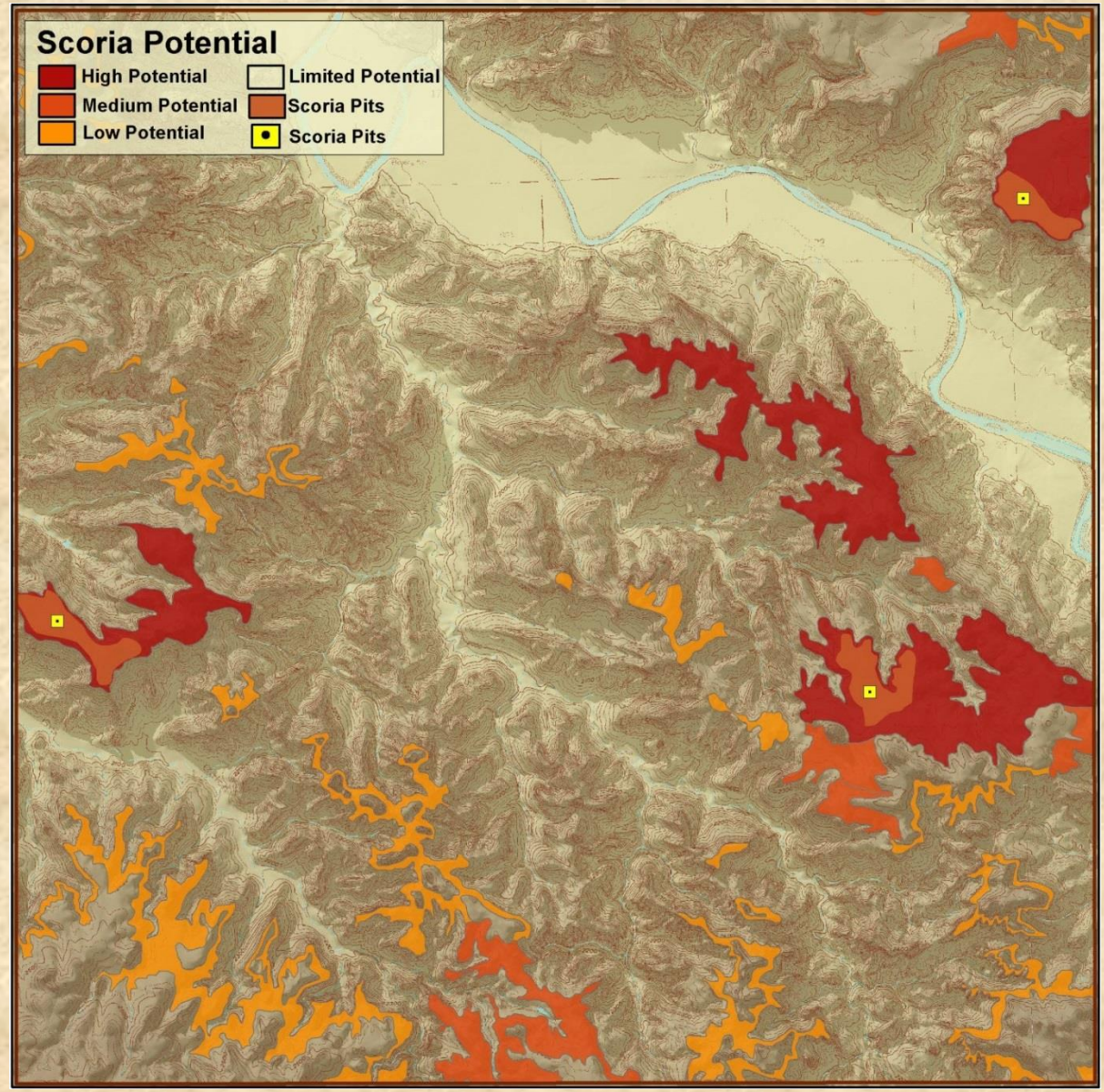
Topographic Maps

Scoria Potential Mapping



DEM &
Hillshading

Scoria Potential Mapping



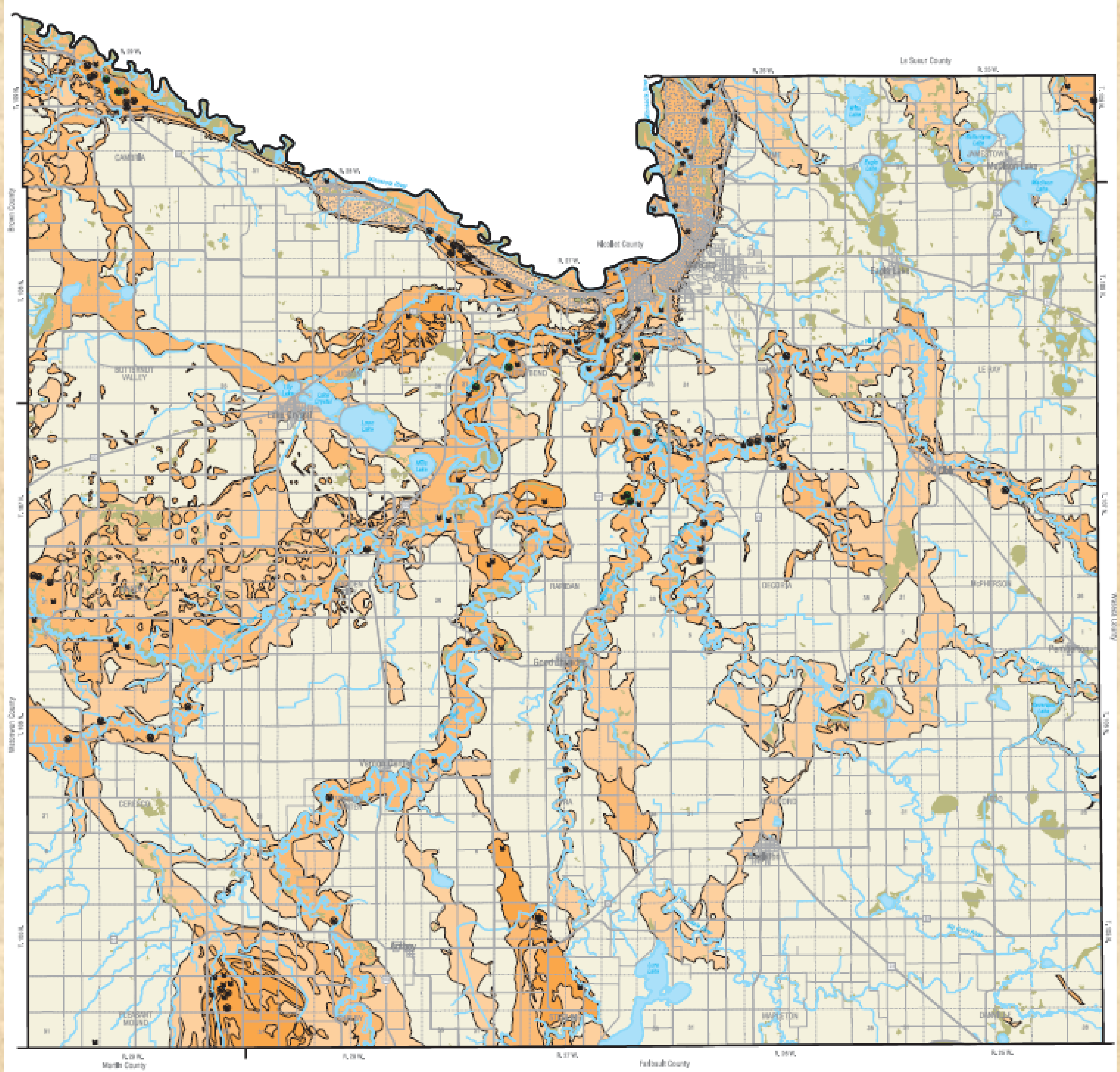
Final Scoria Potential Map

- Thickness
- Overburden
- Areal Extent
- Quality

Services Provided

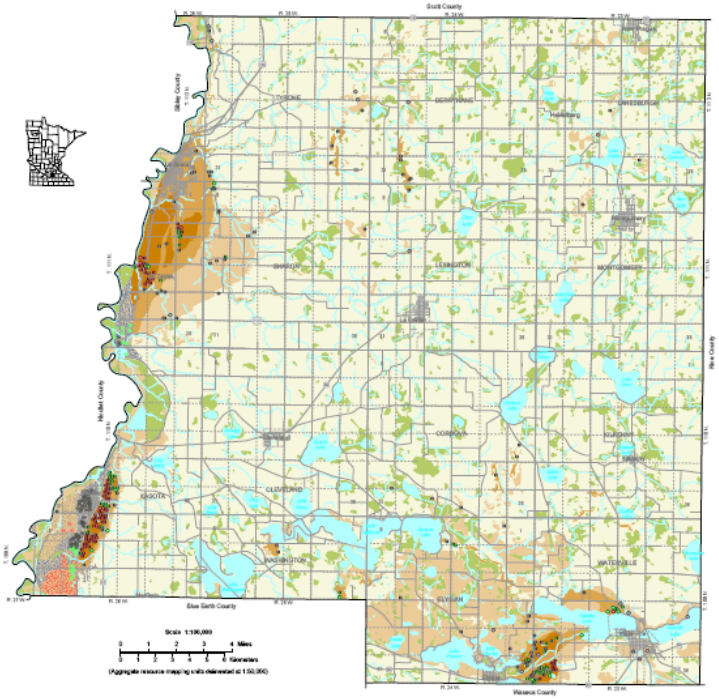
LEVEL OF SERVICES PROVIDED

Category	Basic Project Description
Class I	Data Compilation
Class II	Data Compilation, Minor Geologic Analysis and Interpretation, Reconnaissance and Evaluation
Class III	Data Compilation, Geologic Analysis and Interpretation, Reconnaissance and Evaluation, Minimal Field Work (1-3 days)
Class IV	Data Compilation, Geologic Analysis and Interpretation, Reconnaissance and Evaluation, Moderate Field work (1-2 weeks), Moderate GIS Interpretation and Mapping
Class V	Data Compilation, Geologic Analysis and Interpretation, Reconnaissance and Evaluation. add "GIS Database of field points, pits, and quarries and potential areas. Extensive Field work (3-4 weeks), Extensive GIS Interpretation and Mapping
Site Specific Evaluation	On-Call Services


Le Sueur County
Nicollet County
Faribault County
Martin County

AGGREGATE RESOURCES
LE SUEUR COUNTY, MINNESOTA

Jonathan B. Ellingson
2003



The purpose of this project is to identify and classify potential construction aggregate resources (sand, gravel, and crushed stone) in Le Sueur County, Minnesota. Having locally available, low cost construction aggregates is fundamental to building and maintaining public infrastructure and private sector development. Therefore, this information is intended to assist local planners and others in making comprehensive land-use and zoning decisions regarding aggregate resources, including aggregate resource protection, caressing the burden of development, and promoting orderly and environmentally sound development of the resource. To accomplish these goals, two map plates and a comprehensive data set on CD-ROM were created. Plate A shows a detailed breakdown of all identified and potential aggregate resource deposits. Plate B shows surficial geology and includes a description of the methodology used for mapping. The maps and digital data are designed to provide information to support land use decisions, such as zoning ordinances, permitting decisions, and protection of aggregate resources.

There are several factors related to aggregate resources that affect their availability, quality, and supply. These factors include the transportation costs, the quality of the material, and land-use conflicts. Aggregate materials are typically low-value commodities, which means transportation costs can account for a considerable amount of the delivered price. Having a local supply of aggregate means lower costs for public and private projects. Aggregate products, such as concrete and asphalt, have specific quality requirements depending on the end use.

Therefore, aggregate deposits must be evaluated in addition to quality standards. At the same time, land-use conflicts between aggregate mining and urban development are becoming more common. Land-use conflicts can be caused by cities expanding into adjacent non-urban zones, aggregate resource deposits being covered by new development, or new development occurring adjacent to aggregate sources. As a result, the distance from the aggregate source to its consumers is increasing. Due to the increased cost of aggregate installation and related urban issues, aggregate resources are being depleted rapidly.

With these and other issues in mind, the 1996 Minnesota Legislature passed a law (Minn. Stat. sec 84.94, Aggregate Planning and Protection) that directs the Minnesota Department of Natural Resources, in cooperation with the Minnesota Geological Survey and the Minnesota Department of Transportation (MNDOT), to identify and classify potential aggregate resources where urbanization or other factors are resulting, or may result, in a loss of aggregate resources. When the mapping is completed, the information is provided to local governments and the public. Since this is a second-generation survey of aggregate resources, site-specific evaluations are still necessary prior to any development of the resource, especially in regard to aggregate quality or environmental issues. Factors such as ownership, zoning, projected location of wetlands, environmental permitting, land use, and other individual site characteristics are not part of the geological resource data summarized here.

AGGREGATE POTENTIAL: For the purpose of this study, aggregate potential is defined as an assessment of the relative probability that an aggregate deposit exists within a given area, with emphasis placed upon geologic evidence, parameters, and characteristics of the resource known to exist. Economic feasibility evaluation or other related parameters were not considered in this study. This assessment does not imply that economic aggregate deposits exist everywhere within a given map unit designated as "Potential Sand and Gravel Resources" or "Potential Crushed Stone Resources." Rather, that within such a map unit, geologic processes were active that could have created aggregate deposits at specific sites. Geologic measurements of aggregate deposits remain constant, but economic criteria and environmental permitting vary across time and place. Important site-specific factors such as ownership, zoning, protected waters and wetlands, environmental permitting, distance to markets, royalties, and individual site characteristics, such as thickness of overburden and stripping ratio, were not considered in the delineation of deposits within a given parcel; however, these factors were not excluded in this study.

POTENTIAL SAND AND GRAVEL RESOURCES: Geologic units that are inferred to contain sand and gravel. These units exhibit the geologic characteristics that usually produce sand and gravel deposits. Existing gravel pit and MNDOT aggregate sources lying within these units indicate identified or known resources. The geologic units have the potential for sand and gravel deposits within the following landforms: outwash plains, terraces, and fans; glacial outwash features (channels and terraces), and ice-contact features (eskers and kames). These units typically contain sorted sand and gravel with little silt or clay. For a further discussion of these mapping units, refer to the Classification Methodology of Aggregate Resources section of this plate.

HIGHLY DESIRABLE SAND AND GRAVEL DEPOSITS: Glaciofluvial features, such as terraces and outwash plains. These deposits are very large in areal extent. These deposits consist of sand and gravel with thicknesses typically ranging from 15 to 75+ feet, with less than 5 feet of overburden. The probability that a potential sand and gravel deposit exists within this unit is high to very high. The textural characteristics of these deposits are classified as good to very good. The quality is typically moderately high to very high relative to all deposits within Le Sueur County.

MODERATELY DESIRABLE SAND AND GRAVEL DEPOSITS: Glaciofluvial features, such as outwash channels and terraces; ice-contact features, such as eskers and kames; and weak Holocene age terraces, floodplains, and fans. These deposits are moderately small to large in areal extent with sand and gravel thicknesses typically ranging from 10 to 50+ feet, with less than 10 feet of overburden. The probability that a potential sand and gravel deposit exists within this unit is moderately high to very high. The textural characteristics of these deposits are moderate to very good, with the quality ranging from moderately high to high.

LESS DESIRABLE SAND AND GRAVEL DEPOSITS: Glaciofluvial features, such as outwash channels and terraces; ice-contact features, such as eskers and kames; and alluvial features such as flood plains, terraces, fans, and sand bars. These deposits are moderately small to very large in areal extent and consist of sand and fine sand with thicknesses ranging from 0 to 50+ feet, with overburden thicknesses between 0 to 40+ feet. The probability that a potential sand and gravel deposit exists within this unit is moderate to very high. The textural characteristics of these deposits are moderately poor to good, with the quality ranging from moderately low to high.

