University of Exeter

Centre for Resilience Environment, Water and Waste

SCORe Arc Tool Manual

Sewer Catchment Opportunities for Resilience Tool for identifying areas for Nature-based Solutions

CaSTCo

Making sure that people count at the heart of rivers' recovery

South West Water

Ofwat

This tool was developed by Dr Jessica Kitch for the CaSTCo USTU project with the University of Exeter. For more information on CaSTCo visit https://castco.org/

This tool was built and developed using ArcGIS Pro version 3.3.0

Using a different version could result in the tool looking different and some aspects of the tool not working.

The tool will be shared on GitHub (https://github.com/exeter-creww/CaSTCo-USTU-SCORe-Tool). Any changes and updates will be available here.

Contents

1. Introduction

Storm overflows pose a significant environmental challenge (Perry *et al.*, 2024; Muleta and Knolmar, 2025). In the United Kingdom there has been an increase in political and regulatory pressure to reduce the frequency of discharge events. The Storm Overflows Discharge Reduction Plan (Defra, 2023) for England sets stringent targets for water companies to reduce discharges from storm overflows. The final target of this plan is to not permit any storm overflows to discharge above an average of 10 rainfall events by the year 2050.

Traditionally, water companies have employed hard-engineered or 'grey' solutions, such as storm tanks, in order to reduce storm overflows. Now, there is growing recognition that green or nature-based solutions (NbS) can deliver much wider benefits, for example in terms of carbon storage, biodiversity and amenity value. Often when considering green solutions there appears to be little consideration of the potential contribution of runoff from large permeable areas, such as agricultural land, to combined sewer networks. This is partially because there is a lack of understanding with regards to how permeable areas could contribute runoff to combined sewer systems, as well as which permeable areas could be important contributors.

CaSTCo-USTU (Upstream Thinking Upscaled) is part of the wider CaSTCo (Catchment Systems Thinking Cooperative) Ofwat Innovation Fund project. The scope of the CaSTCo-USTU project was to develop tools for the water industry to support decision-making on where catchment or NbS interventions can and cannot be used to help reduce storm overflow discharges. As part of this project, this tool was developed that can be used to identify permeable surfaces such as grassland that could potentially contribute runoff to the combined sewer network.

1.1. Framework Outline

The CaSTCo-USTU framework has been designed to be replicable by the water industry. The framework utilises geospatial analysis and modelling techniques to identify specific areas within wastewater catchments where permeable surface (e.g. fields and parkland) runoff may contribute to storm overflows. This spatial targeting will allow further investigations and resources to be allocated efficiently. At identified sites, modelling could be undertaken to: a) provide quantitative estimates of the rural runoff contribution from these specific areas and b) explore scenarios where green solutions are applied. Geospatial modelling and opportunity mapping can be undertaken at the regional (e.g. water company) scale, whereas hydraulic modelling could be undertaken at the individual wastewater catchment scale. The SCORe Tool is used for the geospatial analysis aspect of the framework. For more information on the other steps and how they might be conducted see section 13.

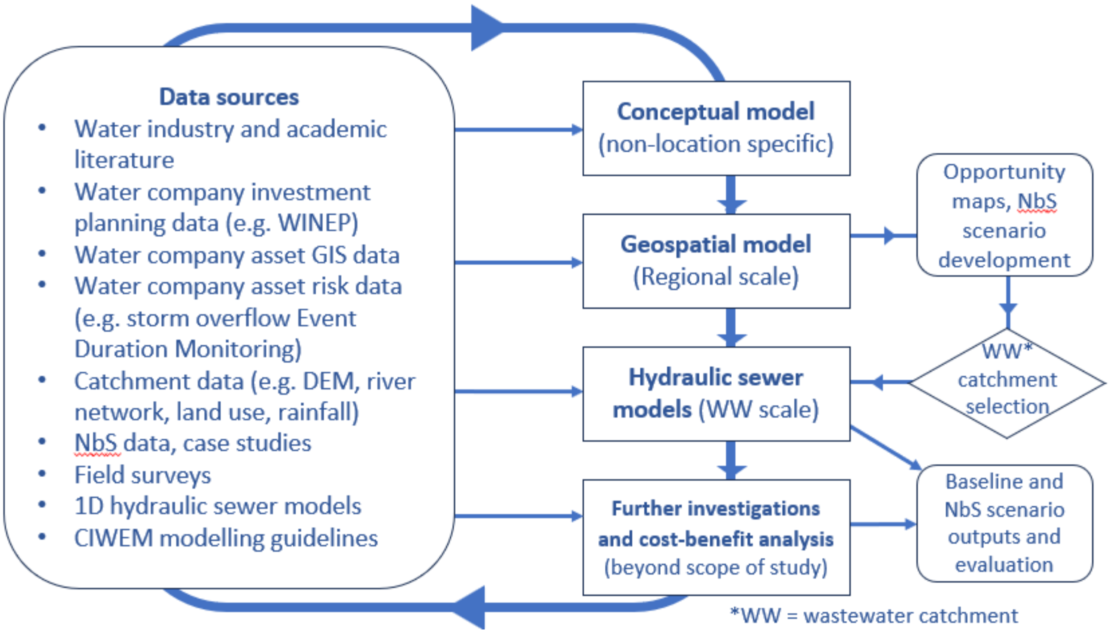
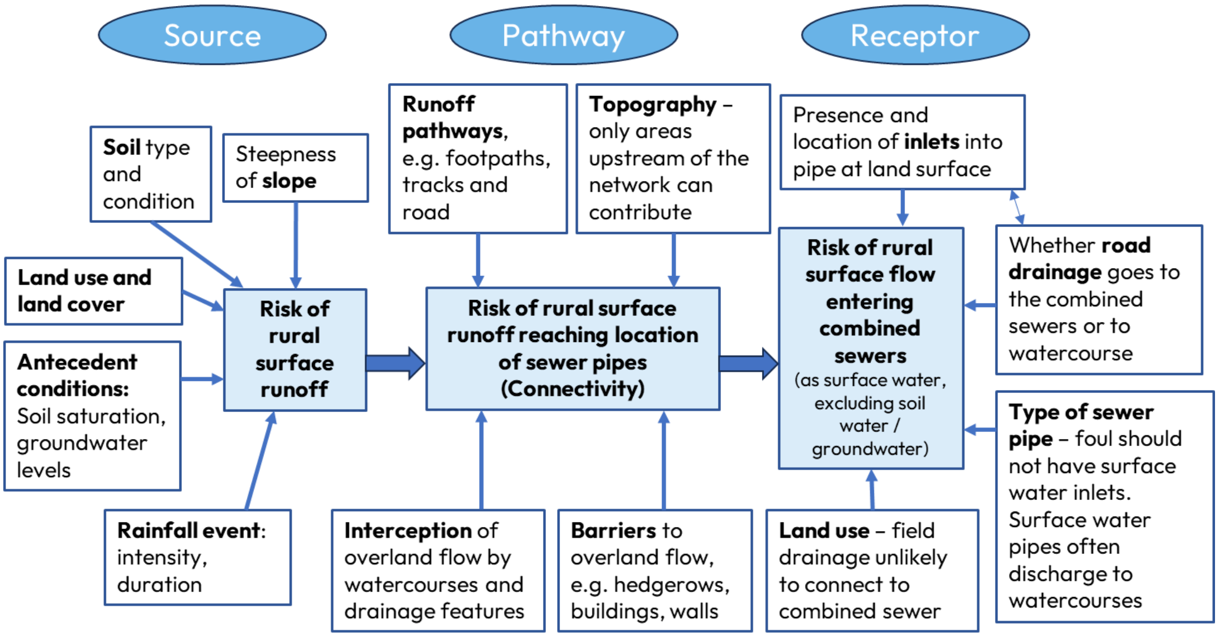


Diagram summarising the CaSTCo-USTU framework

1.2. Conceptual basis for the SCORe tool

Source areas are the opportunity areas for applying green solutions; they are the green space permeable areas that produce runoff that enters the combined sewers. To be a potential opportunity area, the land must produce runoff (be a **source** of runoff), that flows (**pathway**) into a gully or drain that connects into the combined sewers (**receptor**). The main entry points for rural or green space runoff to the combined sewers will be gullies or drains on roads and other paved areas. A key step in identifying opportunity areas is therefore to identify permeable surfaces that potentially drain to roads/gullies that connect to the combined sewers. To do this, however, it is first necessary to determine which areas of land are within the area drained by, or potentially drained by, the combined sewers. This is the topographic catchment or drainage area of the combined sewers, which is largely determined by topography (how the shape and slope of the land determine flow pathways). It is distinct from the term "wastewater catchment", which refers to an area defined by a sewer network that directs wastewater to a specific sewage treatment works.

It is important to emphasise that most road gullies in England do not drain to the combined sewers. Instead, most drain to separate highway or surface water drainage systems that discharge into local watercourses, roadside ditches or the ground (via soakaways or SuDS). Whilst a road may have a combined sewer pipe running underneath it, this does not mean that road drainage connects into the combined sewer pipe. Similarly, the majority of rural land and green spaces do not drain to combined sewers.



Conceptual diagram underpinning development of the SCORe Tool. The SCORe Tool focuses on establishing topographic connectivity (pathway) to receptors (combined sewer inlets).

1.3. Method behind the SCORe Tool

The SCORe Tool uses and builds upon existing geospatial and hydrological tools that meet the requirements of the USTU framework. To further improve the accuracy of the sub-catchments draining to the combined sewer, the digital surface model (DSM) is processed. The DSM is processed by removing surfaces known not to drain to the combined sewer system (or sewer of interest), as well as the river networks. This is accomplished by converting the sewer network and river network into a barrier, like a wall to flow.

Depending on the availability of data, either the sewer pipe, drain/gully or surface is assigned as the area of interest (here defined as a pour points), which will be used to determine the sub-catchment that drains to this area. For more information of pour points see section 7. This will

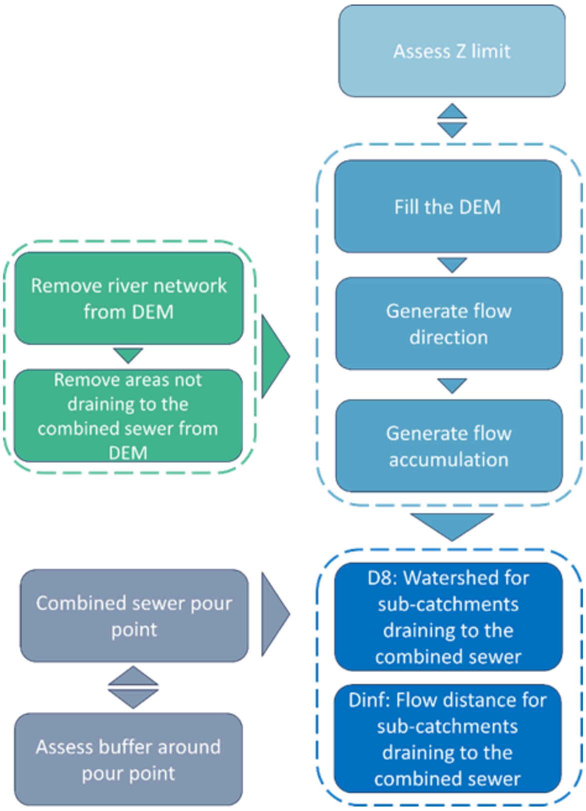


Figure illustrating tool workflow

help ensure only sub-catchments draining to the combined sewer are generated.

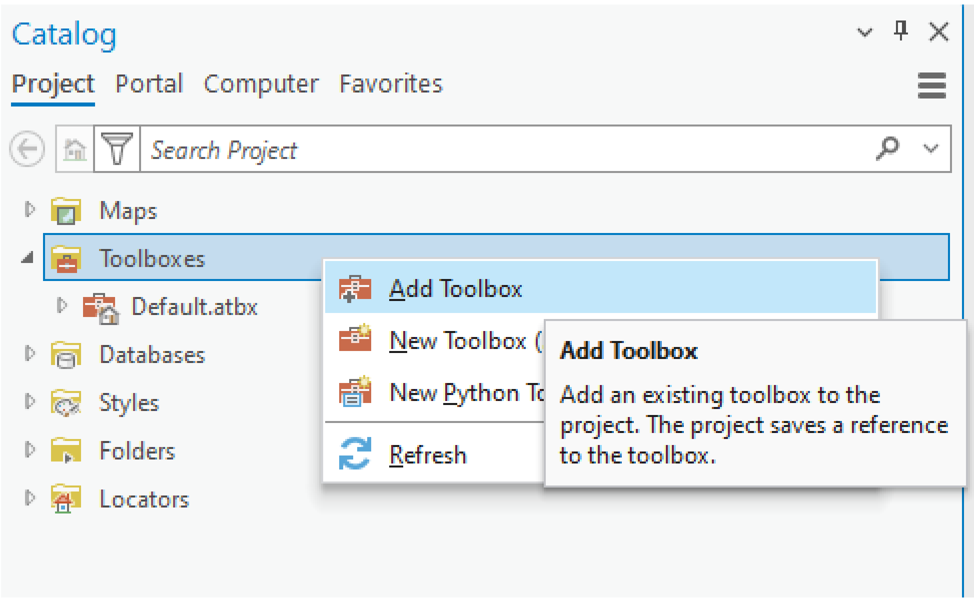
Next the sewer drainage sub-catchments are generated. The first step for this process is to fill depressions in the surface, this conditions the surface to ensure that it is hydrologically connected where appropriate. We limit the change in elevation that could occur when filling depressions to 20cm, for more information on this see section 8.

