Conservation Applications of LiDAR Data

Workshops funded by the Minnesota Environment and Natural Resources Trust Fund

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Conservation Applications of LiDAR Data

Training Modules:

- Basics of Using LiDAR Data
- **Terrain Analysis**
- Hydrologic Applications
- Engineering Applications
- Wetland Mapping
- Forest and Ecological Applications

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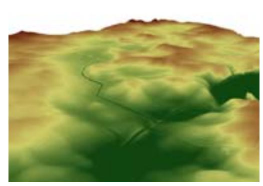
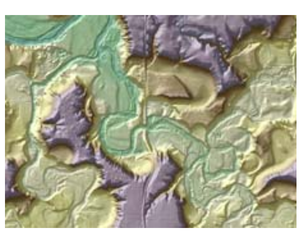
Terrain Analysis



Introduction

The Terrain Analysis Workshop is one of several modules designed to help take your understanding and utilization of LiDAR data to a new level. Specifically, this workshop will help you derive various calculations from a LiDAR DEM to help you better characterize the landscapes you're working in.

- Basics of LiDAR
- Hydrologic Applications
- Engineering
- Wetland Mapping
- Forest and Ecological
- Applications



Introductions - Logistics

Course Instructor – Joel Nelson

Workbooks

Breaks

Restrooms

Introductions – Student Intros

Students

- Who has calculated a terrain attribute?
- Who has done terrain analysis?
- What types of projects/activities are you looking to apply terrain analysis towards?

Course Objectives

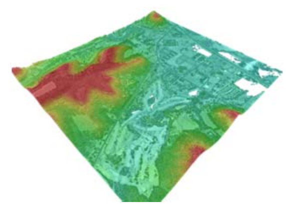
Lecture and Hands-on Format

- LiDAR DEM Data and Terrain Attributes
- Interpretation

Lecture 1: Terrain Analysis

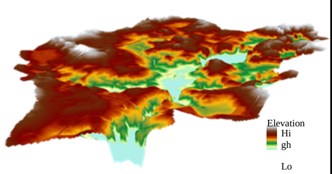
Review

- Raster Processing
- LiDAR products availability and download
- Visualization and Management



DEM Pre-Processing

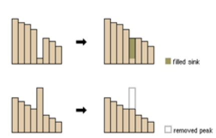
- "Pre-processing" used to describe techniques/tools used to prepare dataset for analysis
- LiDAR data changing this step
- A few Pre-processing Tools
  - Pit-filling
  - Filter
  - Hydrologic Conditioning

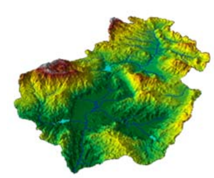


Pit Filling

Pit filling artificially draws base elevation levels in "sinks" or "peaks" to bank-height or surrounding elevation values

Usefulness/appropriateness depends on landscape and data





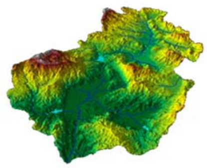
Pit Filling

Useful for:

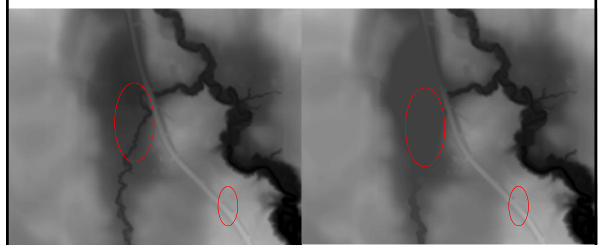
- Removing anomalies and erroneous values
- Closed depression landscapes
- Flood drainage scenarios – fill up water over depressions to force flow

Caveats:

- Data and drainage is being altered, made artificial
- Depicts accurate flow at flood stages or higher

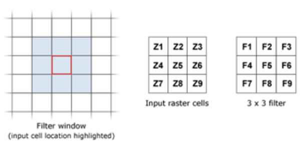


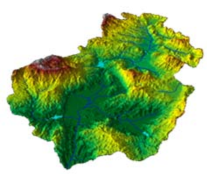
Pit Filling



Filter Analysis

- Low Pass Filter – This is a moving-window analysis that performs neighborhood averaging (9-cell basis)
- Low Pass smooths extremes, high-pass enhances them