POTENTIAL CRUSHED STONE RESOURCES: Carbonate (limestones and dolomites) bedrock from the Prairie du Chien Group and sandstone bedrock from the Jordan Sandstone Formation that are suitable for crushing. These units are inferred to be relatively thick (10 to 50+ feet), with overburden thicknesses ranging from 0 to 50 feet. Quarries located within these units indicate identified or known resources.

HIGHLY DESIRABLE CRUSHED STONE DEPOSITS: Carbonate (limestones and dolomites) bedrock units that are very large in areal extent, and contain materials suitable for crushing. These units have thicknesses ranging from 30 to 50+ feet, with overburden thicknesses typically less than 10 feet. These units have a very high probability of containing potential crushed stone deposits. The quality of these units is high.

MODERATELY DESIRABLE CRUSHED STONE DEPOSITS: Carbonate (limestones and dolomites) bedrock units that are moderate to very large in areal extent, and contain materials suitable for crushing. These units have thicknesses ranging from 20 to 40+ feet, with overburden thicknesses typically less than 10 feet. These units have a high to very high probability of containing potential crushed stone deposits. The quality of these units is high.

LESS DESIRABLE CRUSHED STONE DEPOSITS: Carbonate (limestones and dolomites) and sandstone bedrock units that are moderately large to very large in areal extent, and contain materials suitable for crushing. These units have thicknesses ranging from 10 to 50+ feet, with overburden thicknesses ranging from 0 to 50 feet. These units have a moderately high to very high probability of containing potential crushed stone deposits. The quality of these units is moderately high to very high.

LIMITED POTENTIAL FOR AGGREGATE RESOURCES: Units that generally have little or no potential for significant aggregate resources. These units exhibit geologic characteristics that are typically not considered with significant aggregate deposits. The geologic units having limited potential include collapsed glaciofluvial channels, glacial lake plains, glacial moraines, outwash plains, alluvial terraces, alluvial deposits, or bedrock with overburden thicknesses typically greater than 50 feet. These units typically consist of silty, silt, fine sand, unsorted sediments (till), or very thin layers of sand and gravel. These units may include aggregate deposits that are too small to map.

LIMITED POTENTIAL FOR AGGREGATE DEPOSITS: Units that include glacial features such as collapsed glaciofluvial channels, ground moraines, glacial lake beds, colluvial slopes, and small alluvial features such as flood plains and streams. The probability that a significant aggregate deposit exists within this unit is very low to moderate. The aggregate deposits occurring in this unit are very small to moderately small in areal extent and typically consist of fine material (sand with some gravel). The thicknesses of these aggregate deposits are typically less than 20 feet, with overburden thicknesses sometimes reaching over 100 feet. The textural characteristics are poor to moderately poor with the quality ranging from low to moderate. These units also contain carbonate bedrock units with an overburden thickness of greater than 50 feet. In a few areas on the map, a dotted pattern (bedding oriented stone resources potential) can be seen, only one of these is mapping unit. In this case, there is crushed stone potential, but there is limited sand and gravel potential.

IDENTIFIED AGGREGATE RESOURCES: Areas where aggregate resources (sand, gravel, and/or crushed stone) have been or are currently being mined. All aggregate resource locations have been gathered from several different sources, including topographic maps, aerial photographs, county records, county highway department maps, soil surveys, MNDOT files, fieldwork, and personal observations, and other miscellaneous sources. The pits and quarries range in size from less than 1 acre to greater than 50 acres and may be active, inactive, depleted, or reclaimed. The aggregate quality of the pits varies.

Gravel Pits: Locations were gathered from several different reference sources. Any given pit may be active, inactive, depleted, or reclaimed. The color indicates the relative size of the pit.

- Large - larger than 15 acres
- Medium - approximately 5 to 15 acres
- Small - less than 5 acres.

Gravel Pits - MNDOT files: Locations gathered from ASIS, the Minnesota Department of Transportation's Aggregate Source Information System listing of aggregate sources. Test hole logs, sieve, and quality test data are available. The color indicates the relative size of the pit.

- Large - larger than 15 acres
- Medium - approximately 5 to 15 acres
- Small - less than 5 acres.

Quarries: Ordovician carbonate (limestone and dolomite) quarries used for either crushed stone or dimension stone; and industrial sand quarries where carbonate bedrock is removed to access the Cambrian sandstone bedrock. Any given unit may be active, inactive, depleted, or reclaimed. The color indicates the relative size of the quarry.

- Large - larger than 15 acres
- Medium - approximately 5 to 15 acres
- Small - less than 5 acres.

OTHER FEATURES:

WETLANDS: Wetland area. WATER: Lakes or rivers.

*Areal Extent - the size, horizontal extent, or distribution of a unit (e.g., area or acres).
*Thickness - the vertical dimension of a unit (e.g., thickness in feet or meters).
*Textural Characteristics - particle size distribution, the percent of gravel or sand-sized material in a unit (e.g., sieve analysis).
*Quality - the characteristics of the material - soundness (e.g., magnesium/iron test), durability (Los Angeles wear test), and chemical makeup (chemical/deleterious material such as shale, lime nodes, and unsound chert).

Classification Methodology for Aggregate Resources

The aggregate resources of Le Sueur County were divided into seven categories: 1) highly desirable sand and gravel deposits, 2) moderately desirable sand and gravel deposits, 3) less desirable sand and gravel deposits, 4) highly desirable crushed stone deposits, 5) moderately desirable crushed stone deposits, and 7) limited potential for aggregate deposits.

The sand and gravel resources were divided into these categories based on the host geological features, probability (certainty) that sand and gravel exists within a unit, sand and gravel thickness, overburden thickness, deposit size (areal extent), textural characteristics (sieve analysis), quality (soundness and durability) of the material, and the sediment description as observed in the field (Table 1). For example, a flood plain deposit typically holds sand and gravel, thus the feature map symbol is yellow. If the deposit has a gravel pit located on or adjacent to it and sand and gravel were encountered by drilling during fieldwork, it has a very high probability. If the deposit is 30 feet thick with 2 feet of overburden and covers 40 acres in areal extent, the aggregate thickness, overburden thickness, and deposit size are all in the high to very high category. If the texture indicates a high percentage of gravel and the quality meets MNDOT specifications, then this sand deposit is categorized as a highly desirable sand and gravel deposit. Even if a deposit has good geological characteristics for sand and gravel, one economic factor, such as haul distance or costs, could make a deposit less economically desirable, but economic factors were not considered in this study.

Crushed stone resources were divided into three categories: 1) highly desirable, 2) moderately desirable, and 3) less desirable, based on overburden thickness, deposit thickness, product(s), deposit size, environment of deposition, bedrock description, and quality. The deposit thickness, environment of deposition, and bedrock description took into account the thickness of consolidated beds, the presence of joints and fractured beds, and other field observations. Limestone/dolomite beds that are more massive and dimble create higher quality aggregates. The presence and quantity of interbedded shale lowers the aggregate quality. If the shale/clay was less than 50 feet thick, the unit was considered acceptable, and if it was less than 20 feet thick, it was considered more acceptable. The probability, deposit size, and quality were determined in a similar manner to that of the sand and gravel category.

The areas classified as limited aggregate potential did not meet the above-mentioned criteria for either sand and gravel or crushed stone. The deposits may have been too small in areal extent, not thick enough, have too much overburden, may not have met the quality specifications, or contained material too fine in size.

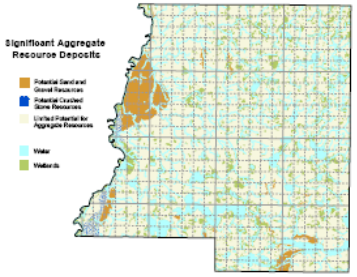
Along with aggregate potential, all known identified sources of aggregate were mapped. The included gravel pits and quarries ranged in size from less than an acre to more than 50 acres. These gravel pits and quarries may be active, inactive, depleted, or reclaimed, but represent an area where aggregate is or has been mined.

Table 1. Sand and Gravel Potential

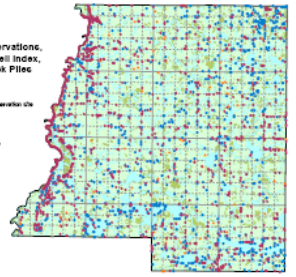
Characteristics	Sand and Gravel Rating: Quality	Moderately	Less	Limited
Surficial Geology Feature	Glaciofluvial outwash, channels and terraces	Outwash channels and terraces, terraces and eskers, alluvial terraces, fans, bars, floodplains	Outwash channels and terraces, terraces and eskers, alluvial terraces, fans, bars, floodplains	Moraines, collapsed channels, glacial lake beds, colluvial slopes, bedrock with overburden
Sediment Description	Sand and gravel	Sand and gravel	Sand, with occasional gravel	Clay/silt/sand with occasional sand and gravel
Probability*	High very high	Moderately high very high	Moderate very high	Very low moderate
Sand and Gravel Thickness (in feet)	40-75+	10-40+	0-40+	0-20+
Overburden Thickness (in feet)	0-5	0-10	0-40+	0-100+
Sand and Gravel Deposit Size (areal extent)	Large to very large (40-80 acres)	Moderately small to large (10-40 acres)	Moderately small to large (10-80 acres)	Very small to moderately small (0-10 acres)
Sand and Gravel Textural Characteristics	Good very good	Moderate very good	Moderately poor good	Poor moderately poor
Sand and Gravel Quality*	Moderately high very high	Moderately high	Moderately low to high	Low moderate

*Probability is the degree of certainty that aggregate exists within a unit.
*Quality is defined in terms of soundness, durability, and mineral makeup.

Note: The units are associated with aggregate potential (probability) (i.e., highly desirable, moderately desirable, less desirable, limited potential for aggregate deposits).



Significant Aggregate Resource Deposits are defined as those deposits most likely to be explored and evaluated for future commercial use. They include all the mineable units of highly desirable sand, gravel, and crushed stone deposits, as well as very large areas of thin sand and gravel that could be blended with coarser material to make more highly desirable deposits.



The field observation sites were logged during the field seasons in the summer and fall of 2002 and spring of 2003. Field work consisted of driving every accessible road in the county looking for outcrops and exposures of geological sediments, as well as driving test holes where needed and where landowner permission was granted. Sediments exposed in road cuts, stream exposures, excavations such as basements, gullied ditches, construction projects, trenches (cattle, pipe, fence), and even animal holes, offered several places where the surficial materials, glacial stratigraphy, and bedrock formations were observed. A total of 1,151 observation sites were logged in the county. The County Well Index (CWI) was used to locate water well records in areas where outcrops were not available. The CWI contains over 40,000 wells statewide. As of 2003, when the CWI data were obtained, approximately 850 of these wells are located in Le Sueur County. Almost two-thirds of the wells contained geological descriptions that were found to be useful for this study. The rock pile sites were observed and recorded during field work and consist of sites where rocks were placed into significant piles that could be used for riprap or for crushing.

Aggregate Resources
Aerial photograph interpretation, fieldwork, and delineation of mapping units by Jonathan B. Ellingson, 2002-2003. County Aggregate Mapping Program, Division of Lands and Minerals, Minnesota Department of Natural Resources. Source information includes aerial photographs from NAPP (National Aerial Photography Program), 1991-1992, 9" x 9" color infrared photos at 1:40,000; DOQs (Digital Orthophoto Quadrangles) at 1:12,000 from USGS (United States Geological Survey); DRGs (Digital Raster Graphics) at 1:24,000 from USGS; Soil Survey of Le Sueur County, Minnesota, published by USDA-SCS (United States Department of Agriculture - Soil Conservation Service), and Soil Survey of Nicollet County, Minnesota, published by USDA-SCS (United States Department of Agriculture - Natural Resources Conservation Service, and CWI (County Well Index) database from the Minnesota Geological Survey, downloaded in 2002.

Base map data sources:
Lakes, wetlands, and rivers from National Wetland Inventory, U.S. Fish and Wildlife Service, compiled at 1:24,000 from aerial photography (1979-1988) and spot field checked.
Public Land Survey - PLS Polys, 2001, Minnesota Department of Natural Resources, Division of Lands and Minerals.
Roads from MnDOT basemap, 2001 - Roads, Minnesota Department of Transportation, Roadway Development Group, Surveying and Mapping Section.
Cities, Townships, Municipal Boundaries from MnDOT Basemap 2001 - Cities and Area, Minnesota Department of Transportation, Roadway Development Group, Surveying and Mapping Section.

GIS database design and cartography by Ronna Johnson. Database assistance by Jason Berkas and Brad Rivers. Portland darting assistance by Ronna Richardson and Jason Berkas.

Prepared with support from Le Sueur County.

This project includes a CD-ROM of maps, data, and metadata in a digital format and the following plates:
Plate A, Report 360, Aggregate Resources — Plate B, Report 360, Surficial Geology

