Groundpoint ENGINEERING

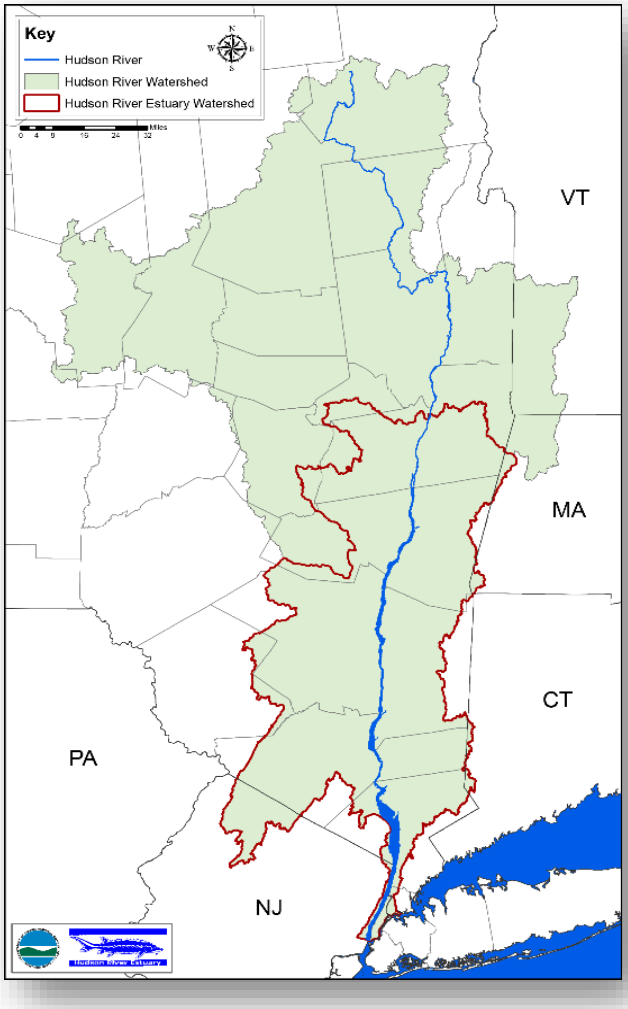
NEW YORK STATE | Department of Environmental Conservation | Hudson River Estuary Program

Cornell CALS College of Agriculture and Life Sciences

New York State Water Resources Institute

Culvert Model Program 2020

Final Report



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Contents

Completed Reports

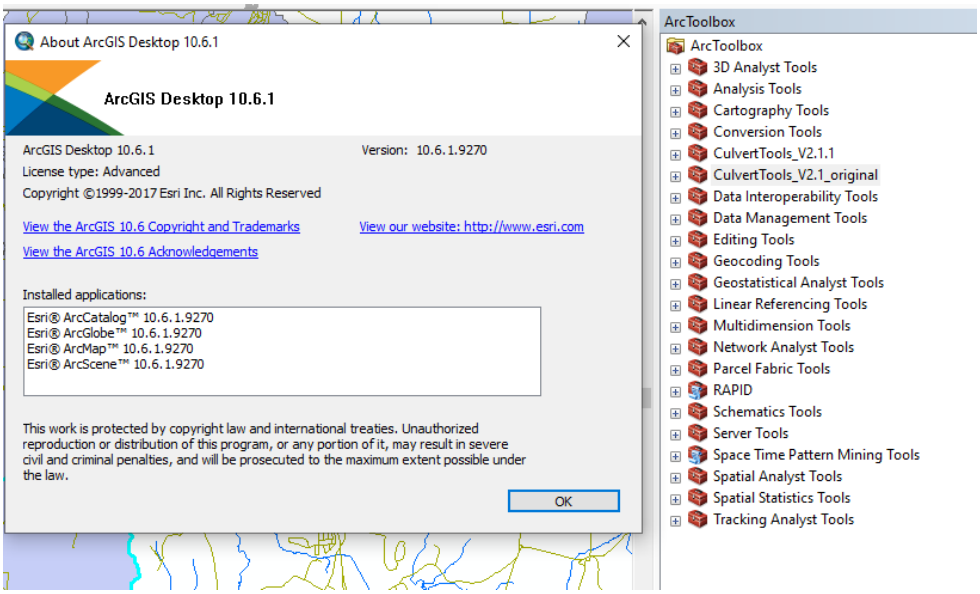
A report titled “May 2020 Cornell Model Preliminary Report” dated 5/8/2020 outlined a number of the activities undertaken to prepare the GIS data and update the model based on errors encountered when attempting to install and run the ArcGIS Toolbox.

