Michigan Geological Survey

ArcGIS Pro Custom Tools Training

MGS Mapping Projects

Basic Requirements:

ArcGIS Pro with all extensions
Access to MGS Cross-Section Toolbox

Data Input Requirements:

The following is a list of datasets that are used for input into custom tools created by the Michigan Geological Survey for creating cross-section views. ****All files are required for the listed tool unless otherwise noted**:**

File Input	File Type	Fields/Data Types	Tool	Description
Cross-Section File Geodatabase	File Geodatabase	NA	MGS – Cross-Section Tool (All Steps); MGS – Cross-Section Tool (Boreholes); MGS – Cross-Section Tool (Segment Profiles); MGS – Cross-Section Tool (Grid Lines)	The file geodatabase to store all the cross-section view files. ***NOTE*: Cannot be the same as default geodatabase.**
Cross-Section Line(s) - **XSEC Field** - **DIRECTION Field**	Polyline Feature Class	XSEC: Text DIRECTION: Text	MGS – Cross-Section Tool (All Steps); MGS – Cross-Section Tool (Boreholes); MGS – Cross-Section Tool (Segment Profiles); MGS – Cross-Section Tool (Grid Lines)	The line feature that contains the cross-section lines. Needs to contain two fields: XSEC and DIRECTION (See Drawing Cross-Section Lines for more detail)
Elevation Units	Text List	NA	MGS – Cross-Section Tool (All Steps); MGS – Cross-Section Tool (Boreholes); MGS – Cross-Section Tool (Segment Profiles); MGS – Cross-Section Tool (Grid Lines)	The elevation units of **every feature in the analysis.** This includes: Surface topography Bedrock Surface topography Groundwater Surface topography Borehole elevations & depths Lithology Table & Screen Table depths
Surface Topography DEM	Raster	Stored in File Geodatabase	MGS – Cross-Section Tool (All Steps); MGS – Cross-Section Tool (Boreholes); MGS – Cross-Section Tool (Grid Lines); MGS – Data Formatting; MGS – Project Creation Tool	The surficial topography DEM raster.
Bedrock Surface Topography DEM (OPTIONAL)	Raster	Stored in File Geodatabase	MGS – Cross-Section Tool (All Steps); MGS – Cross-Section Tool (Segment Profiles);	The bedrock surface topography DEM raster. Generated from bedrock contacts of wells (Previously generated data by user)
Groundwater Surface Topography DEM(s) (OPTIONAL)	Raster	Stored in File Geodatabase	MGS – Cross-Section Tool (All Steps); MGS – Cross-Section Tool (Segment Profiles);	The groundwater surface topography DEM raster(s). Generated from static water level measurements from wells (Previously generated by user)
Lithology Table	Table View	Relate ID: Any Field Type Depth Top: Double Depth Bottom: Double	MGS – Cross-Section Tool (All Steps); MGS – Cross-Section Tool (Boreholes); MGS – Data Reformatting; MGS – Project Creation Tool	Table containing all the lithology units for a well. Can be either user-generated lithology or MGS formatted table.

Borehole Location Points	Points Feature Class	Relate ID: Any Field Type Total Depth: Double Depth to Bedrock: Double (*Optional*) Construction Date: Date (*Optional*)	MGS – Cross-Section Tool (All Steps); MGS – Cross-Section Tool (Boreholes); MGS – Cross-Section Tool (Segment Profiles); MGS – Data Reformatting; MGS – Project Creation Tool	Points feature class for well locations. Can be either user-generated points or MGS formatted points.
Screens Table (OPTIONAL)	Table View	Relate ID: Any Field Type Depth Top: Double Depth Bottom: Double	MGS – Cross-Section Tool (All Steps); MGS – Cross-Section Tool (Boreholes)	Table containing screen intervals for wells. Can be either user-generated or MGS formatted table.

Quick Note for Data and Layers:

It is important to consider data quality before data collection. For example, much of the Wellogic well log data that is available for use can be incomplete or incorrect. We don't want to use these data in our calculations because the accuracy of these datasets will be in question and may not yield the correct interpretation. It is also important to review datasets before using them. The same goes for DEM data and any other data that we download.

