Model My Watershed Technical Documentation

https://wikiwatershed.org/help/model-help/

1. Introduction

Document was last updated on September 23, 2020.

This reference document is intended to provide technical documentation and references for the data layers, data analysis algorithms, models, computational framework, and other components that together create the hydrologic and water quality output delivered by the Model My Watershed web application(https://modelmywatershed.org/)
.

When you first open Model My Watershed you will see a map of the United States (your browser may ask to “Know your location” and then zoom to your location), a side bar on the left with instructions, a “Layers” panel (lower left of the map), and a black bar that borders the top of your web browser (see Fig. 1.1 below). Alternatively, you may see the login screen (see Fig. 1.2 below) which can be activated by clicking “Login” in the upper right hand corner of the black bar (see red arrow on Fig. 1.1 below). You can choose to enter as a guest or register for a free account (generating a Username and Password). The “Login with ITSI” option is for teachers that use The Concord Consortium’s Innovation Technology in Science Inquiry
portal(https://itsi.portal.concord.org/)
for managing online classroom activities and curriculum that promotes the engagement of students in STEM activities through the integrated use of technologies that include modeling, computational thinking, and real-time data acquisition (learn more about Model My Watershed curriculum(https://itsi.portal.concord.org/itsi#high-school-environmental-science)
connected to the ITSI portal.

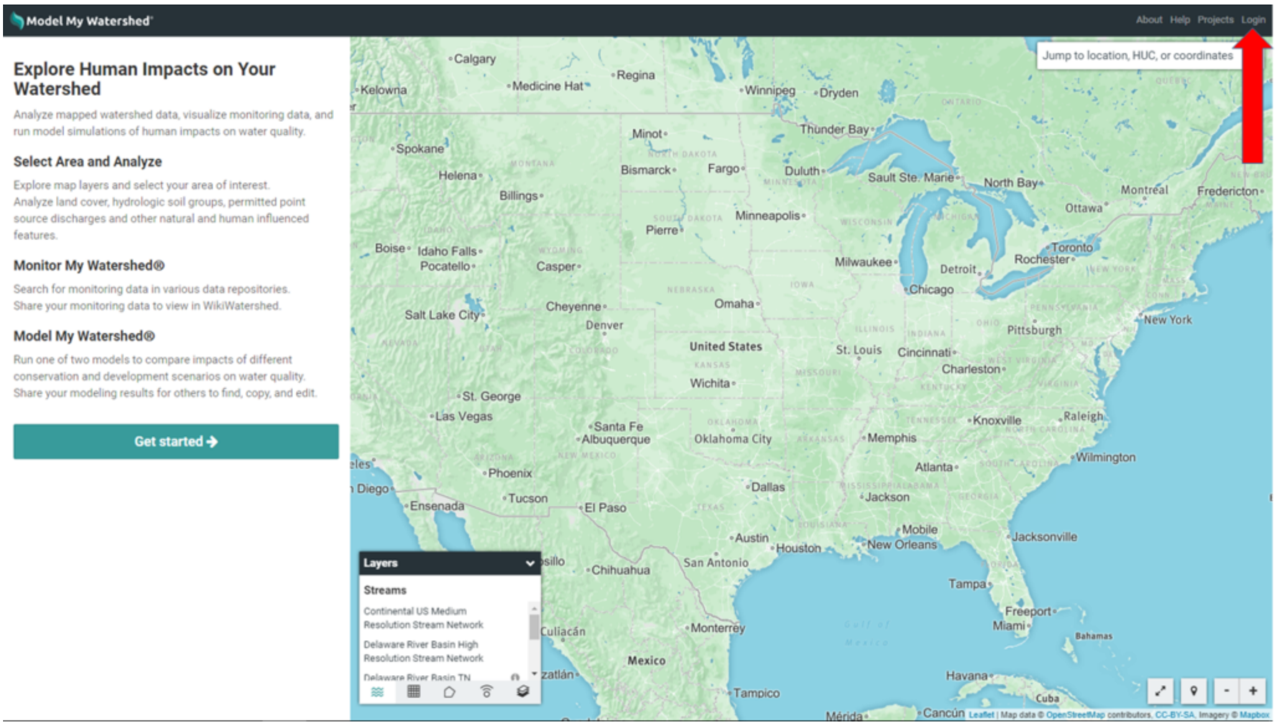


Figure 1.1

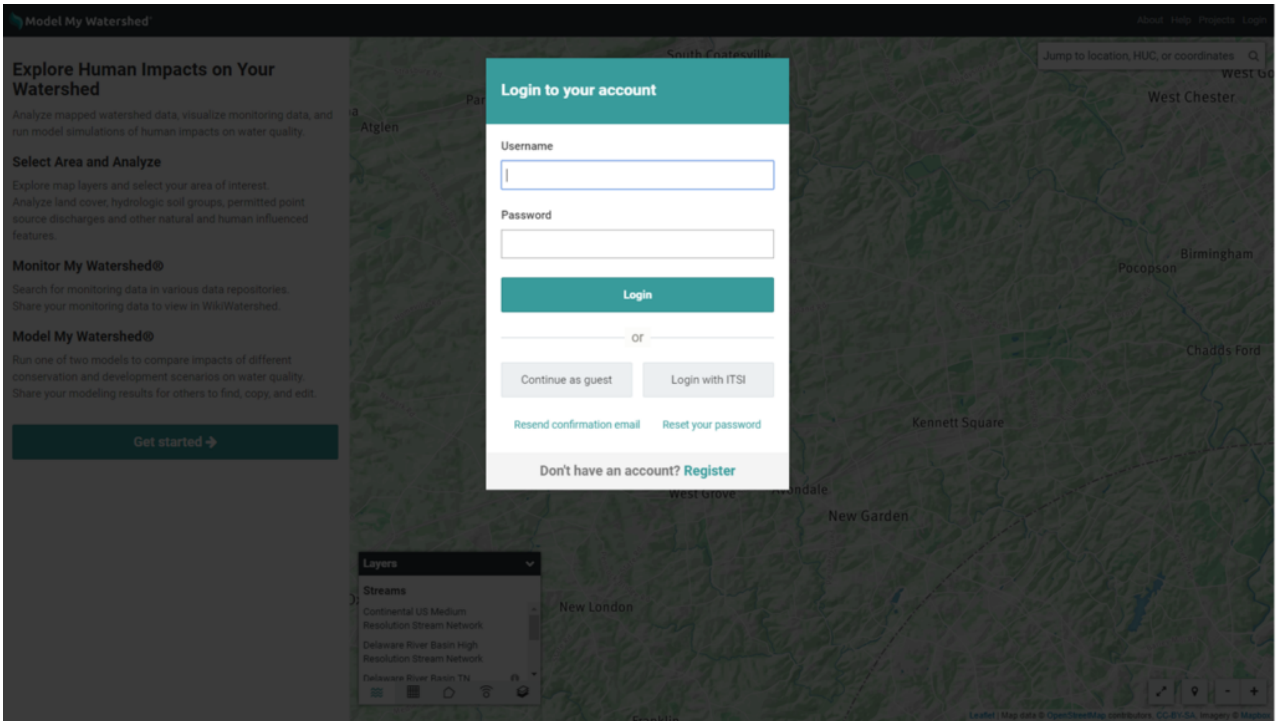


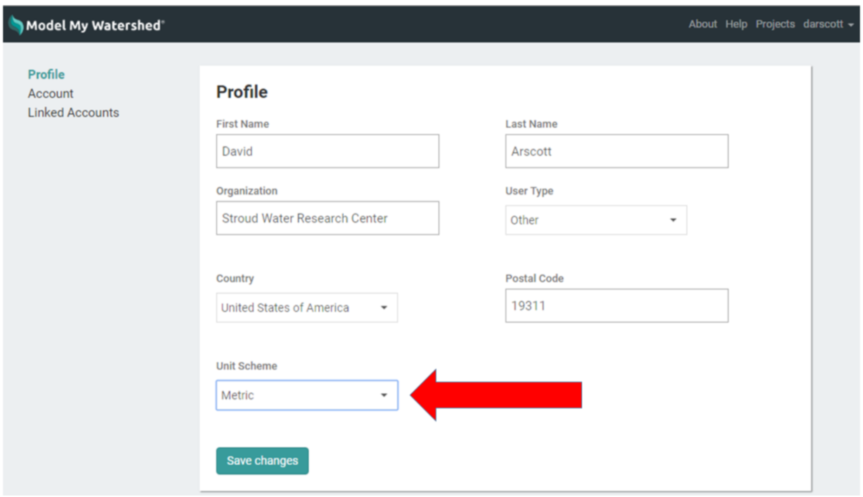
Figure 1.2

2. My Account Page

Profile

Once you have created an account, you can access the details of your account by clicking on your user name in the upper right hand corner of the black bar. You can edit your name, organization, postal code, user type, and country on the “Profile” page.

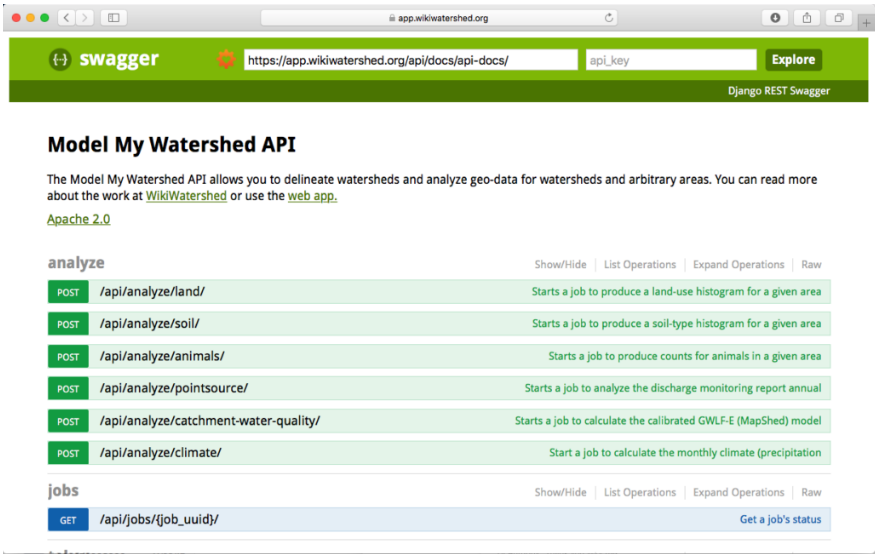
Unit Conversion



You can switch units for any of your projects units by selecting either “Metric” or “US Customary” and then “Save changes”. Now, if you re-open a project, your units will all be converted to the new units option selected. Please note, that to propagate this change in any projects saved to HydroShare, you will need to export your project once again.

Account – API Key

Developers will be most interested in our public web-service Application Programming Interface (API). This modern REST API allows anyone to access nearly every function of Model My Watershed from their own custom scripts or software, written in Python, R or any other modern programming language. This API is our first step toward building two-way interoperability with HydroShare, an online collaborative environment for sharing hydrologic data and models that we will leverage for advanced sharing capabilities for Model My Watershed projects, BMPs and eventually monitoring data. Please explore our new API(https://modelmywatershed.org/api/docs)
which allows you to try the service from a web browser, or read the RESTful Web Services: A Tutorial for more background. Note that to use our API, you will need to register for an account on the Model My Watershed web app(https://modelmywatershed.org/)
and get your API Authorization Key/Token, which is available in the new My Account pages.



Linked Accounts

HydroShare

HydroShare(https://www.hydroshare.org/)
is an online collaboration environment for sharing data, models, and code. In Release 1.22(https://wikiwatershed.org/model-my-watershed-release-1-22/)
(March 2018) we unveiled a powerful new way to share Model My Watershed projects, so that others can find, view and copy any Model My Watershed model project that has been shared publicly. This new Share capability leverages CUAHSI HydroShare, an online collaborative environment for sharing hydrologic data and models. To link your account and share your projects to the HydroShare data portal, follow the steps outline in the “Saving and Sharing Your Project” section below (section 8.2(https://wikiwatershed.org/model-my-watershed-release-1-22/)
.)

3. Layers (Viewable Mapped Data)

Model My Watershed provides a number of geospatial data layers for visualization, analysis and modeling. Detailed information and data sources for each layer are provided below, organized by type, in the order in which they appear in the Layer selector in the lower left of the map.

Layers that are not available for visualization, but are used for analysis and modeling functions, are described under Section 2.6 Additional Data Layers(https://wikiwatershed.org/documentation/mmw-tech/#additional-data-layers)
.

3.1. Streams

Continental US Medium Resolution Stream Network

From NHDplusV2(http://www.horizon-systems.com/NHDPlus/)
Medium Resolution (1:100,000-scale) NHDFlowlines (similar to https://catalog.data.gov/dataset/medium-resolution-national-hydrography-dataset-flowline-feature-line(https://catalog.data.gov/dataset/medium-resolution-national-hydrography-dataset-flowline-feature-line)
or The National Hydrography Dataset (NHD), Medium Resolution Flowlines, DRECP(https://databasin.org/datasets/89e82ce1f6cb42dba509ff46ba51f67f)
)

Unfortunately, the NHD high resolution Flowline vector dataset (nominally at 1:24,000-scale) is not yet available within NHDplusV2.

Blue lines are rendered with styling that depends on user zoom extent and on the stream order.

- Larger streams are attributed with thicker blue lines.
- Small streams appear/disappear as the user zooms in and out of the map area.

Delaware River Basin High Resolution Stream Network

The Delaware River Basin High resolution stream network was derived from the 1/3 arc second (10 m) resolution digital elevation model (DEM) from the USGS national elevation dataset obtained from the National Map(https://www.usgs.gov/core-science-systems/ngp/tnm-delivery/)
using FTP download options for the domain covering the Delaware River Basin.

This work was done by Model My Watershed partners at Utah State University, David Tarboton and Nazmus Sazib, using Terrain Analysis using Digital Elevation Models(http://hydrology.usu.edu/taudem/taudem5/index.html)
(TauDEM) software. Tarboton is the lead developer of the TauDEM software.

The processing steps used were:

- *Define the Delaware River Basin Terrain Analysis domain*. The parts of the DEM that occupied ocean or estuary area identified from National Hydrography Dataset and other data sources were masked out in this DEM, setting a no data value for grid cells more than 100 m from the shore and -50 m for grid cells within 100 m of the coast. This ensured that grid cells adjacent to the shore drained into the ocean/estuary, while at the same time avoiding unnecessary terrain analysis for ocean/estuary areas. The DEM was then clipped to the Delaware River Basin watershed boundary from NHDPlus, with a 5 km buffer around the edges to avoid edge effects where the watershed boundary and DEM are inconsistent.
- *Pitremove*. The TauDEM pitremove function was used to hydrologically condition the DEM. This raised the level of any grid cells completely surrounded by higher terrain to the level of the lowest pour point around their edge so that there is a path of non increasing elevation from each grid cell to the domain edge along which water could drain.
- *D8 flow directions*. The TauDEM D8 flow direction function was used to compute the single flow direction associated with each grid cell to one of its eight adjacent neighbors.
- *D8 Contributing area*. The TauDEM D8 Contributing area function was used to calculate the number of grid cells draining through each grid cell counting itself.

- *Determine outlets to the ocean/estuary*. Outlet points where contributing area is greater than 5000 grid cells (Approx 0.5 km^2) and the flow leaves the domain were determined as the downstream ends of a temporary stream network mapped using TauDEM with 5000 grid cell contributing area threshold. These outlet points were used in calculations below to constrain the work to areas upstream of these outlets. It was deemed not meaningful to delineate a stream network for areas less than 0.5 km^2 draining directly to the ocean.
- *Peuker Douglas valley filter*. The TauDEM Peuker Douglas filter was used to identify valley grid cells. This filter selects all grid cells, examines each set of 2 x 2 grid cells, and unselects the highest elevation cell. Cells remaining selected at the end are “potential valley cells.”
- *Weighted D8 Contributing area*. The TauDEM D8 contributing area function was used with the Peuker Douglas valley filter result as a weighted input. This calculates the number of potential valley grid cells draining through each grid cell.
- *Define stream grid*. The TauDEM threshold function was used to define as candidate stream grids the grid cells in the Weighted D8 contributing area result exceeding input contributing area thresholds. Contributing area thresholds of 20, 50, and 100 grid cells were evaluated. After visual inspection, in comparison to contour crenulations and high resolution NHD streams a threshold of 50 grid cells was chosen.
- *Calculate stream network.* The TauDEM Stream Network function was used to delineate a stream network of lines (GIS vector shapes) from the 50 cell threshold stream grid. The result is a geographic feature set (set of lines) in GIS shapefile format.

Note that this procedure, and in particular the use of the Peuker Douglas valley filter and weighted contributing area functions results in a stream network that adapts to the complexity of the topography. Where the topography is complex, as would be reflected by a high degree of crenulation in contours, the drainage density of the resulting stream network is high and reflects this. Where the topography is less complex (smooth contours) the drainage density is low. The basis for this is that the mapping of valley grid cells produces a skeletonized (disconnected) stream map that reflects the variability of drainage density across the topography. These valley grid cells were then formed into a connected stream network by using them as input to a weighted contributing area calculation that counted only these grid cells.

For additional detail on the rationale for this approach refer to the following references (full citations in References(https://wikiwatershed.org/documentation/mmw-tech/#references)
section in this document): Tarboton & Ames (2001); Tarboton et al. (1992); Tarboton et al. (1991).

For additional detail on the TauDEM software and use of each function refer to TauDEM documentation(http://hydrology.usu.edu/taudem/taudem5/documentation.html)
. The TauDEM software is open source and may be obtained from the following websites:

- Precompiled files and installer(http://hydrology.usu.edu/taudem/taudem5/)

- Source code(https://github.com/dtarb/TauDEM)

Delaware River Basin T(X) Concentration(s) from SRAT

Estimated in-stream baseflow concentrations of Total Nitrogen (TN), Total Phosphorus (TP) or Total Suspended Solids (TSS), derived within the Delaware River Basin from the Stream Reach Assessment Tool (SRAT) modeling effort. SRAT-estimated in-stream concentrations are shown in Model My Watershed by color-coding the NHDplusV2 stream network in colors ranging from green to yellow to orange to red, with greens indicating the lowest concentrations and reds indicating the highest.

The Stream Reach Assessment Tool (SRAT) modeling effort was funded by the William Penn Foundation (WPF) Delaware River Watershed Initiative (DRWI). SRAT is derived from calibrated MapShed model runs of all HUC-12 areas within the Delaware River Basin, downscaling MapShed results to NHDplusV2 catchment scales and routing loads through the NHDplusV2 medium resolution stream network. For more details regarding SRAT, see the SRAT overview(https://www.streamreachtools.org/overview/)

. The Stream Reach Assessment Tool is brought to you through the collaborative work of many DRWI partners(https://www.streamreachtools.org/team/)
.

Many additional SRAT-derived model output data layers can be visualized and analyzed in Model My Watershed, including the visualization of pollutant loading rates and stream concentrations at the NHD catchment and stream segment level. See below for more details.

3.2. Coverage Grids

Land: USGS National Land Cover Database

- NLCD-2011(https://www.mrlc.gov/data/nlcd-2011-land-cover-conus-0)
- Legend to colors and land use types(https://www.mrlc.gov/data/legends/national-land-cover-database-2011-nlcd2011-legend)

Soil: Hydrologic Soil Groups from gSSURGO

Gridded Soil Survey Geographic (gSSURGO) 2016. Database for the Conterminous United States. United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). Obtained from the USDA Geospatial Data Gateway(https://gdg.sc.egov.usda.gov/)
.

For more information and official gSSURGO User Guide, see Description of Gridded Soil Survey Geographic (gSSURGO)
Database(https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053628)
.

Hydrologic Soil Groups is one gSSURGO soil category, based on water infiltration rates during wet, saturated conditions. Low infiltration rate soils translate to high runoff potential. For more information, see these USDA NRCS publications:

- Hydrologic Soils Group (HSG) Questions and Answers(https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1262857&ext=pdf)
- National Engineering Handbook, Part 630 Hydrology, Chapter 7 Hydrologic Soil Groups(https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba)

Elevation and Slope (Percent)

Elevation and Slope coverage grids are visualized based on the National Hydrography Dataset (NHD) plus National Elevation Data Snapshop Digital Elevation Model (NHDPlus V@ NED Snapshot DEM), which are publicly available from the USGS(https://www.usgs.gov/core-science-systems/ngp/national-hydrography/nhdplus-high-resolution)
.

Climate: Mean Monthly Precipitation and Temperature

Gridded mean monthly values for precipitation and temperature were obtained from the PRISM Climate Group(http://prism.nacse.org/)
and are the “AN81m” datasets. Briefly, these layers were created from a modelling effort (Climatologically-Aided

Interpolation process) that utilized nationally available records for the time period 1981-2010. See documentation(http://prism.nacse.org/documents/PRISM_datasets.pdf)
.

Protected Lands

The “Protected Lands” data layer in Model My Watershed was sourced from the National Inventory of Protected Areas assembled and published by the U.S. Geological Survey Gap Analysis Program(https://gapanalysis.usgs.gov/padus/)
in 2016 (Gergely and McKerro, 2016). The Protected Areas Database of the United States (PADUS) is the official inventory of public parks and other protected open space. See factsheet(https://pubs.usgs.gov/fs/2013/3086/)
.

Additional resources for the Protected Areas Database of the U.S.(http://www.protectedlands.net/)

Gergely, K.J., and McKerrow, A., 2016, PAD-US—National inventory of protected areas(https://pubs.usgs.gov/fs/2013/3086/)
(ver. 1.1, August 2016): U.S. Geological Survey Fact Sheet 2013–3086, 2 p..

Reclassification of the PADUS

Table 1. Reclassifications

Reclassifications
Agricultural Easement
Conservation Easement
Natural Resource Area - Local
Natural Resource Area - Federal
Natural Resource Area - State
Natural Resource Area - Unknown
Park or Recreation Area - Federal
Park or Recreation Area - Local
Park or Recreation Area - Private
Park or Recreation Area - State
Park or Recreation Area - Unknown
Natural Resource Area - Private

The Protected Areas Database (PAD) for the US was downloaded via the USGS download site (link provided above). A list of 60 unique descriptions of the designated use types (d_Des_Tp) was compiled from the column in the raw PAD source dataset. From this list, a set of reclassified categories was determined that could describe each one at a more general level (Table 1). Some designated protected areas were removed if they did not fit a reclassification type. The list of unique designated types had each description assigned one of the 12 different reclassifications (Table 2).