With a reconditioned elevation surface, we then calculate the direction of flow along the surface. This can be achieved by two different algorithms, the first of which is called the the Deterministic 8 (D8) flow method. This assumes that water can only flow from a cell to one of the 8 cells that surround it. Alternatively, we can use the D-infinity (DInf) method. The DInf approach works by considering all of the surrounding cells in a 3x3 window to estimate the angle of flow for each cell, which is applied by proportionally assigning water to flow to multiple cells that surround it. For more information on the DInf flow method see section 8. Within the SCORe tool, both of these approaches are available.

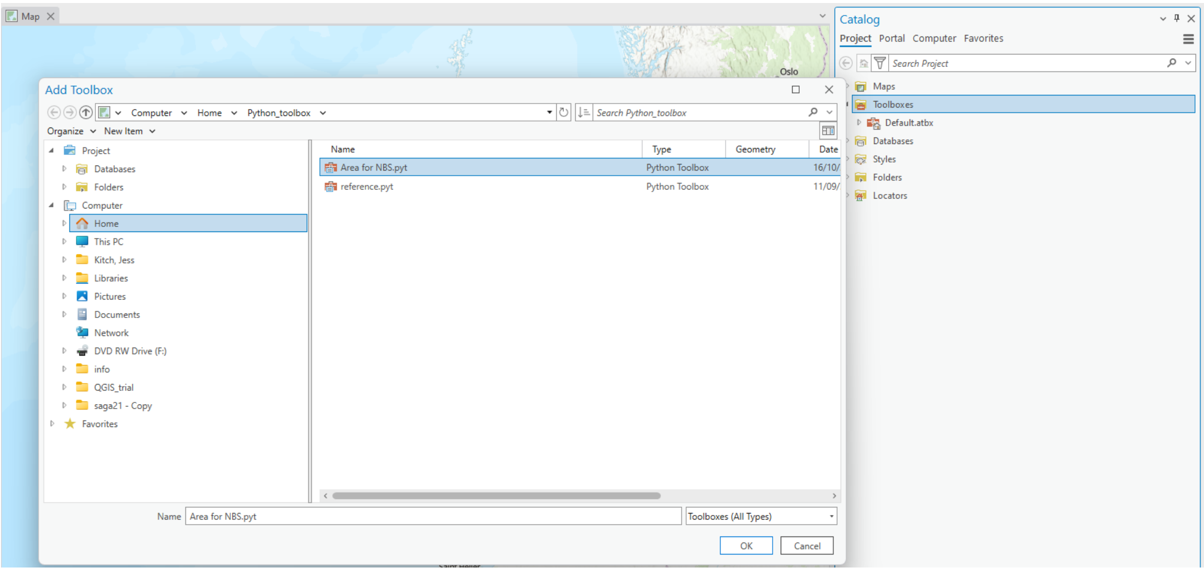
For both flow direction algorithms, the outputted flow direction raster is used to generate flow accumulation, which represents the number of upstream cells that flow to each cell on the raster. The flow accumulation can be useful when assessing the flow pathways draining to the combined sewer network and better understand how runoff moves and is stored across the landscape.

2. How to add the toolbox to ArcGIS

To add a new toolbox right click on the toolbox folder in the Catalog, then click on add Toolbox



This will open a file explorer window. Using this window, select the correct folder location where the toolbox is stored, then select the toolbox needed (SCORe.pyt). Once "OK" is clicked, the toolbox will be added to the toolboxes folder in the Catalog.

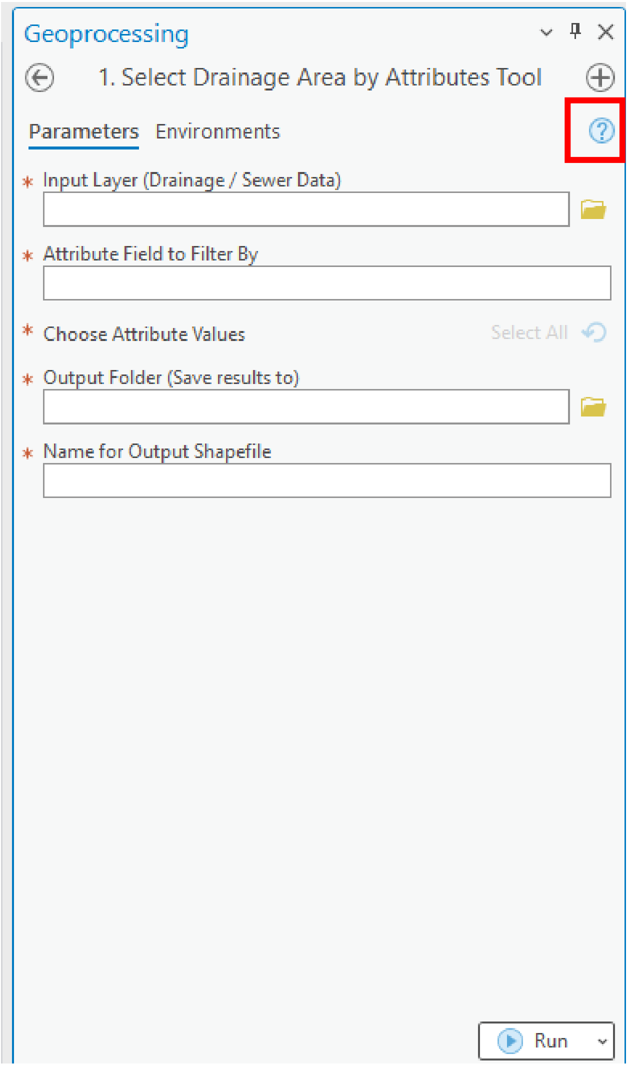


To view the tools in the newly added toolbox, click the drop-down arrow next to the toolbox.

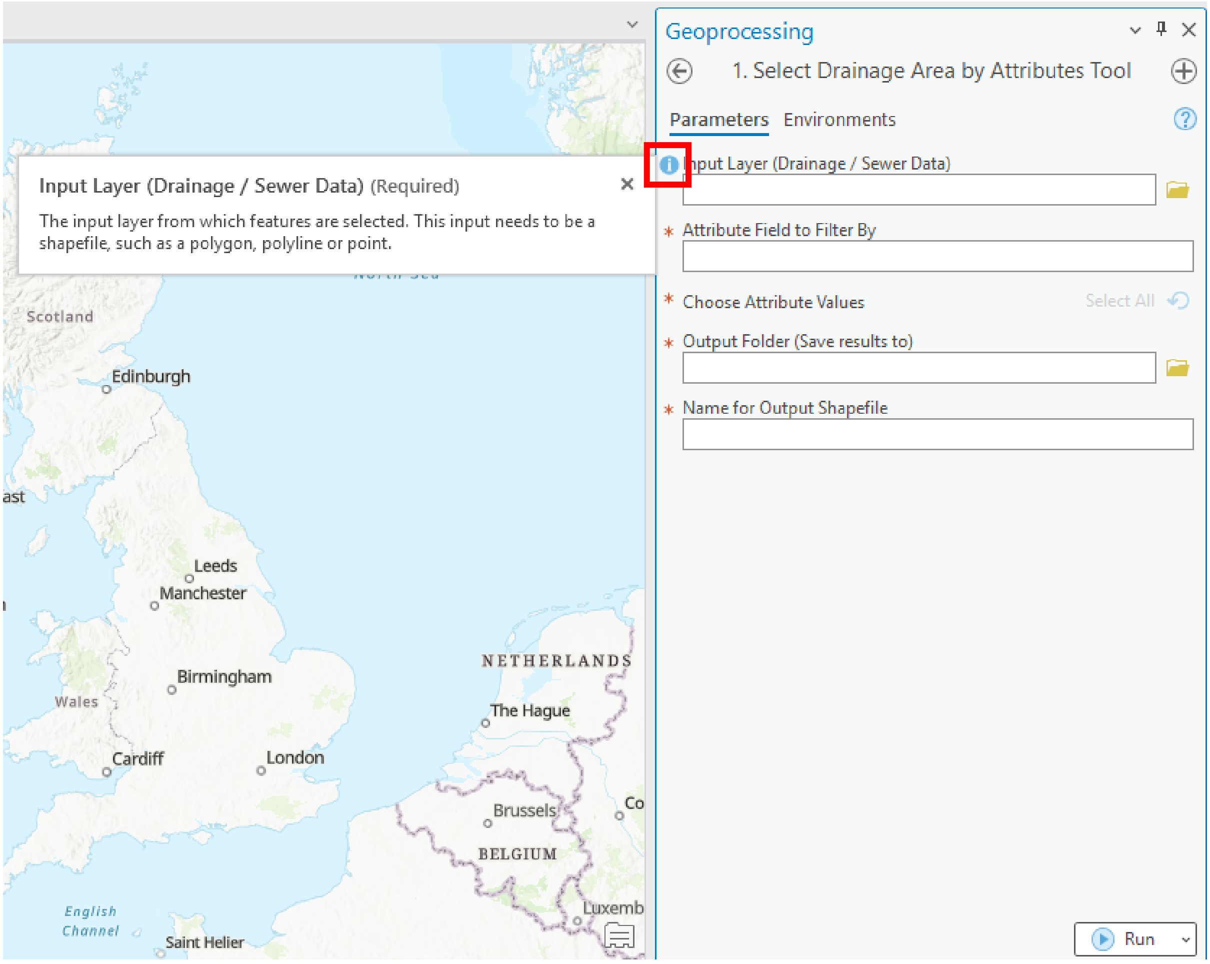
3. Help and guidance in the tool

Each tool in the toolbox has a number of help icons and information boxes built in to help guide the user.

For example, the blue question mark icon  to the right of the GUI will provide information on what the tool does. If the user hovers their cursor over the blue question mark highlighted in the image below an information box will appear to the left of the GUI.



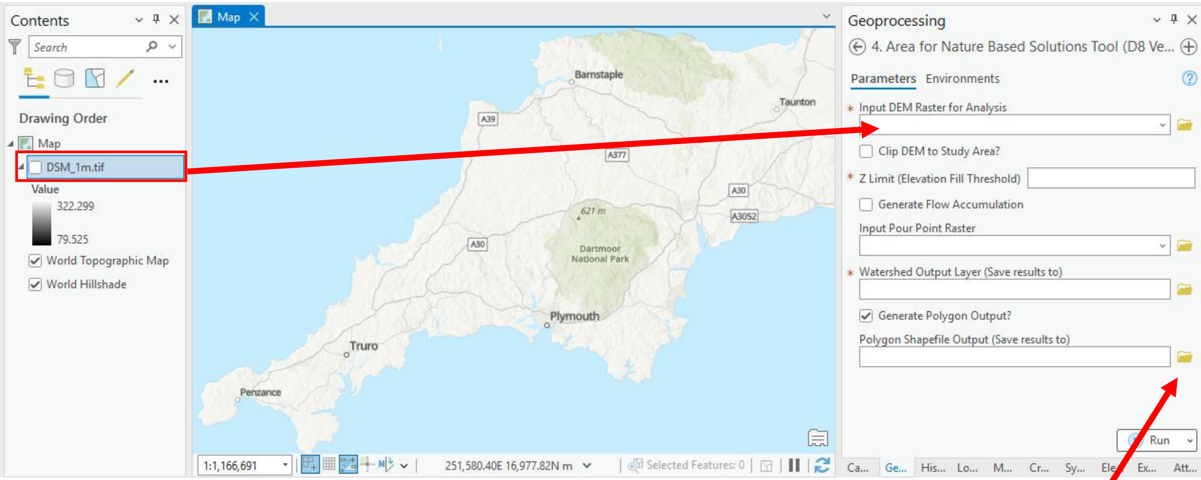
Information on inputs has also been provided. For example, if the user holds their cursor over the white box provided for the input, a blue information icon  will appear. If the user then hovers their cursor over the blue information icon, an information box will appear and provide the user with information on the input required.



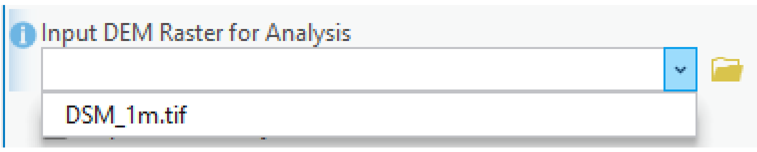
4. Selecting inputs and outputs

4.1. Selecting inputs

To select and provide inputs where required for each tool, the user can use various methods. These include clicking on the folder icon  to open a file explorer window and navigate to the correct layer. The user can also click and drag a layer from the contents to the white box provided for the input.

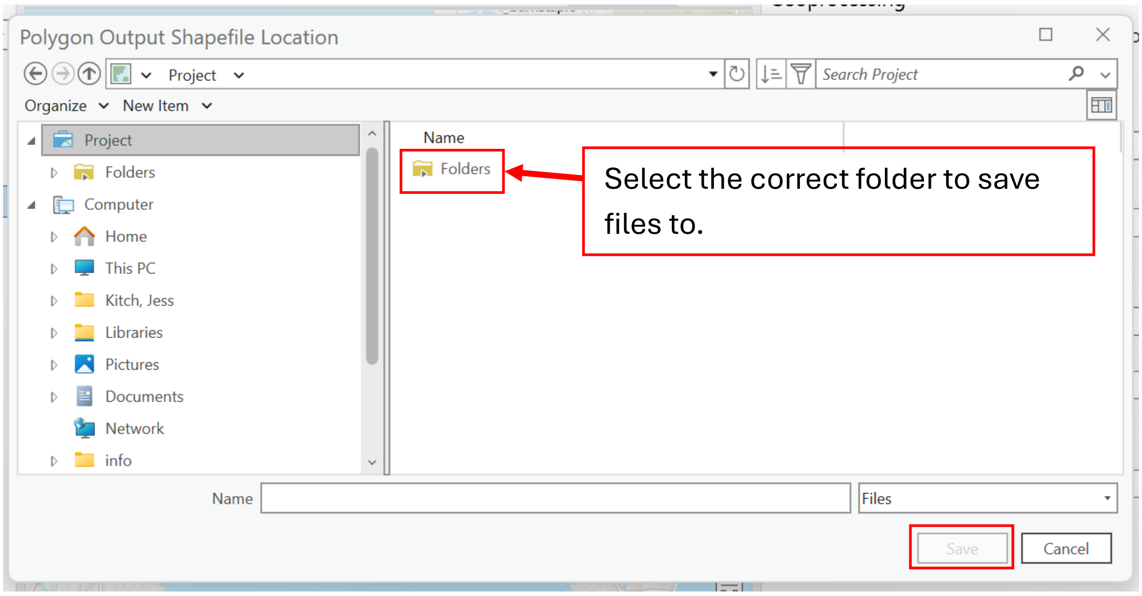


The user can also click on the drop down, and this will provide a list of all the possible inputs that are already open within the ArcGIS project window. The drop down will only show layers that are of the correct file type for each input.



