Estimating Daily Time Series for Pennsylvania Streams – An Application of the Map Correlation Method

Marla Stuckey, PA WSC
Edward Koerkle, PA WSC
James Ulrich, PA WSC

SRBC Water Quality Advisory Committee
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Project Background

- Pennsylvania is working on developing and implementing environmental flow criteria for long-term sustainable management of water in PA's rivers
- Objective: To develop a tool that will simulate a baseline daily flow time series (1960-2008) for ungaged stream locations within PA
  - Define set of index gages
  - Link ungaged stream locations to an appropriate index gage using map correlation method (Archfield 2010)
  - Simulate baseline streamflow conditions at a daily time step using QPPQ approach

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Defining Index Gages

- A composite of the upstream land cover/basin characteristics that can be used to represent other watersheds with similar characteristics
- Initial criteria:
  - Minimal regulation/water use/mining
  - 15% maximum urban development (was relaxed)
  - 15-year minimum period of record during period of 1960-2008 (was relaxed)
- Record was extended, if necessary, to include 1960-2008 using MOVE1

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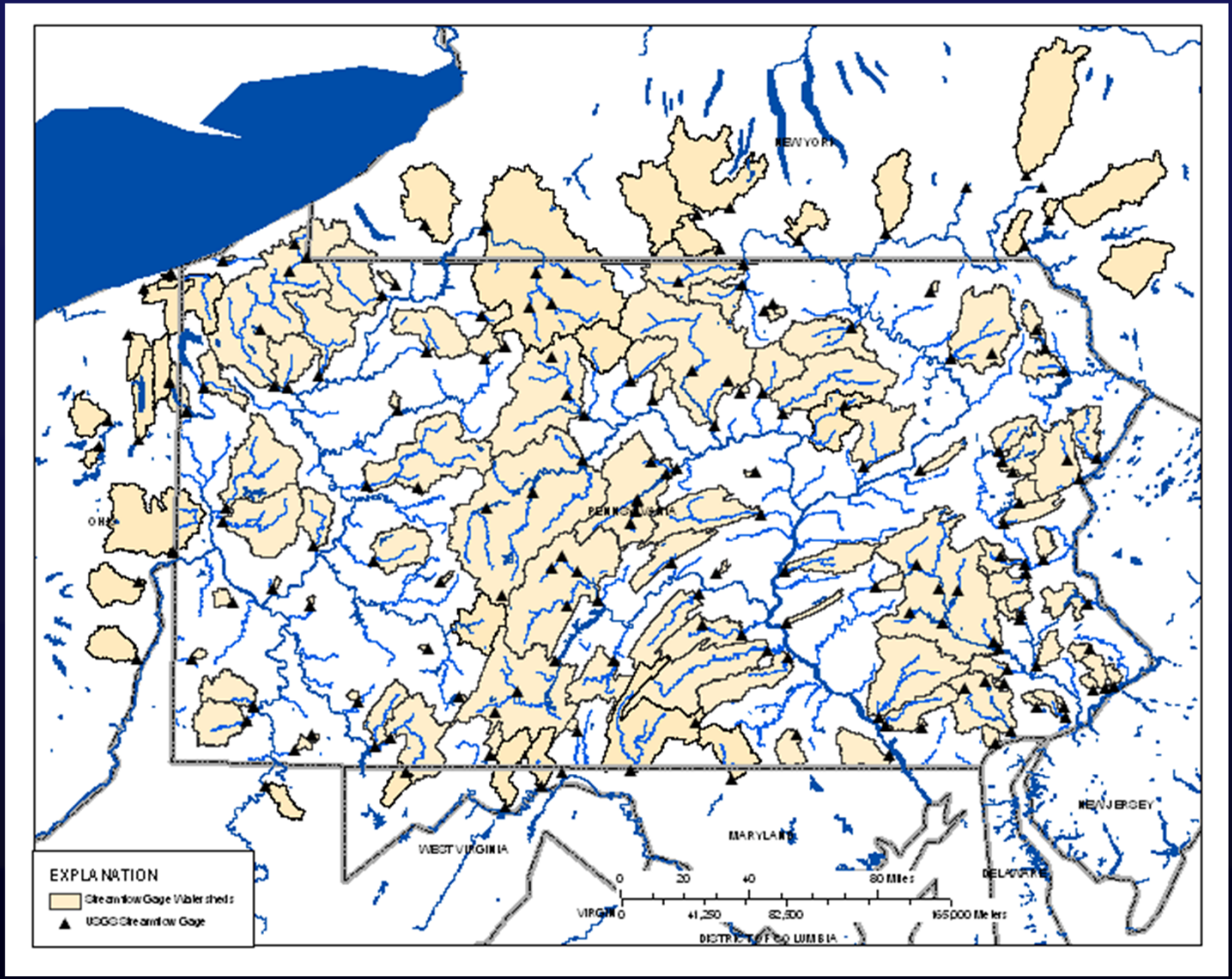
Index Streamgage Watersheds used in Map Correlation Method