These reclassified values were then converted to a list of integer values. This is often done with categorical data stored in a raster format to decrease the overall file size. Once the original PAD shapefile had the reclassifications and raster identification classifiers added, it was converted to a GEOTIFF raster. To do this the National Land Cover Dataset (NLCD) 2011 was used to define the final processing extent, the snap raster, and the cell size. The result is a PAD raster that perfectly overlaps the NLCD raster for the coterminous US.

Table 2. Designated type reclassification

d_Des_Tp	Reclassification
Agricultural Easement	Agricultural Easement
Ranch Easement	Agricultural Easement
Private Agricultural	Agricultural Easement
Conservation Easement	Conservation Easement
Forest Stewardship Easement	Conservation Easement
Other Easement	Conservation Easement
Recreation or Education Easement	Conservation Easement
Unknown Easement	Conservation Easement
Local Other or Unknown	Natural Resource Area - Local
Historic or Cultural Easement	Remove
National Forest	Natural Resource Area - Federal
National Grassland	Natural Resource Area - Federal
National Lakeshore or Seashore	Natural Resource Area - Federal
National Public Lands	Natural Resource Area - Federal
National Wildlife Refuge	Natural Resource Area - Federal
Wilderness Area	Natural Resource Area - Federal
Wilderness Study Area	Natural Resource Area - Federal
Conservation Area	Natural Resource Area - Federal
Federal Other or Unknown	Natural Resource Area - Federal
Inventoried Roadless Area	Natural Resource Area - Federal
Local Conservation Area	Natural Resource Area - Local
State Resource Management Area	Natural Resource Area - State
State Wilderness	Natural Resource Area - State
State Conservation Area	Natural Resource Area - State
Research Natural Area	Natural Resource Area - Unknown
Resource Management Area	Natural Resource Area - Unknown
National Monument or Landmark	Park or Recreation Area - Federal
National Park	Park or Recreation Area - Federal
National Recreation Area	Park or Recreation Area - Federal
National Scenic, Botanical or Volcanic Area	Park or Recreation Area - Federal
Local Park	Park or Recreation Area - Local
Local Recreation Area	Park or Recreation Area - Local
Private Recreation or Education	Park or Recreation Area - Private
State Park	Park or Recreation Area - State
State Recreation Area	Park or Recreation Area - State
Recreation Management Area	Park or Recreation Area - Unknown
Research or Educational Area	Park or Recreation Area - Unknown
Special Designation Area	Park or Recreation Area - Unknown
Private Conservation	Natural Resource Area - Private
Private Forest Stewardship	Natural Resource Area - Private
Private Other or Unknown	Natural Resource Area - Private
State Other or Unknown	Natural Resource Area - State
Not Designated	Remove

The source PAD dataset often had an underlying issue of overlapping polygons. An output raster of this data can only store one value for a given area. Thus, if there were two overlapping polygons with different protection descriptions only one of them will be represented in the final raster output created.

Table 3. Lookup table for reclassification values

Reclassified Description	Color	Raster Value
Park or Recreation Area - Federal	Green/Yellow 1	1
Park or Recreation Area - State	Green/Yellow 2	2
Park or Recreation Area - Local	Green/Yellow 3	3
Park or Recreation Area - Private	Green/Yellow 4	4
Park or Recreation Area - Unknown	Green/Yellow 5	5
Natural Resource Area - Federal	Green Dark 1	6
Natural Resource Area - State	Green Dark 2	7
Natural Resource Area - Local	Green Dark 3	8
Natural Resource Area - Private	Green Dark 4	9
Natural Resource Area - Unknown	Green Dark 5	10
Conservation Easement	Brown/Green	11
Agricultural Easement	Brown 1	12

Active River Area – Northeast and Mid-Atlantic

The “Active River Area” data layer was developed to provide a conservation framework for assessment, protection, management, and restoration of freshwater and riparian ecosystems. The framework identifies five key sub-components of the active river area: 1) material contribution zones, 2) meander belts, 3) riparian wetlands, 4) floodplains and 5) terraces. These areas are defined by the major physical and ecological processes associated and explained in the context of the continuum from the upper, mid and lower watershed in the ARA framework paper (Smith et al. 2008). More details, click here(https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/reportsdata/freshwater/floodplains/Pages/default.aspx)
.

Smith, M.P, R. Schiff, A. Olivero, and J. MacBroom. 2008. The Active River Area: A conservation framework for protecting rivers and streams(https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/Documents/ED_freshwater_ARA_NE2008.pdf)
. The Nature Conservancy. Boston, MA.

Future DRB Urban Land Forecasts (“DRB 2011 Urban Baseline”, “DRB 2100 Centers FX”, “2100 Corridors FX”)

These Delaware River Basin (DRB)-specific data layers were created by Dr. C. Jantz et al. at the Center for Land Use and Sustainability at Shippensburg University. These layers, collectively called DRB2100 Future Forecasts, represent a revised baseline and future growth forecasts (“corridors” and “centers”) for changes (increases or decreases in extent) to “developed land use” in the Delaware River Basin, out to 2100. To develop these forecasts, SLEUTH urban growth model was calibrated for modeling sub-regions over the 2001-2006 time period, and validated for the 2006-2011 time period. The National Land Cover Database (NLCD) urban classes were used to represent urban land cover as developed or not developed for the baseline 2011 layer. Learn more about this project:

- Mapping, modeling, and monitoring land cover in the Delaware River Basin(https://www.ship.edu/Geo-ESS/DRB/Introduction/)
- Forecast Modeling Land Use/Land Cover Change(https://drbp.wpengine.com/modeling/)
- Future Land Cover Scenarios(https://drbproject.org/products/)

Fast-Zonal Statistics API delivers Future (2100) DRB Urban Land Forecasts

The Drexel University College of Computing and Informatics (CCI) and the Academy of Natural Sciences (ANS) of Drexel University developed the fast-zonal statistics (FZS) Application Programming Interface (API) which returns

numerical attributes (mean, sum, and count) for a submitted polygon query region over any regular grid or raster dataset. Common applications of this technology include determining the amount of precipitation or impervious surfaces in a watershed. The API was built using a GeoDjango Web framework, Nginx, Docker, PostGIS, and a novel FZS algorithm produced by the members of this organization (Haag et al. 2020). This algorithm is labeled “fast” because to determine the zonal sum for a polygon over a raster surface, only the cells which intersect the boundary of the polygon must be traversed rather than all the interior cells. This means that computationally the approach scales much better with increased data resolution as the FZS algorithm is constant in relation to the length (meters) of the polygon perimeter rather than its area (meters square). Additional information with how to interact with the API can be found
here: http://watersheds.cci.drexel.edu/docs(http://watersheds.cci.drexel.edu/docs)
.

Haag, S., Tarboton, D., Smith, M. & Shokoufandeh, A. (2020). Fast summarizing algorithm for polygonal statistics over a regular grid. Computers & Geosciences. 10.1016/j.cageo.2020.104524.

https://www.sciencedirect.com/science/article/pii/S0098300419306697(https://www.sciencedirect.com/science/article/pii/S0098300419306697)

Pennsylvania Urbanized Areas

US EPA Urbanized Area boundaries, developed by the USEPA to support a number of analytical needs. In Pennsylvania, these boundaries are used to identify areas within which various municipal entities have a responsibility for reducing pollutant loads (primarily sediment, nitrogen and phosphorus).

Urbanized Area Maps for NPDES MS4 Phase II Stormwater Permits 2010 Urbanized Areas (Newest Maps)(https://www.epa.gov/npdes/urbanized-area-maps-npdes-ms4-phase-ii-stormwater-permits)

DRB Catchment Water Quality Data, T(X) Annual Loading Rates from SRAT Catchments

Estimated average-catchment loading rates for Total Nitrogen (TN), Total Phosphorus (TP), or Total Suspended Solids (TSS), derived within the Delaware River Basin from the Stream Reach Assessment Tool (SRAT) modeling effort. SRAT-estimated loading rates are shown in MMW by shading the NHDplusV2 catchments areas, where darker shades indicate higher mean annual loading rates in mass per unit area (e.g., lbs/acre or kg/ha).

The Stream Reach Assessment Tool (SRAT) modeling effort was funded by the William Penn Foundation (WPF) Delaware River Watershed Initiative (DRWI). SRAT is derived from calibrated MapShed model runs of all HUC-12 areas within the Delaware River Basin, downscaling MapShed results to NHDplusV2 catchment scales and routing loads through the NHDplusV2 medium resolution stream network. More details regarding SRAT(https://www.streamreachtools.org/overview/)

Many additional SRAT-derived model output data layers can be visualized and analyzed in Model My Watershed, including the visualization of pollutant loading rates and stream concentrations at the NHD catchment and stream segment level. See below for more details.

3.3. Boundaries

USGS Subbasin unit (HUC-8)

US Geological Survey Hydrologic Units of the eight-digit level (Hydrologic Unit Code 8), averaging 700 square miles (1,813 square kilometers). Although USGS names the HUC-8 level as “subbasin” scale, these hydrological units are not equivalent to true hydrographic basins or watersheds, because the main river/stream within a given

HUC-8 area can often have contributions from additional, upstream HUC-8 areas.

More info: Hydrological code(https://en.wikipedia.org/wiki/Hydrological_code)

Data source: NHDplusV2(http://www.horizon-systems.com/NHDPlus/NHDPlusV2_home.php)

USGS Watershed Unit (HUC-10)

US Geological Survey Hydrologic Units of the ten-digit level (Hydrologic Unit Code 10), averaging 227 square miles (588 square kilometers). Although USGS names the HUC-10 level as “watershed” scale, these hydrological units are not equivalent to true hydrographic basins or watersheds, because the main river/stream within a given HUC-10 area can often have contributions from additional, upstream HUC-10 areas.

More info: Hydrological code(https://en.wikipedia.org/wiki/Hydrological_code)

Data source: NHDplusV2(http://www.horizon-systems.com/NHDPlus/NHDPlusV2_home.php)

USGS Subwatershed Unit (HUC-12)

US Geological Survey Hydrologic Units of the twelve-digit level (Hydrologic Unit Code 12), averaging 40 square miles (104 square kilometers). Although USGS names the HUC-12 level as “subwatershed” scale, these hydrological units are not equivalent to true hydrographic basins or watersheds, because the main river/stream within a given HUC-12 area can often have contributions from additional, upstream HUC-12 areas.

More info: Hydrological code(https://en.wikipedia.org/wiki/Hydrological_code)

Data source: NHDplusV2(http://www.horizon-systems.com/NHDPlus/NHDPlusV2_home.php)

County Lines

County lines for each state in the continental United States.

More info: County (United States)(https://en.wikipedia.org/wiki/County_(United_States))

Data source: TIGER/Line Shapefile, 2015, nation, U.S., Current County and Equivalent National Shapefile(https://catalog.data.gov/dataset/tiger-line-shapefile-2015-nation-u-s-current-county-and-equivalent-national-shapefile)

Congressional Districts

Congressional Districts for the United States House of Representatives for the 113th Congress: 1/3/2013-1/3/2015.

More info: List of United States congressional districts(https://en.wikipedia.org/wiki/List_of_United_States_congressional_districts)

Data source: https://www.census.gov/geo/maps-data/data/cbf/cbf_cds.html#cd113(https://www.census.gov/geo/maps-data/data/cbf/cbf_cds.html#cd113)

School Districts

School District boundaries in the continental United States.

More information: School district(https://en.wikipedia.org/wiki/School_district)

Data source: School District Boundaries(https://www.census.gov/did/www/schooldistricts/data/boundaries.html)

Pennsylvania Municipalities

Sub-county municipal boundaries for the State of Pennsylvania were developed by various state agencies. Pennsylvania municipality boundaries(http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=41)

3.4. Observations

Weather Stations (214)

A database of national-scale daily weather data (temperature and precipitation) was previously compiled by USEPA for use in various environmental simulation models. In the case of MMW, these data are used to estimate daily weather data (i.e., precipitation and temperature; compiled for the time period 1961-1990) for use in driving the daily runoff and erosion calculations in the Watershed Multi-Year Model (GWLF-E model, described below(https://wikiwatershed.org/help/model-help/mmw-tech/#watershed-multi-year-model)
) (see access USEPA Meteorological Data(https://www.epa.gov/exposure-assessment-models/meteorological-data)
).

This layer can be visualized on the map by clicking on the “Observations” tab of the “Layer” palette and all 214 weather stations can be seen in blue (you may need to zoom in/out on the map). Clicking on the blue circle will pop-up station information specific to each point on the map. Weather data are also described below(https://wikiwatershed.org/help/model-help/mmw-tech/#description-and-editing-of-key-model-input-data-and-parameters)
, and Custom Weather data can be uploaded a Watershed-Multi-Year Model run to generate a new scenario based on user supplied weather data.

3.5. Basemaps

Topography

ESRI World Topographic Map(https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f)

Satellite

ESRI ArcGIS World Imagery(http://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9)

Satellite with Roads

Google Maps hybrid map type(https://developers.google.com/maps/documentation/javascript/maptypes#BasicMapTypes)

Terrain

Google Maps terrain map
type(https://developers.google.com/maps/documentation/javascript/maptypes#BasicMapTypes)

3.6. Additional Data Layers

In addition to the data layers that are visualized on the map, the Model My Watershed web app also has access to additional data layers (not visualized) for use by the various modeling functions.

Animals

Farm animal populations for an area of interest are estimated from county-level data from USDA, by first calculating an average "animals per farmland acres" for each animal type for each county. Data source(https://www.nass.usda.gov/Quick_Stats/index.php)

Point Sources

Point source discharges of pollutants that are permitted under US EPA's National Pollutant Discharge Elimination System (NPDES)(https://www.epa.gov/npdes)
will be listed for any selected Area of Interest under the Analyze tab and the "Pt Sources" sub-tab. These NPDES-permitted discharges are primarily from large municipal and industrial wastewater treatment plants, which are required to submit Discharge Monitoring Reports (DMR). The "Pt Sources" data were created from EPA's DMR database, which can be accessed through EPA's Water Pollution Search web portal(https://echo.epa.gov/trends/loading-tool/water-pollution-search)
. These same data are utilized as input to the MMW Watershed Multi-Year Model(https://wikiwatershed.org/help/model-help/mmw-tech/#gis-based-estimation-of-model-input-parameters)
. For point sources collected within the Delaware River Basin measures of discharge (effluent) and concentration (nitrogen and phosphorus) were taken directly from more detailed state level Discharge Monitoring Reports.

4. Select Area of Interest (AoI)

A suite of tools (within the left menu area) are available to select areas within the lower 48 United States and begin the modeling process by summarizing land use, hydrologic soil groups, and other statistics. Options include: *Select by Boundary*, *Free Draw*, and *Delineate Watershed.*

Modeling options are described in Section 7.0(https://wikiwatershed.org/help/model-help/mmw-tech/#water-quantity-and-quality-models)
and some modeling workflows require that specific Area of Interest tools are used (as noted below):

- In order to use the "**Sub-basin Attenuation(https://wikiwatershed.org/help/model-help/mmw-tech/#subbasin-attenuated-results)**
" sub-routine within the "Watershed Multi-Year Model(https://wikiwatershed.org/help/model-help/mmw-tech/#watershed-multi-year-model)
", the user must define/select an Area of Interest using either the HUC8 or HUC10 "Select by Boundary" choice.
- In order to use the "**Watershed Multi-Year Worksheet(https://wikiwatershed.org/help/model-help/mmw-tech/#watershed-multi-year-worksheet)**
" (a.k.a., BMP Spreadsheet Tool), the user **cannot** use the HUC12 "Select by Boundary" choice.
- Note: the most appropriate size (total area/acreage) of your Area of Interest for use with the **Site Storm Model** (Technical Documentation here(https://wikiwatershed.org/help/model-help/mmw-tech/#site-storm-model)
and Guide here(https://wikiwatershed.org/help/model-help/site-storm-guide/)

) is from 1 to several hundred acres and it is recommended that the model not be run for areas much large than about 1 square mile (640 acres; although modeling larger areas are possible).

- Note: the most appropriate size (total area/acreage) of your Area of Interest for use with the **Watershed Multi-Year Model** (Technical Documentation here(https://wikiwatershed.org/help/model-help/mmw-tech/#watershed-multi-year-model)
) is from several hundred acres to ~1,500 square miles (HUC 8 scale; although modeling larger areas are possible).

4.1. Select by Boundary

Choose a predefined boundary from several boundary types as described above in Section 2.3 Boundaries(https://wikiwatershed.org/documentation/mmw-tech/#overlay-boundary)
. First select the boundary type, then use this selection tool enable a “hover over” function to see the name of each bounded area. Once activated, the user can click on their desired area to generate land use and hydrologic soils analysis within the area (among other statistics).

Available boundary types for area selection are a subset of the boundary types viewable in the Layers Selector in the lower left of map. For more information and data sources for these layers, see Section 2.3 Boundaries (https://wikiwatershed.org/documentation/mmw-tech/#overlay-boundary)
of this guide.

4.2. Draw Area

Note: This Area of Interest tool can also be used to identify a smaller subarea within a larger HUC12 basin for more specialized use of the Watershed Multi-Year Model for developing a Pollution Reduction Plan (PRP) in Pennsylvania as described in Section 7.3(https://wikiwatershed.org/help/model-help/mmw-tech/#watershed-multi-year-worksheet)
.

Free Draw

A tool any user can deploy to draw a polygon and, upon closing the polygon (double click to close), clip land use and hydrologic soil groups (among other statistics) for the area within the polygon.

Square Km

A single click anywhere on the map will result in a 1 km^2 area that will clip land use and hydrologic soil groups (among other statistics) for the area within the polygon.

4.3. Delineate Watershed

Note: This Area of Interest tool can also be used to identify a smaller subarea within a larger HUC12 basin for more specialized use of the Watershed Multi-Year Model for developing a Pollution Reduction Plan (PRP) in Pennsylvania as described in Section 7.3(https://wikiwatershed.org/help/model-help/mmw-tech/#watershed-multi-year-worksheet)
.

This tool selects an Area of Interest by automatically delineating a watershed from a point on a stream network using topographic data represented as a digital elevation model (DEM).

Once the user clicks on the map, the tool moves downhill from that point to “snap” onto a second point on the nearest stream flowline. The tool then calculates the watershed upstream of this second point using the Rapid

Watershed Delineation algorithms(https://github.com/WikiWatershed/rapid-watershed-delineation)
. The methods for moving downhill to the stream and watershed delineation both use a grid of flow directions derived from a digital elevation model (DEM).

The tool returns the delineated watershed area and boundary, which are provided to the Analyze Area of Interest(https://wikiwatershed.org/documentation/mmw-tech/#analyze-area-of-interest-aoi)
functions. Two DEMs and stream networks are presently available for watershed delineation as listed below.

Continental US medium resolution streams and NHDPlus DEM

Selecting “Snap to Continental US medium resolution streams” moves downhill from the point you click to snap onto the nearest point on the medium resolution National Hydrography Dataset (NHDPlus flowline) and calculates the watershed upstream of this point using the 30 m resolution NHDPlus flow direction grid for the continental US.

If the point you click does not have a NHDPlus flowline downstream of it (e.g. is in an internally draining area) the watershed is calculated from the point you click. Learn more about NHDPlus(http://www.horizon-systems.com/nhdplus/)
. The Model My Watershed watershed delineation uses NHDPlus version 2.1 data model with latest content version accessed 11/22/16.

Delaware high resolution streams and 1/3 arc sec (10 m) resolution DEM

Selecting “Snap to Delaware high resolution streams” moves downhill from the point you click to snap onto the nearest point on the Delaware high resolution stream network and calculates the watershed upstream of this point using a 1/3 arc second (10) m resolution digital elevation model for the Delaware River Basin obtained from the National Elevation Dataset.

The stream network snapped to was delineated using TauDEM(http://hydrology.usu.edu/taudem/taudem5/index.html)
as described above (Delaware River Basin High Resolution Stream Network overlay(https://wikiwatershed.org/documentation/mmw-tech/?preview=true#overlays-tab-in-layers-streams)
).

4.4. Upload File

Note: This Area of Interest tool can also be used to identify a smaller subarea within a larger HUC12 basin for more specialized use of the Watershed Multi-Year Model for developing a Pollution Reduction Plan (PRP) in Pennsylvania as described in Section 7.3(https://wikiwatershed.org/help/model-help/mmw-tech/#watershed-multi-year-worksheet)
.

Upload a polygon for your area.

- Must be a shapefile (zip containing shp and prj files) or geojson
- Only the first feature is used

5. Analyze Area of Interest (AoI)

Once an area of interest is selected, Model My Watershed automatically performs geospatial analyses on mapped data layers within the area. Summary statistics are provided in graphs and tables for each of these data layers that impact stormwater runoff and/or water quality:

- **Streams:** For more information on data sources, see Section 3.1 Layers:

Streams(https://wikiwatershed.org/documentation/mmw-tech/#overlays-tab-in-layers-streams)
.

- Stream length and mean channel slope statistics are calculated for each stream order (sum of all segments belonging to a stream order(https://en.wikipedia.org/wiki/Strahler_number) in the area analyzed) from the Continental US Medium Resolution Stream Network(https://wikiwatershed.org/help/model-help/mmw-tech/#overlays-tab-in-layers-streams) .
- Stream length in agricultural and non-agricultural areas is calculated using an implied riparian width of approximately 30 m, and an implied buffer of approximately 15 m, using the following methodology:
    - A stream vector line is rasterized to a 1 pixel string, with pixels the same size as an NLCD pixel (30m). Under the hood, GeoTrellis uses Bresenham's Line Drawing algorithm(https://en.wikipedia.org/wiki/Bresenham%27s_line_algorithm) to rasterize a line to pixels. See the specific GeoTrellis code(https://github.com/locationtech/geotrellis/blob/4a718f2b64e02d2f05f0be6627fd76ec3b9b8d14/raster/src/main/scala/geotrellis/raster/rasterize/Rasterizer.scala#L281-L328) .
    - This approach therefore assumes an implied riparian width of approximately 30m, and an implied buffer of approximately 15 m.

