

Depressional Wetland Mapping in the Prairie Pothole Region

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Outline

- Research Background
- Numerical Representation of Surface Depressions
- Graph Theory-based Contour Tree Method
- Application Example
- Conclusions

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Surface Depressions and Wetland Landscape

§ Anthropogenic processes

Detention basins



Mining



Reservoirs

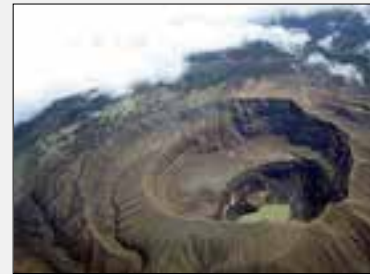


Quarrying



§ Natural processes

Volcanic craters



Vernal pools



Karst sinkholes



Prairie potholes



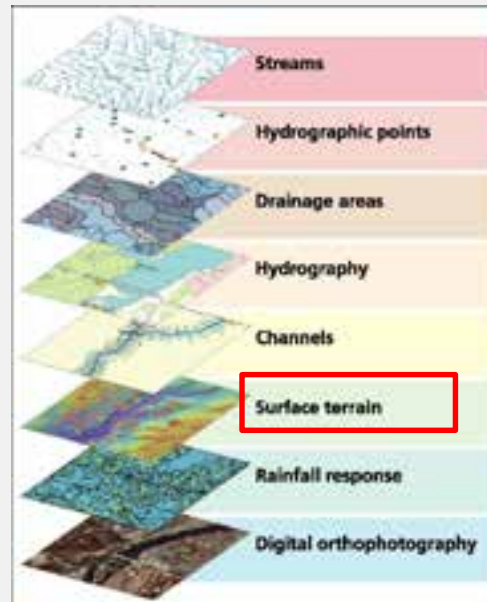
Surface Depressions in Hydrologic Modeling

