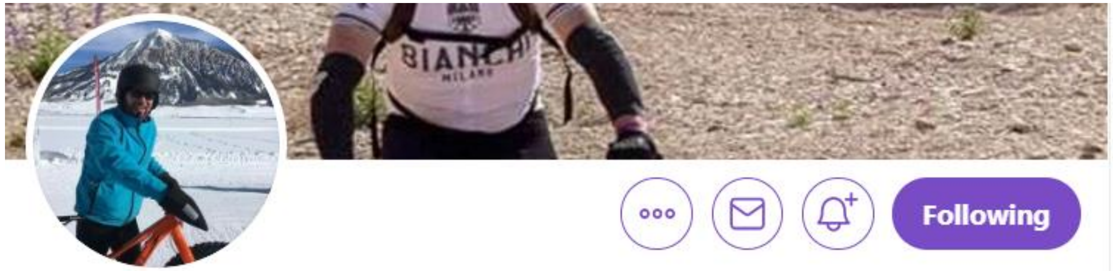
Bill James SWMM5 Network Similarity Scores for Quasi Unitless Testing of H&H Models

Robert Bio: Global Enablement / SWMM5 Features in Innovyze Products InfoSWMM, ICM, ICM_SWMM, XPSWMM && Co-Developer [EPA SWMM 3,4,5+, XPSWMM], SWMM5 help for / http://CIMM.ORG

Charles Rowney: @NCIMM Director of Operations && Senior Research Fellow at UT Austin

CIMM Twitter People



Following

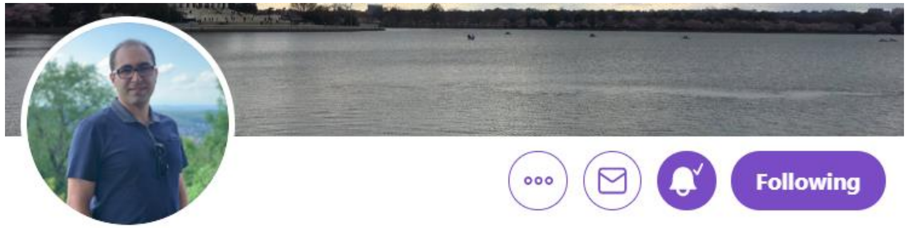
Ben R. Hodges
@H2odges Follows you

Academic. Environmental Fluid Mechanics. Water Resources. Numerical Geek. Weak Bicyclist. Tweets are merely my annoying opinions. #GenderIsaSocialConstruct

benhodges.org Joined January 2010

Abstract

Continental River Dynamics (CRD) is herein defined as modelling the flow dynamics in all channels of a continental-scale river basin using the physics-based Saint-Venant equations. At the boundary of hydraulics and hydrology, CRD requires significant collaborative efforts to make new progress. Six constraints and seven challenges are identified in the areas of dynamics, dimensionality, resolution, uncertainty, model coupling, and data availability. Three key short-term needs for CRD are identified as (1) scaling up Saint-Venant river models to continental scales, (2) standards for integrating river and hydrology models, and (3) methods for effective use of lidar data and synthetic methods for approximating geometry for 1D dynamic models. An over-arching need for comprehensive data collection programs for river geometry is discussed.



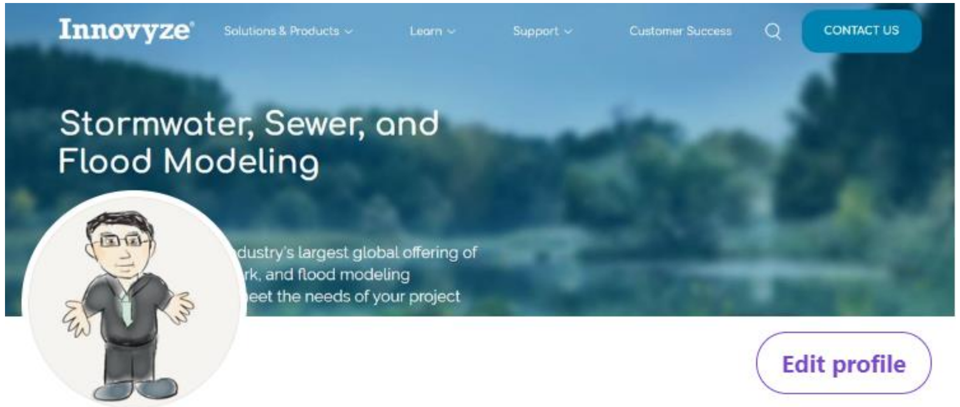
Following

Ehsan Madadi
@EhsanMadadi1 Follows you

Postdoc Fellow at UT Austin, with hobbies of CFD and modeling. I love to learn new things. Early riser, slow walker. Retweets are not endorsement or my opinion

Proud Tabrizian - Love Ames, IA - Falling in Love with Austin, TX
ehsanmadadi.com Joined November 2012

601 Following **253** Followers



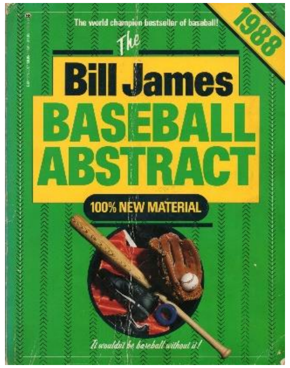
Edit profile

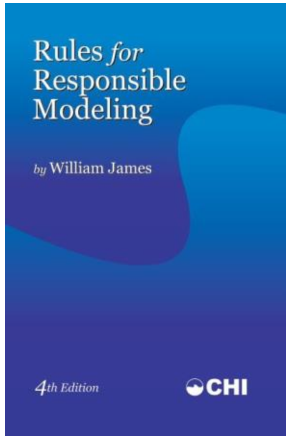
Robert E Dickinson
@RDickinson

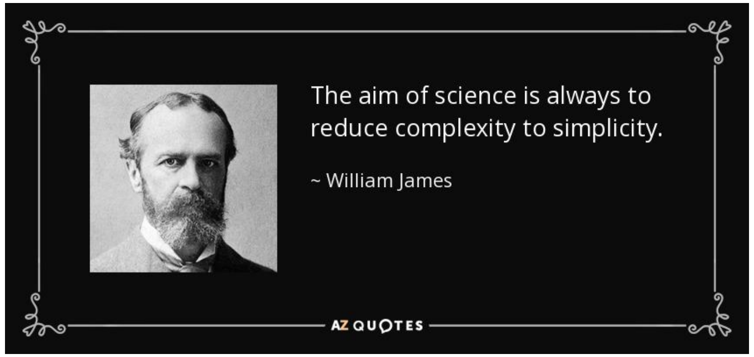
Global Enablement / SWMM5 Features in Innovyze Products InfoSWMM, IW_ICM, IW_ICM_SWMM, XPSWMM && Co-Developer [EPA SWMM 3,4,5+, XPSWMM], SWMM5 for / CIMM.ORG

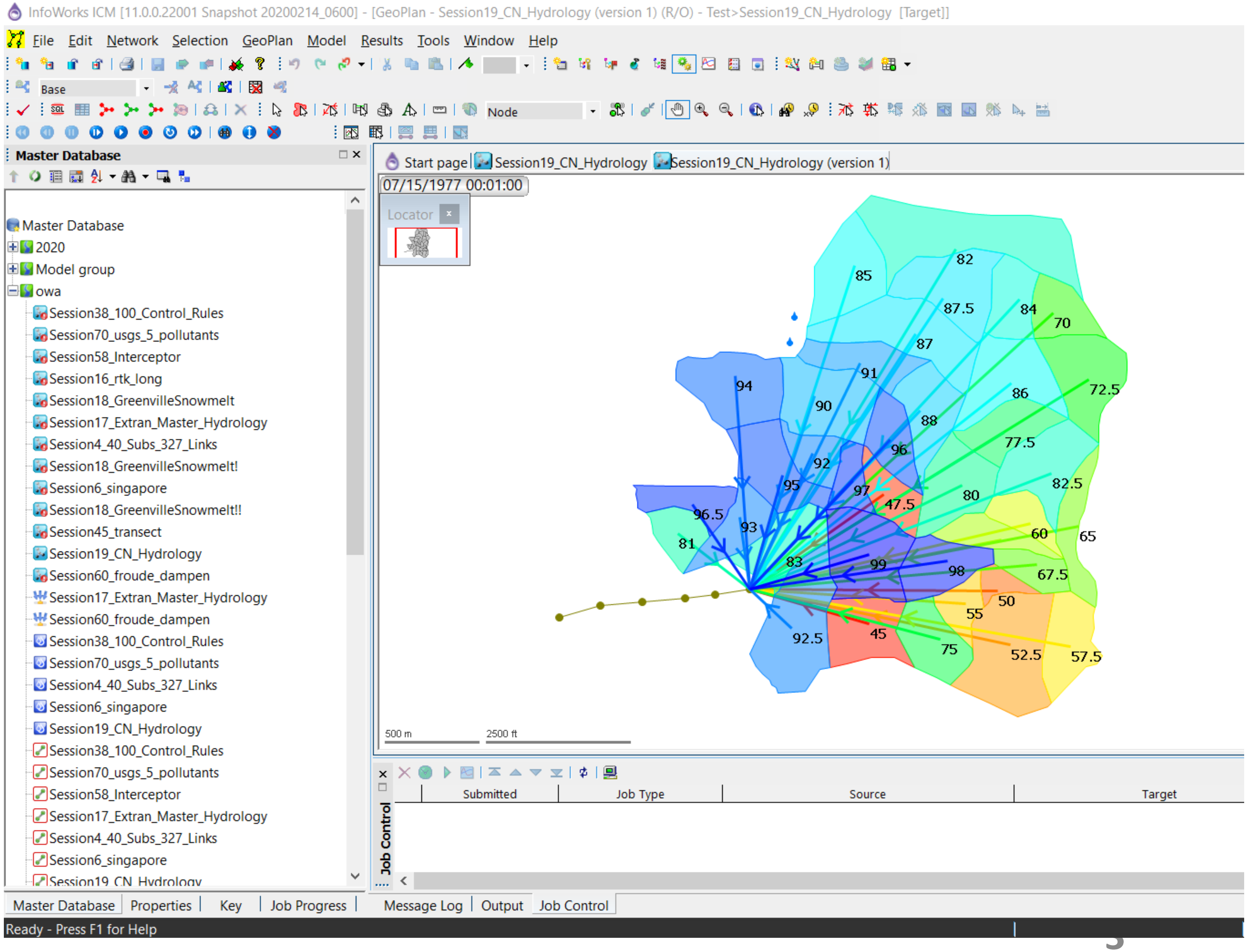
Three Levels of Bill James

1. Bill James the Baseball Writer and Creator of the Baseball Similarity Score
2. William James the Philosopher
3. Bill James of PCSWMM and a SWMM Evangelist









The Other Bill James - Baseball Similarity Score

Similarity Scores

Similarity scores are not our concept. Bill James introduced them in the mid-1980s, and we lifted his methodology from his book *The Politics of Glory* (p. 86-106). To compare one player to another, start at 1000 points and then subtract points based on the statistical differences of each player.

Batters

One point for each difference of 20 games played.
One point for each difference of 75 at bats.
One point for each difference of 10 runs scored.
One point for each difference of 15 hits.
One point for each difference of 5 doubles.
One point for each difference of 4 triples.
One point for each difference of 2 home runs.
One point for each difference of 10 RBI.
One point for each difference of 25 walks.
One point for each difference of 150 strikeouts.
One point for each difference of 20 stolen bases.
One point for each difference of .001 in batting average.
One point for each difference of .002 in slugging percentage.