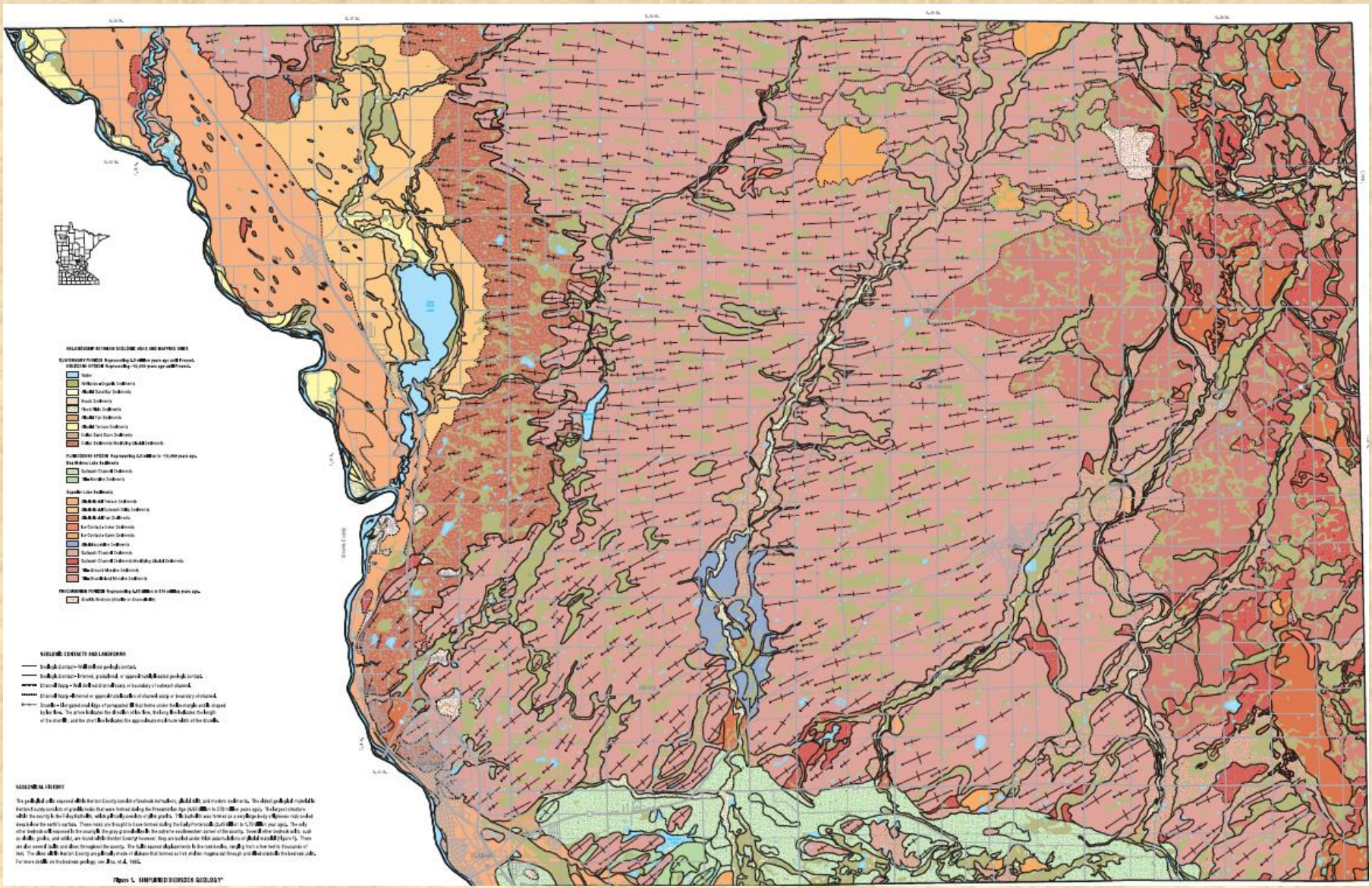
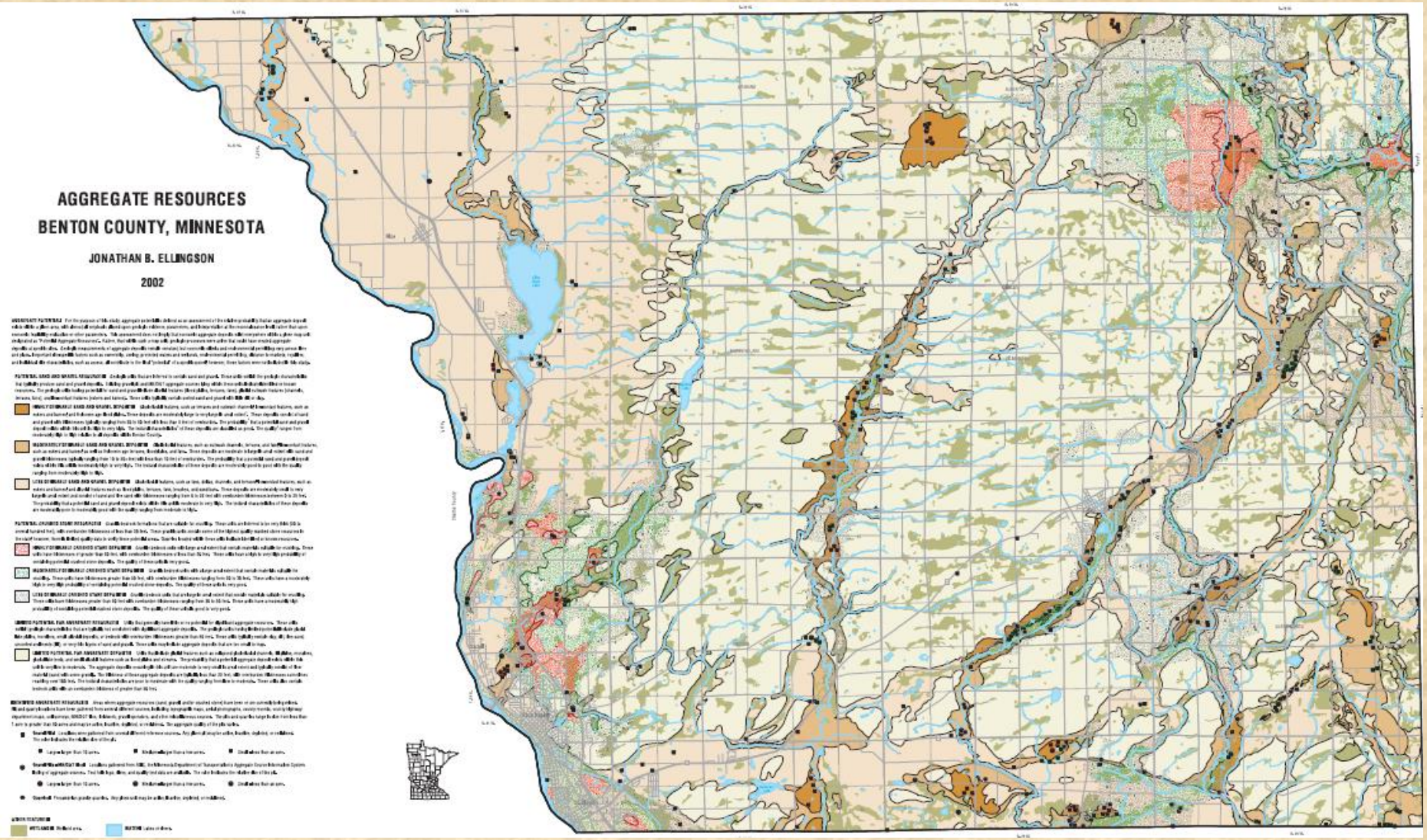


Figure 1. SIMPLIFIED BEDROCK GEOLOGY*

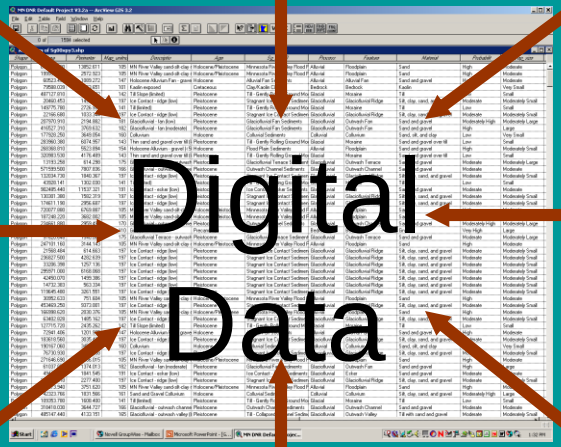

AGGREGATE RESOURCES
BENTON COUNTY, MINNESOTA
JONATHAN B. ELLINGSON
2002


Gravel Pit
Information


Drill Hole Logs


Miscellaneous
Observations


Field Samples


Digital
Data

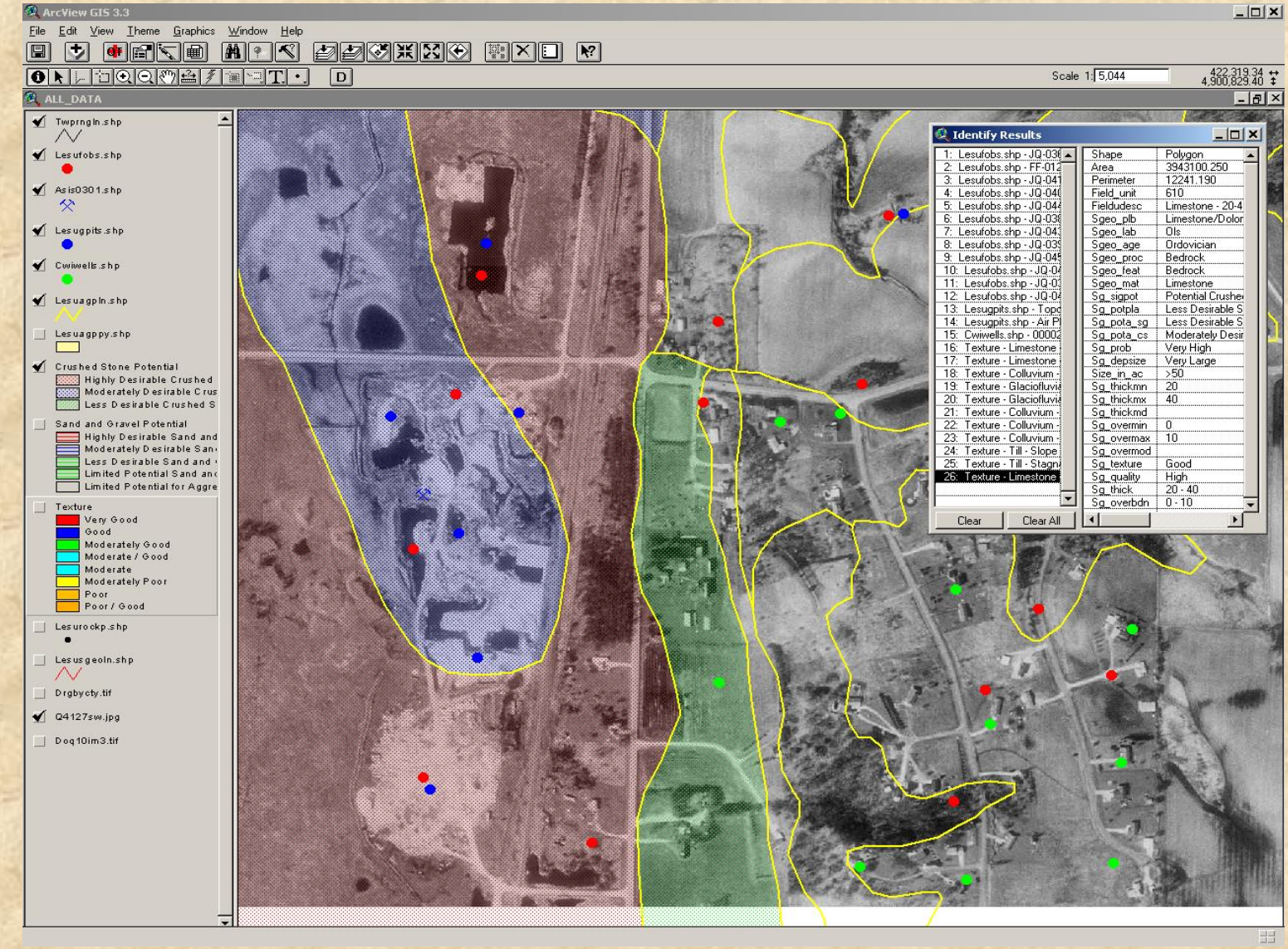

Sieve Data-Texture


Material Observed

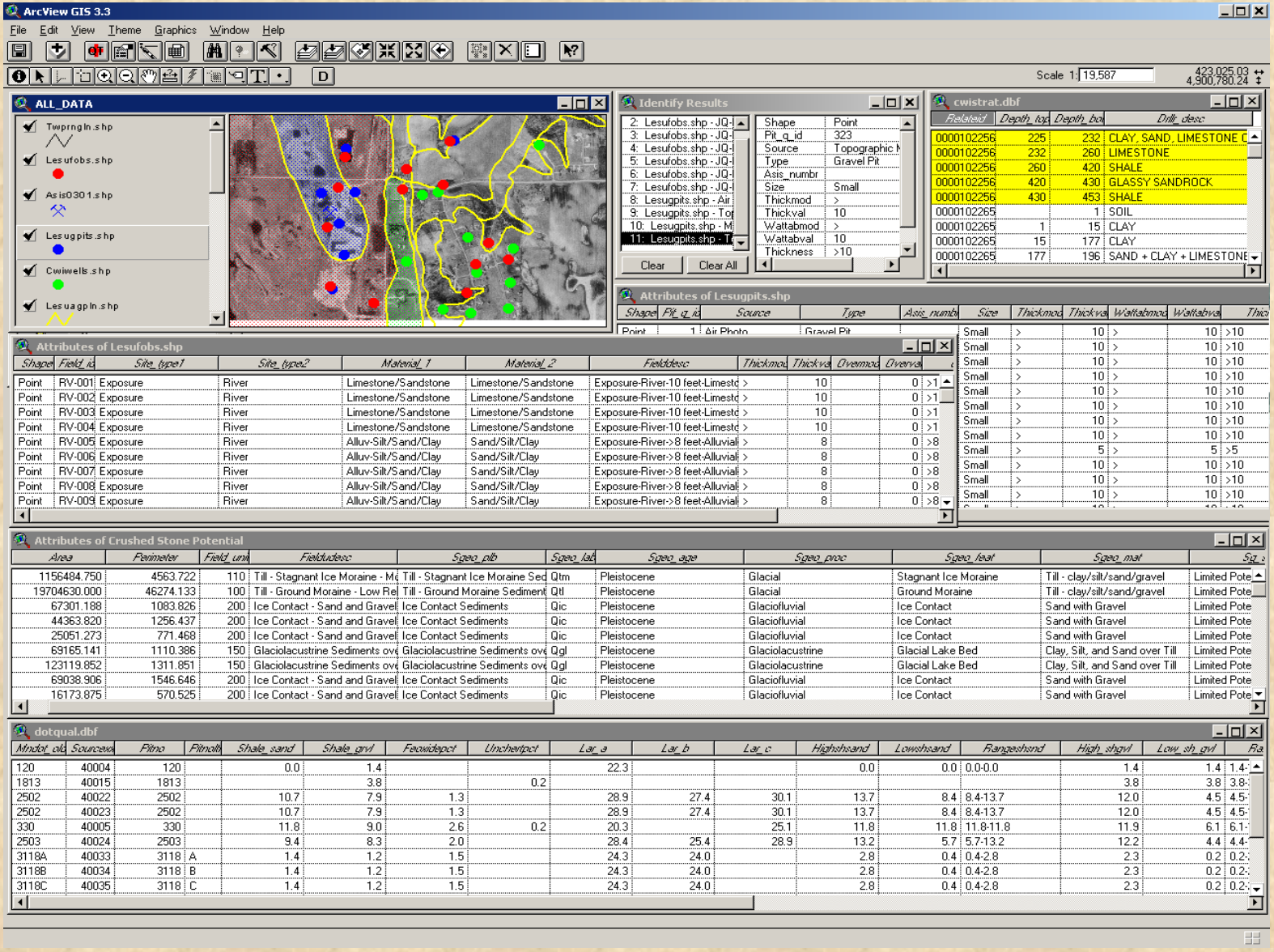

Aggregate Quality


Field Observations

Access Digital Information

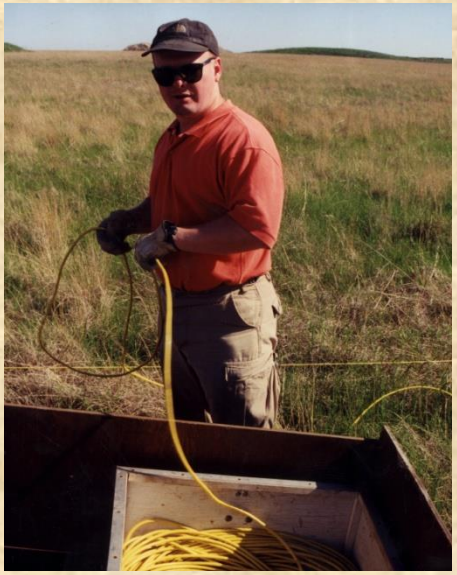


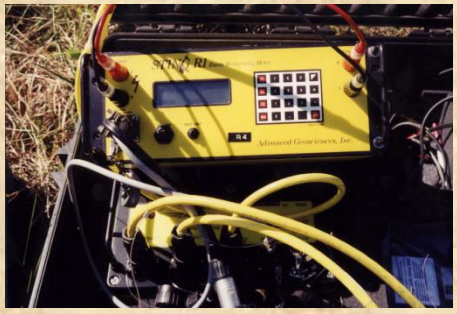
Digital Data



EXPLORATION: TRENCH/BACKHOE

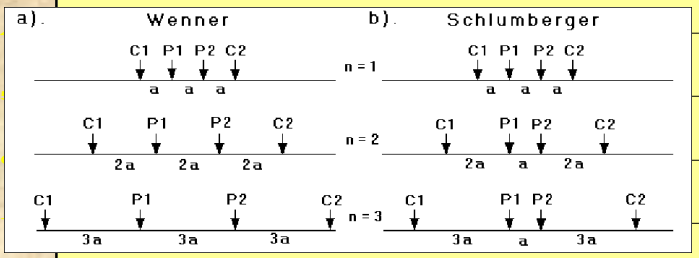
EXPLORATION: GEOPHYSICS – EM RESISTIVITY

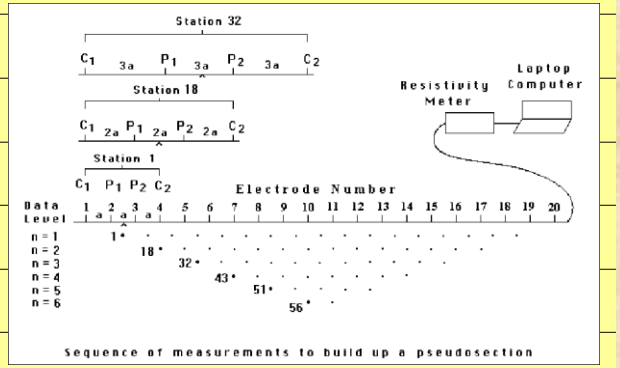


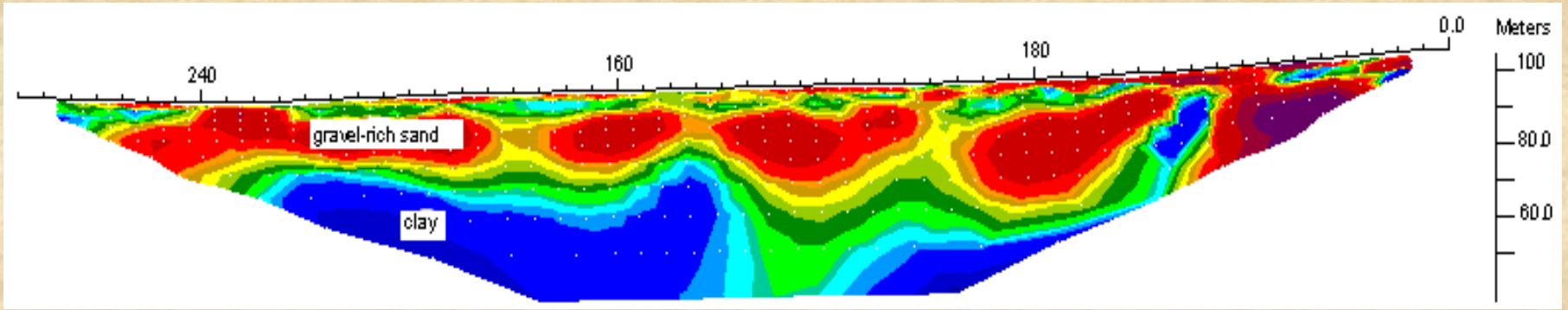


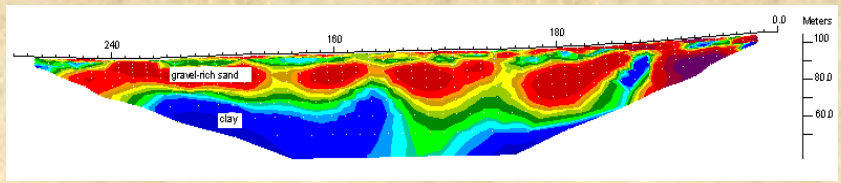
EM RESITIBITY DATA

- Upper – more data / more control / more accurate
- Lower – less data / less control / more interpretive