The Water Cycle

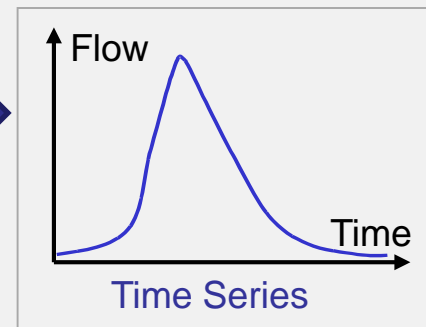


Source: U.S. EPA Office of Water

GIS data layers

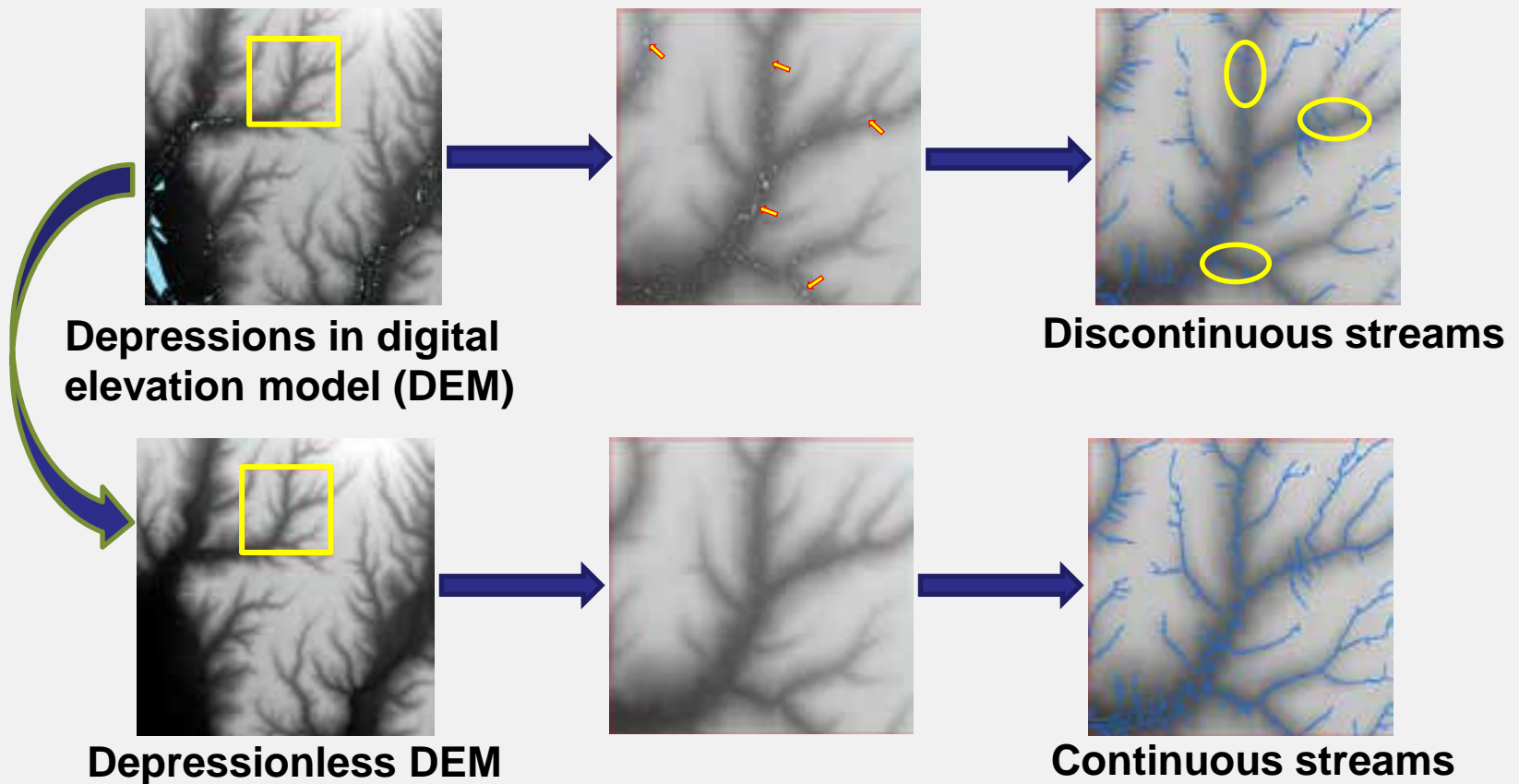


Floodplain mapping



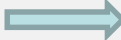
Hydrograph

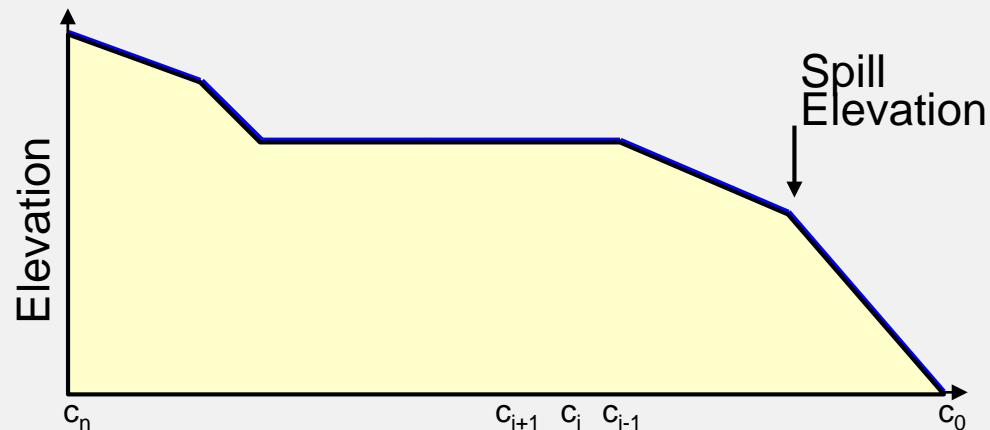
Surface Depressions as Analyses Problems



Methods for Surface Depression Filling

- Early method by [O'Callaghan and Mark \(1984\)](#)
- The most widely-used algorithm, by [Jenson and Domingue \(1988\)](#)
 - Ø ArcGIS, GRASS, TOPOZ, River Tools ...
- The priority-flood algorithm by [Wang and Liu \(2006\)](#)
 - Ø SAGA GIS, Whitebox GAT ...

Longitudinal profile 



Disadvantages of Traditional Methods

- Do not distinguish between real and artifact depressions
- Do not fully exploit high-resolution topographic data (LiDAR, IFSAR, etc.)
- Do not consider dynamic fill-and-spill hydrological processes
- Do not derive quantitative information about nested hierarchical structure

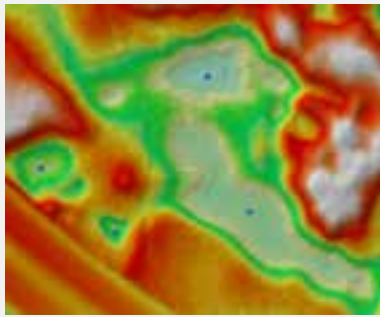
Vernal pools

Prairie potholes

1-m resolution LiDAR DEM



LiDAR DEM shaded relief



1-m resolution aerial imagery



1-m resolution aerial imagery



Outline

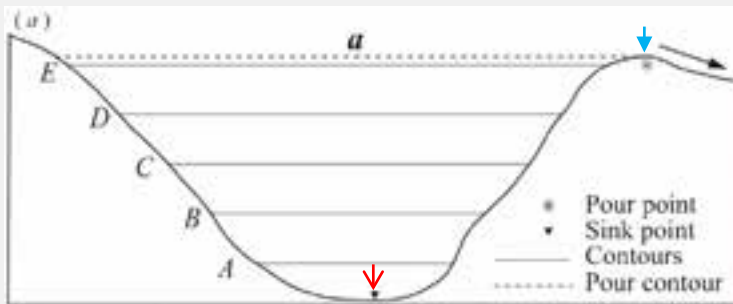
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Numerical Representation of Surface Depressions

