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Hydroperiod Tool Design

Prepared for:

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1.0 Executive Summary

The geospatial modeling tool, the "Hydroperiod Tool" (HT), has been used by St. Johns River Water Management District (SJRWMD) on a variety of projects, most notably the 2012 Water Supply Impact Study, for which it received favorable reviews from the National Research Council. The HT is a custom-built tool operating on Esri software, specifically ArcMap 10.1. SJRWMD is currently upgrading to ArcMap 10.4 and within a few years will be running on a new platform called ArcGIS Pro.

SJRWMD has requested Environmental Systems Research Institute, Inc. (Esri) Professional Services (PS) to provide consulting services for implementation of HT within Arc Hydro (AH) framework. This document describes the implementation of HT within Arc Hydro framework.

1.1 Document history

Table 1. Document Revision History

Version	Description	Date
1	Initial document	8/15/2018
2	Design revisions after initial document review	8/16/2018
3	Addition of Appendix 2	8/23/2018
4	Final document	9/28/2018

2.0 Solution Overview

Basic HT capabilities are implemented as six Arc Hydro python tools in a separate toolset and added to the Arc Hydro Tools Python Toolbox. The following hydroperiod toolset is implemented.

- HydroPeriod.tbx
  - 1. Create WSE and Ponded Depth Rasters
  - 2. Create Classified Depth Raster
  - 3. Calculate Volume Table
  - 4. Calculate Zonal Statistics
  - 5. Calculate Cell Statistics
  - 6. Extract Point Cell Values

The tools leverage existing Arc Hydro database design for feature identification, default layer naming, and time series management. Each tool has help built into the tool following AH tool development practices.

Due to the integrated nature of hydro period analyses, the tools and data structures are designed to be closely tied together. This facilitates enforcement of naming conventions that ensure proper tool operation and minimize user input.

2.1 Database design

Database design is based on Arc Hydro principles.

1. Input feature classes will have “HydroID” field populated for every feature. Three types of feature inputs are expected:
    a. Level “gages” (points). These are points with observation data that will be used to generate the interpolated surfaces.
    b. Zonal polygons. Optional layer used to assign surface statistics to.
    c. Extraction points. Optional layer used to extract values at points of interest.
2. The level tables (discussed in more detail later) will use field “FeatureID” that will contain the “HydroID” of the point feature for which they contain the levels.
3. There are three “level” table types that can be input into the tools:
    a. Time series table. This will contain (at the minimum) the following fields:
        i. FeatureID (long integer)

        ii. TSTime (date/time)
        iii. TSValue (double)

    b. Frequency table. This will contain (at the minimum) the following fields:
        i. FeatureID (long integer)
        ii. FreqCode (string)
        iii. FreqValue (double)

    c. Stage table. This will contain (at the minimum) the following fields (note that there is no specific FeatureID field since the same level applies to all features):
        i. StageValue (double)

4. Remap tables. These tables are used to remap any of the input raster ranges into a different value. These will contain (at the minimum) the following fields:
    a. FromV (double)
    b. ToV (double)
    c. OutV (integer)

5. DEM raster. This can be any Esri supported raster format (grid, tif, or mrf formats are recommended).

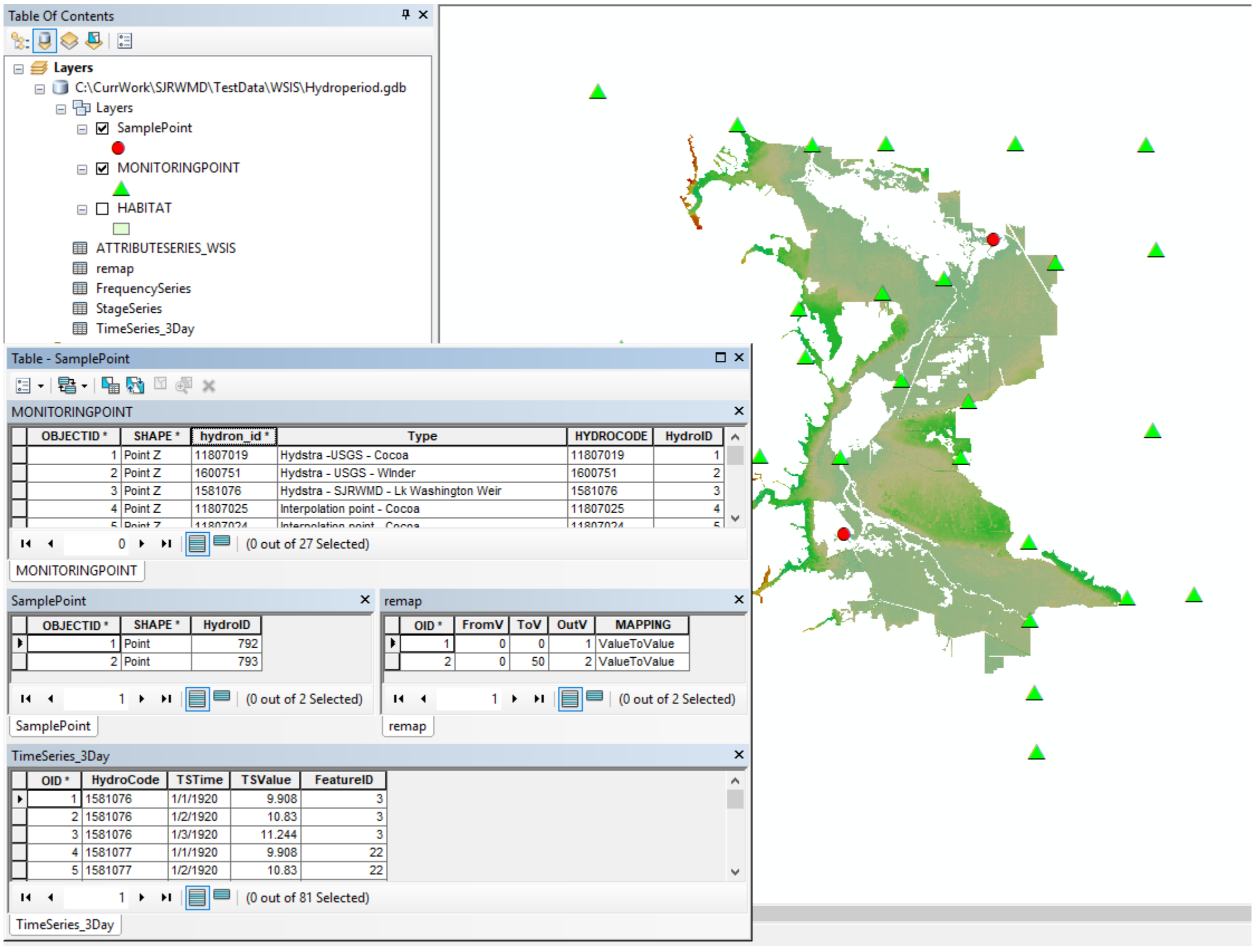
6. Horizonal and vertical units for raster and vector/tabular data will be in consistent units (ft or m) and projection.