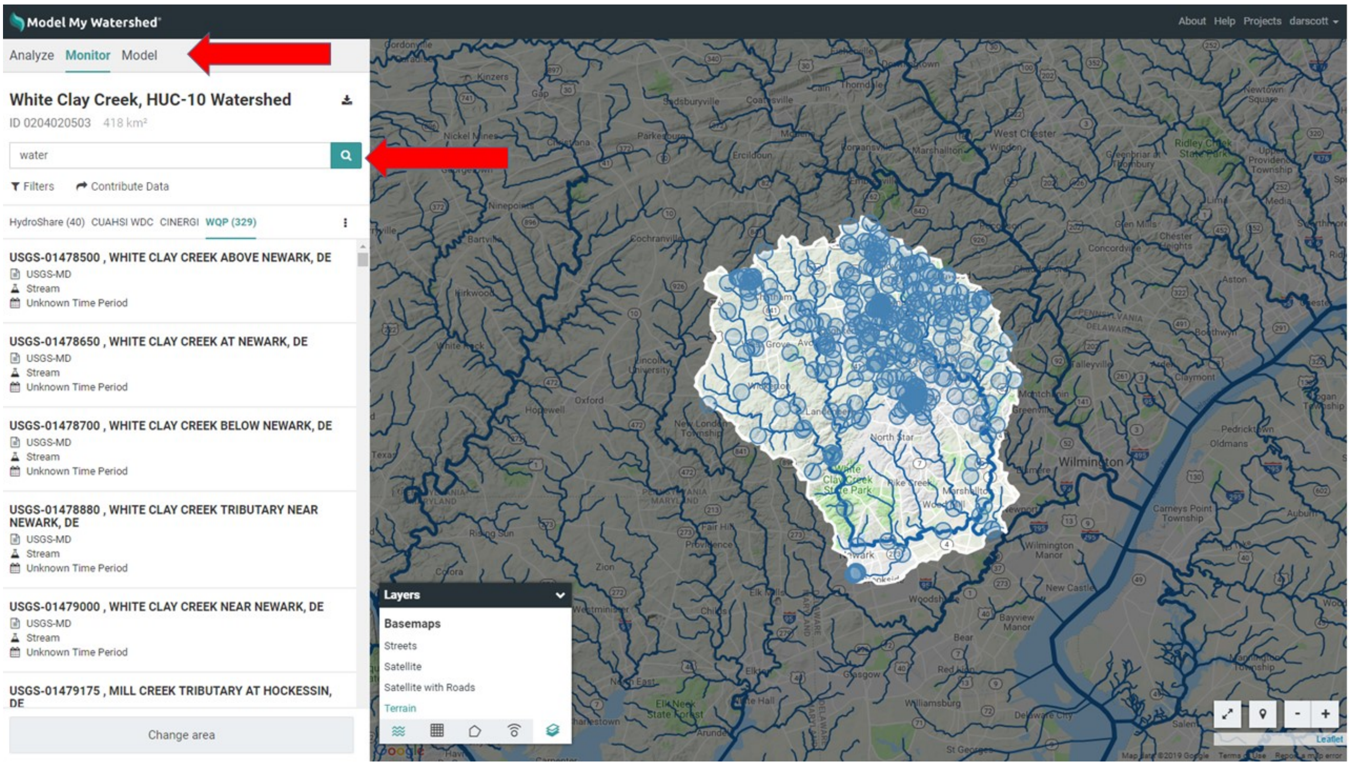
- **Land:** For more information on data sources, see Section 3.2 Layers: Coverage Grids(https://wikiwatershed.org/documentation/mmw-tech/#overlays-tab-coverage) .
    - "Land cover distribution" summary statistics for each land use category (Area, Coverage %, and Active River Area) are computed for your Area of Interest based on the 2011 National Land Cover Database(https://wikiwatershed.org/help/model-help/mmw-tech/#overlays-tab-coverage) . For Active River Area, the ARA coverage grid is used to segment/clip the land area in your Area of Interest to this layer and summarize land cover area within the "Active River Area – Northeast and Mid-Atlantic".
    - Within the drop down selection list, the "Protected lands distribution" selection provides a summary of land Area and Coverage (%) for each Protected Lands(https://wikiwatershed.org/help/model-help/mmw-tech/#overlays-tab-coverage) category in that coverage grid for your Area of Interest.
    - Within the drop down selection list, the "DRB 2100 land forecast (Centers or Corridors)" selection provides a summary of land Area and Coverage (%) for predicted land cover by the year 2100(https://wikiwatershed.org/help/model-help/mmw-tech/#overlays-tab-coverage) for your Area of Interest.
- **Soil:** For more information on data sources, see Section 3.2 Layers: Coverage Grids(https://wikiwatershed.org/documentation/mmw-tech/#overlays-tab-coverage) .
- **Animals:** For more information on data sources, see Section 3.6 Layers: Additional Data Layers(https://wikiwatershed.org/documentation/mmw-tech/#additional-data-layers) .
- **Point Sources:** For more information on data sources, see Section 3.6 Layers: Additional Data Layers(https://wikiwatershed.org/documentation/mmw-tech/#additional-data-layers) .
- **Water Quality** (Delaware River Basin Only): For more information on data sources, see Section 3.2 Layers: Coverage Grids(https://wikiwatershed.org/documentation/mmw-tech/#overlays-tab-coverage) .

6. Monitor

Multi-Catalog Free-Text Search for Datasets

The “Monitor” feature within Model My Watershed allows any user to search multiple data catalogs/repositories for related datasets. After geospatial analysis of an Area of Interest, the user can search within that area for datasets contained in four separate data catalogs: HydroShare, CUAHSI WDC, CINERGI, and WQP (described below). The list of datasets can be filtered by free-text search and by time period coverage. A dataset can be selected for additional details, such as the dataset abstract and links to sources and web services. Once a user clicks on the word “Monitor”, a free-text search box is revealed on the left side panel (see image below). Typing a word or text string and clicking the “search” button will initiate the search.

- HydroShare: HydroShare(https://www.hydroshare.org/)
  is an online collaborative environment for sharing hydrologic data and models. Its goal is to facilitate creation, collaboration around, discovery and access to data and model resources shared by members of the hydrology community.
- CUAHSI WDC: The Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) Water Data Center (WDC) provides tools for data access, analysis and collaboration(https://www.cuahsi.org/data-models/discovery-and-analysis/)
  , including a Catalog of hydrological time series data available as Water One Flow (WOF) and WaterML web services.
- CINERGI(http://earthcube.org/group/cinergi)
  : The Community Inventory of EarthCube Resources for Geosciences Interoperability (CINERGI) Data Portal is part of the Earthcube project. This data discovery and exploration tool for geosciences now features a geoportal interface with over 1,000,000 searchable records. Any user can contribute links to favorite resources so those repositories and datasets become searchable. The portal hosts a large inventory of high quality geoscience information resources, with standard metadata and traceable provenance.
- The Water Quality Portal(https://www.waterqualitydata.us/)
  (WQP) is a cooperative service sponsored by the United States Geological Survey (USGS), the Environmental Protection Agency (EPA), and the National Water Quality Monitoring Council (NWQMC). It serves data collected by over 400 state, federal, tribal, and local agencies.



7. Model Water Quantity & Quality

There are currently two models to choose from to 1) predict how water moves through your Area of Interest and 2) predict the water quality of water running off or your Area of Interest.

7.1. Site Storm Model

The Model My Watershed Site Storm Model simulates a single 24-hour storm by applying a hybrid of the Source Loading and Management Model (SLAMM(http://winslamm.com/)
), TR-55(https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf)
, and the simplest of the Food and Agriculture Organization of the United Nations evaporation models(http://www.fao.org/docrep/x0490e/x0490e00.htm#Contents)
for runoff quantity and EPA's STEP-L model(http://it.tetratech-ffx.com/steplweb/)
for water quality over the selected Area of Interest within the continental United States.

The results are calculated based on actual land cover data (from the USGS National Land Cover Database 2011, NLCD2011) and actual soil data (from the USDA Gridded Soil Survey Geographic Database, gSSURGO, 2016) for the selected land area of interest. For more information and data sources, see Section 2.2 Coverage Grids(https://wikiwatershed.org/documentation/mmw-tech/#overlays-tab-coverage)
.

Learn how to use the Site Storm Model in Model My Watershed(https://wikiwatershed.org/help/model-help/site-storm-guide/)
.

TR-55 Component

This model is used to calculate runoff for all "natural" land-use types. TR-55 curve number information(https://github.com/WikiWatershed/tr-55/blob/develop/tr55/tables.py)

SLAMM Component

The Source Loading and Management Model (SLAMM(http://winslamm.com/)
) is used to calculate runoff for urban land-use types.

- Additional information on SLAMM(http://dnr.wi.gov/topic/stormwater/standards/slamm.html)
- SLAMM curve number information(https://github.com/WikiWatershed/tr-55/blob/develop/tr55/tables.py#L133)

7.2. Watershed Multi-Year Model

The Watershed Multi-Year Model in Model My Watershed simulates 30 years of daily water, nutrient and sediment fluxes using the Generalized Watershed Loading Function Enhanced (GWLF-E) model that was developed for the MapShed(http://wikiwatershed.org/mapshed/)
desktop modeling application by Barry M. Evans, Ph.D., and his group at Penn State University. The GWLF-E model is also one of five watershed models available within EPA's BASINS multi-purpose modeling application(https://www.epa.gov/exposure-assessment-models/basins-framework-and-features#models)
.

Model My Watershed is now the primary framework for running the latest GWLF-E model version, replacing MapShed and BASINS because these two desktop applications are built on the aging MapWindow GIS package(http://www.mapwindow.org/)
 that is no longer supported. For that reason, in late 2014 we ported all GWLF-E code from Visual Basic to Python, with all subsequent code development in this open source repository(https://github.com/WikiWatershed/gwlf-e/)
. Similarly, all of the MapWindow-based geoprocessing routines have been rewritten to operate with the open-source GeoTrellis(https://geotrellis.io/)
 geographic data processing engine and framework, with all new code in this repository(https://github.com/WikiWatershed/model-my-watershed)
.

7.2.1. The GWLF Model

The core watershed multi-year simulation model used in MMW and MapShed (GWLF-E) is an enhanced version of the Generalized Watershed Loading Function (GWLF) model first developed by researchers at Cornell University (Haith and Shoemaker, 1987). The original DOS-compatible version of GWLF was rewritten in Visual Basic by Evans et al. (2002) to facilitate integration with ArcView© and other GIS software packages, and tested extensively in the U.S. and elsewhere. Since 2002 it has been substantially enhanced; see Section 5.2.2 GWLF-Enhancements(https://wikiwatershed.org/documentation/mmw-tech/#enhancements-to-the-gwlf-model)
.

The advantage of GWLF (and GWLF-E) is the ease of use and reliance on input datasets less complex than those required by other watershed-oriented water-quality models such as SWAT, SWMM, and HSPF (Deliman et al., 1999). The model has also been endorsed by the U.S. EPA as a good “mid-level” model that contains algorithms for simulating most of the key mechanisms controlling nutrient and sediment fluxes within a watershed (U.S. EPA, 1999).

The GWLF model provides the ability to simulate runoff, sediment, and nutrient (nitrogen and phosphorus) loads from a watershed given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. It is a continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads based on the daily water balance accumulated to monthly values.

GWLF is considered to be a combined distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios, but each area is assumed to be homogeneous in regard to various “landscape” attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but simply aggregates the loads from each source area into a watershed total; in other words there is no spatial routing. For subsurface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for sub-surface flow contributions. Daily water balances are computed for an unsaturated zone as well as a saturated subsurface zone, where infiltration is simply computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.

With respect to major processes, GWLF simulates surface runoff using the SCS-CN approach with daily weather (temperature and precipitation) inputs from the EPA Center for Exposure Assessment Modeling (CEAM) meteorological data distribution(https://www.epa.gov/exposure-assessment-models/meteorological-data)
. Erosion and sediment yield are estimated using monthly erosion calculations based on the USLE algorithm (with monthly rainfall-runoff coefficients) and a monthly KLSCP values for each source area (i.e., land cover/soil type combination). A sediment delivery ratio based on watershed size and a transport capacity based on average daily runoff is then applied to the calculated erosion to determine sediment yield for each source area. Surface nutrient losses are determined by applying dissolved N and P coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural source area.

Point source discharges can also contribute to dissolved losses and are specified in terms of kilograms per month. Manured areas, as well as septic systems, can also be considered. Urban nutrient inputs are all assumed to be solid-phase, and the model uses an exponential accumulation and wash-off function for these loadings. Subsurface losses are calculated using dissolved N and P coefficients for shallow groundwater contributions to stream nutrient loads, and the subsurface submodel only considers a single, lumped-parameter contributing area.

Evapotranspiration is determined using daily weather data and a cover factor dependent upon land use/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values.

It is beyond the scope of this document to provide specific details on the structure and technical components underlying the original GWLF model. View a copy of the GWLF manual(https://3zlpu231e6hebptt888geo1b-wpengine.netdna-ssl.com/wp-content/uploads/GWLFManual.pdf)
. Additional details on the updated version of this model (GWLF-E) and the geoprocessing routines used in MapShed (and by extension, Model My Watershed) to prepare input data to the model can also be found in the MapShed Users' Manual also available at this website.

7.2.2. GWLF-Enhanced

Since its initial incorporation into MapShed(https://wikiwatershed.org/mapshed/)
 (and its precursor, AVGWLF), the GWLF-E model has been substantially enhanced since 2002 to include a number of routines and functions not found in the original GWLF model.

A significant revision in one of the earlier versions of AVGWLF was the inclusion of a ***streambank erosion routine***. This routine is based on an approach often used in the field of geomorphology in which monthly streambank erosion is estimated by first calculating an average watershed-specific Lateral Erosion Rate (LER). After a value for LER has been computed, the total sediment load generated via streambank erosion is then calculated by multiplying the above erosion rate by the total length of streams in the watershed (in meters), the average streambank height (in meters), and an average soil bulk density value (in kg/m^3). In Mapshed, these stream bank and erosion rate parameters were optimized for models using the high resolution stream flow line dataset available for Pennsylvania. In Model My Watershed, which uses NHDplus v2 medium resolution flow lines, we use a sediment erosion adjustment factor of 1.4 to make bank erosion estimates in Model My Watershed comparable to those in MapShed for Pennsylvania.

In later versions, the original water balance routine within GWLF was extended to simulate ***water withdrawals from surface and groundwater sources***. Within MapShed, information contained in an optional "water extraction" GIS layer can be used to estimate the volume of water taken from various sources within a watershed each month. For surface water withdrawals, the estimated cumulative water volume is subtracted from the simulated "stream flow" component of the monthly water balance calculations. For groundwater withdrawals, this volume is subtracted from the "subsurface" component of the monthly water balance calculations. (Note: this particular routine is not yet implemented in Model My Watershed, although the GWLF-E model does allow for "extracted" water to be simulated).

Other recent model revisions include the implementation of ***an agricultural tile drainage routine***, the capability to consider point source effluent (i.e., flows) in the hydrology for a given area, the incorporation of new routines for more direct simulation of loads from farm animals, a new pathogen load estimation routine, and the ability to consider the potential effects of best management practices (BMPs) and other mitigation activities on pollutant loads.

Another significant change has been an ***improvement in the simulation of hydrology and loads from urban areas***. In the original version of GWLF used with AVGWLF, such simulation could only be accomplished for two basic types of urbanized or developed land (i.e., low-density development and high-density development). However, in very intensively developed watersheds, it may be more appropriate to use more complex routines for a wider range of urban landscape conditions. Consequently, additional modeling routines have been included with the version of GWLF used in MapShed and Model My Watershed to address this situation. These new functions are based on the RUNQUAL model developed by Haith (1993) at Cornell University. With these routines, runoff volumes are calculated from procedures given in the U.S. Soil Conservation Service's Technical Release 55 (U.S. Soil Conservation Service, 1986). Contaminant loads are based on exponential accumulation and washoff functions similar to those used in the SWMM (Huber and Dickinson, 1988) and STORM (Hydrologic Engineering Center, 1977) models. The pervious and impervious fractions of each land use type are modeled separately, and runoff and contaminant loads from the various surfaces are calculated daily and aggregated monthly in the model output. With the RUNQUAL-derived routines, it is assumed that the area being simulated is small enough so that travel times are on the order of one day or less. View a copy of the RUNQUAL manual(https://3zlpu231e6hebptt888geo1b-wpengine.netdna-ssl.com/wp-content/uploads/RUNQUALManual.pdf) that contains more details about this model.

7.2.3. GIS-Based Estimation of Model Input Parameters

Similar to what is done using the desktop version of MapShed, various web-based geoprocessing routines are used to parameterize input data for the GWLF-E watershed model implemented within Model My Watershed.

Once model parameter values have been estimated, they are subsequently written to a model input file that is then automatically processed by the GWLF-E model to simulate hydrology and pollutant transport for the “area of interest” (typically a watershed) identified by the user. To support the modeling process in Model My Watershed, a number of nationally-available data sets are used. Brief descriptions of the key data sets used are provided below, along with a web link that identifies the source of this data.

2011 National Land Cover Dataset

Primarily used to estimate/assign values for curve numbers, various USLE factors, dissolved TN and TP runoff concentrations, impervious surface fractions, and pollutant accumulation rates in urban areas. The 2011 NLCD has been retired and is no longer available from the federal government.

GSSURGO Soils Data

Primarily used to estimate various USLE factors, curve numbers by land use/cover type, available water-holding capacity, soil P content, and dissolved P concentration in runoff (see Description of Gridded Soil Survey Geographic (gSSURGO) Database(https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053628)
).

30-Meter Elevation Data

Primarily used to estimate slope and slope-length by land cover category for use in the USLE soil loss equation and mean watershed slope for use in the streambank erosion equation (see http://eros.usgs.gov/elevation-products(http://eros.usgs.gov/elevation-products)
).

Discharge Monitoring Report (DMR) Data

This represents a national database on “point source” pollutant discharges available from USEPA. (Note: for the Delaware River Basin this data set was enhanced using data available from various state agencies as well). This dataset was used to assign default values for effluent discharges from point sources within a given watershed (see Water Pollution Search(http://cfpub.epa.gov/dmr/ez_search.cfm)
).

Estimates of Shallow Groundwater Nitrogen Concentration

Primarily used to set default values for groundwater N concentration for any given watershed (see Data Sets for GWAVA-DW(https://water.usgs.gov/GIS/dsdl/gwava-s/index.html#gwava-dw)
). This dataset was developed by researchers at the U.S. Geological Survey, and a description of the spatial modeling process used is provided by Nolan and Hitt (2006).

County-Level Farm Animal Populations

These data are available from USDA, and were used to estimate farm animal populations weighted by “farmland acres” for any given watershed (see Quick Stats Tools(https://www.nass.usda.gov/Quick_Stats/index.php)
).

USEPA National Climate Data

A database of national-scale daily weather data was previously compiled by USEPA for use in various environmental simulation models. In the case of MMW, these data were used to estimate daily weather data (i.e., precipitation and temperature; compiled for the time period 1960-1990) for use in driving the daily runoff and erosion calculations in the GWLF-E model (see Meteorological Data(https://www.epa.gov/exposure-assessment-models/meteorological-data)
). This layer can be visualized(https://wikiwatershed.org/help/model-help/mmw-tech/#overlays-tab-observations) on the map by clicking on the “Observations” tab of the “Layer” palette and all 214 weather stations can be seen in yellow. Clicking on the yellow circle will pop-up station information specific to each point on the map. Weather data are also described below(https://wikiwatershed.org/help/model-help/mmw-tech/#description-and-editing-of-key-model-input-data-and-parameters)
, and Custom Weather data can be uploaded a model run to generate a new scenario based on user supplied weather data.

Estimates of Baseflow

This dataset, prepared by the US Geological Survey, depicts estimates of baseflow on a 1-km grid cell basis for the conterminous United States (see Base-flow index grid for the conterminous United States(http://water.usgs.gov/lookup/getspatial?bfi48grd)
). It was created by interpolating baseflow index (BFI) values from USGS stream gages throughout the country. Baseflow is the component of stream flow that can be attributed to groundwater/shallow subsurface discharge into streams. For use in Model My Watershed, this dataset is used to estimate the recession coefficient used by the GWLF-E model. In this case, a regression equation was developed by correlating average BFI values for a number of watersheds across the country against calibrated recession coefficients established by one of the Model My Watershed co-developers (B. Evans) for the same watersheds as part of previous studies.

Estimates of Soil Phosphorus Concentration

This dataset is used to estimate the amount of phosphorus attached to eroded soil generated by precipitation events as well as the concentration of dissolved phosphorus in runoff. The national soil P layer used in Model My Watershed was created using various geo-referenced sample datasets developed by the U.S Geological Survey (see Smith, D.B., W.F. Cannon, L.G. Woodruff, F. Solano, and K.J. Ellefsen, 2014). (See also Geochemical and Mineralogical Maps for Soils of the Conterminous United States(https://pubs.usgs.gov/of/2014/1082/)
). Some example national maps produced by USGS from these sample datasets can be viewed and downloaded from Geochemical and Mineralogical Maps, with Interpretation, for Soils of the Conterminous United States(https://mrdata.usgs.gov/soilgeochemistry/#/detail/element/15)
. Unfortunately, none of the national map layers available at the latter site could be directly used within Model My Watershed due to their generalized nature (particularly with respect to data categorization). Consequently, for use within Model My Watershed, the original geo-referenced sample datasets in Excel file format were obtained from one of the USGS scientists (Federico Solano), and surface interpolation routines were used to create a number of intermediate spatial datasets representing soil P concentrations for different land cover types and soil depths across the country. These were subsequently processed and combined to create one national map depicting mean soil P values (in units of mg of P/kg of soil) at a 1-km grid cell resolution.