4.2. Selecting outputs

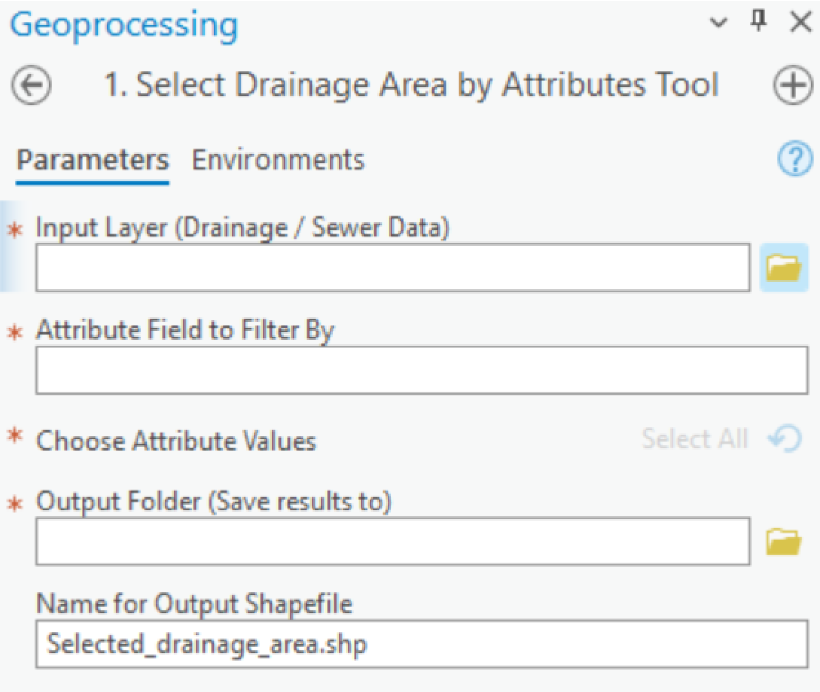
To provide the output location select the folder icon  then use the file explorer window to browse to the correct save location. The file explorer window will look like the following:



Once the correct location has been selected click the ‘save’ button to finish.

5. Select Drainage Area by Attributes Tool

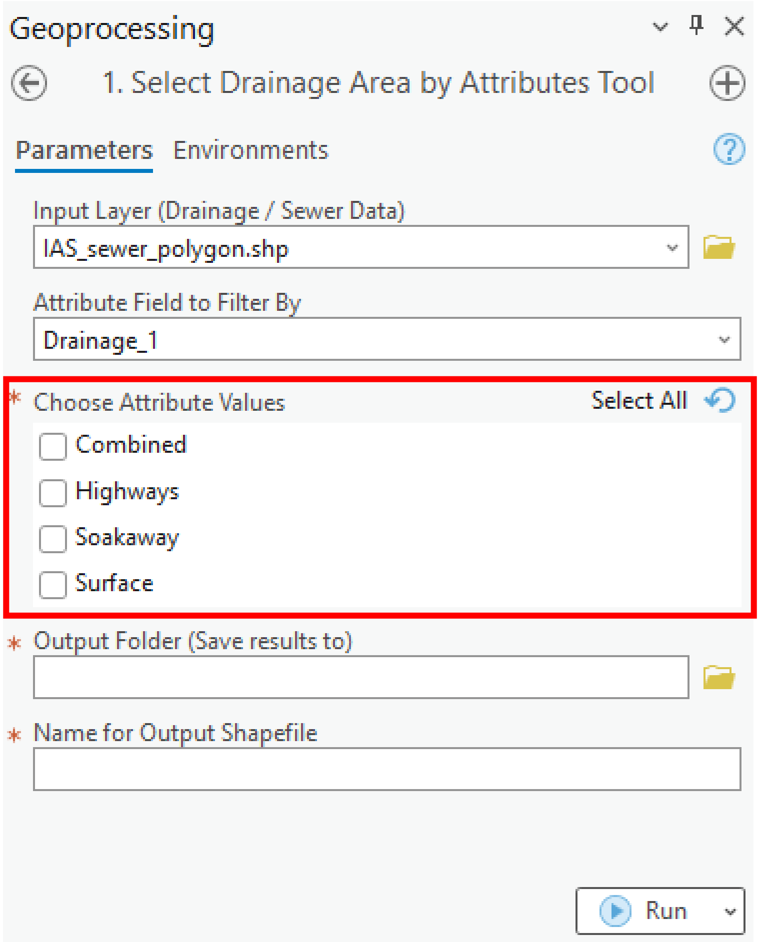
This tool will allow users to extract the relevant data from layers such as impermeable area surveys, gully points and sewer network polylines. This tool will filter data based on the feature attributes and the users' selections. It provides a new output with only the selected data; the output will be a shapefile layer. For example, if an Impermeable Area Survey layer is used, it is possible to extract only those surfaces that have "PF" (for paved surface to foul/combined sewer system) in the "Unique Code" attribute field. The user can select data in relation to the combined sewer network, and this output can be used in Tool 3 Sewer Pour Point Tool. Alternately other data such as areas not draining to the combined sewer network can be selected and this will provide an output that can be used with Tool 2 Add Networks or Barriers to the DEM.



Input Layer (Drainage/Sewer Data): Sewer data is to be input here. This can be selected via file explorer using the file icon or from the ArcGIS project via the drop down of dragging the layer from the contents.

Attribute Field to Filter By: Once the Input feature layer has been selected a drop-down box will become available. The drop down will contain all the names of the fields in the attribute table. Select the one field that contain the relevant information that specifies the type of surface and where which drainage system it drains to.

Choose Attribute Values: Once a field name has been selected another drop down will appear that lists all the options within that field. Tick all the boxes relevant. Only the information corresponding to the selected option will be present in the final output.



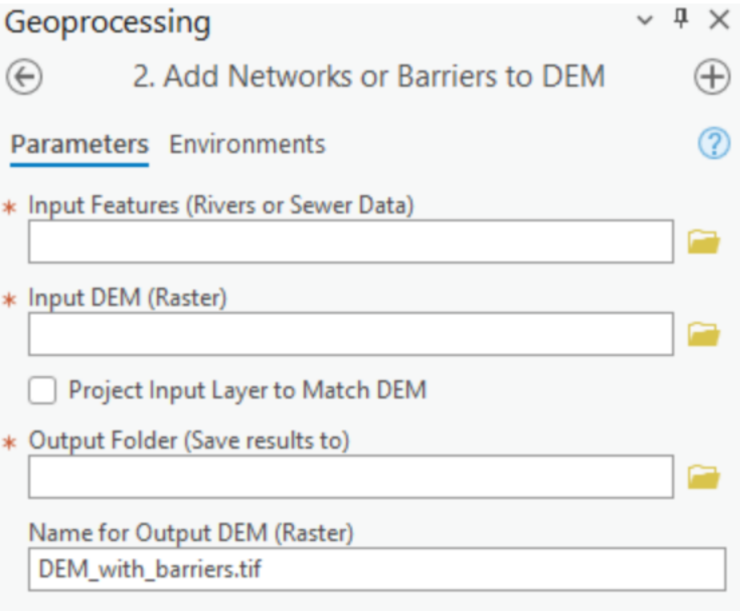
Listed attributes for the user to select from. Check the box of the relevant attribute(s).

Output Folder (Save results to): Select the relevant output folder location using file explorer via the folder icon or type in the folder pathway manually.

Name for Output Shapefile: Input the name for the output layer, if file extension (.shp) is not included this will be auto filled.

6. Add Networks or Barriers to DEM Tool

This tool will add barriers for both/either sewer drainage data or river networks to the DEM being used. The data from the sewer network/river network layer will be converted to no data and essentially removed from the DEM. If a flow pathway crosses an area of drainage not to the combined, runoff will be intercepted by the gullies (drains) in that area and will not drain to the combined sewer. By removing cells within the DEM that are overlayed by the sewer network not draining to the combined/river networks, this ensures that once flow drains to a drain (not combined network) or river network, it cannot flow to the combined sewer. As there is no interest in areas draining to the river network these should also be removed.



Input Features (Rivers or Sewer Data): The layer for this input can be either a polygon, polyline or point. Any sewer network data can be extracted using tool 1. This can be selected via the file icon , the drop down if the layer is open in the project or dragged from the project's contents (See section 4).

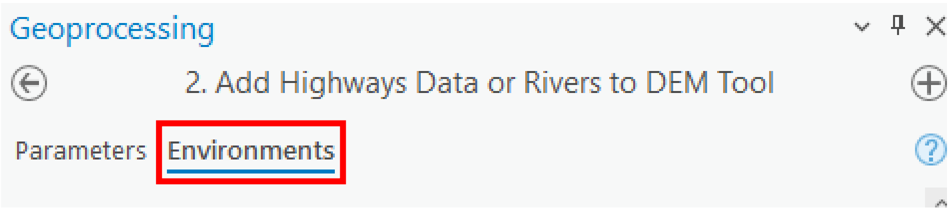
Input DEM (Raster): The DEM can be a DTM or DSM, but the DSM is recommended. DSM/DTM data can be downloaded from here if required (See section 8 for how to download DEM data from the EA). A 1m resolution is also recommended.

Project Input Layer to Match DEM: This is an optional tick box. If the input layer is not of the same map projection as the DEM layer, tick this box. For the analysis to work all projections for layers must be the same as the DEM being used. If the projection of the shapefile matches the projection of the DEM leave this box unticked.

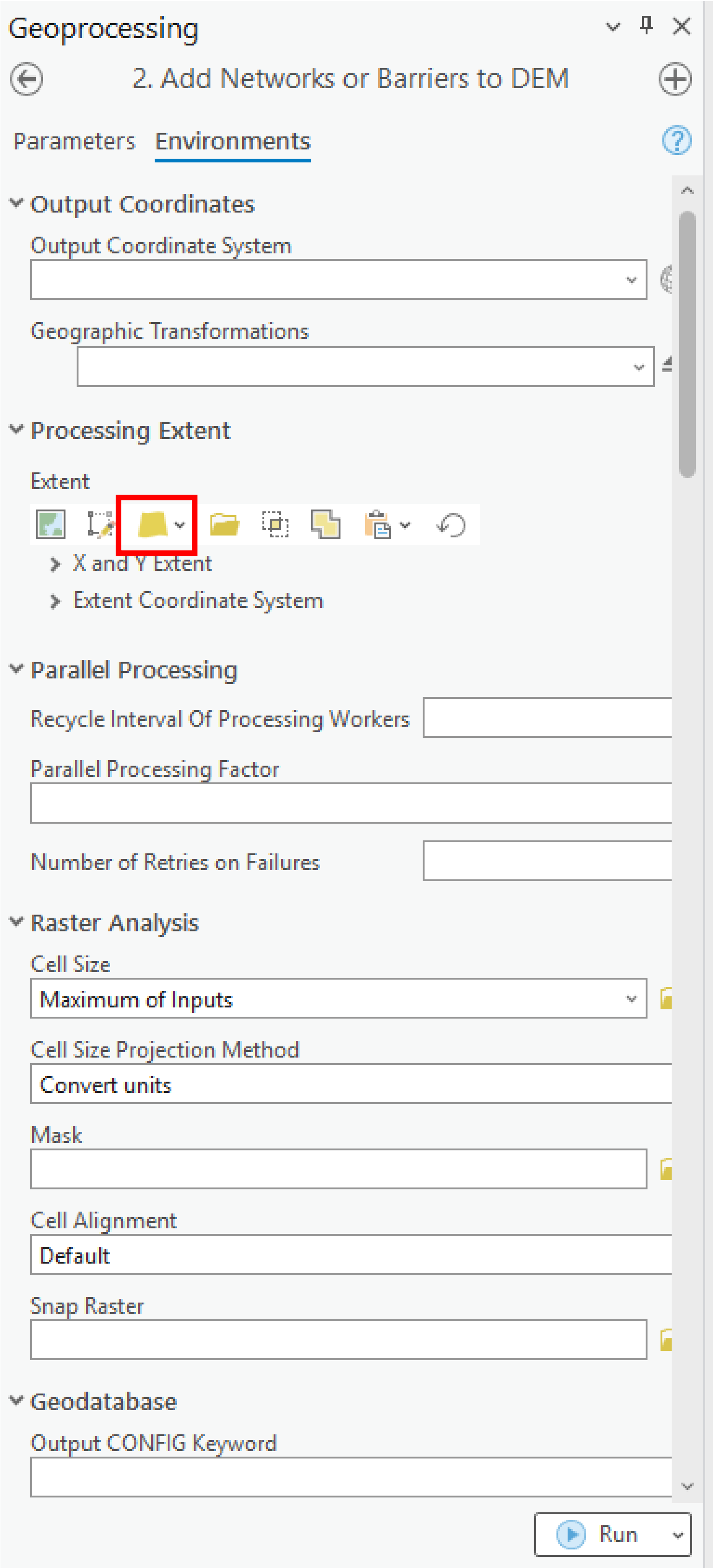
Output Folder (Save results to): Select the relevant output folder location using file explorer via the folder icon or paste in the folder pathway.