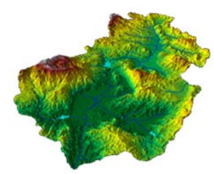
Filter Analysis

Useful for:

- Improving quality of DEM by eliminating spurious data
- Smoothing out local variations – providing more connectivity to results

Caveats:

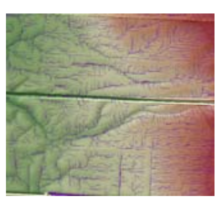
- Averaging out extremes which may be present
- "Dumbing-down" the data
- Not reducing actual resolution – but the appearance of resolution – "fuzzy effect"



Hydrologic Conditioning

Term used to describe any alteration to DEM that improves flow-thru/drainage

Several types, range from manual to fairly automated



Common processes:

- Stream burning – uses stream data to force drainage
- Bridge/obstruction removal involves manual editing, some processes working towards automated
- Hydrologic breaklines – optional/additional data used to identify water edge boundaries

Hydrologic Conditioning

Useful for:

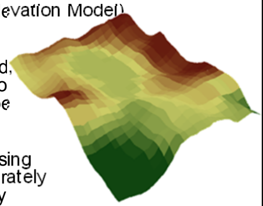
- More accurately modeling flow of water in a DEM
- Deriving more accurate

Caveats:

- Using streams or any other data with LiDAR requires data to be of the same resolution or spatial quality
- Flow/drainage often is dependent on scale

Terrain Analysis

- What is it? – many things
- Includes the use of a (Digital Elevation Model) DEM to model the landscape
- Provides a quantitative, detailed, objective, repeatable process to accurately model real landscape processes
- Coupled with GIS/Remote Sensing technologies, allows us to accurately characterize large areas quickly
- Helps to describe, analyze, and interpret any topographically-related feature – soils, vegetation, wildlife, etc.



Terrain Analysis – History

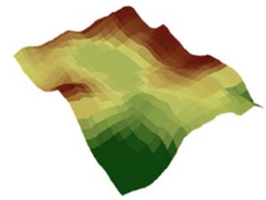
Concept has been in existence more than 20 years

Early pioneers include Wilson, Gallant, Moore, Gessler – "Terrain Analysis: Principles and Applications"

Early applications included:

- Soil Mapping
- Hydrologic Mapping
- Wildlife/Habitat Modeling

LiDAR creating renewed interest in terrain analysis



Terrain Analysis

Advantages -

- Coupled with GIS/Remote Sensing technologies, allows us to accurately characterize large areas quickly – days vs. months
- Quantitative, repeatable – non-subjective
- Helps to describe, analyze, and interpret any topographically-related feature – soils, vegetation, wildlife, etc.
- Results aren't numerical only – spatial
- Consistent with level of detail needed for conservation plans

Cost Benefits of Terrain Analysis Seven Mile Creek Watershed

Walking survey took 10 days and about 300 labor hours with 3 people

- Total cost = $9,500 or about $413/ditch mile

It is estimated that it would take ~10 years at a cost of ~$100,000 in labor to conduct the same survey for the rest of the County

Source: Brown Nicollet Cottonwood Water Quality Board

Courtesy of the Brown, Nicollet, Cottonwood Water Quality Board

Cost Benefits of Terrain Analysis

Pilot Study Watershed – Seven Mile Creek

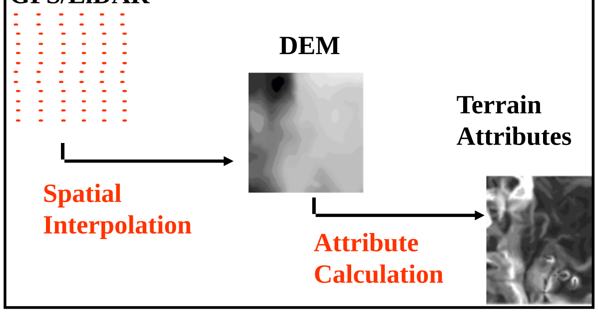
- LiDAR-based GIS survey was completed in a matter of hours
- A county-wide survey identifying most of the largest contributing areas could be done in a matter of weeks
- Terrain analysis requires far less time and resources than field-based surveys

Terrain Attributes

Divided into primary and secondary (compound) attributes.