Estimates of Soil Nitrogen Concentration

Estimates of soil nitrogen concentration are needed to calculate the amount of nitrogen attached to eroded soil produced by precipitation events in a given area. Within Model My Watershed, these estimates are derived from a national soil nitrogen map produced by research scientists at the Oak Ridge National Laboratory (see Hargrove and Post, 1998). In this latter study, this map was developed from a USDA National Soil Characterization Database linked back to spatial information in a STATSGO soil map using soil taxonomic relationships (see A New High-Resolution National Map of Vegetation Ecoregions Produced Empirically Using Multivariate Spatial Clustering(http://geobabble.org/~hnw/esri98)
). For use in Model My Watershed, the national soil nitrogen layer was provided directly by Dr. William Hargrove, one of its' principal developers.

Learn More About GWLF-E Algorithms

Those interested in learning more about how various equations and algorithms are used to estimate values for various GWLF-E model parameters can find additional details in the MapShed Users Manual available for download on the MapShed web page(https://wikiwatershed.org/mapshed/)
.

7.2.4. Description and Editing of Key Model Input Data and Parameters

Weather Data

The Watershed Multi-Year Model is informed by estimates of average daily precipitation and temperature data (source for initial data input is average daily from 1961-1990 provided from the USEPA, as described above(https://wikiwatershed.org/help/model-help/mmw-tech/#overlays-tab-observations)
). The model utilizes the nearest two weather stations (214 available across the coterminous US) to calculate an average daily value prior to feeding into the model.

Custom weather data can be added to a Watershed-Multi Year Model scenario via the "Weather Data" button (located along the grey horizontal bar above the map window view after you "Add changes to this area" by clicking the green text in the upper right corner of your map view).

Your custom weather data file must adhere to these requirements in order to upload without error:

- It must be a CSV (comma-separated value) file that is formatted to include three columns: Date, Precipitation, and Temperature.
- Your file name cannot contain spaces. E.g., "My Weather Data.csv" will cause an upload error; "My_Weather_Data.csv" will upload properly.
- The file must include a "header/label" row in row 1 (view a sample: weather_data_sample.csv(https://wikiwatershed.org/wp-content/uploads/weather_data_sample.csv)
).
- The Date column must be formatted as mm/dd/yyyy.
- The Precipation and Temperature columns must contain properly formatted numeric data.
- The file must include at least three years and no more than 20 years of daily data (1,095 – 7,300 rows of data, plus one row with header/labels).

Once you select a file, click "upload" to check that your file is acceptable for use. If acceptable, you will see summary text of how many years and the time period. Click "Done" to complete your scenario modeling run.

Your custom weather file remains as a stored file associated with your project. You can then modify Land Cover and/or Conservation Practices (see next sections). If you would like to add additional scenarios based on your custom weather data, you can either repeat the upload process described above or click on the New Scenario down arrow, click on the three dots to the right of the Scenario Name and select "Duplicate". This will create a new scenario that is based on your custom weather file.

You can remove or return to the original weather data by selecting the “Weather Data” icon and selecting the radio dial next to “Available Data”.

After a Watershed Multi-Year Model has been run for an area of interest within the Delaware River Basin, additional scenarios can be run using future weather predictions. Predictions of daily precipitation (P) and temperature (daily maximum, T_{max}, and minimum, T_{min}, and average, T_{avg}) for 2080-2100 were obtained from the World Climate Research Programme’s Coupled Model Intercomparison Project phase 5 (CMIP5) (Taylor et al., 2012). Two sets of predictions were used: Representative Concentration Pathway (RCP) 4.5 and 8.5. CMIP5 data were bias-corrected and spatially downscaled to 1/8° resolution (~12 km) (available at https://gdo-dcp.ucllnl.org/downscaled_cmip_projections/) (Mauer et al., 2007; Bureau of Reclamation, 2013). Daily downscaled CMIP5 data for 38 different climate projections (19 each for both RCP 4.5 and 8.5) were collected for historic (2000 – 2019) and future (2080 – 2099) time periods for a grid that encompassed all the counties that intersected the Delaware River Basin. The entire grid domain was 36 rows x 24 columns and contained 864 grid cells. The Delaware River Basin itself contained 225 grid cells. For each grid cell, P and T_{avg} daily time series, averaged by each RCP, were generated for both time periods. Additionally, following Maimone (2019), four seasonal sets of precipitation delta change factors between the historic and future time periods and averaged by RCP, were calculated for each grid cell. Delta change factors are the percent change between the future and historic periods for each integer percentile value of precipitation. These factors were used to replicate the observed distribution of storm event frequency and magnitude and the inter-event duration; further details on this procedure are available in Ensign (2020).

Land Cover

As described in Section 5.2.3, information on the type and areal extent of land use/cover within a given area of interest is extracted from the National Land Cover Dataset (NLCD 2011) developed by the U.S. Geological Survey. Based on local information, however, a user may find that the land cover estimates provided via this approach may not accurately reflect the land use/cover distribution within a given area of interest (or they may wish to conduct “what if” analyses based on different land cover distributions). If so, the user can adjust the area values calculated from the NLCD data layer by using the “**Land Cover**” option associated with the “Add changes to this area” button shown in Figure 1.

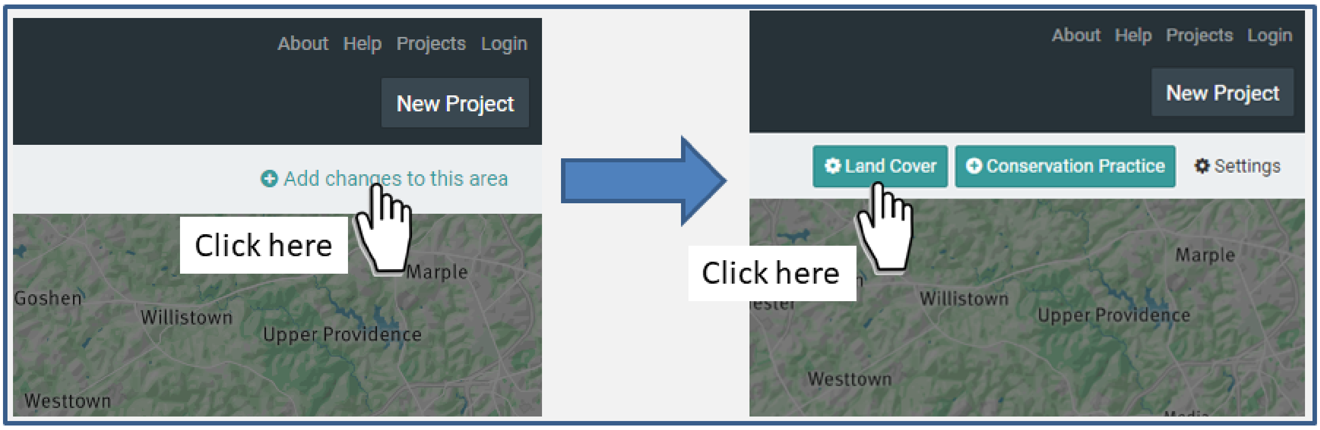


Figure 1

Upon selecting this option, the user is presented with a table like the one shown in Figure 2. At this point, the user can make changes by typing in new values for any of the categories shown. The user may make as many changes as desired, with the only requirement being that the new “Total” area must be equal to the initial total.

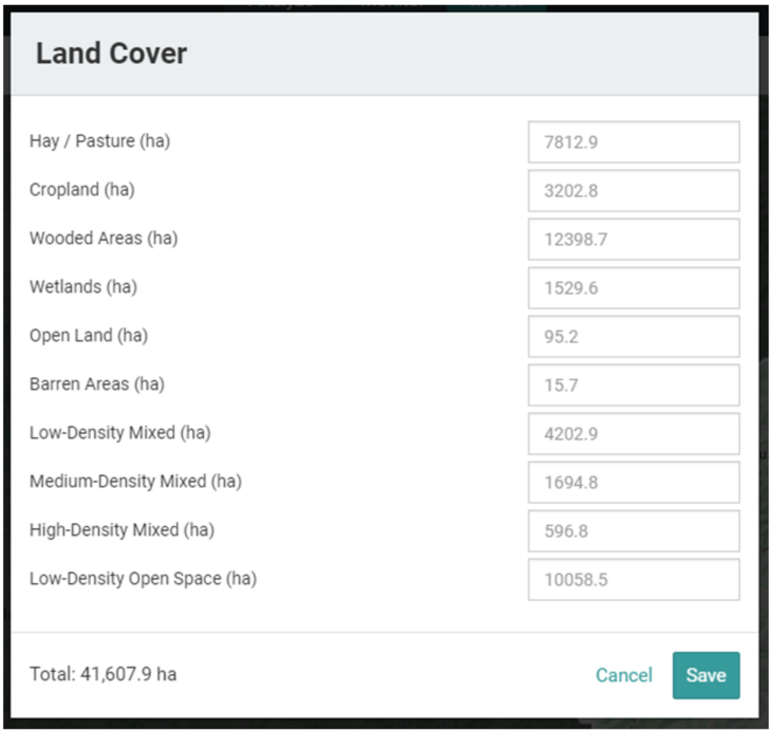


Figure 2

Conservation Practices

With the “**Conservation Practice**” option associated with the “**Add changes to this area**” tool in Model My Watershed, a user may simulate the potential load-reduction effects that might result from the implementation of a range of conservation practices (e.g., agricultural BMPs, urban storm-water BMPs, stream restoration activities, etc.). Upon initiating this option, the user is presented with a selection of practices from which to choose as shown in Figure 3. Upon selecting (i.e., clicking on) one of the practices, another window pops up that lets the user know how many units of measure (e.g., hectares, kilometers, etc.) are available for implementing the practice selected (see Figure 4). For example, in Figure 4, this window relays the information that 200.07 hectares of cropland are available for potential Cover Crop implementation in this particular watershed. In this case, the user would enter a value equal to or less than this number, and then click on the “**Apply**” button. Other practices can also be selected and “implemented” in a similar fashion.


Land Cover
Conservation Practice
Rural
Cover Crops
No Till Agriculture
Conservation Tillage
Reduced Tillage
Nutrient Management
Livestock Waste Man.
Poultry Waste Man.
Veg Buffer Strips (Rural)
Streambank Fencing
Streambank Stabilization (Rural)
Urban
Veg Buffer Strips (Urban)
Streambank Stabilization (Urban)
Surface Water Retention
Infiltration / Bioretention
Vegetated Buffer Strips (Rural)
Areas of trees and/or grasses planted along streams or lakes that are designed to capture and renovate surface runoff and shallow subsurface flow from agricultural and urban areas via the processes of filtration, infiltration, absorption, adsorption, uptake, denitrification, volatilization, and deposition. A buffer width of 30 m (roughly 100 ft) is assumed.
Figure 3

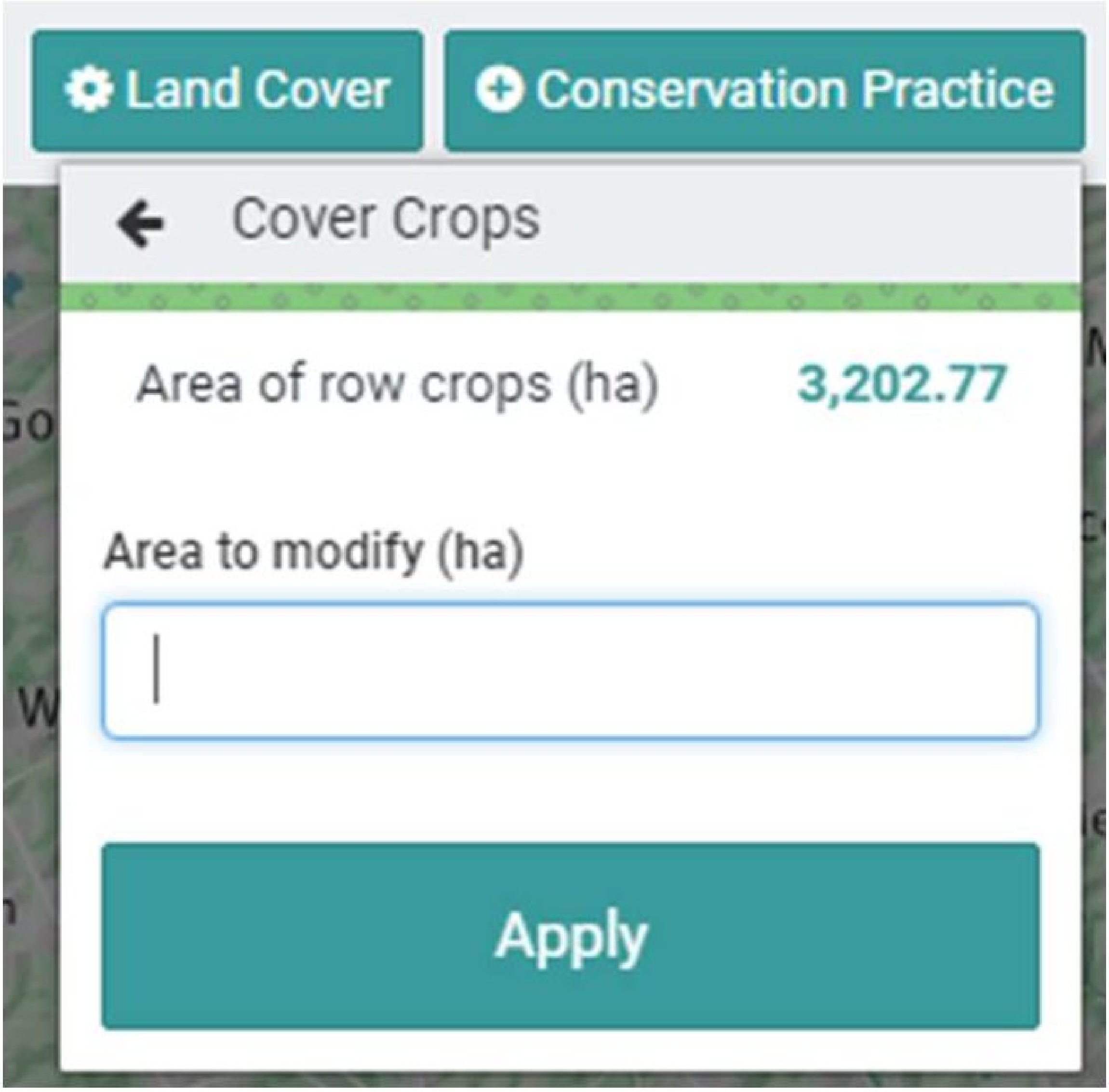


Figure 4

Settings

Like most comprehensive simulation models, the GWLF-E model utilizes a wide range of parameters that effect the calculation of various hydrologic and pollutant load estimates provided as output. Summary descriptions of how values for many of these parameters are initially estimated are provided in Section 7.2.3 above. Within Model My Watershed, the user has the opportunity to edit some of the key parameter estimates via the "**Add changes to this area**" tool provided in Model My Watershed after an initial model run has been executed as shown in Figure 1. In this case, some of these key parameter values can be revised using the "**Settings**" option.

Once this particular option is initiated, the user is then presented with a series of tables (see Figure 5) that show the current calculated and default parameter values for the current model run. These can be changed by simply entering a new value and then clicking on the "**Save**" button at the bottom of each table. More information on how these values are calculated, and how they might reasonably be changed, is provided in the following sub-sections.

Efficiencies

The values provided in this table (see Figure 5) are the current BMP reduction coefficients used to simulate potential sediment, nitrogen and phosphorus load reductions based on the implementation of a number of conservation practices or BMPs described earlier. These are primarily based on typical values found in the literature or as used by the USEPA in their Chesapeake Bay Watershed Model. New values can be entered by the user and applied to the next model run by clicking on the "**Save**" button located at the bottom of the window. These new values supplied by the user are presumed to be based on better locally-derived estimates of these coefficients. (Note that revisions to the "tillage-related" values are not currently allowed due to the complexity involved in calculating these coefficients within Model My Watershed. It is expected, however, that such changes will be allowed in future versions.)

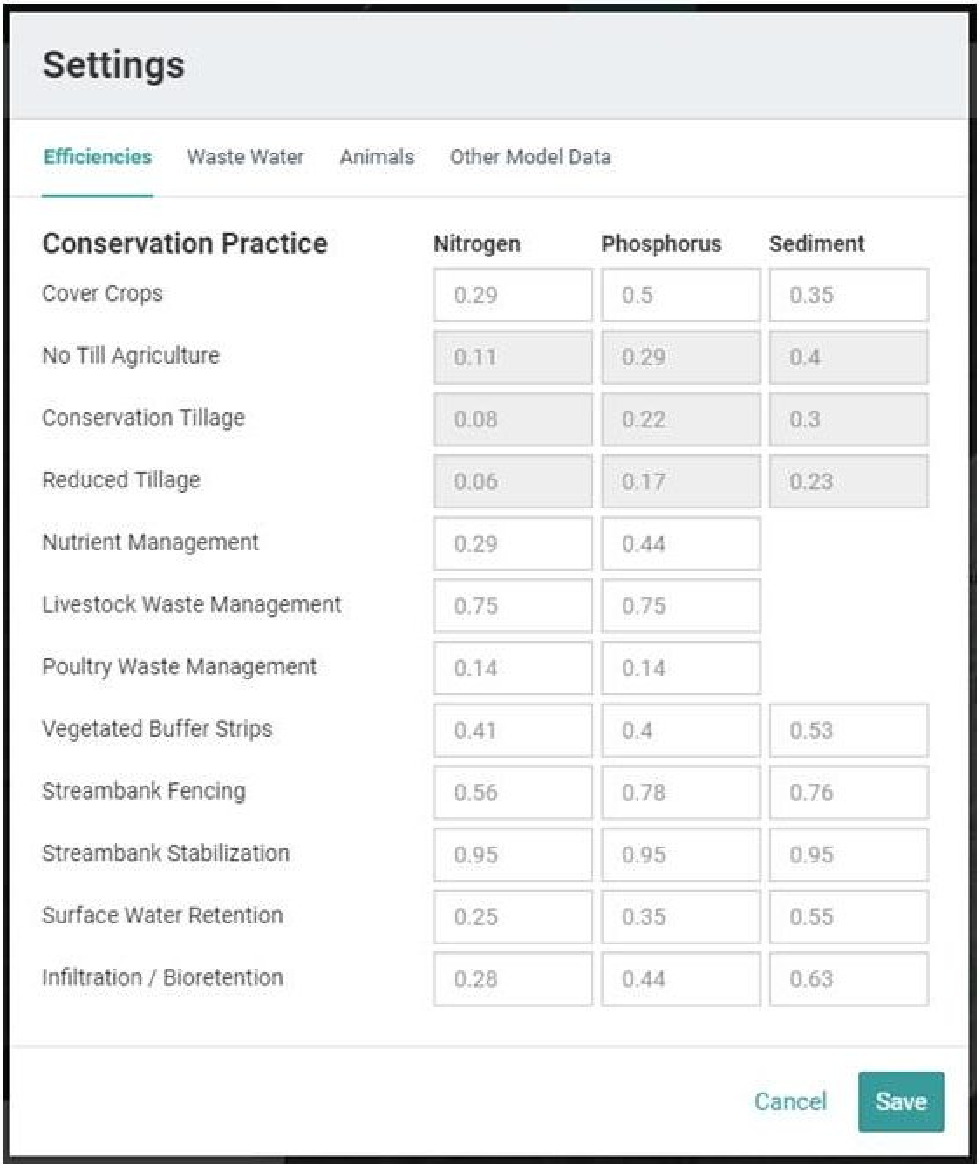


Figure 5

Waste Water

Wastewater Treatment Plants

The estimated values for Wastewater Treatment Plants shown in Figure 6 (assuming they are non-zero) for Total Nitrogen, Total Phosphorus and Daily Effluent Discharge volume (in million gallons/day) are based on discharge data compiled by the USEPA (see Section 5.2.3 above), and represent the total (summed) loads and/or volumes for one or more dischargers located within the area of interest (AOI). Any revisions to these cells should also represent the total loads and volume of all dischargers within the user-defined AOI.

Number of Persons on Different Septic System Types

The values indicated for “normally functioning systems” are calculated in Model My Watershed using an estimate of the average number of persons per acre in “Low-Density Mixed” areas. In these areas, it is assumed that the populations therein are served by septic systems rather than centralized sewage systems. All homes in such areas are assumed to be connected to “normally functioning” systems rather than those that experience “surface breakouts” (surface failures), “short-circuiting” to underlying groundwater (subsurface failures), or have direct conduits to nearby water bodies. The values pertaining to any system type, however, can be adjusted by the user based on local information.