The processing time for all tools is directly tied to the size of the input datasets. Very large datasets (state-wide or larger) can take days to finish processing. For the quickest results clip your data down to only what you need.

Note: These tools were designed specifically for MGS mapping projects. Each user's case will vary for their project needs.

The data produced from the cross-section tools are as follows:

- A dataset for each cross-section line with a custom Cross-Section Projection assigned to it for each subsequent dataset. Each dataset includes the following:

File Output	Description	File Type
Surface Topography Profile	Profile view of the surface topography DEM. Named as XSEC_{Cross Section Name}_TOPO_{V.E.}x	Polyline Feature Class
Borehole Sticks with Lithology Segmentation	Profile view of the boreholes with segmented units based on position of lithology along borehole depths. Named as XSEC_{Cross Section Name}_LITH_{V.E.}x	Either Polyline Feature Class or Polygon Feature Class (Depends on user choice)
Screen Sticks	Profile view of the screened intervals in the wells. Named as XSEC_{Cross Section Name}_SCRNS_{V.E.}x	Either Polyline Feature Class or Polygon Feature Class (Depends on user choice)
Bedrock Surface Topography Profile (if provided)	Profile view of the bedrock surface topography DEM. Named as XSEC_{Cross Section Name}_BDRK_{V.E.}x	Polyline Feature Class
Groundwater Surface Topography Profile(s) (if provided)	Profile view of the groundwater surface topography DEM(s). Named as XSEC_{Cross Section Name}_{Years analyzed}_{V.E.}x	Polyline Feature Class

Cross-Section Grid	The grid-lines profile view that is built around all viewable datasets. Named as XSEC_{Cross Section Name}_{V.E.}x_Frame_{Elevation Units}	Polyline Feature Class
Cross-Section Labels	The labels for the grid-lines to display elevation increments and distance markers. Named as XSEC_{Cross Section Name}_{V.E.}x_Labels_{Elevation Units}	Points Feature Class

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OPTION 1: Cross-Section Only (Wellogic Data)

Step 1: Setup the workspace and prepare the DEM

1. Begin by opening a new map in ArcGIS Pro.
2. Obtain the appropriate elevation data and place it into the map (1-meter-resolution DEMs are recommended for areas less than 10 mi^2 in size). Merge DEMs as necessary to make a single raster file. **Make sure the elevation unit for the DEM is in feet for the next step.**
3. Next, ensure you have a proper polygon to encase your project area. Existing township or county boundaries work well, or you can make a custom polygon to suit the project's needs.
4. Acquire the Wellogic water well data for the project. Download all the counties that are needed for the extent of the project area. If there are multiple counties in the project area, merge the water well points together into one shapefile as well as the lithology tables.
    a. Note: The tools are designed to only work with well data in this specific format.
5. Add the *MGS_XSEC_TOOLS_v2.atbx* toolbox to your project by right clicking on *Toolboxes* in the catalog, navigating to where you stored the downloaded tools, and selecting the toolbox.

