United States Department of Agriculture

March 2018

# User Guide: Vernal Pool Detection With Lidar

# Authors

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# Scope and Purpose

Vernal pools are ephemeral bodies of water that hold water for brief periods each spring and provide critical habitat for a variety of amphibians, crustaceans and plants. These pools are isolated surface depressions that are disconnected from permanent water bodies or flows of water. The plant and animal species that rely on vernal pools benefit from this lack of a connection to permanent sources of water because it generally excludes fish from the pool, thus limiting the amount of predation that these species encounter. As temperatures rise during the late spring and early summer months, vernal pools begin to dry up, eventually completely. These ephemeral pools typically reform the following spring when snow melt accumulates, thus creating a cycle that particular species depend on.

Habitat provided by vernal pools is easily damaged by soil compaction, and removal of adjacent tree cover that provides shade. Climate change and land use transitions pose additional threats to vernal pools and the species that depend on them. Many states have adopted Best Management Practices that seek to conserve vernal pool habitat. Wildlife biologists in the Forest Service have similarly identified vernal pools as a priority concern.

One of the main challenges for land managers and wildlife biologists is locating vernal pools in an efficient way. This challenge stems from their ephemeral nature, their presence under forest canopies and their generally small size. Because of these factors, field surveys and aerial imagery are insufficient for efficiently identifying vernal pools at any significant scale. However, lidar data is uniquely equipped to provide a means of identifying potential vernal pools, as lidar derived data has been shown to accurately represent bare earth surfaces, even in heavily forested areas. Knowing this, the White Mountain National Forest (WMNF) , through funding support from the Geospatial Technology and Applications Steering Committee (GeoTASC), and contracted through the Geospatial Technology and Applications Center (GTAC) is seeking the development of a remote sensing workflow that uses lidar derivatives to identify surface depressions that could potentially be vernal pools.

The exercises included in this guide provide specific instructions for performing a remote sensing workflow that identifies potential vernal pools in the White Mountain National Forest, i.e., isolated surface depressions that are likely to hold water. To complete the workflow, you will need access to ArcMap (version 10.1 or later).

# Methodology

## Existing Methods

The methodology for this workflow is based on a fusion of two articles: Wu et al. (2014) & Wu et al. (2015). The 2014 paper provides guidance on how to refine a set of topographic depressions to exclude those that do not meet the basic definition of a vernal pool. The 2015 paper introduces the concepts that underlie the custom Arc Toolbox used in this workflow.

To map vernal pools in eastern Massachusetts, Wu et al. (2014) employed a stochastic depression analysis that drew on lidar data and color-infrared (CIR) aerial photographs. The authors iteratively applied a depression filling algorithm to identify pixels from a 1-meter digital elevation model (DEM) that were classified as a depression 80% of the time. Depressions that did not fit the author's definition of a vernal pool were then removed based on their overlap with buffered NHD layers and their dominant land cover type (retained if forest, grassland, or wetland), which helped exclude points that were connected to water systems or were in urban/suburban areas.

Building on that earlier work, Wu et al. (2015) present a novel methodology for identifying and characterizing surface depressions on 1-meter DEMs based on the concept of pour contours, which are linear representations of pour points (see figure 1). The algorithm developed by the authors first identifies seed contours (A, C, and F in figure 1) on a DEM, which are closed contours containing a sink point, before analyzing the surrounding topography from the bottom up to identify nested depressions within the pour contour extent (e in figure 1(a)). The number of contours identified within a depression depends on user defined variables and the complexity of the depression itself. Wu et al (2015) applied this tool to a study area in central Minnesota and compared the results to previous methods, particularly those detailed in Wu et al. (2014). Results of the new method were shown to be less computationally demanding and much more detailed due to the ability to generate contours within a depression along with geometric statistics. In addition, the workflow is executed in ArcMap (10.2 or later), making the methods simpler to replicate. However, the results of these two methods were not compared in terms of accuracy. The count and total area of depressions were compared, but the author's primary conclusion was that the Contour Interval parameter was what impacts the total count and area of the outputs from their workflow (this is discussed further below).

