

A Selective Drainage Toolbox to Hydro-enforce Culverts and other features in Lidar-based Elevation Rasters

Ryan Thompson, rcthomps@usgs.gov, Hydrologist, Huron
SD

Curtis Price, Physical Scientist, Rapid City SD
U.S. Department of the Interior
U.S. Geological Survey
Dakota Water Science Center

Outline

- Background: Study that identified need for Tools
- Study area & methodology
- Processing using Global Selective Drainage tool
- Reviewing potential culvert locations identified
- WBD update & development of 14- & 16-digit hydrologic units
- Collaborator applications for data layers
- Questions?

Study Background

- Develop methodology for utilizing lidar data to:
 - Identify locations of culverts/bridges, etc
 - Produce a hydro-enforced (culvert aware), lidar-derived dem that can be used for resource management
 - Refine watershed boundaries
 - Develop a densified drainage network
- Update WBD with refined boundaries, develop 14- and 16-digit units
- Develop tool to identify areas where NHD updates may be warranted.

Collaboration

- USGS Dakota Water Science Center
- City of Sioux Falls
- Lincoln County
- South Dakota Department of Transportation
- East Dakota Water Development District
- City of Harrisburg
- MAGIC
- USGS National Geospatial Program

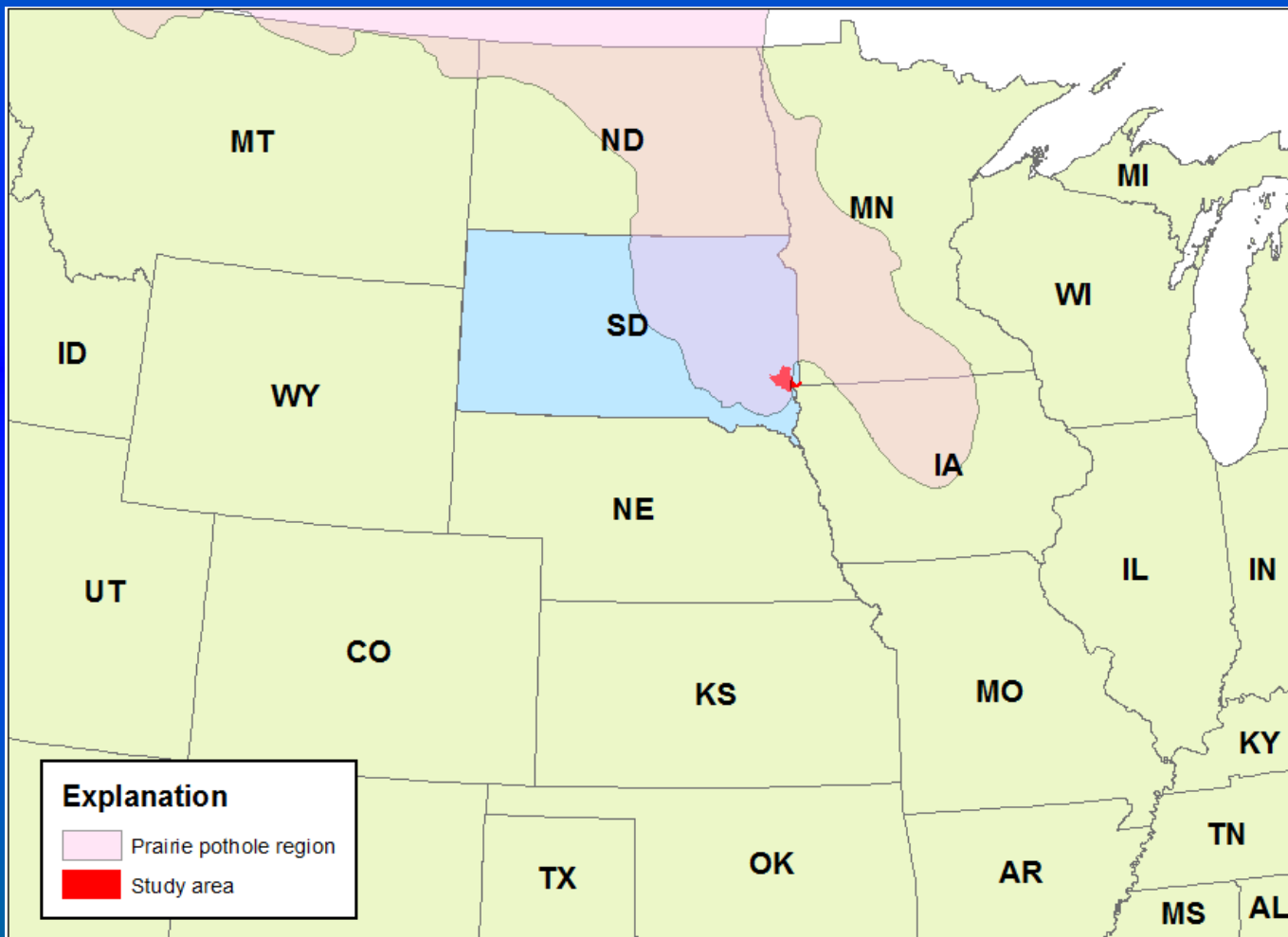
Collaboration- cont'd

- The five state & local collaborating agencies agreed to ground-truth the “assumed” culvert locations in their respective areas to the extent needed for their uses. This helped greatly to keep total project costs down.

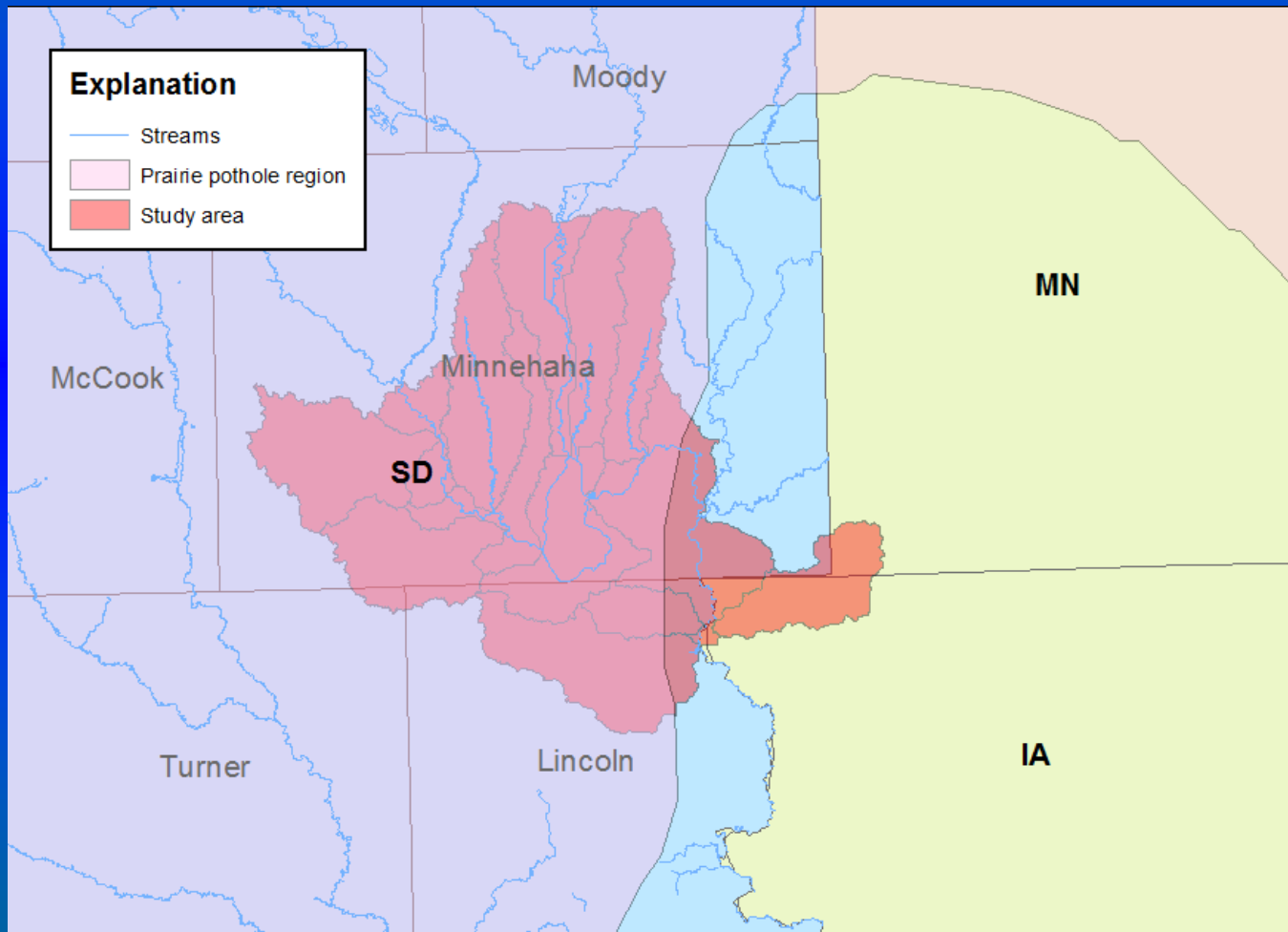
Background

- Location & Physiography of Study Area
- Hydrography of Study Area
- Basis of methodology
- Data availability