Name for Output DEM (Raster): Input the name for the output layer, if file extension (.tif) is not included this will be auto filled.

Before pressing run the extent needs to be set to the DEM being used. To do this go to the environments tab.



Then set the processing extent to the DEM.



This icon allows the user to set the processing extent to that of a layer. Clicking the drop-down arrow will provide a selection of layers to choose from. Select the DEM layer.

When the highlighted option is clicked, a drop down will appear listing all the layers in your project, select the DEM from that list.

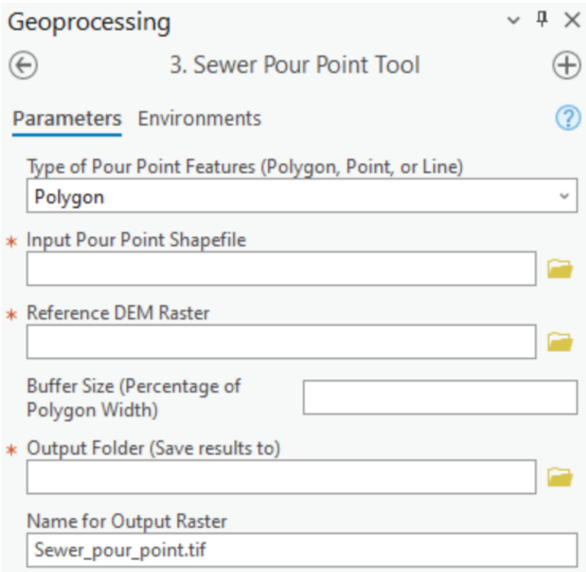
If both drainage areas (not to the combined) and river networks are required the tool will need to be first run with one of the inputs, then the output DEM from this run will need to be used as the Input DEM when running the tool, a second time with the other Polygon/Polyline/Point input option.

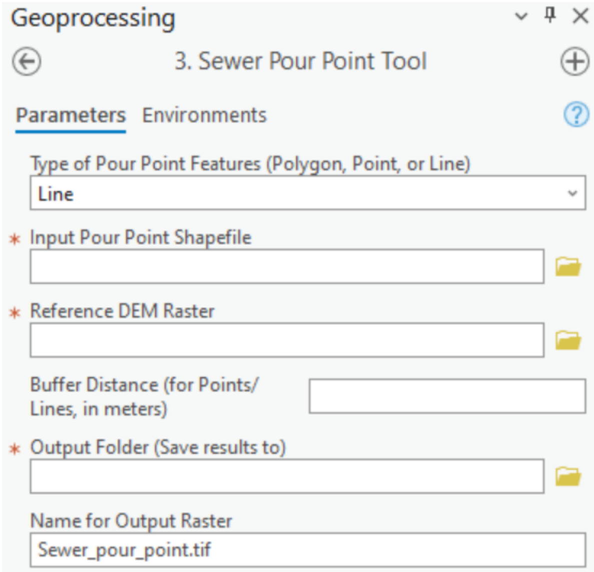
For example: First run the tool using a layer with the drainage data and use the original DEM. Tick the box “Project Input Layer to Match DEM” if the map projection does not match the DEM. Fill in the output file pathways and layer name. Once the tool has completed, change the polygon/polyline/point input to the river network layer. This time the Input DEM will need to be the output from running the tool with the drainage network as the polygon/polyline/point input. Again, tick the project shapefile box if the river network layer projection does not match the projection of the DEM. Then fill in the output folder pathway and output layer name.

7. Sewer Pour Point Tool

The pour point tool is used to generate a layer that can be used to help delineate watersheds. A pour point is an outlet and where water flows out from an area. For this tool the pour point will consist of combined sewer data and can be a polygon, point or polyline layer.

The output from Tool 1 can be used as an input for this tool, if the relevant data regarding the combined sewer network was selected. The areas with potential for nature-based solutions is based on areas that drain to the combined sewer network as this is the network contributing to issues such as CSO discharges. To generate catchment areas that relate to the combined sewer network this information should be used as a pour point.





Type of Pour Point Features (Polygon, Point, or Line): From the drop down select the type of shapefile that will be used for the pour point.

Input Pour Point Shapefile: This input relates to the output from tool 1 when the data relating to the combined sewer network was selected. This can be selected via the file icon, the drop down if the layer is open in the project or dragged from the project's contents.

Reference DEM Raster: This input is generated when using tool 2. Only the final output from tool 2 should be used. For example, if tool 2 was ran twice so both the highways drainage network and river network was included then the output from the second tool run should be used here. This can be selected via the file icon , the drop down if the layer is open in the project or dragged from the project's contents. This input is used to ensure the pour point output is snapped to the DEM raster, this is important for the last tool(s).

Buffer Size (Percentage of Polygon Width)/Buffer Distance (for Point/Lines, in meters): This section is dependent on what shapefile type is used. If a Polygon shapefile is used then Buffer Size will be the option, whereas if a line or point shapefile is used then Buffer Distance will be the option.

If the Input Pour Point Shapefile layer consists of polygons and these over or underrepresent the area (e.g. the polygons have been drawn too large or too small) a buffer can be applied to edit the size of the polygons. I whole number should be used e.g. 10 and not a fraction like 0.1 to represent 10%. A negative number will reduce the size of the polygons, whilst a positive number will increase the size of the polygons. A percentage character is not required, only the positive or negative value is required.

If a line or point file is used, then the user can provide a buffer distance to buffer the feature by. This value uses meters as the unit of measurement. A negative value will decrease the size of the feature, whilst a positive number will increase the feature size. Furthermore, if the Input Pour Point Shapefile layer is a polyline/point layer, then roads or gullies could be underrepresented, and a positive buffer can be applied to increase the area.

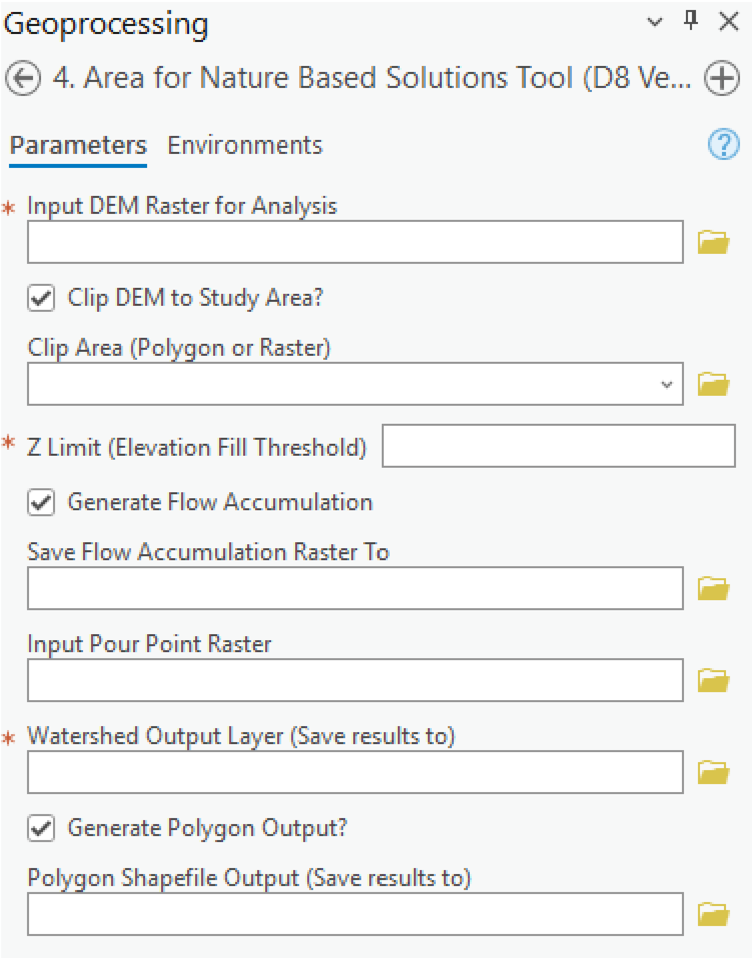
Output Folder (Save results to): Select the relevant output folder location using file explorer via the folder icon or paste in the folder pathway.

Name for Output Raster: Input the name for the output layer, if file extension (.tif) is not included this will be auto filled. The output is saved as a .tif as this is the file type required for tool 4.

8. Area for Nature Based Solutions Tool

Two flow methods have been used to develop the Area for Nature Based Solutions, resulting in two versions of the tool. The two flow methods used include Deterministic 8 (D8) and D-infinity (DInf). The D8 method directs all water to the steepest neighbouring cell, while the DInf method splits the flow between two neighbouring cells to more closely represent how water moves. The user will need to choose whether they want to create catchment outputs using either DInf or D8, and select the corresponding tool. Both tools require the same inputs, the only difference is the flow method used to generate the catchments with potential for NbS.

8.1. Area for Nature Based Solutions Tool (D8 Version)



Input DEM Raster for Analysis: This is where the DEM with added barriers from Tool 2 can be used. This will provide the topographic information required to produce the catchments that drain to the combined sewer. This can be selected via the file icon , the drop down if the layer is open in the project or dragged from the project's contents.

Clip DEM to Study Area?: If the user is interested in a particular area, for example a waste water catchment, then a shapefile or raster of a catchment boundary can be used here to clip the DEM. By doing catchments draining to the combined sewer will only be produced for the area provided as this input. This is optional and only tick the box if this step is required.

Clip Area (Polygon or Raster): Provide the shapefile/raster of the boundary to clip the DEM to. This can be selected via the file icon , the drop down if the layer is open in the project or dragged from the project's contents.

Z limit (Elevation Fill Threshold): A Z limit is the elevation fill threshold i.e. the maximum depth for holes (sinks) in your terrain data. If a sink is deeper than this limit, the tool will not fill it. A fill of 0.2 is recommended due to the likelihood of not filling barriers (e.g. walls, hedgebanks) and leaving them remaining in the DEM. It is important to keep realistic barriers to flow as this will help to not overestimate the catchment areas draining to the combined sewer network. A default value of 0.2 has been set but can be changed by the user.

Generate Flow Accumulation: This is optional. If flow accumulation is required tick this box. Flow accumulation can be useful when investigating flow pathways.

Save flow Accumulation Raster to: If the Generate Flow Accumulation box was checked a save location for the flow accumulation output will be required. Select the desired folder for this and provide a file name for the output file, any name must end in .tif as the output is a Raster file.

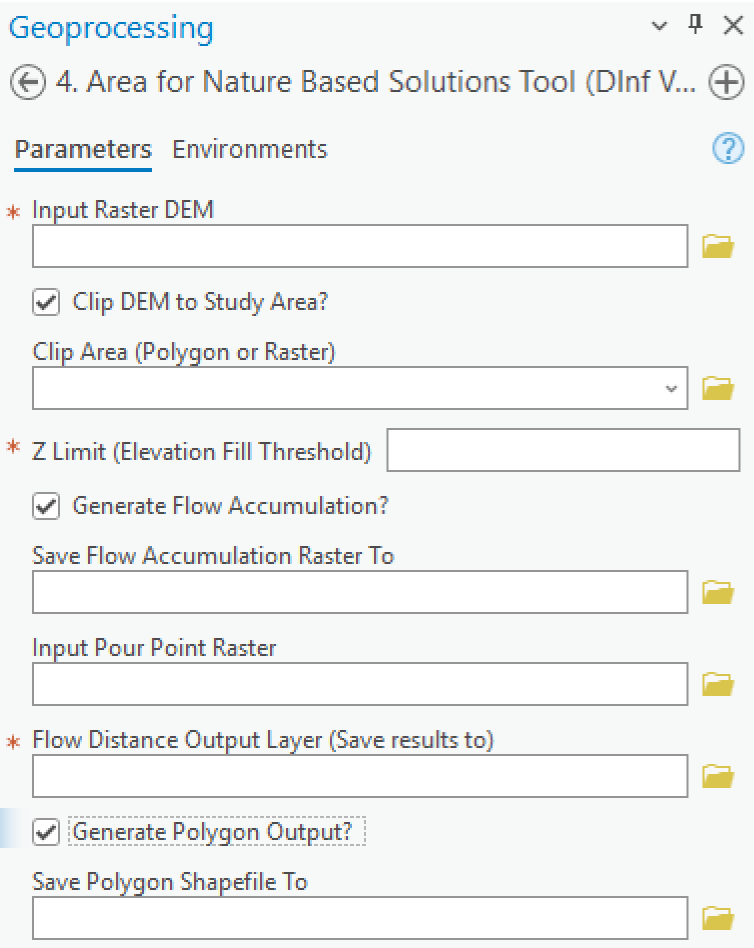
Input Pour Point Raster: The output from tool 3 should be used here. This can be selected via the file icon , the drop down if the layer is open in the project or dragged from the project's contents.

Watershed Output Layer (Save results to): Select the desired folder to save the output and provide a file name for the output file, any name must end in .tif as the output is a Raster file.

Generate Polygon Output?: This is optional. If the user would like a shapefile polygon layer of the output instead/alongside of the original raster output, tick this box.

Polygon Shapefile Output (Save results to): Select the desired folder to save the output and provide a file name for the output file, any name must end in .shp as the output is a Shapefile file.

8.2. Area for Nature Based Solutions Tool (DInf Version)



Input DEM Raster for Analysis: This is where the DEM with added barriers from Tool 2 can be used. This will provide the topographic information required to produce the catchments that drain to the combined sewer. This can be selected via the file icon , the drop down if the layer is open in the project or dragged from the project's contents.