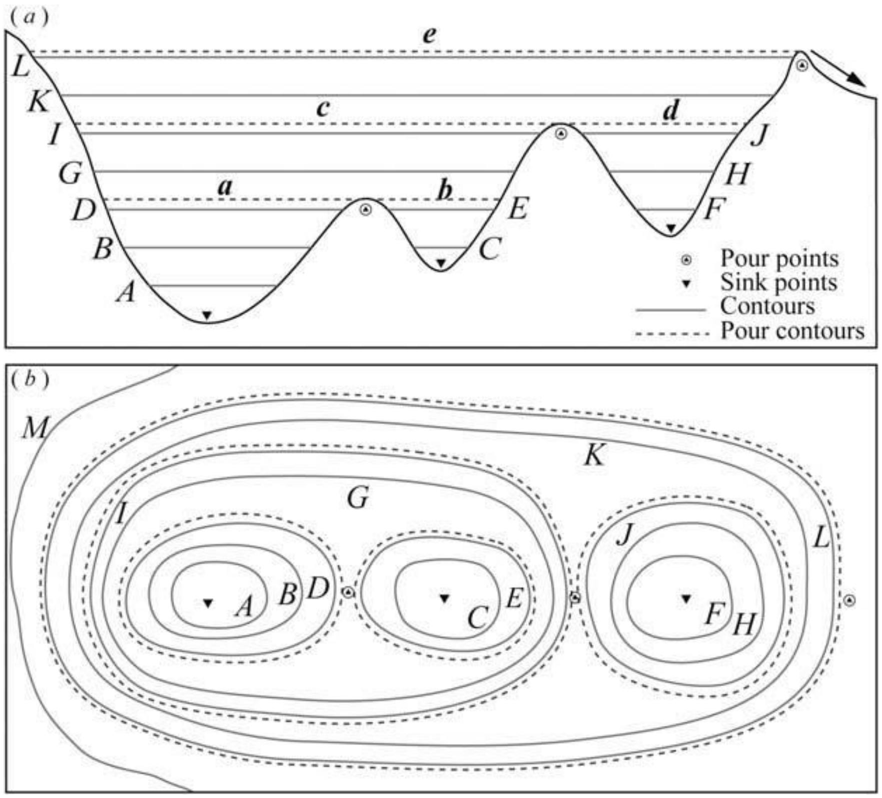


*Figure 1. A composite surface depressions with nested hierarchical structure: (a) longitudinal profile; (b) contour representaion (Wu et al. 2015, p.2045).*

## Remote Sensing Workflow

The geospatial tools that Wu et al. (2015) created for their surface depression identification workflow are contained within a publicly accessible Arc Toolbox called Contour Tree Tools. The two tools that represent step 1 and step 2 of the process are the **Extract Sink** tool and the **Identify Depression Hierarchy** tool respectively. To use these tools, all you need is a DEM, preferably with 1-meter spatial resolution, and ArcMap 10.2 or higher. Before running the Extract Sink tool, however, you need to use the Focal Statistics tool in ArcMap to “smooth” the DEM, which is intended to limit irregularities in the DEM caused by data noise.

With the smoothed DEM as the only data input, the Extract Sink tool extracts surface depressions that meet the two basic parameters of the tool: Depression Minimum Size and Buffer Distance. The Depression Minimum Size parameter allows the user to set a minimum threshold in meters squared. All sinks below this threshold will be excluded from the output dataset. The Buffer Distance parameter adds a user-defined buffer distance to sinks identified by the tool. By adding this buffer, the tool ensures that generated contours are closed and that the boundaries of sinks are not underestimated in the output.

The raster output from the Extract Sink tool is used as the input into the Identify Hierarchy Depression tool (step 2). The purpose of this tool is to take the sinks identified in the first step and to convert them into a shapefile format so that a hierarchy of contours can be established within each sink. Parameters for this tool include minimum area, minimum depth, contour interval and base contour. Minimum area and depth are rather self-explanatory parameters that you set in meters. The base contour sets the height (above sink bottom) at which the first contour will be established, and it should be left at its default of 0. The contour interval parameter determines the vertical spacing in meters between each contour line generated within sinks. This parameter is perhaps the most important, largely because it can directly affect the outputs more so than any other parameter and can override the minimum depth parameter. The minimum depth value has to be equal to or greater than the contour interval value. If the minimum depth threshold is lower than the contour interval, then the depth threshold won't be properly applied. The algorithm for this tool creates contours within each sink, and if the contour interval is greater than the depth of the sink the depression cannot be included in the output. For example, if the minimum depth is set to 0.5 meters and the contour interval is set to 1.0 meters, the outputs will only contain sinks with a depth of 1.0 meters or greater. This is because the contour interval value is also the minimum depth for which a depression will be included in the output. To mitigate this potential issue, it is recommended that you use a very small contour interval such as 0.1.