Location & Physiography

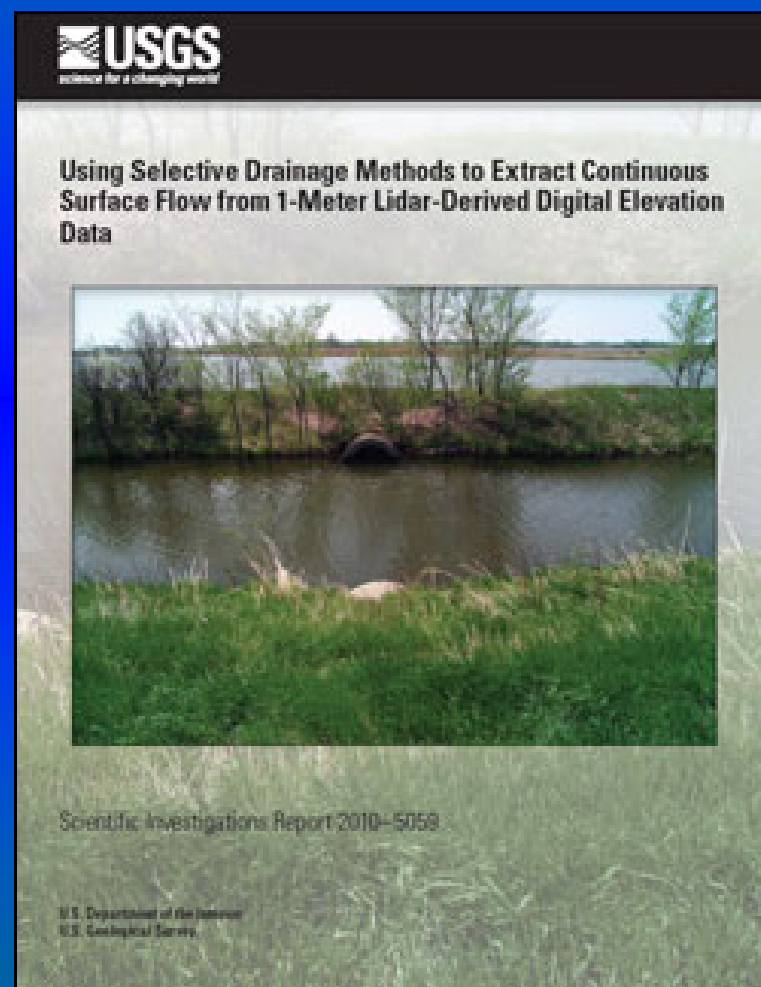


Hydrography



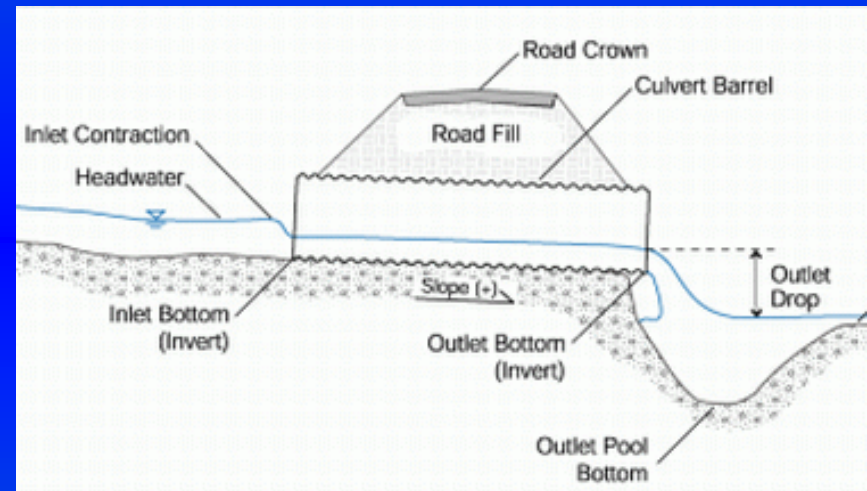
Basis of methodology

- Builds on Selective Drainage methods pioneered by Poppenga, Worstell, Stoker & Greenlee at EROS
- USGS SIR 2010-5059
- <https://pubs.usgs.gov/sir/2010/5059/>

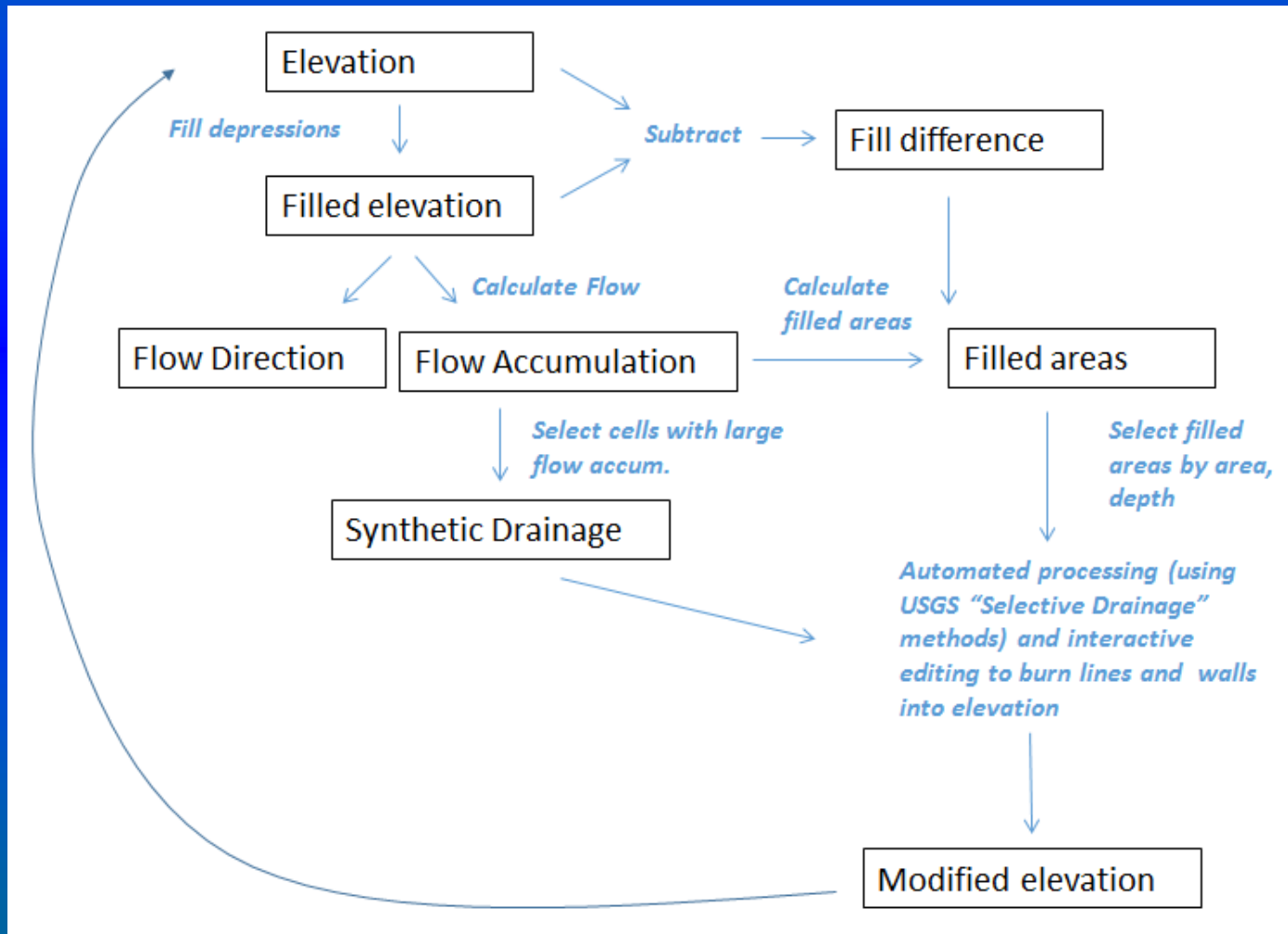


Basis of methodology- cont'd

- Lidar-based bare earth DEMs typically only have bridges hydro-enforced
- Roadbeds and other built infrastructure will act as dams unless any culverts present are hydro-enforced