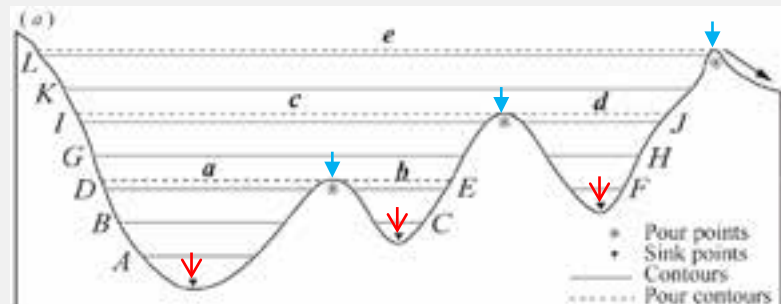
A simple surface depression

A compound surface depression

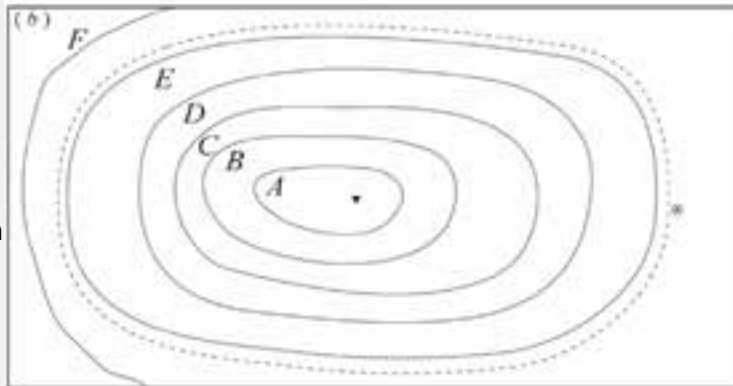
Longitudinal profile



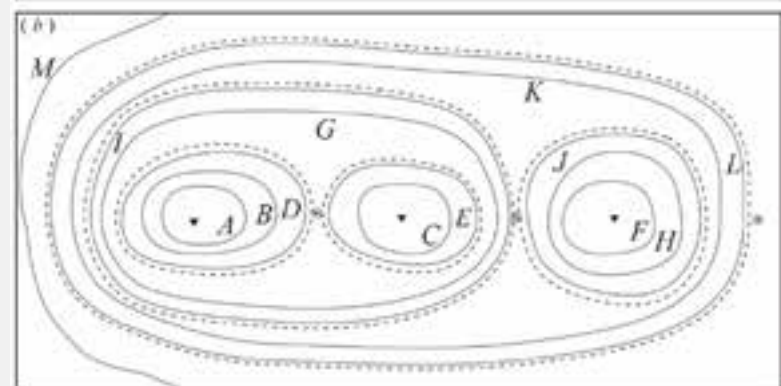
Longitudinal profile



Contour representation



Contour representation



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Graph Theory-based Contour Tree Method

§ Node

∅ Contour lines

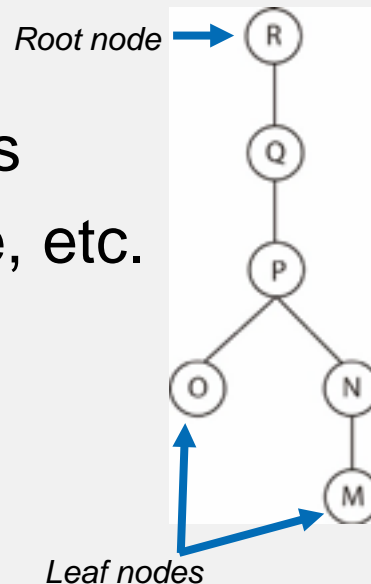
§ Link

∅ Adjacency
(topology)

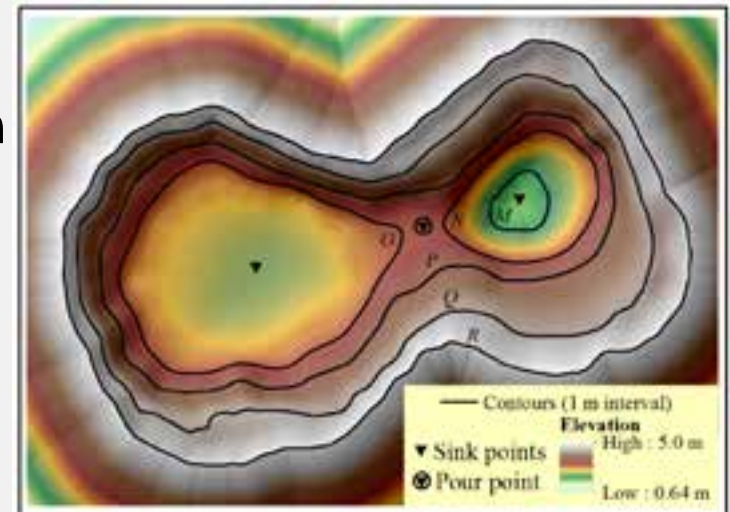
§ Node attributes

∅ Area, shape, etc.
(geometry)

