Collaborative Watershed Modeling using the Internet
Modeling Large River Systems

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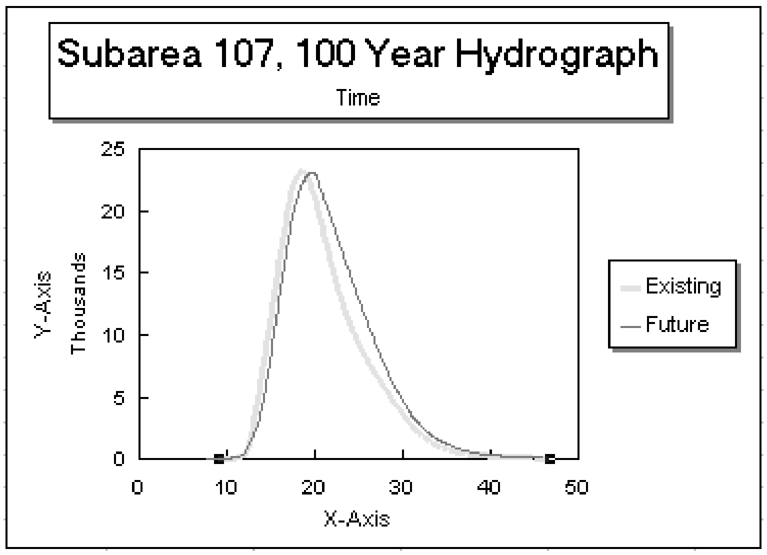
Introduction

The concept behind the Pa. Act 167 legislation is now commonly understood and accepted. What the Act proposes is that for a given watershed, the developments/developers nearest the bottom of the watershed should get rid of their runoff as quickly as possible (without harming their streams) before the peak flow from upstream reaches them. For developers at the top of the watershed, the goal is the opposite, to delay the release of their water as long as is reasonably possible so that the lower subareas have more time to get rid of their water.



Hydrograph showing delayed peak and increased volume after development

The ultimate result at the bottom of the watershed is a hydrograph with a somewhat longer peak and a delayed peak time (as seen in the hydrograph at left). At present, the Pennsylvania Department of Environmental Protection (PaDEP) is advocating groundwater recharge, which would tend to reduce the volume of runoff and peak time delay, but recharge requires care in limestone areas, and large developments with streets will find it difficult to recharge all of their runoff. BMP's can reduce the volume and timing of the hydrograph as well, but at this time there are few "hard numbers" to show what effect they have, especially in larger storms. At any rate, with or without infiltration and BMPs, the watershed must be modeled in some way to determine peak flows, volumes, and timing, so that a runoff control strategy can be developed, and problem sites can be identified and mitigated.

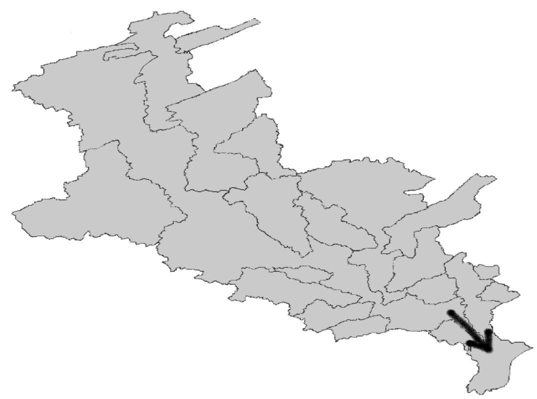
In conformance with Act 167, Pa DEP has divided the entire state into over 300 watersheds. A watershed wide storm water management plan is to be provided for each of these watersheds, with the goal of having no increase in peak flow after the watershed is fully developed at some time in the future. Each of these watersheds will most likely follow the accepted theory that the upper reaches of the watershed should delay their runoff, and the lower reaches should facilitiate the flow of runoff to the receiving waters.

In addition to dividing the State into over 300 watersheds, Pa DEP placed these watersheds into 13 Major River groups, such as the Allegheny, Monongahela, Juniata, Schuylkill, and Lehigh Rivers. These 13 major groups feed into 3 major rivers (the Ohio, Susquehanna, and Delaware) and are at the headwaters of 3 other major bodies of water (Lake Erie, Genesee, and Potomac Rivers).

When comparing one of the 300 delineated watersheds to a map of a major river, such as the Schuylkill, the major difference is the scale of the watershed. In the figure at right is Mill Creek, one of the PaDEP delineated watersheds, which covers 57 sq. miles in one county (Lancaster). Below that is the Schuylkill River watershed, which covers 1,916 square miles in 11 counties (including Philadelphia County). The Schuylkill River watershed encompasses 17 PaDEP designated watersheds.