Step 2: Data Formatting

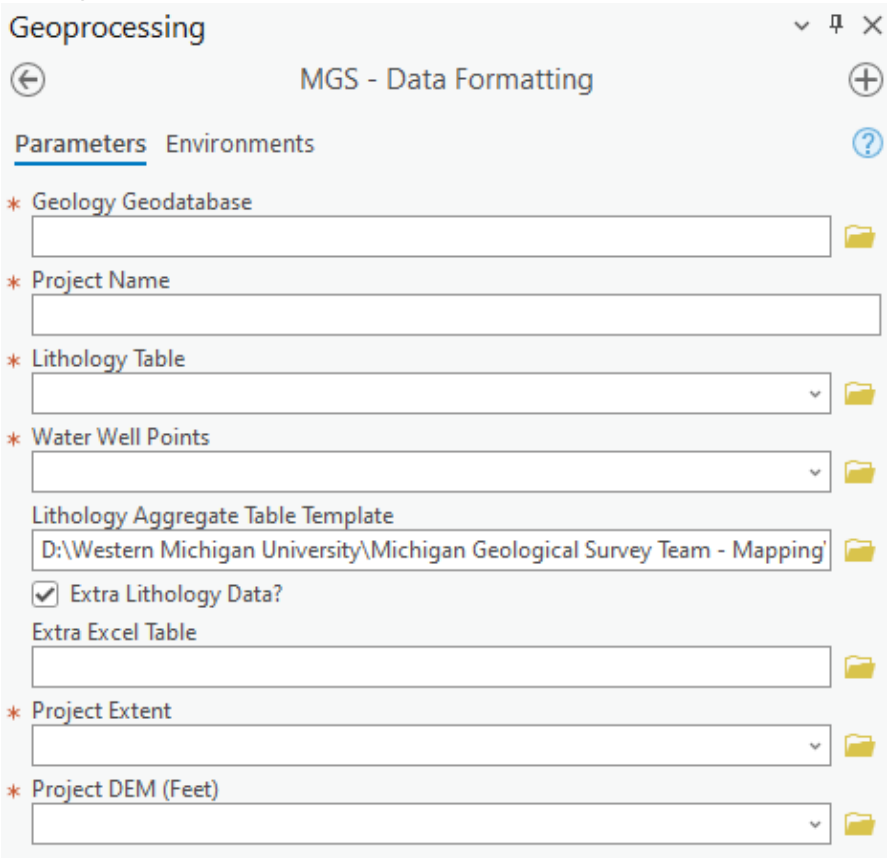

Figure 1: *Screenshot of MGS - Data Formatting custom Python script in the ArcGIS Pro software.*

1. Open the Data Formatting Tools inside the MGS toolbox and select the "MGS – Data Formatting" tool. See in **Figure 1.**

2. Create/Select a geology geodatabase for the project. ****IMPORTANT NOTE: This should be separate from your default geodatabase.****
3. Provide the name of the project. *No special characters or spaces except for underscores and cannot begin with a number.*
4. Select the Wellogic lithology table and water well points.
5. Provide the lithology aggregate Excel spreadsheet.
    a. Provided in the cross-section tools package.
6. Select the polygon used for the project's extent.
    a. Note: Projects larger than one county will take significantly longer to process.
7. Select the project DEM.

Step 3: Groundwater Level Raster Creation (Optional)