Contour tree graph

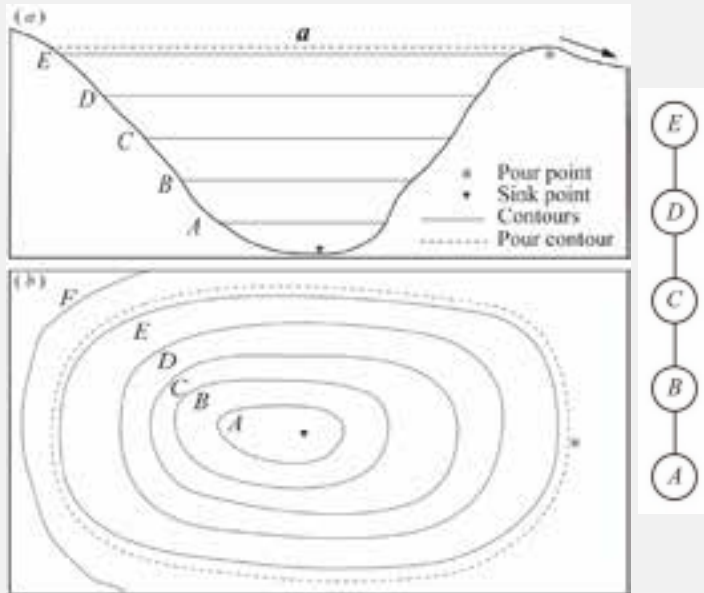


Plan view of contour representation

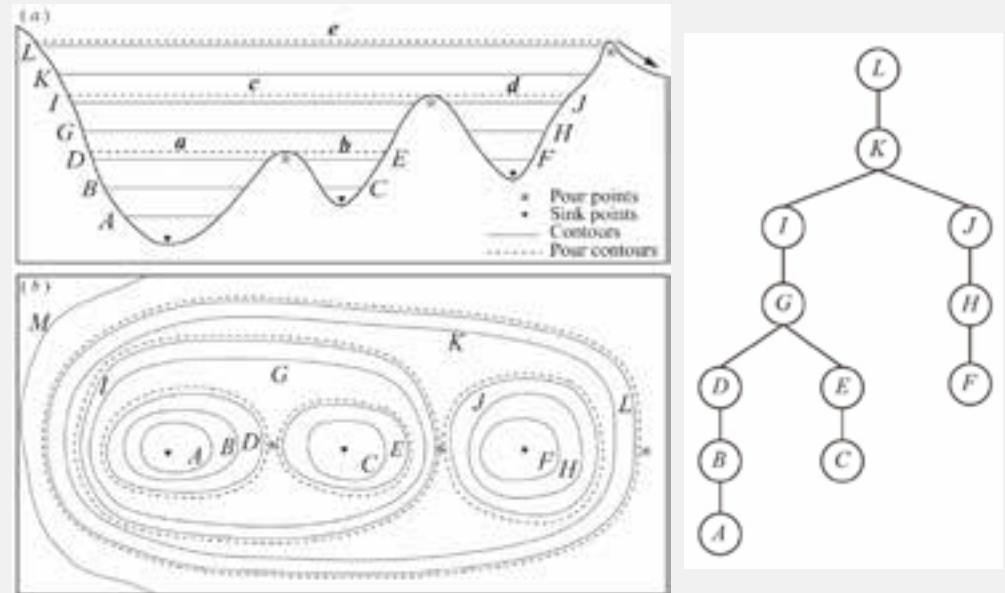


Contour Tree Representation of Depressions

A simple surface depression

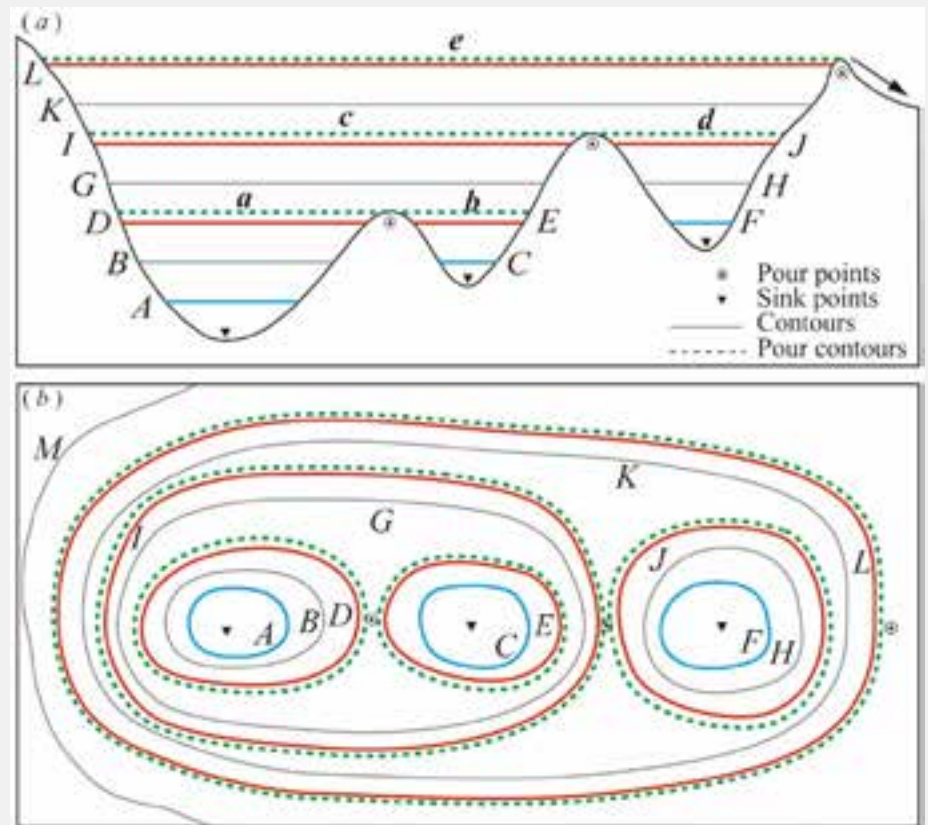


A composite surface depression



Key Concepts

- § Sink point
- § Pour point
- § **Seed contour**
- § **Pour contour**
- ∅ **Quasi-pour contour**
- ∅ **True-pour contour**