Mill Creek Watershed

If the DEP delineated watersheds in the Schuylkill River basin are considered as subareas, then it is apparent that the same conditions apply as far as runoff timing. If the runoff at the bottom of the Schuylkill River is not gone before the peak flow comes from upstream, future development could cause an increase in peak flow. The effect of Pa. Act 167 is unknown in these large watersheds, because they have not been studied. The sheer size of these watersheds makes them difficult if not impossible for one entity to model with any degree of precision.



Schuylkill River Watershed

On a smaller scale, the Conestoga River is a small river that runs through Lancaster County and drains into the Susquehanna River near Pennsylvania's border with Maryland. The Conestoga River watershed consists of 4 DEP delineated subwatersheds for the three creeks that drain into the Conestoga (Mill, Little Conestoga, and Cocalico) and the remaining area, which is designated as the Conestoga River watershed. The Lancaster County Engineer's Office has completed studies on the three creeks, and will next begin work on the entire Conestoga River watershed. This means that the results from the previous three watersheds must be merged into the model. This merging of the watersheds will be greatly facilitated by the fact that all of the watersheds involved are primarily located in Lancaster County. In a larger river system, the constituent watersheds would not be located in the same county, so some type of collaboration would be necessary.

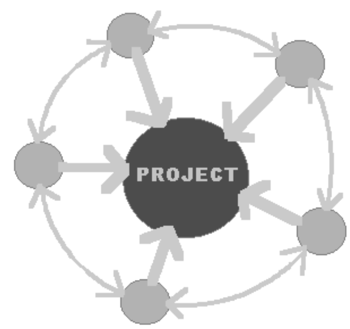
<u>Single Computer Modeling of Large Watersheds using TR20</u>

The staff of the Lancaster County Engineer's Office uses TR20 to model the PaDEP designated watersheds, and an in-house developed Visual Basic program called "Stremtul" as a front end for TR20. The most recent version of Stremtul is 2.3. Stremtul allows "point and click" to create a link from one project (the Conestoga River, known as the Parent) to as many as 10 upstream projects (the Mill, Little Conestoga, and Cocalico Creeks, known as the Children). This means that

Stremtul will insert the most recently run hydrograph from a Child project into the Parent project at the location where the link was set. If a Child project is then loaded and some of the settings changed, the resultant hydrograph at the pour point will also change after the model is run. The next time the Parent project is loaded and run, STREMTUL will see a link to the Child project, go to the Child project, get the last hydrograph (for the pour point of the watershed) and insert that hydrograph into the Parent's TR20 input file. Because each Child project is checked every time TR20 is run for the Parent project, the most up-to-date hydrographs are always included in the Parent project's model. The TR20 command used to add a hydrograph into the model is the ADDHYD statement. This is fairly straightforward when all of the hydrographs are stored locally, meaning on a hard drive in the computer or on a network.

<u>Collaboration on Large Projects</u>

When a project can not be done on one computer or on one network, the internet is sometimes used to draw the various components together. The internet, or World Wide Web, is being used by Civil Engineers in government, private practice, and academia to collaborate on building projects, site developments, infrastructure, and a wide variety of projects in general. When using the internet in this way, the general schematic of the process is that of a wagon wheel, with the project at the center, and input from various professionals, who can be geographically separated, as the spokes of the wheel. Collaboration among these professionals can be thought of as the rim of the wheel. This works well when all the participants are each working on a different part of the same project and have the ability to work somewhat independently of the others. For example, after the building footprint is determined, design of the mechanical, electrical, and plumbing work can begin without everyone waiting for the foundation engineer to design the foundation - the other professionals can assume that the foundation engineer will "make it work".



Normal collaboration on a large project.

This method of collaborating does not work as well for hydrologists, who could also use the internet to collaborate on a large project (i.e. by modeling different parts of the same large watershed), but are in the unique position of being governed by a certain law of nature - water flows downhill. This means that a hydrologist at the bottom of the watershed must wait for the upstream modeling to be finished before beginning his or her own model. Because of this, the schematic for internet collaboration by hydrologists would look more like a tree, with the ultimate goal, the modeling of the entire watershed, at the base of the tree.

By using the Internet, theoretically any number of watershed models could be combined to model very large watersheds. The advantage of doing this is that:

1. Modeling the larger watershed in pieces makes the task more manageable - for any one County to model the Schuylkill River would be a monumental task, but the 11 PaDEP watersheds that drain into the river are or soon will be modeled individually by the various counties they are located in.

