Sinkhole Verification Methodology - Phase 2

Crawford Stewardship Project citizen science methods for assessment of karst geology in Crawford County

› OVERVIEW :

This document is intended to serve as a reference for volunteer citizen scientists assisting Crawford Stewardship Project with their Karst Landscapes and Groundwater Susceptibility Survey of Crawford County. Sinkholes, and other karst features (such as disappearing/sinking streams, swallets, and blind valleys) constitute direct conduits to groundwater, and are the main focus of this exercise. Caves and springs are also karst features, but will be identified through different methodologies and datasets. This volunteer effort will assess the local presence of sinkholes using a web-based interface and a sink location dataset prepared by Legion GIS, LLC.

The sink location dataset was produced through hydrological analysis of a 5-foot resolution “bare-earth” DEM (Digital Elevation Model). The DEM was derived from data collected by remote sensing (LiDAR) in 2011. It is considered “base-earth” because the data collection process penetrates the tree canopy, and post-processing is performed to remove buildings. This elevation model was analyzed with computer software to mark closed depressions (basins, or sinks) deeper than 1 foot within the study area. These are the points with which we will be working.

The goal is for participants to assess sink points through visual observations against various basemaps. Volunteers will not be adding or moving points; we will simply be sorting them into categories based on a visual assessment.

› ABOUT THE REFERENCE BASEMAPS :

In the karst viewer app, we have added four alternate basemaps, all of which are intended to help with the visual assessment of sinks. Users can change the basemap using the layers panel.

Simple Basemaps

- *Aerial Imagery* - Aerial imagery, sometimes called “orthophotography”, is very useful in providing easy-to-understand context for sinks. Proximity to buildings and vegetation coverage are two aspects of a sink’s location that will show up clearly in aerial imagery, but may be difficult to ascertain by using some of the other basemaps below. Making an assessment of a sink should always involve looking using this basemap. The imagery we are using is Mapbox’s Satellite layer (https://mapbox.com/maps/satellite/).
- *USGS Topo* - The USGS basemap is a good place to look for made-made features, like quarries or old farmsteads, that may not be apparent in aerial imagery. For example,

historic quarries may be overgrown and not visible in aerials, but would be clearly marked on the USGS topo.

LiDAR-derived Elevation Basemaps

The other two basemaps, *SW WI Hillshade* and *Topographic Position Index*, are considered "elevation derivatives", as they are derived from a DEM. In fact, these basemaps are derived from the same 5-foot resolution DEM that was used to generate the sink location points.

- *SW WI Hillshade* - A hillshade or "hillshade relief" is a rendering which simulates the illumination of a DEM by a lightsource. The hillshade provides a visually pleasing effect which also accentuates the hills and valleys of a landscape. Because of this, you may find that the hillshade layer is more easy to interpret/understand than the TPI map.
- *Topographic Position Index*- The Topographic Position Index (TPI) shows an index value for each cell that is based on its similarity to surrounding cells. This means that certain features will pop out much more clearly

You are encouraged to check both of these basemaps. As you work, you'll see that while certain elevation features may be very easy to see on one, they may be indecipherable on the other.

Caveats of Elevation Basemaps vs. Aerial Imagery

There are obvious advantages to referencing against LiDAR-derived data — with the particular distinction that LiDAR DEMs provide an unimpeded look at the bare-earth surface, without the forest canopy, buildings or other objects getting in the way. In addition, elevation data can be rendered to display in various ways, including hillshade, slope, directional aspect, even elevation contours. Nonetheless, there are some definite disadvantages as well. For one, despite the high resolution of LiDAR data, the resolution is not always enough to discern the finer details of topology; in addition, modern aerial imagery is collected at a resolution which is significantly more fine-grained, with many WI counties now moving to acquire 6-inch imagery (that is, 1 pixel is 6 inches square). By referencing against aerial imagery, we can take advantage of the higher information density such images can provide. Because of this, aerial imagery makes for an excellent reference dataset.