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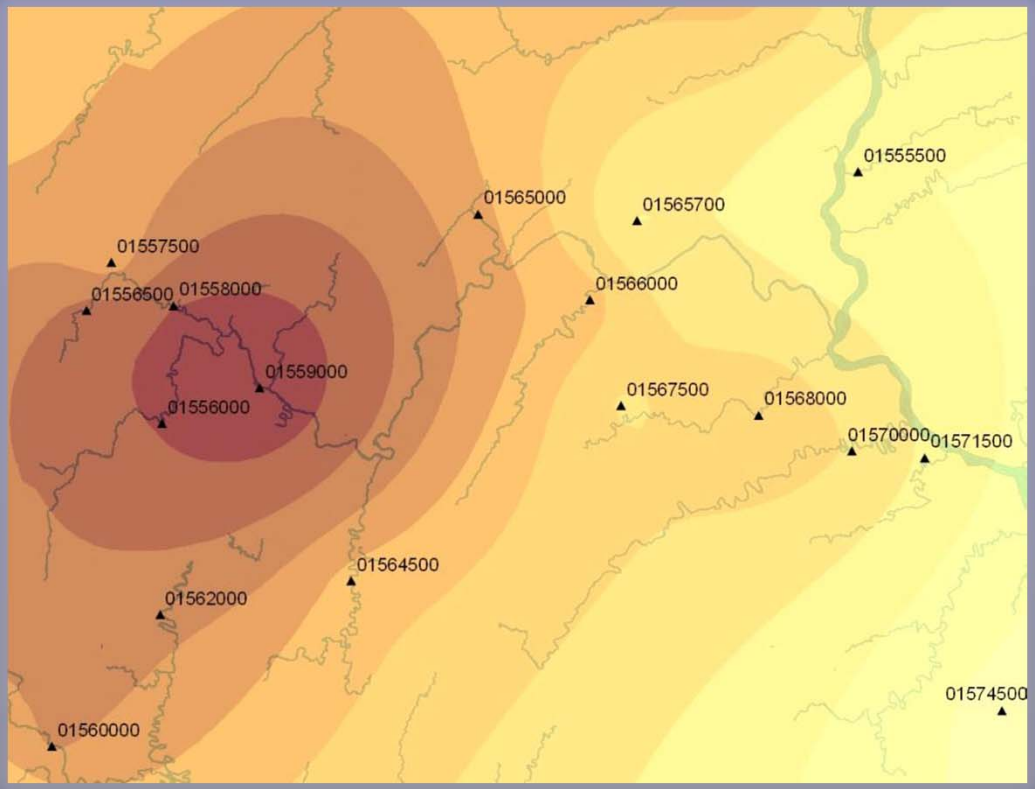
157 gages selected as index streamgages in PA, NY, MD, WV, OH

Map Correlation Method

- Introduced by Archfield (2009) for use in selecting index gages
- Based on geostatistics
- Develops correlation map for each index gage based on cross-correlation of streamflows at the index gage and all other index gages



- For any ungaged location, the index gage with the highest correlation for that particular point is selected as the best correlated index gage