Clip DEM to Study Area?: If the user is interested in a particular area, for example a waste water catchment, then a shapefile or raster of a catchment boundary can be used here to clip the DEM. By doing catchments draining to the combined sewer will only be produced for the area provided as this input. This is optional and only tick the box if this step is required.

Clip Area (Polygon or Raster): Provide the shapefile/raster of the boundary to clip the DEM to. This can be selected via the file icon , the drop down if the layer is open in the project or dragged from the project's contents.

Z limit (Elevation Fill Threshold): A Z limit is the elevation fill threshold i.e. the maximum depth for holes (sinks) in your terrain data. If a sink is deeper than this limit, the tool will not fill it. A fill of 0.2 is recommended due to the likelihood of not filling barriers (e.g. walls, hedgebanks) and leaving them remaining in the DEM. It is important to keep realistic barriers to flow as this will help to not overestimate the catchment areas draining to the combined sewer network. A default value of 0.2 has been set but can be changed by the user.

Generate Flow Accumulation: This is optional. If flow accumulation is required tick this box. Flow accumulation can be useful when investigating flow pathways.

Save flow Accumulation Raster to: If the Generate Flow Accumulation box was checked a save location for the flow accumulation output will be required. Select the desired folder for this and provide a file name for the output file, any name must end in .tif as the output is a Raster file.

Input Pour Point Raster: The output from tool 3 should be used here. This can be selected via the file icon , the drop down if the layer is open in the project or dragged from the project’s contents.

Flow Distance Output Layer (Save results to): Select the desired folder to save the output and provide a file name for the output file, any name must end in .tif as the output is a Raster file.

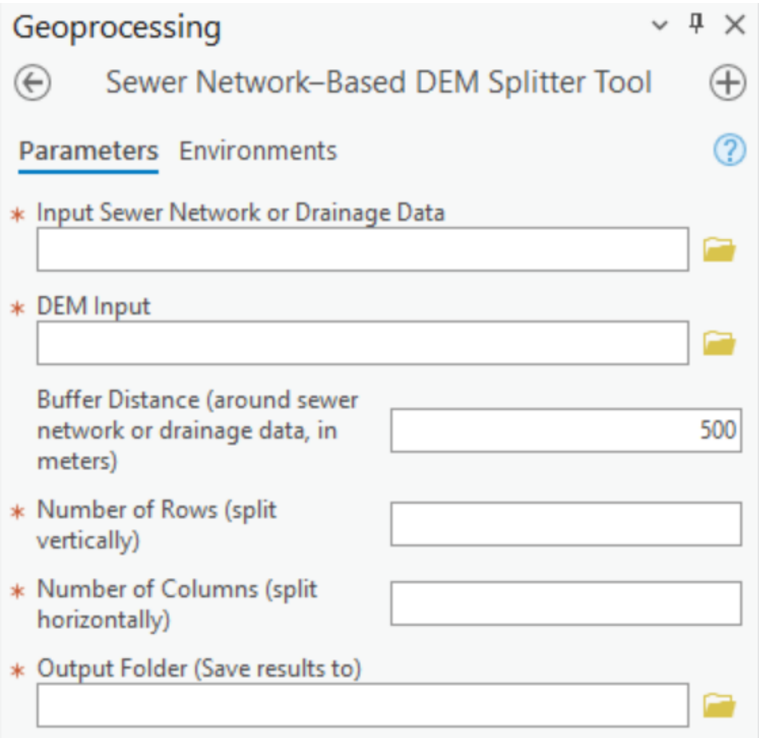
Generate Polygon Output?: This is optional. If the user would like a shapefile polygon layer of the output instead/alongside of the original raster output, tick this box.

Polygon Shapefile Output (Save results to): Select the desired folder to save the output and provide a file name for the output file, any name must end in .shp as the output is a Shapefile file.

9. Sewer Network-Based DEM Splitter Tool

9.1. Running the tool

If the area for analysis is large there could be computational issues regarding the computer memory required to run the tool for a large DEM area. This tool would need to be used before using tools 1 – 4. If it is not possible to run the tool due to a lack of computational memory, this tool can be used. This tool will first reduce the size of the DEM by clipping it to the sewer network/drainage layer. A buffer will be applied to the sewer network/drainage layer to ensure any potential areas draining to the combined sewer are captured. It is recommended to use a larger buffer of 500 – 1000m. Once the DEM is clipped to the buffered sewer network/drainage area it will be clipped to a grid and individual DEM layers provided. The number of individual DEMs produced will be dependent of the user specified row and columns for the grid. Each individual DEM will then need to be used were appropriate in the other tools in the toolbox. This will result in the user having to run the other tools multiple times and then merge the outputs to create a single final output. If the user needs to merge the Raster outputs use the 'Mosaic to new Raster' tool in ArcGIS (information on this tool can be found here). If the user needs to merge the Shapefile outputs use the 'Merge' tool in ArcGIS (Information on this tool can be found here).



Input Sewer Network or Drainage Data: This is where the sewer network or drainage data layer should be provided. This input should be a Shapefile polygon, point or line.

This can be selected via the file icon , the drop down if the layer is open in the project or dragged from the project's contents.

DEM Input: This is where the user should provide the DEM that covers the area of interest.

Buffer Distance (around sewer network or drainage data, in meters): The size of the buffer for the sewer network/drainage data must be provided. This value is in meters and a default value of 500 has been provided but can be changed.

Number of Rows (split vertically): The user must define the number of rows for the grid that will be used to split the DEM layer into smaller raster files.

Number of Columns (split horizontally): The user must define the number of columns for the grid that will be used to split the DEM layer into smaller raster files.

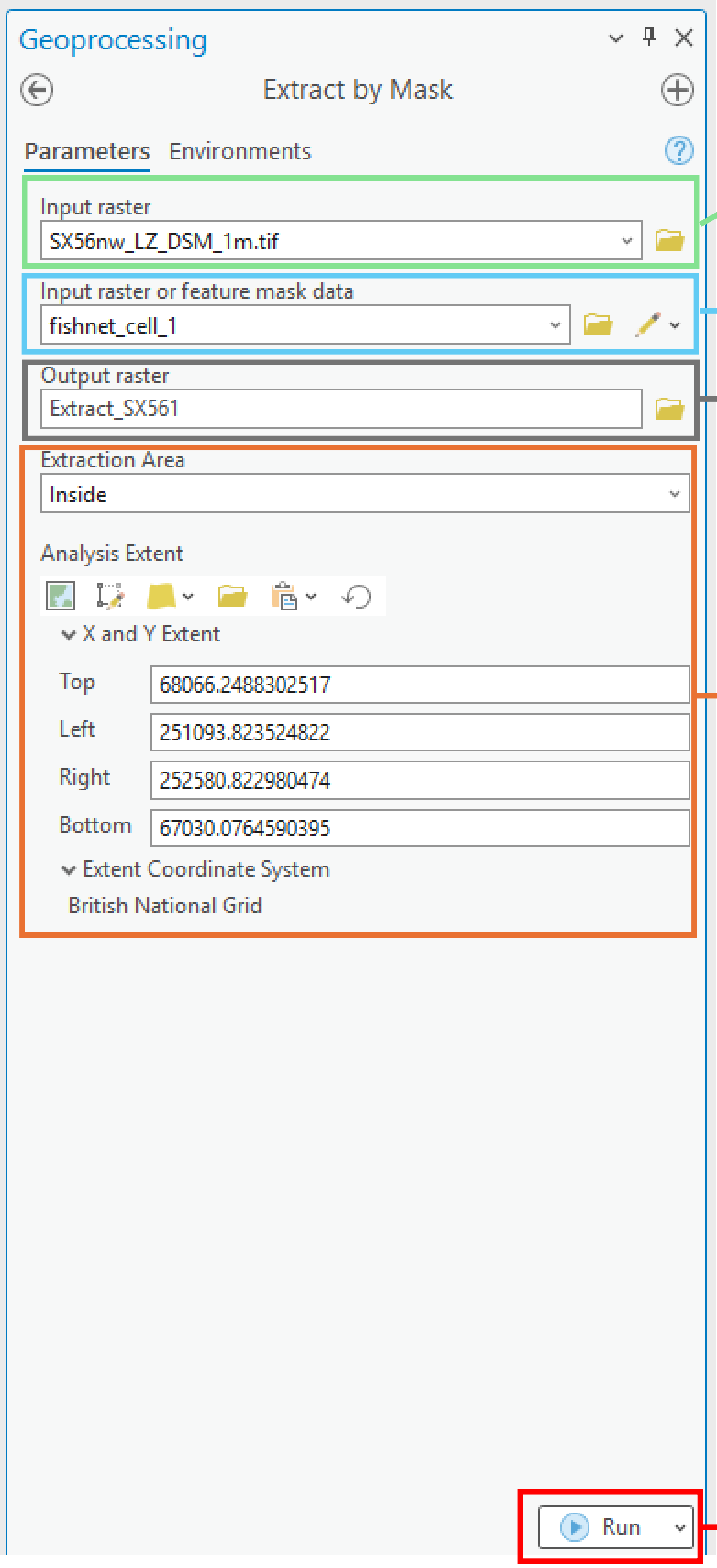
Output Folder (Save results to): The user must provide the output folder path where the new smaller DEMs will be saved. Only the file pathway is required, names will be automatically generated and numbered.

9.2. Merging the final DInf/D8 outputs back into one layer

Due to the buffer applied to the layers when running the Sewer-network based DEM splitter tool, the final outputs (both raster and shapefile) from tool 4 D8 or DInf version will need to be clipped the unbuffered fishnet cells. The unbuffered fishnet cells will all contain the name 'fishnet_cell_' within the name will be a number to help identify which cell it is. The total number of cells will be based on the number of rows and columns set by the user. The user will need to clip their final outputs to the corresponding fishnet cell layer. There are two tools within ArcGIS that can be used for this, and it will be dependent on whether the final output is a raster of a shapefile.

9.2.1. Final output is Raster

If the final output is a raster the 'Extract by Mask' tool will be required to clip the raster to the fishnet cell. This tool will need to be run for each output layer



Provide the final output from tool 4 here. It must be a raster

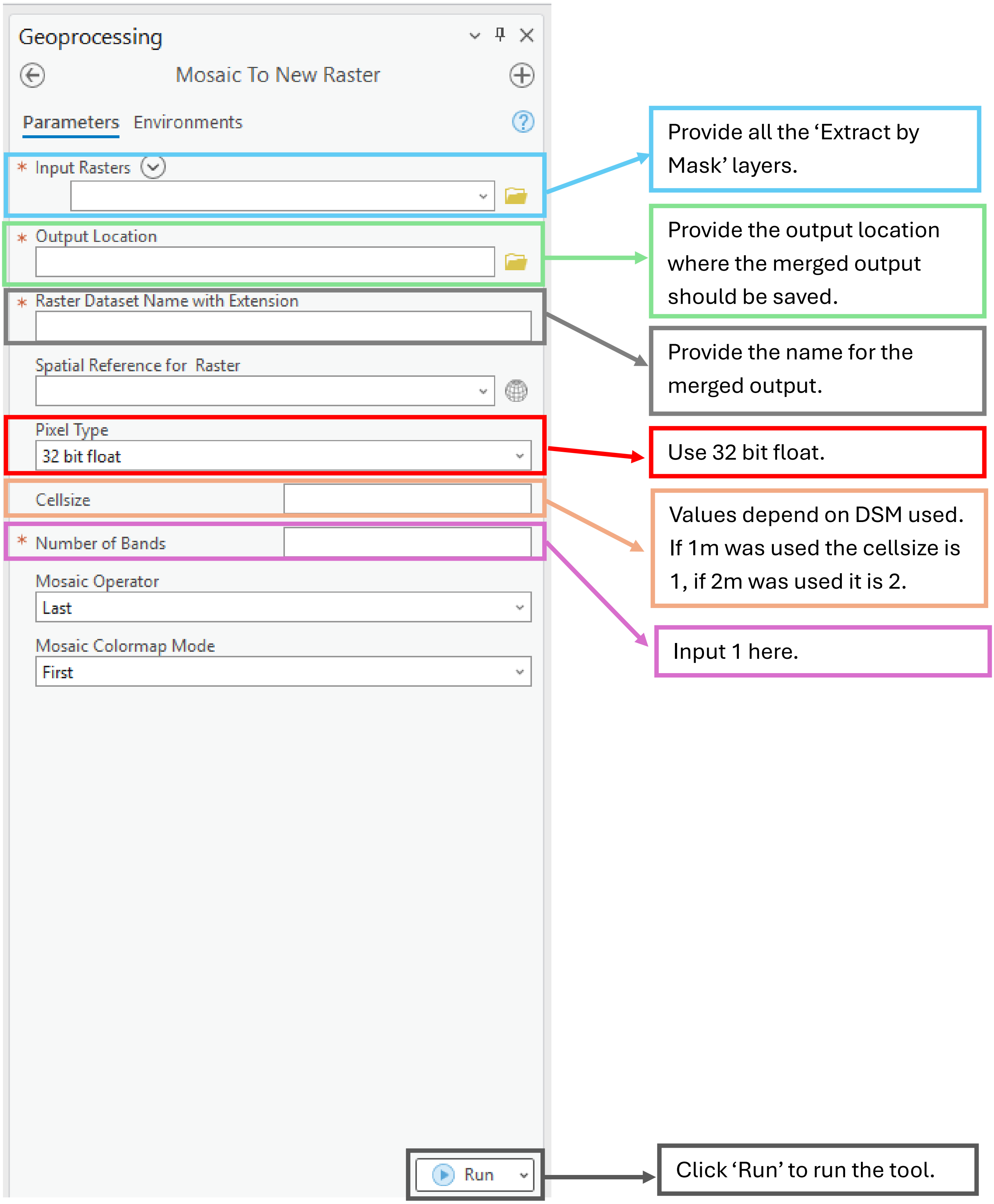
Provide the fishnet cell shapefile here.