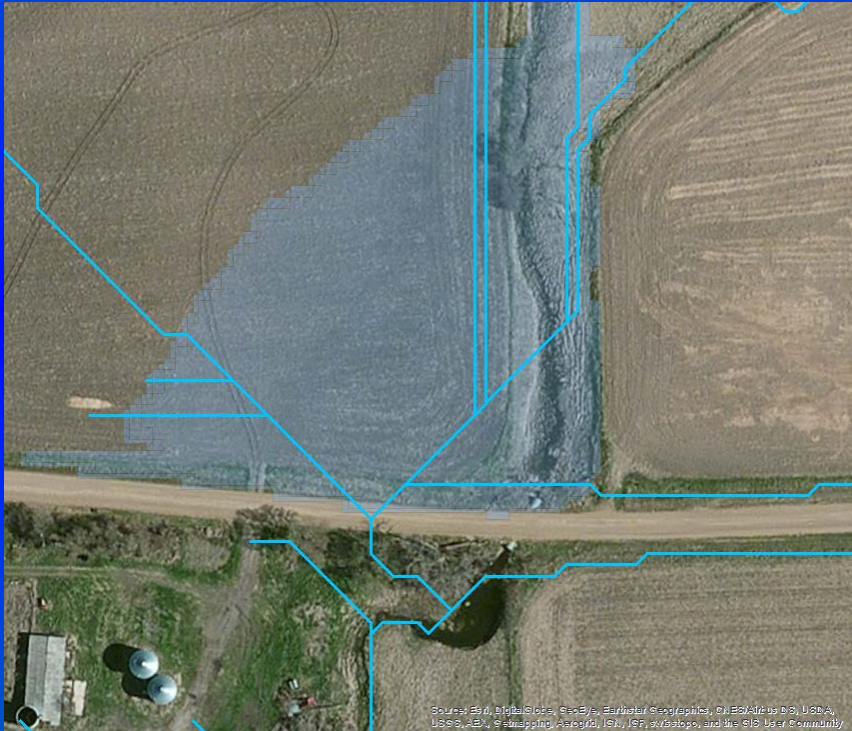
Basis of methodology- cont'd



Example



Example, cont'd



Data availability

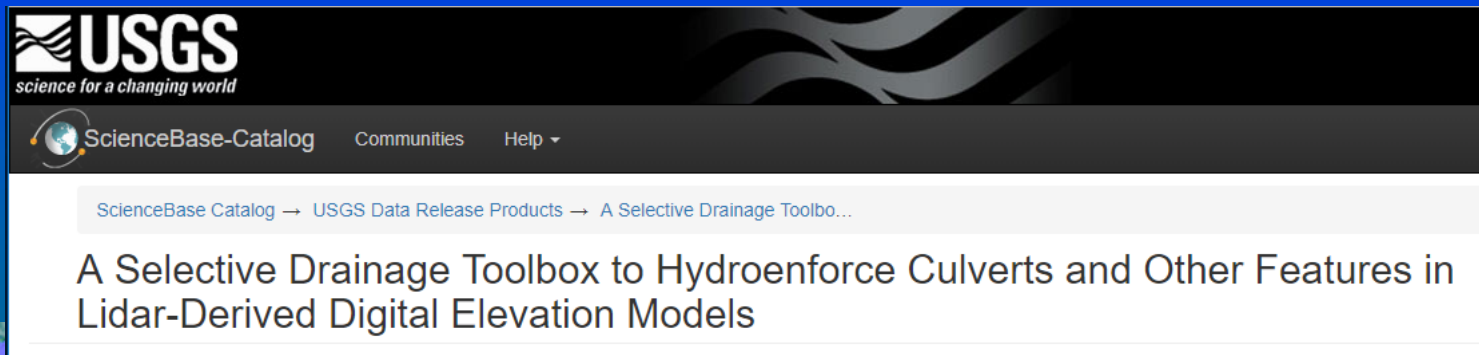
- Lidar data available in much of eastern SD
 - Lidar-based 2008 NED in SD
 - Lidar-based 2008 dem (state maintained) for Iowa and Minnesota
 - 2012 acquisition .las file covering Sioux Falls urban area
- Pictometry imagery available for Lincoln & Minnehaha Counties

Data availability- cont'd

- Culvert data initially available
 - Culverts 30 inches & larger on State & Federal highways
 - Sioux Falls Stormwater System
 - Culverts 30 inches & larger on Minnehaha County roads
- Additional culvert inventories completed
 - Culverts on Lincoln County roads
 - Culverts on local/Township roads in Minnehaha County

Global Selective Drainage Toolbox

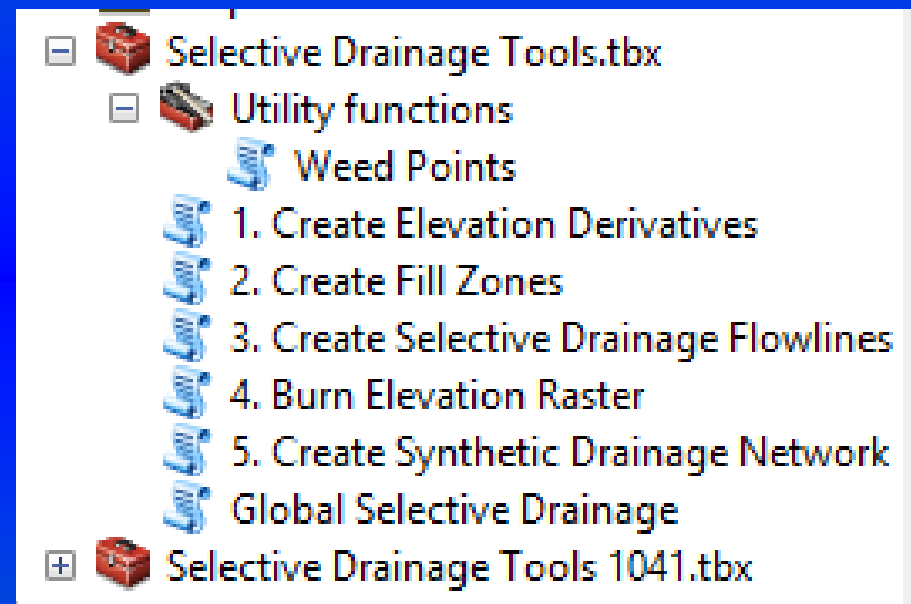
- ArcGIS Toolbox developed by Curtis Price
- Released on ScienceBase 9/25/18
 - <https://doi.org/10.5066/F7TQ60FD>
 - ArcGIS 10.4
 - User Guide available
- Currently updating to ArcGIS 10.6/ArcGIS Pro



The screenshot shows the USGS ScienceBase Catalog interface. At the top left is the USGS logo with the tagline "science for a changing world". Below the logo is a navigation bar with "ScienceBase-Catalog", "Communities", and "Help" (with a dropdown arrow). The breadcrumb trail reads "ScienceBase Catalog → USGS Data Release Products → A Selective Drainage Toolbo...". The main content area displays the title "A Selective Drainage Toolbox to Hydroenforce Culverts and Other Features in Lidar-Derived Digital Elevation Models".

Processing with Global Selective Drainage Toolbox

- Available tools
 - Utility function for DEM setup/preparation
 - Tools 1, 2, & 3 are included in the Global tool
 - Tools 4 & 5 are used to enforce and evaluate identified culverts
- Some tools may not appear if you have not enabled an extension they need



Processing with Global Selective Drainage Tool

- Terminology:
 - Drain line- potential culvert location(s) identified by the tool
 - Search distance- the maximum distance allowed between the min point of a fill poly and the endpoint of its potential drain line/culvert
 - Max & min culvert fill zone areas- can be used to filter out large waterbodies or very small depressions
 - Pour point distance- the maximum length allowed for the drain line feature
 - Iterations- allows possible identification of multiple culverts for a given fill poly

Tool 1: Create elevation derivatives

1. Create Elevation Derivatives

Elevation raster

Output fill raster
C:\Users\jcthomps\Documents\ArcGIS\Default.gdb\fill

Output fdr raster
C:\Users\jcthomps\Documents\ArcGIS\Default.gdb\fdr

Output fac raster

Output diff raster (optional)

Output flow lines (optional)

Minimum area (optional)
1000

Minimum area units (optional)
CELLS

1. Create Elevation Derivatives

Create elevation derivatives from an input elevation dataset. Outputs include fill and flow direction rasters. Optional outputs include fill difference and flow accumulation rasters, and flow lines. A minimum fill area criteria can be set.