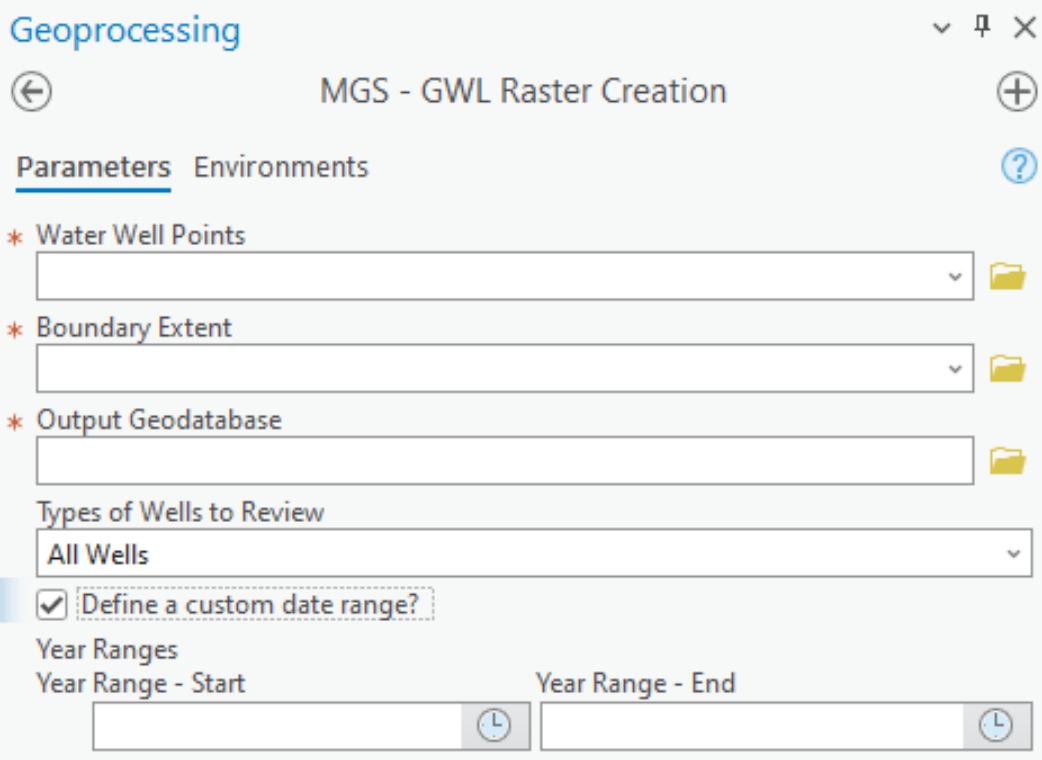

***Figure 2**: Screenshot of MGS – GWL Raster Creation custom Python script in the ArcGIS Pro software.*

This tool is used to generate groundwater rasters across several year increments to see how it changes over time. This can also be used to delineate between bedrock and drift aquifer systems if the need arises. These are later used in the cross-section tool to predict water levels along the cross-section.

1. Select "**MGS – Raster Creation**" tool below the Data Formatting tool seen in *Figure 2*.
2. Once the tool is open, define the wells to be used in the analysis. These features must have gone through the Project Creation* tool or the Data Formatting tool (see discussion of Data Formatting tool). **For more information on the Project Creation Tool, review the Wellogic Data training document – ArcGIS_Pro_TrainingDocument_WellogicData_20240507**
3. Define the desired boundary of the rasters. You can use the previously defined project extent or choose a new one.

4. Select the geodatabase where you would like to store the output rasters.
5. Select the types of wells to review.
    a. **All Wells** = Every well in the feature class.
    b. **Bedrock Wells** = All the wells designated as "Bedrock Aquifers"
    c. **Drift Wells** = All the wells designated as "Glacial Drift Aquifers"
6. Define a custom date range if needed.
    a. Note: The standard format will be a groundwater surface encompassing all wells drilled in the area, all wells drilled before 2000, and 5-year increments after 2000 to the current year.

Step 4: Drawing Cross-Section Lines

1. Before using the cross-section tool, you must create cross-section lines on your map. Start by creating a new Polyline feature class in your default geodatabase.
2. Create two text string fields within the feature class called **"XSEC"** and **"DIRECTION"** (case sensitive).
3. Use the **"XSEC"** to name the cross-section(s).
4. In the **"DIRECTION"** field, you must specify the quadrant you would like the cross-section to start analyzing (or drawing) from. You must use one of the following codes below in order to define the drawing direction:
    a. If the direction is labeled as W-E, NW-SE, or E-W, the script will be reading the cross-section from the **Northwest quadrant.**
    b. If the direction is labeled SW-NE, S-N, or N-S, the script will be reading the cross-section from the **Southwest quadrant.**
    c. If the direction is labeled as NE-SW, the script will be reading the cross-section from the **Northeast quadrant.**
    d. If the direction is labeled as SE-NW, the script will be reading the cross-section from the **Southeast quadrant.**

    ****IMPORTANT NOTE: Without the addition of these fields the tool will fail.****
5. Draw all necessary cross-section lines and fill out the required information in the attribute table. ***DISCLAIMER*** The number of wells will determine the length of time needed to process the cross-section lines. The length of the line will also increase the processing time.

Step 5: Cross-Section Tool (All Steps)