7. An optional configuration file in “txt” format specifying interpolation technique parameters can be provided. If not present, ArcGIS default parameters will be used.

The tools will expect these types of input data structures and will not operate if one of these types is not provided as input. All vector data will be stored within a single geodatabase/feature dataset and will be in the projection matching the projection of the DEM.

2.1.1 Example input data structures

The following figures represent a valid sample dataset.



The map contains:

1. DEM (seg8newag15). Note that the DEM structure controls the raster outputs for the following parameters:
    a. Raster format (e.g. if DEM is in tif format, all the outputs will be in tif).
    b. Cell size.
    c. Analysis extent.
    d. Raster “snap” environment.
2. Monitoring point feature class (MonitoringPoint). It has HydroID field. It also has an optional field that is a global external identifier (HydroCode/HYDRON_ID).
3. Zone polygon feature class (HABITAT). It has HydroID field.
4. Sample point feature class (SamplePoint). It has HydroID field.

5. Time series table (ATTRIBUTESERIES_WSIS). It has fields: FeatureID (pointing to the HydroID of the point in the MonitoringPoint FC), TSTime with data/time of the observation, and TSValue with the water surface elevation at that point for that time. Optionally it has HydroCode pointing to the global identifier (HYDRON_ID).
6. Time series table (TimeSeries_3Day). This is a subset time series table with only the first 3 days (used for example purposes).
7. Remap table (remap). It has fields: FromV, ToV, and OutV.

2.1.2 Output data structures

Tools create numerous output data structures. To ensure consistency of application and result data, all the results are placed in predetermined data and naming structure with minimal user input. The following are user specified naming parameters:

1. Target directory where initial interpolated data are stored. Once that folder is defined, all results related to that interpolation will be stored in that folder. This includes both raster data that will be store in the Esri GRID format as well as vector and tabular data that will be stored in the output geodatabase created in the target directory.
2. Ponded depth raster prefix (8 characters max). This prefix will be used to name output ponded depth rasters. Default is “PD”.
3. Water surface elevation (WSE) raster prefix (8 characters max). This prefix will be used to name output optional WSE rasters. Default is “WSE”.
4. Classified raster prefix (8 characters max). This prefix will be used to name output classified rasters. Default is “CDR”.

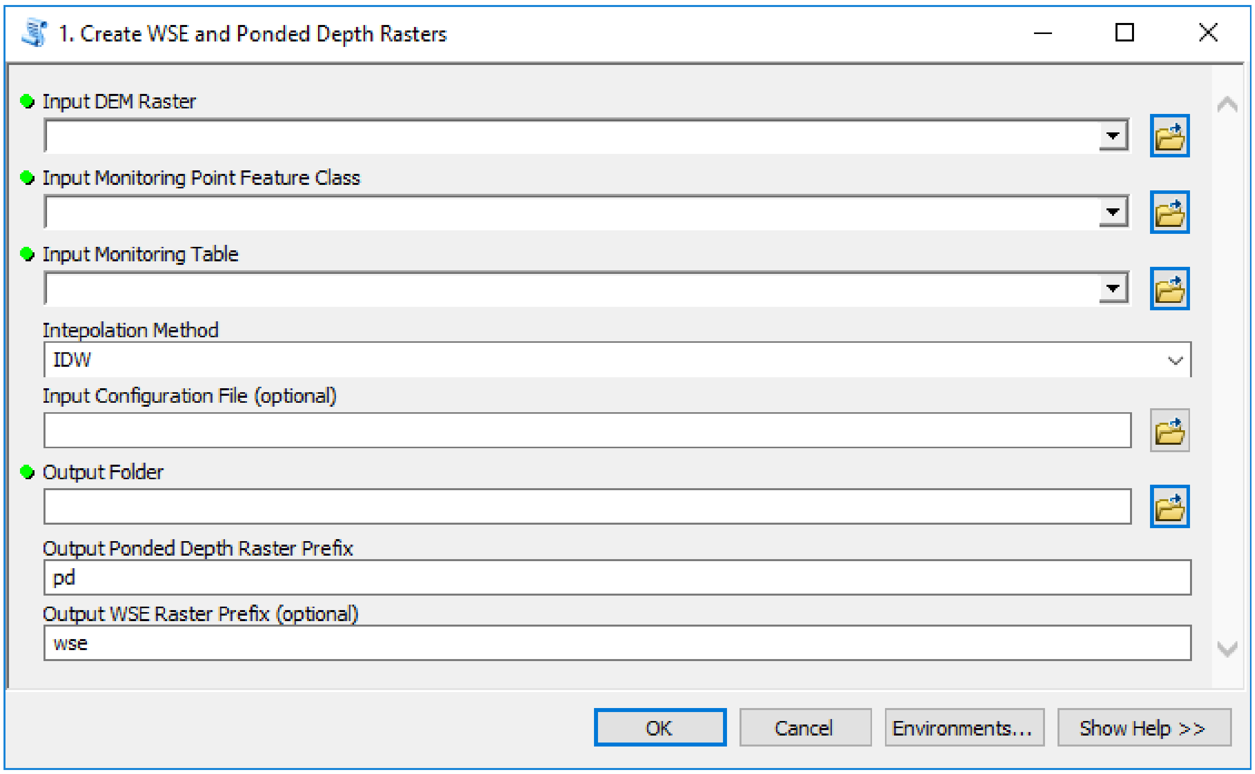
Specific tool outputs are described in the tool section.

2.2 Tool operations

The following sections present operation for the six HT tools. Tools operate on the data structures described above.

2.2.1 Create WSE and Ponded Depth Rasters

This tool creates water surface elevation (WSE) and ponded depth (PD) rasters from stage recorder location(s) data by interpolation, using interpolation technique specified by the user in the "Interpolation Method". Inputs and outputs are provided on the following figure. If WSE raster prefix is not provided (as optional input), WSE rasters are not saved. If configuration file is not provided, default ArcGIS surface interpolation parameters are used for the selected interpolation method.



The tool performs the following actions:

1. If a geodatabase with the same name as the output folder does not exist (in that folder), it will be created. This gdb will be used to store output data (vector/tables).

2. Check for existence of a "Layers" folder in the output folder. If one does not exist, the tool creates it.

    a. If one does exist and it contains rasters with the same prefix as provided in the tool UI, the tool provides the message about it and quits (there is no overwriting of existing layers).

3. If optional configuration file is provided, it is copied into the output folder.

    a. If a file with that name already exists in the output folder, it is overwritten.

4. Checks if the input table has one of the following fields:

   a. "TSValue" – in that case it recognizes that this is a time series table and performs time series processing. The input table also needs to have "TSTime" and "FeatureID" fields.

   b. "FreqValue" – in that case it recognizes that this is a frequency series table and performs frequency series processing. The input table also needs to have "FreqCode" and "FeatureID" fields.

   c. "StageValue" – in that case it recognizes that this is a stage series table and performs stage series processing.