The output from step 2 contains attribute information on the extent and nesting of contours within a depression as well as information related to the storage volume, depth, perimeter and other geometric properties of surface depressions. The way these statistics are conveyed, however, is rather cryptic and convoluted. Therefore, the final exercise provides instructions on how to generate zonal statistics for each potential vernal pool (PVP) using the smoothed DEM and the shapefile output from step 2.

Before generating the final PVPs shapefile, it is necessary to eliminate sinks that are located in areas where natural vernal pools are not expected to be (e.g., immediately adjacent to a road). To accomplish this, the workflow incorporates a buffered National Hydrography Dataset (NHD), a buffered roads dataset and a National Land Cover Dataset (NLCD). By removing sinks that are located within the buffered areas or in the land cover categories that don't support natural vernal pools, you will be limiting the amount of errors of commission in the final PVP dataset. In some instances, other ecological data may be appropriate to incorporate here because it can help identify areas more likely to support vernal pools due to the area's ecological characteristics.

The final step in the workflow is to generate a variety of zonal statistics pertaining to the PVPs and to identify the X and Y coordinates in decimal degrees for each PVP. Once that is complete, the attribute table containing this information can be exported and opened in Excel. The coordinates provide more direct locations for survey efforts to identify indicator species that would confirm vernal pool habitat.

# Validation

With the final data table in hand, wildlife biologists can travel to PVP locations to verify whether or not a given PVP should be certified. They'll do this by inputting the X and Y coordinates into a GPS and assessing the PVP for certain characteristics that are outlined below.

## Vernal Pool Validation Process

This section outlines what qualifies a PVP to be labeled as a confirmed vernal pool (CVP). That is, what indicator species are biologists looking for in the field when they visit PVP locations and what other characteristics play a role in making this final determination? The terminology and criteria for a confirmed vernal pool vary based on the state in which the vernal pools are being identified. The criteria discussed here are based on New Hampshire's "Identification and Documentation of Vernal Pools in New Hampshire" (2004) document.

The characteristics that scientists focus on when they go out into the field to verify a PVP are broken into biological and physical characteristics. The biological characteristics include "evidence of amphibian breeding" and "the presence of vernal pool indicator species" (Tappan and Marchand 2004). The indicator species in this instance are those that rely on vernal pools for a portion or all of their life cycle. The six indicator species for vernal pools in New Hampshire are:

| | |
|---|---|
| -Fairy shrimp | -Jefferson salamander |
| -Spotted salamander (figures 2 and 3 ) | -Marbled salamander |
| -Blue-spotted salamander | -Wood frog |

One of the physical characteristics that indicates a vernal pool is that the pool is isolated from permanently flowing water (Tappan and Marchand (2004)). Intermittent streams may be present for portions of the year, but the pool has to be isolated for some of the year. The second qualifying physical characteristic is that the pool has distinct dry and wet cycles; the wet cycle is characterized by at least 2 months of water content in the spring and/or summer and the dry cycle is indicated by evidence of the pool drying up or no fish being present. During extremely dry years, a CVP may not contain water and support lifecycle functions.

The WMNF survey form (see Appendix 1-<u>will be added later</u>) that is used to assess a PVPs has several categories that surveyors need to fill out. Some categories are reserved for describing the physical environment, including the landscape setting, surrounding forest type, and overstory density. Other categories describe the vernal pool in terms of its size, estimated wet and dry periods, and the species present in the pool. The species information includes fields for the egg masses identified in the pool.