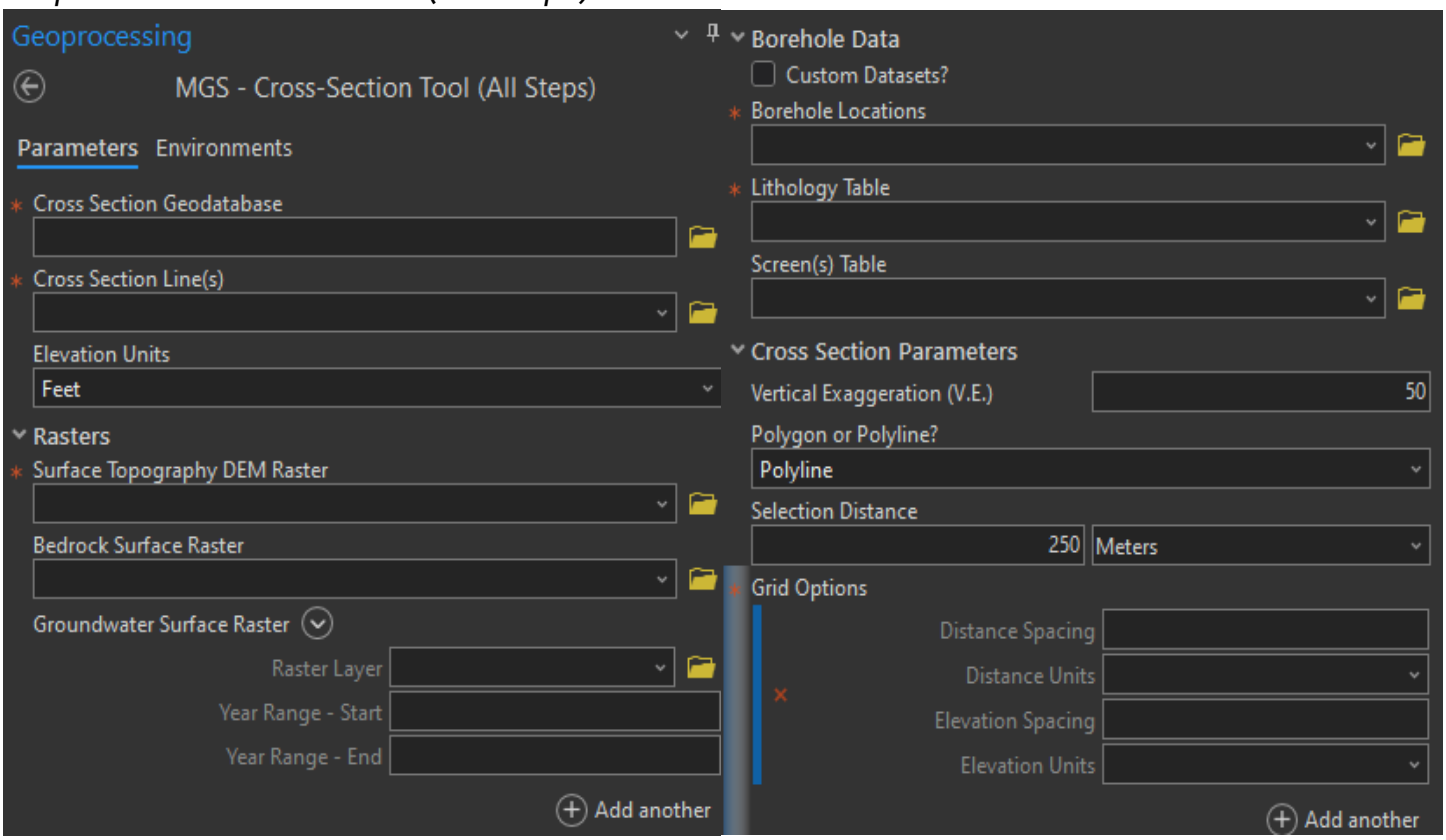

Figure 3: *Screenshot of MGS – Cross-Section Tool (All Steps) custom Python script in the ArcGIS Pro software for Wellogic input.*

1. Create a cross-section geodatabase for the cross-section files.
    a. Warning: Files may be erased if the files are placed in an existing geodatabase or if the tool is run again in the same geodatabase.
    b. ****IMPORTANT NOTE: This geodatabase must be separate from your default geodatabase or the tool may fail.****
2. Open the "MGS – Cross-Section Tool (All Steps) under the Cross Section Tools Toolset
    a. Several of the steps have been separated out of the "All Steps" script to be repeated upon changes made to other datasets. These include "Borehole Only", "Segment Profiles Only", and "Grid Line Creation Only". Remember, default names will be overwritten when running these tools. If you wish to keep any of your original outputs then you must rename them.
3. Select the newly created cross-section geodatabase.
4. Select the cross-section feature class.
5. Select the elevation units for **all your features.** The default is set to feet units.
6. Select the surface DEM used for the project.
7. Select the bedrock surface raster and the groundwater surface raster(s) (Optional)
    a. Note for Cross-Sections: These surfaces are generated in sections of confidence (solid line) and inferred (dashed lines). Anomalies in the groundwater levels often come from areas where there are no wells drilled within the selected time interval to support the predicted groundwater level.