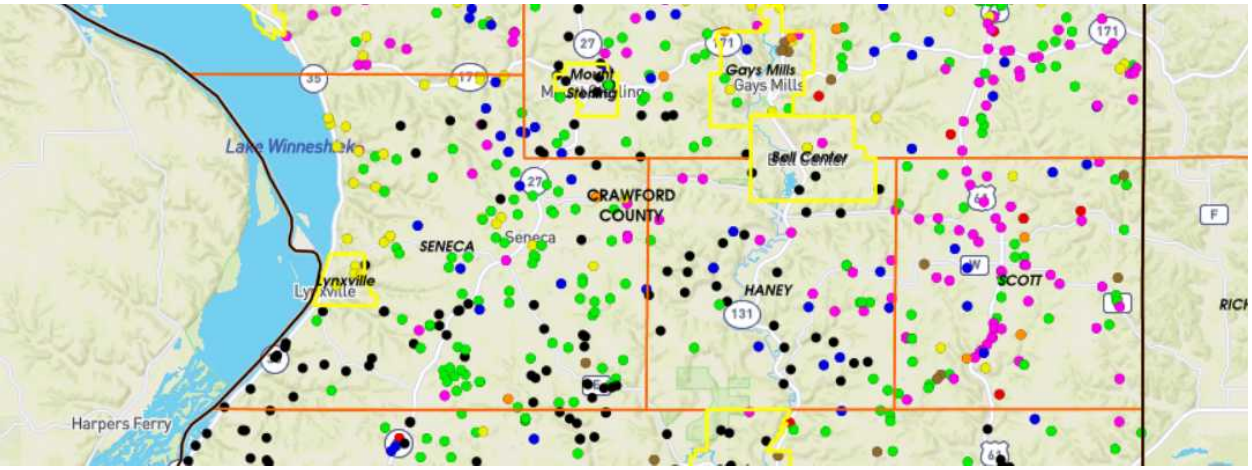
> METHODOLOGY :

The "Karstography" app provides an easy way to perform categorization of sinks based on visual analysis. The steps are

1. Select a sink
2. Assess the sink
3. Submit assessment

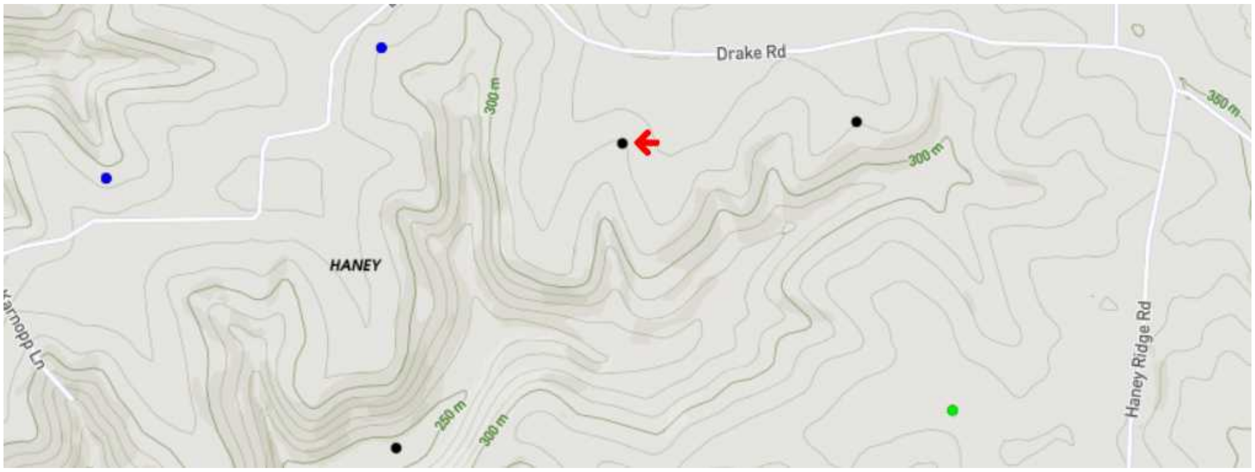
1 - Select a Sink

Begin by activating the appropriate layers on the map. By default, you'll see a layer showing sinks that have already been categorized as Sinkholes (green dots), as well as a layer showing a heatmap visualization of the density of these Sinkholes. In the Layers panel, you can turn these two layers off, and then turn on the appropriate "Sink" layer depending on the depth of sink subsets you are going to be working on. The points will appear in many different colors, so your map will look something like this:



Each color corresponds to a sink category, while black points are sinks that have not yet been assessed. Zoom to an area with black points. The image below shows the southeast corner of Haney township.

We can see that three sinks have already been assessed (two are blue for "Catchment Basin" and one is green for "Sinkhole") while three have not been assessed. We'll click on the top middle sink. A red arrow indicates that the sink is selected.