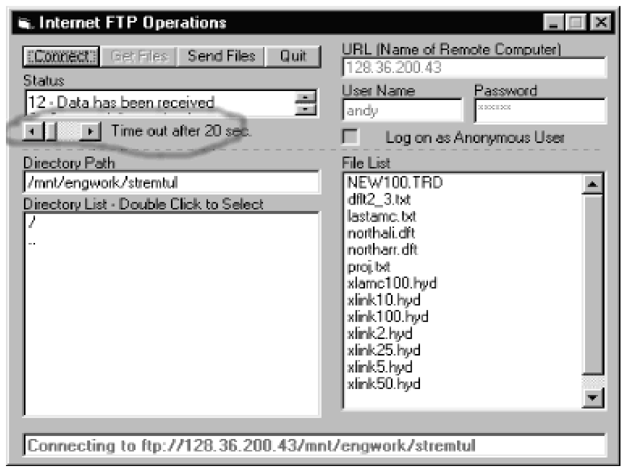
2. The information for the smaller, designated watersheds is gathered, kept, and updated locally - this means, for example, that changes in the watershed are known to the local government, and can be added to the model. Also, the designated watersheds are modeled by people who know the area.

3. More people can contribute to the model, making the process faster. This also means that the smaller designated watersheds are updated relatively frequently, so the major river watershed, if modeled collaboratively, would have fresher data than if it was modeled in one big piece.

<u>Internet Modeling of Large Watersheds using TR20</u>

As stated previously, the Stremtul front end for TR20 can merge numerous watersheds by creating links between a Parent watershed and up to 10 Child watersheds located on the same computer or network. Stremtul also allows these links to be created over the Internet.

Stremtul accomplishes this by using its own FTP (File Transfer Protocol) sub-program. The heart of this sub-program is the Internet Transfer Control included with Visual Basic. If the user creates a project and wants to include a link to a remote sub-project or "Child", they must have permission to access that computer, and will need the URL (address) of the computer, as well as a user name and password. The user also needs to know where on the remote computer the link information is stored. Stremtul then stores this information with the project (the password is encrypted) so that next time, it can connect to the remote computer and find the information it needs without any additional input.



Internet import/export window in Stremtul

After a watershed model is run, using the "FTP Export" button allows the user to send their most recent watershed model results to a remote computer connected to the internet. By exporting the model results, someone else can possibly incorporate those results into their watershed model. The only restriction is that the owner of the remote computer must provide permission to connect, permission to write files to their computer, and a directory where the files can be written. As with linking to a remote computer, the first time the results are exported involves manually entering the URL (address) of the computer, as well as a user name and password, and browsing to the directory where the link information will be stored. Stremtul will store this information and make it the default the next time the results of the watershed model are exported.

The information used to summarize the watershed model consists of at most 70 kB or so of hydrographs and other information. The hydrographs are in standard TR20 format, containing the starting time, time increment, and the upstream area in square miles. There is also room to provide a base-flow, although none was entered in the hydrograph below. The exported hydrograph has the format shown below (the middle of this hydrograph was removed to save space);

```
 7 READHD 8     1                                                           XS  1 O4
 7 READHD 9      11.5000       .1000     57.4000       .0000             A 1  S 1
 8                    0.          1.          1.          1.          2.
 8                    3.          4.          5.          6.          8.
 8                   10.         13.         16.         20.         25.
 8                   31.         39.         48.         60.         75.
 8                  100.        150.        265.        491.        820.
 8                 1213.       1664.       2130.       2596.       3121.
 8                11102.      10988.      10852.      10698.      10528.
 8                10342.      10143.       9934.       9715.       9487.
 8                 9251.       9008.       8761.       8511.       8260.
 8                    8.          7.          6.          5.          5.
 8                    4.          4.          3.          3.          2.
 8                    2.          2.          1.          1.          1.
 8                    1.          1.          1.          1.          0.
 9 ENDTBL
```

Each hydrograph is about 5 or 6 kB in size. Although TR20 provides a hydrograph for each subarea, only the last hydrograph is necessary for the downstream watershed, so this is the only hydrograph exported. In addition to the hydrographs, several other small files are exported to the remote computer to describe the watershed. The first one is the defaults file (dflt2_3.txt) - not all of the settings are used, just the ones that influence the last hydrograph from the subarea. Only 9 of the first 10 lines are used, and these are shown here;

```
 1                                  Antecedent Moisture Condition (AMC)
 70                                 100 Year Rainfall Intensity x 10
 62                                 50 Year Rainfall Intensity x 10
 55                                 25 Year Rainfall Intensity x 10
 50                                 10 Year Rainfall Intensity x 10
 41                                 5 Year Rainfall Intensity x 10
 31                                 2 Year Rainfall Intensity x 10
 0.1                                Time increment in hours
 63                                   Not used - Number of subareas
yes                                 Were small (2-50 yr)storms run (Yes) or no
```