- Primary attributes are calculated directly from the elevation data.
  - Examples: Aspect, slope, catchment area, profile curvature, etc.
- Secondary attributes involve combinations of primary attributes and are indices that describe the **spatial variability** of specific process occurring n the landscape such as the potential for sheet erosion (Moore et al., 1991).
  - Examples: Wetness index, Stream power index, etc.

Calculations Overview Example

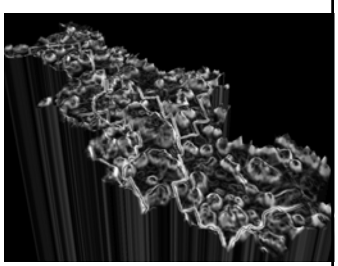


Aspect

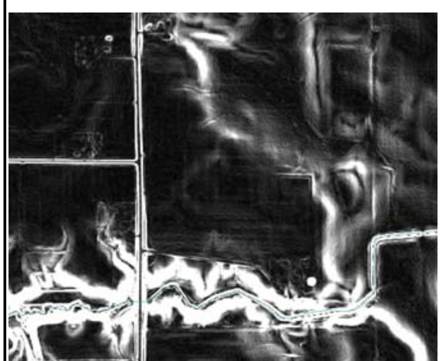
- Defines the cardinal direction (0 – 360 degrees) a surface is facing
- Uses - Fire management, soil moisture, evapotranspiration, flora and fauna distribution and abundance

Slope

- Describes overland and subsurface flow velocity and runoff rate.
- Slope quantifies the maximum rate of change in value from each cell to its neighbors.



Slope



Beauford Sub-Watershed

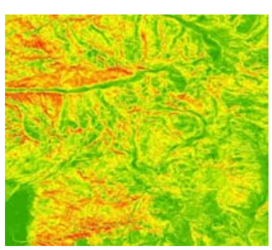
Blue Earth County Minnesota

High
Low

Slope

Use/Significance

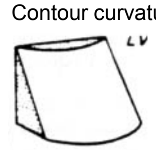
- Overland and subsurface flow
- Velocity and runoff rate
- Precipitation
- Vegetation
- Geomorphology
- Soil water content
- Land capability class

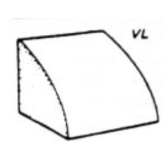


Curvature

- Plan Curvature: measured perpendicular to the direction of descent
- Describes converging/diverging flow
- Contour curvature

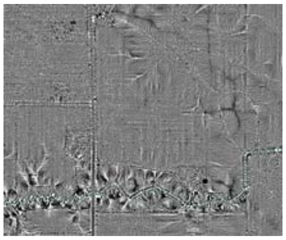
- Profile Curvature: measured in the direction of maximum descent or aspect direction.
- Measure of flow acceleration, erosion/deposition rate



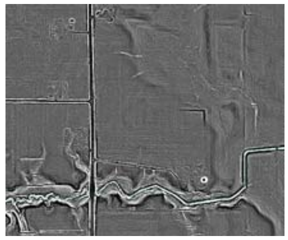


Curvature

Plan



Profile



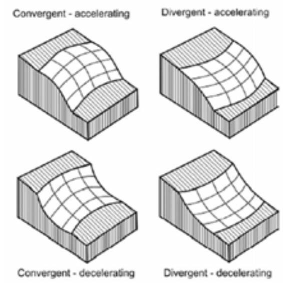
Concave

Convex

Curvature

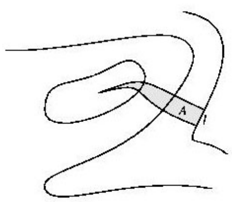
Use/Significance

- Plan Curvature
  - Converging/diverging flow
  - Soil water content
  - Soil characteristics
- Profile Curvature
  - Flow acceleration
  - erosion/deposition rate
  - geomorphology