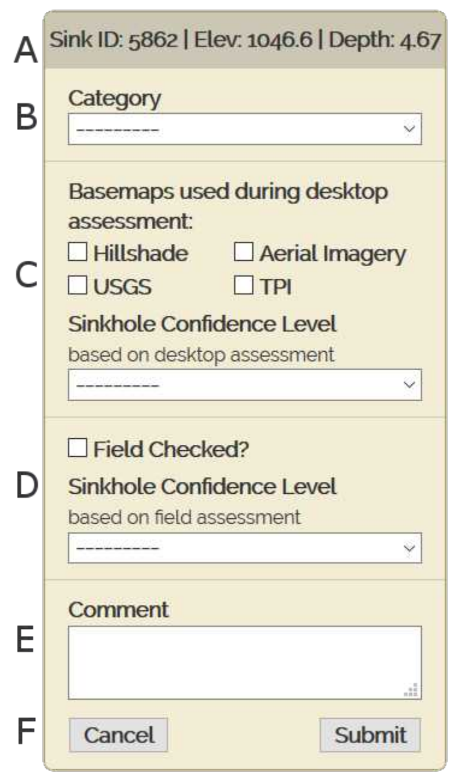


Make sure the arrow points to the sink you meant to select. It's best to zoom in further and reselect if the arrow seems to point somewhere besides the sink.

Once a sink is selected, an assessment form will open on the left-side of the page.

2 - Assess the Sink

The top of the assessment form (**A**) shows the sink's database id, elevation in feet, and depth in feet.



The goal of the assessment is to use the dropdown in section **B** to place the sink into one of seven categories:

- Catchment Basin
- Sinkhole/Karst Feature
- Quarry
- Ditch/Culvert
- Building Foundation
- Other
- Unknown

If you are performing a desktop assessment, you'll use one or more basemaps to come to your decision about the category. Check the boxes in section **C** for each basemap you look at. If you think you have found a Sinkhole/Karst Feature, you must also choose a **Sinkhole Confidence Level (based on desktop assessment)**. Options are "Possible" or "Probable".

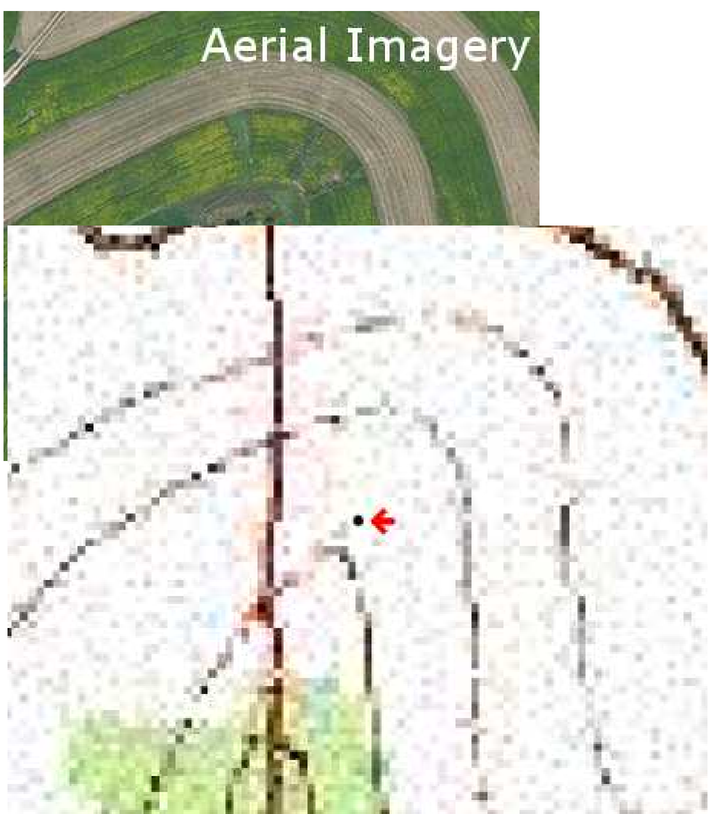
If you are performing a field assessment, you will not be looking at basemaps so section **C** will be empty (unless the sink has already been examined), and you need to fill out section **B** and **D**.