5. For time and frequency processing:

   a. It creates a unique (on "FeatureID"), sorted (on "TSTime/FreqCode") list of values and processes each unique sort value. The list is assigned an integer index starting with 1 (for the lowest values) and incremented by 1. This index is used in the naming of the resulting rasters.

   b. For each unique value (index) it assigns the proper measurement value to the corresponding point and performs surface interpolation.

      i. If WSE prefix is supplied, the interpolated surface is stored.

      ii. Subtracts the DEM from the WSE surface, eliminates negative values, and stores the result as the ponded depth raster.

6. For stage processing:

   a. It creates a unique, sorted (on "StageValue") list of values and processes each unique sort value. The list is assigned an integer index starting with 1 (for the lowest values) and incremented by 1. This index is used in the naming of the resulting rasters.

   b. For each unique index it creates a constant value raster (there is no surface interpolation since the raster is of constant value).

      i. If WSE prefix is supplied, the value raster is stored.

      ii. Subtracts the DEM from the WSE surface, eliminates negative values, and stores the result as the ponded depth raster.

7. Naming of the output rasters has the following structure:

    a. PD_i, where “PD” is a ponded depth prefix provided by the user through the “Output Ponded Depth Raster Prefix” entry (should be limited to 8 characters), “_” is a constant separator literal, and “i” is the unique level index.

    b. WSE_i, where “WSE” is a water surface elevation prefix provided by the user through the “Output WSE Raster Prefix” entry (should be limited to 8 characters), “_” is a constant separator literal, and “i” is the unique level index.

8. All the raster results are stored in the “Layers” folder under user provided folder (“Output Folder” entry). Each category of rasters will be stored in their own folder named using the raster prefix (e.g. PD or WSE).

9. Creates a mosaic dataset (in the output geodatabase that will be created in the output folder) referencing created rasters, their index, and input TSTime/FreqCode. The name of the mosaic dataset is PD_mds, where “PD” is a ponded depth prefix provided by the user through the “Output Ponded Depth Raster Prefix” entry and “_mds” is a constant literal.

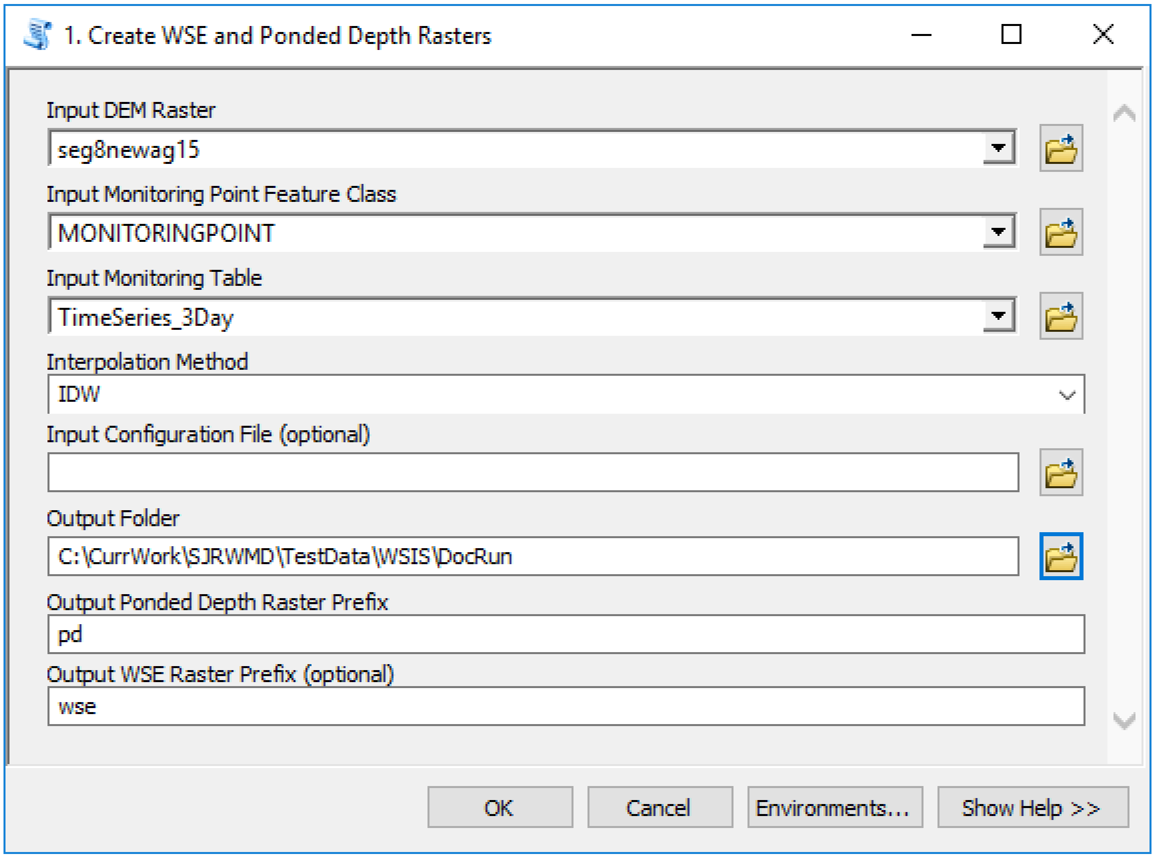
10. Parameters for the interpolation techniques are stored in the optional configuration file (txt format). If the file is not provided, standard ArcGIS interpolation parameters are used for the selected interpolation method.

11. Tool operates on the selected set of inputs (points and series). The data from the input layers are copied (with the same feature class/table name as of the input) into the output gdb.

12. If only one gage is available, the interpolation method entry is ignored and a horizontal surface is created instead.

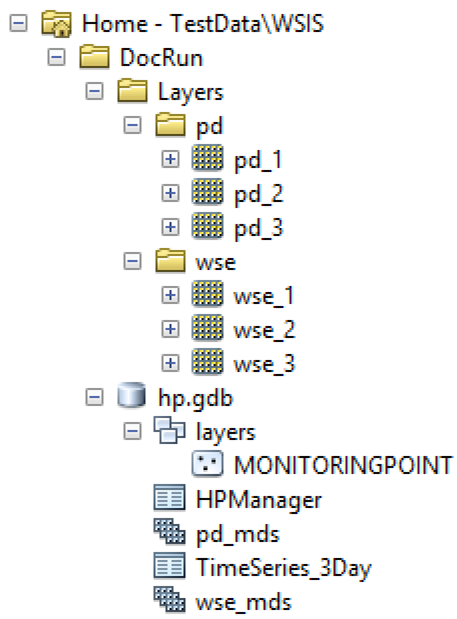
The created data structures are now completely independent from the input data and can be treated as an independent dataset.