Simplification of Contour Trees

§ Single-branch contour tree

∅ Only root node left

§ Multi-branch contour tree

∅ Smaller compact tree

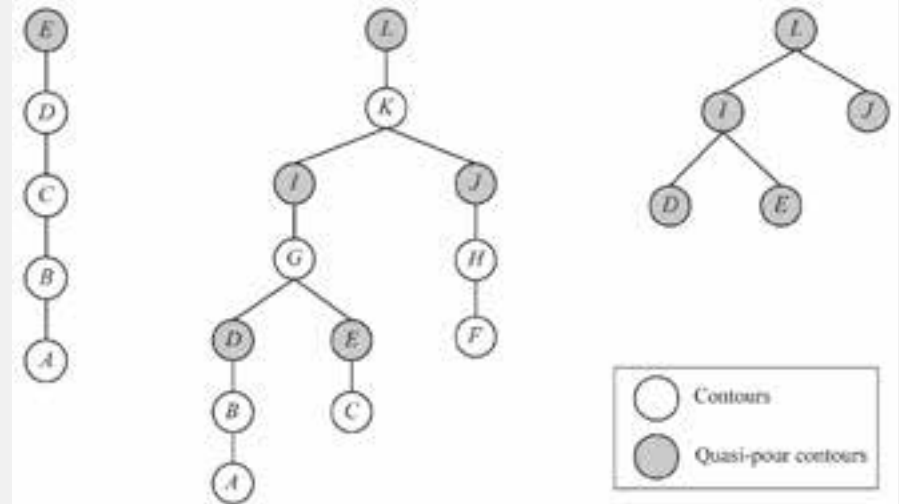
§ Simplified contour tree

∅ Depression tree

Single-branch
contour tree

Multi-branch
contour tree

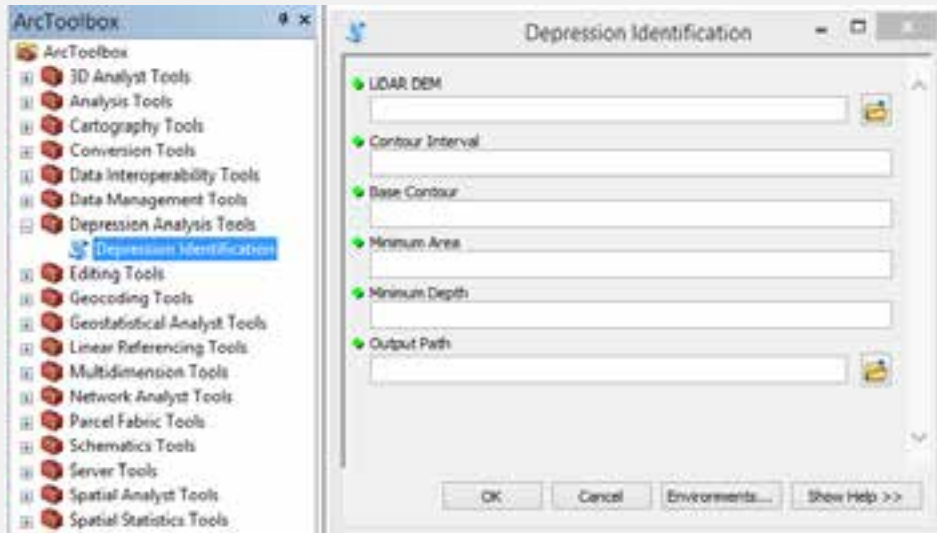
Simplified
contour tree



Computation Procedures and Pseudo Codes

- Implemented using C++, Python, and ArcGIS
- Fully automated

ArcToolbox



Pseudo codes

(a)	(b)
<pre> Function Identf(QuasiPairContour LBQ ← SEED level ← 1 condition ← true While condition While LBQ is not empty s ← LBQ.top() LBQ.pop(s) While s.OUIN ≠ -1 and s.CE < s.OCE: r ← CONTOUR(s.OUIN) If s.NBR = 1 Then x ← r End If End While UBQ.push(s) End While If UBQ.size > 0 Then QPOUR.add(level, UBQ) level ← level + 1 While UBQ is not empty s ← UBQ.top() UBQ.pop(s) If s.OUIN ≠ -1 and s.CE < s.OCE: r ← CONTOUR(s.OUIN) If s.NBR > 1 and FLAG[r] = false LBQ.push(s) FLAG[r] ← true Else condition ← false End If End While End Function </pre>	<pre> Function Identf(TruPairContour D = contour interval W = contour elevation difference For level = 1 to max(level) LBQ ← QPOUR[level] For each quasi pair contour (s) in LBQ low ← s.CE high ← s.CE + D While (high - low < W) mid ← (low + high) / 2 If contour(mid) is closed and only encloses contour(s) Then low ← mid Else If contour(mid) is open high ← mid End If End While If contour(high) is closed contour Then UBQ.push(high) Else If contour(mid) is closed contour Then UBQ.push(mid) Else If contour(low) is closed contour Then UBQ.push(low) End If End For TPOUR.add(level, UBQ) End For End Function </pre>

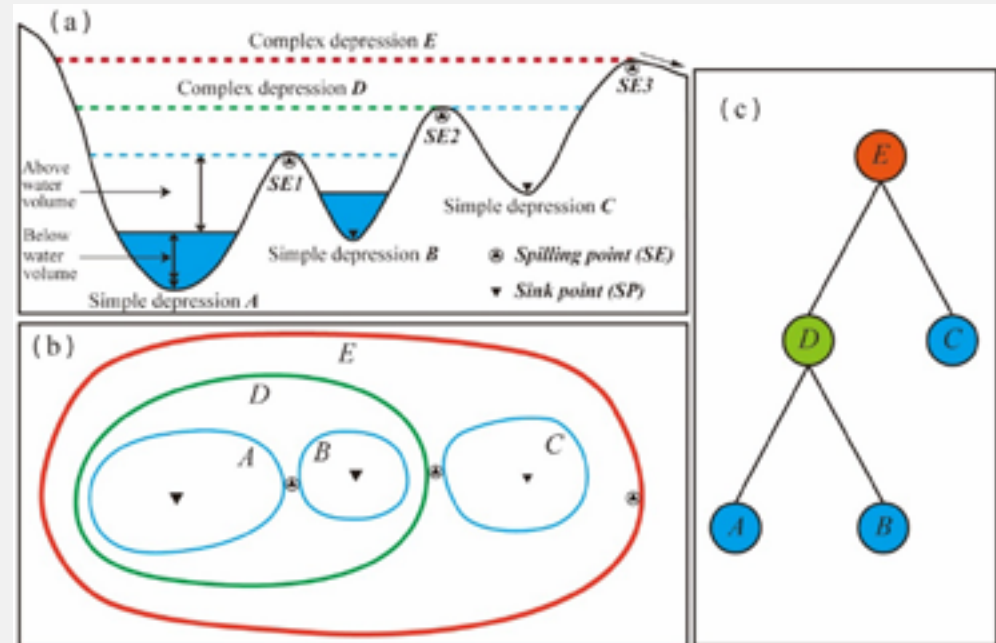
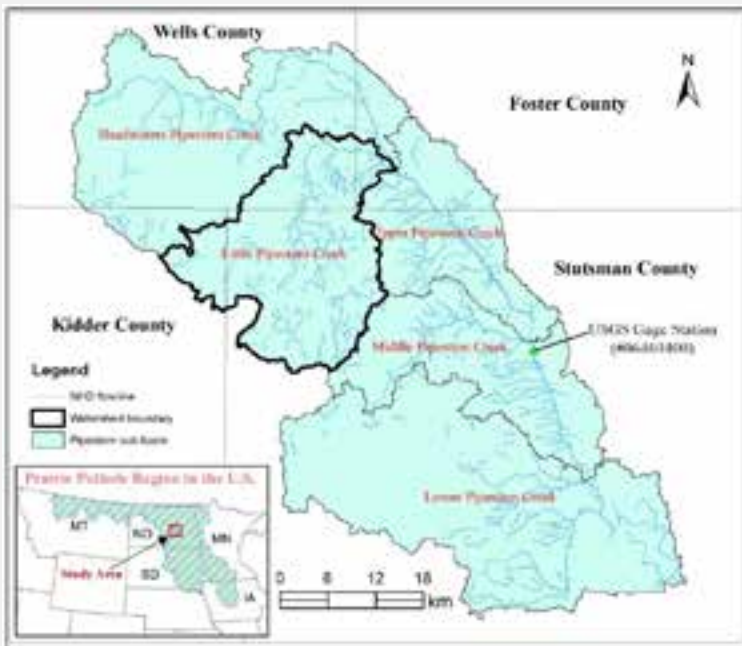
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Application Example