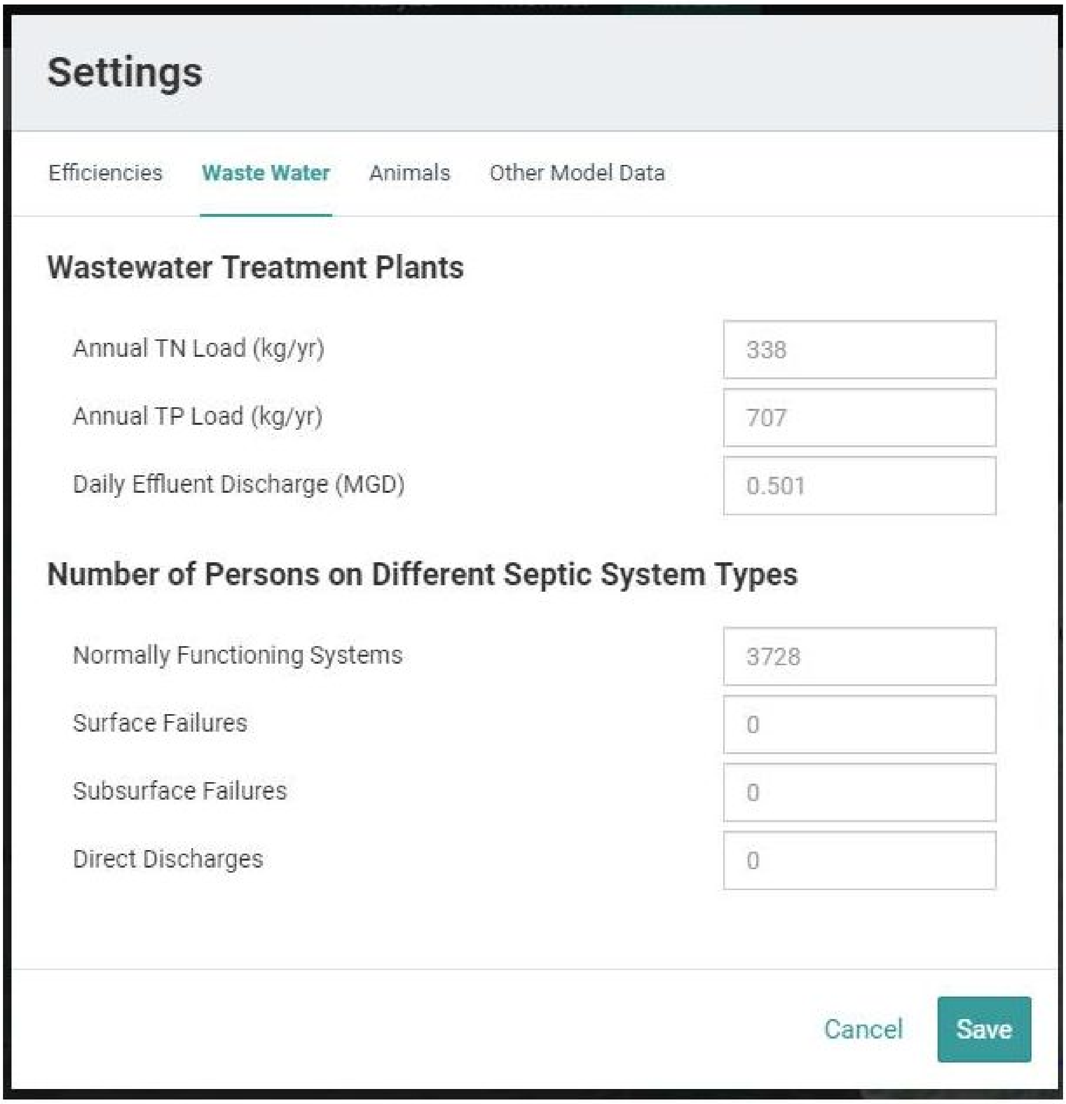


Figure 6

Animals

Animal Populations

As described earlier in Section 7.2.3, estimates of the number of farm animals contained within any given area are made using county-level census data on farm animal populations compiled by the U.S. Department of Agriculture. The calculated values for any given animal type, such as those shown in Figure 7, are only estimates, and may be updated with better local information on actual farm animal populations where possible. Within Model My Watershed, certain animals are automatically designated as “grazing” (e.g., dairy cows) or “non-grazing” (e.g., chickens), and these designations affect whether or not nutrient loads from such animals are deposited on pasture land or not. However, these designations can be changed by making the appropriate selection in the associated “pull-down” menu (i.e., “Yes” or “No”).

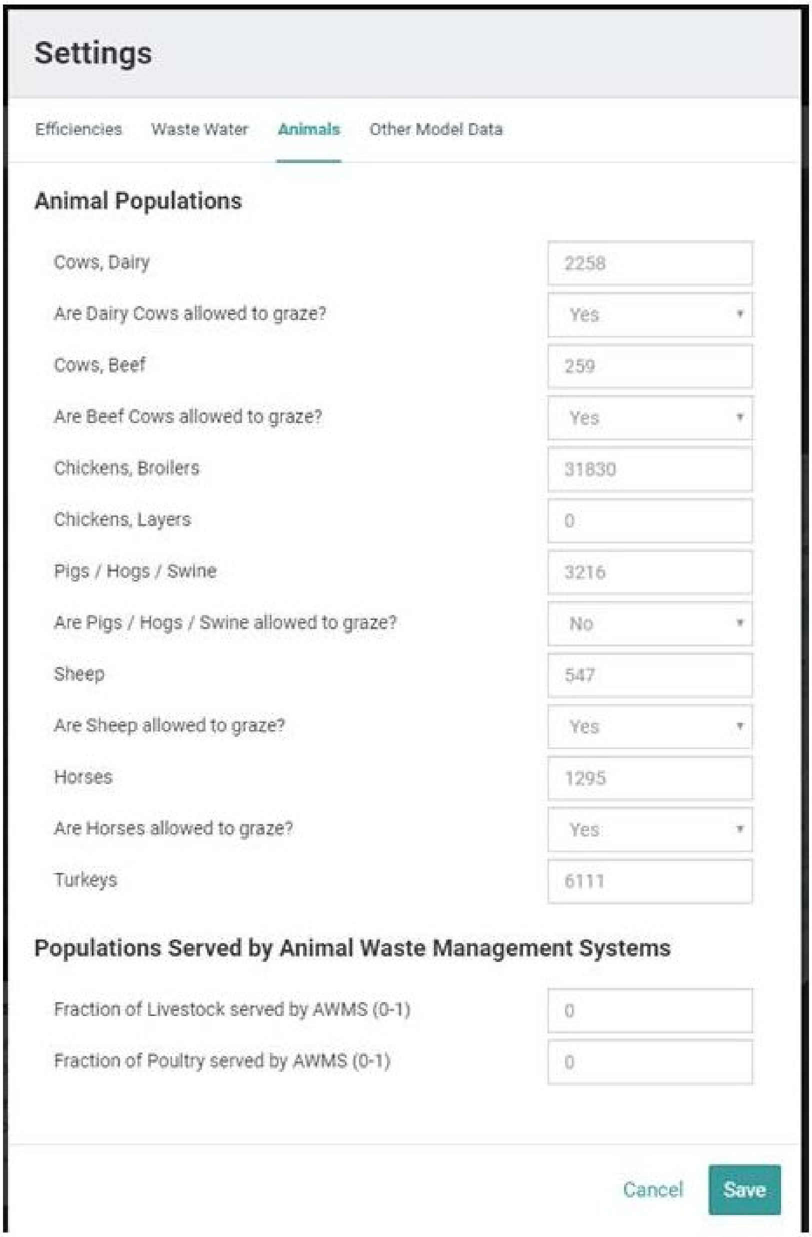


Figure 7

Populations Served by Animal Waste Management Systems

Animal Waste Management Systems (AWMSs) are designed for the proper handling, storage, and utilization of wastes generated from animal confinement operations, and typically include a means of collecting, scraping, or washing wastes from confinement areas into appropriate waste storage structures. Lagoons, ponds, or steel or concrete tanks are common structures used for the treatment and/or storage of liquid wastes, while storage sheds or pits are used to store solid wastes. Controlling runoff from roofs, feedlots, and “loafing” areas are also part of these systems. Adequate storage ensures wastes are only applied when crops can use the accompanying nutrients and soil and weather conditions are appropriate.

In this table, values from 0-1 are used to indicate the fraction of the total livestock population (e.g., cows, pigs, sheep, and horses) and/or the total poultry population (e.g., chickens and turkeys) that are believed to be served by AWMSs pertaining to each type in the area of interest. For example, if it is believed that the wastes from 35% of the livestock are treated by an AWMS, then a value of 0.35 would be entered in the appropriate cell. In the GWLF-E model, values greater than zero are used to calculate a reduction coefficient which is subsequently used to reduce nutrient loads from farm animal populations in the area of interest.

Other Model Data

Other model data, as shown in Figure 8, refers to estimated or default values set for various model parameters that affect the amounts of sediment, nitrogen and/or phosphorus that are generated within a given area of interest, and are subsequently transported and delivered to the outlet of that area. Within Model My Watershed, these parameter values are either calculated using various datasets (as described in Section 7.2.3 above), or based on typical values used in the literature.

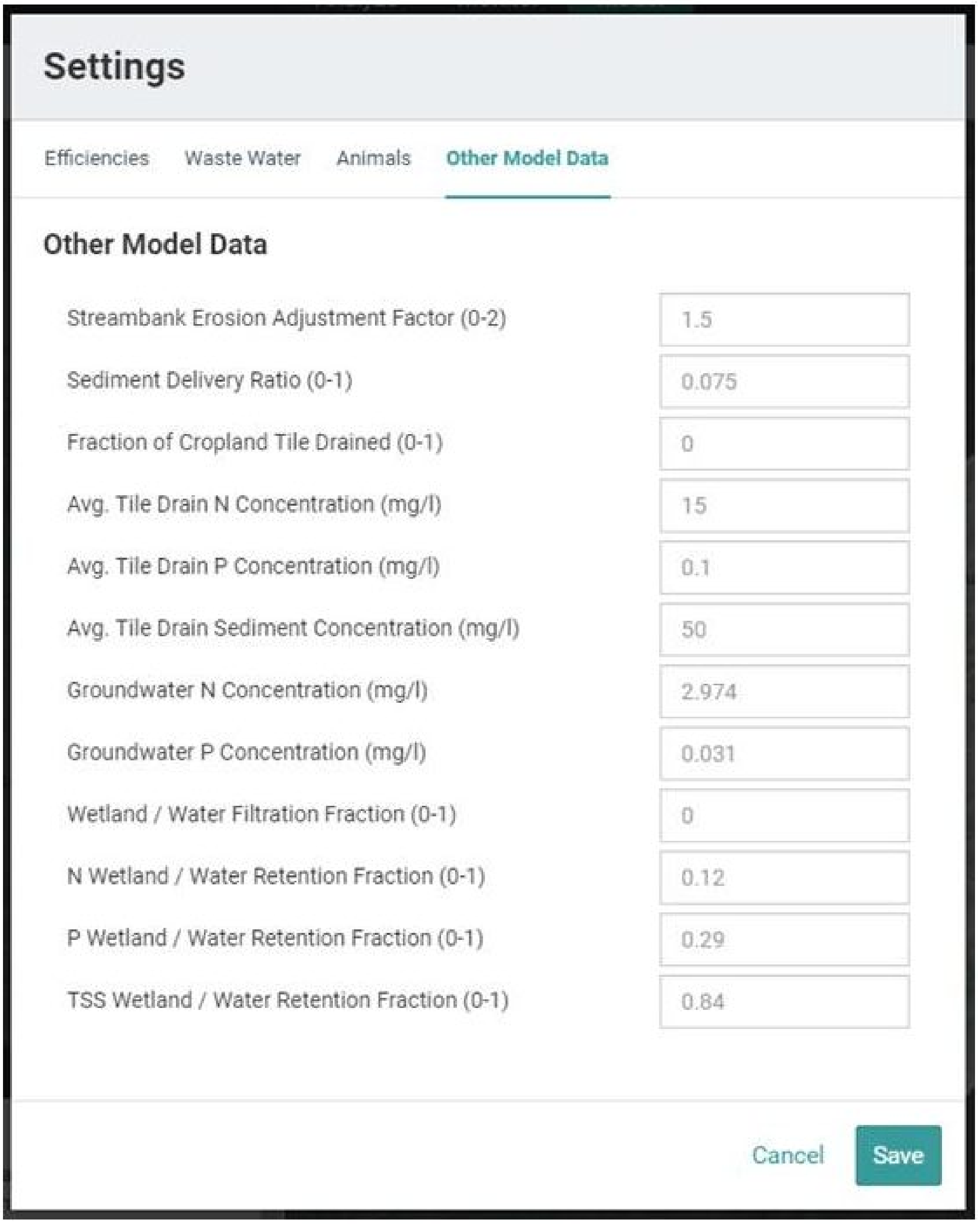


Figure 8

Streambank Erosion Adjustment Factor

Within Model My Watershed, the sediment and nutrient loads produced by eroding streambanks are estimated using an approach developed by Evans et al. (2003). This approach is based on a methodology often used in the field of geomorphology in which monthly streambank erosion is estimated by first calculating an average watershed-specific lateral erosion rate (LER) using the following equation:

$LER = a * q^{0.6}$

where: LER = an estimated lateral erosion rate in meters/month

a = an empirically-derived constant related to the mass of soil eroded

from streambanks depending upon various watershed conditions, and

q = monthly stream flow in cubic meters per second.

Within Model My Watershed, after a value for LER has been computed, the total sediment load generated via streambank erosion is then calculated by multiplying the above erosion rate by the total length of streams in the watershed (in meters), the average streambank height (in meters), and an average soil bulk density value (in kg/m3). By adjusting the “streambank erosion factor” subsequent to a particular model run, one can increase or decrease the amount of streambank-eroded sediment, nitrogen and/or phosphorus simulated by GWLF-E. By default, this parameter value is set to “1.5” to account for the difference in the density of the stream network data layer used by Evan et al. (2003) in their original study and that of the NHD stream network used in Model My Watershed (in this case, the Model My Watershed stream layer is less dense than the other). As shown in Figure 8, users can increase this value up to 2, or decrease it to 0 (which would result in no streambank-generated loads).

Sediment Delivery Ratio

A sediment delivery ratio is based on the premise that a certain percentage of the material eroded from the land surface (usually the heavier soil particles) is deposited prior to reaching nearby water bodies. Empirically, the amount that does reach the outlet of a given watershed (called sediment yield) has been related to watershed size. Following the procedure described in Vanoni (1975), sediment delivery ratios calculated by Model My Watershed are based on the relationship:

$SDR = 0.451(b^{-0.298})$

where: SDR = sediment delivery ratio, and

b = size of the watershed in square kilometers.

After the initial model run, this particular parameter value can be adjusted to increase or decrease the amount of the internally-generated sediment load that is subsequently delivered to the watershed outlet. In this case, a value of 1 would imply that 100% of the generated sediment load would be delivered to the watershed outlet. Such cases are rare, however, since sediment delivery ratios for watersheds that range in size from about 10 to 1000 square kilometers (3.86 to 386 square miles) vary from about 0.15 to 0.05 when using the Vanoni method.

Fraction of Cropland Tile Drained

The GWLF-E model contains a relatively simple algorithm to account for the use of tile drains in agricultural areas of a watershed, as well as to estimate nutrient and sediment loads delivered by such systems. As shown in past studies completed in North America, water volumes in tile drains are typically about 40-60% of the total surface and subsurface runoff in agricultural landscapes with such systems (e.g., Tan et al., 2002 and Patni et al, 1996). Additionally, these and similar studies suggest that median values of nitrogen, phosphorus, and sediment concentration within tile drains are typically on the order of 15, 0.1, and 50 mg/l, respectively (e.g., Barry et al., 1993 and Fleming, 1990).

In GWLF-E, 50% of the surface and subsurface flow for each month based on weather inputs are re-distributed to tile drain flow in areas identified as being served by such systems. More specifically, tile drain flow for a watershed is estimated using information on the amount of cropland and the extent of tile-drained land in cropped areas. Information on the presence of cropland is extracted by Model My Watershed from the land use/cover layer, and information on the extent of tile-drained areas in a given watershed (i.e., “Fraction of Cropland Tile Drained”) is specified by the user.

Algorithmically, tile drain flow for a watershed is calculated using the equation:

TDF = 0.5 * CROPFLOW * FRACTILE

where: TDF = Total tile drain flow (in volume of water per month)

CROPFLOW = Total volume of surface and subsurface flow in cultivated

areas of the watershed per month

FRACTILE = Fraction of cultivated area that is tile-drained

Once the volume of tile drain water per month is calculated (in this case, liters of water), this volume is then multiplied by the “event mean concentrations” given above for nitrogen, phosphorus, and sediment (i.e., 15, 0.1, and 50 mg/l) to calculate loads for each in units of kg/mo. By default, the value for this parameter is “0”; however, the user can adjust this based on local information.

Average Tile Drain N Concentration

As indicated above, the default value for this parameter is 15 mg/l. However, the user may change it based on local knowledge or information.

Average Tile Drain P Concentration

As indicated above, the default value for this parameter is 0.1 mg/l. However, the user may change it based on local knowledge or information.

Groundwater N Concentration

An estimate of groundwater N concentration is used to calculate subsurface nitrogen loads delivered to the watershed outlet. As described in Section 7.2.3, this value is estimated based on the use of a national groundwater N concentration map previously developed by the USEPA. However, the user may wish to adjust this value based on more local knowledge or information.

Groundwater P Concentration

An estimate of groundwater P concentration is used to calculate subsurface phosphorus loads delivered to the watershed outlet. For use in GWLF-E, values for groundwater P concentration are estimated based on the use of a regression equation that relates groundwater P concentration to groundwater N concentration as calculated by Model My Watershed (and as described above). However, the user can adjust this value based on more local knowledge or information.

Wetland / Water Filtration Factor

In the GWLF-E model, a fairly simple attenuation routine has been implemented that allows the user to account for (i.e., approximate) the “pollutant-retention” effect of lakes, ponds and/or wetlands within the watershed being simulated. This tool is based on an empirical approach that reduces nutrient and sediment loads generated within the watershed using editable reduction coefficients and a user-specified estimate of the land area “drained” by such features. For example, in a watershed with the following conditions and settings:

- Initial (“pre-retention”) sediment load: 1000 kg/yr

- Percent of watershed area drained by wetlands/lakes/ponds: 60% (0.60)
- Sediment reduction coefficient: 0.88

the sediment load would be “re-calculated” as:

Re-calculated load after retention = (initial load of the drained area – (reduction coefficient x (initial load of the drained area)) + (percent area undrained x initial load)

= ((0.60 x 1000) – (0.88 x (0.60 x 1000))) + (0.40 x 1000)

= (600 – 528) + 400

= 472 kg/yr

As evident from the above discussion, the “retention” routine is fairly simple and is not intended to rigorously simulate the physical, chemical and biological processes that actually influence the transport of nutrients and sediment in watersheds where lakes, ponds and wetlands exist. However, this empirically-based approach does attempt to account for reduced loads that do occur as a result of these processes. In cases where such processes and reductions are significant, not accounting for them in some fashion may result in over-estimation of nutrient and sediment loads. In fact, in watersheds where many lakes, ponds and wetlands exist, it is highly likely that simulated pollutant loads will be significantly over-estimated unless attenuation is considered. Moreover, this problem typically becomes accentuated with very large watersheds (e.g., greater than the size of a typical HUC12 watershed, which has an average size of around 40 square miles in the conterminous U.S.).

In Model My Watershed, an option exists that allows users to invoke the attenuation (i.e., sub-basin modelling) routine for HUC10- and HUC8-size watersheds (see Figure 9 below). In this case, a value for a factor similar to the “wetland / water filtration factor” is automatically calculated using information on the extent of water and wetland acres that have already been derived by USGS for NHD catchments across the country (see Attributes for NHDPlus Catchments (Version 1.1) for the Conterminous United States: NLCD 2001 Land Use and Land Cover(https://pubs.er.usgs.gov/publication/dds49015)
). In cases where this factor has not been automatically calculated (e.g., with HUC12 basins or HUC10 and HUC8 basins where the “sub-basin modeling” option has not been used), the user has the ability to initiate the simple attenuation routine within GWLF-E by supplying a value between 0-1 for this parameter.

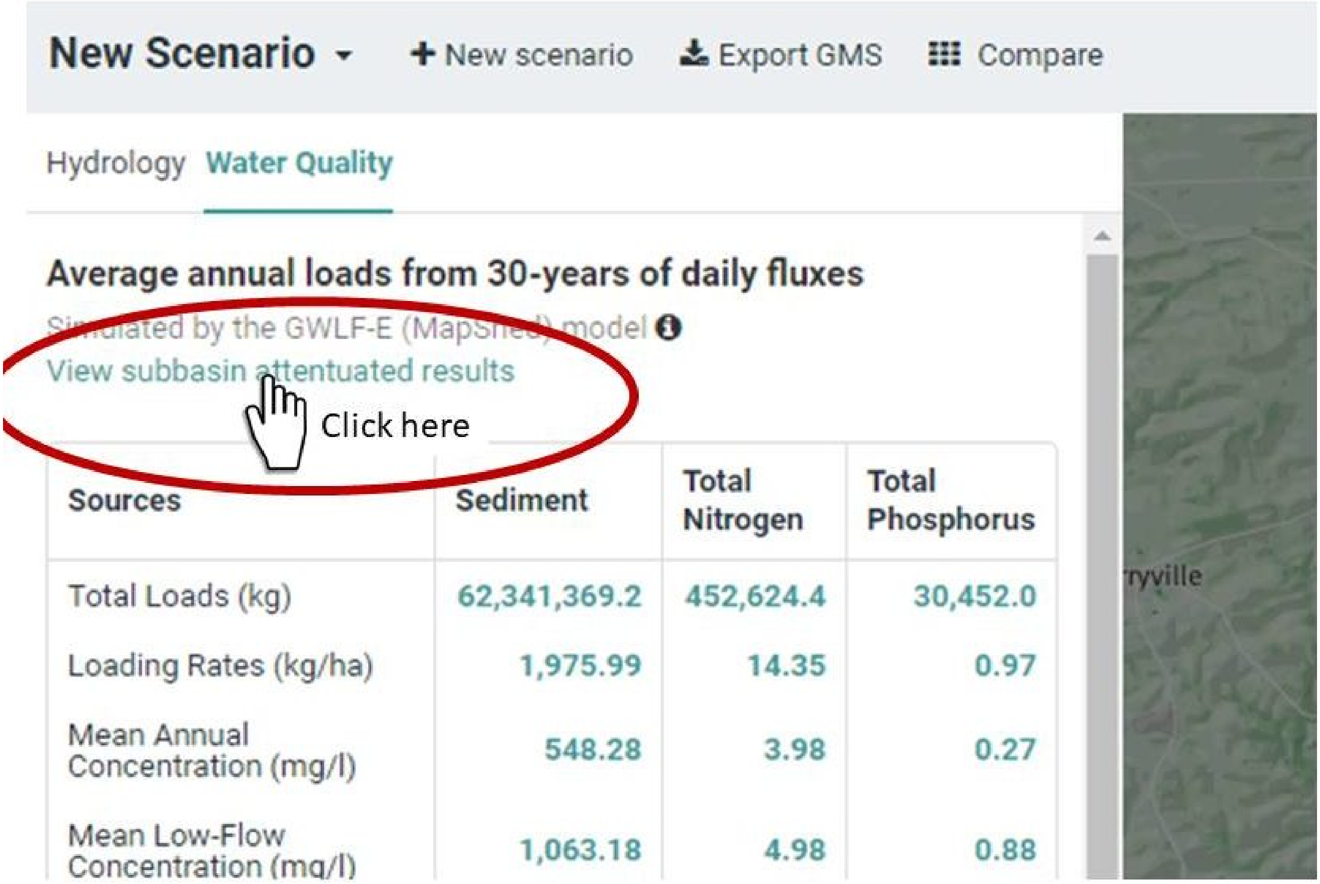


Figure 9

N Wetland / Water Retention Fraction

This factor indicates the typical fraction of the incoming nitrogen load to a wetland area or water body that is “retained” by these features. The default value of 0.12 is representative of the average value reported in the literature associated with the pollutant-reducing effects of such BMPs as constructed wetlands and storm-water retention/detention ponds. As with other parameters discussed above, this value can be changed by the user based on local knowledge or information.