Since Stremtul allows a watershed to be modeled with a storm tracking across the watershed, two files are used to describe if and how this was done. The first is called Northali.dft and the second is called Northarr.dft - the files are virtually identical. Five of the six lines are used to describe the characteristics of the tracking storm;

```
on                      Is the storm tracking turned on or off
 10.36212               The actual watershed scale compared to the screen scale
 5                      Storm direction (1-8, with 1 = North and 4 = South
 8                      Storm tracking speed, in mph
 280          645         Not used - Storm tracking icon location
 1.83                   Time (hr.s) for the storm to track across the watershed


on
 10.36212
 5
 8
 280          645
 1.83
```

In the example above, the two files are identical, but this isn't always the case. The first file, Northarr.dft is a snapshot of the settings made when TR20 was last run. The second file, Northarr.dft, is the settings when FTP export was selected - this was to avoid some obscure problems when the various settings used for the constituent watersheds were checked against one another.

Another file exported is called proj.txt, and includes general useful information about the watershed;

```
Mill                            The name of the watershed
08/10/2001 3:49:46 PM           The time when tr20 was last run
05/08/2000 10:44:56 AM          The time when the project was created
08/10/2001 3:58:35 PM           The time when the project was exported
```

Lastly, if any Antecedent Moisture Condition (AMC) in the watershed was edited, a file called lastamc.txt is exported. It contains only one line, which is the AMC of the last subarea in the watershed. By using these 6 files, Stremtul can completely describe a watershed.

Compatibility with Other Hydrology Programs

The files exported by Stremtul are not presently compatible with other watershed modeling software, and were not intended to be. However, it appears that most of these other programs allow the user to import entire hydrographs from sources outside of the modeled area. Although there is more to merging projects than just inserting a hydrograph (time increments must match, for instance), the following information shows that it is possible to import hydrographs into a variety of modeling programs - this is not a comprehensive list, nor is it a detailed investigation. The main point of interest is that it is possible to link different watersheds together using different modeling software. A few of these programs, and the ways by which hydrographs can be inserted into the models are;

HEC-1 Flood Hydrograph Package (U.S. Army Corp of Engineers) - a hydrograph from an upstream model can be input using the following lines;

```
KK   100
KM     HYDROGRAPH FROM UPSTREAM MODEL
BA  35.1
QI    24      24      24      26      33      50      86     189     376     516
QI   594     657     710     760     801     839     910    1044    1287    1921
QI  2995    3953    4599    5077    5363    5374    5099    4603    3980    3325
QI  2719    2200    1844    1540    1251     994     777     605     471     365
QI   281       0       0       0
```

The "KK" line starts a new computational block, "KM" provides a place to label the hydrograph, "BA" gives the basin area in square miles.

HEC-HMS Hydrologic Modeling System (U.S. Army Corp of Engineers) - This successor to HEC-1 allows the user to add upstream modeling results by using a "Source" element. From the HEC-HMS User's Manual, Version 2.1, p. 43,

"The source can be used to represent boundary conditions to the basin model such as ... contributing area modeled in a separate basin model."

SWMM, Storm Water Management Model (U.S. EPA) - The SWMM Version 4 User's Manual, on page 44, describes the use of a "Combine Block" as follows,

"The output of any other model can also be combined or collated with SWMM files by the Combine Block if the model output is in SWMM interface format C ...".

A Proposal for Further Study

Although a comprehensive investigation of these stormwater modeling programs is beyond the scope of this paper, it is evident that the resulting hydrographs from TR20, HEC-1, HEC-HMS, and SWMM models can theoretically be interchanged, provided that the hydrograph is in the correct format, and provided that supporting information is available to describe the upstream watershed. There may be additional modifications necessary to correct for certain idiosyncracies of each model, but these should not be insurmountable.

In order to promote the exchange of watershed data, a centrally located internet file server (preferably run by PaDEP) could be used to securely store and retrieve the modeling results of all PaDEP designated watershed studies. By assigning each watershed a unique number, anyone could find the information they were interested in. Security could be accomplished by preventing anyone but the County or entity responsible for a watershed from exporting information about it, although anyone could import the information from the server. The information stored could consist of the last (most downstream) hydrograph, starting time, time interval, rainfall information, storm direction, storm velocity, etc. A committee of interested parties could develop a standard format for the information to be stored in. Simple computer programs could take the standard results and adapt them to work in any hydrology program that allows the import of upstream data.