*Figure 2: Spotted Salamander eggs found in a vernal pool (Image Credit: Leighlan Prout)*

*Figure 3: Spotted Salamander (Image Credit: Peter Paplanus, http://bit.ly/2fw5Avj)*

*Figure 4: Vernal pool on the WMNF (Image Credit: Leighlan Prout)*

# Data Related Topics

The data for this workflow was acquired and prepared for you for the most part. But what if you want to recreate this workflow using your own data? The first section outlines the data provided to you and the folder structure used to organize the data and the outputs. The second section includes information that will help you replicate this workflow using your own dataset, including how to download the appropriate data, project rasters and vectors into the same coordinate system, and maintain a consistent set of raster properties.

## Folder Content and Structure

The VernalPools.zip needs to be unzipped before you can begin using the data. If you don't already have it, you will need to download 7-Zip, which has Tech Approval from the Forest Service. Once you have installed 7-Zip, you can right click the .zip folder and select "Extract All" or hover over the 7-Zip option and choose between "Extract Here" or "Extract Files." "Extract All" and "Extract Here" will unzip the folders in its current folder, while choosing the "Extract Files" option will allow the user to specify a specific folder location to place the data in. ReadMe.txt files are included in the major folders and they provide basic details about the contents of each folder. Below is a basic outline of the Folder Structure.

- VernalPools
    - Data—*this contains all necessary raster and vector data for this workflow.*

        - DEM
        - Refinement_Data
            - ELT
            - NHD
            - NLCD
            - Roads
        - StudyArea
    - Exercises—*this includes 3 step-by-step exercises that walk you through the workflow.*
    - Outputs—*this is where you will save data that you manipulate in the workflow.*
        - DEM
        - Final_Outputs
        - Refinement_Data
            - ELT
            - NHD
            - NLCD
            - Roads
        - Step1
        - Step2
    - Contour Tree Tools Public.tbx (Arc Toolbox)—*this is the toolbox used in the workflow.*

## Accessing Data on Your Own

### Roads

To find the most up to date infrastructure data for your given study area, the first step should be to contact the GIS coordinator for your respective National Forest.

### National Land Cover Database

The National Land Cover Dataset (NLCD) provides comprehensive information at a 30-meter resolution about land cover for the entire U.S. The most recent NLCD is available for 2011, but should be available for 2016 in the near future. This dataset and other earlier versions can be found at common geospatial data websites such as The National Map (https://viewer.nationalmap.gov/basic/) and the Geospatial Data Gateway (https://datagateway.nrcs.usda.gov/). The dataset provided for this user guide covers all of New Hampshire and was ordered from the Geospatial Data Gateway.

### National Hydrography Dataset

The National Hydrography Dataset (NHD) is a free dataset that offers comprehensive information about the location of water features across the entire U.S. Like the NLCD, the NHD can be accessed from The National Map (https://viewer.nationalmap.gov/basic/) and the Geospatial Data Gateway (https://datagateway.nrcs.usda.gov/).

### ELT (Ecological Land Types)

This is a dataset created by researchers at the WMNF. When working in another National Forest, you should contact scientists on the forest that may have data related to vernal pools and the ecological characteristics likely to support vernal pools. The main contacts that provided the ELT data for this project have specialties in wildlife, hydrology and soil science. For this workflow, there is an optional step for selecting PVPs within ELTs likely to support vernal pools. This step is optional both because it could exclude legitimate vernal pools by ignoring PVPs outside of these ELTs and because not all Forests data on the ELTs that support vernal pools. The instructions provided for integrating ELTs into the workflow would work equally as well with a different dataset, such as Land Type Associations (LTAs).

# Data Properties

## Projections

One of the most important steps to undertake before processing any data is normalizing projections for all your datasets. ArcMap has the capacity to mitigate many of the issues associated with projections because of its 'project on-the-fly' ability, but it is common practice to project all datasets into the same coordinate system before performing analysis. Typically, geospatial and remote sensing specialists use a UTM projection that corresponds to their given study area. In the conterminous U.S., UTM zones range from UTM zone 10N to UTM zone 19N. Before you do any analysis with your datasets, use the basic Project or Project Raster tools in the Arc Toolbox to normalize the projections of all of your data. This will help avoid any potential processing issues down the line.