Then there is a positional adjustment. Each position has a value, and you subtract the difference between the two players' position. James just uses primary position, but we computed an average position for players who had more than one primary position. (See Ernie Banks)

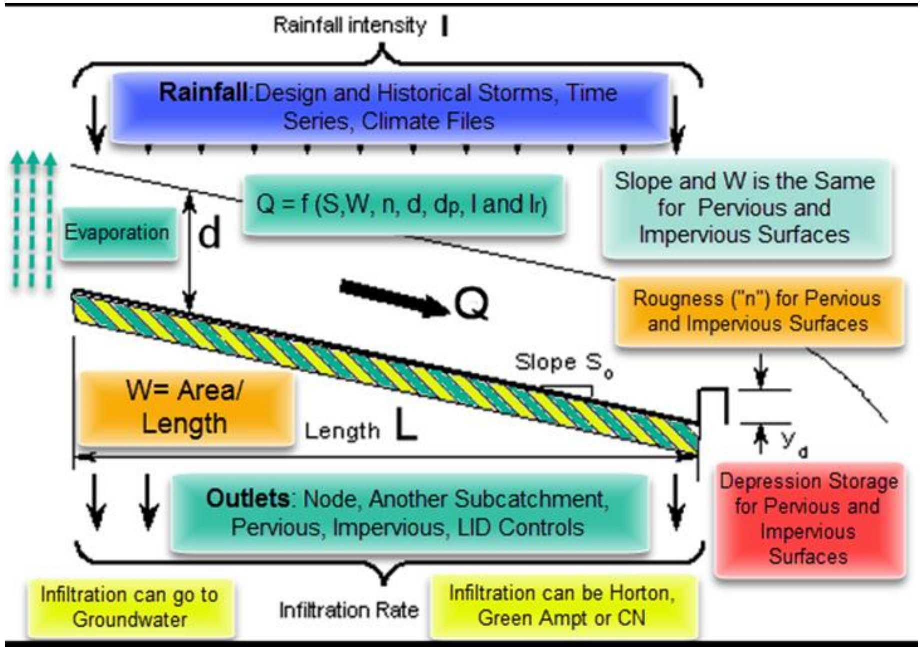
Similarity Scores

Explanation of Similarity Scores

Similar Batters	Similar Batters through 27
1. Hack Wilson (880.8) *	1. Mickey Mantle (935.8) *
2. Giancarlo Stanton (858.2)	2. Frank Robinson (932.0) *
3. Paul Goldschmidt (854.7)	3. Ken Griffey Jr. (930.5) *
4. Wally Berger (846.5)	4. Hank Aaron (887.5) *
5. J.D. Drew (843.4)	5. Miguel Cabrera (876.4)
6. Kevin Mitchell (842.5)	6. Eddie Mathews (873.3) *
7. Carlos Gonzalez (841.1)	7. Albert Pujols (865.3)
8. J.D. Martinez (836.2)	8. Mel Ott (858.2) *
9. Tommy Henrich (833.7)	9. Andruw Jones (848.3)
10. Larry Doby (829.7) *	10. Joe DiMaggio (837.8) *
* - Signifies Hall of Famer	* - Signifies Hall of Famer

The baseball player being compared in this table is Mike Trout. We would like a metric that is also unique for comparing models.

EPA SWMM5 has Many Versions, Bug Fixes, New Features



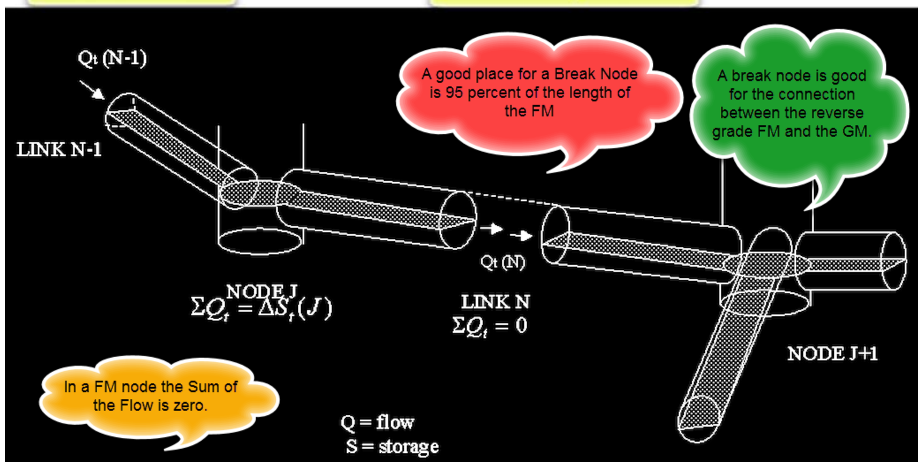


Table 1. SWMM History

Release Date	Versions	Developers	FEMA Approval	LID Controls	
08/09/2018	SWMM 5.1.013	EPA	Yes	Yes	
03/14/2017	SWMM 5.1.012	EPA	Yes	Yes	
08/22/2016	SWMM 5.1.011	EPA	Yes	Yes	
08/20/2015	SWMM 5.1.010	EPA	Yes	Yes	
04/30/2015	SWMM 5.1.009	EPA	Yes	Yes	
04/17/2015	SWMM 5.1.008	EPA	Yes	Yes	
10/09/2014	SWMM 5.1.007	EPA	Yes	Yes	
06/02/2014	SWMM 5.1.006	EPA	Yes	Yes	
03/27/2014	SWMM 5.1.001	EPA	Yes	Yes	
04/21/2011	SWMM 5.0.022	EPA	Yes	Yes	
08/20/2010	SWMM 5.0.019	EPA	Yes	Yes	
08/17/2005	SWMM 5.0.005	EPA, CDM	Yes	No	
11/30/2004	SWMM 5.0.004	EPA, CDM	No	No	
11/25/2004	SWMM 5.0.003	EPA, CDM	No	No	
10/26/2004	SWMM 5.0.001	EPA, CDM	No	No	
2001–2004	SWMM5	EPA, CDM	No	No	
1988–2004	SWMM4	UF, OSU, CDM	No	No	**In-kind UF. CDM**
1981–1988	SWMM3	UF, CDM	No	No	**In-kind UF. CDM**
1975–1981	SWMM2	UF	No	No	**In-kind UF**
1969–1971	SWMM1	UF, CDM, M&E	No	No	

EPA SWMM5 has Many Versions, Bug Fixes, New Features

Improvements:

12. When a subcatchment with LID controls receives runon from another source (e.g., a subcatchment, LID drain or outfall node) the runon is now distributed only across the non-LID area of the sub- catchment instead of the full area. If a single LID takes up the full subcatchment area then the runon is directed onto the LID.
13. Storage node HRT was added to the state variables saved in the Hot Start file.
14. The threshold value for reporting a non-zero runoff result was changed from 0.001 cfs to 0.001 inches/hr.
15. The calculation of overall flow routing mass balance was modified to account for cases where some flow streams, like total external inflow, are negative.
16. The "Surface Runoff" label in the Runoff Continuity Report was replaced with "Total Runoff" since the value reported consists of both surface runoff and LID drain flow.
17. The "Internal Outflow" label in the Flow Routing Continuity Report was replaced with "Flooding Losses" to improve clarity.
18. The pollutant washoff routines were moved to a new code module (surfqual.c) and revised to account for the reduction in pollutant load that results from runoff flow reduction by LID units.
19. Initial flows for Steady Flow routing are now ignored since they are not used in the routing calculation and the initial volume associated with them contributed to system mass balance error.
20. The various types of lateral inflows to conveyance system nodes are now evaluated at the date/time for the start of the routing time step instead of at the end of the time step.
21. The final runoff and routing time steps are adjusted to insure that the simulation's total duration is not exceeded.
22. When evaluating user-supplied math expressions, any NaN (Not a Number) result (caused by an underflow, overflow or divide by zero) is set to 0 so that the NaN doesn't propagate through subsequent calculations.

Bug Fixes:

23. The evaporation rates read from a time series would only change when a new day was reached (even though values at more frequent intervals were present) and could cause a run to stop pre- maturely in some rare cases.
24. The runoff read from a Hot Start file should have been assigned to a subcatchment's newRunoff property, not to oldRunoff.
25. An indexing bug that caused Hot Start files with snowmelt parameters to be read incorrectly was fixed.
26. The setting for a non-conduit link read from a Hot Start file was not being used to initialize the link.

Table 1. SWMM History

Release Date	Versions	Developers	FEMA Approval	LID Controls	
08/09/2018	SWMM 5.1.013	EPA	Yes	Yes	
03/14/2017	SWMM 5.1.012	EPA	Yes	Yes	
08/22/2016	SWMM 5.1.011	EPA	Yes	Yes	
08/20/2015	SWMM 5.1.010	EPA	Yes	Yes	
04/30/2015	SWMM 5.1.009	EPA	Yes	Yes	
04/17/2015	SWMM 5.1.008	EPA	Yes	Yes	
10/09/2014	SWMM 5.1.007	EPA	Yes	Yes	
06/02/2014	SWMM 5.1.006	EPA	Yes	Yes	
03/27/2014	SWMM 5.1.001	EPA	Yes	Yes	
04/21/2011	SWMM 5.0.022	EPA	Yes	Yes	
08/20/2010	SWMM 5.0.019	EPA	Yes	Yes	
08/17/2005	SWMM 5.0.005	EPA, CDM	Yes	No	
11/30/2004	SWMM 5.0.004	EPA, CDM	No	No	
11/25/2004	SWMM 5.0.003	EPA, CDM	No	No	
10/26/2004	SWMM 5.0.001	EPA, CDM	No	No	
2001–2004	SWMM5	EPA, CDM	No	No	
1988–2004	SWMM4	UF, OSU, CDM	No	No	**In-kind UF. CDM**
1981–1988	SWMM3	UF, CDM	No	No	**In-kind UF. CDM**
1975–1981	SWMM2	UF	No	No	**In-kind UF**
1969–1971	SWMM1	UF, CDM, M&E	No	No	

Lew Rossman Brilliant Architecture of SWMM5 Engine and UX

SWMM55.013_CIMM-DLL (Global Scope)

```
enum  NoneAllType {
      NONE,
      ALL,
      SOME};

#define MAX_STATISTICAL_RESULTS 15     // CIMM
enum  StatsType {
      SIM,            // Simulated Mean
      OBS,            // Observed Mean
      RMSE,           // Root Mean Square Error
      MAE,            // Mean Average Error
      MSLSE,          // Mean Simple Least Square Error
      STDSIM,         // Simulated Standard Deviation
      STDOBS,         // Simulated Standard Deviation
      SkewnessSim,    // Skewness of Simulated
      KurtosisSim,    // Kurtosis of Simulated
      SkewnessObs,    // Skewness of Observed
      KurtosisObs,    // Kurtosis of Observed
      LogNASH,        // Log Nash-Sutcliffe Efficiency
      IndexD,         // Index of Agreement
      ISE,            // Integral square error
      NASH};          // Nash-Sutcliffe Efficiency
```

Name	Date modified	Type	Size
Ubrowser.pas			
Ucalib.pas			
Uclipbrd.pas			
Ucombine.pas			
Ucoords.pas			
Udxf.pas			
Uedit.pas			
Uexport.pas			
Uglobals.pas			
Ugraph.pas			
Uimport.pas			
Uinifile.pas			
Ulegend.pas			
Ulid.pas			
Umap.pas			
Uoutput.pas			
UpDnEdit.pas			
Uproject.pas			
Ustats.pas			
Utools.pas			
Uupdate.pas			
Uutils.pas			
Uvalidate.pas			
Uvertex.pas			
VirtList.pas			
XPForm.pas			
Xprinter.pas			
Epaswmm5.stat			
objprops.txt	11/10/2018 5:47 PM	Text Document	51 KB
Readme.txt	3/24/2014 3:00 PM	Text Document	2 KB
viewvars.txt	1/20/2018 10:57 PM	Text Document	33 KB