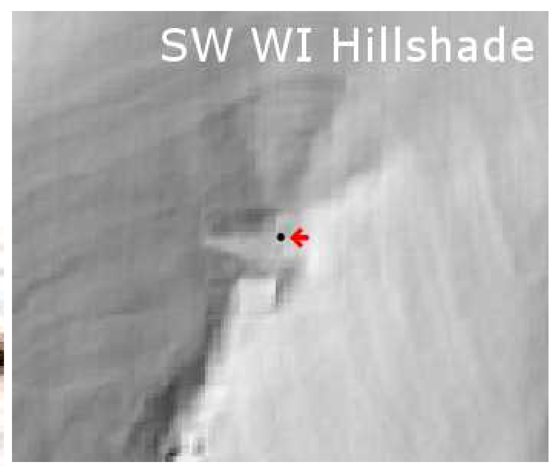
Comments are always helpful, and necessary if you have selected the Other or Unknown categories.

In our example, we have now zoomed in on the selected sink, and the default basemap, *Open Street Map*, does not help us very much. All we can tell is that the sink is near the top of a contour.

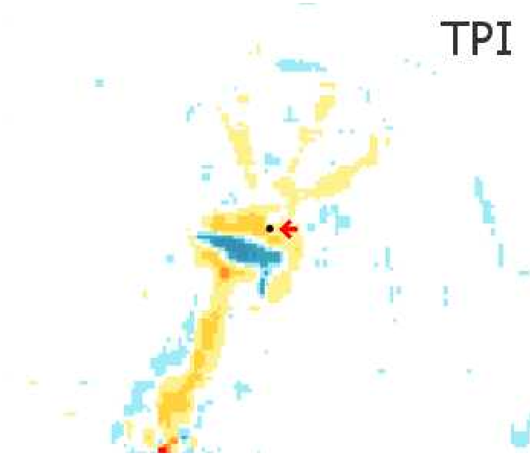
However, when we switch to some of the other basemaps, using the Layers panel, we begin to get a clearer picture of the sink. The *Aerial Imagery* basemap shows vegetation around the sink point, and crop fields following the contours of the hill.

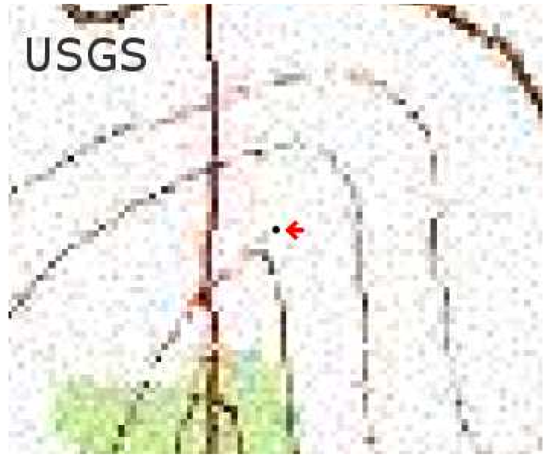
The *SW WI Hillshade* basemap clearly shows a large depression (this is the sink itself) with three channels running downhill through the field toward it. The downhill edge of the depression is a straight berm that crosses the top of the ravine. Beyond this berm, we can see that the ravine continues downhill.



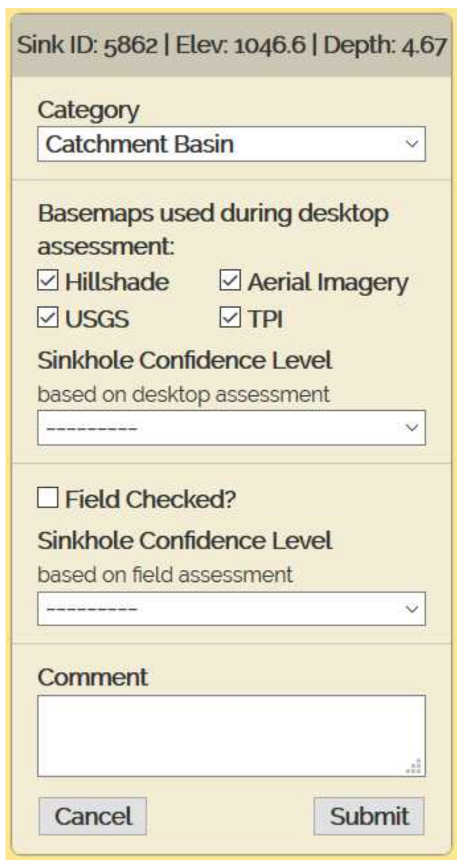


The *TPI* (Topographic Position Index) shows this berm very clearly, while the *USGS* basemap offers no useful insight in this case.
We conclude that this is a catchment basin. To learn more about why this is the correct category





see “More about the other categories” below. Our filled out assessment form will look like this, and we are ready to click Submit:


Sink ID: 5862 | Elev: 1046.6 | Depth: 4.67

Category

Catchment Basin

Basemaps used during desktop assessment:

☑ Hillshade ☑ Aerial Imagery

☑ USGS ☑ TPI

Sinkhole Confidence Level

based on desktop assessment

☐ Field Checked?

Sinkhole Confidence Level

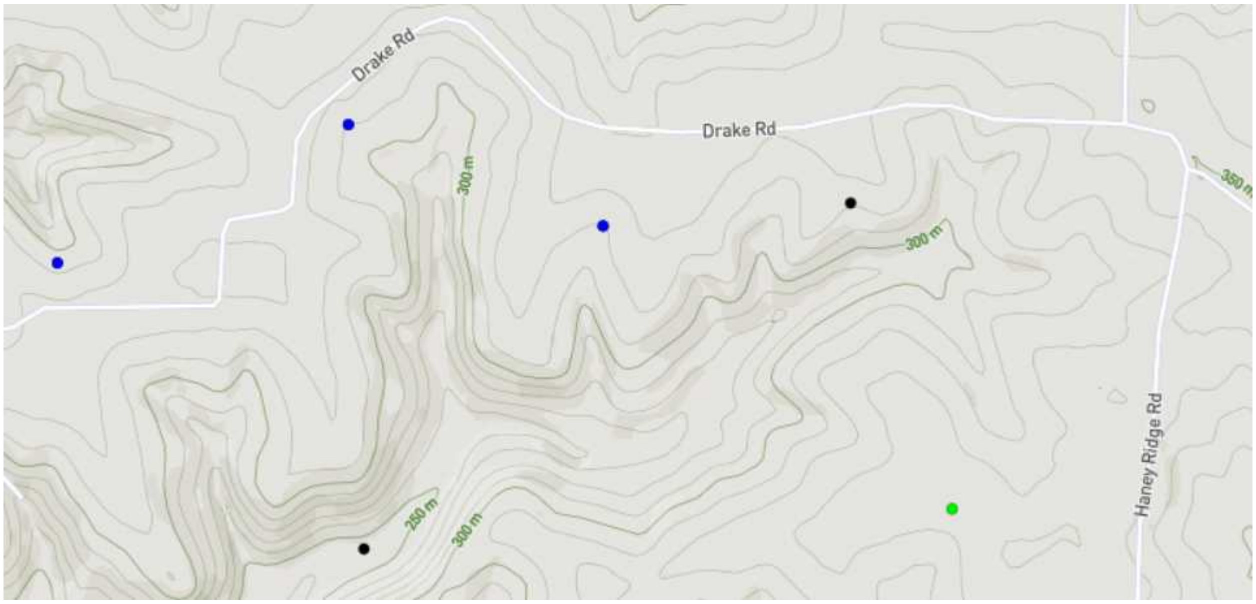
based on field assessment

Comment

Cancel Submit

3 - Submit Assessment

When you are finished with an assessment, click the Submit button. The sink layer will refresh, and the black dot will (in this case) turn to blue.



Both the “Sinkholes” and “Sinkholes Heatmap” layers are dynamic, so if you have found a sink, it will be reflected with a new point in the Sinkholes layer, and the heatmap will expand.

What a “Sinkhole/Karst Feature” Looks Like

Sinkholes are holes or depressions that form when water washes sediment down into cracks and voids in karst bedrock and/or a subterranean void collapses. Sinkholes are notable as otherwise-inexplicable closed depressions in areas underlain by at least one layer of carbonate bedrock.

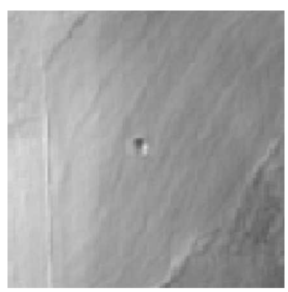
Using the Basemaps to ID karst features:
The three basemaps most useful for identifying sinkholes are *SW WI Hillshade*, *Aerial Imagery*, and *Topographic Position Index* (TPI), generally in that order. The hillshade layer allows the viewer to see the land surface as it would look with vegetation and structures peeled off. Aerial imagery allows the viewer to see land types, uses, and finer grained images of the landscape. TPI makes it easy to see major slope and elevation changes within the context of their immediate surroundings, sometimes highlighting features that are not very clear in the hillshade.