   b. For groundwater levels, input the years you would like included in the analysis for the confidence of the surface. These years should match the years of the wells that were selected to create the groundwater raster. If left blank this will include all years.
8. Select the reformatted water well points.
9. Select the reformatted Wellogic lithology table.
10. Select the screen table created by the data formatting tool *(Optional)*
11. Choose your vertical exaggeration (V.E.).
    a. 50 – 100x Recommended. Default is 50.
12. Choose whether you would like the borehole lithologies to be represented by polylines or polygons.
    a. Note: Polylines are easier to read on dense cross-sections.
13. Choose how far away from the cross-section line wells should be selected to be included in the cross-section.
    a. 250 Meters is recommended and is the default.
14. Choose your grid spacing for the cross-section frame.
    a. Recommendation if Elevation Units are in Feet = Distance: 2000 feet and Elevation: 50 feet.
15. Run the tool.
16. Complete your layout. See completed cross-section in **Figure 4**.

OPTION 2: Cross-Section Only (Custom Datasets)

The following instructions are for creating cross-sections from custom datasets that were not output from either the project creation tool or the data formatting tool.

Step 1: Prepare the Workspace

1. Begin by opening a new map in ArcGIS Pro.
2. Obtain the appropriate elevation data (1-meter-resolution DEMs are recommended for areas less than 10 mi^2 in size). Merge DEMs, if necessary, to make a single raster file.
3. Create a geodatabase specifically for storing the cross-section files. ****IMPORTANT NOTE: This must be separate from your default geodatabase or the tool may fail.****
4. Add the *MGS_XSEC_TOOLS_v2.atbx* toolbox to your project by right clicking on *Toolboxes* in the catalog, navigating to where you stored the downloaded tools, and selecting the toolbox.

Step 2: Prepare Inputs

****IMPORTANT NOTE: All files used for tool inputs (other than rasters) must be in geodatabases****

1. Borehole Data
   ****IMPORTANT NOTE: Locations, lithology, and screens must all be separate files or the tool will fail. If the information for one or more of these inputs is in a single file, copy it to use as additional input****
   a. Borehole Locations
      i. This must be a point feature layer in a geodatabase.
      ii. Fields
         1. Relate Field (ID shared between all the tables with well information)
         2. Depth Drilled (Data Type-Double)
         3. Depth to Bedrock (Data Type-Double) *(Optional)*

4. Completion Date (Data Type-Date) *(Optional)*

b. Lithology Table
   i. Fields
      1. Relate Field
      2. Depth: Top (Data Type-Double)
      3. Depth: Bottom (Data Type-Double)

c. Screens Table *(Optional)*
   i. Fields
      1. Relate Field
      2. Depth: Top (Data Type-Double)
      3. Depth: Bottom (Data Type-Double)

2. Surface Rasters *(Optional)*
   a. Bedrock Surface
   b. Groundwater Surface(s)

Step 3: Drawing Cross-Section Lines

1. Before using the cross-section tool, you must create cross-section lines on your map. Start by creating a new Polyline feature class in your default geodatabase.
2. Create two text string fields within the feature class called “XSEC” and “DIRECTION” (case sensitive).
3. Use the “XSEC” to name the cross-section(s).
4. In the “DIRECTION” field, you must specify the quadrant you would like the cross-section to start analyzing (or drawing) from. You must use one of the following codes below in order to define the drawing direction:
   a. If the direction is labeled as W-E, NW-SE, or E-W, the script will be reading the cross-section from the **Northwest quadrant.**
   b. If the direction is labeled SW-NE, S-N, or N-S, the script will be reading the cross-section from the **Southwest quadrant.**
   c. If the direction is labeled as NE-SW, the script will be reading the cross-section from the **Northeast quadrant.**
   d. If the direction is labeled as SE-NW, the script will be reading the cross-section from the **Southeast quadrant.**
5. Draw all necessary cross-section lines and fill out the required information in the attribute table.
6. ***DISCLAIMER*** The number of wells will determine the length of time needed to process the cross-section lines. The length of the line will also increase the processing time.