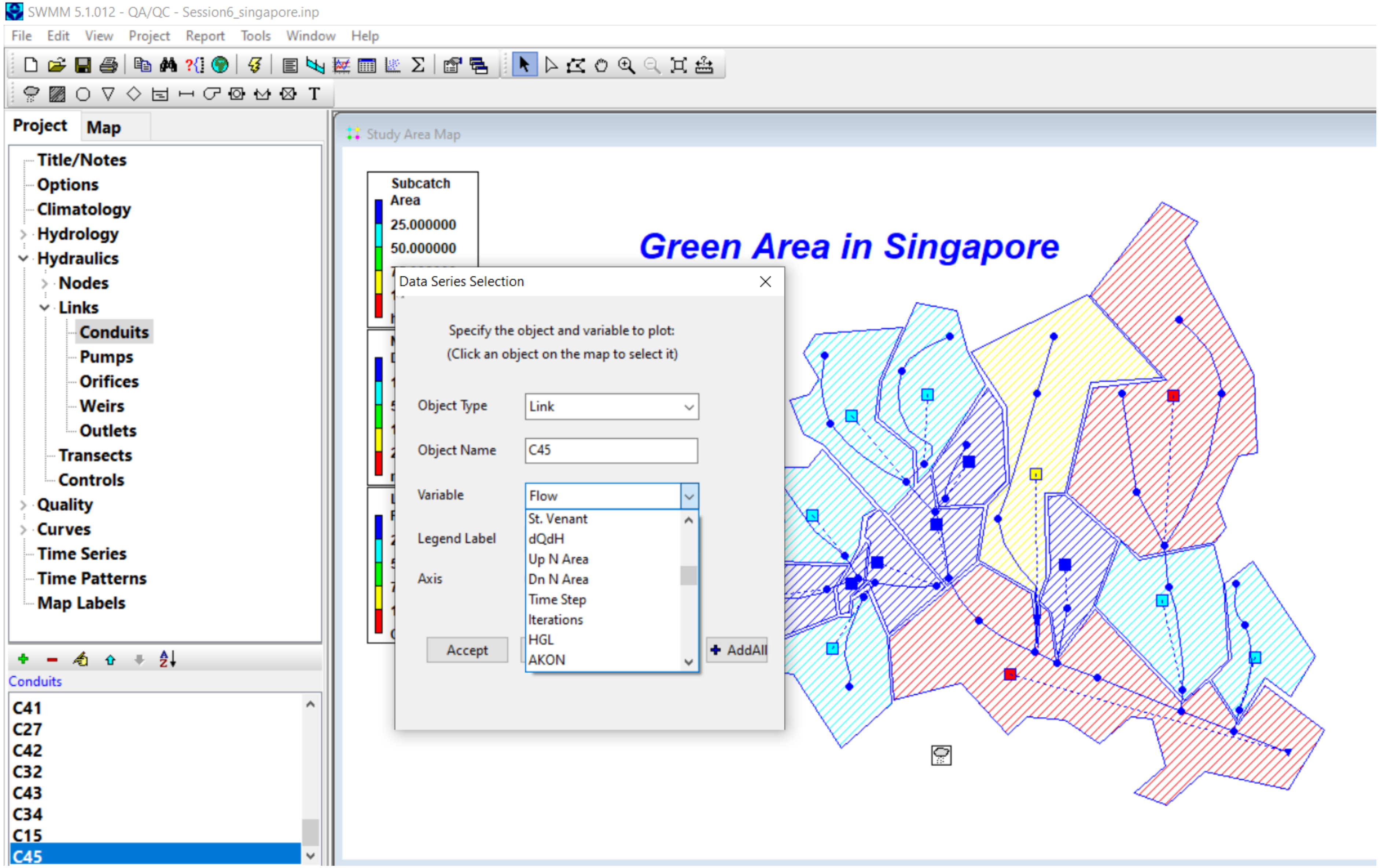
viewvars.txt - Notepad

File Edit Format View Help

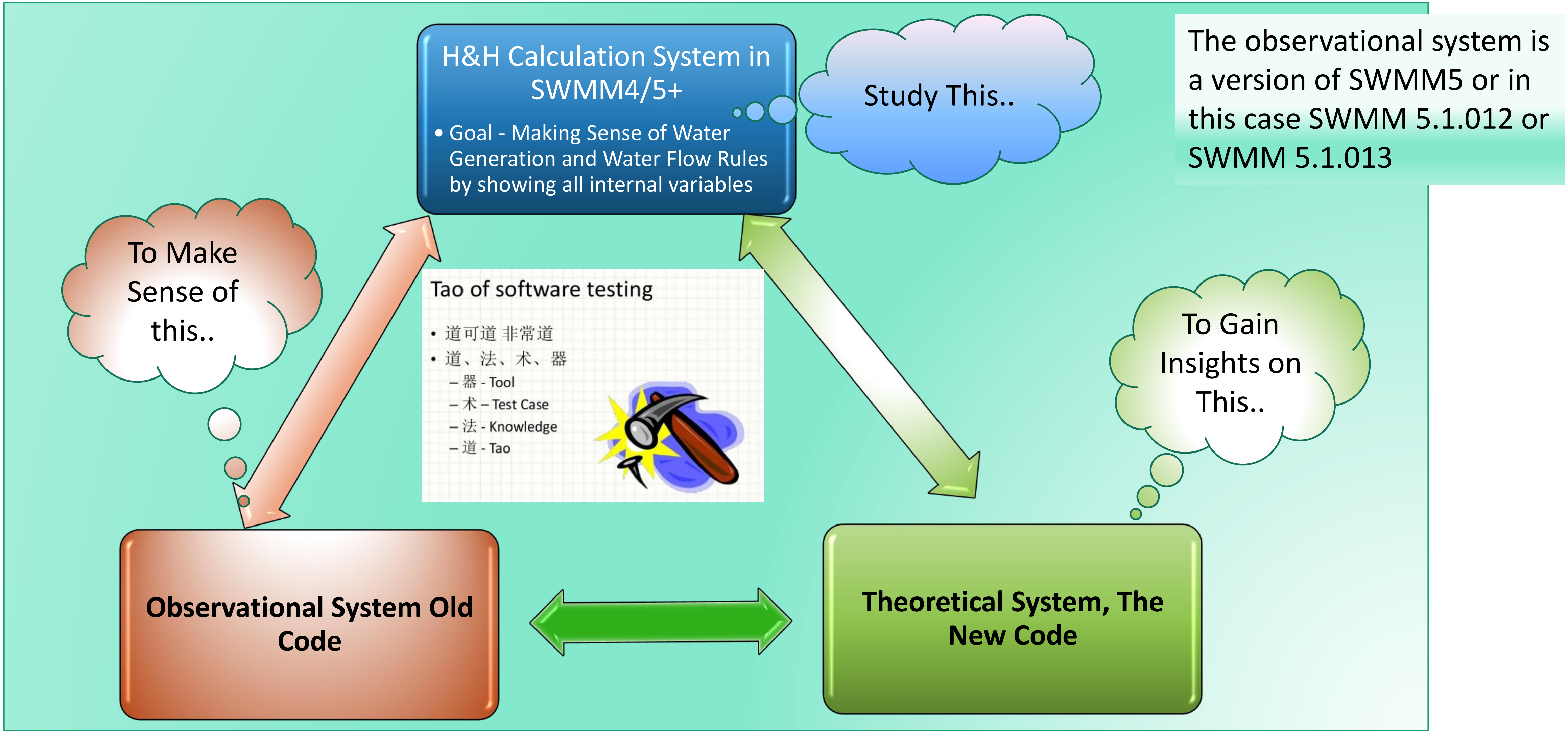
```
(Name: 'FU';
SourceIndex: 62;
DefIntervals: (25,50,75,100)),

(Name: 'Soil Moisture';
SourceIndex: 63;
DefIntervals: (25,50,75,100)),

(Name: 'IMD';
SourceIndex: 64;
DefIntervals: (25,50,75,100)),

(Name: 'IMDbyEvent';
SourceIndex: 65;
DefIntervals: (25,50,75,100)),

(Name: 'Soil Saturation';
SourceIndex: 66;
DefIntervals: (25,50,75,100)),

(Name: 'Infiltration Time';
SourceIndex: 67;
DefIntervals: (25,50,75,100)),

(Name: 'Infiltration Loss Only';
SourceIndex: 68;
DefIntervals: (25,50,75,100)),
```

Ln 1, Col 1

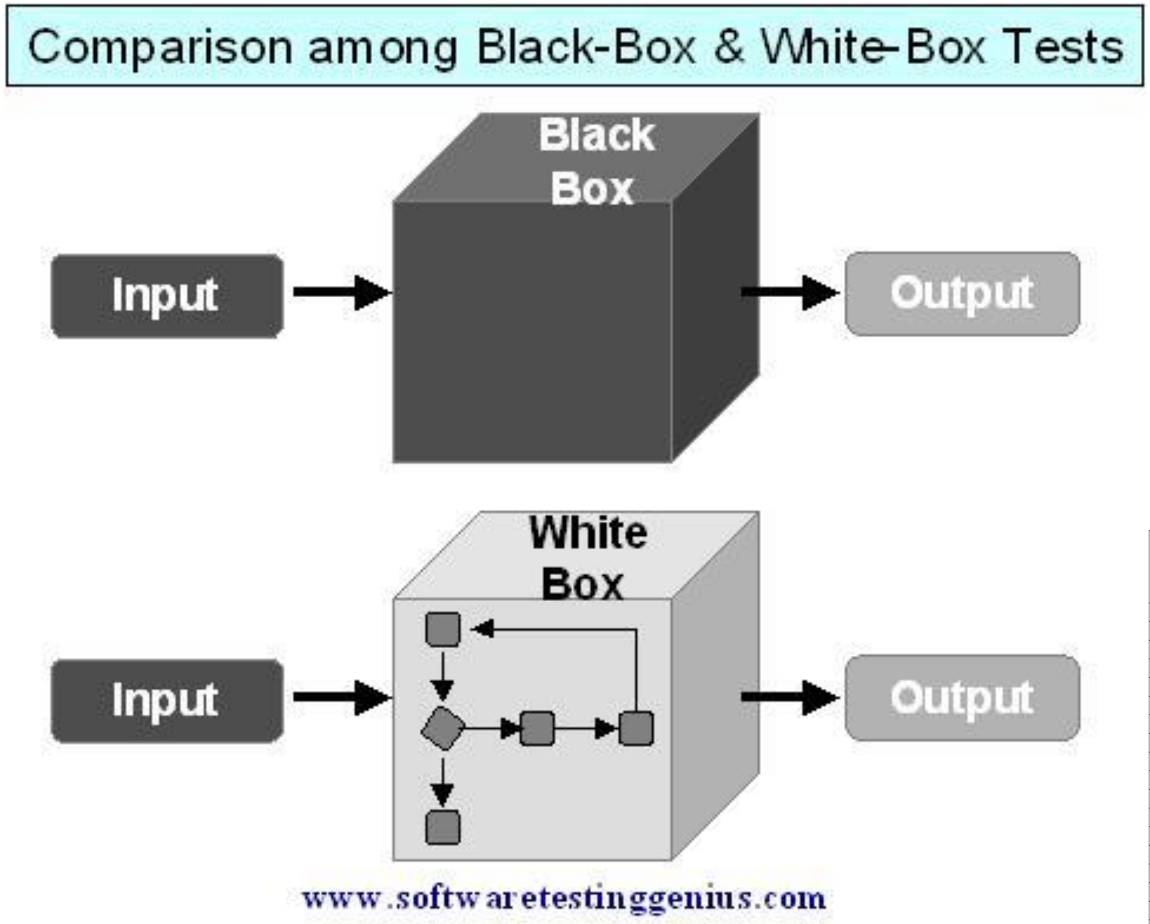
Lew Rossman Brilliant Architecture of SWMM5 Engine and UX Allows New Views of the Model



SWMM5.1.013 Simulations Versus Observation



SWMM5+ Testing as Black and White Boxes



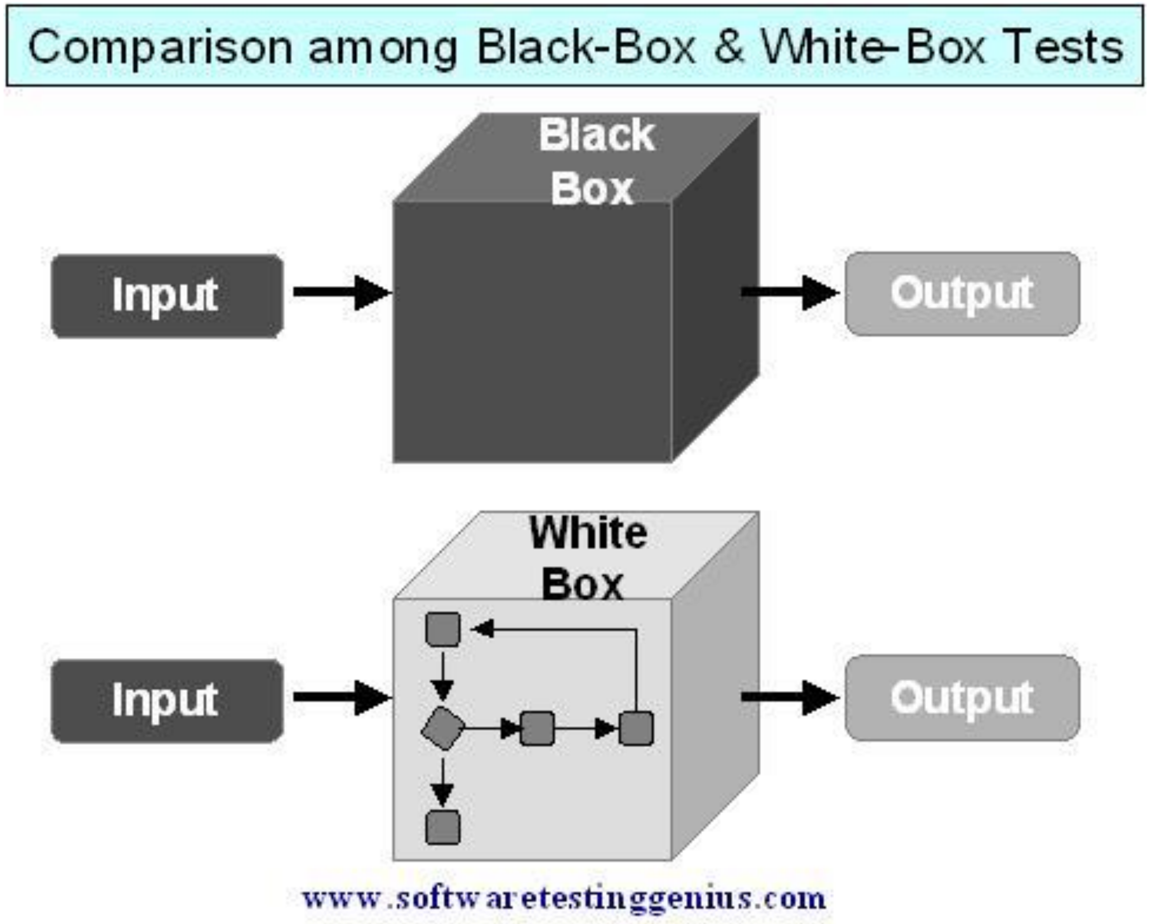
Objective Function (Fitness Evaluation Method) :