P Wetland / Water Retention Fraction

This factor indicates the typical fraction of the incoming phosphorus load to a wetland area or water body that is “retained” by these features. The default value of 0.29 is representative of the average value reported in the literature associated with the pollutant-reducing effects of such BMPs as constructed wetlands and storm-water retention/detention ponds. As with other parameters discussed above, this value can be changed by the user based on local knowledge or information.

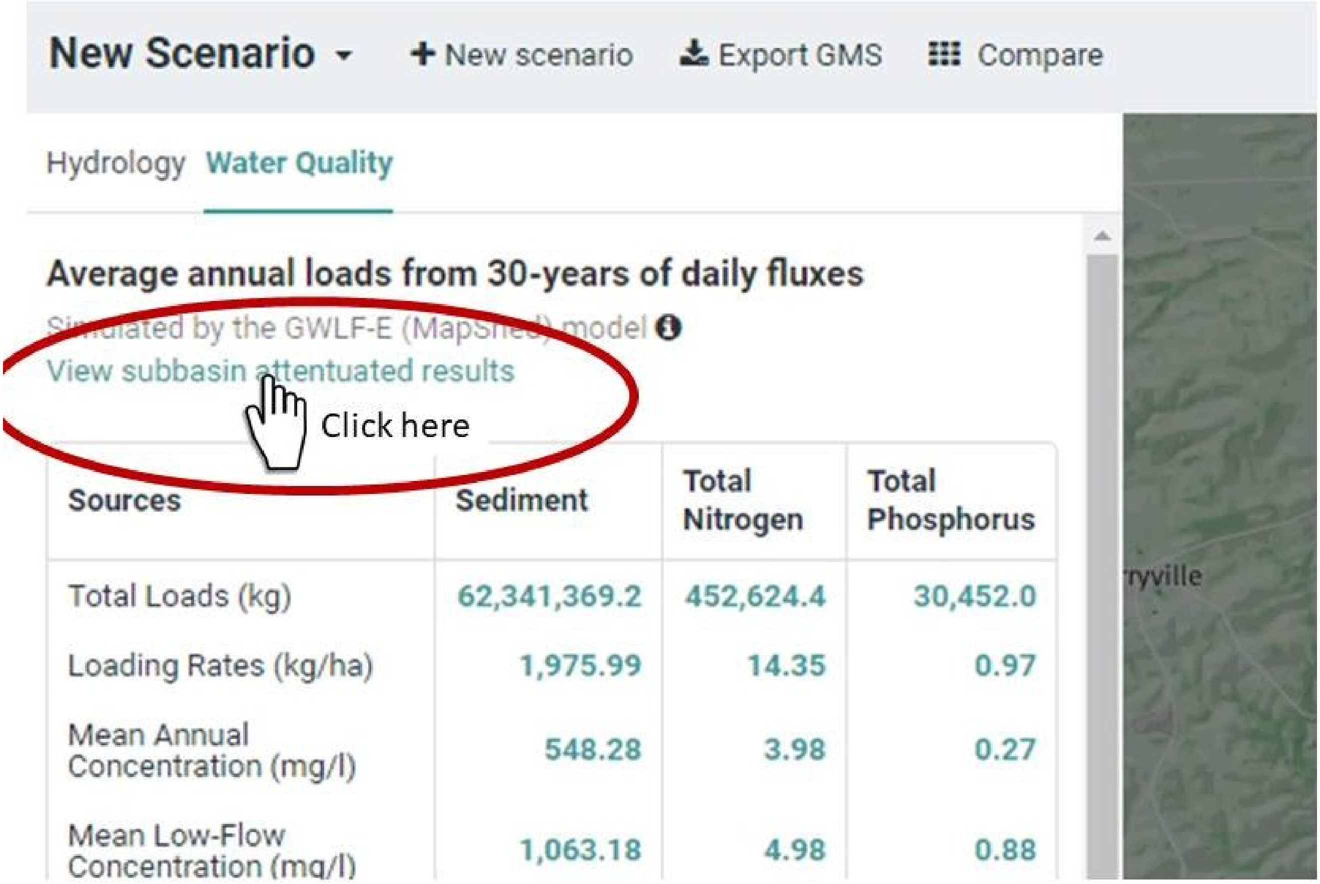
TSS Wetland / Water Retention Fraction

This factor indicates the typical fraction of the incoming TSS (sediment) load to a wetland area or water body that is “retained” by these features. The default value of 0.84 is representative of the average value reported in the literature associated with the pollutant-reducing effects of such BMPs as constructed wetlands and storm-water retention/detention ponds. As with other parameters discussed above, this value can be changed by the user based on local knowledge or information.

7.2.5. Subbasin Attenuated Results

Subbasin Modeling

In Model My Watershed, an option exists that allows users to invoke the attenuation (i.e., sub-basin modelling) routine for HUC10- and HUC8-size watersheds (see figure below). To access this tool you must: (1) select an area using “Select boundary” and USGS Subbasin unit (HUC-8) or USGS Watershed unit (HUC-10); (2) Model your area using the Watershed Multi-Year Model; (3) click from the “Hydrology” tab to the “Water Quality” tab; (4) click on the “View subbasin attenuated results” text (in green near the top of the Average annual loads table (see Figure below). This subbasin modeling algorithm was developed by Scott Haag (Academy of Natural Sciences of Drexel University) and Barry Evans (Penn State University, ANS of Drexel, and Stroud Water Research Center) and was first released as the Stream Reach Assessment Tool(https://www.streamreachtools.org/)
(SRAT).



Stream Reach Assessment Tool Overview

The Stream Reach Assessment Tool (SRAT) was originally designed to integrate dozens of datasets to provide the following information specific to the Delaware River Basin:

1. The mean annual pollutant load delivered to each of over 15,000 stream reaches in the Delaware River Basin from the immediate catchment of the stream reach. These loads are expressed as total loads (lbs/year) and loading rates (lbs/acre) for total nitrogen (TN), total phosphorous (TP) and total suspended sediment (TSS), and are segregated into each of the major sources affecting water quality (e.g., point sources, agriculture and urban/suburban runoff)

2. The mean annual in-stream concentration (in mg/l) for each of the pollutants analyzed that aggregates pollutant loads from all upstream sources.
3. Location and relative impact of point sources across the Basin.

Due to the influence of tides in coastal areas, it should be noted that SRAT estimates of TN, TP and TSS in these areas are not as accurate as they are in non-tidal areas due to the mixing of freshwater with estuarine and/or ocean waters which may significantly alter estimated pollutant concentrations.

As part of the SRAT development process, a limited amount of calibration was done to improve the overall accuracy of estimates produced using this approach. A more detailed explanation of this calibration is provided in SRAT Model Calibration(http://wikiwatershed.org/wp-content/uploads/SRAT-Model-Calibration.pdf)
.

SRAT Interpretation Assistance

Nitrogen and Phosphorus

High nutrient concentrations (particularly phosphorus in freshwater systems) can result in excessive plant growth (e.g., nuisance algae) and lower dissolved oxygen levels in streams. As a result, the level of nutrients in a stream is one good indicator of water quality.

In most fresh water bodies, phosphorus is the limiting nutrient for aquatic growth. Conversely, in most estuarine systems, nitrogen is the limiting nutrient. In some cases, however, the determination of which nutrient is the most limiting is difficult. For this reason, the ratio of the amount of N to the amount of P is often used to make this determination (Thomann and Mueller, 1987). If the N/P ratio is less than 10, nitrogen is limiting. If the N/P ratio is greater than 10, phosphorus is the limiting nutrient.

If the nutrient load to a water body can be reduced, the available pool of nutrients that can be utilized by plants and other organisms will be reduced and, in general, the total biomass can subsequently be decreased as well (Novotny and Olem, 1994). In most efforts to control eutrophication processes in water bodies, emphasis is placed on the limiting nutrient. This is not always the case, however. For example, if nitrogen is the limiting nutrient, it still may be more efficient to control phosphorus loads if the nitrogen originates from difficult to control sources such as nitrates in ground water.

Nutrient (i.e., nitrogen and phosphorus) loads primarily originate from wastewater treatment plants and agricultural land. Watersheds with high farm animal populations also tend to have higher nutrient loads. In this case, much of the animal waste is used as an organic fertilizer on surrounding cropland, which contributes to the nutrient loads emanating from these areas.

Sediment

With respect to stream health, high suspended sediment loads can reduce sunlight penetration through the water column, which may negatively impact various aquatic organisms. Such loads can also result in sediment build-up on the streambed that can degrade living conditions for benthic organisms. With respect to sources, sediment primarily originates from non-vegetated landscapes that are prone to surface erosion such as cropland. Streambank erosion is also a very important source of sediment, particularly in urbanized watersheds where the extent of impervious surface areas can lead to excessive “high-energy” runoff that can significantly erode streambanks during high-flow events. For the purposes of SRAT, simulated TSS (total suspended solids) estimates are for all practical purposes estimates of suspended sediment (TSS samples can include solids from other sources such as wastewater treatment plants; but these are considered to be negligible at the scale at which these analyses are done).

Pollutant Thresholds

Provided below is a table that presents some “threshold” values for nutrients and sediment that are intended to help determine whether a given watershed or stream segment might be impaired with respect to water quality. It must be understood, however, that these values are provided for guidance purposes only, and that actual impairments may vary based on many factors that interact at any given location. In the case of the values from Sheeder and Evans, both loading rate and in-stream concentration values are given. These latter values are to be interpreted as approximate “breakpoints” between impaired and unimpaired watersheds that were based on an analysis of observed stream data for 29 watersheds in Pennsylvania. The in-stream concentration values developed by USEPA and NJDEP, on the other hand, represent “targets” that each agency believes should be met to ensure unimpaired conditions within the general region of the Delaware River Basin. In the case of the USEPA values, a range is given for TN and TP due to that fact that values were developed for different ecoregions across the U.S, and the DRB covers two of these regions.

From the table, it can be seen that a threshold value of 0.1 mg/l seems appropriate for TP. Although the values range considerably for TN, it should be noted, as described earlier, that the value for TP is usually more important due to the fact that it is the limiting nutrient for most streams in the Delaware River Basin. In the case of TSS, NJDEP has set different threshold values for TSS depending upon whether the streams do or do not support trout.

Yields and Concentration Thresholds:

	TN	TP	TSS
Sheeder and Evans	13.0 kg/ha (14.6 lb/ac)	0.30 kg/ha (0.34 lb/ac)	785 kg/ha (882 lb/ac)
Sheeder and Evans	3.0 mg/L	0.07 mg/L	197 mg/L
USEPA	0.07-1.0 mg/L	0.006 - 0.1 mg/L	---
NJDEP	10.0 mg/L	0.1 mg/L	25 - 40 mg/L (trout vs. non trout)

*Note the actual nitrogen values given in Sheeder and Evans are for inorganic N only, and are lower than those shown in the table above. The ones shown above have been adjusted upwards to account for organic N as well. Also note that the TN values for NJDEP are for nitrate-N only. In this case, the value appears to be based on the national 10 mg/l drinking water standard rather than ecological or nutrient enrichment factors.

Sources:

Novotny, V., and H. Olem. 1994. Water Quality: Prevention, Identification, and Management of Diffuse Pollution. Van Nostrand Reinhold, New York.

Thomann, R.V., and J.A. Mueller. 1987. Principles of Surface Water Quality Modeling and Control. Harper & Row, New York.

Sheeder, S.A., and Evans, B.M. 2004. Estimating nutrient and sediment threshold criteria for biological impairment in Pennsylvania watersheds. J. Am.Water Res. Assoc. 40, 881–888.

7.2.6. Model Calibration

Overview

As described elsewhere in the technical documentation for Model My Watershed, there are two basic modelling approaches included in this tool. The simpler model provides pollutant load estimates based on literature-based “event mean concentrations” and user-supplied rainfall values. The other more comprehensive “multi-year” model is based on the ***MapShed*** desktop software application developed by Dr. Barry Evans and his group at Penn State University (Evans and Corradini, 2016). The ***MapShed*** model itself includes a GIS-based front-end for assembling input data for an enhanced version of the GWLF model originally developed by Haith and Shoemaker (1987). This enhanced model (called GWLF-E) is the model upon which the “multi-year” model included in Model My Watershed is based.

To provide a preliminary assessment of the accuracy of the multi-year model, a limited amount of calibration was performed using modeled results and observed stream data for 39 test watersheds located in specific geographic regions located around the country. Due to a lack of time initially assigned to this particular task under current Model My Watershed funding, the limited calibration was undertaken using stream data and load calculations previously compiled by one of the lead modelers involved in the development of the “multi-year” model included in the Model My Watershed application (i.e., Dr. Evans) as part of other projects that he has conducted over the last 15 years or so (e.g., Evans et al., 2002; Evans, 2007; and Evans, 2010).

As part of these earlier projects, daily stream flow and water quality data were obtained from USGS National Water Information System(https://waterdata.usgs.gov/nwis)
, and daily and/or monthly pollutant loads for calibration periods ranging from about 1990 to 2015 were subsequently computed for each corresponding drainage area using a variety of statistical methods (primarily the FLUX model from the U.S. Army Corps of Engineers [Walker, 1999]). For the purposes of the current assessment, loads previously computed in this fashion were then used as the “observed” loads against which Model My Watershed-simulated loads were compared. Figure 1 depicts the distribution of these different test sites across the country, and Table 1 summarizes the size, pollutant loads, and original calibration periods associated with each of these sites.

Using the previously-derived observed load estimates described above, mean annual loads (and loading rates) were computed for each of the test sites and compared against the corresponding estimates from Model My Watershed. In this case, Model My Watershed-based load estimates were derived using the sub-basin modeling routines that account for in-stream attenuation as nitrogen, phosphorus and sediment loads travel to the outlet of any given drainage area. A primary focus of this particular activity was to “fine-tune” the attenuation factors in order to achieve a “best-fit” between the observed and predicted loads across the 39 test sites.

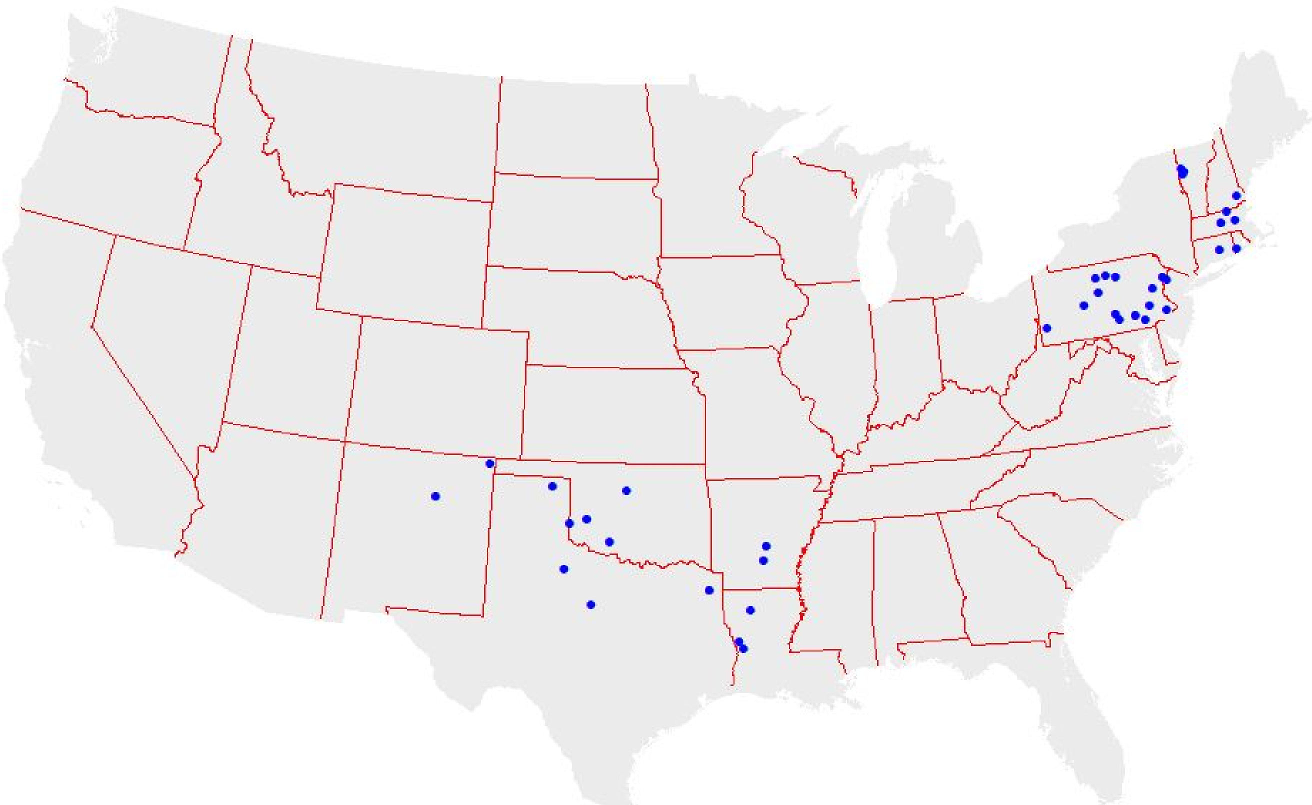


Figure 1. Location of pollutant loading calibration test sites within the conterminous United States.

Table 1. Summary data for calibration test sites.

Test Site	Location	Size (sq km)	Total Nitrogen	Total Phosphorus	Sediment	Original Calibration Period
Bayou Annacoco	LA	995	X			1997-2006
Bayou Toro	LA	357	X	X		1997-2006
Beech Creek	PA	444	X	X		1990-1996
Big Sandy Creek	TX	749	X		X	1997-2006
Black Cypress Creek	TX	925		X	X	1997-2006
Bushkill Creek	PA	303	X	X	X	1989-1999
Carrizozo Creek	NM	505	X	X	X	1997-2006
Chartiers Creek	PA	712	X	X		1990-1996
Chiques Creek	PA	280	X	X	X	2002-2014
Clearfield Creek	PA	977	X	X		1990-1996
East Cache Creek	OK	1787	X	X	X	1997-2006
Elk Creek	OK	1430	X	X		1997-2006
Elm Fork / North Fork	TX/OK	2178	X	X	X	1997-2006
Gallinas Creek	NM	759	X	X	X	1997-2006
Hurricane Creek	AR	510	X	X	X	1997-2006
Kettle Creek	PA	638	X	X	X	1990-1996
Lamprey River	NH	474	X	X	X	1997-2004
Laplatte River	VT	114	X	X		1997-2004
Lehigh River	PA	3520	X	X	X	1989-1999
Lewis Creek	VT	199	X	X	X	1997-2004
Little Otter Creek	VT	148	X	X	X	1997-2004
Lycoming Creek	PA	558	X	X	X	1990-1996
Moro Creek	AR	997	X	X	X	1997-2006
Paulins Kill	NJ	326	X	X	X	2006-2015
Pawcatuck Creek	CT/RI	764	X		X	1997-2004
Pequea Creek	PA	397			X	1989-1999
Pine Creek	PA	2552	X	X	X	1990-1996
Saline Bayou	LA	653	X	X		1997-2006
Salmon River	CT	259	X	X		1997-2004
Schuylkill River	PA	4903	X	X		1990-1996
Sherman Creek	PA	633	X	X	X	1990-1996
Skeleton Creek	OK	1026	X	X		1997-2006
South Fork Wichita River	TX	1479	X	X	X	1997-2006
Squannacook River	MA/NH	171	X	X	X	1997-2004
Sudbury River	MA	275	X	X		1997-2004
Ware River	MA	249		X		1997-2004
Wissahickon Creek	PA	165			X	1989-1999
Wolf Creek	TX	2038	X	X	X	1997-2006
Yellow Breeches Creek	PA	566	X	X		1990-1996
Total Sites			35	34	25	

Model Results and Discussion

As described above, Model My Watershed was used to estimate nutrient and sediment loads for each of the calibration test sites. As part of the calibration process, the loads delivered to the outlet of the drainage areas represented by the calibration test sites were calculated and subsequently compared to the observed loads at each outlet. With the new attenuation routine implemented in Model My Watershed, nutrient and sediment loads are attenuated (i.e., reduced) as the loads move from upstream NHD catchments to downstream NHD catchments based on the presence (percent) of open water and wetland areas within each intervening catchment down to the drainage area outlet. During the calibration process, the attenuation rates were incrementally adjusted in successive model runs until a “best fit” was achieved across all of the test sites in terms of matching observed and simulated loads. Table 2 shows these loads (expressed as loading rates in kg/ha) for each of the calibration sites.

Figures 2 through 4 graphically show the comparisons between the observed and simulated loads for the calibration points using the mean annual loading rate (in kg/ha) as a standardized unit of measure. As can be seen from these figures, the Model My Watershed model simulations provided reasonably good estimates of the total nitrogen and total phosphorus loads on a mean annual basis (i.e., R^2 = 0.93 and R^2 = 0.83, respectively). In the case of total suspended sediment (TSS) loads, the model results were less accurate (R^2 = 0.75).

As can be seen for TN, estimates from Model My Watershed were under-predicting loads by about 7% on average. In this case, it is suspected that the under-prediction may be due, in part, to the general unavailability of good data on nitrogen discharges from wastewater treatment plants across the country. In Model My Watershed, data from the USEPA is used to estimate nitrogen loads from these sources. However, in many states only ammonia concentrations (which are general a very small fraction of TN) are typically required by regulatory agencies and subsequently reported to EPA.

Additionally, in Model My Watershed, county-level data on farm animal populations from USDA are used to estimate animal numbers for any given watershed or area of interest based on an area-weighted basis (i.e., area of agricultural land). It is highly unlikely, though, that farm animal populations are as uniformly distributed as this algorithm implies. In general, the problem of under-estimating TN appears to worsen in watersheds having very large TN loading rates (e.g., higher than about 10 kg/ha). For example, in two of the test sites used in Pennsylvania (i.e., Lehigh River and Chiques Creek), it is known that the farm animal populations and/or TN loads from wastewater discharges are higher than those estimated by Model My Watershed based on locally-available data.