Provide output location where the clipped layer should be saved and provide a name.

Leave as default settings.

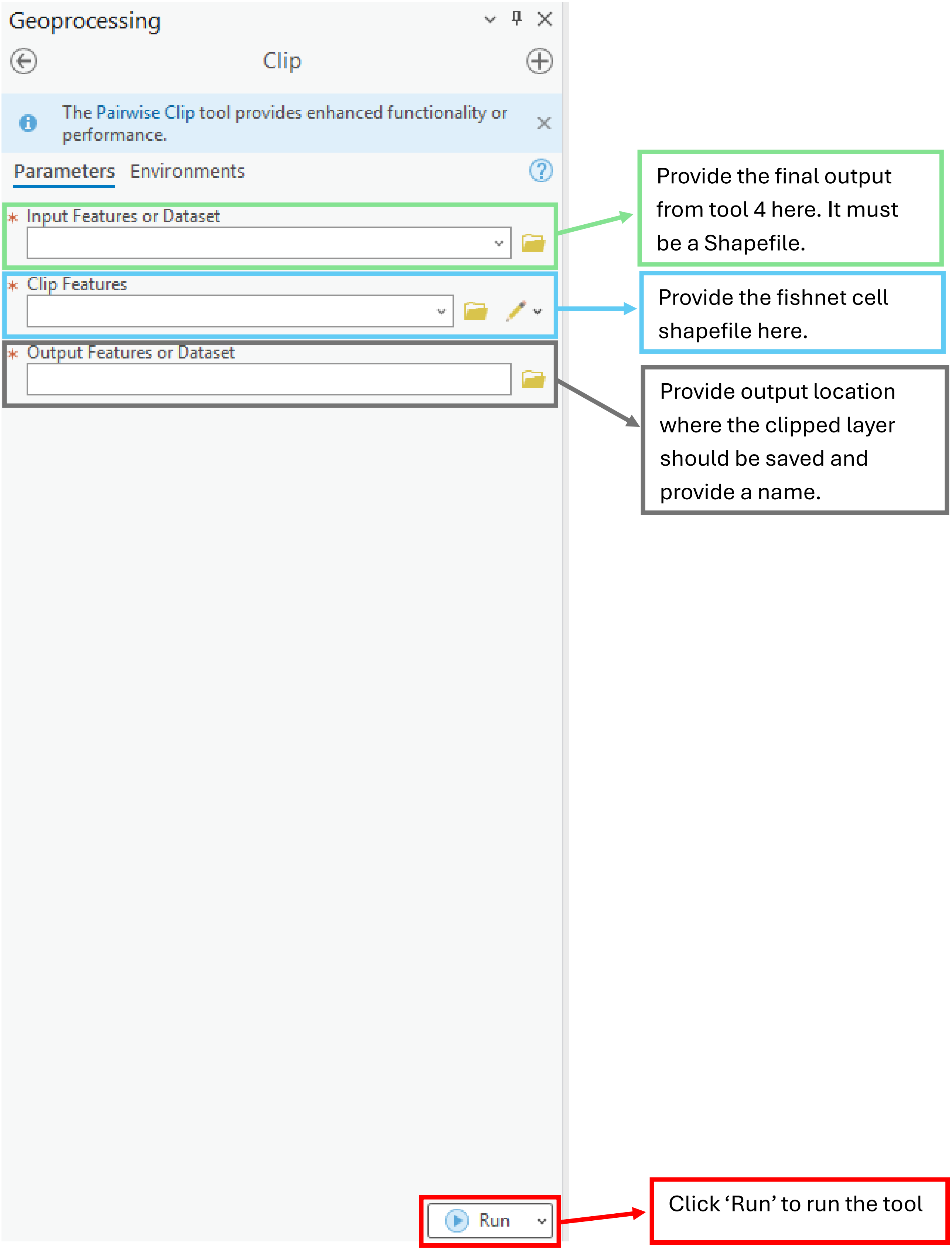
Click run to run the tool.

Next the outputs from the 'Extract by Mask' tool will need to be merged to create one final layer containing all the sub-catchments. The tool in ArcGIS that can do that is called 'Mosaic to New Raster'.

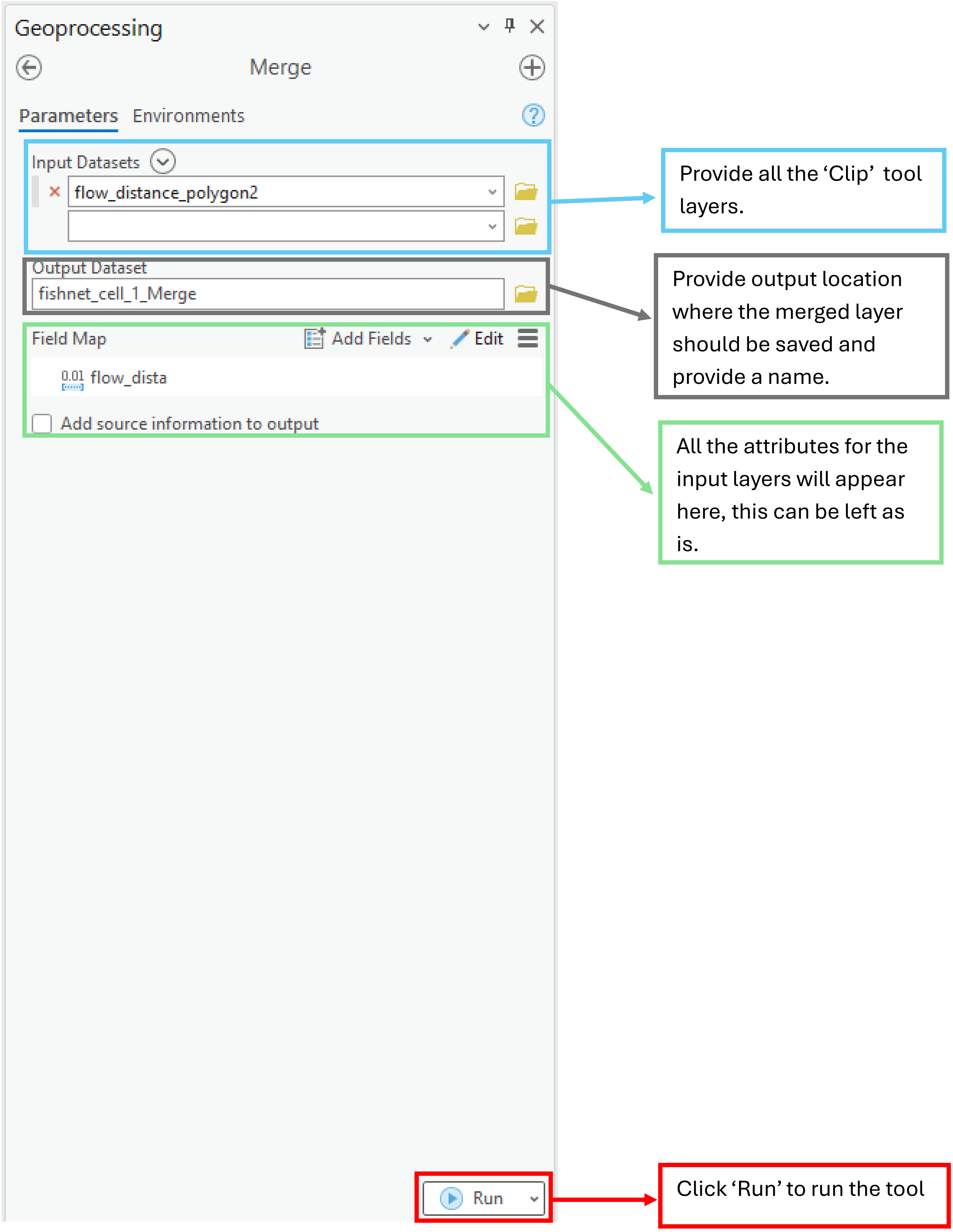


9.2.2. Final output is Shapefile

If the final output is a Shapefile the 'Clip' tool will be required to clip the Shapefile to the fishnet cell. This tool will need to be run for each output layer.

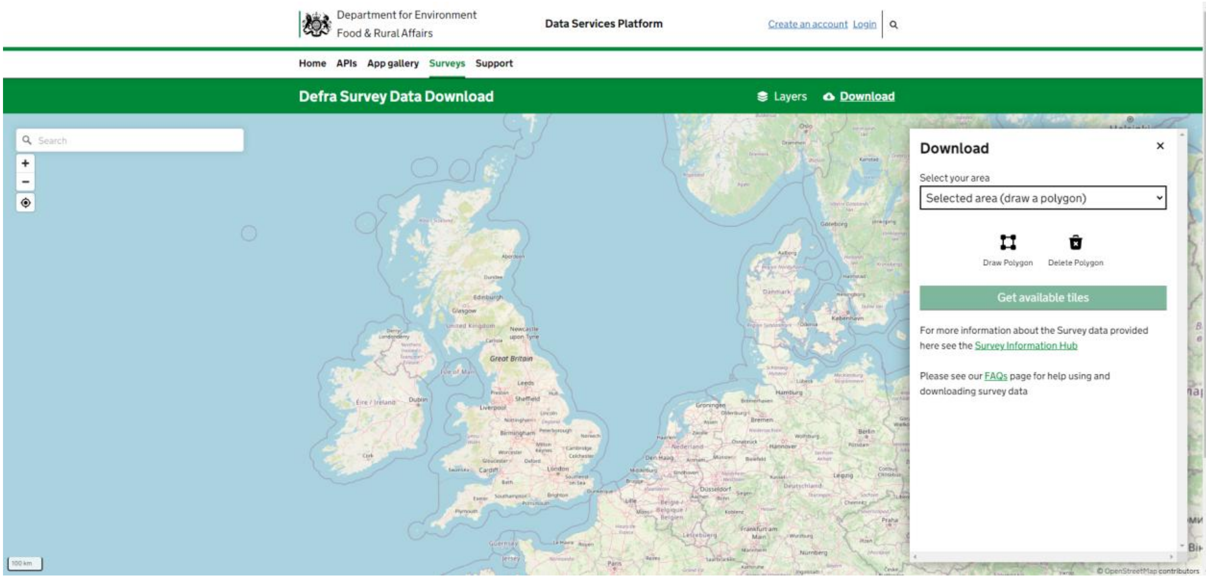


Next the outputs from the 'Clip' tool will need to be merged to create one final layer containing all the sub-catchments. The tool in ArcGIS that can do that is called 'Merge'.

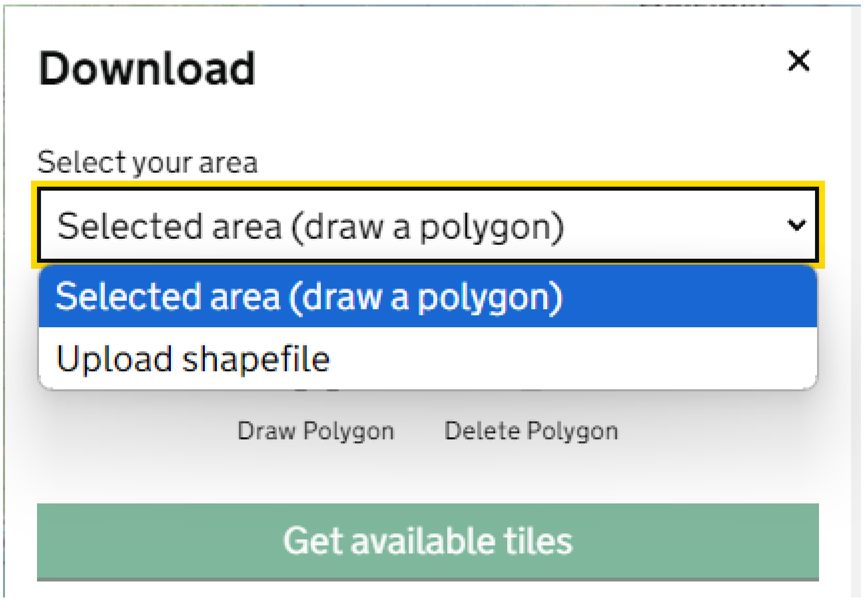


10. How to download Lidar data from the EA

DSM/DTM data can be downloaded from here if required. The link will open the following page.

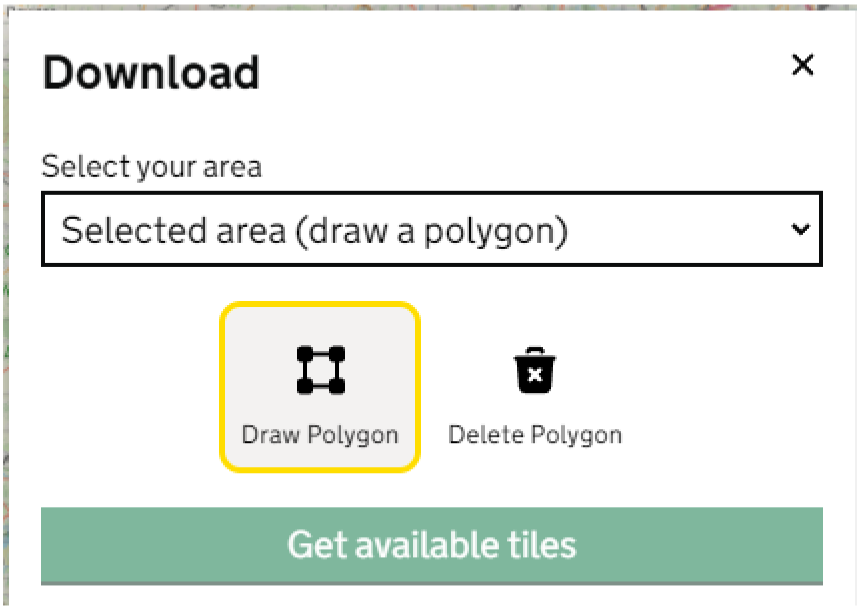


There are two options for selecting the data for the area of interest. These options are selected from the drop-down menu.