2.2.1.1 Example run



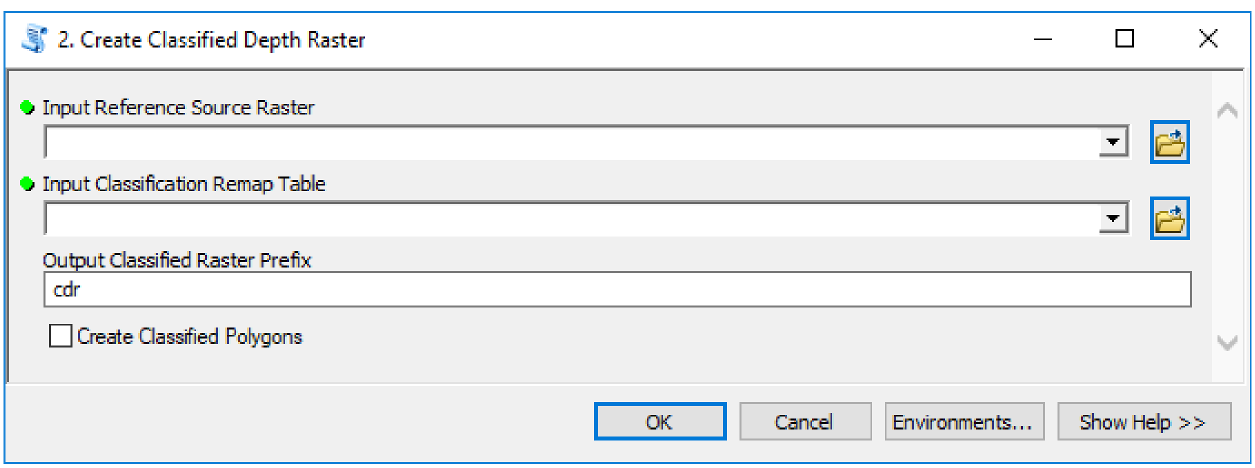
2.2.1.2 Example output structure

The following data structures were created as a result of the tool run (folder "DocRun" was provided as output folder).



2.2.2 Create Classified Depth Raster

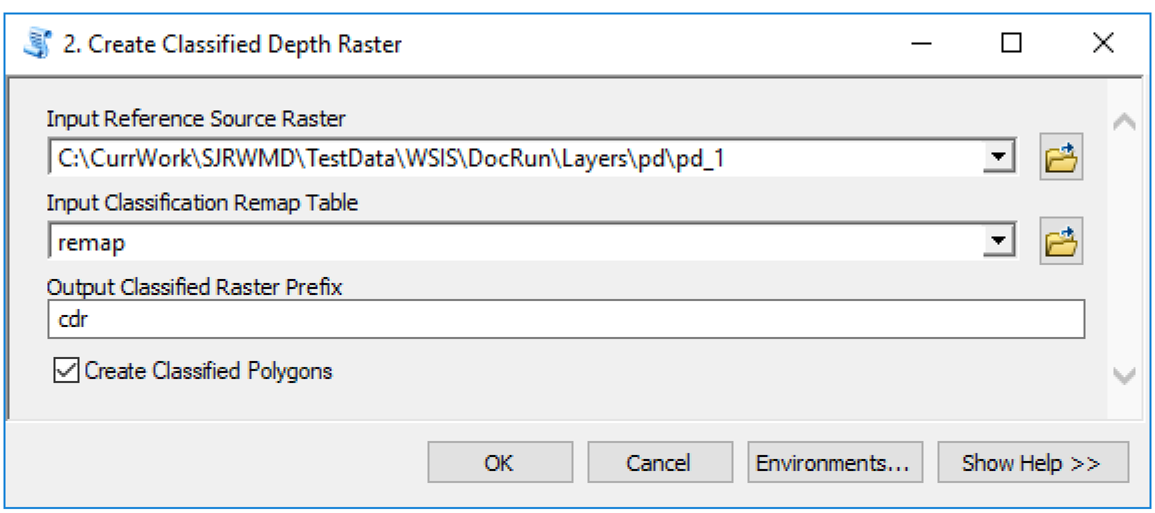
This tool creates classified depth raster (CDR) and optionally a polygon feature class (CDFC) from PD or WSE rasters and classification remap table. Operation is performed for all rasters referenced by the reference source raster (for example, if a ponded depth raster is selected, then the classification will be performed for all the ponded depth rasters in the folder where the reference raster resides based on the reference raster prefix). Results are placed in the same parent folder where input rasters are, but in the separate subfolder named using the provided prefix. Inputs and outputs are provided on the following figure. If "Create Classified Polygons" check box is not checked, the CDFC polygons are not saved.



The tool performs the following actions:

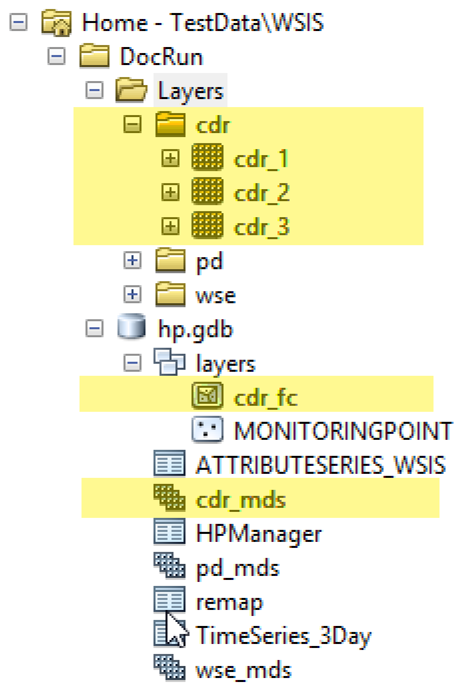
1. Identifies the location of the output rasters based on the location of the input reference raster.
2. Identifies the rasters to process based on the prefix of the selected reference raster. All rasters with the same prefix will be processed.
    a. If rasters with the same prefix already exist in the output folder, the tool will provide an error message and quit (no auto overwriting).
3. Applies classify by table function to generate the reclassified raster. Stores the resulting raster with the provided prefix and same index as the input raster.
4. Creates a mosaic dataset (in the output geodatabase) referencing created rasters, their index, and input TSTime/FreqCode. The name of the mosaic dataset is CDR_mds, where "CDR" is a classified raster prefix provided by the user through the "Output Classified Raster Prefix" entry (should be limited to 8 characters) and "_mds" is a constant literal.
5. If CCP option is selected, it creates polygons (not generalized) for each class in classified rasters and stores them in the polygon feature class named CDR_fc, where "CDR" is a classified feature class prefix provided by the user through the "Output Classified Raster Prefix" entry and "_classifiedPoly" is a constant literal. Polygons are tagged (attribute) by the index of the raster. Feature class is stored in the output geodatabase.
    a. Polygon area is calculated in m2 ("Aream2" field) and acres ("Areaacres" field).
6. Copy the reclass table into the output gdb.