Table 2.Comparison of observed and simulated loads for the calibration sites.

Bayou Annacoco	3.85	NA	NA	1.96	NA	NA
Bayou Toro	4.61	0.72	NA	3.44	0.22	NA
Beech Creek	1.58	0.12	NA	5.35	0.20	NA
Big Sandy Creek	0.11	NA	30.7	0.63	NA	71.3
Black Cypress Creek	NA	0.26	23.2	NA	0.24	124.5
Bushkill Creek	2.51	0.15	34.0	1.50	0.07	106.2
Carrizozo Creek	0.02	0.004	0.9	0.07	0.01	14.1
Chartiers Creek	6.17	0.58	NA	6.29	1.18	NA
Chiques Creek	47.80	2.32	881.5	43.36	2.71	1085.4
Clearfield Creek	4.34	0.22	NA	2.92	0.31	NA
East Cache Creek	2.10	0.49	263.4	2.67	0.23	400.5
Elk Creek	2.10	0.23	NA	3.17	0.24	NA
Elm Fork / North Fork	0.40	0.07	33.6	0.87	0.09	132.2
Gallinas Creek	1.0	0.17	89.0	0.12	0.01	14.3
Hurricane Creek	2.45	0.26	37.3	1.95	0.11	214.8
Kettle Creek	3.25	0.13	248.0	2.27	0.16	97.8
Lamprey River	0.60	0.17	14.6	2.08	0.12	181.2
Laplatte River	3.30	0.75	NA	2.31	0.50	NA
Lehigh River	14.16	0.73	133.9	9.75	1.08	488.9
Lewis Creek	3.29	0.39	81.6	2.94	0.34	97.9
Little Otter Creek	3.91	0.62	207	3.35	0.56	188.3
Lycoming Creek	3.26	0.13	206.0	3.80	0.29	188
Moro Creek	3.06	0.27	37.1	1.82	0.06	191
Paulins Kill	5.72	0.20	37.7	6.39	0.38	346.6
Pawcatuck Creek	1.96	NA	30.3	7.45	NA	272.1
Pequea Creek	NA	NA	1458.0	NA	NA	1050.8
Pine Creek	3.18	0.19	238.0	4.14	0.29	136.4
Saline Bayou	2.37	0.25	NA	2.72	0.12	NA
Salmon River	2.55	0.08	NA	3.33	0.24	NA
Schuylkill River	18.72	1.33	NA	17.99	1.94	NA
Sherman Creek	5.73	0.20	368.0	11.96	0.65	315.3
Skeleton Creek	4.23	0.23	NA	3.96	0.30	NA
South Fork Wichita River	0.69	0.27	43.4	0.27	0.03	22.8
Squannacook River	2.58	0.17	11.6	3.82	0.15	236.8
Sudbury River	2.88	0.21	NA	3.78	0.35	NA
Ware River	NA	0.14	NA	NA	0.19	NA
Wissahickon Creek	NA	NA	1242.0	NA	NA	1849
Wolf Creek	0.21	0.003	0.3	0.25	0.03	18.1
Yellow Breeches Creek	10.94	0.40	NA	13.77	0.81	NA

NA – In-stream sample data not available

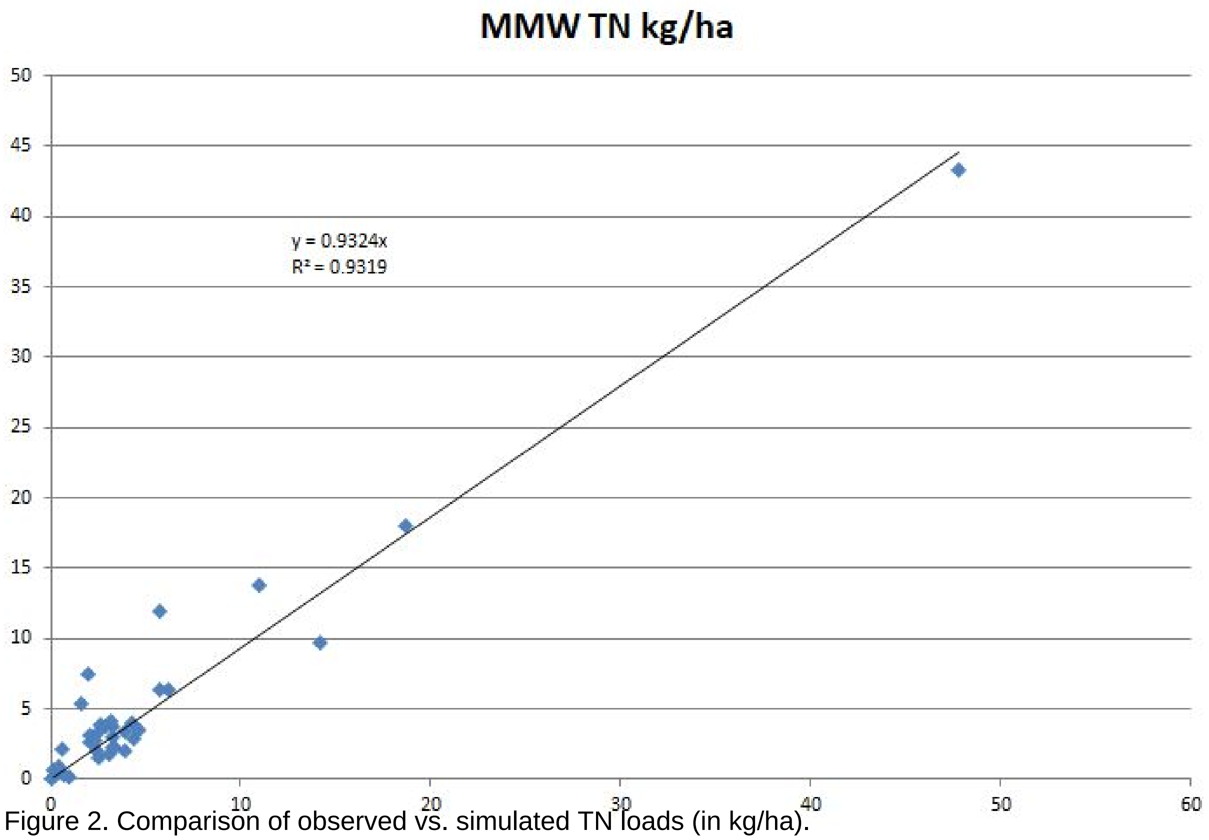


Figure 2. Comparison of observed vs. simulated TN loads (in kg/ha).

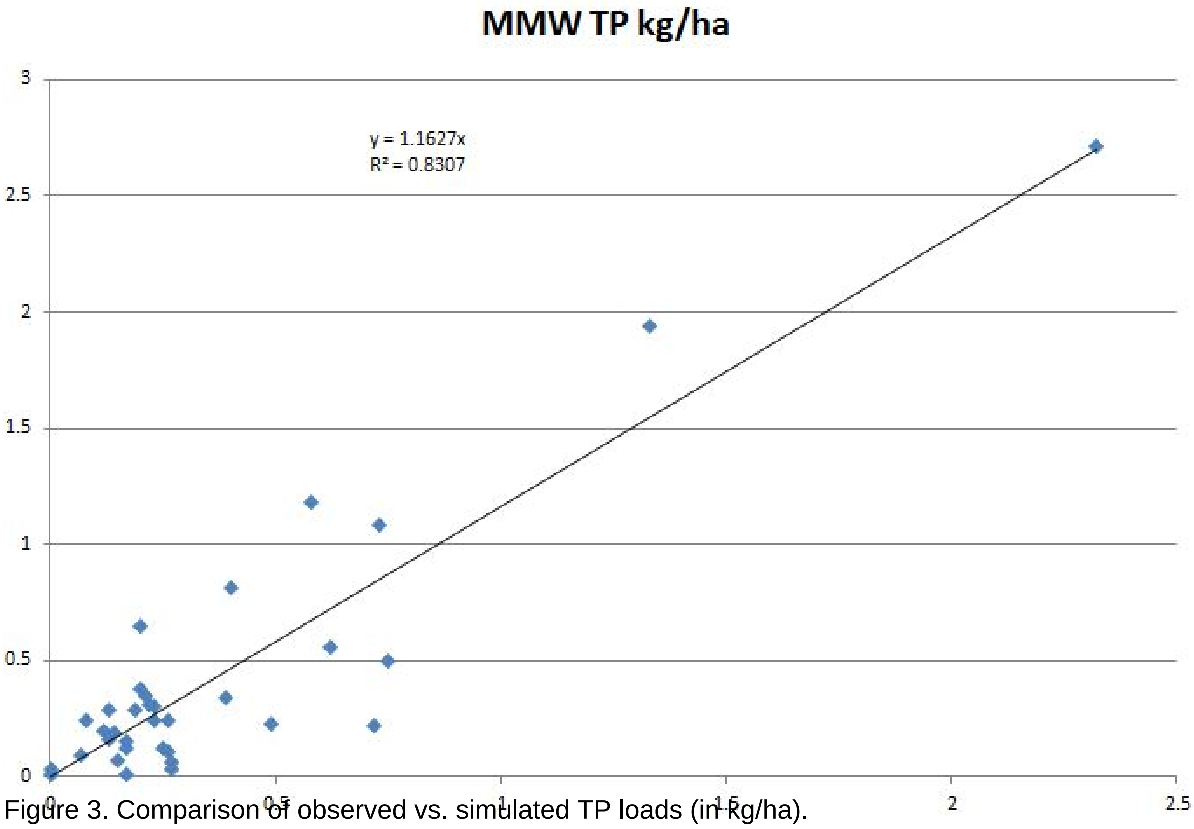


Figure 3. Comparison of observed vs. simulated TP loads (in kg/ha).

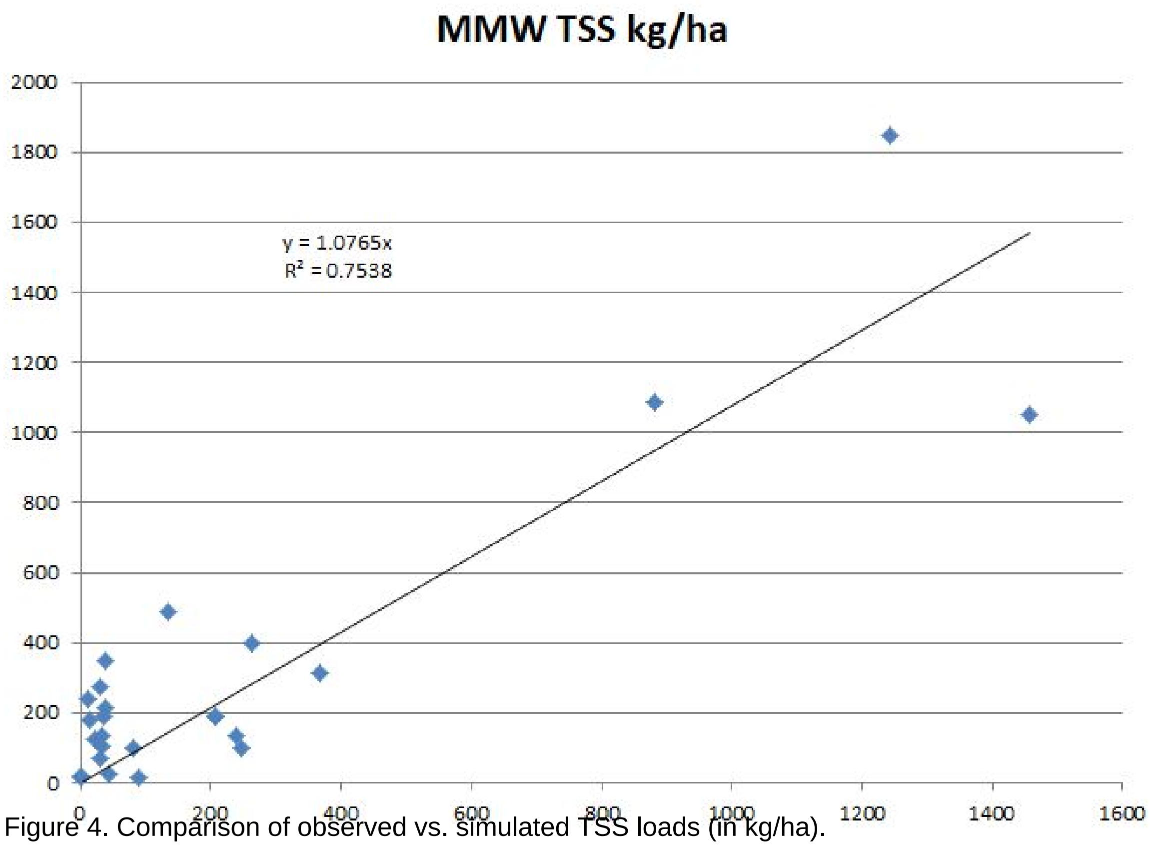


Figure 4. Comparison of observed vs. simulated TSS loads (in kg/ha).

In the case of TP, Model My Watershed-predicted loads were about 16% higher on average than observed loads. Also, as shown by the lower R^2 value (0.83), Model My Watershed was less accurate in predicting these loads than TN, particularly in cases where lower loading rates occurred (below about 1 kg/ha). As with TN, it may be that inaccurate estimates of wastewater discharges and farm animal populations are adversely influencing TP load estimates from Model My Watershed. Since much of the phosphorus load generated within a given watershed is also attached to stream-transported sediment, however, it is also possible that inaccurate estimates of sediment loads (as discussed below) are also adversely affecting these load estimates.

As shown in Figure 4, sediment loads predicted by Model My Watershed are about 8% higher than observed loads on average, and the R^2 value (0.75) is lower than that for either TN or TP. This is not surprising as in-stream samples of sediment are known to be very problematic, and it could be that some of the inaccuracy in the modeled results comes from the use of imprecisely-calculated “observed” values. It is also likely that prediction errors may be arising due to the more “empirical” nature of the streambank erosion routine in the GWLF-E model in comparison to those used for calculating sediment erosion from upland sources. However, it is hoped that future improvements in this routine that allow for better distribution of streambank-eroded loads on a stream segment basis (rather than the more “uniform” approach used now) will improve these results. In any case, it is believed that the simulation results do capture the relative magnitudes of sediment loads in streams that are relatively “natural” versus those heavily influenced by agriculture and human development reasonably well.

As described earlier, only a limited amount of calibration could be performed due to a lack of funding to accomplish this activity in the original scope of work. However, with future funding, it is anticipated that additional calibration work will be completed. In particular, as implied by the map in Figure 1, additional work needs to be undertaken in other regions of the country that have different weather patterns, landscape conditions, cropping practices, etc. from those reflected by the locations of existing test sites used for this limited calibration in order to provide a higher level of confidence in the pollutant loading estimates produced by Model My Watershed elsewhere across the country. For those so inclined, Model My Watershed currently provides the ability to download an input (gms) file generated for any given watershed or area of interest. Once downloaded, this file

can be read by the desktop version of the GWLF-E model(https://wikiwatershed.org/help/model-help/mapshed/#software-downloads)
and then subsequently edited to support other calibration efforts.

References Cited

Evans, B.M., D.W. Lehning, K.J. Corradini, G.W. Petersen, E. Nizeyimana, J.M. Hamlett, P.D. Robillard, and R.L. Day. 2002. A comprehensive GIS-based modelling approach for predicting nutrient loads in watersheds(http://www.spatialhydrology.net/index.php/JOSH/article/view/13)
. J. Spatial Hydrology 2(2).

Evans, B.M. 2007. Summary of Work Undertaken Related to Adaptation of AVGWLF for Use in New England and New York. Final Report to the New England Interstate Water Pollution Control Commission, Penn State Institutes of Energy and the Environment, 116 pp.

Evans, B.M. 2010. Adaptation of the AVGWLF Watershed Model for Use in Texas and Surrounding States: Phase 1. Report to the Texas State Soil and Water Conservation Board, Penn State Institutes of Energy and the Environment, 157 pp.

Evans, B.M., and K.J. Corradini. 2016. MapShed Users Guide(http://wikiwatershed.org/wp-content/uploads/MapShedManual.pdf)
(Version 1.5), Penn State Institutes of Energy and the Environment, Penn State University, 140 pp.

Haith, D.A., and L.L. Shoemaker. 1987. Generalized Watershed Loading Functions for Stream Flow Nutrients(https://doi.org/10.1111/j.1752-1688.1987.tb00825.x)
. Water Resources Bulletin, 23(3), pp. 471-478.

Walker, W. W. 1999. Simplified Procedures for Eutrophication Assessment and Prediction: User Manual. Prepared for U.S. Army Corps of Engineers, Instruction Report W-96-2, 239 pp.

7.3. Watershed Multi-Year Worksheet

Watershed Multi-Year Model for Analysis of Sub-Area Within a Larger HUC12

This particular tool was created to meet the needs of users in Pennsylvania that are conducting watershed modeling activities related to the development of a Pollution Reduction Plan (PRP) as part of an NPDES permit renewal for regulated areas that are responsible for managing urban stormwater runoff.

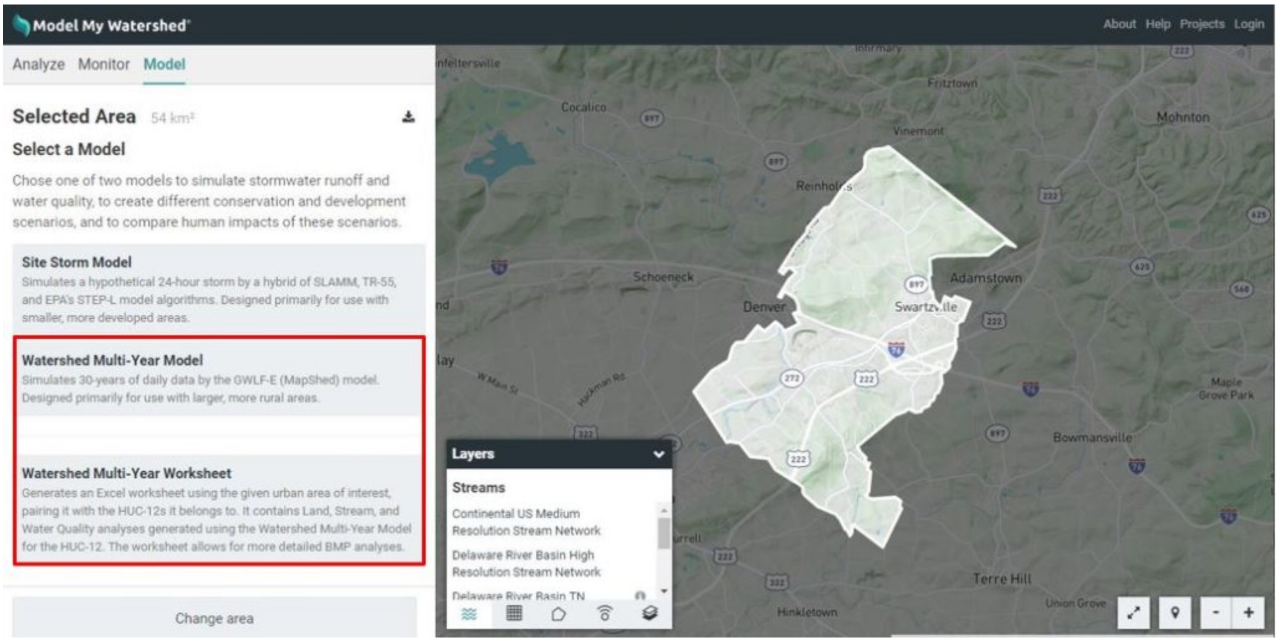
In developing a PRP, an analysis of the pollutant load contributed by a smaller area (typically, a municipality or similar urbanized area) within a larger watershed (in this case, a HUC12 basin) must be completed. After the loads for the “urbanized” area have been established, an analysis must then be conducted to estimate the potential load reduction that might be achieved via the implementation of various stormwater control measures.

Currently, sediment load reductions of 10% from existing loads are required in Pennsylvania. Although this tool is geared towards users in Pennsylvania, its application to similar problems in other areas outside of Pennsylvania are certainly possible.

With this tool, users are required to identify the smaller area of interest (AoI) such as a municipality, urban planning area, etc. using one of three options provided in Model My Watershed as described in Sections 4.2 through 4.4 above (i.e., “Draw Area”, “Delineate Watershed” or “Upload File”).

Once this area has been defined, the user must then select the second (lower) of the two Watershed Multi-Year Model options shown in Figure 4.1 to simulate hydrology and pollutant loads for the AoI. With the first (upper) option, the model is only used to generate hydrology and pollutant load output for a single, selected AoI. With the second (lower) option, however, land cover distribution and pollutant load data are automatically written to an Excel-formatted “BMP Spreadsheet Tool” that is subsequently made available for download to the user.

With this latter BMP tool, it is possible for users to conduct a wider range of load reduction scenarios than is possible using the more stream-lined “Conservation Practices” option described in Section 7.2.4. With this tool, the HUC12 basin within which the specified AoI is located is automatically identified. Also, if the AoI spans more than one HUC12 basin, additional BMP spreadsheets are filled out based on land cover data and load estimates for each HUC12 basin, and then made available for download by the user automatically.