Step 4: Cross-Section Tool (All Steps)

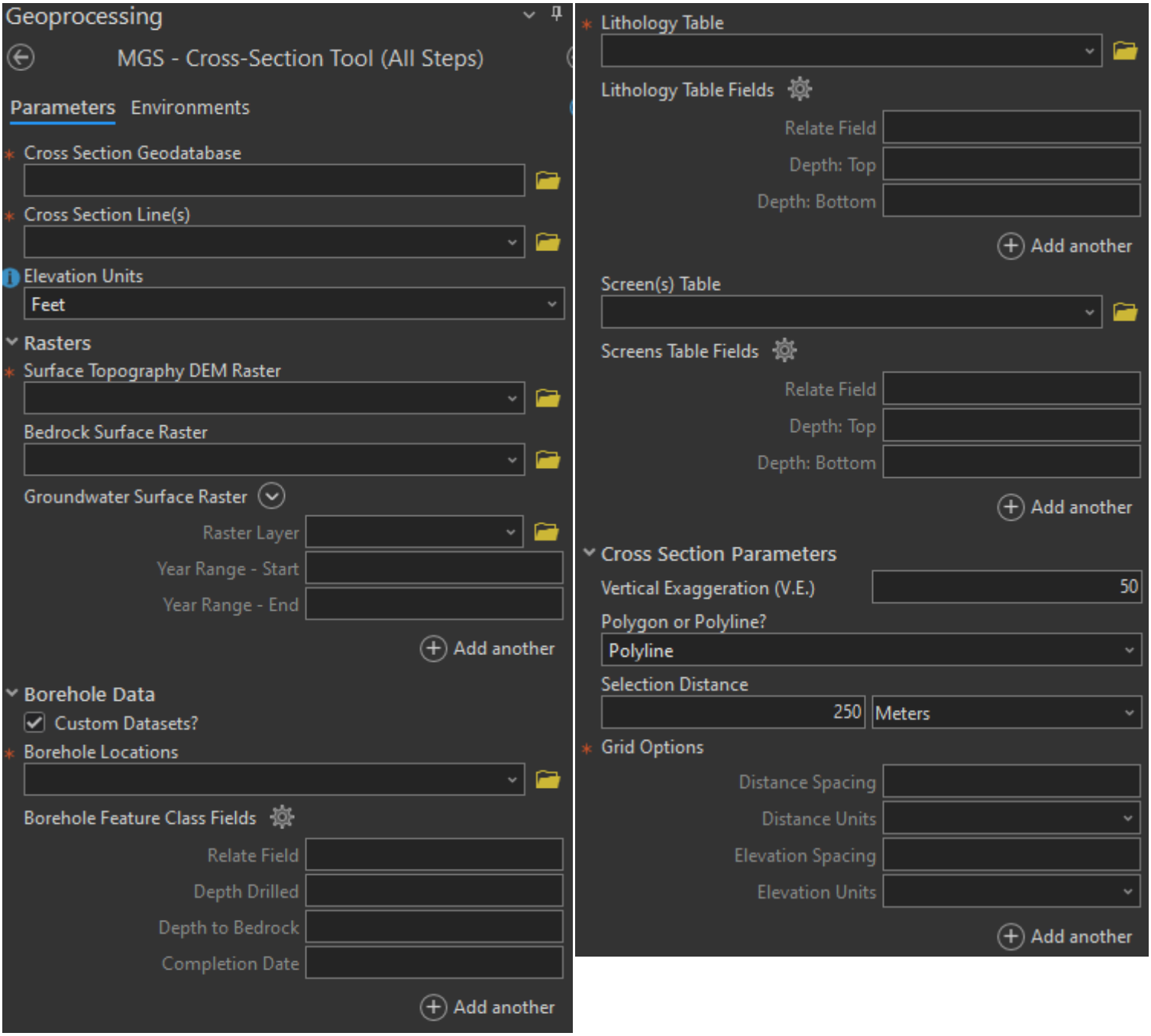

Figure 4: *Screenshot of MGS – Cross-Section Tool (All Steps) custom Python script in the ArcGIS Pro software.*