240
160
180
0.0
Meters
100
80.0
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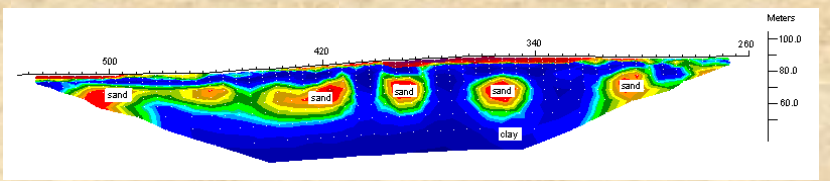
gravel-rich sand
clay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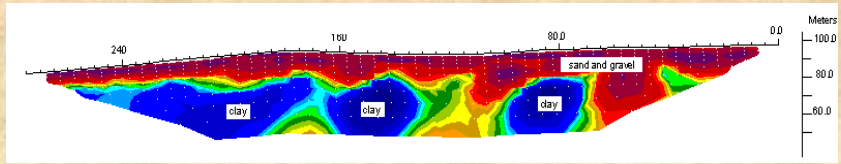
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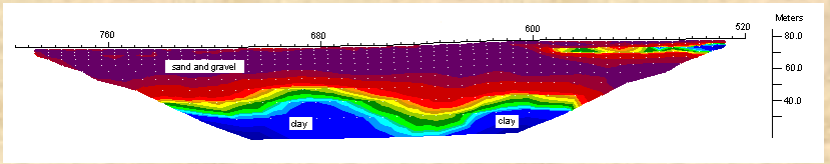
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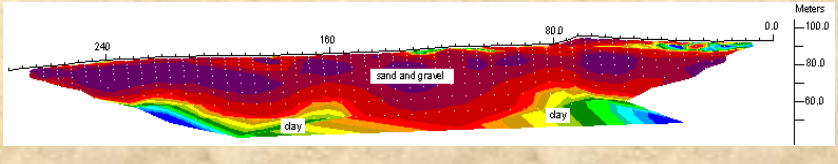
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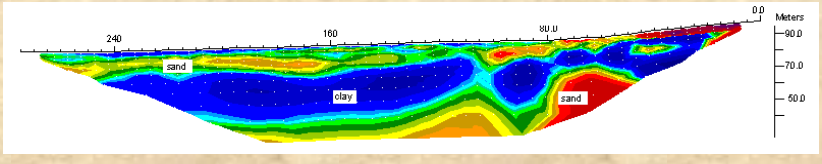
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sand
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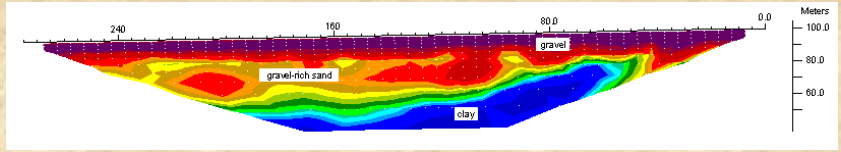
sand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gravel
gravel-rich sand
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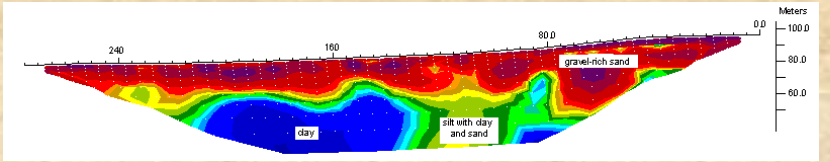
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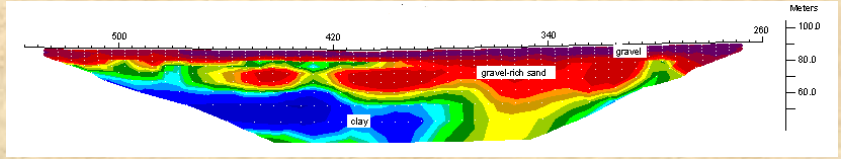
gravel-rich sand
clay
silt with clay and sand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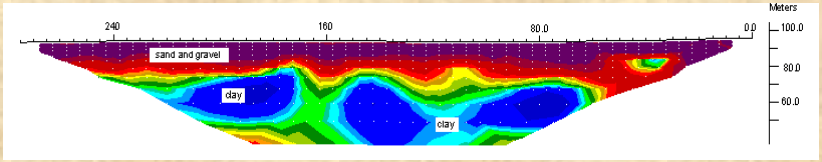
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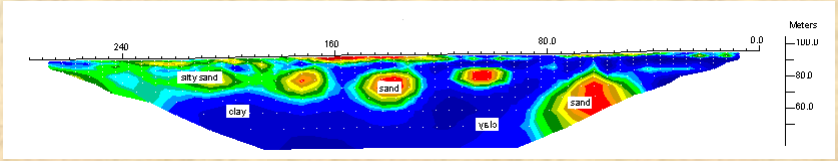
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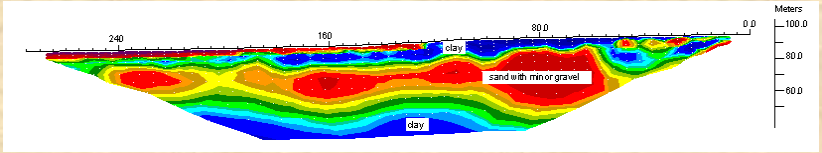
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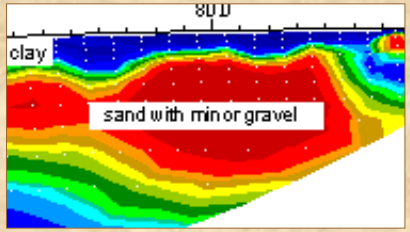
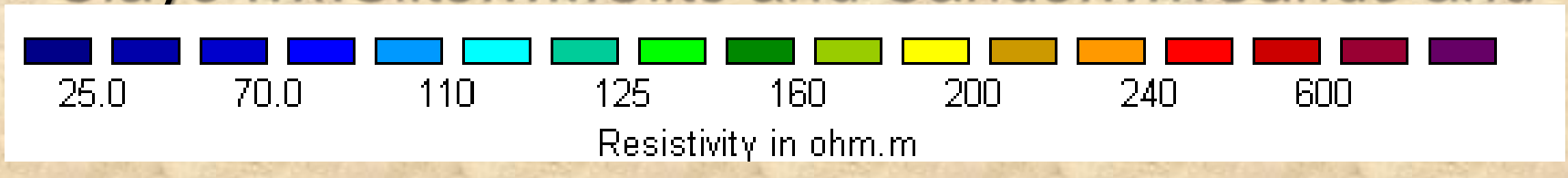
clay
sand with minor gravel
clay

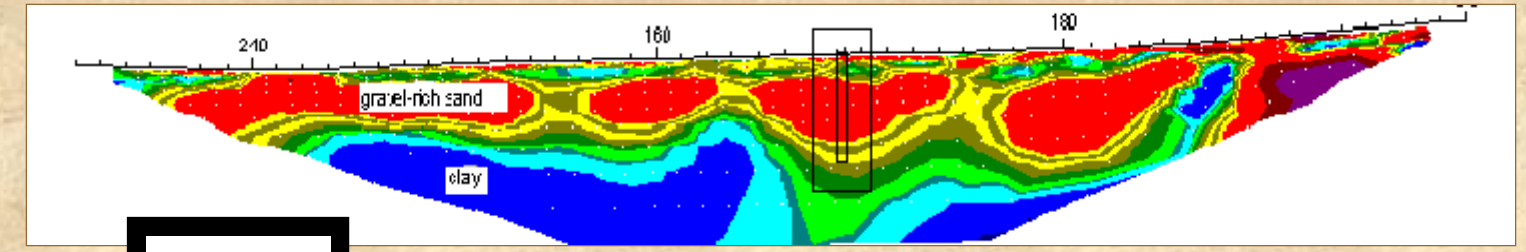
EM RESISTIVITY DATA

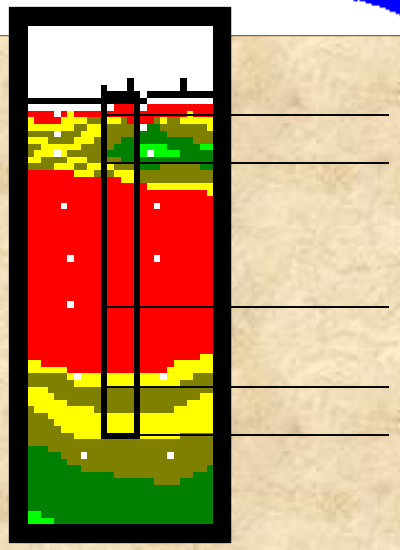


Material (Clay, Sand) vs. Resistivity (Ohm-meters)

Clays …..Silts……Silts and Sands……Sands and







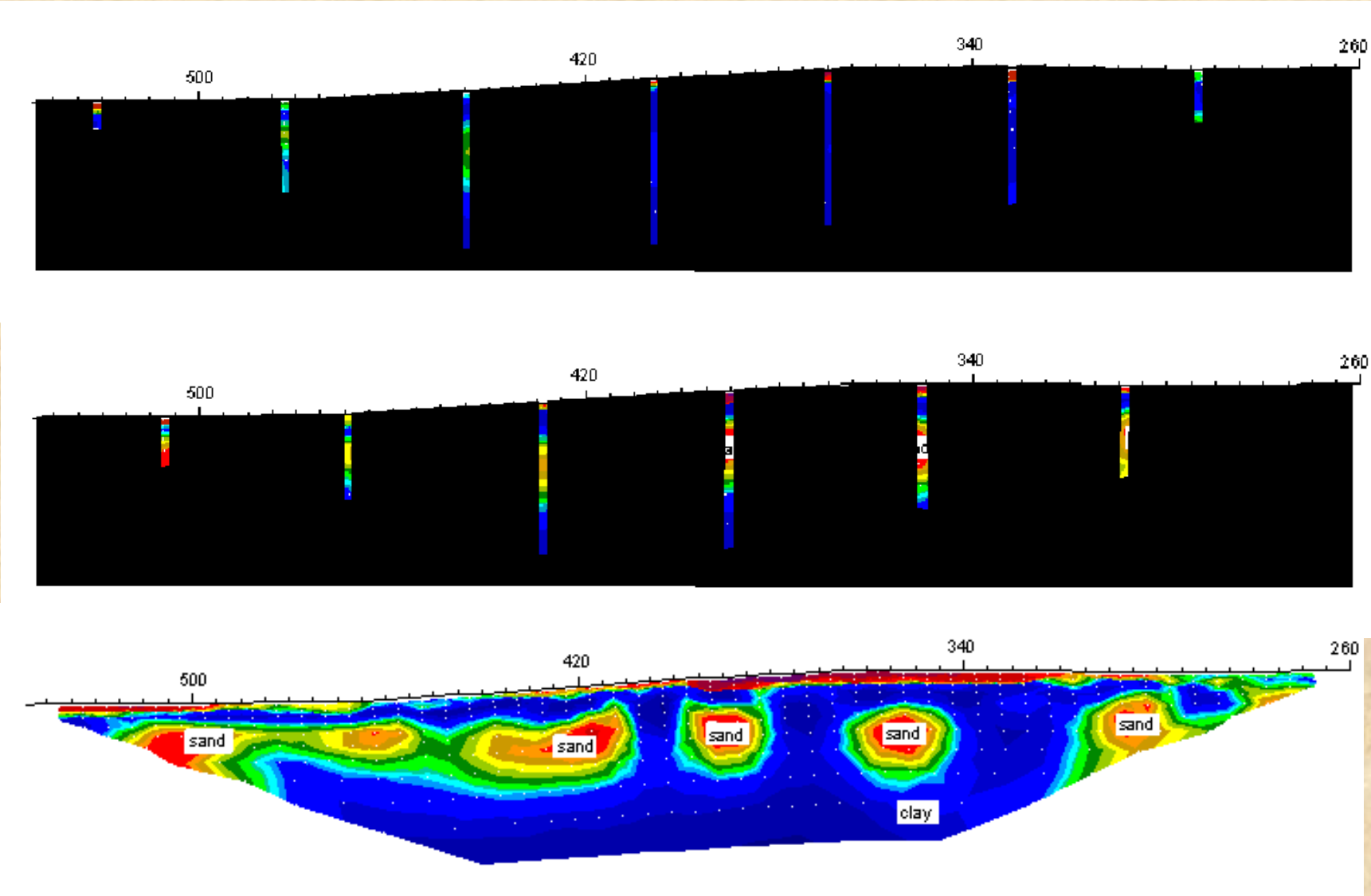
0 TO 19’ Silt

19 to 65’ Sand and Gravel

65 to 90’ Sand with Gravel

91 to 105’ Sand

CONTINUITY OF A RESOURCE (Between Drill Holes)



CONCLUSION / QUESTIONS

- Aggregate Resource Issues
  - Supply / Demand Issues - Increase Demand
  - Scarcity Areas – Increase Use of Alternates / Scoria
  - Quality Issues - Transportation, Erionite, GVL vs. CS
  - Increasing need for Aggregate Resource Mapping

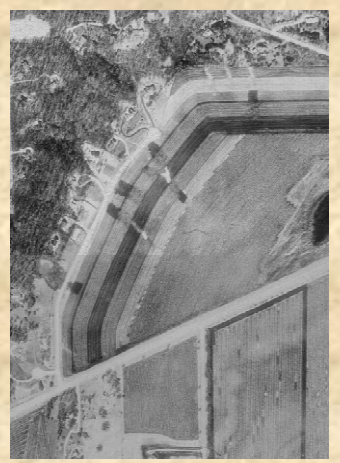
SUSTAINABILITY IN MINING

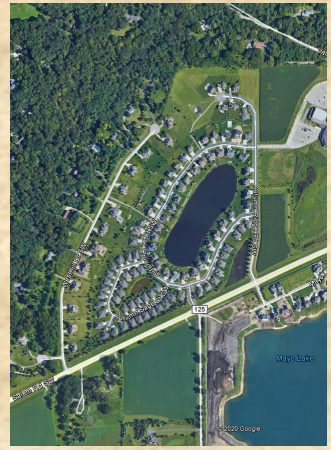
- Integrated Approach to Decision Making
- Balanced Approach
  - Environment, Economic, and Social Issues
  - Based on Sound Science, Economic Integrity, Environmental Analysis, & Social Considerations
  - 3 P's – People, Profit, and Planet
  - 3 Legged Stool – Environment, Economy, and Social

MINING = OPPORTUNITY

"Mining gives land-use planners the opportunity to maximize the potential of the land and resources involved and create new opportunities for creative and beneficial solutions."