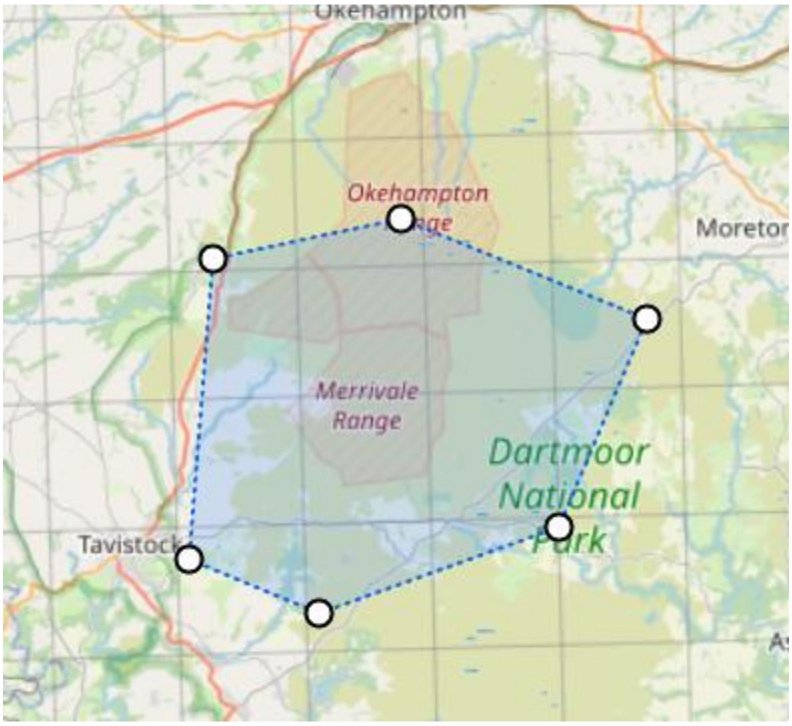


10.1. Select Area by Polygon

If you want to draw a polygon select the ‘Selected area (draw a polygon)’ from the drop-down menu, then click on the draw polygon icon.



This will allow you to draw a polygon for the area of interest. To draw the polygon, click on the map, each click will create a point, and these will form the shape of the polygon. When placing the last point to complete the polygon you will need to double click rather than just click once, this will indicate that this is the last point and no more will be drawn. An example is below.



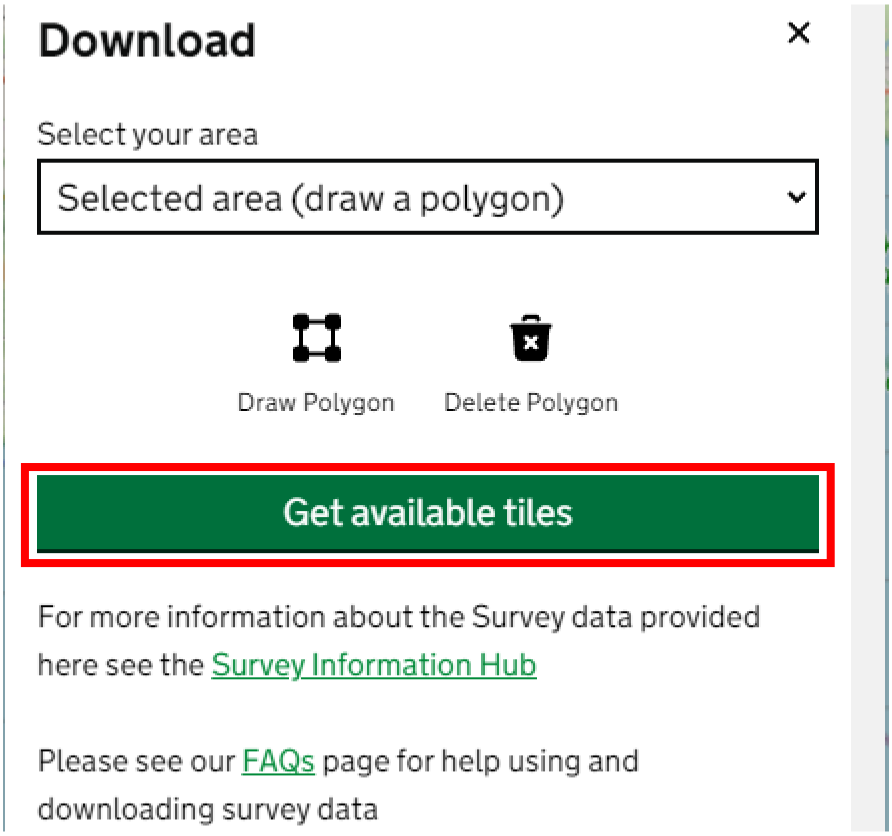
10.2. Select download data area using a shapefile

The second drop down option is 'Upload shapefile'. For this the shapefile you want to use must be put into a zip file. The zip file must contain the .shp, .sbx, .sbn, .prj, . dbf,

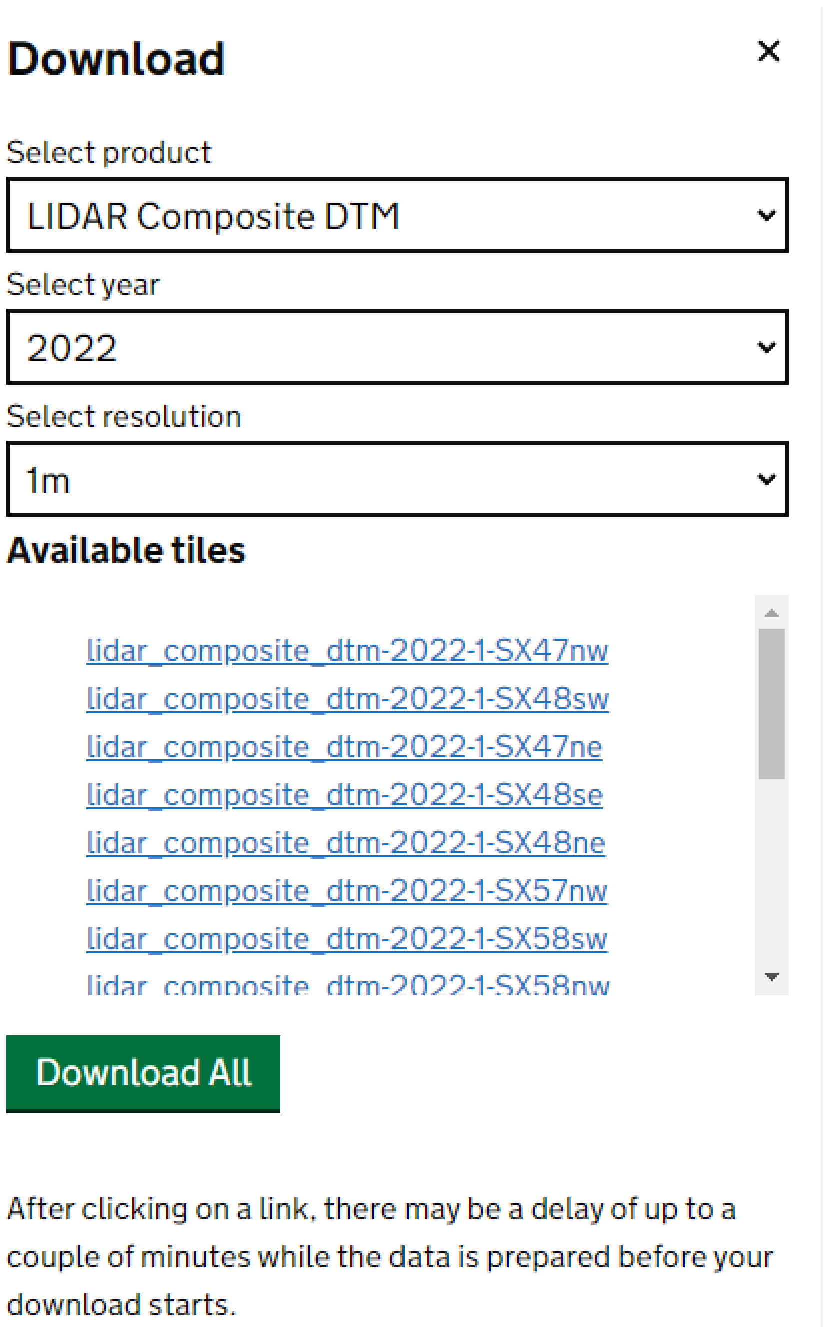
.cpg layers associated with the shapefile layer. This shapefile can then be selected using the 'choose file' option or dragged and dropped from the folder in file explorer. Once the shapefile has been added, click the 'Get available tiles' option to show the relevant data layers.

Downloading the relevant data

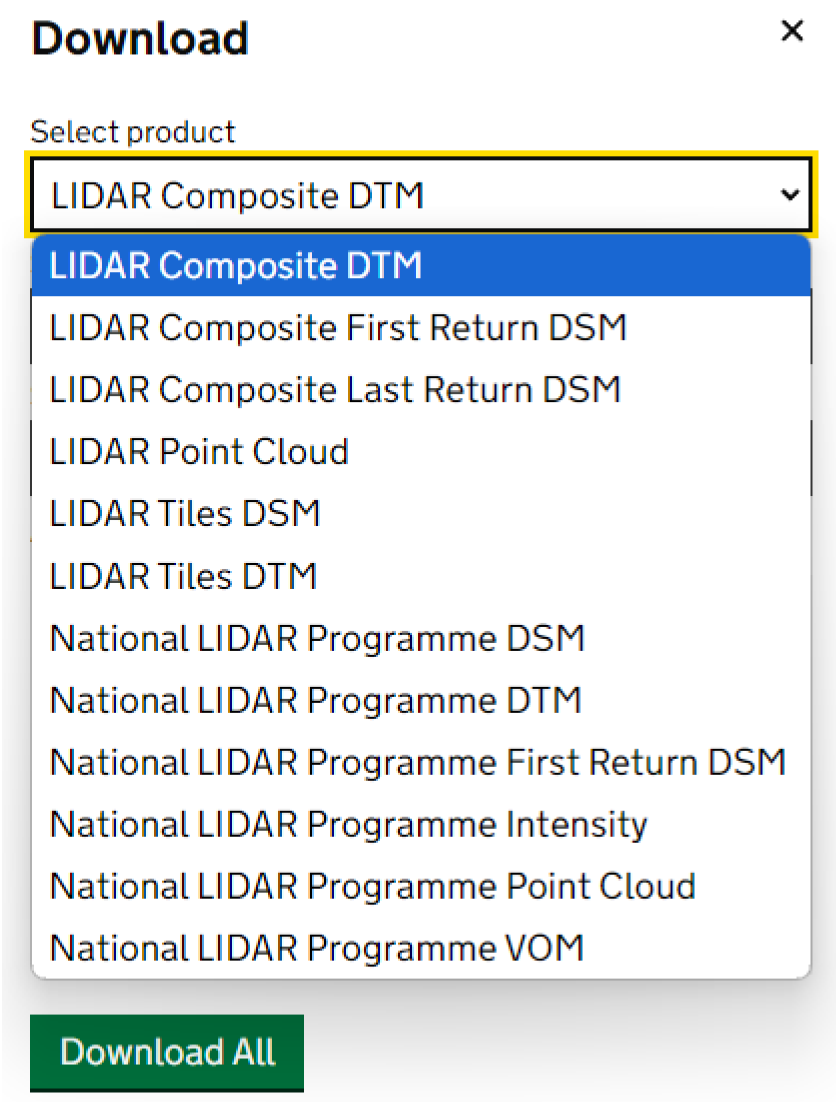
Once the polygon has been drawn, select the 'Get available tiles' option



Once this is selected a new option window will open

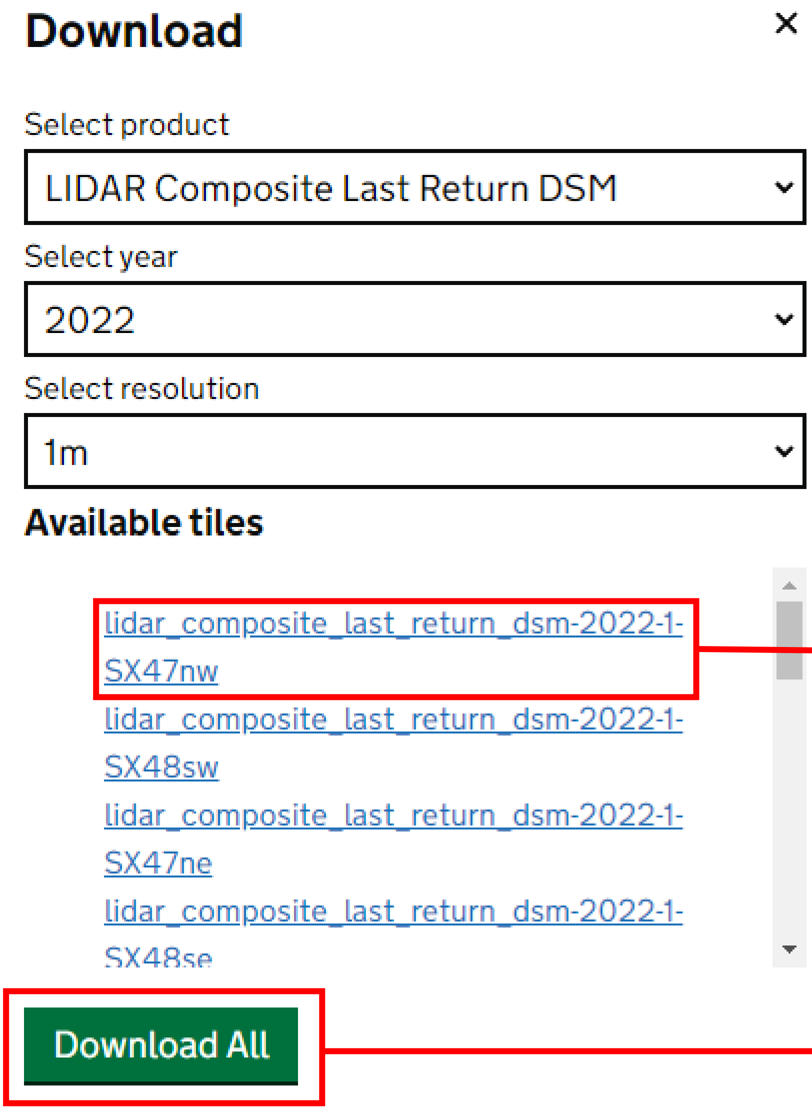


The default option will be 'LIDAR Composite DTM', however there are many options in the drop-down menu.