OK Cancel Environments... << Hide Help Tool Help

Tool 2: Create fill zones

2. Create Fill Zones

● Elevation raster

● Fill raster

● Flow direction raster

● Flow accumulation raster

● Fill zone raster

● Fill zone polygons

● Pour points

● Minimum points

Minimum area (optional) 1000

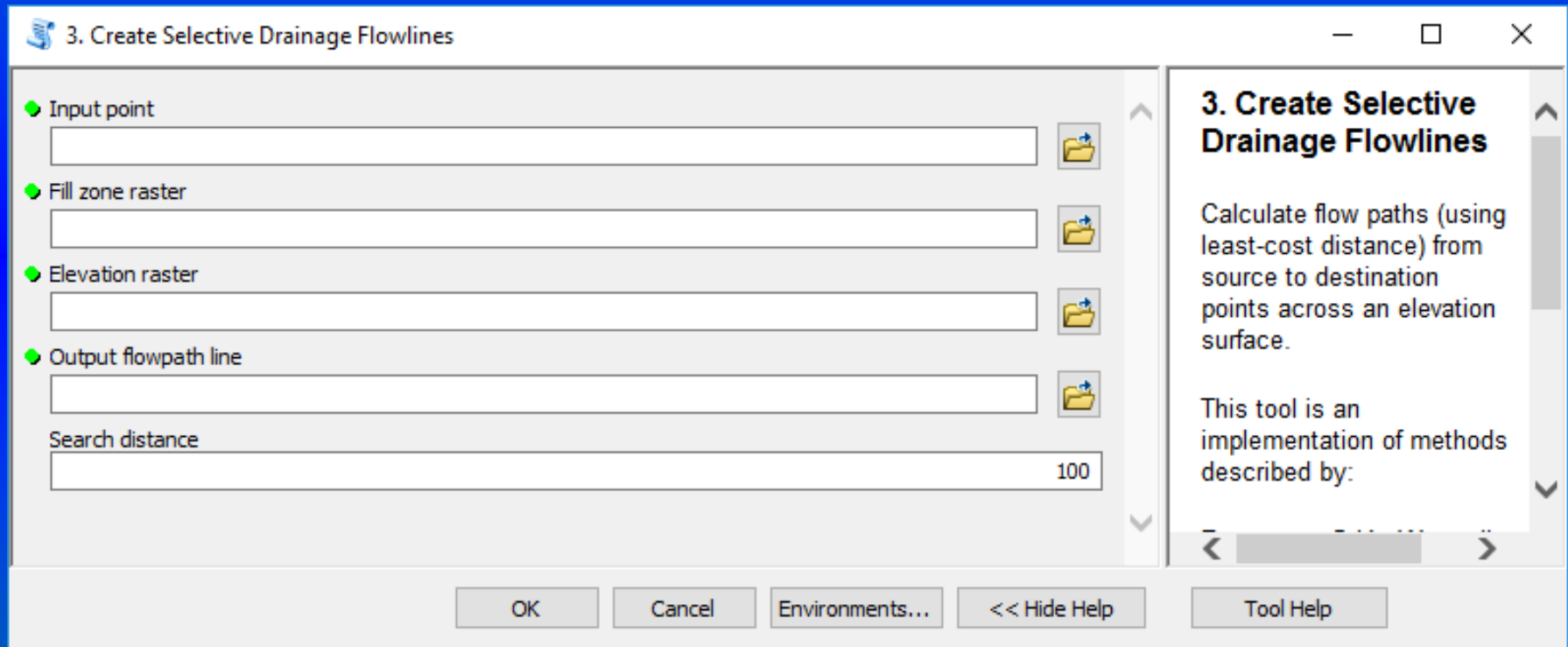
Minimum area units (optional) CELLS

2. Create Fill Zones

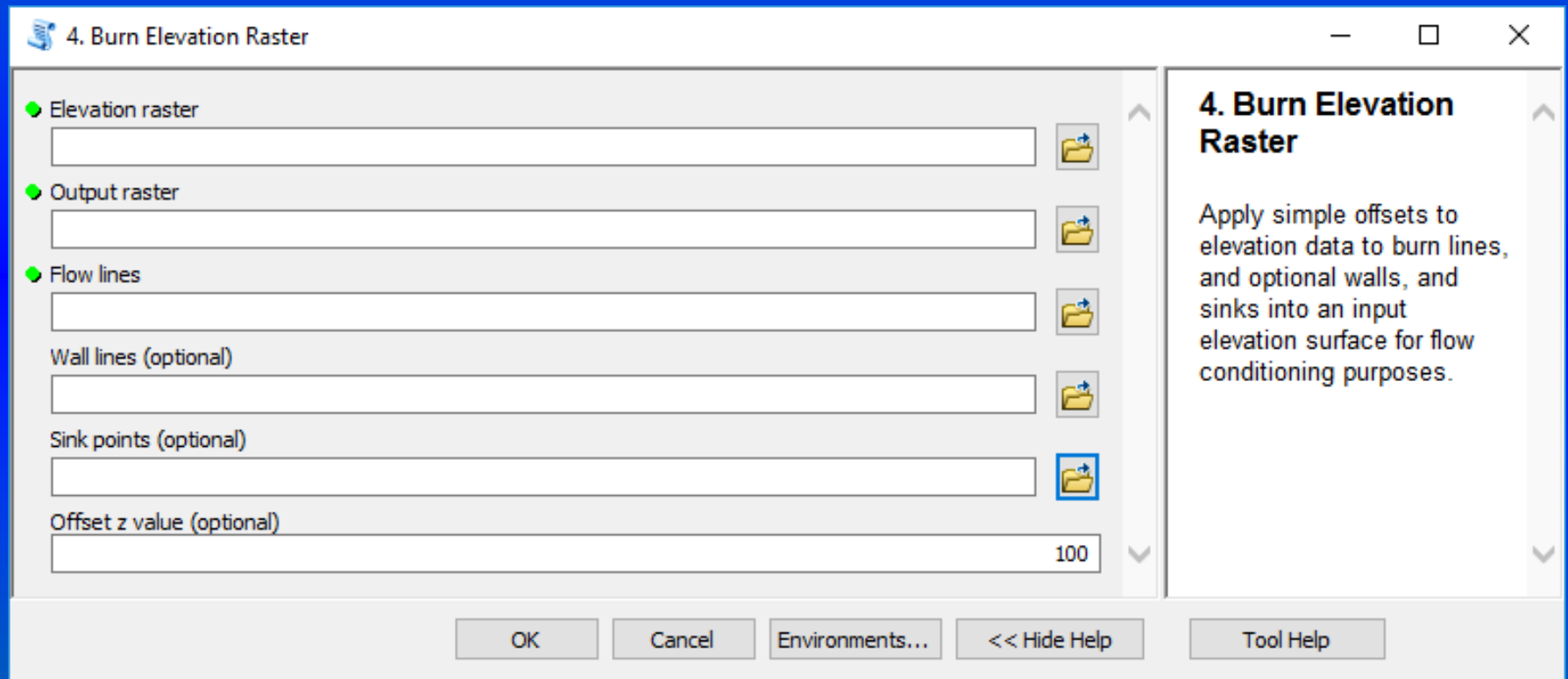
Create fill zone polygon and raster datasets from elevation derivatives. Fill zones attributes (area, volume, depth) are calculated for each fill zone. Also minimum points and pour points feature classes are created.

OK Cancel Environments... << Hide Help Tool Help

Tool 3: Create selective drainage flowlines



Tool 4: Burn elevation raster



Tool 5: Create synthetic drainage network

5. Create Synthetic Drainage Network

Flow direction raster

Flow accumulation raster

Output lines

Minimum area (optional) 1000

Area units (optional) CELLS

OK Cancel Environments... << Hide Help Tool Help

5. Create Synthetic Drainage Network

This tool can be used to create a synthetic drainage network based on input flow direction and flow accumulation rasters. Density of the output drainage network can be varied by use of a minimum threshold for stream initiation.

| | FID | Shape * | GRIDCODE | DRNCELLS | DRNAREA |
|---|-----|----------|----------|----------|---------|
| ▶ | 0 | Polyline | 1 | 4255 | 425500 |
| | 1 | Polyline | 4 | 1552 | 155200 |
| | 2 | Polyline | 3 | 605 | 60500 |
| | 3 | Polyline | 7 | 437 | 43700 |

Processing with Global Selective Drainage Tool

Global Selective Drainage

Elevation raster

Output fill zone polygons
C:\Users\jcthompson\Documents\ArcGIS\Default.gdb\fill_poly

Output fill zone min points
C:\Users\jcthompson\Documents\ArcGIS\Default.gdb\min_pt

Output fill zone pour points
C:\Users\jcthompson\Documents\ArcGIS\Default.gdb\pour_pt

Output fill drain lines
C:\Users\jcthompson\Documents\ArcGIS\Default.gdb\drain_line

Minimum fill zone area (optional)
1000

Fill zone area units (optional)
CELLS

Search distance (optional)
90

Max culvert fill zone area
10000

Culvert fill zone area units
CELLS

Pour point distance (optional)
67.5

Maximum iterations (optional)
3

Global Selective Drainage

This script locates potential culverts.