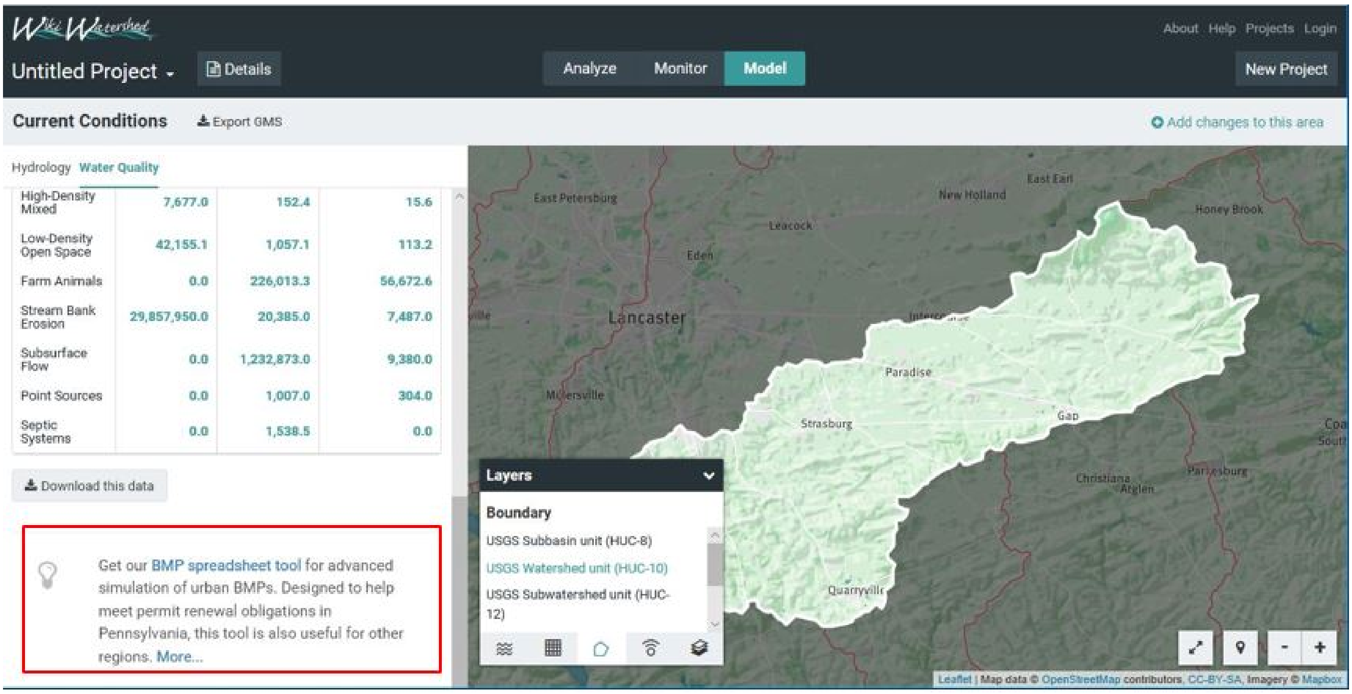
(https://wikiwatershed.org/wp-content/uploads/options-executing-watershed-multiyr-model.jpg)

Figure 4.1. Two options for executing the Watershed Multi-Year Model.

The BMP Spreadsheet Tool described above was made available in previous versions of Model My Watershed, and can also be accessed by clicking on the appropriate link on the Water Quality output tab as shown in Figure 4.2 below if the first (upper) Watershed Multi-Year Model option shown in Figure 4.1 is selected. In this case, however, the Excel-formatted spreadsheet that is made available for download does not have land cover data and model results automatically entered as described above. Rather, the user must copy and paste this information manually as described in the user manual that can also be downloaded below.

Also included in this manual are instructions on how to use the spreadsheet tool for conducting various BMP scenarios once the required land cover and load data have been entered either manually or automatically as described in this subsection. Copies of a blank spreadsheet tool and one filled in with sample data can be downloaded below.

- Model My Watershed BMP Spreadsheet Tool User Manual(https://wikiwatershed.org/wp-content/uploads/MMW_BMP_Spreadsheet_Tool_UserManual.pdf)
- Model My Watershed BMP Spreadsheet Tool (blank)(https://wikiwatershed.org/wp-content/uploads/MMW_BMP_Spreadsheet_Tool-Blank.xlsx)
- Model My Watershed BMP Spreadsheet Tool (example)(https://wikiwatershed.org/wp-content/uploads/MMW_BMP_Spreadsheet_Tool-Example.xlsx)



(https://wikiwatershed.org/wp-content/uploads/accessing-bmp-spreadsheet-manual-entry.jpg)

Figure 4.2. Accessing the BMP Spreadsheet Tool for manual data entry and BMP scenarios.

Note: if you are unable to see the link to download the Watershed Multi-Year Worksheet, you may need to use the scroll bar on the left panel or the zoom out feature in your browser settings.

8. Saving and Sharing Your Project

There are two options to Save and Share your Model My Watershed project if you have registered for a free account (i.e., you must have registered for an account). First, make sure you are logged in to your account before you begin a new project.

8.1. Save/Share Using Model My Watershed

Saving your Project. Start a new project by Selecting an Area. Once you have selected and analyzed an Area of Interest AND run either the Site Storm Model or the Watershed Multi-Year Model, your project will automatically be saved to your “Projects”, which can be found by clicking the word “Projects” in the upper right hand corner of the top black bar. Any updates you make to a project, will automatically be saved (thus overwriting your past project with the new edits, no need to click a “save” button). You can Name/Rename or Delete your project in the upper left corner (in the black bar) while viewing your project OR, you can Rename, Delete, Share, and Launch your project from the “projects” page (which lists all of the projects you’ve “saved”).

Sharing your Project. Sharing your project with others from Model My Watershed is simple and can be accessed in two locations. Once you have run either the Site Storm Model or the Watershed Multi-Year Model (and you’re “logged in”), a “Share” button will appear in the upper right hand corner of the black bar. Your click will open a window that contains two options for sharing, “Link Sharing” and “HydroShare Export”. Turn “Link Sharing” on by clicking the “Off” toggle, then copy the URL by clicking “copy”. You can paste this URL into an email or any other document to send to others. The recipient of the URL can click on the link or paste into their web browser to view your project (view only). Projects shared in this way are not editable by the recipient, but remain editable by you (the owner).

8.2. Save/Share Using HydroShare

HydroShare(https://www.hydroshare.org/)
is an online collaboration environment for sharing data, models, and code. When you export to HydroShare, your project will be made public under a Creative Commons 4.0 license(https://creativecommons.org/licenses/by/4.0/)
.

In order to use this feature, you must:

- Register(https://www.hydroshare.org/sign-up/?next=/my-resources/)
  for a HydroShare account.
- Once you have your HydroShare login credentials, return to Model My Watershed and link your Model My Watershed account with your HydroShare account by clicking on the login text (where your Username is shown in the upper right corner of the black bar) and then click on “Linked Accounts.” You will then be prompted to enter your username and password for your HydroShare account (you should only need to do this once to activate the linking of these two accounts).
- Now that your accounts are linked, you can share projects via Hydroshare with the following steps (you need to do this for each project you wish to share via HydroShare):
  - Either (a) click on “Share” within a project you have modeled (upper right corner of the black bar), OR (b) from the “Projects” page you can click on “Share” for any project
  - Click on the “Off” toggle button under “HydroShare Export” to turn it “On”
  - Enter the “Title” of your project and an “Abstract” (these two fields are required but can be renamed/edited within HydroShare. The Keywords are optional.
  - Click “Export” and wait for the project results to be transmitted to your HydroShare account (be patient, this may take 30-60 seconds).
  - Once complete, open a new web-browser window and go to the HydroShare website(https://www.hydroshare.org/)
    , login, click on “My Resources” and you will see a list of all of the projects you have saved/shared to HydroShare. Click on a project to see the metadata and all other data transmitted to your HydroShare account.
  - You can re-open your Model My Watershed project directly from your HydroShare account by clicking on the “Open with…” button towards the upper right corner of your project page and choose to “View” or “Edit” in Model My Watershed. Once clicked, a new tab in your browser will open to your Model My Watershed Project.

Linking and saving your project to HydroShare has several benefits:

- All data files are automatically saved to your HydroShare-My Resources area. That includes all “Analyze” data such as the Land Cover, Soil Types, Animals data and the Model Output files. In addition your “Area of Interest” polygon is exported in multiple GIS formats (.shp, .geojson).
- Your project will now be “discoverable” by anyone within Model My Watershed using the “Monitor” search and should be a resource result under the HydroShare data catalog (see Monitor(https://wikiwatershed.org/documentation/mmw-tech/#monitor)
  section above to learn how to use).
- You can share your project within HydroShare and transfer “Ownership” of a copy of the project to any other HydroShare member. They can reopen your Model My Watershed project directly from HydroShare using the “Open with” button in the upper right corner of your HydroShare project page. When you share a project in this manner, the new owner can then edit and modify the project that you started. Any changes they make will be saved separately from your original project and saved to the new owners account (either in Model My Watershed or re-shared back to their HydroShare account).
- HydroShare offers features to make your project open to the public (default setting for all Model My Watershed projects – but you can modify to make Private), “Publish” your project to generate a

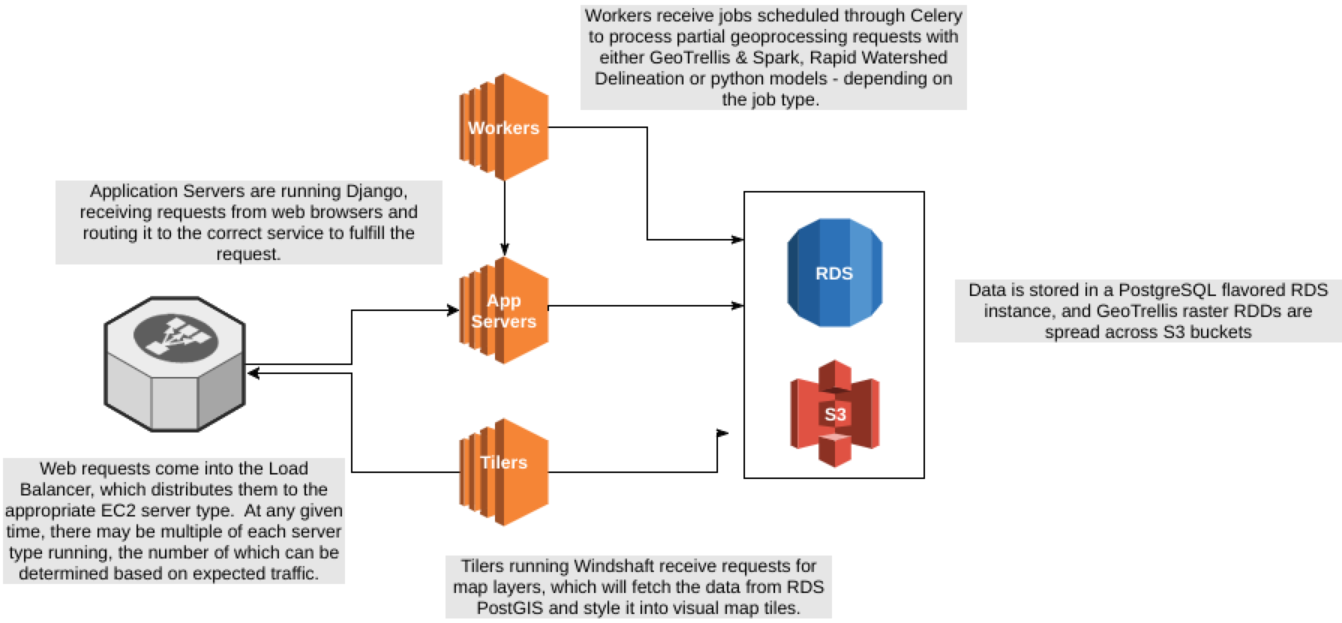
permanent DOI code (Digital Object Identifier) (warning: *when you are ready to permanently publish, click the Publish button at the top of the page in HydroShare to request your DOI. Reminder: You may no longer edit your resource, once you have permanently published it.)*, and you can download all of the files saved to the project.

9. Framework for Web App

The WikiWatershed web application functions by being built from many frameworks and components executed within an Amazon Web Service based cloud infrastructure, most of which is not visible to the user. Its principal design goals are to allow intensive geoprocessing and spatial modeling for arbitrarily defined geographies and to process variable user loads — all while delivering output at speeds suitable for the web. The entire software stack is open source and available on the WikiWatershed GitHub repository(https://github.com/WikiWatershed)
. The following is an explanation of what specific technology is used to achieve that goal.

9.1. Framework Diagram

A simplified architectural diagram showing these high level components.



9.2. Computation and Execution

The core functionality of the Model My Watershed web application runs on the following services and frameworks.

Amazon EC2 is the main computation service that provides CPU, memory and I/O (input/output) resources to the application code. The code and its dependencies are compiled into Amazon Machine Images (AMI) which can then be loaded onto EC2 instances and added to a fleet of servers responding to web requests and computing model results. The application decouples various processing roles from each other by isolating logical functionality into their own AMI so that scaling can happen for specific components of the system independently of each other. The main categories of server types are:

- AppServer: handles web requests and initializing modeling jobs
- Worker: handles the asynchronous execution of geoprocessing and modeling tasks

- Tiler: handles requests to generate map tiles from vector based data sources

AWS ElasticLoadBalancer (ELB) and **AutoScalingGroups** (ASG) are utilized to distribute web traffic to multiple EC2 instances, the number of which can be controlled through an ASG profile, which can increase the capacity of the infrastructure by adding or removing EC2 instances of any particular type.

Celery is an open source distributed task queue. Long-running geoprocessing requests are decomposed into jobs which do partial calculation concurrently across the worker machines, which are then reassembled and returned to the user.

Apache Spark is a fast and general engine for large-scale data processing with tight integration with our main geoprocessing tool, GeoTrellis (see description below).

Spark Job Server is a project providing a standard HTTP based interface into a Spark Context, allowing us to submit Scala based Spark jobs from our Python code.

Django Web Framework is a Python WSGI compatible framework that serves the backend API routes, provides an interface into the backend database, and handles our user authentication workflows.

9.3. Data Storage

Raster analysis and model data are chunked and stored as RDDs, a Spark data format, on **Amazon Simple Storage Service**, S3. S3 provides low latency, redundantly distributed object storage with an HTTP interface. Our source code can make use of a spatial indexing system allowing us to read subsets of the raster data to do our analyses and modelling routines.

Rapid Watershed Delineation requires disk access to its raster and vector input, which is stored on a snapshot of an Amazon Elastic Block Store (EBS) volume. This data volume can be attached to running instances of the Worker EC2 type as they come online.

Amazon's **Relational Database Service** provides us with a general purpose database, with a PostgreSQL compatible protocol. The PostGIS spatial extension is enabled to allow us to store and query geometry data.

9.4. Geoprocessing

GeoTrellis(https://geotrellis.io/)
is an open-source raster-focused geoprocessing engine. It is maintained by Azavea, Inc. but belongs to LocationTech and Eclipse Foundation open source group.

- Provides raster processing at web speed
- Community support: 6,500 commits, 14 releases; 54 contributors

Windshaft is a web-based map server built on top of Mapnik, a popular vector rendering engine. Windshaft is used to convert our vector data sources into styled map images that can be overlaid or selected in the app.

9.5. Model Execution

Both the Site Storm Model and Watershed Multi-Year Model have been created as open source Python modules, available for installation from the Python Package Index.

The workflow of doing spatial analysis on both vector and raster data sources, aggregating and aligning the intermediate data input and the actual execution of the model is orchestrated through all of the technologies listed above, often in seconds, to produce the results that are provided to the user.

10. References

Barry, D.A.J., D. Goorahoo, and M.J. Goss. 1993. Estimation of nitrate concentrations in groundwater using a whole farm nitrogen budget(https://acsess.onlinelibrary.wiley.com/doi/10.2134/jeq1993.00472425002200040019x)
. J. Environ. Qual. 22: 767-775.

Bureau of Reclamation. 2013. Downscaled CMIP3 andCMIP5 climate and hydrology projections: Release of downscaled CMIP5 projections, comparison with preceding information, and summary of user needs. Denver, CO: U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center.

Deliman, P.N., R.H. Glick, and C.E. Ruiz, 1999. Review of Watershed Water Quality Models. U.S. Army Corps of Engineers, Tech. Rep. W-99-1, 26 pp.

Ensign, S. 2020. Modeling future climate for Model My Watershed. HydroShare: doi:10.4211/hs.60058ceda8334e68be141516c5b8de3f(https://www.hydroshare.org/resource/60058ceda8334e68be141516c5b8de3f/)

Evans, B.M., D.W. Lehning, K.J. Corradini, G.W. Petersen, E. Nizeyimana, J.M. Hamlett, P.D. Robillard, and R.L. Day. 2002. A comprehensive GIS-based modelling approach for predicting nutrient loads in watersheds(http://www.spatialhydrology.net/index.php/JOSH/article/view/13)
. J. Spatial Hydrology 2(2).

Evans, B.M., S.A. Sheeder, and D.W. Lehning, 2003. A spatial technique for estimating streambank erosion based on watershed characteristics(http://www.spatialhydrology.net/index.php/JOSH/article/view/14)
. J. Spatial Hydrology 3(2).

Fleming, R.J. 1990. Impact of agricultural practices on tile water quality. Proc. ASAE Summer Meeting, June 24-27, Columbus, Ohio.

Haith, D.A., and L.L. Shoemaker. 1987. Generalized Watershed Loading Functions for Stream Flow Nutrients(https://doi.org/10.1111/j.1752-1688.1987.tb00825.x)
. Water Resources Bulletin 23(3): 471-478.

Haith, D.A. 1993. RUNQUAL: Runoff Quality from Development Sites: Users Manual. Dept. Agricultural and Biol. Engineering, Cornell University, 34 pp.

Huber, W.C., and R.E. Dickinson. 1988. Storm water management model, version 4: User’s manual. Cooperative agreement CR-811607. U.S. Environmental Protection Agency, Athens, GA.

Hydrologic Engineering Center. 1977. Storage, treatment, overflow, runoff model (STORM). U.S. Army Corps of Engineers, Davis, CA.

Maimone, M., S. Malter, J. Rockwell, and V. Raj. 2019. Transforming global climate model precipitation output for use in urban stormwater applications. J. Water Resour. Plann. Manage 145(6): 04019021.

Mauer, E.P., L. Brekke, T. Pruitt, and P.B. Duffy. 2007. Fine resolution climate projections enhance regional climate change impact studies. *EOS Transactions of AGU* **88**, 504. https://doi.org/10.1029/2007EO470006(https://doi.org/10.1029/2007EO470006)

Nolan, B. T., and K.T. Hitt. 2006. Vulnerability of shallow groundwater and drinking-water wells to nitrate in the United States(https://doi.org/10.1021/es060911u)
. Environ. Sci. Technol. 40: 7834-7840.

Patni, N.K., L. Masse, and P.Y. Jui. 1996. Tile effluent quality and chemical losses under conventional and no-tillage: flow and nitrate. Trans. of ASAE, 39 (5): 1665-1672.

Smith, D.B., W.F. Cannon, L.G. Woodruff, F. Solano, and K.J. Ellefsen. 2014. Geochemical and mineralogical maps for soils of the conterminous United States(https://doi.org/10.3133/ofr20141082)
. U.S. Geological Survey, Open-File Report 2014-1082, 386 pp.

Taylor, K.E., R.J. Stouffer, and G.A. Meehl. 2012. An overview of CMIP5 and the experiment design. *Bulletin of the American Meteorological Society* **93**, 485–98. https://doi.org/10.1175/BAMS-D-11-00094.1(https://doi.org/10.1175/BAMS-D-11-00094.1)

Tan, C.S., C.F. Drury, W.D. Reynolds, P.H. Groenevelt, and H. Dadfar. 2002. Water and nitrate loss through tiles under a clay loam soil in Ontario after 42 years of consistent fertilization and crop rotation(https://doi.org/10.1016/S0167-8809(01)00359-0)
. Agricul., Ecosys. & Environment. Vol. 93, pp. 121-130.

Tarboton, D. G., and D. P. Ames. 2001. Advances in the mapping of flow networks from digital elevation data(http://hydrology.usu.edu/dtarb/asce2001.pdf)
, in World Water and Environmental Resources Congress, Orlando, Florida, May 20-24, ASCE.

Tarboton, D. G., R. L. Bras, and I. Rodriguez-Iturbe. 1992. A Physical Basis for Drainage Density(http://dx.doi.org/10.1016/0169-555X(92)90058-V)
, Geomorphology 5(1/2): 59-76.

Tarboton, D. G., R. L. Bras, and I. Rodriguez-Iturbe. 1991. On the Extraction of Channel Networks from Digital Elevation Data(http://dx.doi.org/10.1002/hyp.3360050107)
, Hydrologic Processes, 5(1): 81-100.

U.S. Environmental Protection Agency. 1999. Protocols for developing nutrient TMDLs. EPA 841-B-99-007. Office of Water (4503 F), Washington, D.C.

U.S. Soil Conservation Service. 1986. Urban hydrology for small watersheds. Technical Release NO. 55 (2nd edition). U.S. Department of Agriculture, Washington, DC.

Vanoni, V.A. (Ed.). 1975. Sedimentation Engineering. American Society of Civil Engineers, New York, NY.

11. Credits

STROUD
WATER RESEARCH CENTER WikiWatershed is an initiative of Stroud™ Water Research Center(https://www.stroudcenter.org/)
. The Stroud Center seeks to advance knowledge and stewardship of freshwater systems through global research, education, and watershed restoration.

Documentation Contributors

- Anthony Aufdenkampe, Ph.D., LimnoTech

- David Arscott, Ph.D., Stroud Water Research Center
- Barry Evans, Ph.D., Penn State Institutes of Energy and the Environment
- David Tarboton, Ph.D., Utah State University
- Matt McFarland, Azavea
- Steven Kerlin, Ph.D., Stroud Water Research Center
- Sara Geleskie Damiano, Stroud Water Research Center

Collaborating Organizations

- Academy of Natural Sciences of Drexel University
- Azavea
- Concord Consortium
- LimnoTech
- Millersville University
- Penn State Institutes of Energy and the Environment
- University of Washington
- Utah State University

See the Model My Watershed page(https://wikiwatershed.org/model/)
 for more information about these organizations and individuals.

12. Send Us Feedback

Please help us improve this guide. You can leave feedback by looking for the “Was this helpful? Yes or No” text at the end of each section. If your answer is no, or if you see something that needs to be changed, please use the “Suggest an edit” link and fill out a quick form. Your feedback will not be displayed on the web page but will be emailed to the webmaster.

Additional resources can be found on the Model My Watershed help page (https://wikiwatershed.org/help/model-help/(https://wikiwatershed.org/help/model-help/)
). If you’ve reviewed the resources and still need help, or if you would like to report a bug, please use our contact form (https://wikiwatershed.org/contact/(https://wikiwatershed.org/contact/)
).