Reports titled “June 2020 Cornell Model Processing Report - <NAME> County” dated 6/8/2020 were prepared for each County outlining the data and processing steps completed for each individual area, including specific details for that County as necessary. Reports were completed for the six counties of:

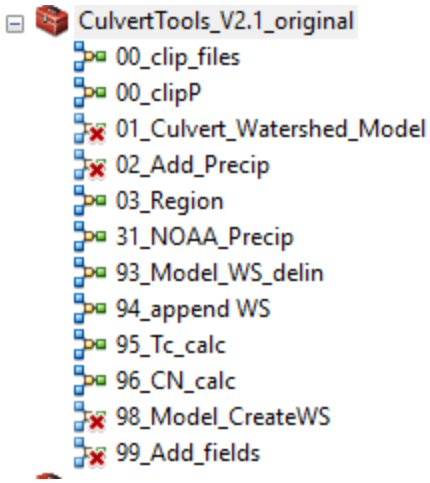
Columbia
Delaware
Greene
Orange
Rockland, and
Ulster

Summary of Completed Modeling Activities

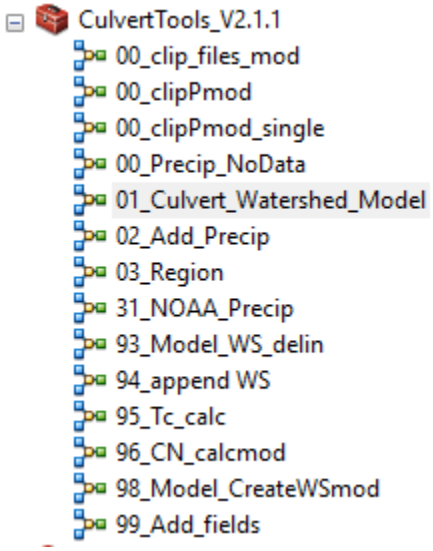
The python script portions of the model worked fine and without issue based on the latest model instructions. ArcMap 10.6.1 was used as it was the reference implementation on which the existing documentation was based on August 2019.



The ArcGIS Toolbox “CulvertTools_V2.1”, had several errors of unknown origin when installing using ArcMap 10.6.1. Several of the ArcMap models within the toolbox were modified slightly in ArcMap 10.6.1 and the result saved as “CulvertTools_V2.1.1”.



It was determined that the errors associated with running the models were largely related to the handling of variables and parameters between each of the models. For example, some models relied on a pathname variable to locate a required input data layer, while others relied on that data layer to be active in the ArcMap table of contents. The models were modified to allow parameters to be passed between each model using variable path names only. As such, when running the model in V2.1.1., the user should now only need to enter the three digit project code (i.e., ABC) and the path name once, and all the models should run successfully. None of the model logic or geoprocessing steps were modified. Any changes made to a model within the toolbox were annotated with "_mod".



There was an issue with one County where a small watershed ended up with multi-part geometry as a result of using the "simplify" parameter when converting from raster to vector, and that multi-part geometry caused an error in the flow length geoprocessing calculation and subsequent Time of Concentration. The parameter setting was not changed, but it is something to watch out for in future implementations of the model. Once the offending record was identified and "removed", the models all ran as intended.

Attempts to run the model tools in ArcMap 10.8 failed repeatedly and it was determined that any remedy regarding conflicts in the Model Builder construct within ArcMap 10.8 was beyond the scope of this project.

Suggestions for Future Work

Multiple Culverts

Review of the current model documentation and the "final" output files generated by the python scripts (*.csv files) indicates a need for additional documentation regarding how the output files filter and "remove" records, in particular related to multiple culverts at a single crossing. A generic example of the explanation included in the County Reports is provided below.

It appears that when combing the capacity of multiple culverts at a single crossing, the total sum of the capacity of those culverts is then re-assigned to the "first" culvert on the list, and all other culverts are "removed" from the list. This approach to calculating "crossing capacity" could lead to some confusion as to the capacity of the individual culvert versus the capacity of the crossing. Some additional attention to outputting the capacity of all individual culverts separately from the calculated capacity of each crossing would be useful.

GIS Functionality

The current output files in *.csv format are not readily displayed or analyzed in ArcGIS. Modifying the workflow to "push" those model outputs back to the "All_Culverts" shapefile for further display and analysis would significantly aid users in visualizing the locations of problematic crossings and evaluating any patterns (spatial or otherwise) in the data. As of right now, converting the *.csv tables and joining them back to the culvert point file requires a level of GIS technical skill that may be beyond the skill set of a broad spectrum of stakeholders that could benefit from enhanced spatial visualization and analysis.

Culvert Control

Initial documentation of the model dating back to 2014-2015 indicated some attention being paid to various flow control conditions at each culvert. The capacity calculator appears to be readily adaptable to scenarios other than inlet control (the current condition), and could be enhanced to use other conditions based either on field survey observations, user input, or by calculating and reporting a "worst case" scenario.

Time of Concentration (Tc)

The current "Kirpich method" for calculating Time of Concentration (Tc) could be enhanced to include additional approaches, including other overland flow approaches used in both TR55 and rational method calculations. The current method seems heavily dependent on empirical constants that may or may not calibrate well in different hydrologic or geomorphic conditions, or apply well based on watershed size, infiltration characteristics, or slope.