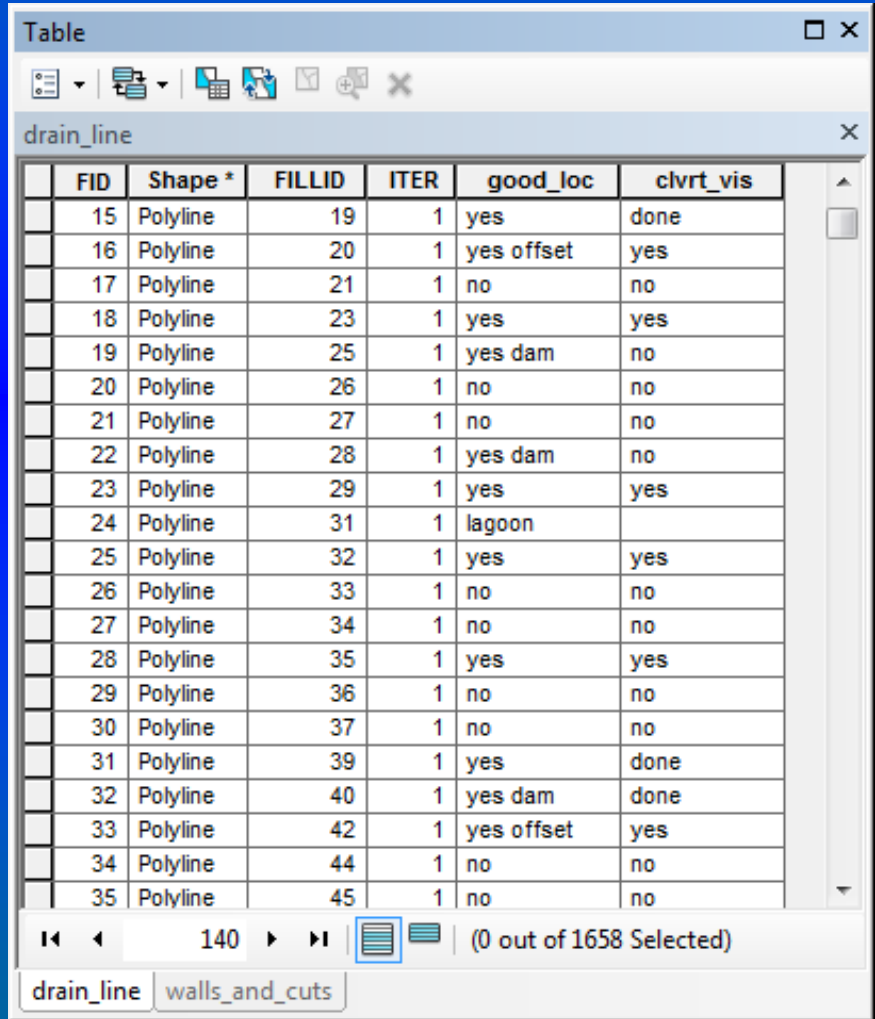
OK Cancel Environments... << Hide Help Tool Help

Processing with Global Selective Drainage Tool

- Tips:
 - Depending on your dem resolution, you may want to run the tool on subsets of the total study area. The Arc tools will honor an extent, but not a processing mask.
 - When finding what your optimal processing area is, consider using just one iteration (default is 3).
 - Process a buffer beyond your expected study area boundary.
 - As you develop your layer of culverts, attribute them to identify source.

Processing with Global Selective Drainage Tool

- May want to add notes to the drain_line attribute table for use in verification of culvert presence
 - Does the location “make sense”?
 - Is a culvert visible in the basemap imagery?

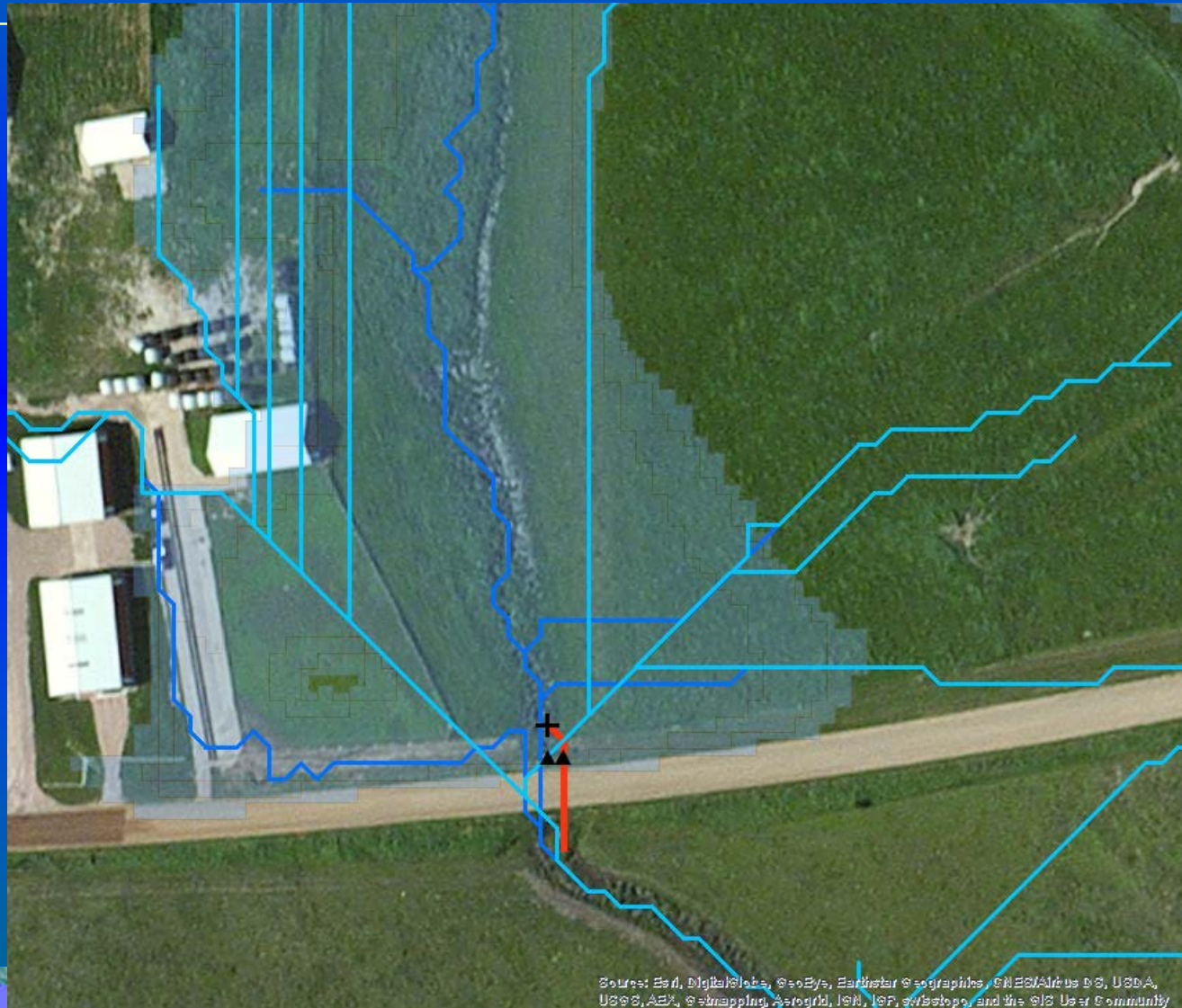


The screenshot shows a software window titled "Table" with a toolbar and a table of data. The table has the following columns: FID, Shape *, FILLID, ITER, good_loc, and clvrt_vis. The data rows are numbered 15 through 35. The table is currently displaying 21 rows of data.

| FID | Shape * | FILLID | ITER | good_loc | clvrt_vis |
|-----|----------|--------|------|------------|-----------|
| 15 | Polyline | 19 | 1 | yes | done |
| 16 | Polyline | 20 | 1 | yes offset | yes |
| 17 | Polyline | 21 | 1 | no | no |
| 18 | Polyline | 23 | 1 | yes | yes |
| 19 | Polyline | 25 | 1 | yes dam | no |
| 20 | Polyline | 26 | 1 | no | no |
| 21 | Polyline | 27 | 1 | no | no |
| 22 | Polyline | 28 | 1 | yes dam | no |
| 23 | Polyline | 29 | 1 | yes | yes |
| 24 | Polyline | 31 | 1 | lagoon | |
| 25 | Polyline | 32 | 1 | yes | yes |
| 26 | Polyline | 33 | 1 | no | no |
| 27 | Polyline | 34 | 1 | no | no |
| 28 | Polyline | 35 | 1 | yes | yes |
| 29 | Polyline | 36 | 1 | no | no |
| 30 | Polyline | 37 | 1 | no | no |
| 31 | Polyline | 39 | 1 | yes | done |
| 32 | Polyline | 40 | 1 | yes dam | done |
| 33 | Polyline | 42 | 1 | yes offset | yes |
| 34 | Polyline | 44 | 1 | no | no |
| 35 | Polyline | 45 | 1 | no | no |