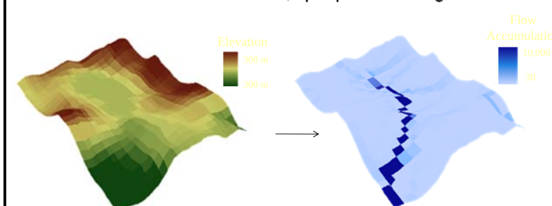
Catchment Area

- Measure of surface or shallow subsurface runoff at a given point on the landscape
- Combines the effects of upslope surface drainage area and convergence of runoff
- Also called flow accumulation



Terrain Attributes: Catchment Area or Flow Accumulation

- Primary attribute representing the drainage area of any given cell
- Indicates overland flow paths
- Also known as catchment area, upslope contributing area



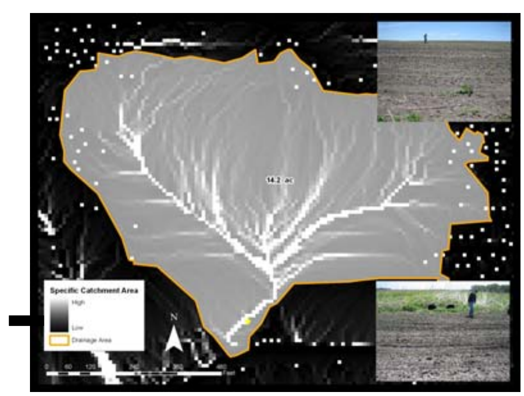
Catchment Area

Beauford Sub-Watershed

Blue Earth County Minnesota

High

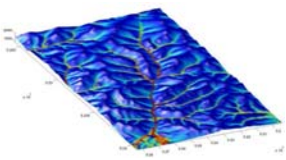
Low



Flow Accumulation

Use/Significance

- Runoff volume
- steady-state runoff rate
- soil characteristics
- soil-water content
- geomorphology



Secondary Terrain Attributes

Second derivative calculations (combinations of primary terrain attributes)

Compound Topographic Index - CTI

Stream Power Index - SPI

Secondary Terrain Attributes

Stream Power Index

SPI = ln (A * Slope)

Compound Topographic Index

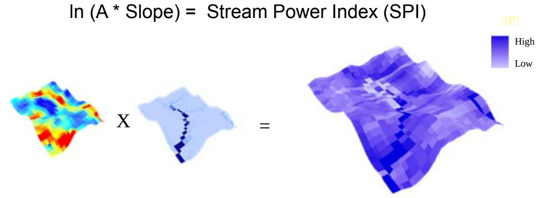
CTI = ln (A / Slope)

Where "A" = Flow Accumulation

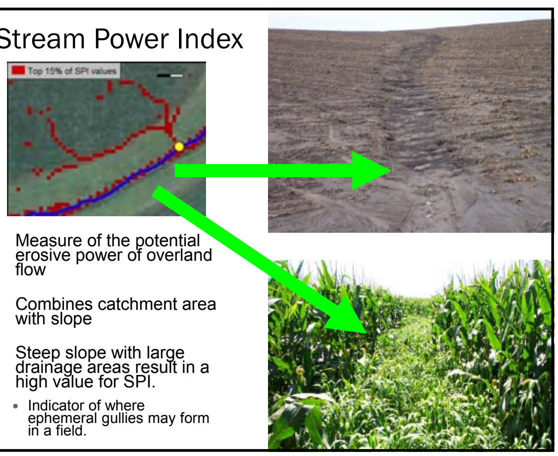
Terrain Attributes: Stream Power Index

- Secondary attribute: product of Slope and Flow Accumulation
- Quantifies the potential erosive power of overland flow
- Isolates areas with large catchments and steep slopes

ln (A * Slope) = Stream Power Index (SPI)



Stream Power Index



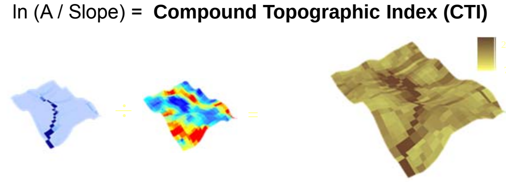
- Measure of the potential erosive power of overland flow
- Combines catchment area with slope
- Steep slope with large drainage areas result in a high value for SPI.
  - Indicator of where ephemeral gullies may form in a field.