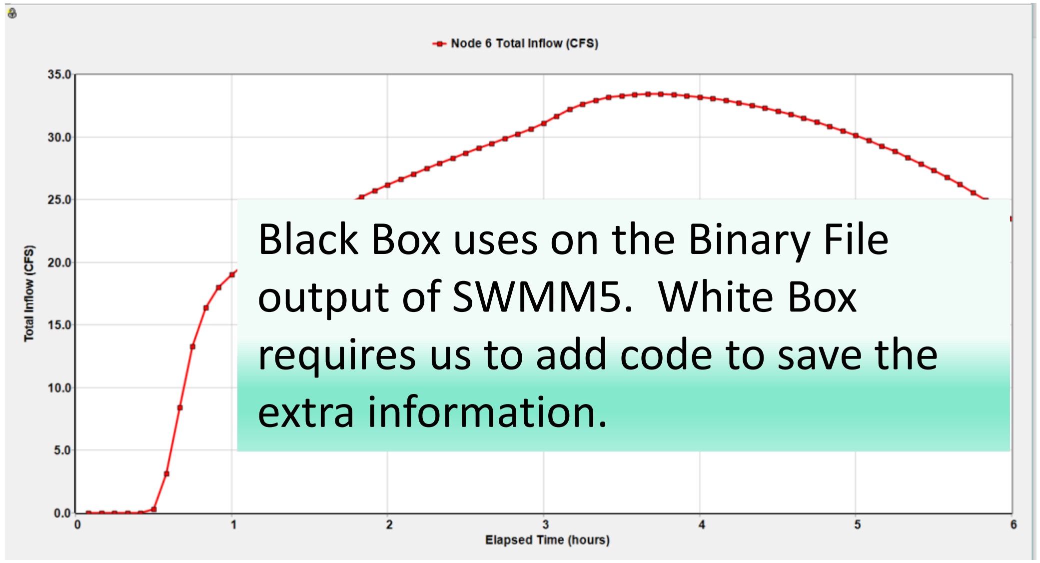
- Type #1: [RMSE] Root Mean Square Error (Ideal Value: 0.0)
- Type #2: [SLSE] Simple Least Square Error (Ideal Value: 0.0)
- Type #3: [MLSE] Mean Least Square Error (Ideal Value: 0.0)
- Type #4: [DTV] Difference in Total Volume (Ideal Value: 0.0)
- Type #5: [NSEC] Nash-Sutcliffe Efficiency Criterion (Ideal Value: 1.0)
- Type #6: [R-Square] R^2 (Ideal Value: 1.0)
- Type #7: [MCE] Modified Coefficient of Efficiency (Ideal Value: 1.0)
- Type #8: [DRMSE] Dimensionless Root Mean Square Error (Ideal Value: 0.0)
- Type #9: [DSLSE] Dimensionless Simple Least Square Error (Ideal Value: 0.0)

We want to combine Black Box and White Box Simulation Model Testing.

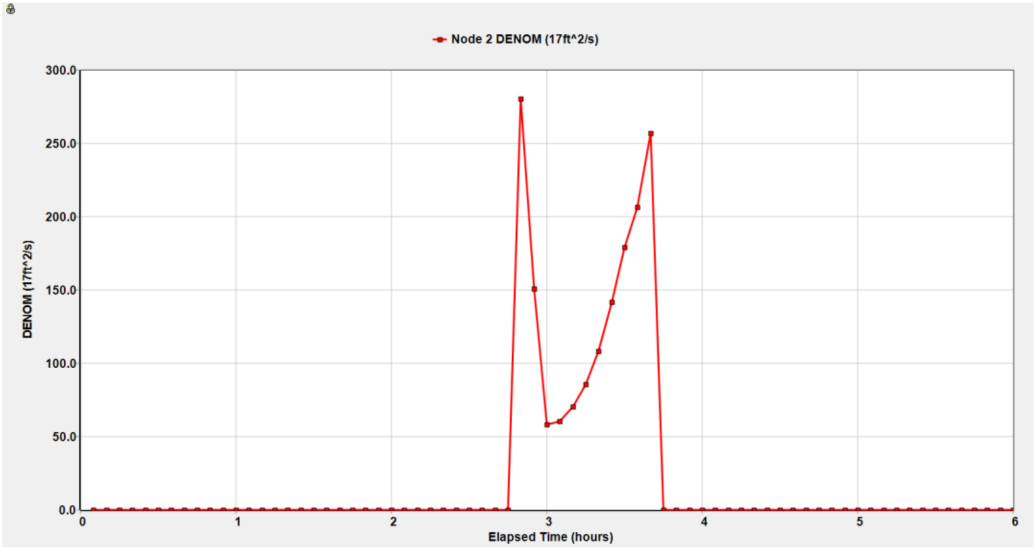
Days	Hours	UH2 (10cfs)	UH3 (11cfs)	DWFFlow (12cfs)	OUTFlow (13cfs)	INFlow (14cfs)	NODE_CE (15cfs)	DQDH (16ft^2/s)	DENOM (17ft^2/s)	Node F (18#)	YCROWN (19ft)
0	00:05:00	0.000	0.000	0.000	0.000	0.000	0.000	0.442	0.000	0.000	12.000
0	00:10:00	0.000	0.000	0.000	0.000	0.000	0.000	2.061	0.000	0.000	12.000
0	00:15:00	0.000	0.000	0.000	0.000	0.000	0.000	4.956	0.000	0.000	12.000
0	00:20:00	0.000	0.000	0.000	0.000	0.000	0.000	8.035	0.000	0.000	12.000
0	00:25:00	0.000	0.000	0.000	0.000	0.000	0.000	10.143	0.000	0.000	12.000
0	00:30:00	0.000	0.000	0.000	0.000	0.000	0.000	11.872	0.000	0.000	12.000
0	00:35:00	0.000	0.000	0.000	0.000	0.000	0.000	13.467	0.000	0.000	12.000
0	00:40:00	0.000	0.000	0.000	0.000	0.000	0.000	14.925	0.000	0.000	12.000
0	00:45:00	0.000	0.000	0.000	0.000	0.000	0.000	16.256	0.000	0.000	12.000
0	00:50:00	0.000	0.000	0.000	0.000	0.000	0.000	17.503	0.000	0.000	12.000
0	00:55:00	0.000	0.000	0.000	0.000	0.000	0.000	18.746	0.000	0.000	12.000
0	01:00:00	0.000	0.000	0.000	0.000	0.000	0.000	20.080	0.000	0.000	12.000
0	01:05:00	0.000	0.000	0.000	0.000	0.000	0.000	21.320	0.000	0.000	12.000
0	01:10:00	0.000	0.000	0.000	0.000	0.000	0.000	22.507	0.000	0.000	12.000
0	01:15:00	0.000	0.000	0.000	0.000	0.000	0.000	23.635	0.000	0.000	12.000
0	01:20:00	0.000	0.000	0.000	0.000	0.000	0.000	24.724	0.000	0.000	12.000
0	01:25:00	0.000	0.000	0.000	0.000	0.000	0.000	25.767	0.000	0.000	12.000
0	01:30:00	0.000	0.000	0.000	0.000	0.000	0.000	26.769	0.000	0.000	12.000
0	01:35:00	0.000	0.000	0.000	0.000	0.000	0.000	27.731	0.000	0.000	12.000
0	01:40:00	0.000	0.000	0.000	0.000	0.000	0.000	28.653	0.000	0.000	12.000
0	01:45:00	0.000	0.000	0.000	0.000	0.000	0.000	29.538	0.000	0.000	12.000
0	01:50:00	0.000	0.000	0.000	0.000	0.000	0.000	30.383	0.000	0.000	12.000
0	01:55:00	0.000	0.000	0.000	0.000	0.000	0.000	31.194	0.000	0.000	12.000

SWMM5+ Testing as Black and White Boxes





Black Box uses on the Binary File output of SWMM5. White Box requires us to add code to save the extra information.



SWMM5 Output Tables – Input Or Simulated

1. Pollutant Summary
2. Land Use Summary
3. Rain gage Summary
4. Subcatchment Summary
5. Node Summary
6. Link Summary
7. Cross Section Summary
8. Shape Summary
9. Transect Summary
10. LID Control Summary
11. LID Performance Summary
12. Rainfall File Summary
13. Rainfall Dependent I/I Summary
14. Routing Time Step Summary
15. Time-Step Critical Elements
16. Highest Flow Instability Indexes
17. Continuity Runoff Quantity
18. Continuity Runoff Quality
19. Continuity Flow Routing
20. Continuity Quality Routing
21. Subcatchment Runoff Summary
22. Groundwater Summary
23. Subcatchment Washoff Summary
24. Node Depth Summary
25. Node Inflow Summary
26. Node Surcharge Summary
27. Node Flooding Summary
28. Storage Volume Summary
29. Outfall Loading Summary
30. Link Flow Summary
31. Flow Classification Summary
32. Conduit Surcharge Summary
33. Pumping Summary
34. Link Pollutant Load Summary
35. Simulation Date and Time Summary
36. Detailed Node, Link and Subcatchments

SWMM5 Native Output Variables

1. air temperature (degrees F or C)
2. total rainfall (in/hr or mm/hr)
3. total snow depth (in or mm)
4. average losses (in/hr or mm/hr)
5. total runoff flow (flow units)
6. total dry weather inflow (flow units)
7. total groundwater inflow (flow units)
8. total RDII inflow (flow units)
9. total direct inflow (flow units)
10. total external inflow (flow units)
11. total external flooding (flow units)
12. total outflow from outfalls (flow units)
13. total nodal storage volume (ft^3 or m^3)
14. actual evaporation (in or mm)
15. potential ET (in or mm)

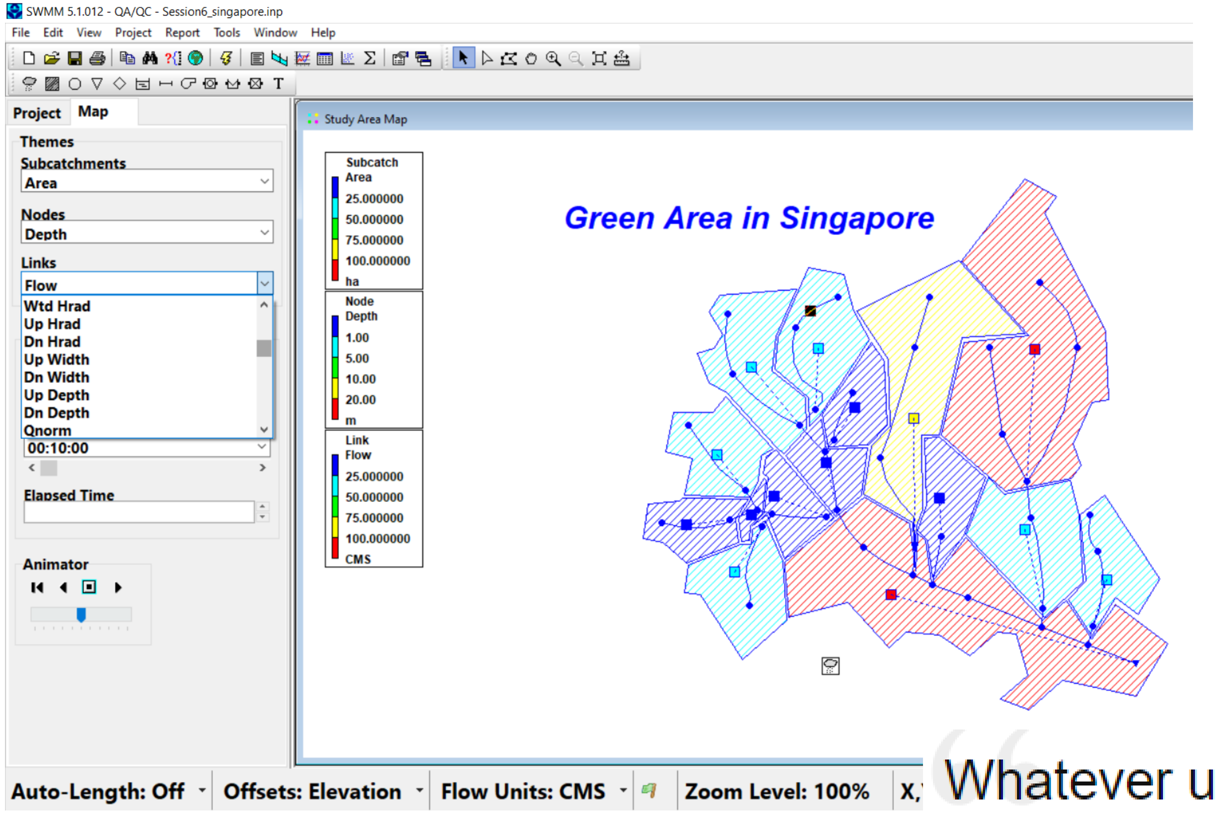
System Wide Output Variables

1. **Link** low rate (flow units)
2. average water depth (ft or m)
3. flow velocity (ft/sec or m/sec)
4. volume of water (ft3 or m3)
5. capacity (fraction of full area filled by flow for conduits; control setting for pumps and regulators)
6. concentration of each pollutant (mass/liter)