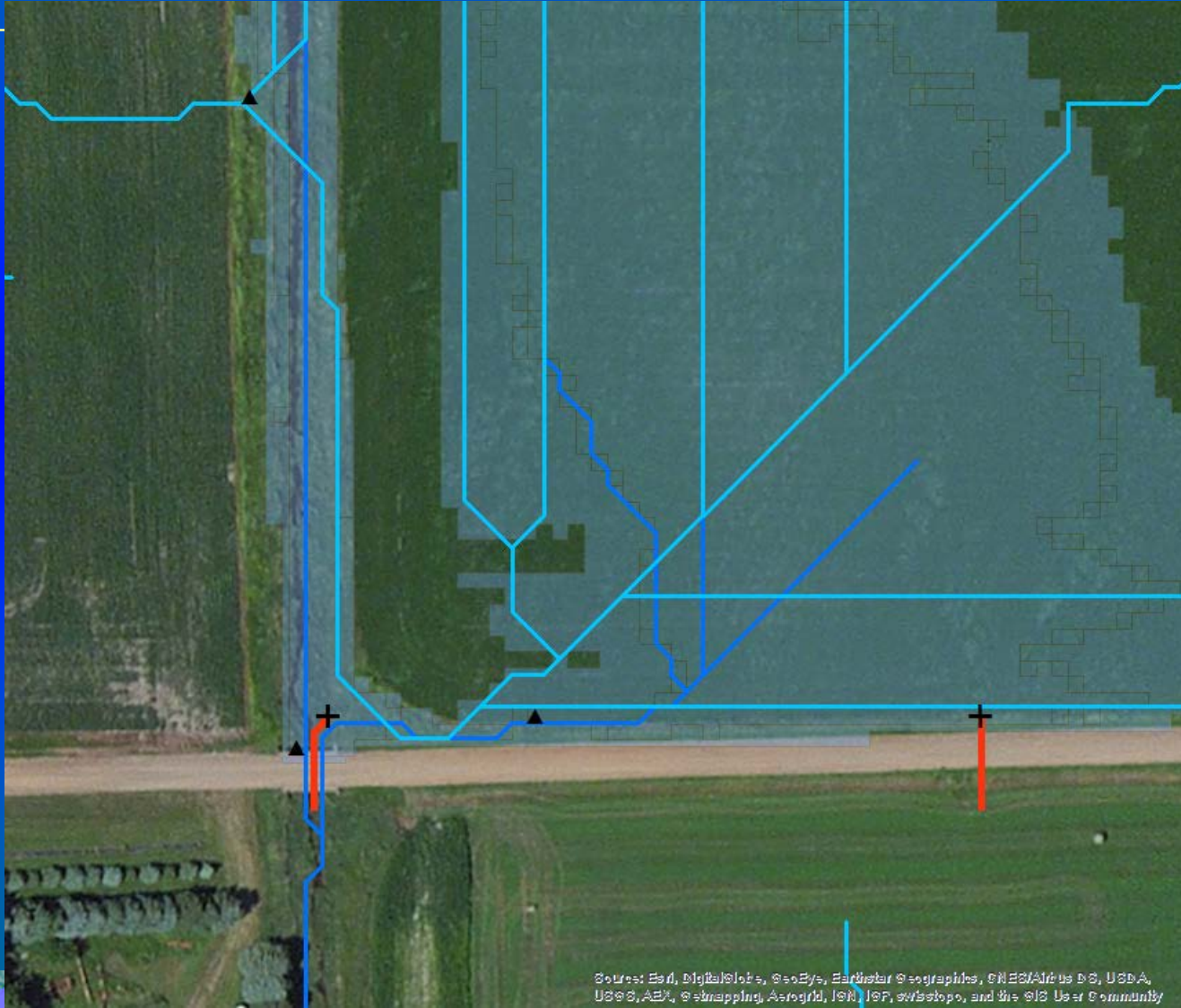
The interface also shows a status bar at the bottom with the text "(0 out of 1658 Selected)" and a list of layers: "drain_line" and "walls_and_cuts".

Reviewing assumed culvert locations



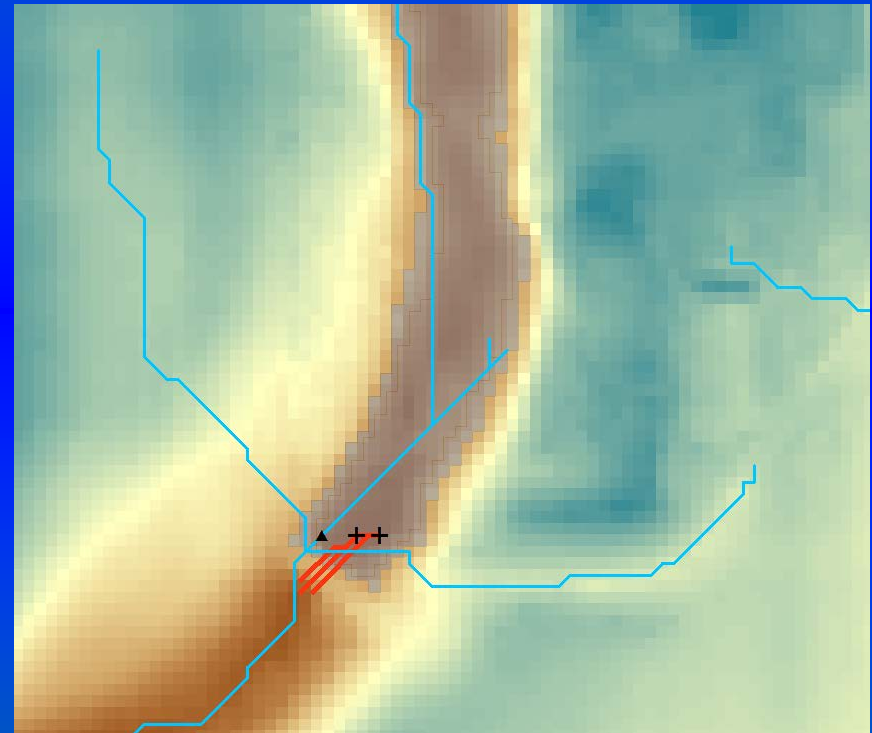
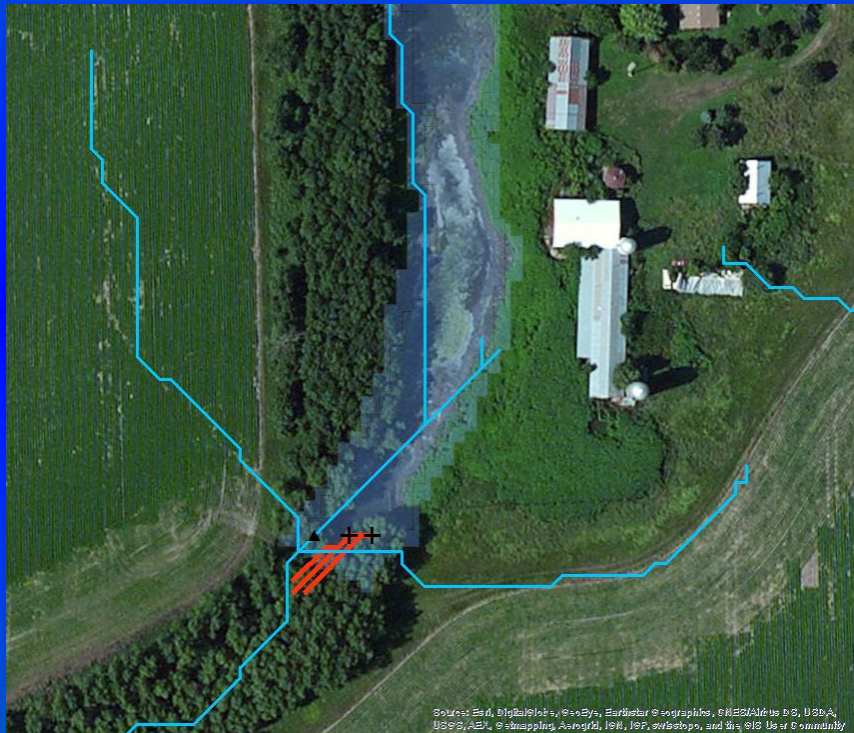
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroX, Swiremap, AeroGrid, IGN, IGP, Swiremap, and the GIS User Community

Reviewing assumed culvert locations



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, IGP, swisstopo, and the GIS User Community