Terrain Attributes: Compound Topographic Index

CTI = Ln (A / S)

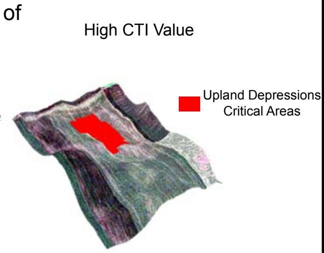
- Secondary attribute: divide flow accumulation by slope
- Also referred to as the "Steady State Wetness Index" or "Wetness Index"
- Identifies areas where water collects or ponds in a landscape

In (A / Slope) = **Compound Topographic Index (CTI)**



Compound Topographic Index (CTI)

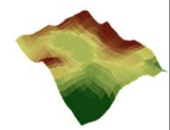
- Measure of the potential wetness in any portion of the landscape
- Combines catchment area with slope
- Low slope and/or large catchment equal high potential for water to collect
  - Indicator of potential wetlands, different soil types



Lecture 1: End Questions?

Lecture 2: Performing Terrain Analysis

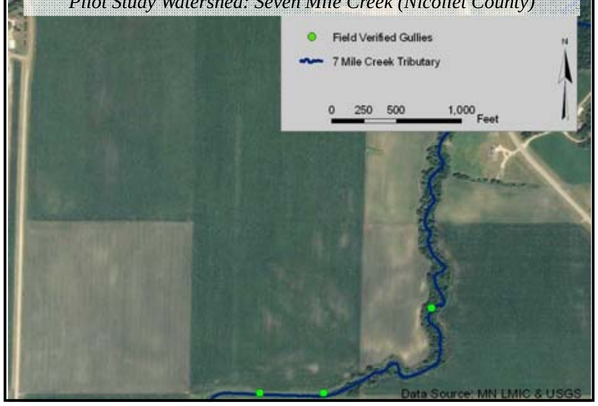
Performing Terrain Analysis - Principles

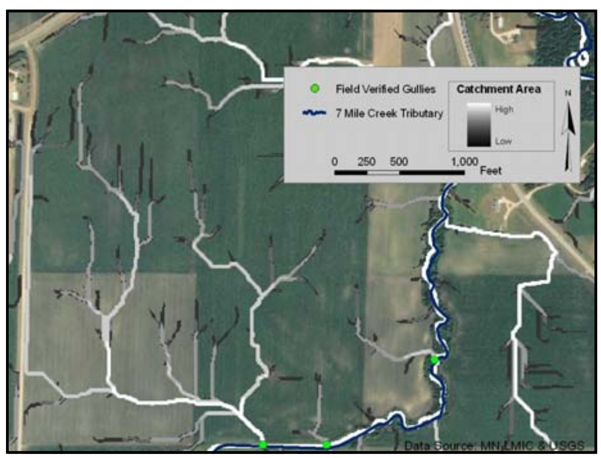


- Dependable method to quantify and describe the landscape
- Iterative process that builds on what's learned in previous steps
- Adaptable — dependent on landscape feature of interest
- Relative – Terrain attributes are indices
- Dynamic – Improvements to algorithms and software allow for solutions to previous problems and issues
  - Process that's followed, but not necessarily same each time it's performed
  - Always supplement terrain analysis with field-visits, ancillary data, or on-site knowledge useful