"Sustainability considers the needs of the current and future generations!"



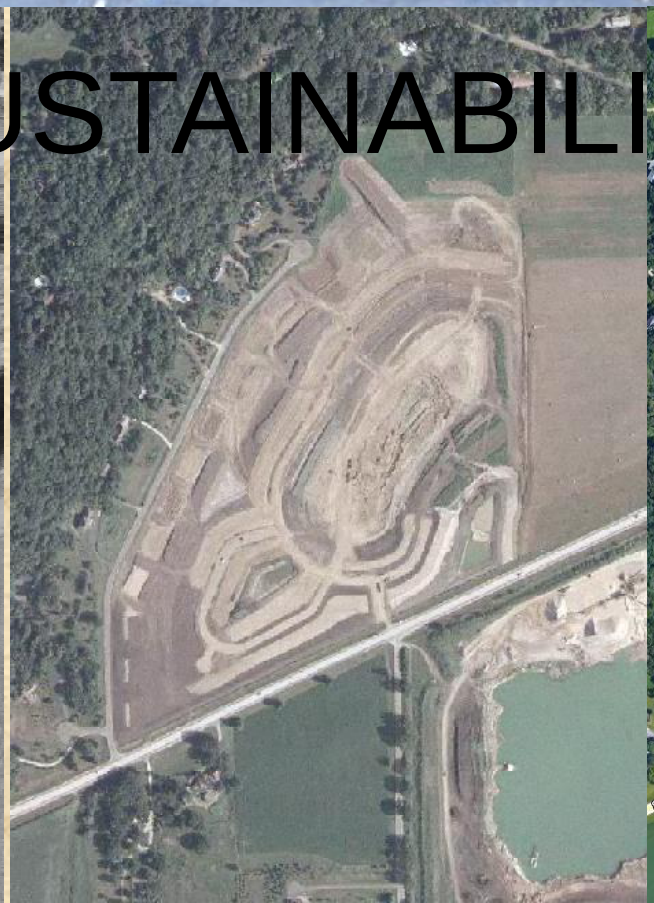


ONE PARCEL – MANY NEEDS

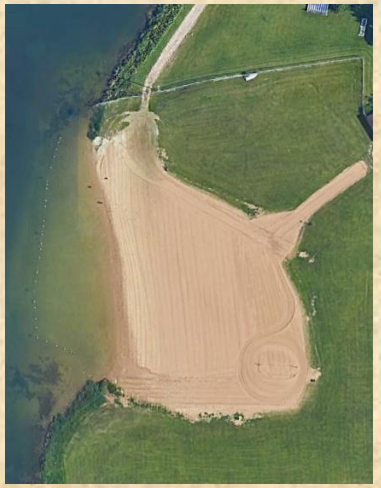
- No natural lakes in Olmsted County
- Need more wetlands and associated habitat
- Need Wildlife habitat – ducks, geese, etc…
- Need Affordable Aggregate Resources – roads/houses
- Need Land for Development – space for homes
- Need Diversity in Urban Development Properties

- <u>Ex: What do we have – Agriculture Land.</u>
- Look at Mining as an opportunity to benefit all involved – economy, social, and environmental needs.

SUSTAINABILITY



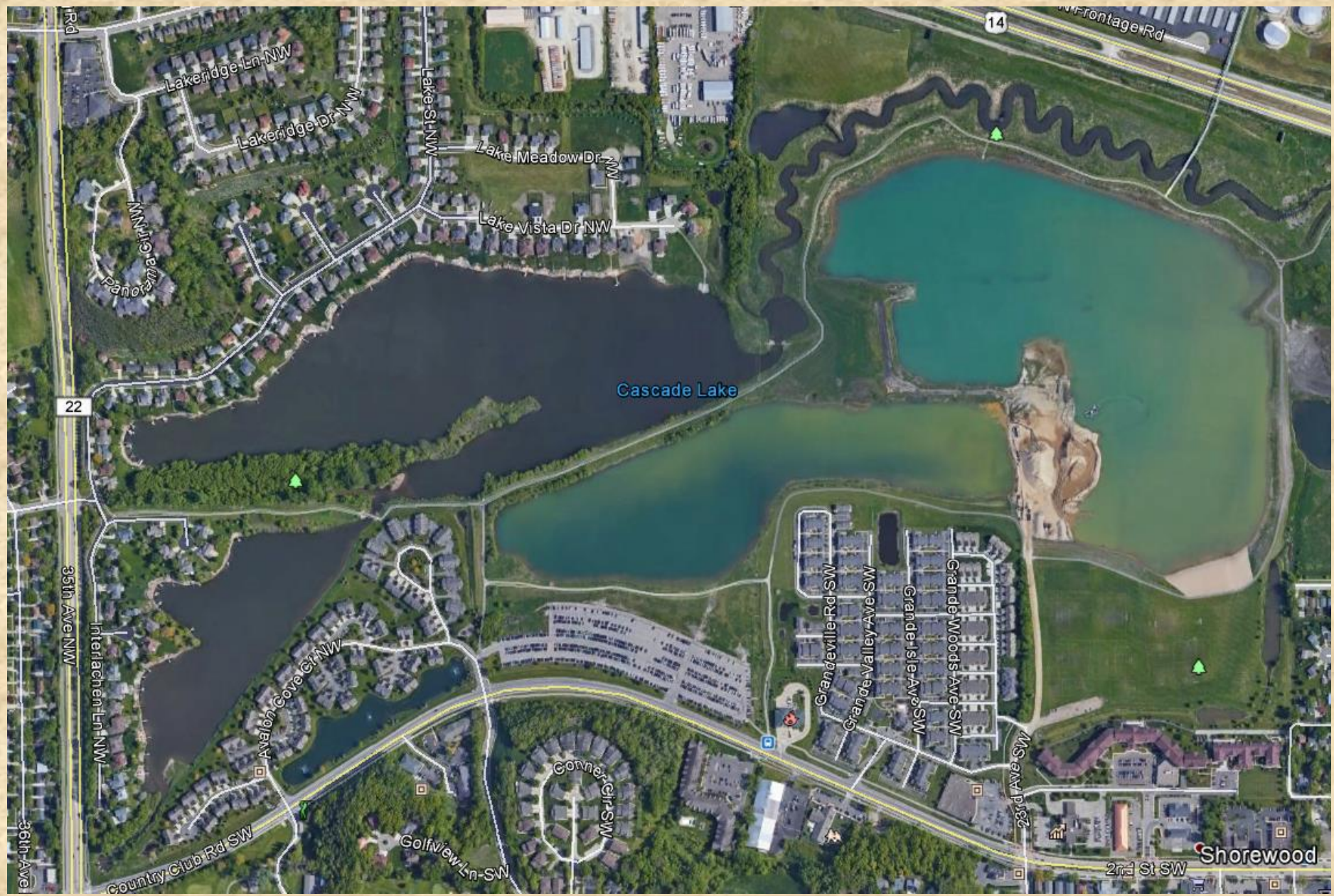
SUSTAINABILITY



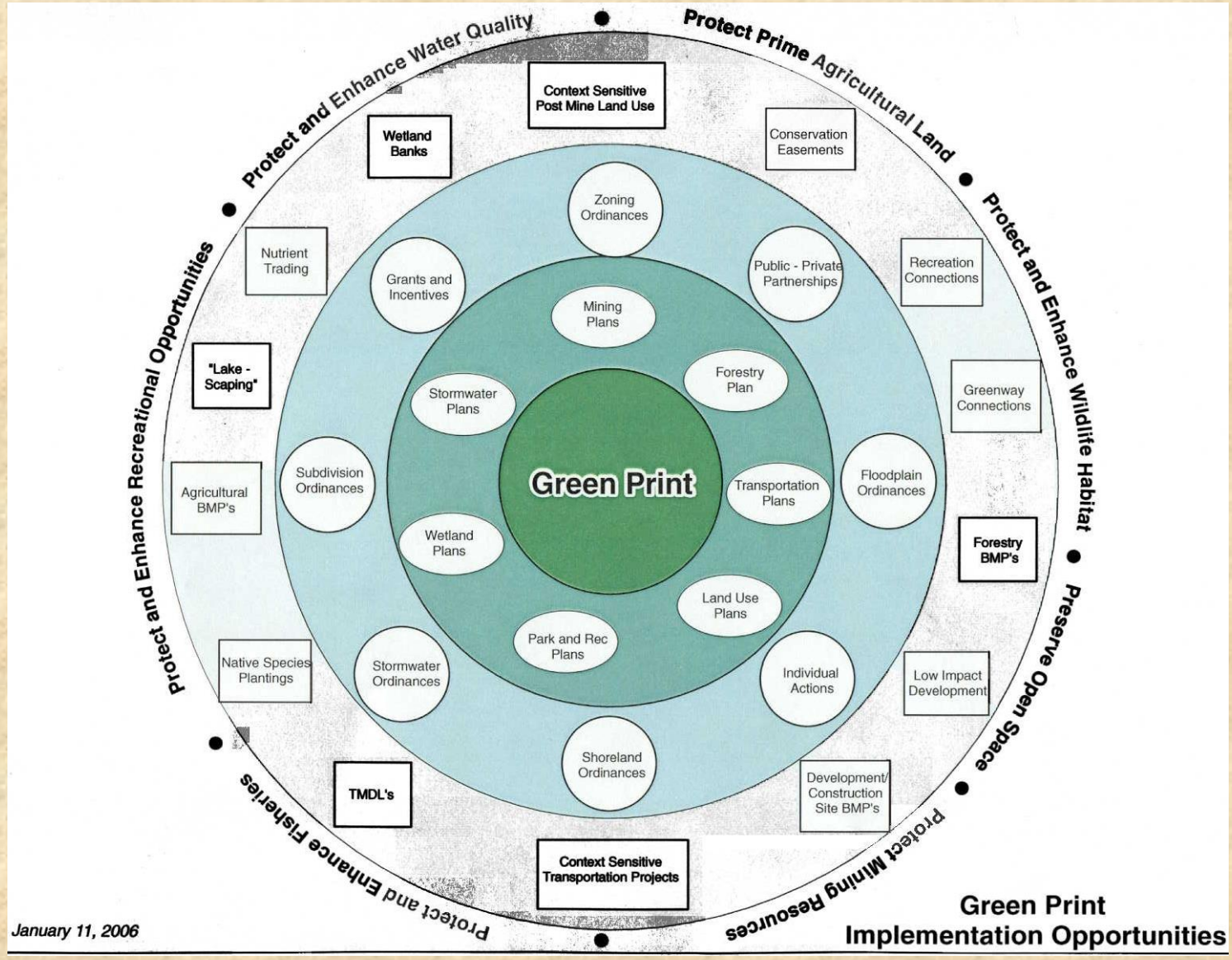
- Sustainability considers the needs of the current and future generations!

- “Establishing meaningful relationships with key constituencies based on mutual trust and a desire for mutually beneficial outcomes, including those inevitable situations that require informed trade-offs”


TRAIL EXTENSION
PROJECT BOUNDARY
POSSIBLE BUILDING SITE
PARKING (30)
ALTERNATIVE PAVING MATERIAL, TYP.
BERM & SCREENING
CROSSING
BOAT HOUSE
OVERLOOK
SEATING NODE
SEATING & EDUCATIONAL NODE
SEATING NODE
BOARDWALK
BOAT LAUNCH
TYPICAL TRAIL
FISHING PIER
FISHING
PROPOSED WETLAND MITIGATION AREA: 1.8 ACRES
WETLAND
PICNIC AREA
MANOR WOODS SUBDIVISION (APPROVED)
EDUCATIONAL NODE
CREEK CHANNEL
CREEK CHANNEL
EDUCATIONAL NODE
PORTAGE
FISHING PIER
CROSSING
PLAY AREA
OVERLOOK
MANORWOODS LAKE
POSSIBLE SHALLOW MARSH HABITAT
CASCADE LAKE
SEATING NODES
SEATING NODES
PICNIC AREA
FISHING
TOP OF BERM
SEATING NODE
FISHING
BERM W/MAINTENANCE ROAD & SCREENING
TYPICAL TRAIL
SEATING NODES
PRIVATE DOCK
FISHING PIER
CROSSING
PICNIC AREA
FISHING
PICNIC AREA
BOAT LAUNCH/RENTAL
SEATING NODE
CROSSING
FISHING
FISHING PIER
FISHING
PROJECT BOUNDARY
AMPHITHEATRE
BEACH
BEACH HOUSE
PLAZA AREA
GRANDVILLE SUBDIVISION (APPROVED)
VISITOR CENTER
PICNIC AREA
AVALON COVE SUBDIVISION
MAYO PARKING LOT
MULTI-USE OPEN SPACE
PARKING (300)
BERM & SCREENING
FIRE STATION
GATEWAY
POND


Lakeridge Ln NW
Lakeridge Dr NW
Lake St NW
Lake Meadow Dr NW
Lake Vista Dr NW
Panorama Ct NW
14
Frontage Rd
Cascade Lake
22
35th Ave NW
Interlachen Ln NW
Avalon Cove Ct NW
Golfview Ln SW
Conner Ct SW
County Club Rd SW
36th Ave
Grandeville Rd SW
Grande Valley Ave SW
Grande Isle Ave SW
Grande Woods Ave SW
23rd Ave SW
2nd St SW
Shorewood

BLUE EARTH COUNTY – GREEN PRINT



PITS VS. QUARRIES

- Types of Pits
  - Gravel Pit
  - Sand Pit
  - Barrow Pit.
- Types of Quarries
  - Crushed Stone
  - Dimension Stone
  - Industrial Sand

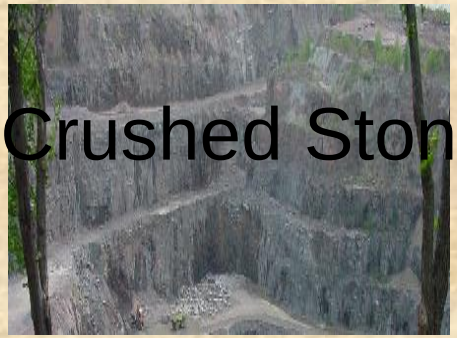
TYPES OF PITS

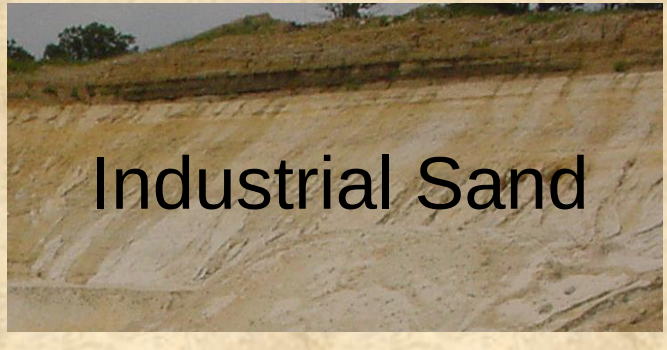
- Unconsolidated Material
- Different Composition
- Gravel, Sand, or Clay
- The type of material determines type of pit

QUARRIES

- Consolidated bedrock is mined (same rock type).