Other helpful layers to use:
- Unselecting the “Sinks” or “Sinkholes” layers to remove the points can help visualize the feature more clearly and completely, especially if you are zoomed in on a small sink.
- Activating the “Carbonate Bedrock” layer can give an indication of whether the area is underlain by carbonate (and therefore karstic) bedrock.

One of the best indications of sinkholes is the presence of other nearby sinkholes, as this indicates that the underlying bedrock contains fractures, voids, or other underground karst features.

Other indications of sinkholes (using *SW WI Hillshade* or *TPI* basemap):
 - a marked depression in an otherwise smooth or level area.
 - feature shows evidence of soil loss into the sink (exposed soil, steep banks)
 - evidence of inflow without outflow

Other indications of sinkholes (using the *Aerial Imagery* basemap):
 - a dark or discolored patch or spot strongly resembling a hole (on open ground only)
 - a dark spot in woodlands which is clearly distinct from the shadows of the trees
 - tillage lines or irregular field margins indicating avoidance of a spot (in ag. land)
 - an access road or logging road swerving around a point
 - a patch of trees in the middle of a field
 - a visible heap of garbage

Please mark "PROBABLE" if:
- the above criteria and your evaluation of the point lead you to believe with 80% confidence that the point is a sinkhole.

Please mark "POSSIBLE" if:
 - feature seems to meet the above criteria, but is too dark, blurry or indistinct to be 80% sure
 - feature is a closed depression in a drainage channel underlain by carbonate bedrock
 - feature appears to be a sinkhole, but is situated immediately adjacent to a stream or wetland system

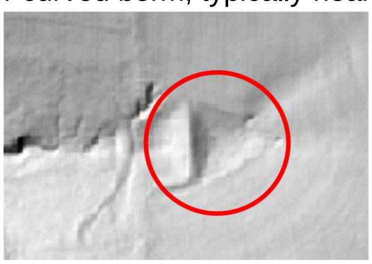
Other karst features:

Swallets/disappearing streams/blind valleys
- These are much harder to pinpoint through this methodology, and not nearly as common as sinkholes, but any valley or channel underlain by carbonate bedrock and ending in a natural-looking closed depression is a good suspect.

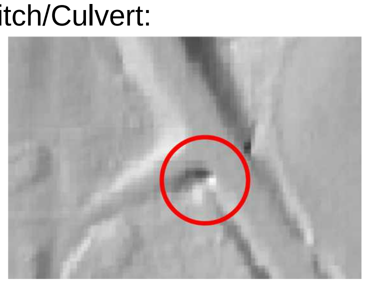
Springs and caves are also important karst features on the landscape, but will not be evaluated by this methodology because they are either underground or not easily noted using LiDAR or aerial imagery. Also, there are other existing data layers (though limited) for these features.

More about the other categories

- Catchment Basin
  - Catchment basins, i.e. cattle ponds or flood containment dams/berms, show up very clearly on the hillshade basemap. They are characterized by a man-made linear or curved berm, typically near the top of a ravine or narrow valley.



- Quarry
  - Quarries are typically large, very clearly delineated pits, and can easily be identified on the aerial imagery basemap. Also, quarries are typically marked on the USGS Topo basemap.
- Ditch/Culvert
  - Often, sink points are generated along roadsides, in ditches or next to culverts. These are relatively easy to distinguish with the hillshade basemap. For example, the image below shows a road, with a driveway extending to the southwest. The corner in the red circle has been flagged as a “sink”, but we would categorize this as a Ditch/Culvert:



- Building Foundation

    - Sometimes a very rectangular depression is the remains of an old building foundation. Look for other buildings in the vicinity or evidence of road access. Old farmsteads and barns could be present on the USGS Topo basemap.
- Other
    - If the sink you are evaluating does not fit any of the above criteria, but you think you know what it is, choose "Other" and leave an explanation in the comment field.
- Unknown
    - Choose unknown if the sink you are evaluating does not fit any of the above options. Leave a comment if appropriate.