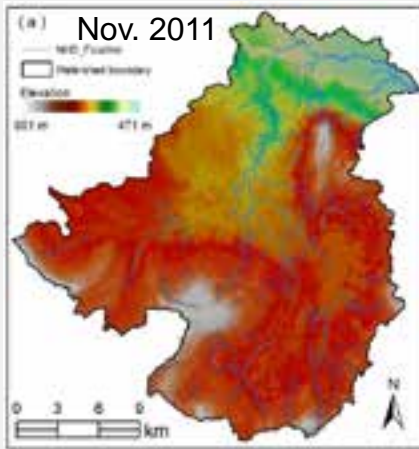
Pipestem Watershed, North Dakota

Estimation of depression storage capability

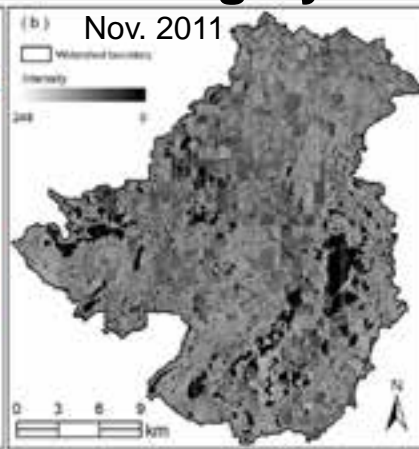


Hydrologic Connectivity of Prairie Potholes

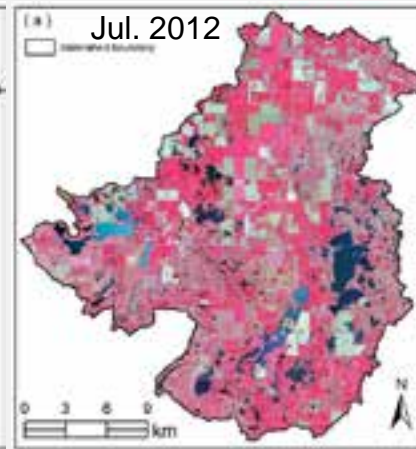
**LiDAR DEM
shaded relief**



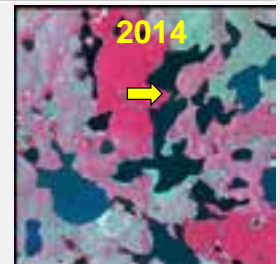
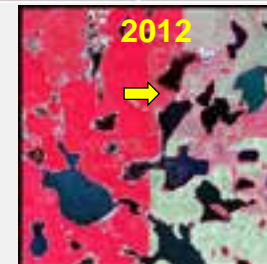
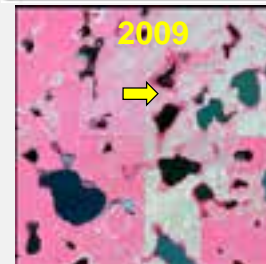
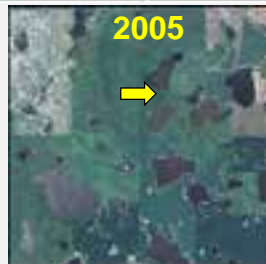
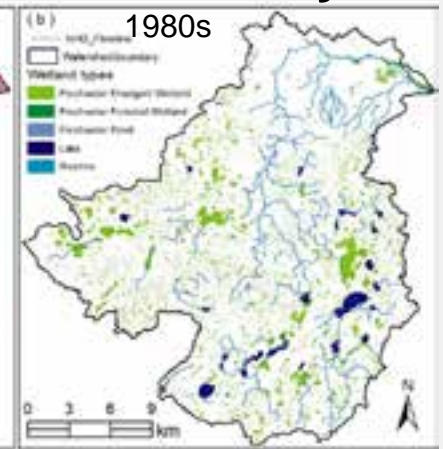
**LiDAR intensity
imagery**



**Aerial
photographs**



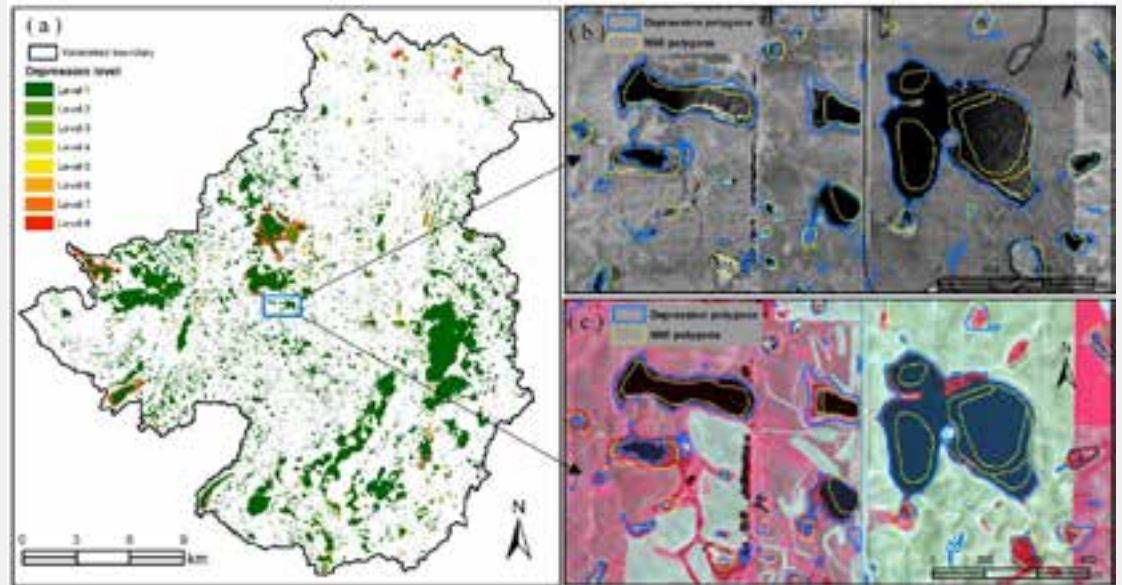
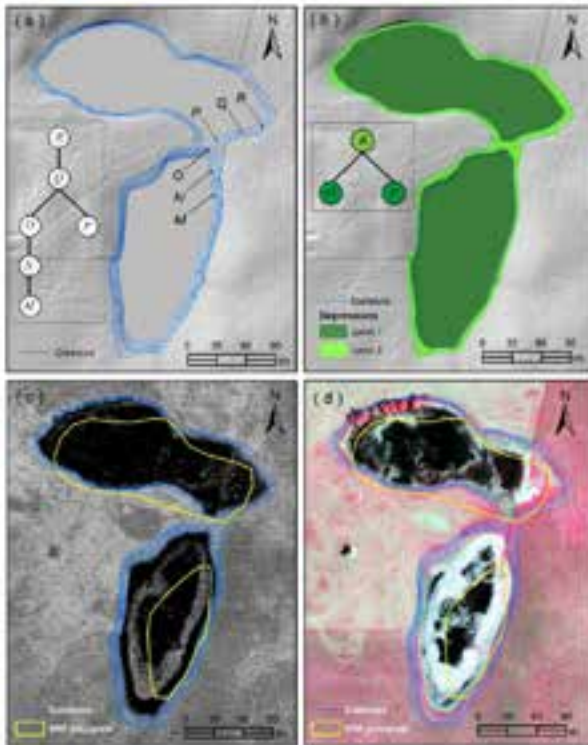
**National Wetlands
Inventory**