2.2.2.1 Example run



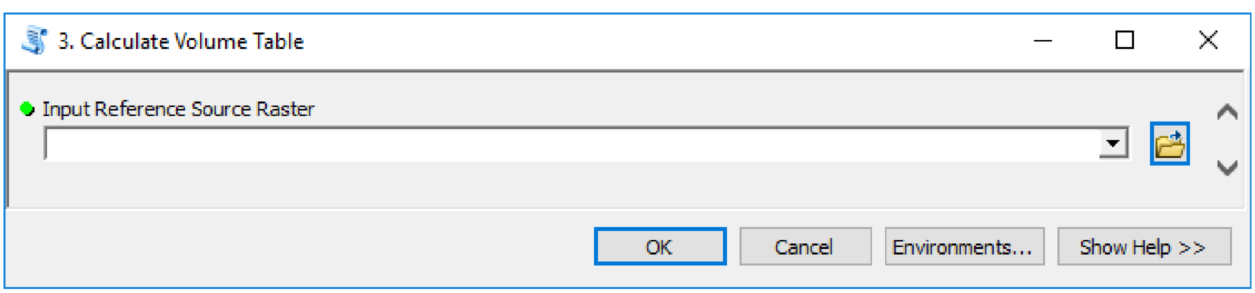
2.2.2.2 Example output structure

The following data structures were created as a result of the tool run (highlighted in yellow).



2.2.3 Calculate Volume Table

This tool calculates total volume (in m3) of each raster in the input folder and stores the values in the output volume table referenced by the raster names. Operation is performed for all rasters referenced by the reference source raster (for example, if a ponded depth raster is selected, then the volume calculation will be performed for all the ponded depth rasters in the folder where the reference raster resides based on the reference raster prefix). Inputs are provided on the following figure (there are no user specified outputs).

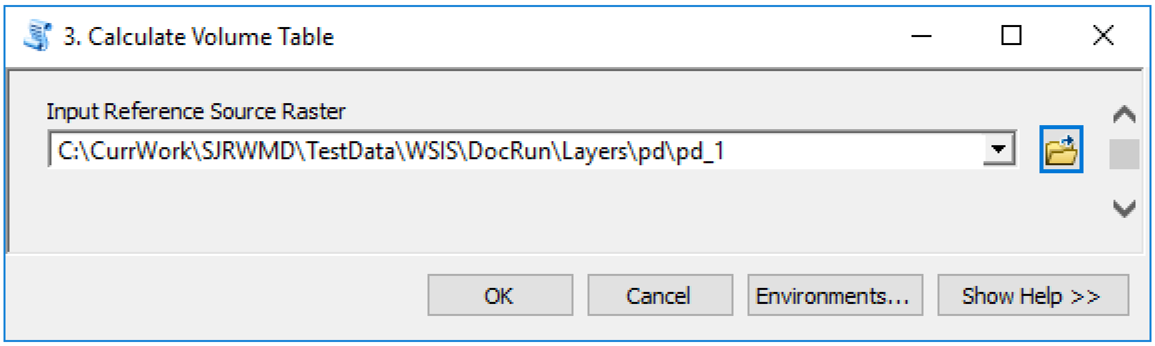


The tool performs the following actions:

1. Identifies the rasters to process based on the prefix of the selected reference raster. All rasters with the same prefix will be processed.

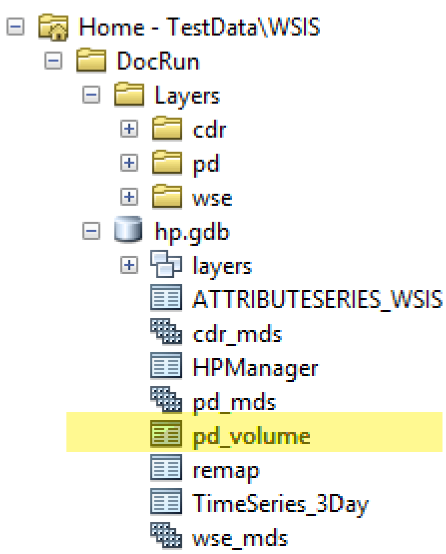
2. Applies volume calculation for the raster (sum of all the values multiplied by the cell area). Stores the resulting value in the output volume table referenced by the raster for which the computation was performed (prefix and same index as the input raster). The volume table will have name PRE_volume where "PRE" is the raster prefix and "_volume" a constant literal and is stored in the output geodatabase.

2.2.3.1 Example run



2.2.3.2 Example output structure

The following data structures were created as a result of the tool run (highlighted in yellow).

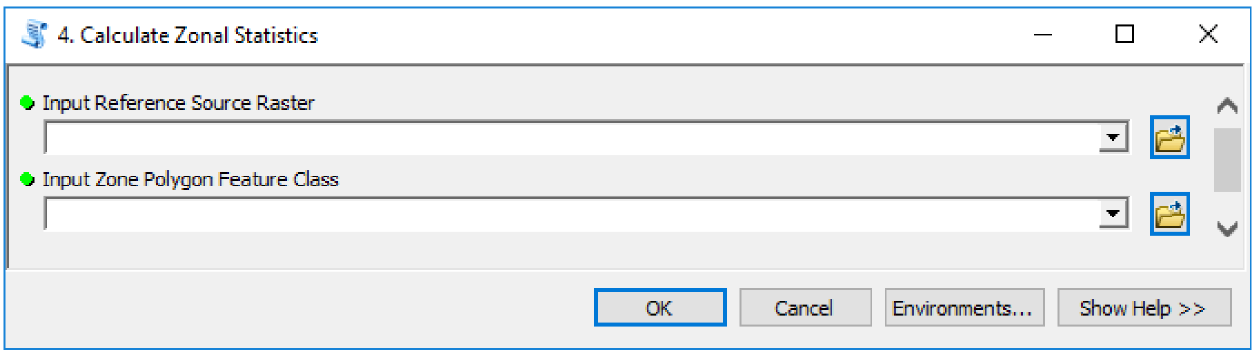


pd_volume

OBJECTID *	NAME	HPINDEX	volume
1	pd_1	1	4016.317155
2	pd_2	2	24617.459654
3	pd_3	3	72510.989121

2.2.4 Calculate Zonal Statistics

This tool calculates zonal statistics for all rasters referenced by the reference source raster (for example, if a ponded depth raster is selected, then the statistics will be calculated for all the ponded depth rasters in the folder where the reference raster resides based on the reference raster prefix) and zones defined in the input zone polygon feature class. The results are stored in the output zonal statistics table referenced by the zone and raster names (index). Inputs and outputs are provided on the following figure.

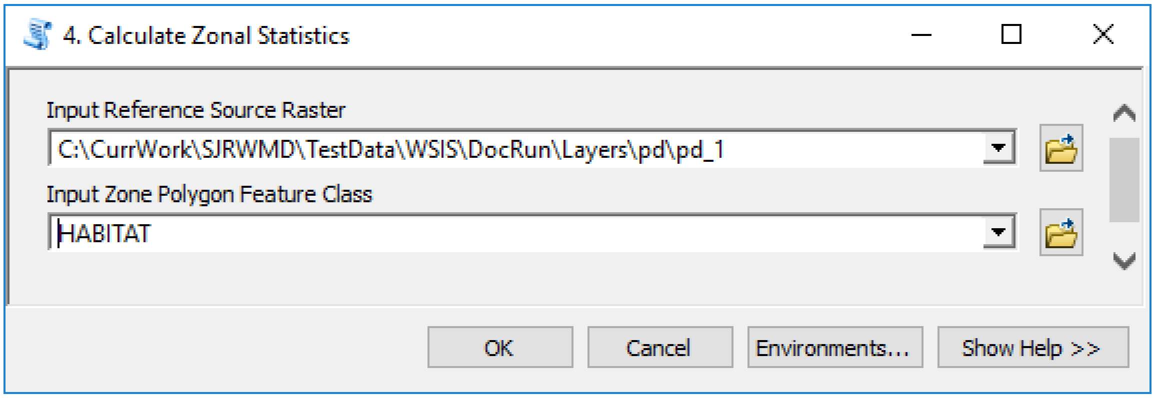


The tool performs the following actions:

1. Identifies the rasters to process based on the prefix of the selected reference raster. All rasters with the same prefix will be processed.