7. **Node** water depth (ft or m above the node invert elevation)
8. hydraulic head (ft or m, absolute elevation per vertical datum)
9. stored water volume (including ponded water, ft^3 or m^3)
10. lateral inflow (runoff + all other external inflows, in flow units)
11. total inflow (lateral inflow + upstream inflows, in flow units)
12. surface flooding (excess overflow when the node is at full depth, in flow units)
13. concentration of each pollutant after any treatment applied at the node (mass/liter)

14. **Subcatcatchment** rainfall rate (in/hr or mm/hr)
15. snow depth (in or mm)
16. evaporation loss (in/day or mm/day)
17. infiltration loss (in/hr or mm/hr)
18. runoff flow (flow units)
19. groundwater flow into the drainage network (flow units)
20. groundwater elevation (ft or m)
21. soil moisture in the unsaturated groundwater zone (volume fraction)
22. washoff concentration of each pollutant (mass/liter)

Now there is too Much Output



- 20+ Metrics
- Subcatchment
- Link
- Node
- System

We want robust complex comparisons that are simple to grasp but backed up by other more rigorous statistics.

"Whatever universe a professor believes in must at any rate be a universe that lends itself to lengthy discourse. A universe definable in two sentences is something for which the professorial intellect has no use. No faith in anything of that cheap kind!

William James the Philosopher

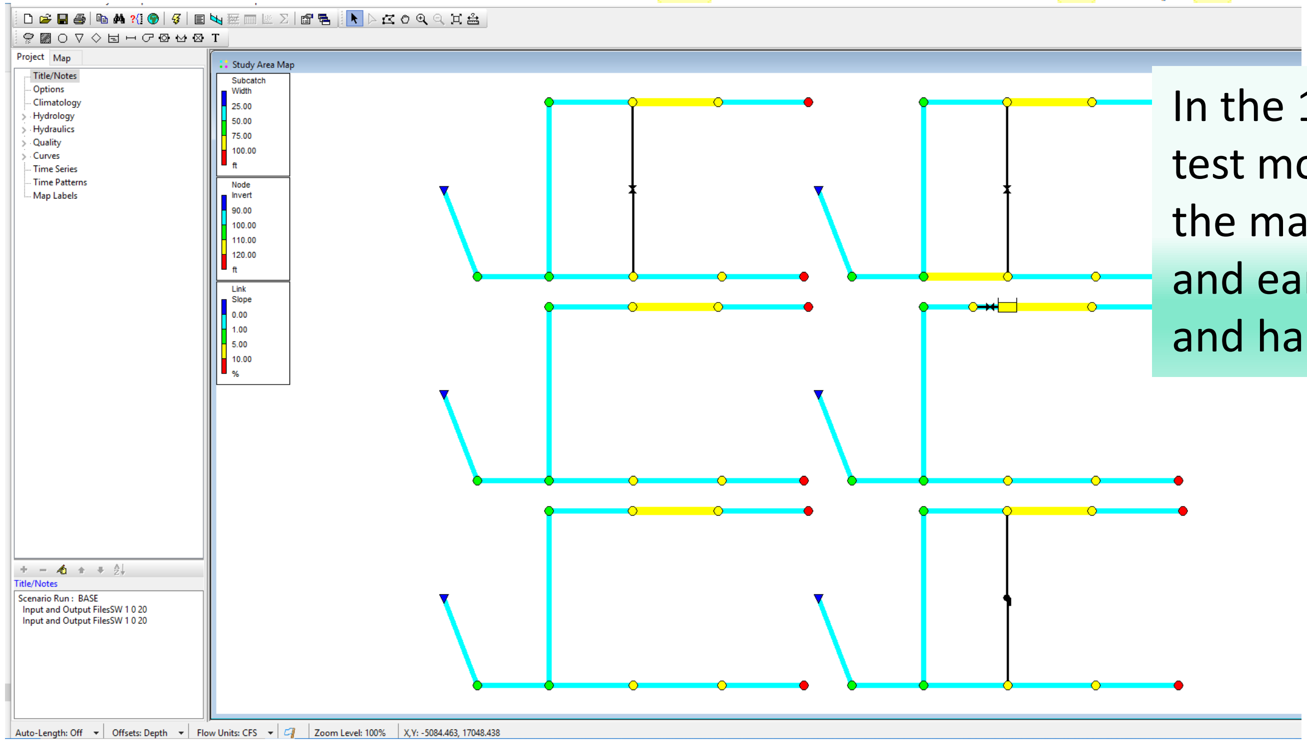
William James

SWMM 1, 2, 3, 3.5, Extran 3 Test Models

n swmm_crada_files

Name	Date modified	Type	Size	Folder
SWDAT1.DAT	5/19/1989 8:39 AM	DAT File	27 KB	SWMM4 (D:\SWM...
SWDAT2.DAT	2/16/1989 4:07 PM	DAT File	6 KB	SWMM4 (D:\SWM...
SWDAT3.DAT	5/27/1989 10:35 AM	DAT File	6 KB	SWMM4 (D:\SWM...
SWDAT4.DAT	5/19/1989 7:17 AM	DAT File	5 KB	SWMM4 (D:\SWM...
SWDAT5.DAT	5/18/1989 2:36 PM	DAT File	6 KB	SWMM4 (D:\SWM...
SWDAT6.DAT	5/30/1989 7:41 AM	DAT File	1 KB	SWMM4 (D:\SWM...

- Limited Tests
- Slow
- Mainframes



In the 1970's, 1980's the test models were small as the mainframe computers and early PC's were slow and hard to use.

SWMM 4/5 Test Models

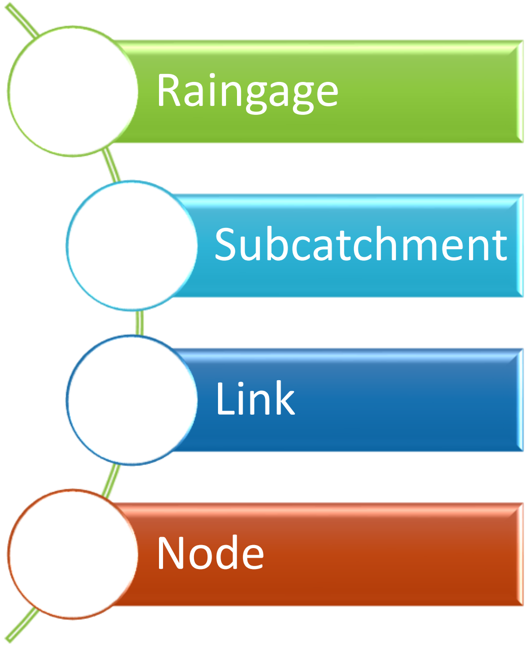
- More Tests
- Faster
- Tools on PC

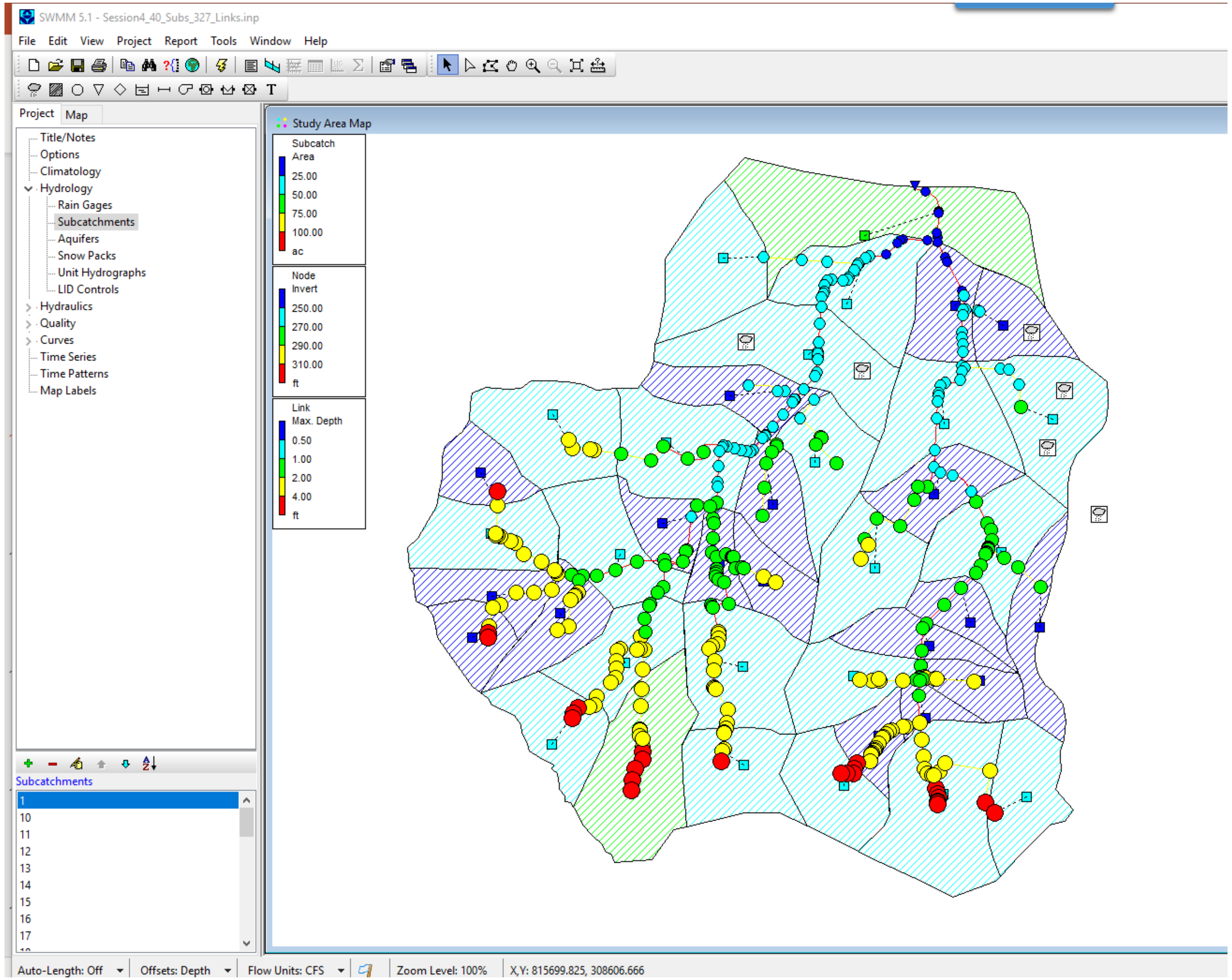
SWMM4 and SWMM5 had hundreds of test models but they were also small and did not cover ALL of the SWMM4 or SWMM5 code. SWMM4 is post 1988 and SWMM 5 post 2001/2002.