Identification of Surface Depressions

Contour tree method

Detected depression polygons vs. National Wetlands Inventory polygons



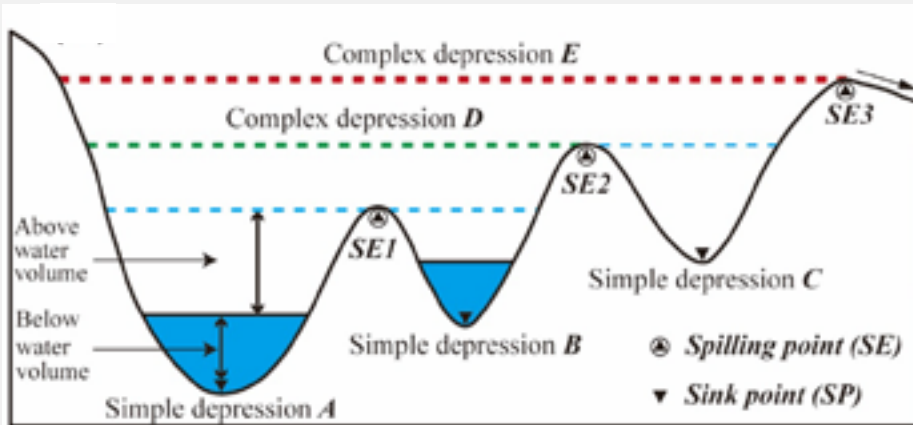
Depression Storage Capability

§ Below-water volume

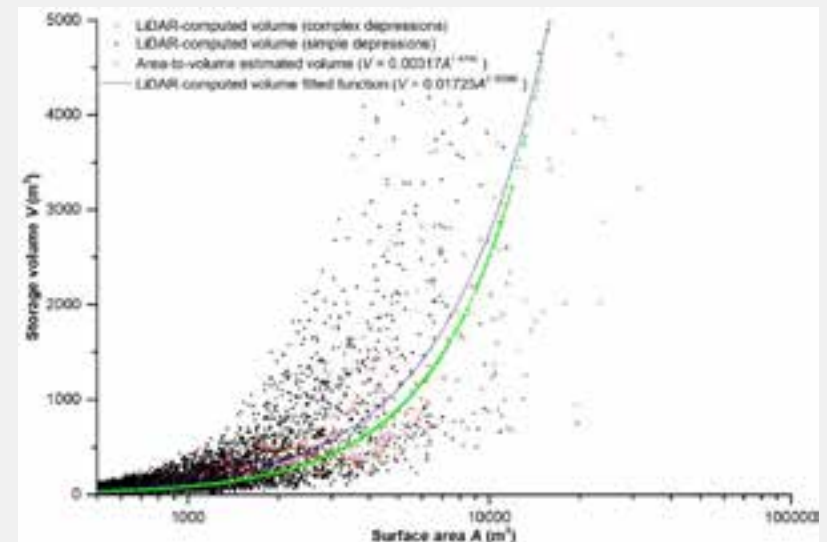
$$V_{bw} = 0.25A^{1.4742}$$

§ Above-water volume

$$V_{aw} = (Z' C - S)' R^2$$



Empirical function fitting



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Conclusions

- Detection, delineation, and characterization of surface depressions across scales
- Derivation of geometric and topological properties
- Simulation of filling-merging-spilling hydrological processes
- Functionally effective and computationally efficient

Questions



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