The ideal way to project data is to identify a dataset you have with the desired projection information and to point to that dataset when you use the Project tool (ArcMap) on one of your other datasets. To do this, you can import the projection information from the desired dataset or you can select the desired dataset's projection information if it is loaded in your ArcMap session. In Figure 5, the red arrow points to the drop down menu you would click to select the Import option. You would then navigate to the location of the dataset with the desired projection information and import it. The green arrow is pointing to the Layers dropdown where you can select the projection information from a layer that is already loaded into your ArcMap.

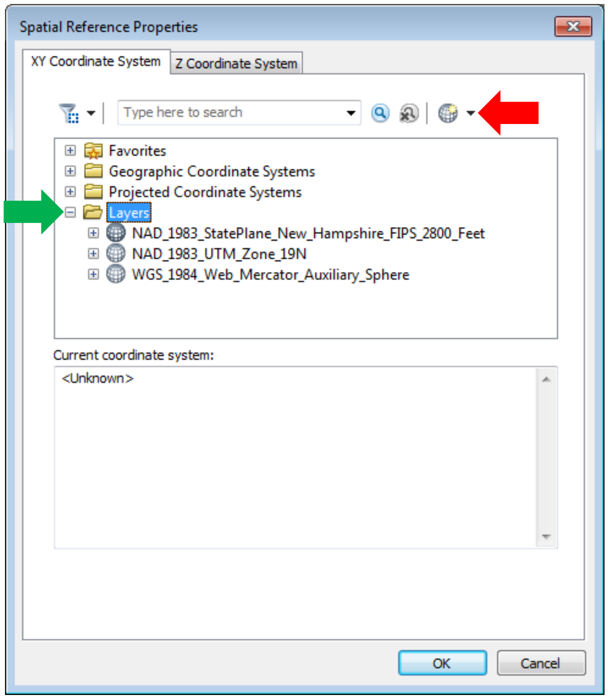


*Figure 5: Spatial Reference Properties in ArcMap*

## Raster Data Properties

While many geospatial technology users understand and are well versed in the importance of data projection, raster data properties are another pivotal component to understand prior to beginning a project. The initial lidar-derived DEM tiles that were provided by WMNF were floating point, 32 bit data (see Figure 6). What does this mean? Floating point is identified in the Pixel Type category of the raster properties, and it means that this raster dataset contains decimal values. The alternative is integer, which, of course, means that the data is conveyed in whole number values and is not as specific/nuanced as the floating point data. The pixel depth, which is 32 bit in the Figure 6, refers to the radiometric resolution of the raster data. The majority of raster products these days are captured with this resolution, but are often recalibrated to 16 or even 8 bit resolution in order to cut down on processing time. For this workflow, you will maintain the same raster information as shown in Figure 6.