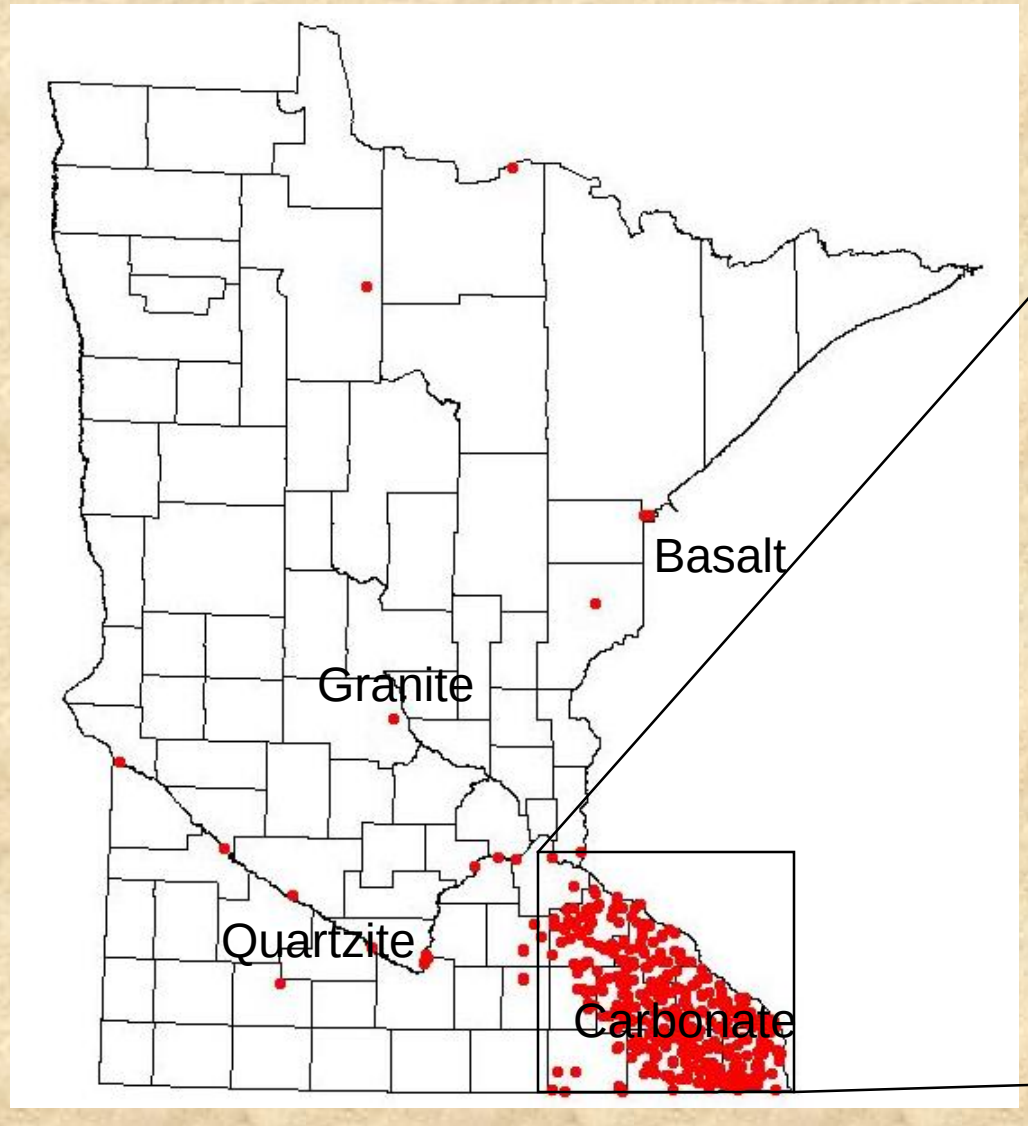
- Limestone, Granite, Dolomite, Quartz Sand, Quartzite, Basalt, Gneiss, Etc.

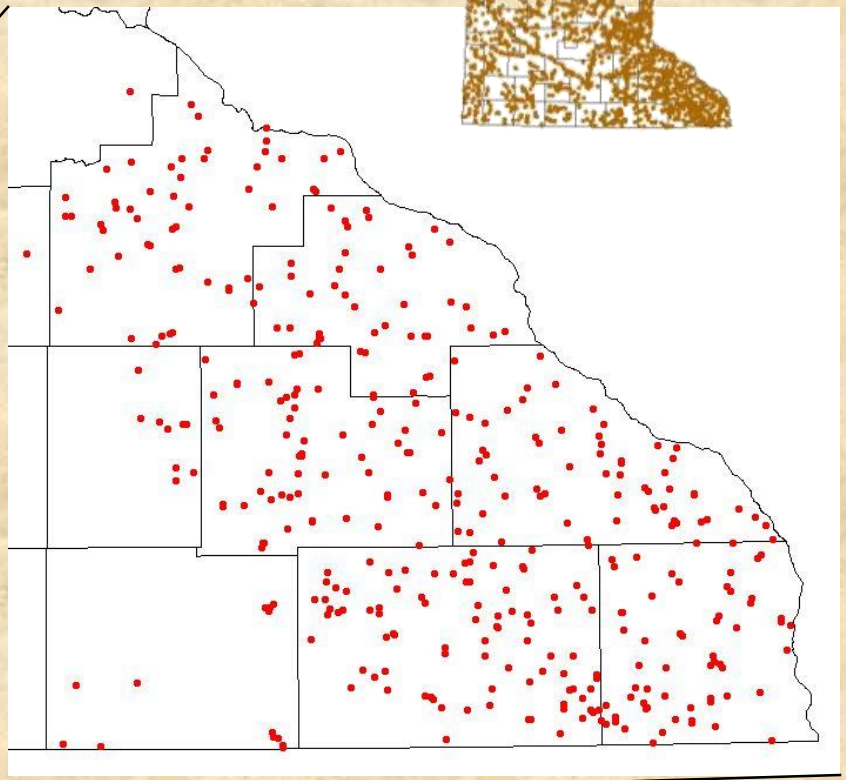


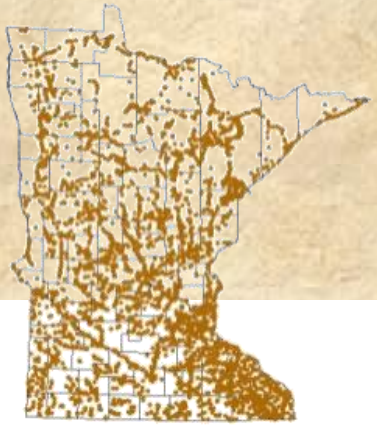


QUARRIES

Distribution of Quarries in MN







MN/DOT – Aggregate Source Information System (ASIS)

MINING AGGREGATE RESOURCES

- Sand and Gravel
  - Mining Above WT
  - Mining Below WT
- Crushed Stone
  - Mining Above WT
  - Mining Below WT

- Type of Mining Affects
  - Post-Mine Land-Use
  - Reclamation Plan
  - Mine Planning
  - Staged Reclamation
  - Maximize Resource

AGGREGATE MINING

Sand and Gravel Mining – Above Water Table

Unconsolidated Material

AGGREGATE MINING

Sand and Gravel Mining

- Crushing and Processing
- Grates/Shakers/Complex Systems

Desired Product Specifications

AGGREGATE MINING

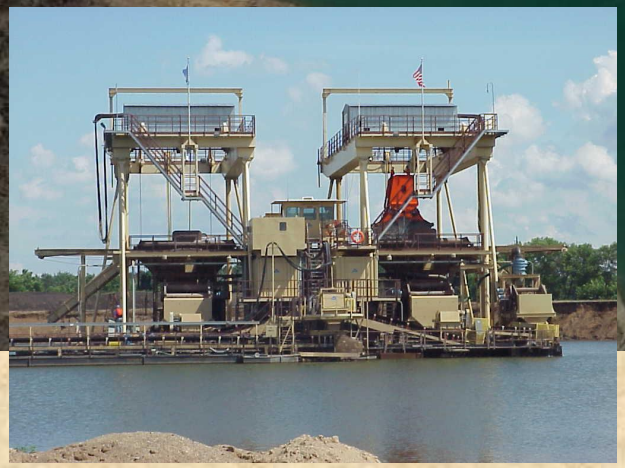
Sand and Gravel Mining – Below the water table

- Backhoe – material piled, processed, etc…
- Typically used in smaller S&G pits

AGGREGATE MINING

Sand and Gravel Mining – Below the Water Table

- Floating Dredge – Pipeline Slurry to Land
- Typical in moderately sized sand and gravel pits with fairly thick deposits



AGGREGATE MINING

Sand and Gravel Mining – Below the Water Table

- Floating Dredge to conveyer to stockpile
- Typical in larger S&G Pits – Thick Deposits

AGGREGATE MINING

Crushed Stone Mining

- Remove overburden – to expose the bedrock
- Used to construct berms to preserve topsoil and act as a screen – noise, dust, visual, safety

AGGREGATE MINING

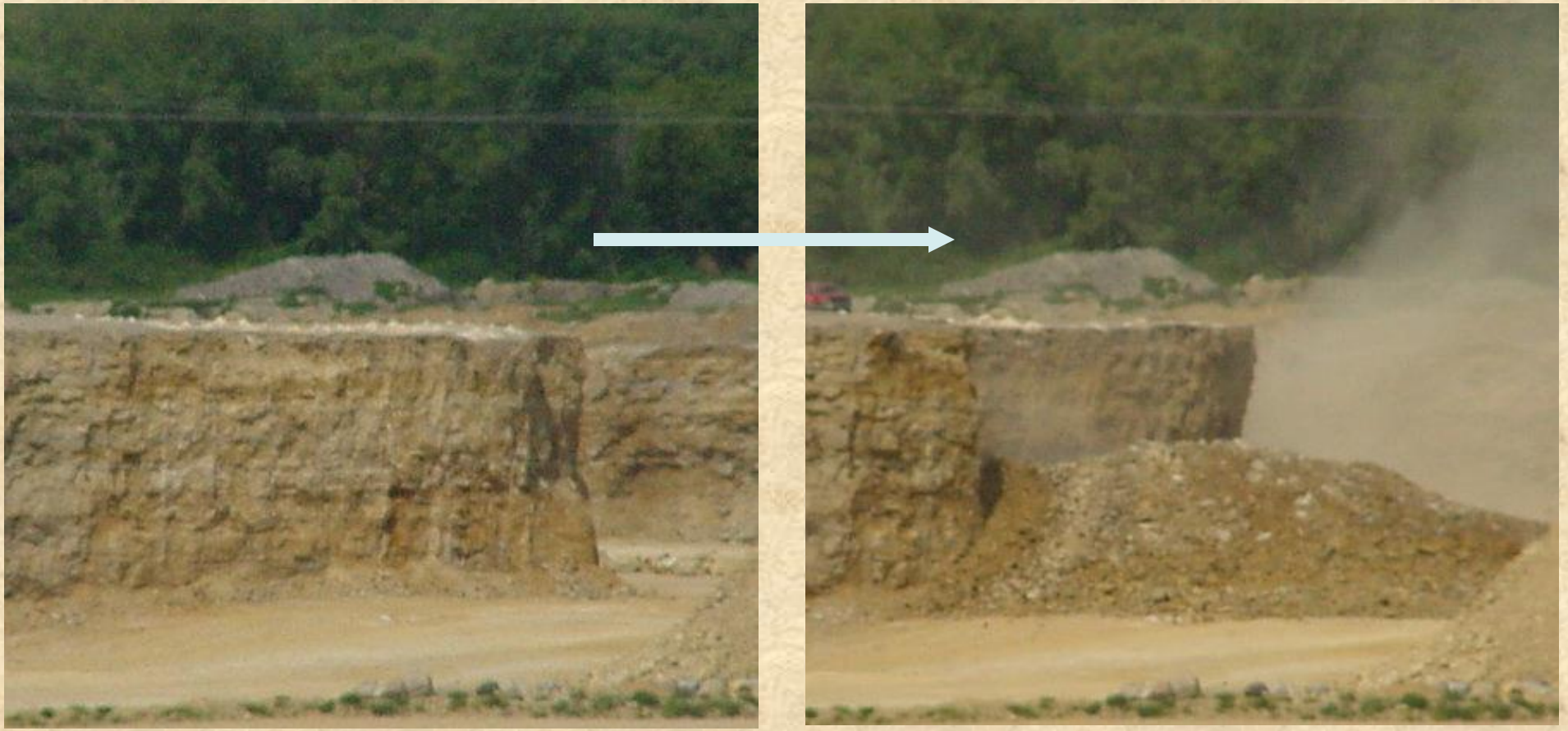
Crushed Stone Mining – Drilling

AGGREGATE MINING

Crushed Stone Mining - Blasting

BLASTING – FRAGEMENT ROCK

Pick it up, fragment it, set it down – minimize energy wasted - which minimizes noise, ground vibration, & flyrock - wasted energy



AGGREGATE MINING

Crushed Stone Mining – Mined in Benches

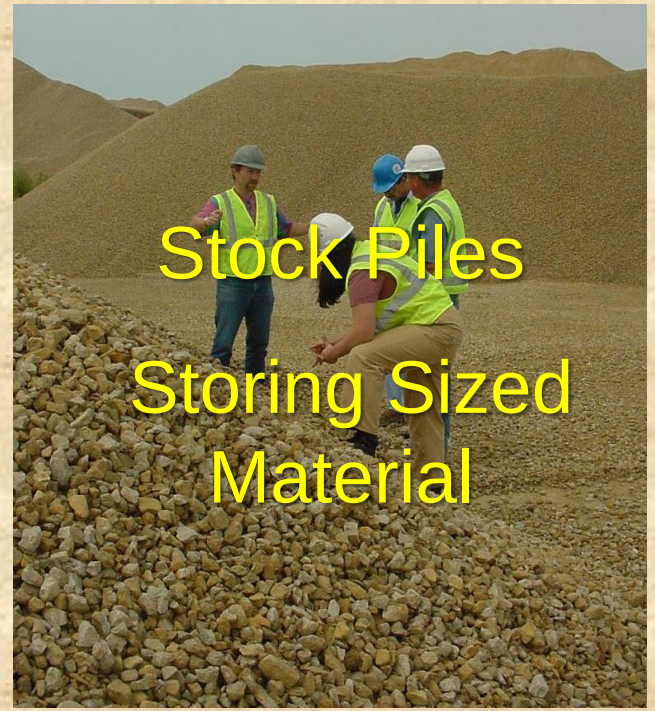

Chower Ave S
W Blackdog Rd
126th St
Cliff Rd W
Embassy Rd
Cliff Rd
35W
Dupont Ave S