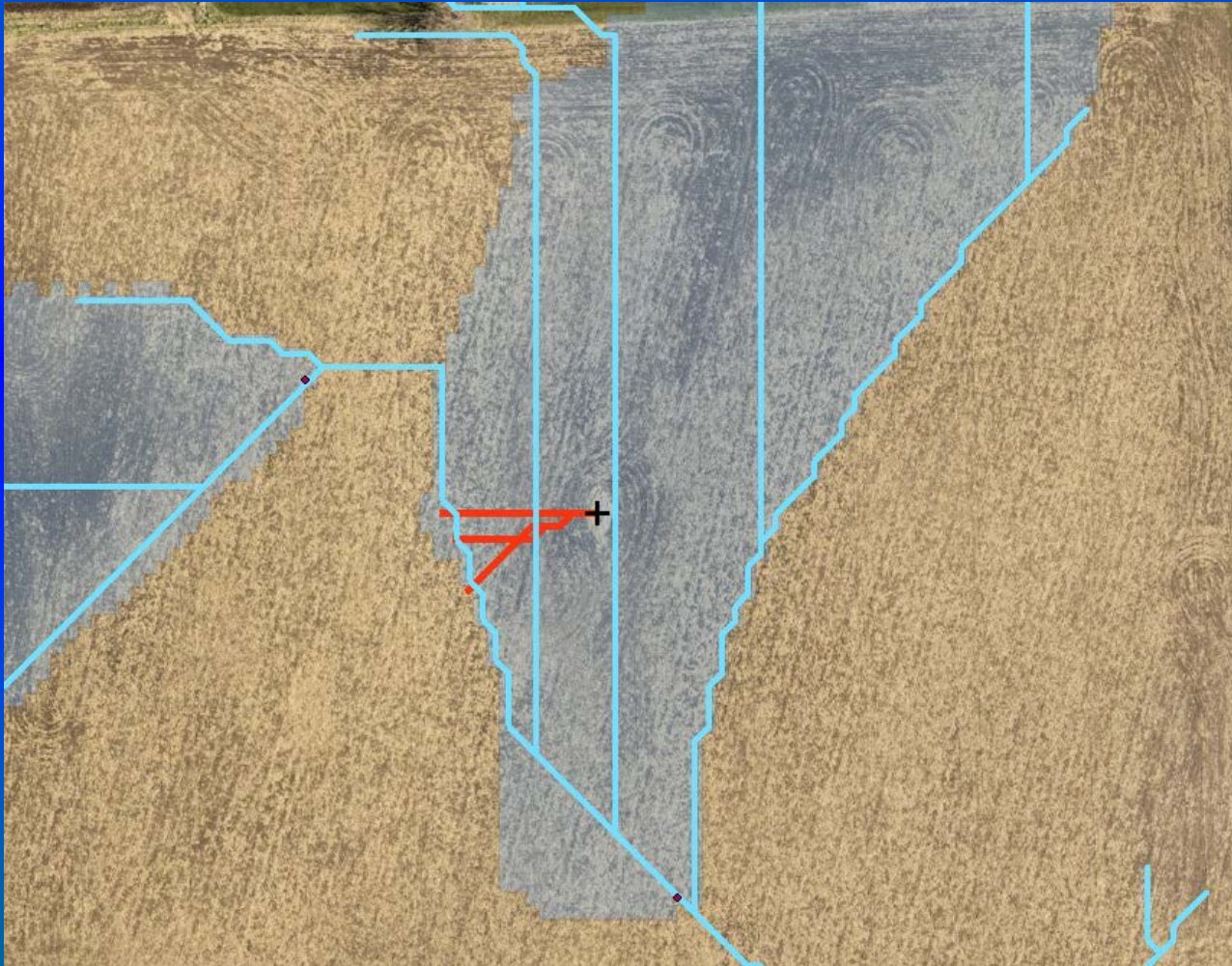
Reviewing assumed culvert locations



Reviewing assumed culvert locations



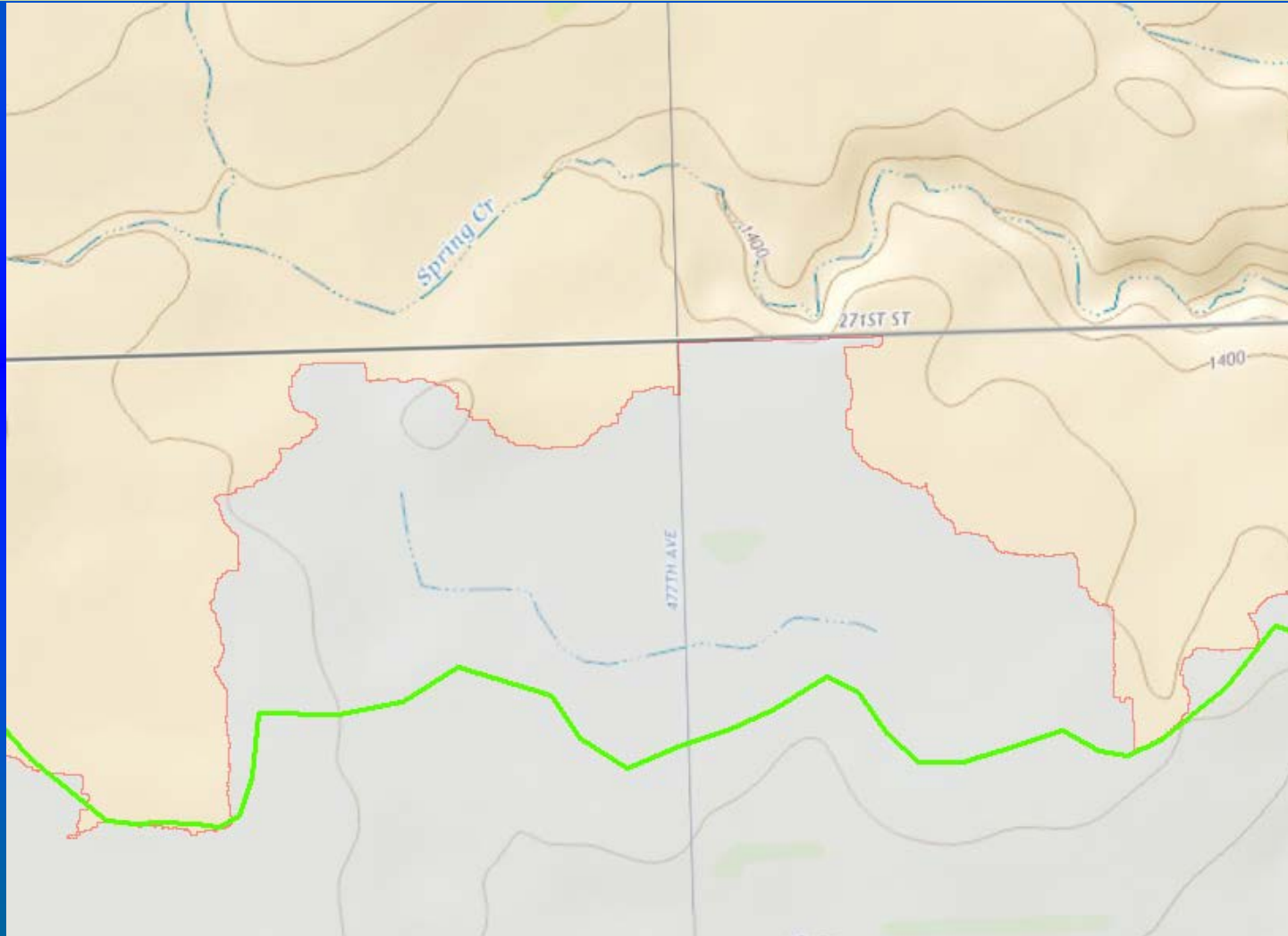
Reviewing assumed culvert locations



WBD updates & additions



WBD updates & additions- cont'd