1. Open the "MGS – Cross-Section Tool (All Steps) under the Cross Section Tools Toolset
    a. Several of the steps have been separated out of the "All Steps" script to be repeated upon changes made to other datasets. These include "Borehole Only", "Segment Profiles Only", and "Grid Line Creation Only". These can be useful for making adjustments to be specific pieces of your cross-sections without having to run the All-Steps tool. Remember, default names will

be overwritten when running these tools. If you wish to keep any of your initial outputs then you must rename them.

2. Select the newly created cross-section geodatabase.
3. Select the cross-section feature class.
4. Select the elevation units for **all your features.** The default is set to feet units.
5. Select the surface DEM used for the project.
6. Select the bedrock surface raster and the groundwater surface raster(s) **(Optional)**
    a. Note for Cross-Sections: These surfaces are generated in sections of confidence (solid line) and inferred (dashed lines). Anomalies in the groundwater levels often come from areas where there are no wells drilled within the selected time interval to support the predicted groundwater level.
    b. For groundwater levels, input the years you would like included in the analysis for the confidence of the surface. These years should match the years of the wells that were selected to create the groundwater raster. If left blank this will include all years.
7. Select the "Custom Datasets" check box.
8. Borehole Data

    ****IMPORTANT NOTE: Borehole Locations, Lithology**

    a. Provide the Borehole Locations for your map area.
        i. Fields
            1. Relate Field (ID shared between all the tables with well information)
            2. Depth Drilled (Data Type-Double)
            3. Depth to Bedrock (Data Type-Double) **(Optional)**
            4. Completion Date (Data Type-Date) **(Optional)**
    b. Select the lithology table.
        i. Fields
            1. Relate Field
            2. Depth: Top (Data Type-Double)
            3. Depth: Bottom (Data Type-Double)
    c. Select the screen table created by the data formatting tool **(Optional)**
        i. Fields
            1. Relate Field
            2. Depth: Top (Data Type-Double)
            3. Depth: Bottom (Data Type-Double)
9. Cross Section Parameters
    a. Choose your vertical exaggeration (V.E.).
        i. 50 – 100x Recommended. Default is 50.
    b. Choose whether you would like the borehole lithologies to be represented by polylines or polygons.
        i. Note: Polylines are easier to read on dense cross-sections.
    c. Choose how far away wells should be selected to be included in the cross-section.
        i. 250 Meters is recommended and is the default.
    d. Choose your grid spacing for the cross-section frame.
        i. Recommendation if Elevation Units are in Feet = Distance: 2000 feet and Elevation: 50 feet.
    e. Run the tool.
    f. Complete your layout. See completed cross-section in **Figure 5.**

Additional Notes

The *Templates* folder incudes several formatting and symbology files for symbolizing several of the toolboxes outputs which include:

GWL Colors

- Function: Folder containing several symbologies for different well types and time periods of groundwater levels

Cross_Section_CoordinateSystem.prj

- Function: Custom coordinate system for the cross-sections. This is hard-coded into the scripts and not required to run them but it may be necessary to add additional layers to the cross-section that were not created using the MGS toolbox

LithologyClasses_YYYYMMDD.xlsx

- Function: MGS's system for simplyfying Wellogic data into aggregated lithology classes. This file is required for running both the Project Creation tool and the Data Reformatting tool

LithSticks_UPDATE_YYYYMMDD.lyrx

- Function: Symbology for borehole lines

NAD_1983_Hotine_Oblique_Mercator_Azimuth_Natural_Origin.prj

- Function: Custom coordinate system for the project creation tool. This is hard-coded into the scripts and not required to run them but it may be necessary to add additional layers to the project that were not created using the MGS toolbox

ScreensSticks_UPDATED_20240125.lyrx

- Function: Symbology for screen lines

Figure 5: Example final cross-section layout view (Credit: Garrett Ringle)