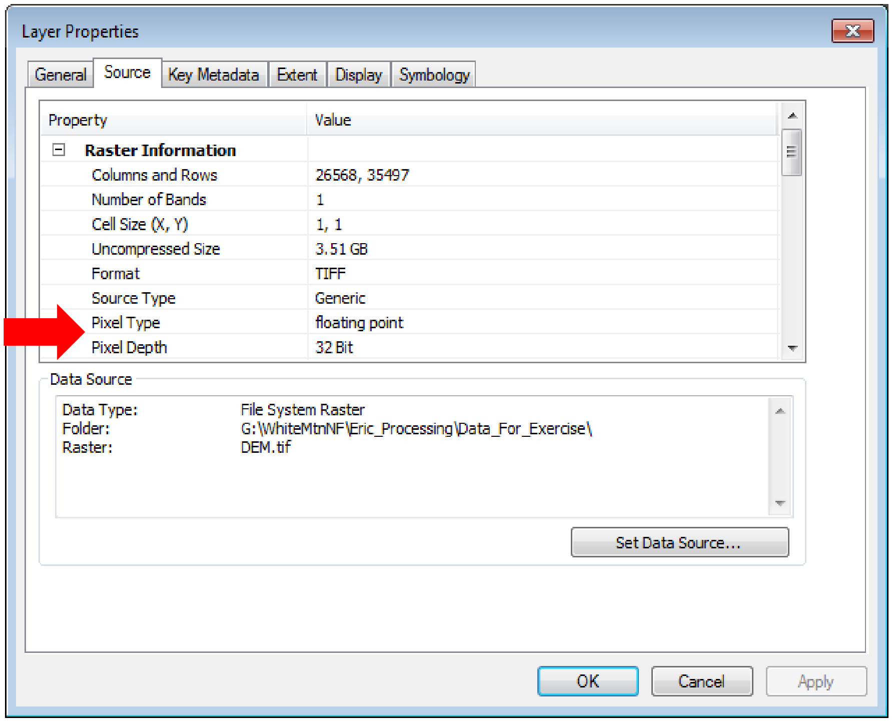


*Figure 6: Layer Properties, Source Tab in ArcMap*

If a raster does not have the desired pixel type or depth, you can use the **Copy Raster** tool (see Figure 7) to make a new version of that raster with the desired pixel depth and type. The **Pixel Type (optional)** parameter allows you to select from a variety of pixel type and depth combinations. If you select the **Show Help >>** button at the bottom of the tool's window, help information is displayed pertaining to the tool's general purpose, the purpose of each parameter, and what the available options for each parameter signify.

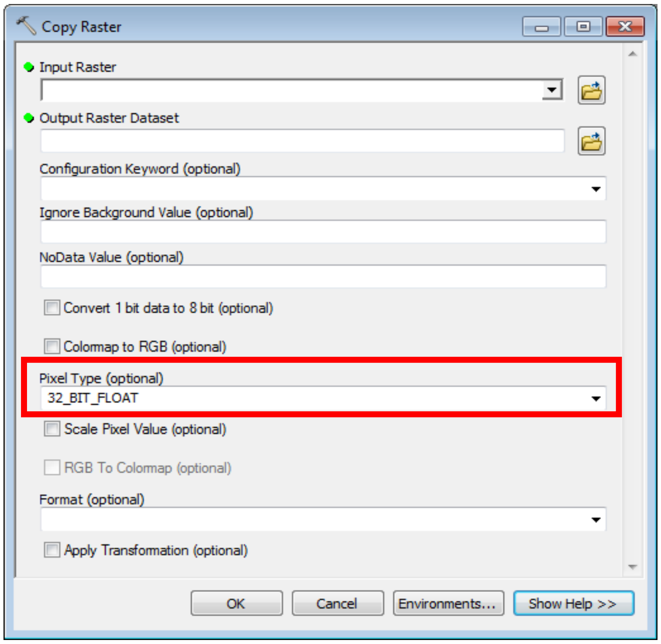


*Figure 7: Copy Raster tool in ArcMap*

# Potential Errors/ Issues

The primary issue encountered when developing this workflow occurred when we attempted to rerun the Identify Depression Hierarchy tool using the same output folder as a previous attempt. This is mentioned in the exercises, but it is worth repeating that every time you run either the step 1 or step 2 of the tool, you will need to create a new folder for the outputs. The issues come from the default outputs from each tool that the user can't control; when you try to save over the outputs of another iteration, you risk crashing ArcMap or receiving an error from the process.

[I am currently working with the researcher who created the toolbox to figure out a bug with the Identify Depression Hierarchy tool. The issue is that the Minimum Depression parameter in the tool does not work properly. It includes depressions below the depth threshold that have Min and Max values that cross a whole number value. For example, a depression with a Minimum of 38.9999 and a Max of 39.1 would be included in the outputs even if the minimum depth threshold is set to .3048. This is because the algorithm isn't properly recognizing the decimals; instead, it is recognizing the integer change and interpreting that as satisfactorily above the depth threshold. This won't be detrimental to the final dataset because we can always manually remove the depressions that are below the depth threshold of .3048]

# References

Tappan, A., Marchand, M., 2004 "Identification and Documentation of Vernal Pools in New Hampshire." *New Hampshire Fish and Game Department Nongame and Endangered Wildlife Program*.

Wu, Q.; Lane, C.; & Liu, H. 2014. An effective method for detecting potential woodland vernal pools using high-resolution LiDAR data and aerial imagery. Remote Sensing. 6(11): 11444-11467.

Wu, Q.; Liu, H.; Wang, S.; Yu, B.; Beck, R.; & Hinkel, K. 2015. A localized contour tree method for deriving geometric and topological properties of complex surface depressions based on high-resolution topographical

# Photo Sources:

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