Tabular results after running the Culvert_Eval.py script. Note the Records shown are actual numbers from a sample County.

Table	Records	Notes
ABC.csv	1313	NAACC raw data extract
ABC_field_data.csv	813	This is a "trimmed down" version of the NAACC raw data, custom formatted for use in the Cornell Model to support capacity calculations.
ABC_not_extracted.csv	500	Data not used because one or more data elements did not conform to the expected input format or were missing information.
All_Culverts.csv	813	Output from the GIS processing. Each record has A/Tc/CN/P*/SS
Model outputs		
ABC_Sorted	813	All_Culverts.csv sorted by Barrier ID
ABC_skipped_culverts	35	From the All_Culverts.csv file (i.e., they went through the GIS process) but were skipped in calculating peak flow for one reason or another 1: CN=0 5: Tc_hr=0 29: Area_sq_km<0.01
ABC_Not_modeled	535	500+35=35 35 "skipped culverts" from above plus the 500 "not extracted". See Column E Modeling_notes
ABC_Current_runoff**	778	813-35=778 Peak flows calculated from the GIS exported files excluding the "skipped culverts".
ABC_StreamStatsAreaBasedQ	778	StreamStats peak flow values calculated for the same points as above.
ABC_culv_geom	813	From "field_data" above with only the relevant geometry information extracted for calculating culvert capacity. Includes the same records as found in "All_culverts.csv" as both are lists of individual culverts with valid culvert geometry information.
ABC_capacity_output**	740	73 less records of the original 813 above. This file is based on the crossing location (Survey ID), not individual culverts (Barrier ID). Capacity values for crossings with multiple culverts are equal to the sum of the all culverts at that location. As such, only the first culvert record is kept from the original culvert geometry file, and any remaining culvert records for that location are dropped after combining the capacity calculation into a single value. Exercise caution when using the Barrier ID, and refer to "Flags" values >1 for locations with multiple culverts.
ABC_model_output	705	This represents the results of the capacity_output file described above MINUS any culvert records which may have been removed as a result of the "skipped culverts" process. Any "skipped culvert" records which are also

		"multiple culverts" will have already been removed in the capacity_output file. Hence the difference between the # of records here and in the capacity_output above will be equal to or less than the # of "skipped culverts".
ABC_Return_periods	705	See above comment. A trimmed down version of the model_output file showing the max return period storm runoff that a given crossing can pass based on it's capacity.

*Precipitation values for all return intervals (1, 2, 5, 10, 25, 50, 100, 200, 500). Note that the return intervals in the StreamStats file differ slightly.

** Peak flow results (runoff) are based on the original "field_data" records minus those "skipped" because of certain GIS results (e.g., area too small, Tc or CN = 0, etc.) regardless of their capacity result. Capacity calculations are based on the original "field_data" records minus any records that represent an additional (e.g., second, third, fourth, etc.) culvert at the same crossing location, regardless of their GIS result. The final "model_output" table reconciles those separate lists.

References

This reference information was included in each of the County processing reports.

General Information

General Information regarding WRI support for Culvert Prioritization as a part of their broader Aquatic Connectivity and Barrier Removal effort can be found at:

https://wri.cals.cornell.edu/hudson-river-estuary/watershed-management/aquatic-connectivity-and-barrier-removal-culvert-dams/culverts/

Documentation on the Culvert Model

Reports and instructions regarding how the model works and using the model can be found at:

https://wri.cals.cornell.edu/sites/wri.cals.cornell.edu/files/shared/2013-Walter-Culverts_technical_report-Jan2014.pdf

https://wri.cals.cornell.edu/sites/wri.cals.cornell.edu/files/shared/2014-Walter-UndersizedCulverts-final-Feb2015.pdf

https://wri.cals.cornell.edu/sites/wri.cals.cornell.edu/files/shared/documents/2015_Walter_Culverts_Final.pdf

https://wri.cals.cornell.edu/sites/wri.cals.cornell.edu/files/shared/CornellCulvertsModelInstructions_RevisedAug2018.pdf

Documentation on the latest WRI supported version of the model, sample data and full model code along with an ArcGIS toolbox can be found at:

https://github.com/SoilWaterLab/CulvertModel_2.1

Additional Articles

Rapid Remote Assessment of Culvert Flooding Risk, Feb 18, 2020, Truhlar, A.M., et al., J. Sustainable Water Built Environ., 2020, 6(2): 06020001. https://ascelibrary.org/doi/10.1061/JSWBAY.0000900

The Light at the End of the Culvert, May 1, 2018, M. Lung, A. Meyer, R. Marjerison & B.G. Rahm (2017) Talk of the Towns, Association of Towns of the State of New York. Vol. 31, May/June. https://wri.cals.cornell.edu/sites/wri.cals.cornell.edu/files/shared/documents/2017_Lung_NYAT_Culverts.pdf