All Files > SWMM5 QAQC Files

Name	Updated	Size
More Complicated QA QC Files for SWMM 5	Jun 28, 2018 by Robert Dickinson	17 Files
Other SWMM5 Files	Jun 28, 2018 by Robert Dickinson	594 Files
SWMM 5 Files from SWMM4 Extran	Jun 28, 2018 by Robert Dickinson	160 Files
SWMM5 Files from SWMM4 Runoff	Jun 28, 2018 by Robert Dickinson	266 Files

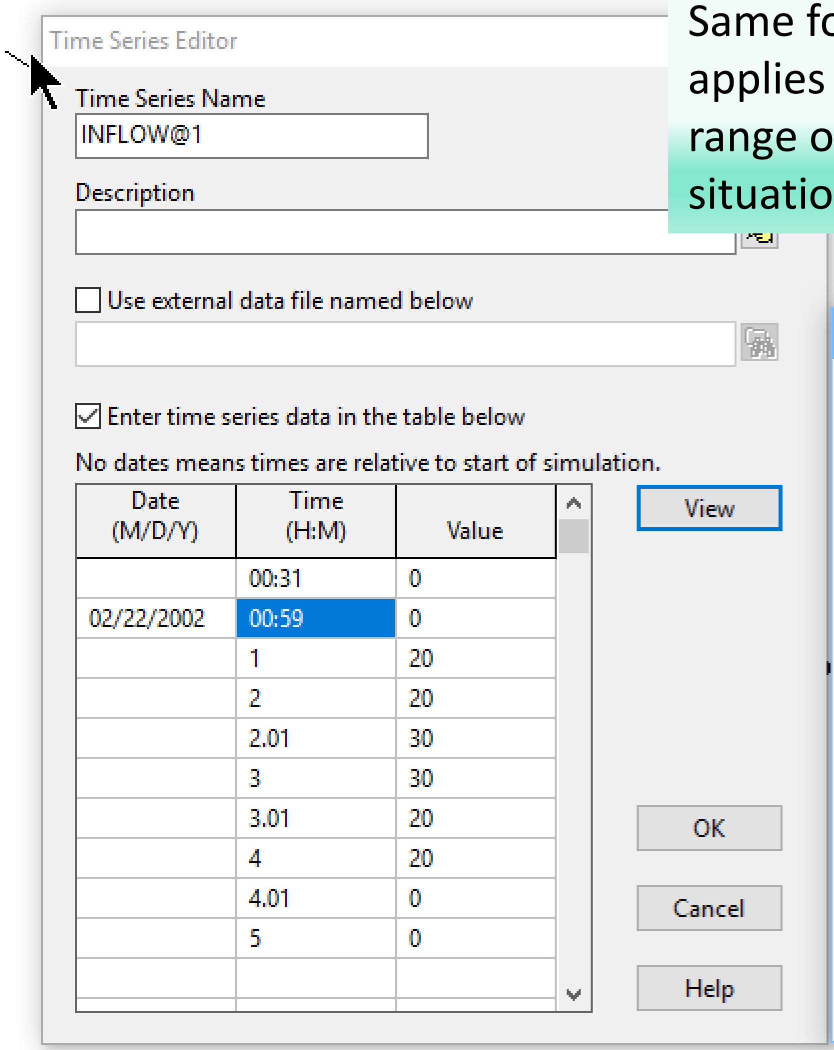
All Test Models have the Same ID’s



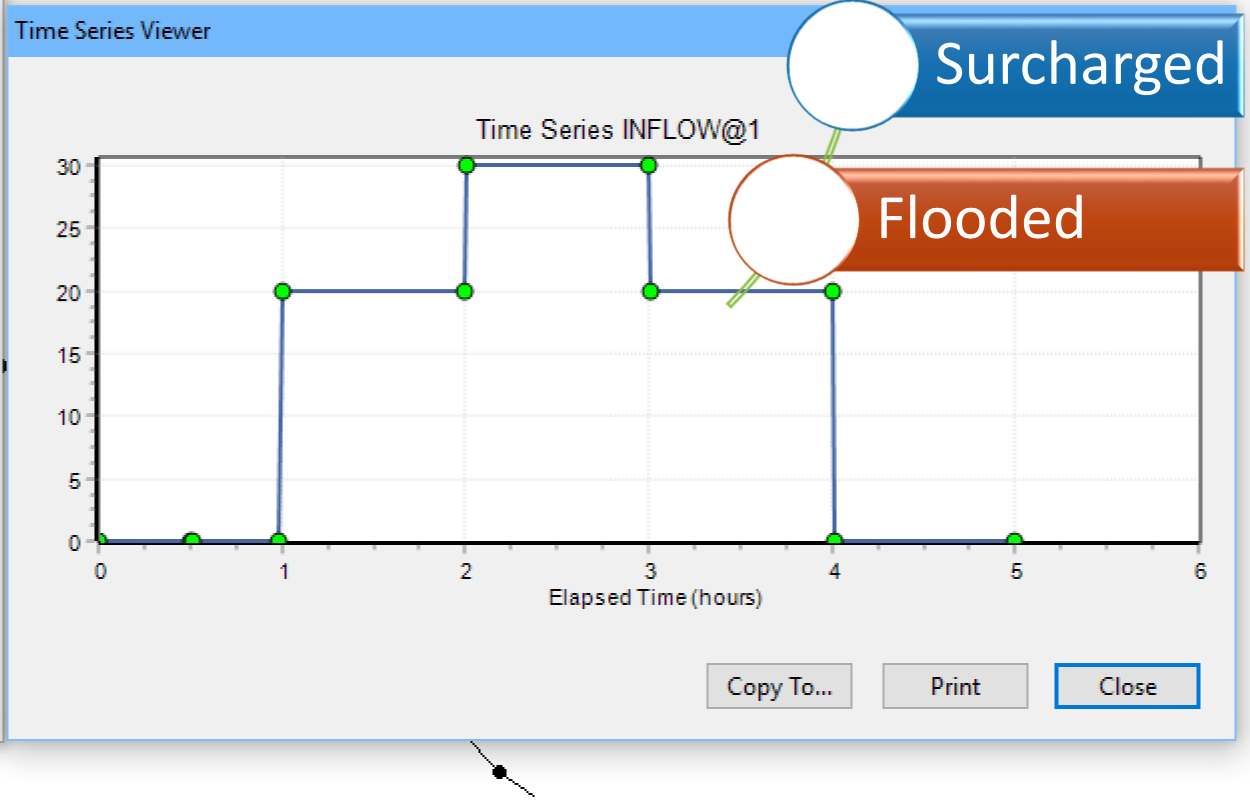


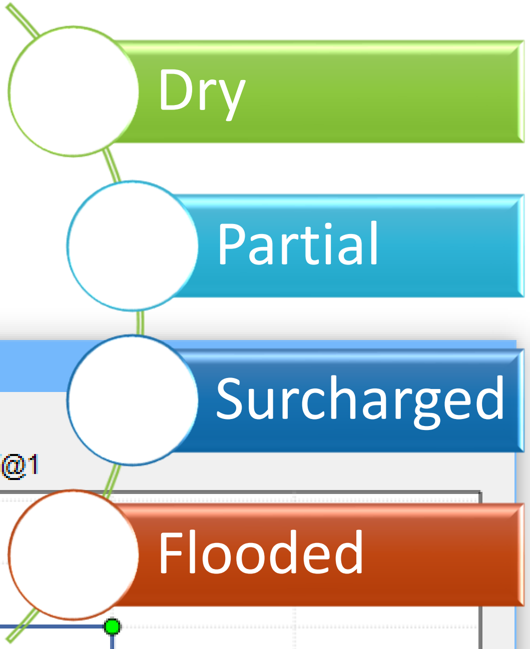
Step 5 for Testing – All Simulation Models have the same ID’s. Nodes, Links and Subcatchments/Raingages.

Forcing Function for Hydraulics

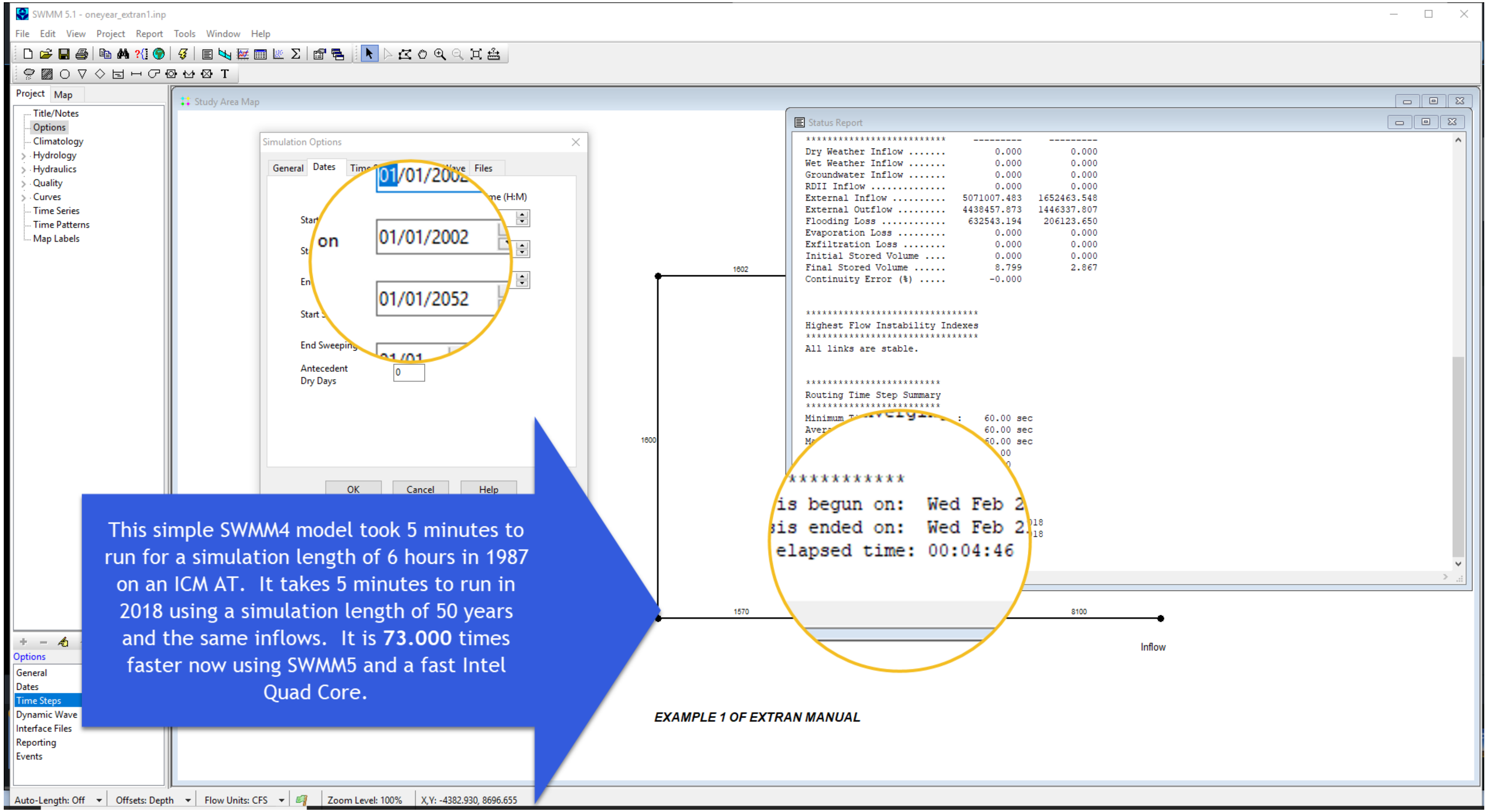


Same forcing function or time series applies to all models showing the range of possible hydraulics situations.