Example: Using Flow Accumulation to Identify Gullies

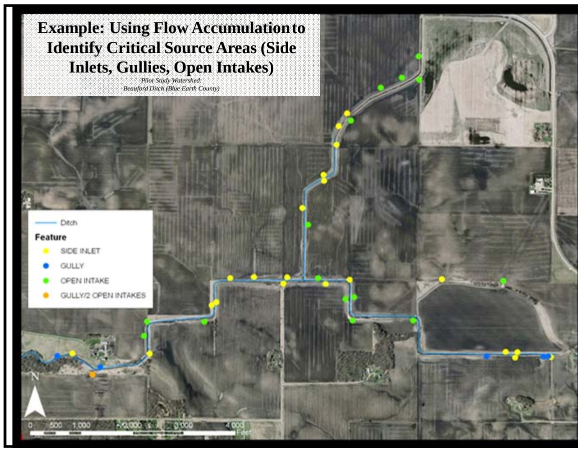
Pilot Study Watershed: Seven Mile Creek (Nicollet County)





Example: Using Flow Accumulation to Identify Critical Source Areas (Side Inlets, Gullies, Open Intakes)

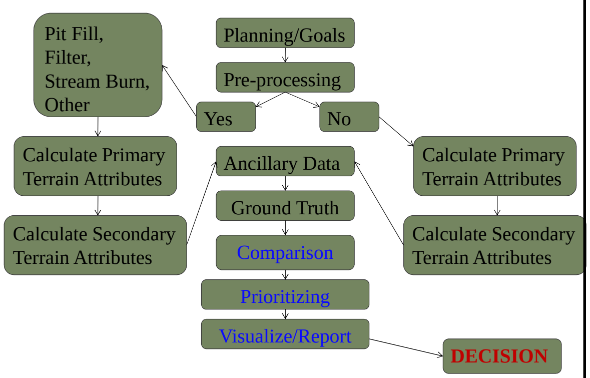
Pilot Study Watershed: Beauford Ditch (Blue Earth County)



Example: Using Flow Accumulation to Identify Critical Source Areas (Side Inlets, Gullies, Open Intakes)

Pilot Study Watershed: Beauford Ditch (Blue Earth County)

Process



Pre-planning - Strategies

Analysis goals? – Develop these first

- Pre-processing and progression of your calculations and may be different depending on:
  - Landscape
  - End Products – Flow network of watershed vs. specific erosion problem areas
  - Focus – Uplands, lowlands, both
  - In-house or Public – Presentation of terrain attributes can be complex

Courtesy of the Brown, Nicollet, Cottonwood Water Quality Board

Pre-planning - Strategies

Landscape – physiographic characteristics of the landscape modeled will influence decisions

High relief, dendritic natural drainage

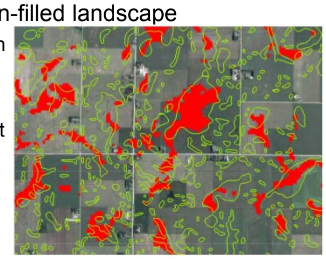
- flow networks are fairly contiguous
- pit filling can be appropriate (few natural pits in this landscape)

Pre-planning - Strategies

Landscape – physiographic characteristics of the landscape modeled will influence decisions

Low relief, depression-filled landscape

- Flow networks often irregular, local
- pit filling, stream burning can mimic flood stage flow, not typical conditions
- Run both filled and unfilled



Ancillary Data

Terrain Attributes alone based solely on topography

Utilize other information to help make better decisions

- Landuse Data
- Management Data
- Aerial Photography
- Existing Conservation Practices
- Distance to water

Ancillary Data – Aerial Photography

- Particularly useful
- In limited situations, can use to validate/verify ground conditions
- Higher quality orthophotos often flown with LiDAR data
- Can also clarify unexplained anomalies or uneven terrain
- Does not replace ground truth
- Is a dated product

Ground Truthing

Very necessary step to relate mapping to our planning goals

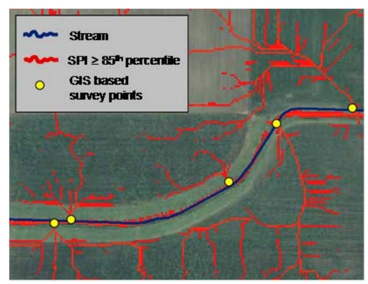
Important step in comparing terrain attribute threshold values to real-world conditions