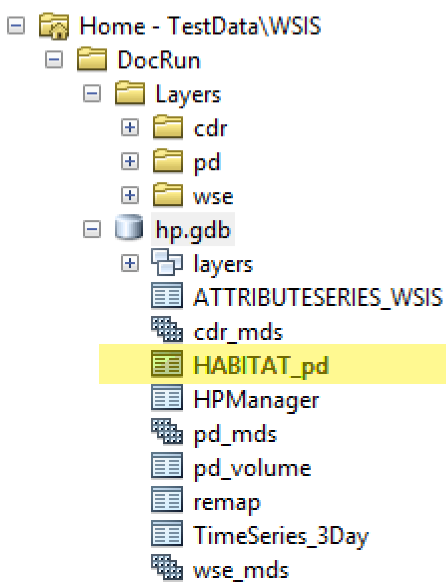
2. Applies statistics calculation for the raster (all standard statistics by the "Zonal Statistics as Table" function). Stores the resulting values in a table referenced by the raster for which the computation was performed (prefix and same index as the input raster). The zonal statistics table will have name ZPFC_PRE where "ZPFC" is the name of the zonal feature class and "PRE" is the raster prefix, and is stored in the output geodatabase.

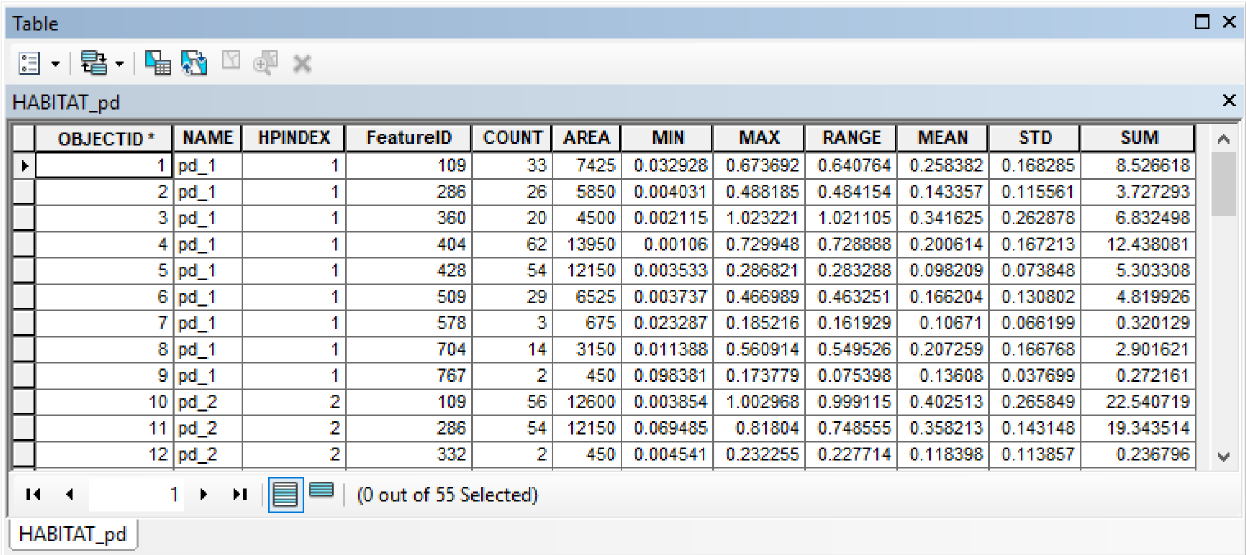
2.2.4.1 Example run



2.2.4.2 Example output structure

The following data structures were created as a result of the tool run (highlighted in yellow).





Table

HABITAT_pd

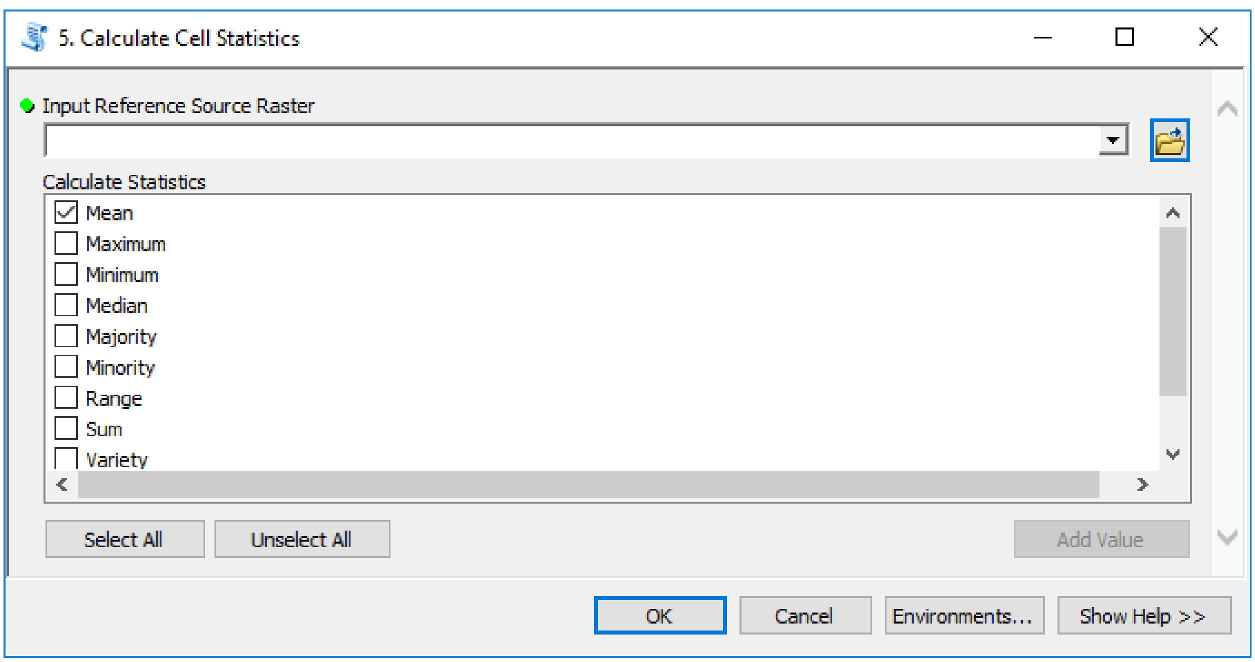
OBJECTID *	NAME	HPINDEX	FeatureID	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	pd_1	1	109	33	7425	0.032928	0.673692	0.640764	0.258382	0.168285	8.526618
2	pd_1	1	286	26	5850	0.004031	0.488185	0.484154	0.143357	0.115561	3.727293
3	pd_1	1	360	20	4500	0.002115	1.023221	1.021105	0.341625	0.262878	6.832498
4	pd_1	1	404	62	13950	0.00106	0.729948	0.728888	0.200614	0.167213	12.438081
5	pd_1	1	428	54	12150	0.003533	0.286821	0.283288	0.098209	0.073848	5.303308
6	pd_1	1	509	29	6525	0.003737	0.466989	0.463251	0.166204	0.130802	4.819926
7	pd_1	1	578	3	675	0.023287	0.185216	0.161929	0.10671	0.066199	0.320129
8	pd_1	1	704	14	3150	0.011388	0.560914	0.549526	0.207259	0.166768	2.901621
9	pd_1	1	767	2	450	0.098381	0.173779	0.075398	0.13608	0.037699	0.272161
10	pd_2	2	109	56	12600	0.003854	1.002968	0.999115	0.402513	0.265849	22.540719
11	pd_2	2	286	54	12150	0.069485	0.81804	0.748555	0.358213	0.143148	19.343514
12	pd_2	2	332	2	450	0.004541	0.232255	0.227714	0.118398	0.113857	0.236796