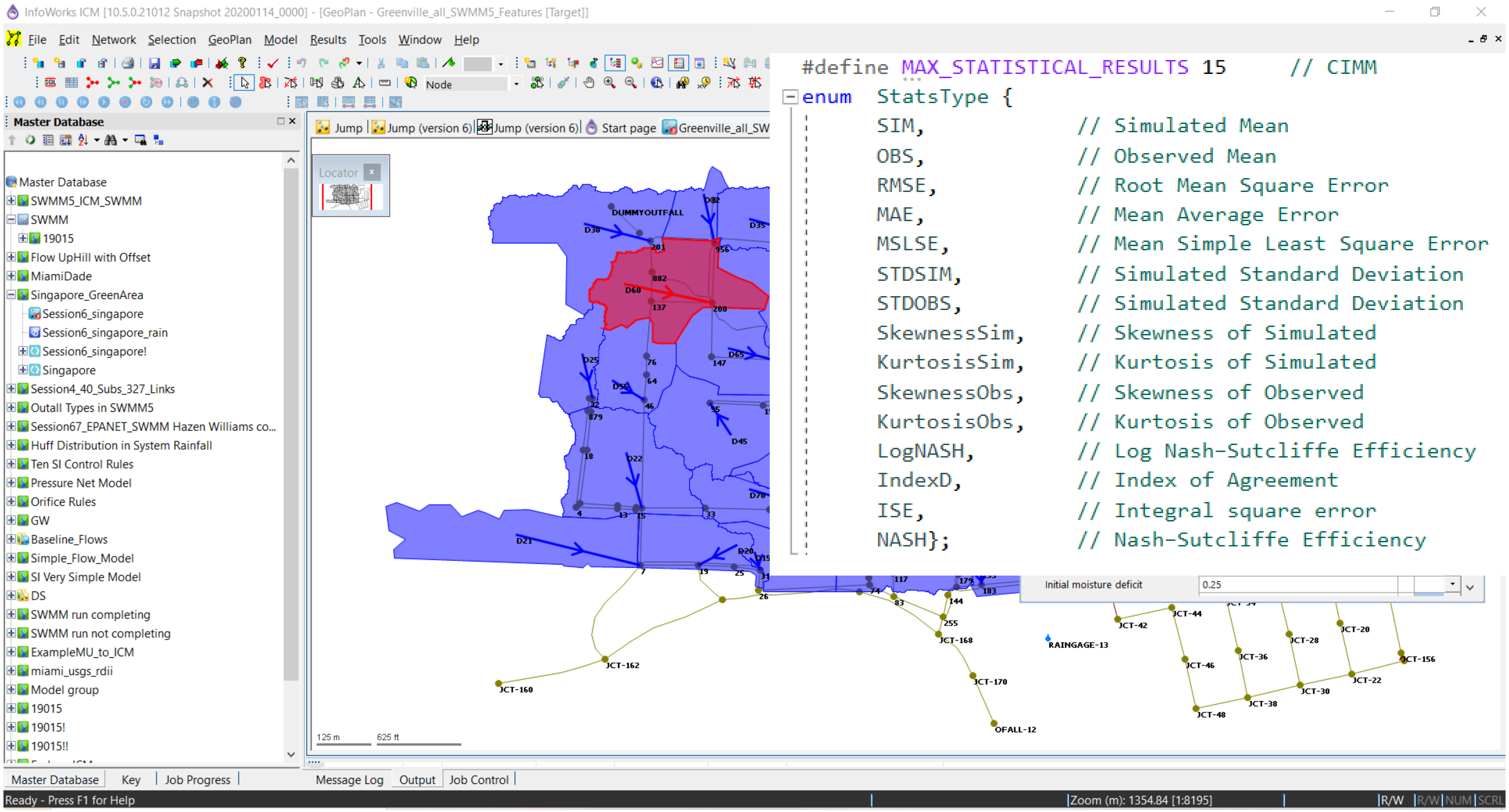


Base Extran/SWMM4 Model from 1987

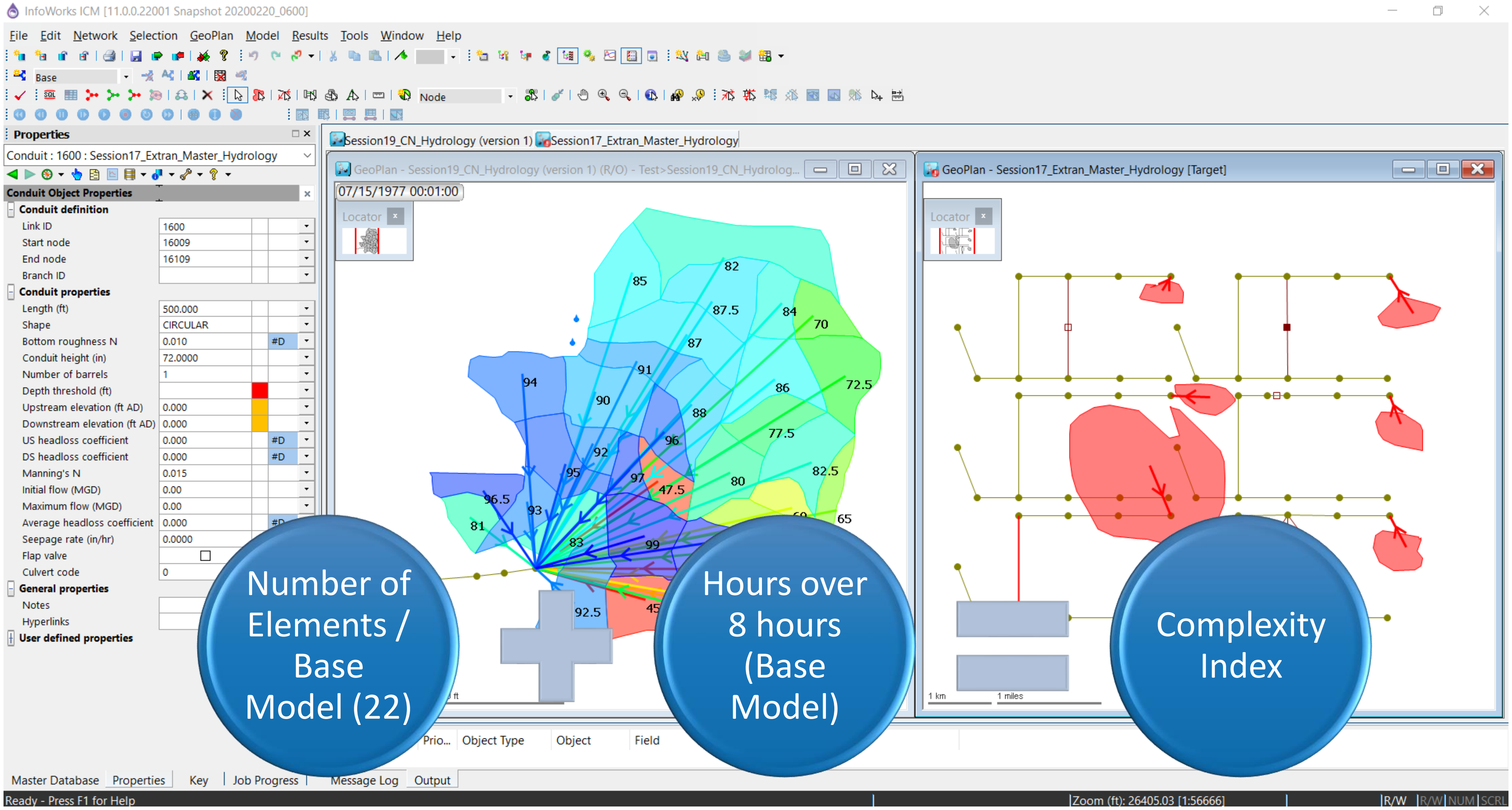


This simple SWMM4 model took 5 minutes to run for a simulation length of 6 hours in 1987 on an ICM AT. It takes 5 minutes to run in 2018 using a simulation length of 50 years and the same inflows. It is **73.000** times faster now using SWMM5 and a fast Intel Quad Core.

15+ Statistical Methods for Each Element



Complexity Index based on 2000+ Text Models / Base Model



SWMM Output API from OWA

```c
#define MAX_STATISTICAL_RESULTS 17     // NCIMM
enum  StatsType {
        SIM,            // Simulated Mean
        OBS,            // Observed Mean
        RMSE,           // Root Mean Square Error
        MAE,            // Mean Average Error
        MSLSE,          // Mean Simple Least Square Error
        STDSIM,         // Simulated Standard Deviation
        STDOBS,         // Simulated Standard Deviation
        SkewnessSim,    // Skewness of Simulated
        KurtosisSim,    // Kurtosis of Simulated
        SkewnessObs,    // Skewness of Observed
        KurtosisObs,    // Kurtosis of Observed
        LogNASH,        // Log Nash-Sutcliffe Efficiency
        IndexD,         // Index of Agreement
        ISE,            // Integral square error
        KGE,            // Kling-Gupta
        R,              // Correlation coefficient
        NASH};          // Nash-Sutcliffe Efficiency
```

swmm_output.c | output.c | objects.h | rain.c | rdii.c | routing.c | massbal.c

SWMM55.013_June2018-DLL | (Global Scope)

```c
/*
 * swmm_output.c - SWMM Output API
 *
 *      Author: Colleen Barr
 *          US EPA - ORD/NHEERL
 *
 *      Modified by: Michael E. Tryby,
 *                   Bryant McDonnell
 *
 */

#include "swmm_output.h"

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include "errormanager.h"
#include "messages.h"
//#include "datetime.h"
#define _CRT_SECURE_NO_DEPRECATE
```

Our Statistical Measures are computed using OWA SWIG related C code for reading a binary file in SWMM5.

Model Network SWMM5 Process Coverage

```
Opening C:\SWMMandSoftware\SWMM5.013_June2018\EPASWMM5.1.013\Swmm5.1.013UpdateTests\SWMM5_NCIMM\lakes.inp
 Number of rain gages ......       1   Number of subcatchments ...   1653   Number of LID Controls. ...   1653   LID Coverage..............      0
 Number of outfalls.........      27   Number of dividers.........      0   Number of storages.........    128   Number of nodes ...........   2417
 Number of links ...........    2921   Number of pumps..... ......      0   Number of weirs.. .........     46   Number of Transects........      8
 Number of Conduits ........    2875   Number of orifices.. ......      0   Number of outlets .........      0   Number of control rules....      0
 Number of curves...........     153   Number of aquifers. .......      0   Number of unit hydrographs.      0
 Number of time series......       1   Number of patterns. .......      0   Number of shapes... .......      0
 Number of snowmelt.........       0   Number of pollutants ......      0   Number of land uses .......      0
 Flow Units .................. CFS   Surcharge Method ......... EXTRAN   Rainfall/Runoff ............. YES
 RDII ........................ NO    Snowmelt .....................  NO   Groundwater .................. NO
 Infiltration Method .  GREEN_AMPT   Flow Routing Method ..... DYNWAVE   Water Quality ...............  NO
 Maximum Trials ...........      8   Number of Threads ........      8   Head Tolerance ......... 0.005000
 Routing Time Step ........  30.00   Wet Time Step .......... 00:00:30   Dry Time Step .......... 00:00:00
 Variable Time Step .......... YES   Ponding Allowed .............  NO
 Complexity Index......... 1906.91   Total Duration............  48.00
```

```
 Opening C:\SWMMandSoftware\SWMM5.013_June2018\EPASWMM5.1.013\Swmm5.1.013UpdateTests\Hydrology\125_Subs_Horton.inp
 Number of rain gages ......       1   Number of subcatchments ...    125   Number of LID Controls. ...    125   LID Coverage..............      0
 Number of outfalls.........      35   Number of dividers.........      0   Number of storages.........      1   Number of nodes ...........    881
 Number of links ...........     881   Number of pumps..... ......      3   Number of weirs.. .........     11   Number of Transects........      0
 Number of Conduits ........     863   Number of orifices.. ......      3   Number of outlets .........      1   Number of control rules....      4
 Number of curves...........      10   Number of aquifers. .......      1   Number of unit hydrographs.     31
 Number of time series......      10   Number of patterns. .......     32   Number of shapes... .......      4
 Number of snowmelt.........       0   Number of pollutants ......      0   Number of land uses .......      0
 Flow Units .................. CFS   Surcharge Method ......... EXTRAN   Rainfall/Runoff ............. YES
 RDII ........................ YES   Snowmelt ....................  NO   Groundwater .................YES
 Infiltration Method .      HORTON   Flow Routing Method ..... DYNWAVE   Water Quality ...............  NO
 Maximum Trials ...........      8   Number of Threads ........      1   Head Tolerance ......... 0.005000
 Routing Time Step ........  60.00   Wet Time Step .......... 00:05:00   Dry Time Step .......... 01:00:00
 Variable Time Step .......... YES   Ponding Allowed .............  NO
 Complexity Index......... 8238.55   Total Duration............ 768.00
```

EPA SWMM5 has Over 500 Functions or Units

```
//-----------------------------------------------------------------------------
//   Conveyance System Node Methods
//-----------------------------------------------------------------------------
int     node_readParams(int node, int type, int subIndex, char* tok[], int ntoks);
void    node_validate(int node);

void    node_initState(int node);
void    node_initInflow(int node, double tStep);
void    node_setOldHydState(int node);
void    node_setOldQualState(int node);

void    node_setOutletDepth(int node, double yNorm, double yCrit, double z);
void    node_setDividerCutoff(int node, int link);

double  node_getSurfArea(int node, double depth);
double  node_getDepth(int node, double volume);
double  node_getVolume(int node, double depth);
double  node_getPondedArea(int node, double depth);

double  node_getOutflow(int node, int link);
double  node_getLosses(int node, double tStep);
double  node_getMaxOutflow(int node, double q, double tStep);
double  node_getSystemOutflow(int node, int *isFlooded);
void    node_getResults(int node, double wt, float x[]);
```

UNIT TESTING is a level of software **testing** where individual **units**/ components of a software are tested. The purpose is to validate that each **unit** of the software performs as designed.
A **unit** is the smallest testable part of any software. It usually has one or a few inputs and usually a single output.