For the tool, it is recommended that the 'LIDAR Composite Last Return DSM' is selected. The year can also be selected and the most recent year is recommended. You can also select the resolution and for the DSM the option is 1m or 2m. It is recommended that a resolution of 1m is used.

The tiles that fall within the area of interest are listed. This tiles can be downloaded individually by selecting each option. Download all is an option, however this does not always work and sometimes only provides the first DEM tile, therefore it is recommended to download each tile individually.

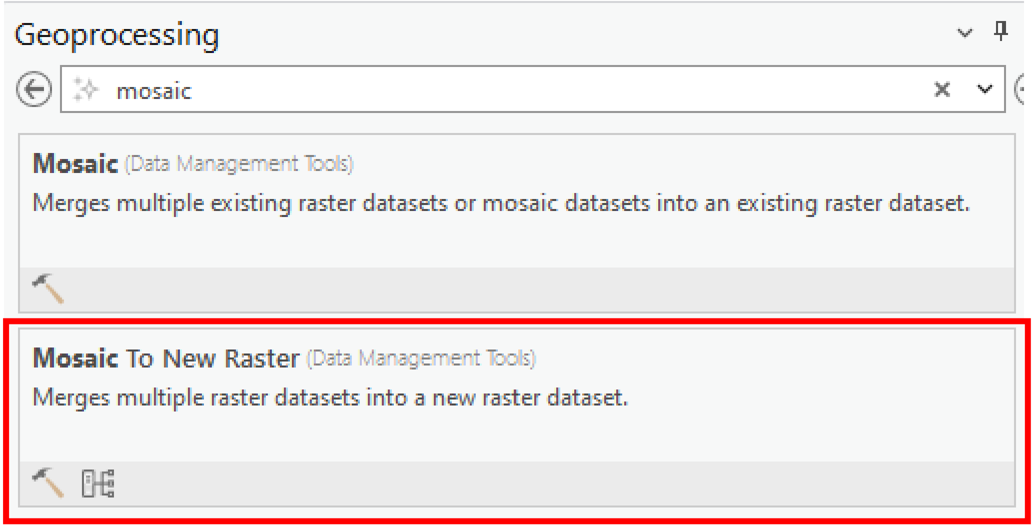


Select the individual tiles.

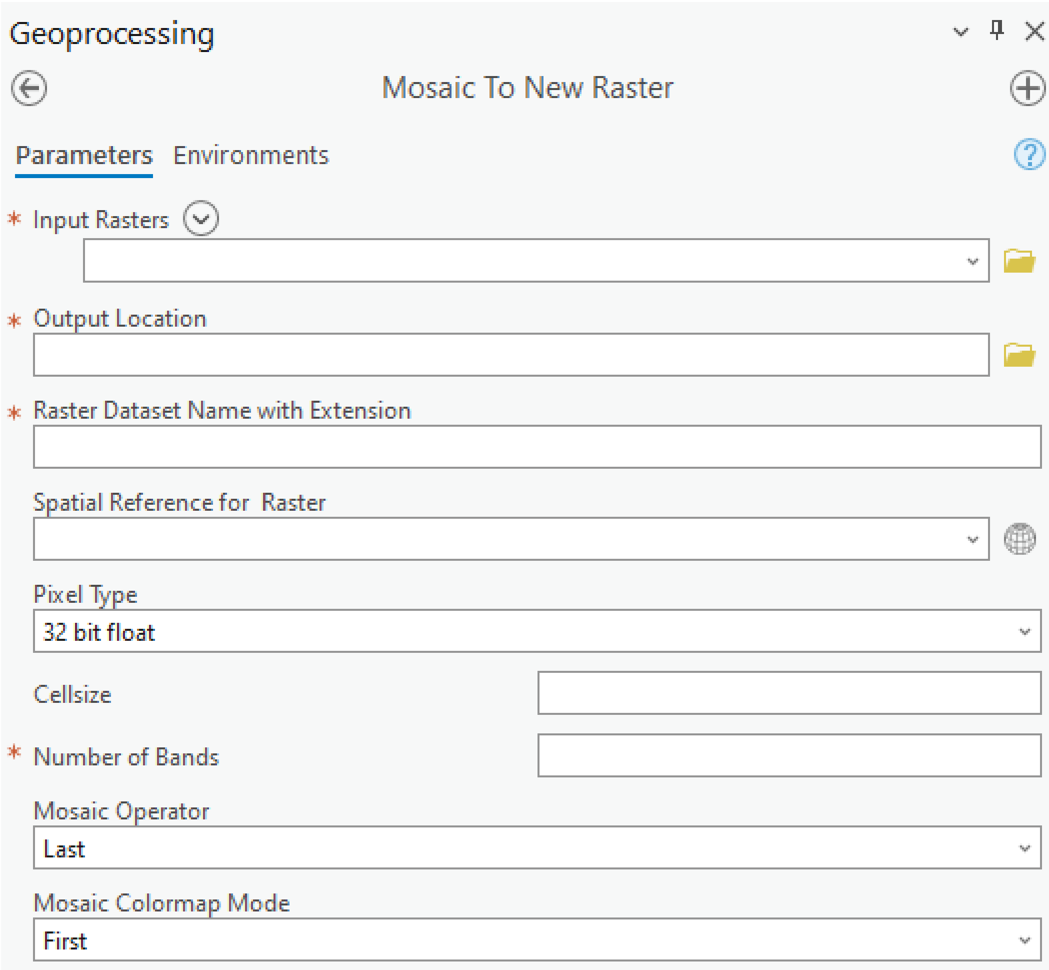
Select 'Download All' to download all the tiles at once.

10.3. Create one DSM from multiple tiles

If multiple tiles are downloaded they will need to be mosaiced together to create one DSM to be used with the tools. To do this open ArcGIS and find the 'Mosaic to New Raster' tool in Geoprocessing.



The 'Mosaic To New Raster' tool interface looks like the following



Input Rasters: This is where all the downloaded DSM tiles must be loaded. This can be selected using the drop down, file icon or dragged and dropped.

Output Location: This is where the output folder pathway must be included. This can be selected using the file icon or copied and pasted into the box.

Raster Dataset Name with Extension: This is where you need to type the name of the final output file. The file extension will also need to be included as the default is not TIFF and that is the file type needed for the tools. An example name is DSM_Catchment.tif

Spatial Reference for the Raster: For this option select one of the DSM tiles.

Pixel Type: From the drop down, menu select the ‘32 bit float’

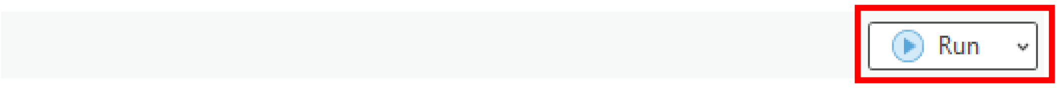
Cellsize: The cellsize will be the same as the resolution of the DSM tiles

Number of Bands: This will be 1

Mosaic Operater: Leave as default

Mosaic Colormap Mode: Leave as default

Once all the options are filled in and selected, click run.



The final output from this is what will be used as the DSM in the tools.

11. Error messages

ERROR 010658: Failure in distributed raster analytics operation

This error is in relation to the DEM. It is unclear what causes this error but clipping the data to a polygon shapefile can resolve the error. This error can occur when running tool 4 (D8 Version) or 4 (DInf Version). When running tool 4, click on the check box for clip DEM then provide the shapefile in the relevant place as previously discussed.

ERROR 000800: The value is not a member of Point x-coordinate | Point y-coordinate | Point x- and y-coordinate notation.

This error relates to the shapefile type used with tool 1, 2 and 3. If a point file has been used this error may appear. This is in relation to the shapefile being a point and therefore not having a width and length like a polygon in a polygon shapefile. To resolve this issue instead of using the tool right click on the point shapefile. Then select 'Data' then select 'Export Features' from the options. The input file will be the one you have already selected. Provide a file location and name in the 'Output Feature Class' box. Then select the 'Filter' drop down. In the 'select a field' drop down select the attribute that has the information regarding drainage type, similarly to the method for tool 3 or 4. The select 'included the value(s)' from the second drop down. Use the third drop down to select all the values you want to include in the new file to be used as a pour point. Click 'ok' for the layer to be generated. After the layer has been generated, navigate to the attribute table

Error: Possible credentials issue

```
RuntimeError: Failed to add data. Possible credentials issue.
```

- Export the layer and save in a new location

12. Interpreting the Results

12.1. D8 vs DInf

Field data has not been collected to verify which flow direction method produces a more realistic and/or robust result for the sub-catchment areas. Therefore, information in the manual regarding the differences between the flow direction methods have been outlined and the option to choose between the two has been provided. Trials have shown that the DInf flow direction method can sometimes provide a sub-catchment in an area the D8 flow direction method did not. Therefore, it may be beneficial to use the DInf flow method as it could provide more potential areas for NbS. However, the DInf method could be overestimating sub-catchment areas but, in this case, it may be better to have more potential areas to assess then to miss potential areas and opportunities for NbS. It may be beneficial to run the analysis with both D8 and DInf and compare or combine the results to ensure all potential areas have been produced.

12.2. Extracting permeable potential opportunity areas

If the tool is being used to assess permeable opportunity areas for NbS, then after the geospatial analysis conducted with the SCORe tool, the user must extractonly permeable areas draining to the combined sewer network, from the sewer sub-catchment layer. The user could use a GIS layer of impermeable areas and erase those from the sub-catchments produced by the tool. Datasets such as OS MasterMap have this data available, although it is not open source.

12.3. Catchment suitability

Some of the catchments produced by both DInf and D8 flow direction methods may be small in size and therefore, unsuitable for NbS. A screening may be required with a suitable size threshold; this would remove any unsuitable results. Furthermore, the DInf flow direction method can provide very large catchment areas (the D8 does not do this) and these catchments areas may need to be refined to be of better use, the flow pathways from the flow accumulation output can be helpful for this.

It is important to emphasise that the topographic catchments generated using the SCORe methodology will not all be suitable for green solutions to storm overflows. For example, there may be barriers to flow that were not represented in the DEM, which means that flow generated in an area of interest is not actually directed towards the expected area of PF. Furthermore, many areas may not produce enough runoff to be worth intervening on, for example due to a combination of the soil conditions (well-draining), gradient, land cover (e.g. forested areas tend to produce less runoff than grassland) and upslope contributing area (an area at the bottom of a larger contributing area is more likely to produce runoff). This is why further desk-based analysis and in-field surveys are required to provide further screening of potential opportunity areas (see Section 13).

13. Next Steps

The following steps should be conducted after the geospatial analysis; this includes conducting a desktop survey using street view software (e.g. Google Street View) to assess the potential contributing areas for barriers to flow. Due to the 1m resolution of the DSM (recommended) used, some barriers may not be included. Barriers to flow can include walls and hedgebanks, and these can be located using street view software. Wet weather surveys will also need to be conducted after the street view survey. The wet weather surveys should be conducted during heavy rainfall events, and ideally when the ground has been left saturated after a period of wet weather. These conditions will enable overland flow to be visible during a site visit. The flow accumulation output from the tool can be used to help with identifying flow pathways and where water may be exiting an area and entering the combined sewer network. These steps combined will further refine the areas with potential for NbS.

The use of hydraulic modelling is also recommended to assess the potential for NbS at a selected site, as well as compare different NbS. Hydraulic modelling will enable a better understanding of the potential for NbS to reduce overland flow entering the combined sewer network. A variety of software can be used, such as InfoWorks. Furthermore, natural capital accounting can be used to compare NbS to grey infrastructure. This step will assist with understanding the costs and benefits of each solution and inform decisions regarding which solution to deploy.

References

Defra (2023) *Storm Overflows Discharge Reduction Plan*. Department for Environment, Food and Rural Affairs.

Muleta, T.N. and Knolmar, M. (2025) ‘Ecological impacts of combined sewer overflows on receiving waters’, *Discover Water*, 5(1), p. 24. Available at: https://doi.org/10.1007/s43832-025-00212-2

Perry, W.B. *et al*. (2024) ‘Addressing the challenges of combined sewer overflows’, *Environmental Pollution*, 343, p. 123225. Available at: https://doi.org/10.1016/j.envpol.2023.123225.