1 (0 out of 55 Selected)

HABITAT_pd

2.2.5 Calculate Cell Statistics

This tool calculates cell statistics based on all rasters referenced by the reference source raster (for example, if a ponded depth raster is selected, then the statistics will be calculated for all the ponded depth rasters in the folder where the reference raster resides based on the reference raster prefix). The result is a raster with statistics per cell (e.g. average value for each cell for all the ponded depth rasters). Inputs and outputs are provided on the following figure.



The tool performs the following actions:

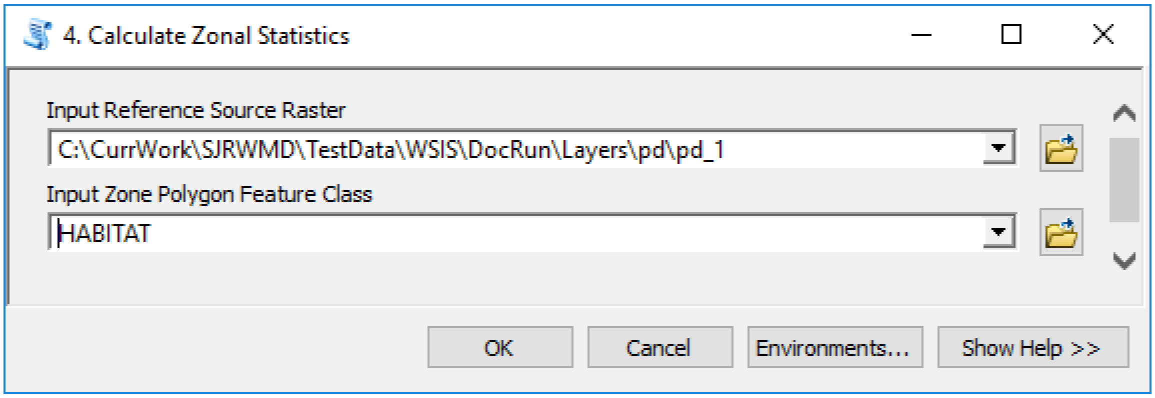
1. Identifies the location of the output rasters based on the location of the input reference raster.

2. Identifies the rasters to process based on the prefix of the selected reference raster. All rasters with the same prefix will be used in the statistics calculations.

3. Applies selected statistics calculation(s) for the rasters (all standard statistics supported by the "Cell Statistics" function). All selected statistics are performed. Stores the resulting raster(s) in the output folder using the name PRE_xxx where "PRE" is the raster prefix and "_xxx" a literal indicating the performed statistics:

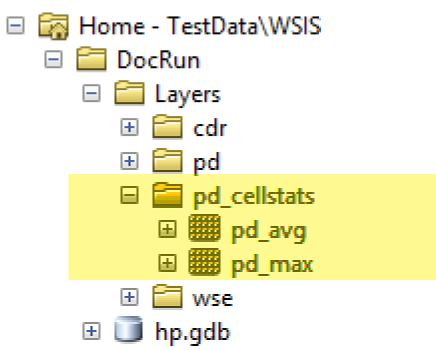
Statistics	**xxx suffix**
Mean	avg
Maximum	max
Minimum	min
Median	med
Majority	mjr
Minority	mnr
Range	rng
Sum	sum
Standard Deviation	std

2.2.5.1 Example run



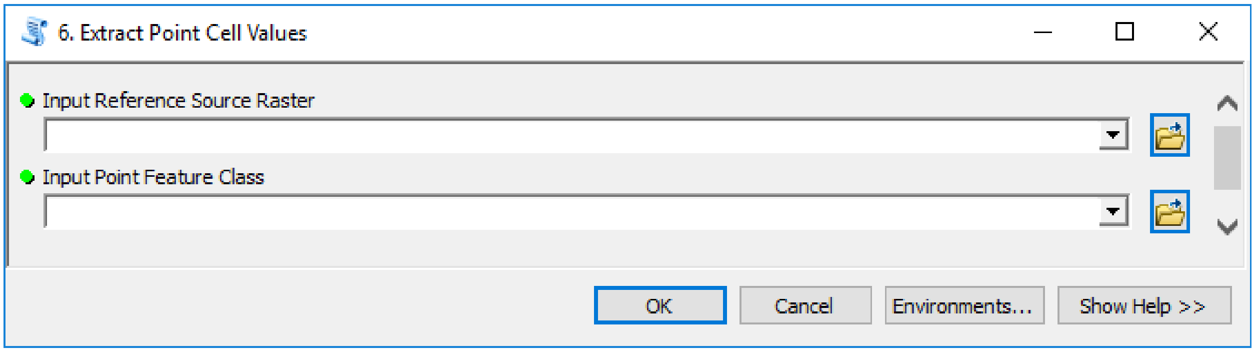
2.2.5.2 Example output structure

The following data structures were created as a result of the tool run (highlighted in yellow).