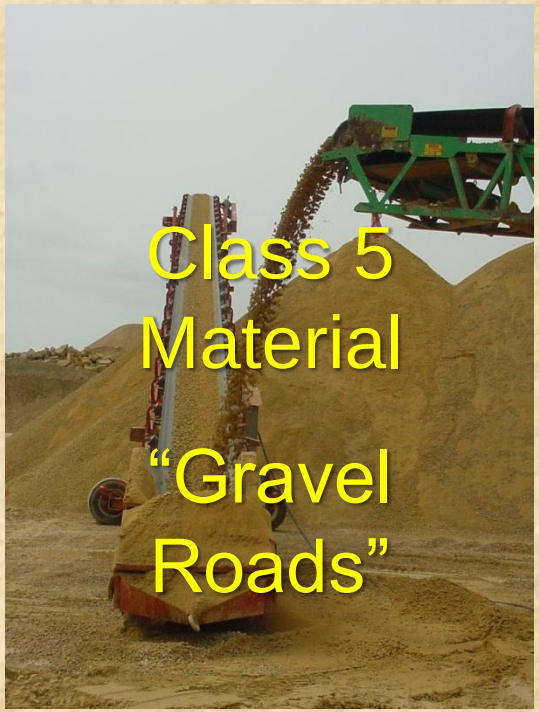
AGGREGATE MINING

Crushed Stone Mining-Crushing/Processing

AGGREGATE MINING

Crushed Stone Mining – Crushed Sizes





RECLAMATION

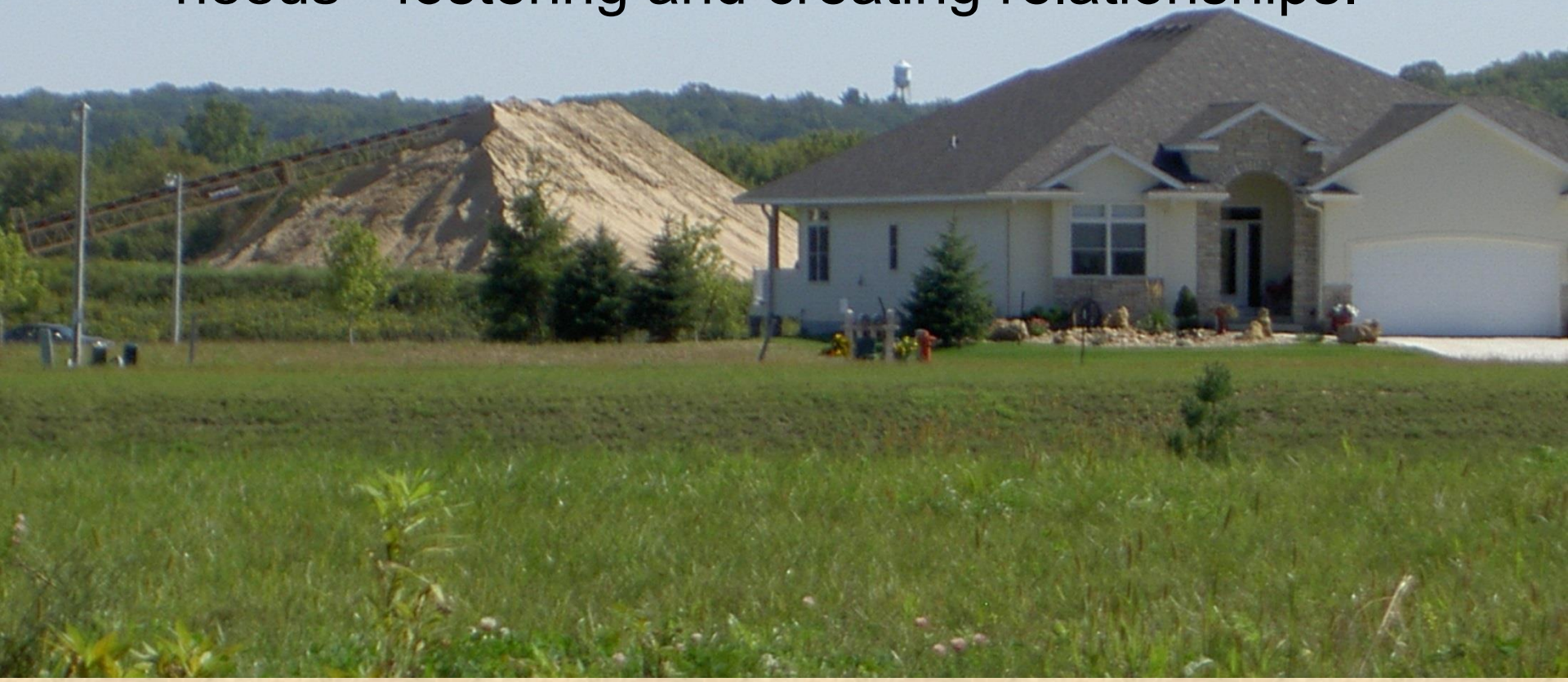
- Mine land reclamation, if done properly, returns the land to its original or better condition than the pre-mining condition
- Mine land reclamation is a social obligation of a mining company to the society

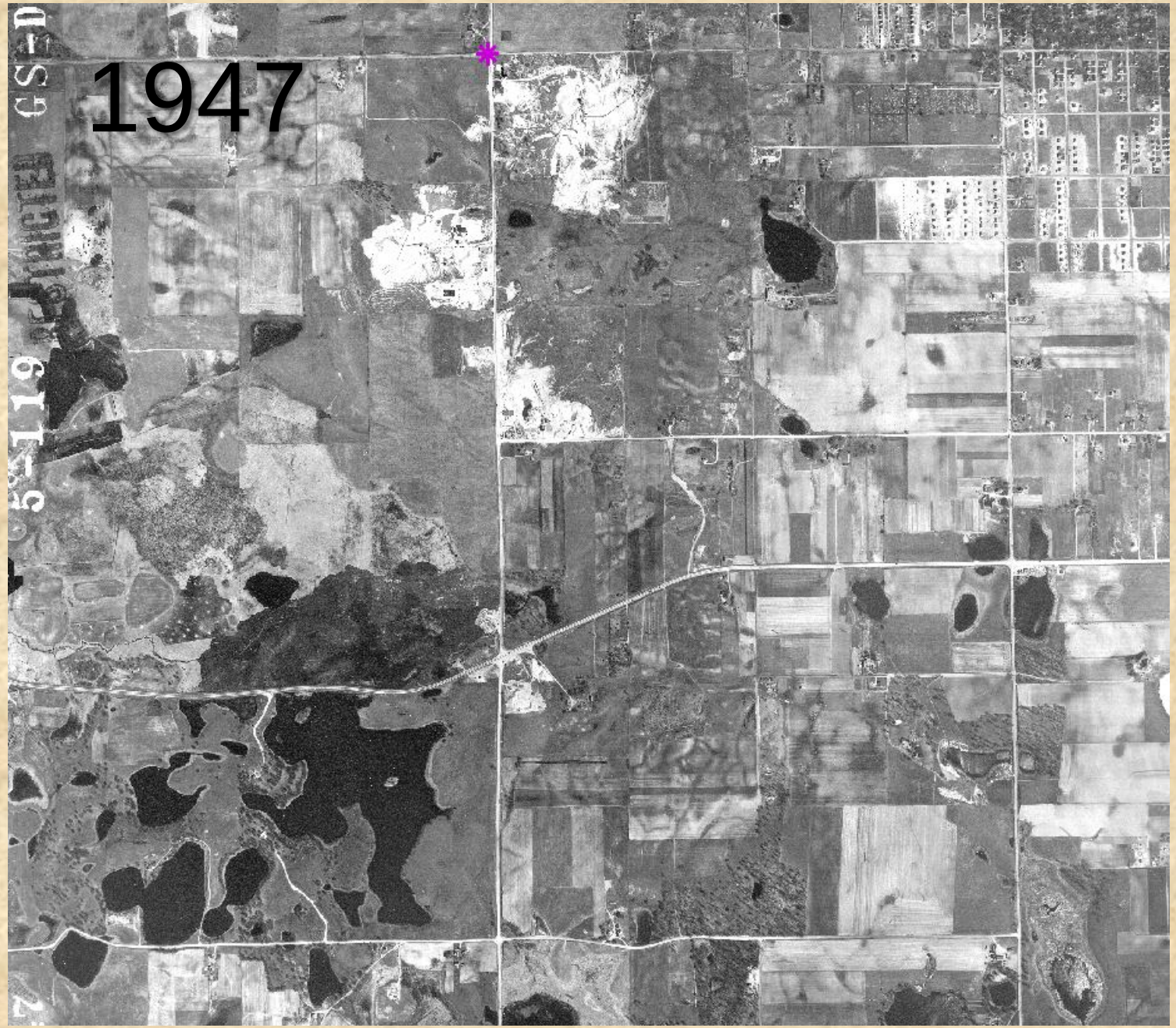
POST-MINE LAND-USE

- Mining gives land-use planners the opportunity to maximize the potential of the land and resources involved and create new opportunities for creative and beneficial solutions

“Mining is a Temporary Land-Use”

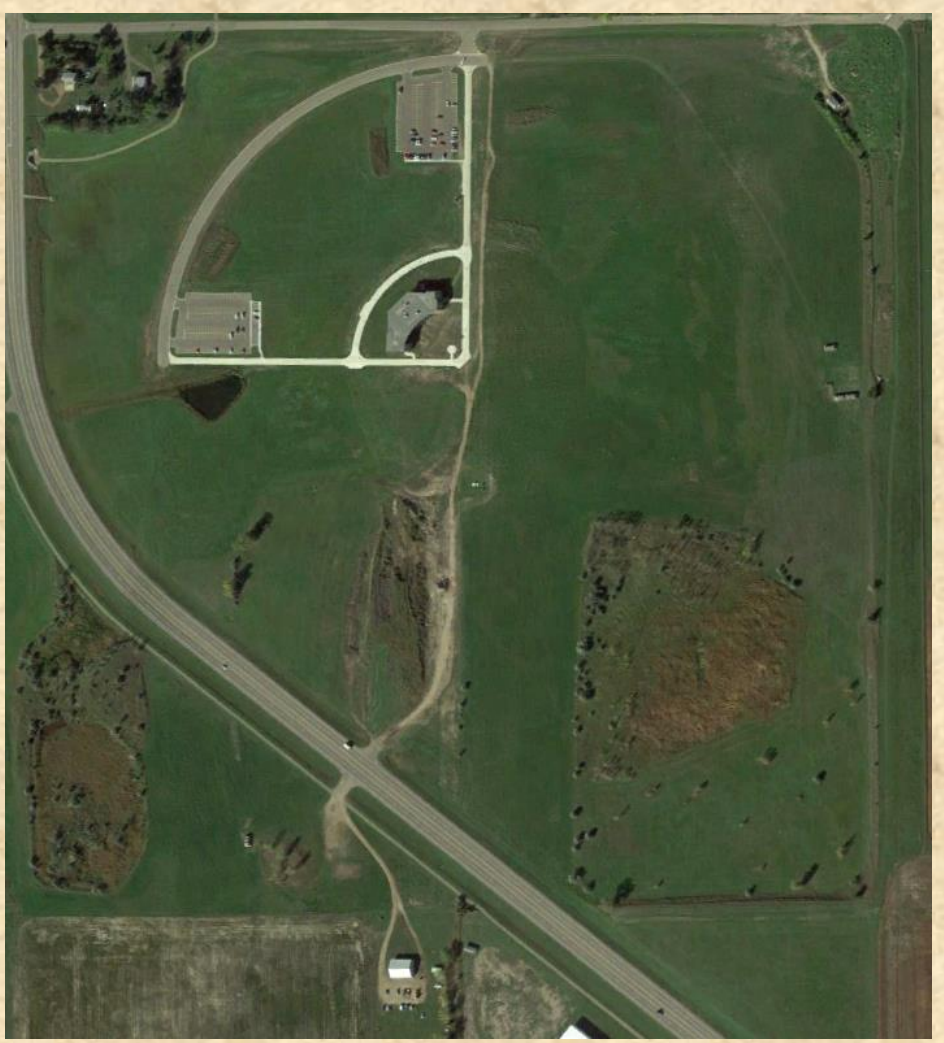
“Look at Mining as an opportunity to benefit all involved – economy, social, and environmental needs - fostering and creating relationships.”