SWMM5.1.013 Generation of Calibration Files

```
EXTERN TFile
Finp,                    // Input file
Fout,                    // Output file
Frpt,                    // Report file
Fclimate,                // Climate file
Frain,                   // Rainfall file
Frunoff,                 // Runoff file
Frdii,                   // RDII inflow file
Fhotstart1,              // Hot start input file
Fhotstart2,              // Hot start output file
Finflows,                // Inflows routing file
Foutflows,               // Outflows routing file
Flog,                    // Other SWMM5 Output File Comparion log    // NCIUMM 2018
FoutCompare,             // Other SWMM5 Output File                  // "
Fall_log,                // All log files combined                   // "
FcalibrationS,           // Calibration file Innovyze RED 2016       // Storage Vol
FcalibrationR,           // Calibration file Innovyze RED 2016          Runoff
FcalibrationE,           // Calibration file Innovyze RED 2016          Groundwater
FcalibrationG,           // Calibration file Innovyze RED 2016          Groundwater
FcalibrationH,           // Calibration file Innovyze RED 2016          Node Depth
FcalibrationNH,          // Calibration file Innovyze RED 2016          Node Head
FcalibrationNF,          // Calibration file Innovyze RED 2016          Node Floodi
FcalibrationL,           // Calibration file Innovyze RED 2016          Node Latera
FcalibrationQ,           // Calibration file Innovyze RED 2016          Link Q
FcalibrationV,           // Calibration file Innovyze RED 2016          Link V
FcalibrationD,           // Calibration file Innovyze RED 2016          Link D
FcalibrationHGL,         // Calibration file Innovyze RED 2016          Link HGL
FcalibrationNA,          // Calibration file Innovyze RED 2018          Node Area
FcalibrationNSA;         // Calibration file Innovyze RED 2018          Node DQDH
```

› SWMMandSoftware › SWMM5.013_June2018 › EPASWMM5.1.013 › Swmm5.1.013UpdateTests

Name	Date modified	Type	Size
Calibration_Files	1/27/2019 1:11 PM	File folder	
DataFiles	1/27/2019 12:54 PM	File folder	
Hydraulics	1/28/2019 3:17 PM	File folder	
Hydrology	1/27/2019 2:15 PM	File folder	
InfoSWMM Model Folders	2/24/2019 5:25 PM	File folder	
LEW_update_v5113	1/27/2019 1:11 PM	File folder	
LID	1/27/2019 1:11 PM	File folder	
NCIMM_ROUTING	1/8/2019 9:00 AM	File folder	
Orifices	1/9/2019 7:33 PM	File folder	
OWA_EXAMPLES	1/27/2019 1:11 PM	File folder	
OWA_EXTRAN	1/27/2019 1:11 PM	File folder	
OWA_ROUTING	1/27/2019 1:11 PM	File folder	
OWA_update_v5111	1/27/2019 1:11 PM	File folder	
OWA_USER	1/27/2019 1:11 PM	File folder	
Pumps	1/13/2019 5:21 PM	File folder	
SWMM5_NCIMM	2/13/2019 11:48 PM	File folder	
v12	2/25/2019 3:57 PM	File folder	
v13	2/25/2019 4:47 PM	File folder	
Weirs	1/13/2019 5:27 PM	File folder	
WQ	12/19/2018 6:09 PM	File folder	
XPSWMM	1/22/2019 12:01 PM	File folder	
cleanup.bat	1/27/2019 12:57 PM	Windows Batch File	4 KB
hydraulics_only.bat	1/11/2019 7:39 PM	Windows Batch File	28 KB
hydrology_only.bat	1/11/2019 9:46 PM	Windows Batch File	32 KB
make_dir.bat	11/8/2018 9:20 AM	Windows Batch File	1 KB
NCIMM_REGRESSION_STATS.BAT	1/11/2019 9:44 PM	Windows Batch File	75 KB
OWA_ONLY.BAT	1/27/2019 12:58 PM	Windows Batch File	27 KB
SWMM5.DLL	1/25/2019 9:18 PM	Application extens...	425 KB
SWMM5.EXE	1/1/2019 8:20 PM	Application	110 KB

Bill James Model Similarity Score based on System Variables

25. Baffaut (1988) sequentially ranked the objectives of her modeling effort, considering that: firstly, the runoff volumes should be correct, on the average; secondly, the peak discharges should match, on the average; thirdly, the times-to-peak should be correct on the average; and lastly, the root mean square of the hydrograph shape should match on the average. To avoid the problem of an evidently poor evaluation being computed for a relatively small error in timing, but for an otherwise good fit, the standard square error of the shape was weighted 0.7, and the volume 0.3.

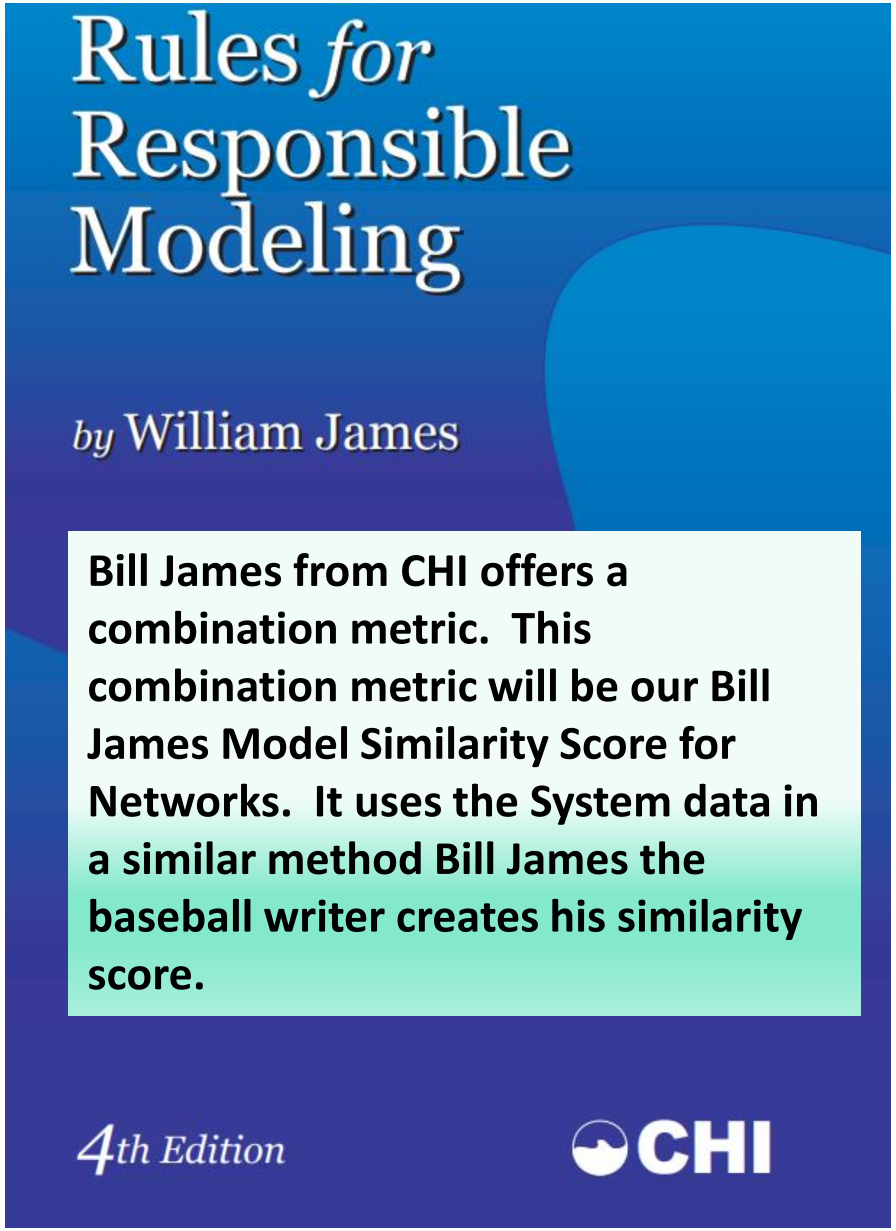
The equations used are:

$$\text{volume difference} = \frac{1}{N}\sum \frac{V_m - V_p}{V_m}$$

$$\text{peak difference} = \frac{1}{N}\sum \frac{P_m - P_p}{P_m}$$

Performance Evaluation Functions 201

$$\text{time difference} = \frac{1}{N}\sum \left(T_m - T_p\right)$$

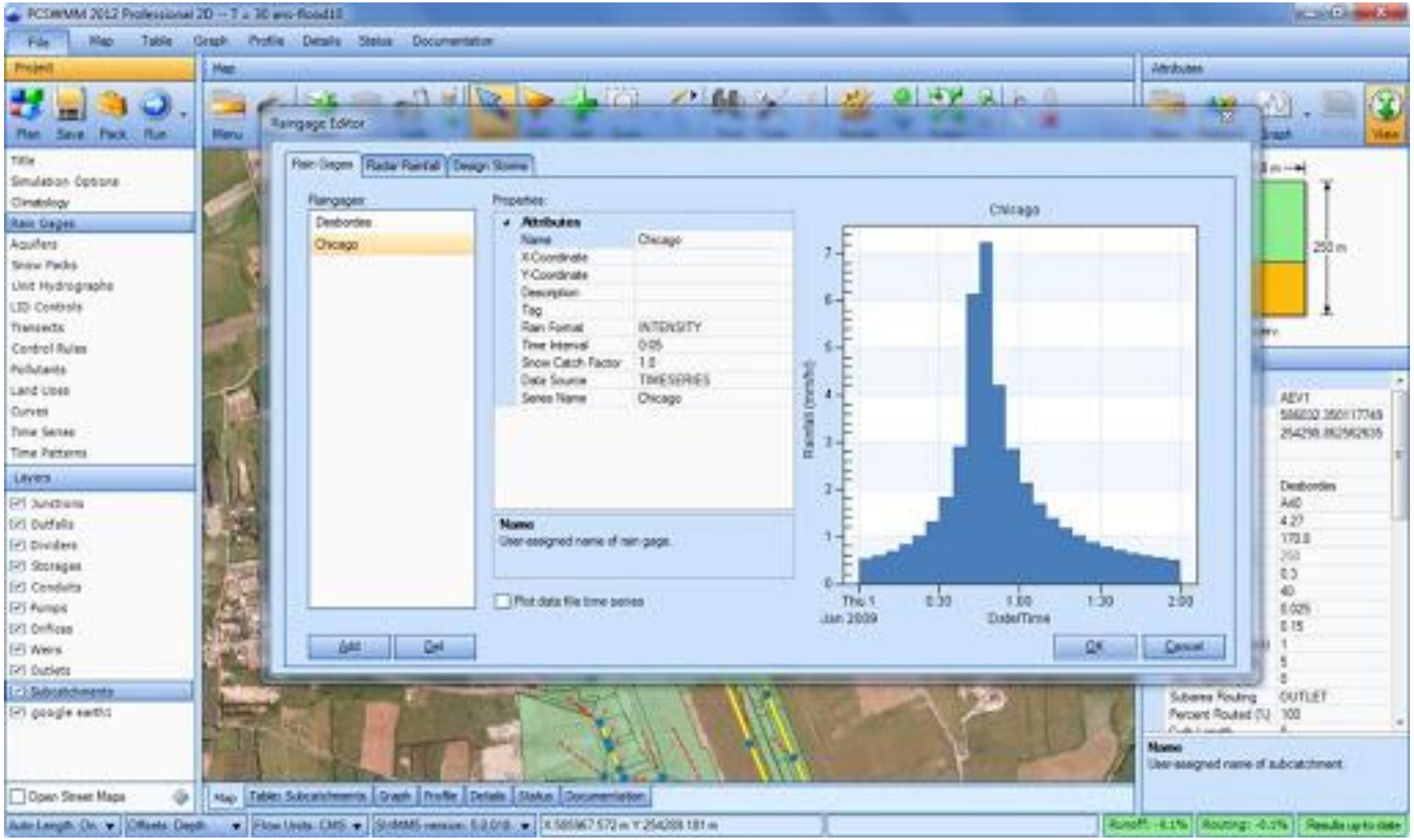


Bill James from CHI offers a combination metric. This combination metric will be our Bill James Model Similarity Score for Networks. It uses the System data in a similar method Bill James the baseball writer creates his similarity score.

The Bill James – SWMM5 Similarity Score

A Similar SWMM 5 Model has a score of 1000.

For each volume, peak and timing difference for the System Wide Variables subtract 1 score for each percent difference.



Thank You, SWMM Users, CHI and Bill James!

Thank You, Other Canadians Anthony Kuch, Mike Gregory and Rob James for at least 24 years of help with SWMM.