2.2.6 Extract Point Cell Values

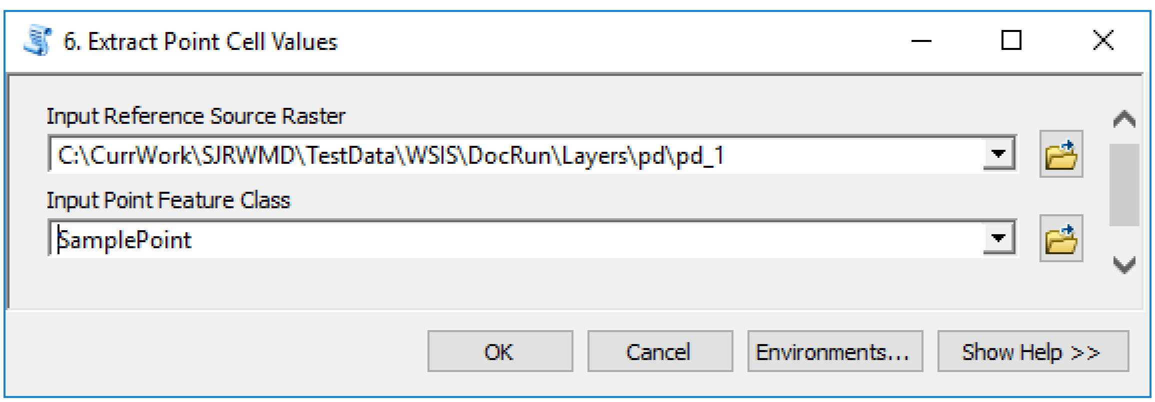
This tool extracts raster values for all rasters referenced by the reference source raster (for example, if a ponded depth raster is selected, then the values will be extracted for all the ponded depth rasters in the folder where the reference raster resides based on the reference raster prefix) at points defined in the input point feature class (a “push-pin” function). The results are stored in the output point series table referenced by the point and raster names (prefix/index). Inputs and outputs are provided on the following figure.



The tool performs the following actions:

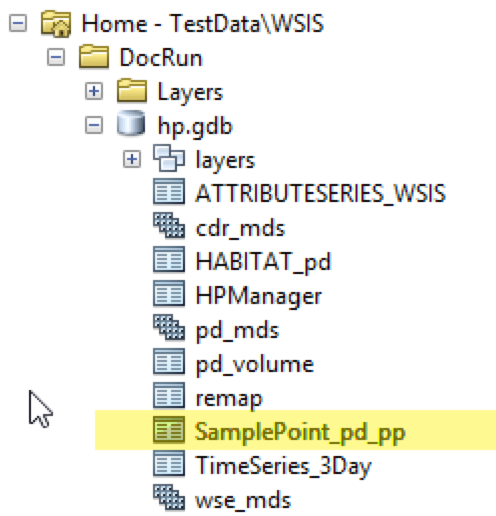
1. Identifies the rasters to process based on the prefix of the selected reference raster. All rasters with the same prefix will be processed.
2. For each point in the point feature class, it creates the list of values for each of the rasters to process. Each value is added as a row in the output table referenced by:
    a. HydroID of the point (FeatureID in the table), raster prefix, raster index, and original TsTime/FreqCode/StageValue.
    b. Value is stored in the "IntpValue" field.
3. The point series table will have name PFC_PRE_pp where "PFC" is the name of the point feature class, "PRE" is the raster prefix, and "_pp" a constant literal and is stored in the output geodatabase.

2.2.6.1 Example run



2.2.6.2 Example output structure

The following data structures were created as a result of the tool run (highlighted in yellow).



SamplePoint_pd_pp

OBJECTID *	FeatureID	NAME	HPINDEX	HPPREFIX	HPTYPE	TSTime	TSValue
1	792	pd_3	3	pd	TSTIME	1/3/1920	0.869108
2	793	pd_3	3	pd	TSTIME	1/3/1920	0.988389
3	792	pd_2	2	pd	TSTIME	1/2/1920	0.432592
4	793	pd_2	2	pd	TSTIME	1/2/1920	0.589202
5	792	pd_1	1	pd	TSTIME	1/1/1920	0.10281
6	793	pd_1	1	pd	TSTIME	1/1/1920	0.13218

3.0 Appendix 1: Interpolation techniques

The following interpolation techniques are supported by the tool. Each following section identifies which parameters are configurable through the configuration text file and the format of that file. The keywords must be entered **exactly**.

Note that the cell size, snap raster, mask, and processing extent environment are all set to the reference raster and cannot be changed through the configuration files.

3.1 IDW

http://desktop.arcgis.com/en/arcmap/10.5/tools/spatial-analyst-toolbox/idw.htm

```
Idw (in_point_features, z_field, {cell_size}, {power}, {search_radius}, {in_barrier_polyline_features})
```

- in_point_features – passed by the calling program.
- z_field – passed by the calling program.
- cell_size – passed by the calling program (defined by the input DEM).
- {power}, {search_radius}, {in_barrier_polyline_features} – read from the configuration file.

3.1.1 Configuration file format - fixed

```
power=2

search_radius=FIXED 15 3
```

3.1.2 Configuration file format - variable

```
power=2

search_radius=VARIABLE 12 50040
```

3.2 Kriging

http://desktop.arcgis.com/en/arcmap/10.5/tools/spatial-analyst-toolbox/kriging.htm

`Kriging (in_point_features, z_field, semiVariogram_props, {cell_size}, {search_radius}, {out_variance_prediction_raster})`

- in_point_features – passed by the calling program.
- z_field – passed by the calling program.
- cell_size – passed by the calling program (defined by the input DEM).
- semiVariogram_props, {cell_size}, {search_radius}, {out_variance_prediction_raster} – read from the configuration file.

3.2.1 Configuration file format

```
kriging_model=Spherical 113.004691

search_radius=VARIABLE 12 50000
```

3.3 Natural Neighbor

http://desktop.arcgis.com/en/arcmap/10.5/tools/spatial-analyst-toolbox/natural-neighbor.htm

`NaturalNeighbor (in_point_features, z_field, {cell_size})`

- in_point_features – passed by the calling program.
- z_field – passed by the calling program.
- cell_size – passed by the calling program (defined by the input DEM).

3.3.1 Configuration file format

No user specified parameters are possible.

3.4 Spline

http://desktop.arcgis.com/en/arcmap/10.5/tools/spatial-analyst-toolbox/spline.htm

`Spline (in_point_features, z_field, {cell_size}, {spline_type}, {weight}, {number_points})`

- in_point_features – passed by the calling program.
- z_field – passed by the calling program.
- cell_size – passed by the calling program (defined by the input DEM).
- {spline_type}, {weight}, {number_points} – read from the configuration file.

3.4.1 Configuration file format

```
spline_type=REGULARIZED

weight=0.2

number_points=4
```

3.5 Spline with barriers

http://desktop.arcgis.com/en/arcmap/10.5/tools/spatial-analyst-toolbox/spline-with-barriers.htm

`SplineWithBarriers (Input_point_features, Z_value_field, {Input_barrier_features}, {Output_cell_size}, {Smoothing_Factor})`

- in_point_features – passed by the calling program.
- z_field – passed by the calling program.

- cell_size – passed by the calling program (defined by the input DEM).
- {Input_barrier_features}, {Smoothing_Factor} – read from the configuration file.

3.5.1 Configuration file format

```
Smoothing_Factor=1
```

3.6 Trend

http://desktop.arcgis.com/en/arcmap/10.5/tools/spatial-analyst-toolbox/trend.htm

Trend (in_point_features, z_field, {cell_size}, {order}, {regression_type}, {out_rms_file})

- in_point_features – passed by the calling program.
- z_field – passed by the calling program.
- cell_size – passed by the calling program (defined by the input DEM).
- {order}, {regression_type}, {out_rms_file} – read from the configuration file.

3.6.1 Configuration file format

```
regression_type=LINEAR

order=1
```