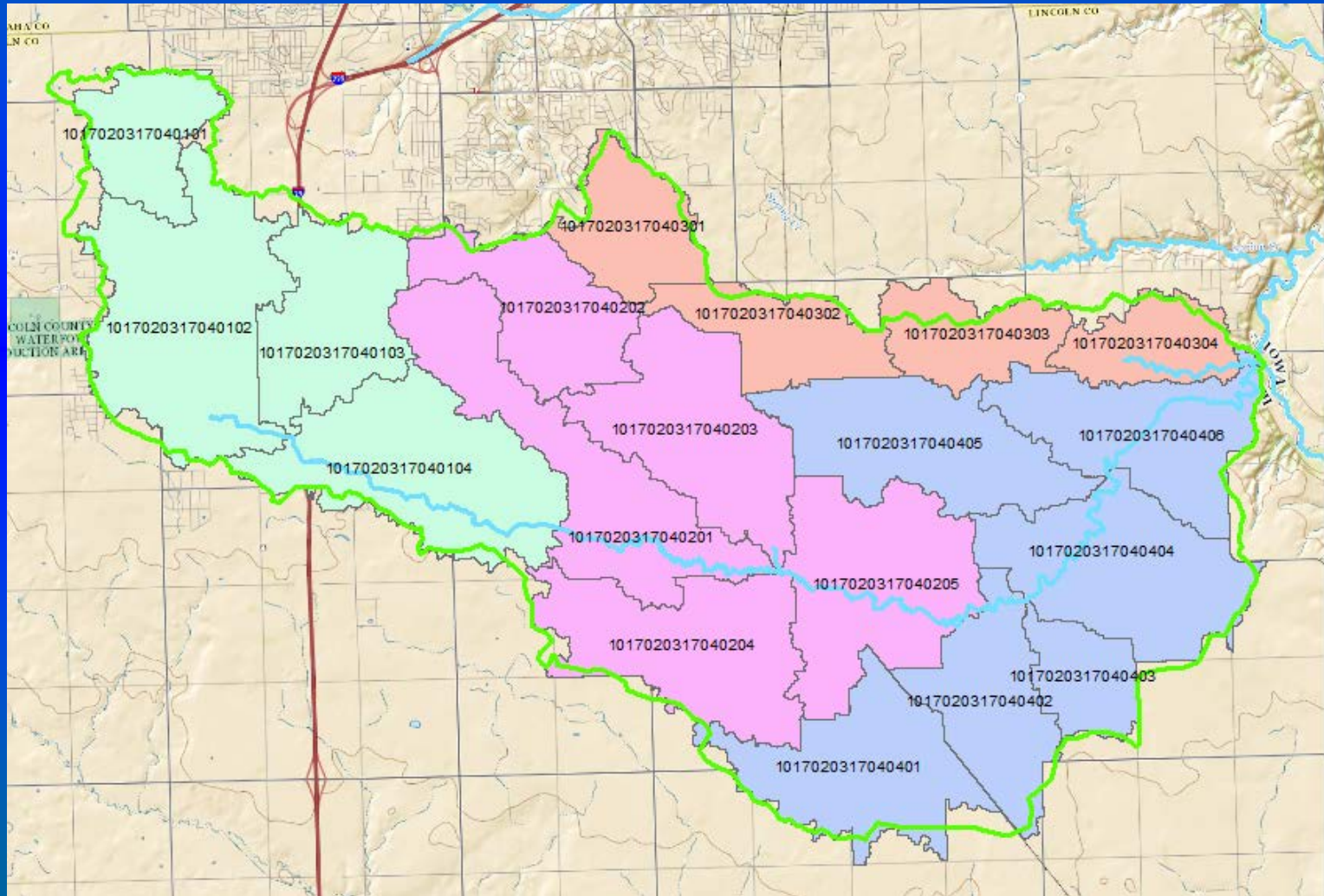
WBD updates & additions- cont'd



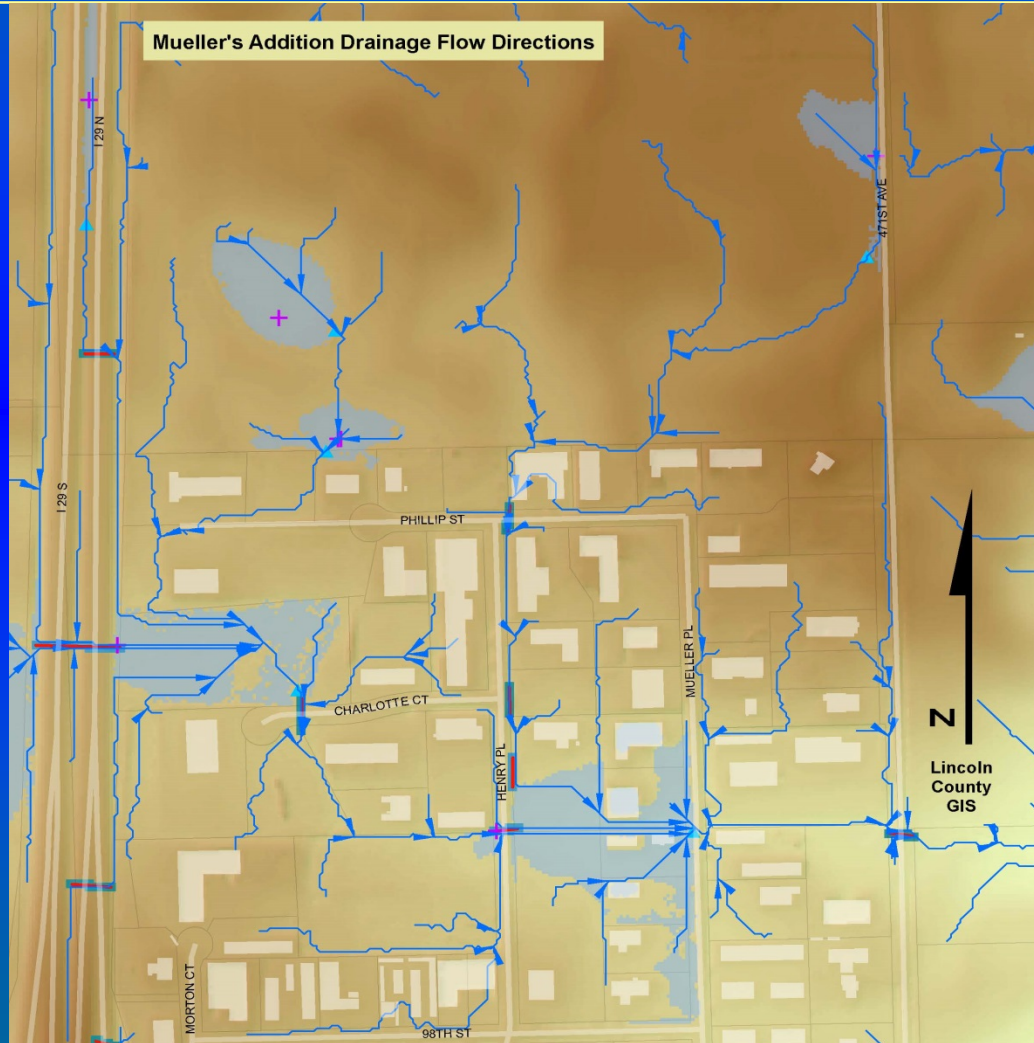
WBD updates & additions- cont'd



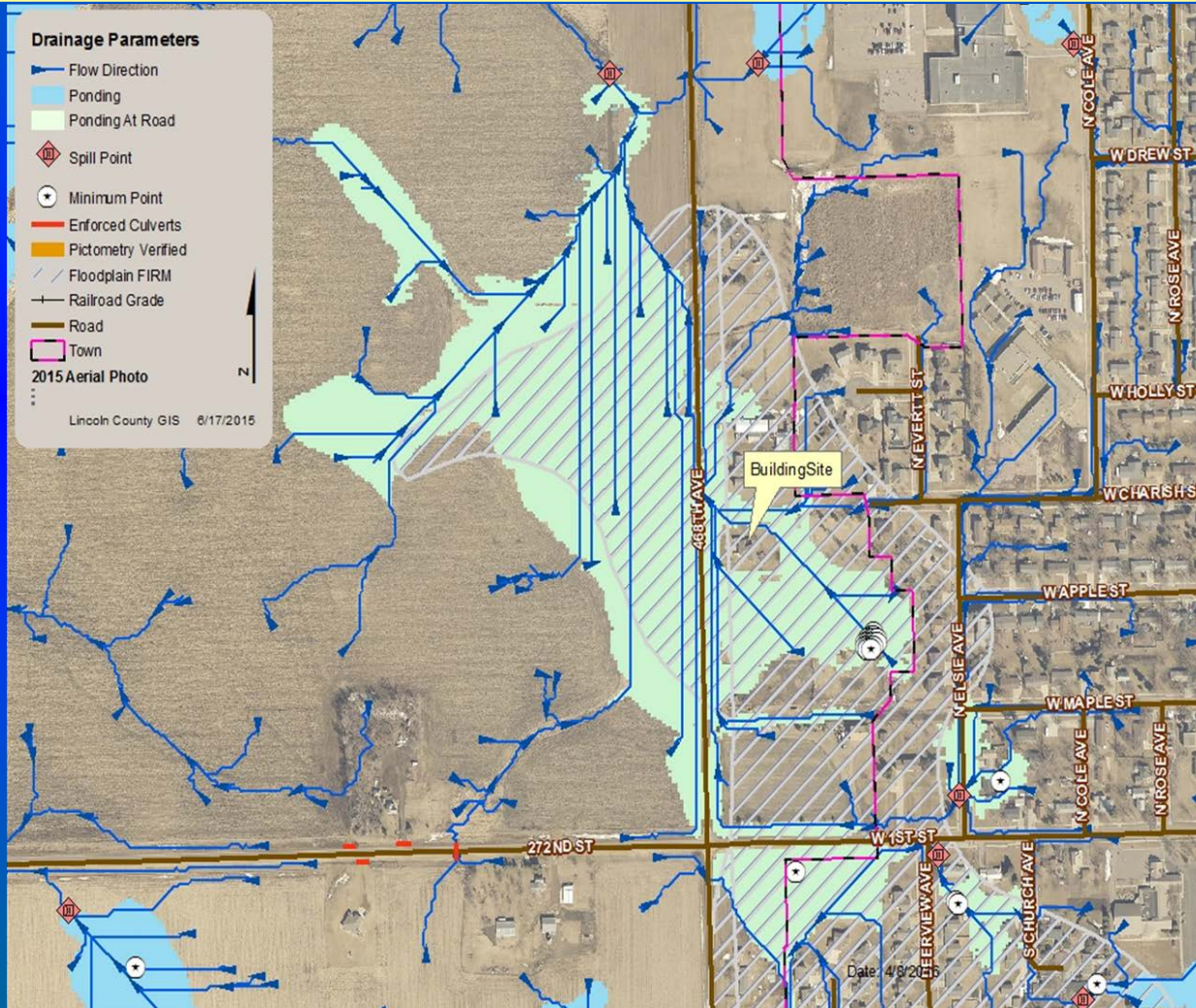
WBD updates & additions- cont'd



Collaborator applications



Collaborator applications



Questions?