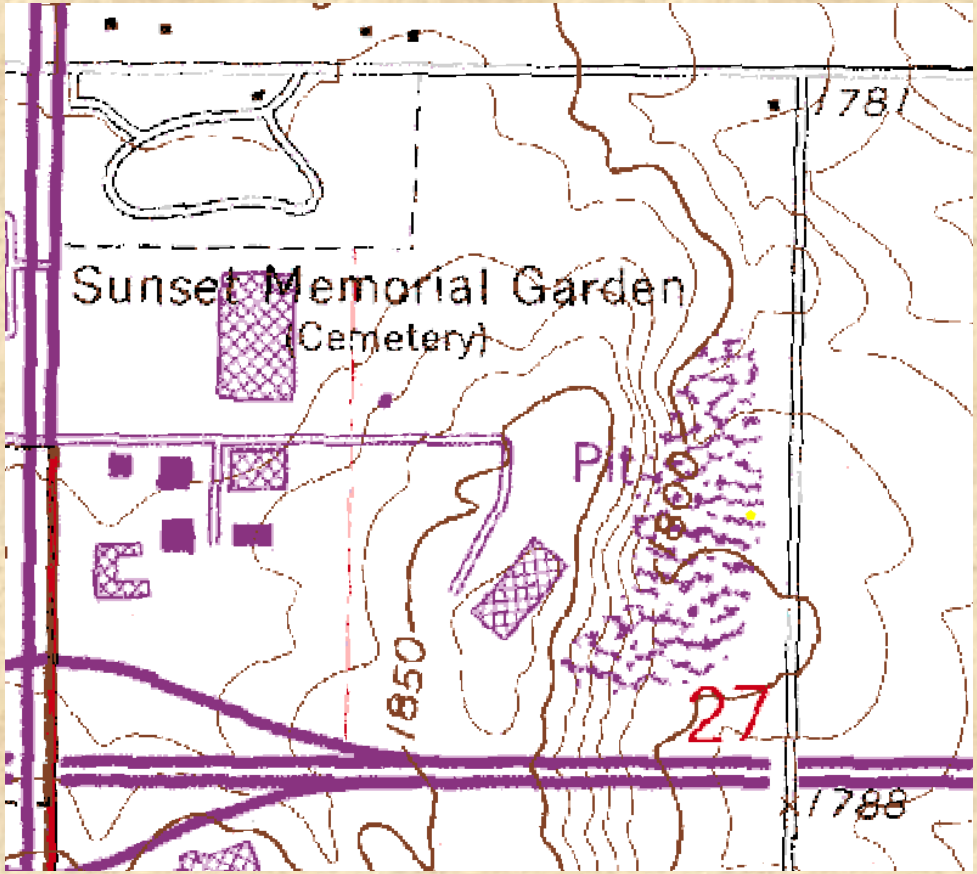

1947

Post-Mine Land-Use

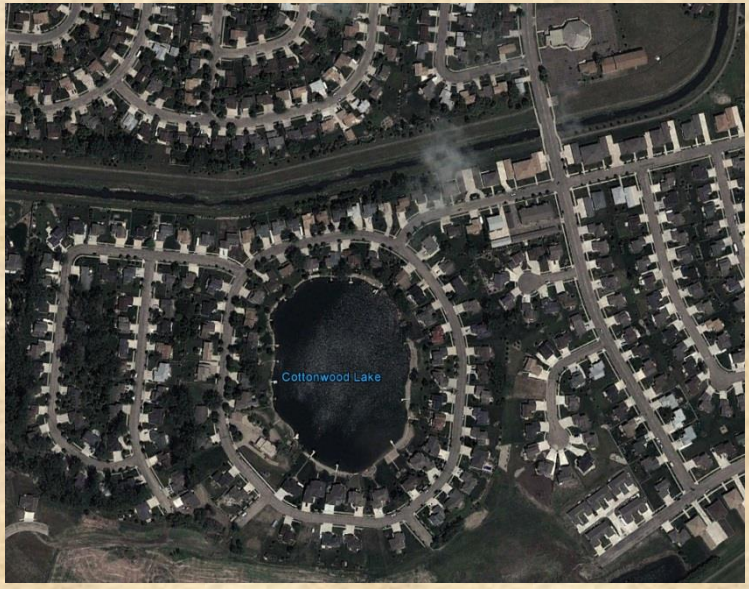
Post-Mine Land-Use



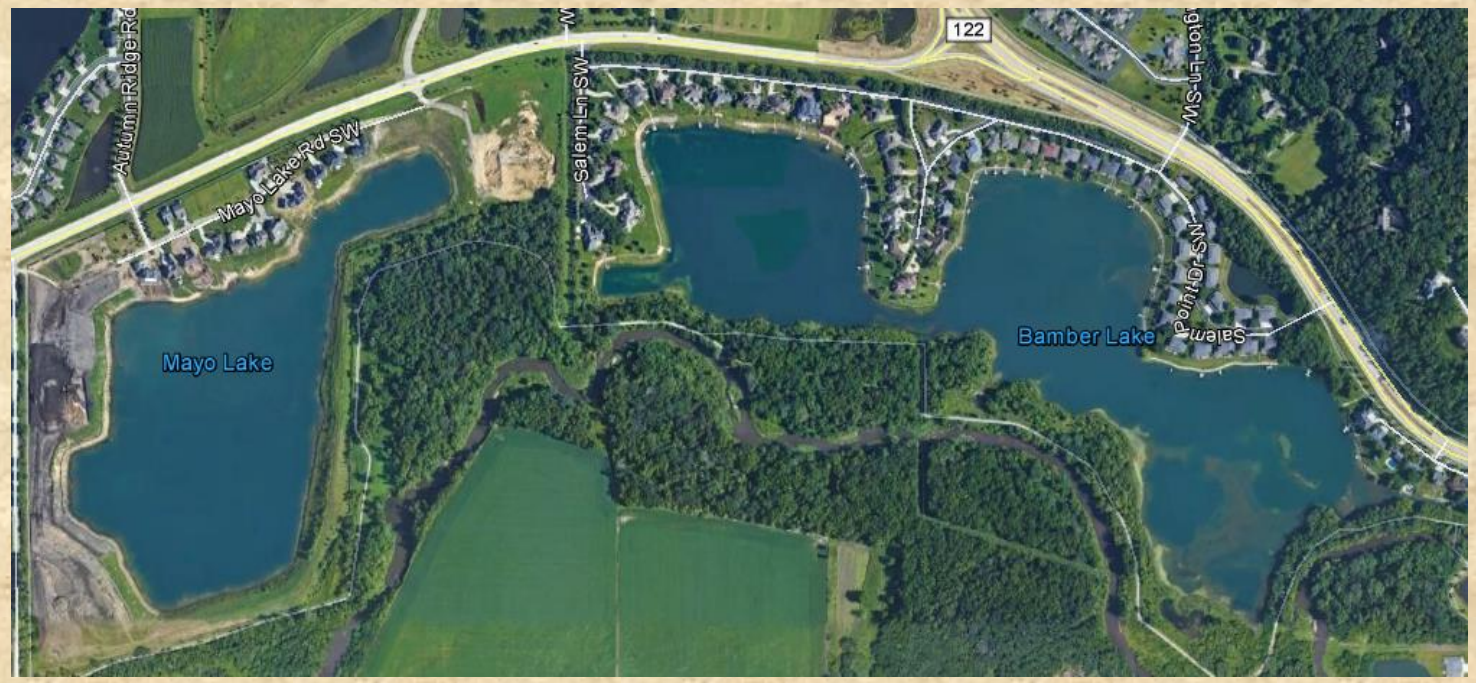
Post-Mine Land-Use



Post-Mine Land-Use




1991


122
Mayo Lake Rd SW
Salem Ln SW
Salem Ln SW
Salem Pointe Dr SW
Mayo Lake
Bamber Lake


FOSTER AREND
PARK
SWIMMING PICNICKING CANOEING

RECLAMATION


Roller Coaster,
Fiesta Texas

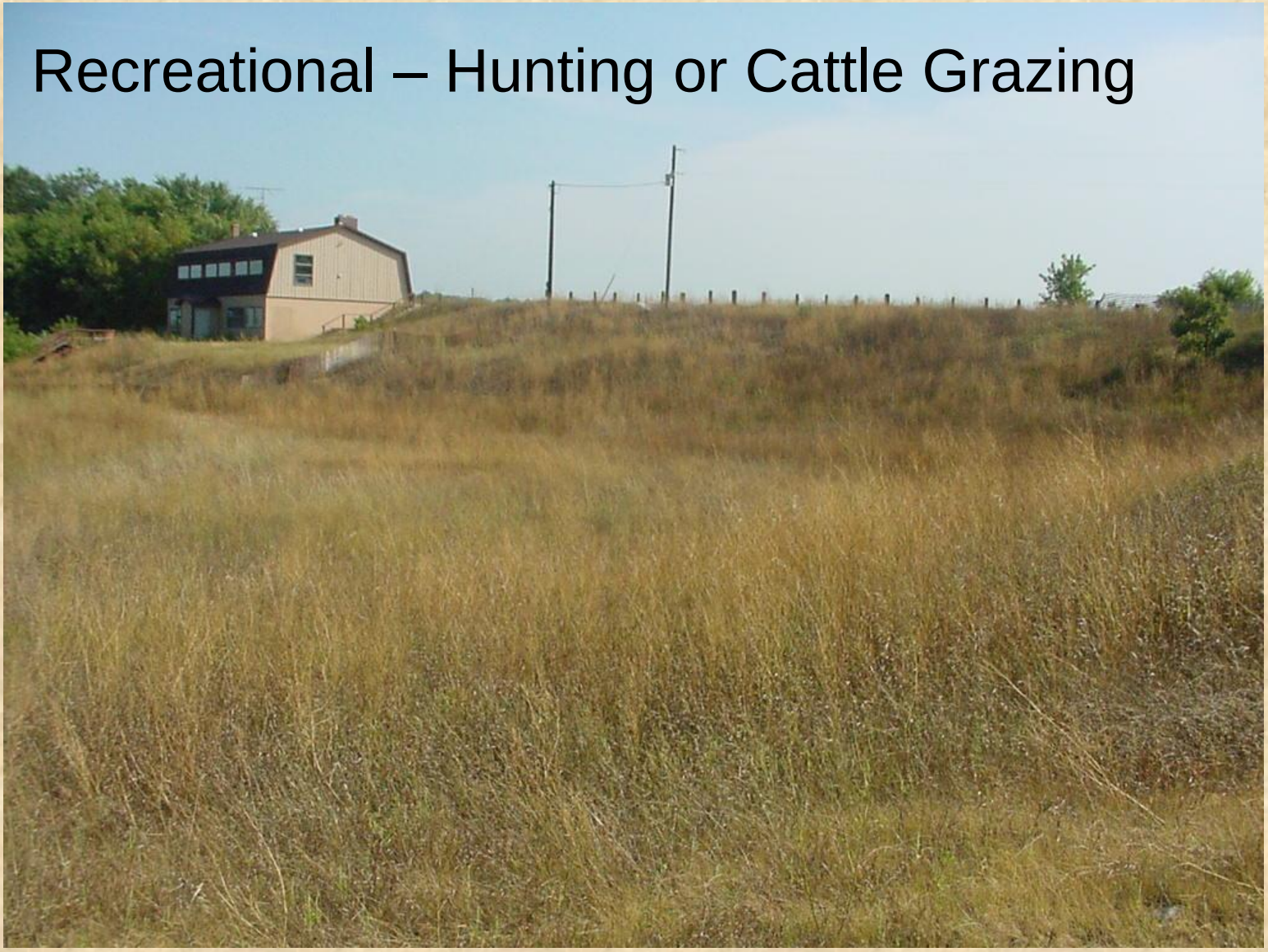
BEST MANAGEMENT PRACTICES (BMP)

- Sustainability considers the needs of the current and future generations!
- Using an Integrated Approach to Decision Making / Balanced Approach
  - Environment, Economic, and Social Issues
- “Mining gives land-use planners the opportunity to maximize the potential of the land and resources involved and create new opportunities for creative and beneficial solutions.”
- Mining = Opportunity to create beneficial solutions

RECLAMATION

RECLAMATION

RECLAMATION



RECLAMATION

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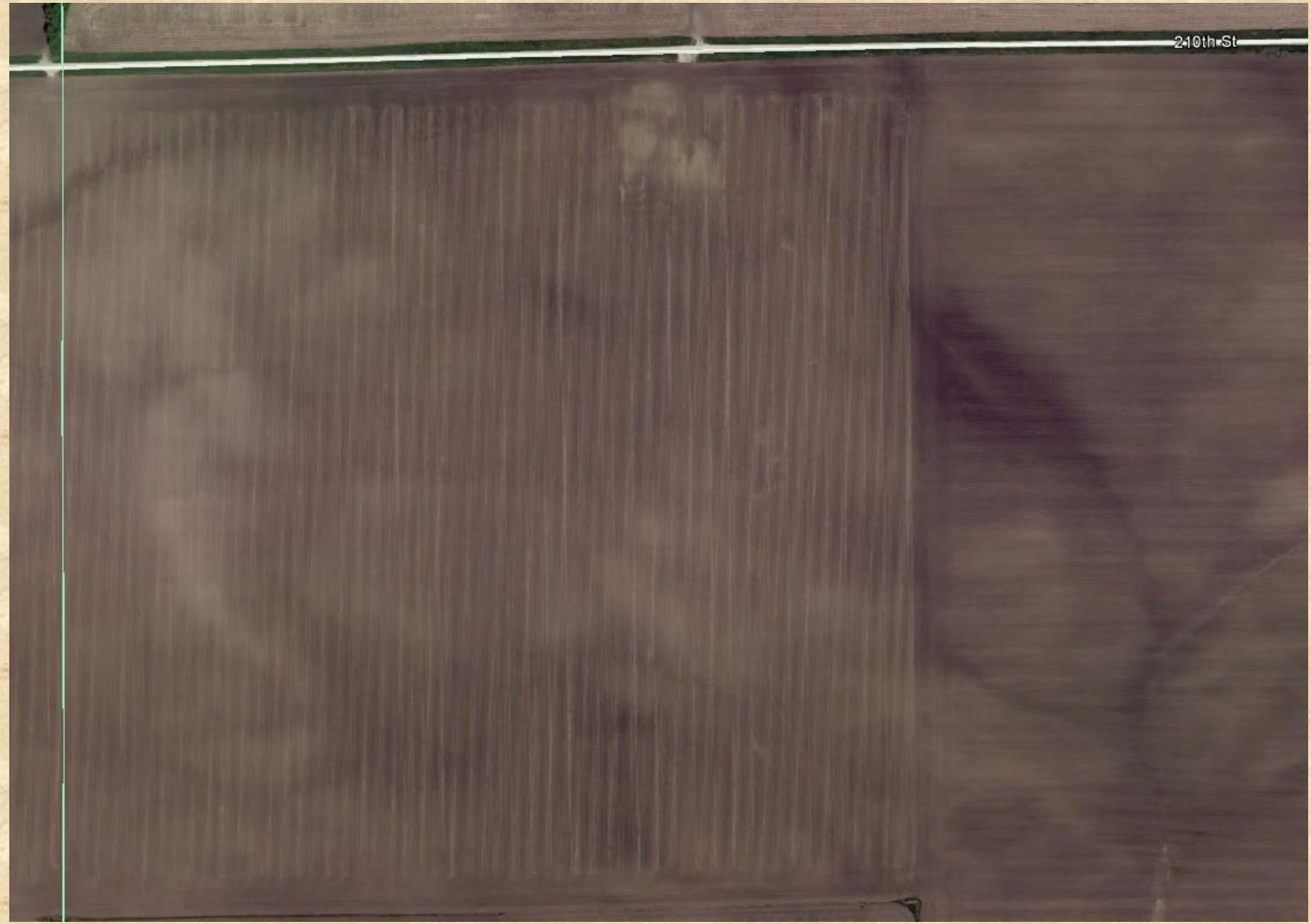
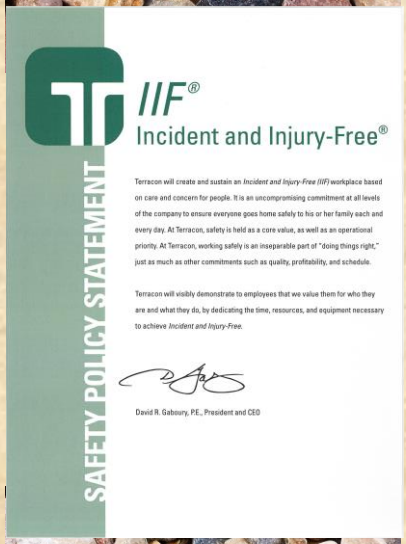
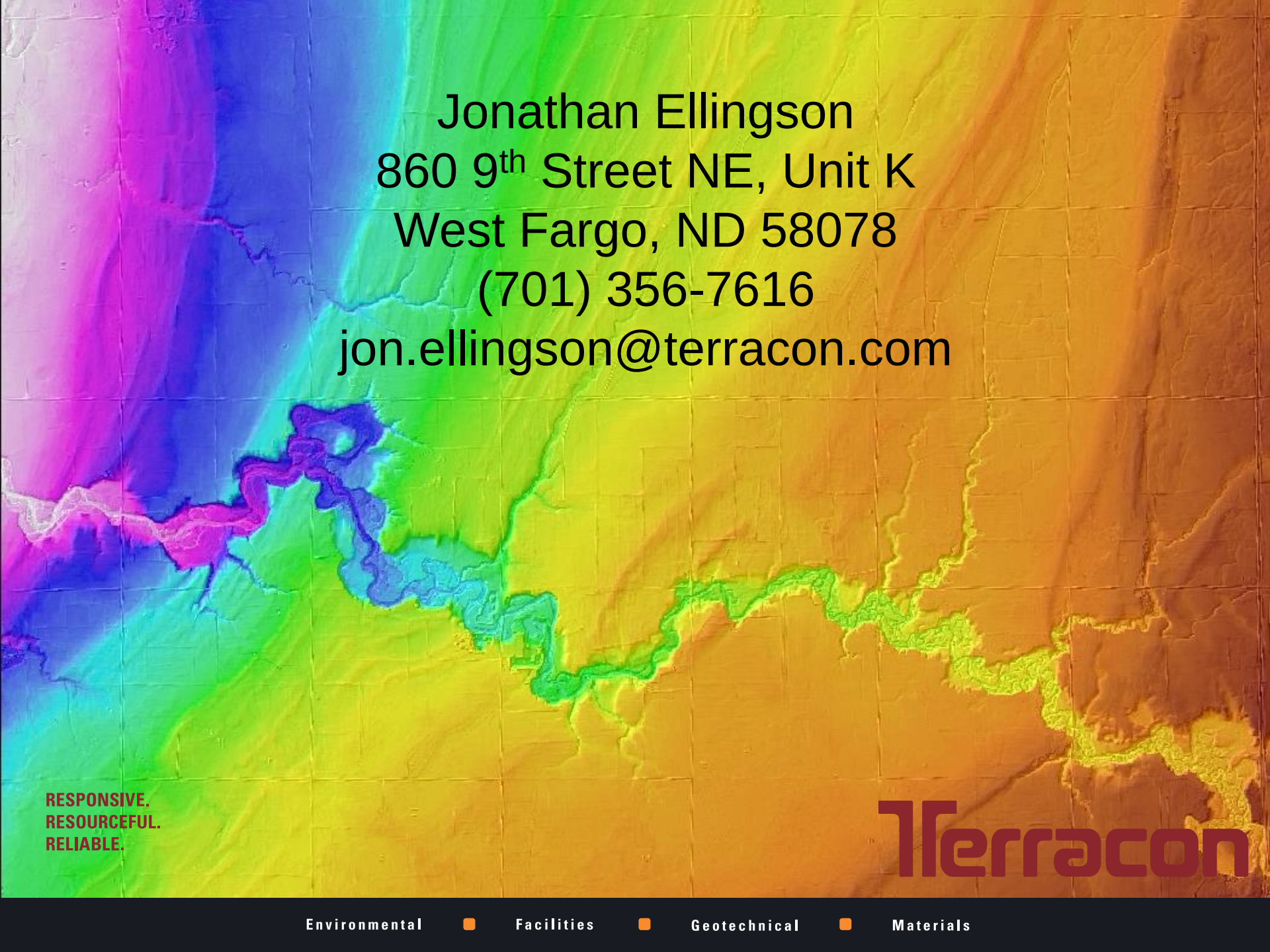

210th St

CONCLUSION / QUESTIONS



- Aggregate Resource Issues
  - Supply / Demand Issues - Increase Demand
  - Scarcity Areas – Increase Use of Alternates / Scoria
  - Quality Issues - Transportation, Erionite, GVL vs. CS
  - Increasing need for Aggregate Resource Mapping
  - Developing Aggregate Resources below Watertable
  - Planning / Partnerships - Sustainable Development
  - Reclamation / Post-Mine Use Success – Plan Early



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jon.ellingson@terracon.com

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