Strategies

- Basic ground truthing overall – randomly select some areas to do exhaustive
- Windshield
- Detailed

Comparison

- Identify points where terrain attributes indicate area of interest
- Compare attribute values with ground truth data at same location



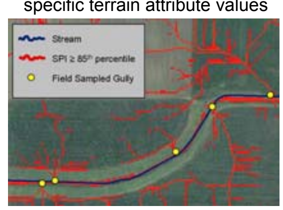
Comparison

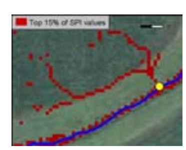
- Compare real-world features to terrain analysis identified features (i.e. gully, depression, etc.)
- Create table/matrix that identify errors
  - Type I Error – False Positive – Terrain Analysis indicated feature that wasn't there
  - Type II Error – False Negative - Terrain Analysis indicated no feature, but one existed

	Identified	Not Identified	Total Present
SDP 3 Gully	31	1	32
SDP 2 Gully	17	5	22
SDP 1 Gully	17	12	29
Total*	65	18 (Type II Error)	83
No Feature	43 (Type I Error)		

Prioritizing – Percentile Ranking

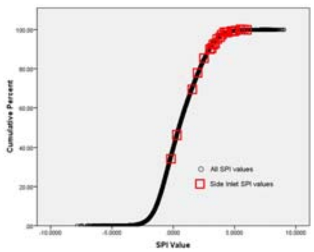
- Terrain attributes converted to percentiles and ranked
- Allows comparison amongst all values within a given area (watershed, county, etc.)
- Percentiles allow more uniform comparison than guessing random values
- Percentiles visually depict spatial distribution of upper X% of specific terrain attribute values





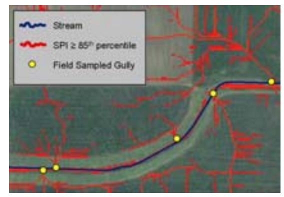
Prioritizing - Percentile Ranking

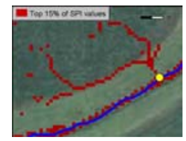
- Plot of all SPI values in watershed
- Side Inlet locations correspond to upper end values of SPI



Prioritizing - Percentile Ranking

- How-To
- First extract all individual cell records – export point
- Several Methods
  - Statistical Software Package
  - Excel 2007 – "percentile" command – very simple
    - Limited to a little over 1 million records – often more with LiDAR derived terrain attributes





Prioritizing

Big picture analysis – account for all that terrain analysis doesn't

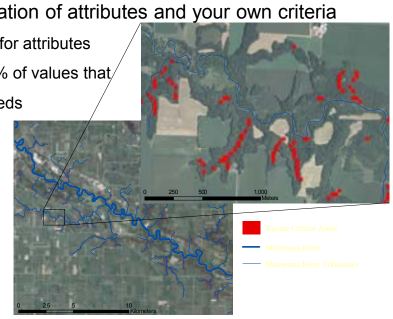
- Proximity to water
- Landscape position relative to ancillary data of interest
- Location within the watershed
- Costs
  - Survey
  - Remediation/Attenuation
  - Labor

Visualization

GIS – Terrain Analysis

Identify via combination of attributes and your own criteria

- Alter symbology for attributes
- Display upper X% of values that satisfy goals/needs



Terrain Analysis Caveats/Limitations

Same limitations as LiDAR data in general

- Cost
- File Size/Computing Power
- Expertise/Training

Does NOT

- Replace local knowledge
- Make fieldwork unnecessary/obsolete
- Transfer well to non-like landscapes when comparing values
- Treat man-made structures differently than "natural" ones

Terrain Analysis Caveats/Limitations

General GIS/Terrain Analysis

- Results are only as good as what you put into the analysis
  - Data
  - Assumptions
  - Effort
  - Ground Truthing/Error Checking
- Terrain Analysis pertains to surface flow only
- No automated or step-by-step process that's a one-size-fits-all terrain analysis

Questions?

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