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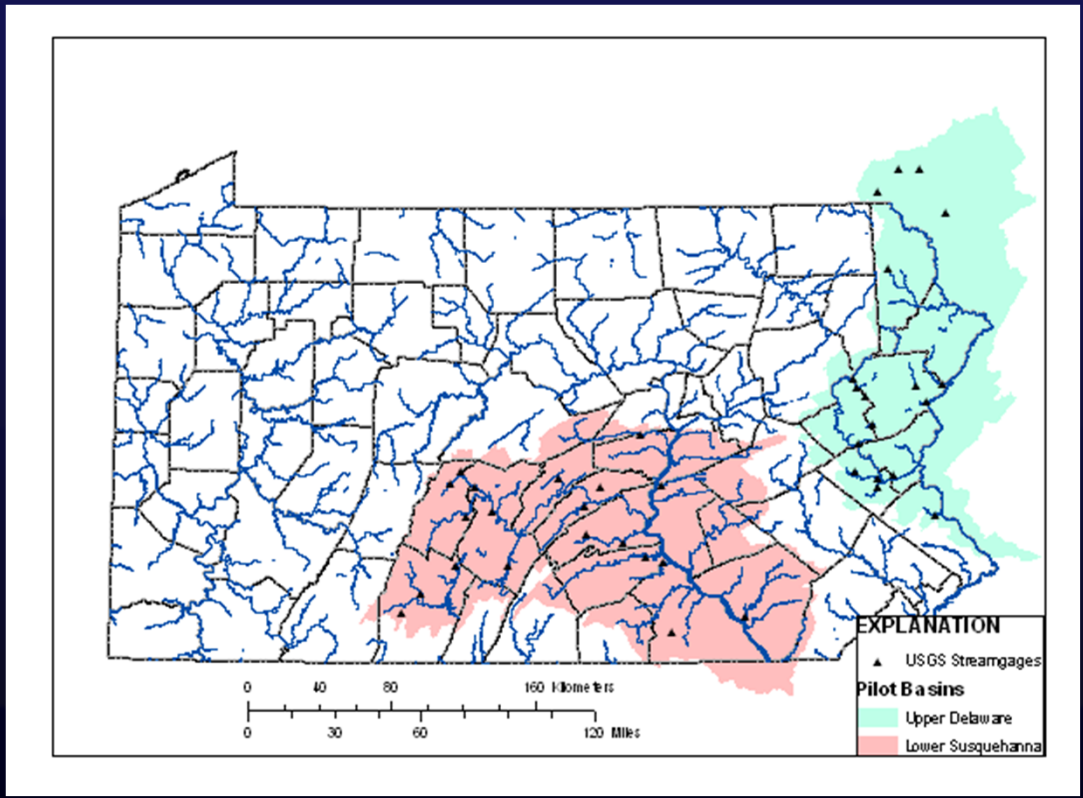
Map Correlation Method – Use in PA

- Tested method in 2 pilot basins
- Opportunities for potential improvement of method:
  - Correlating flow exceedances vs. logs of streamflows
  - Basin centroid distance vs. basin outlet distance
  - Spatial anisotropy
- Compare map correlation results to traditional closest gage method



Location of pilot basins used to test map correlation method in Pennsylvania

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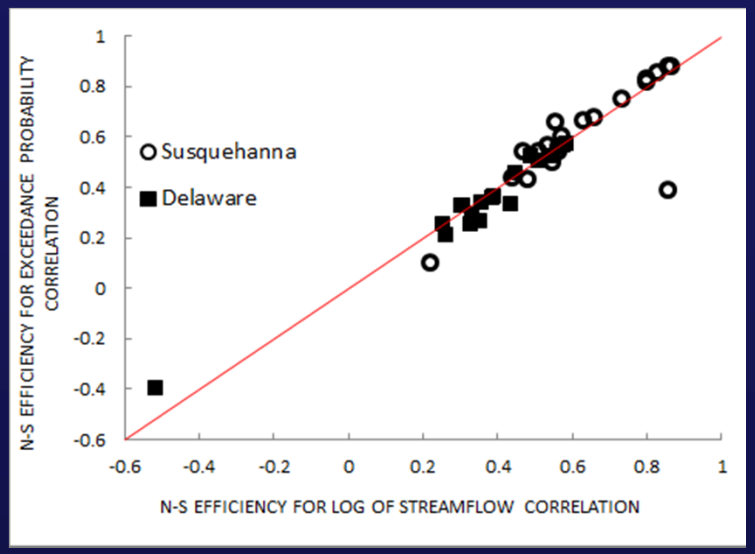
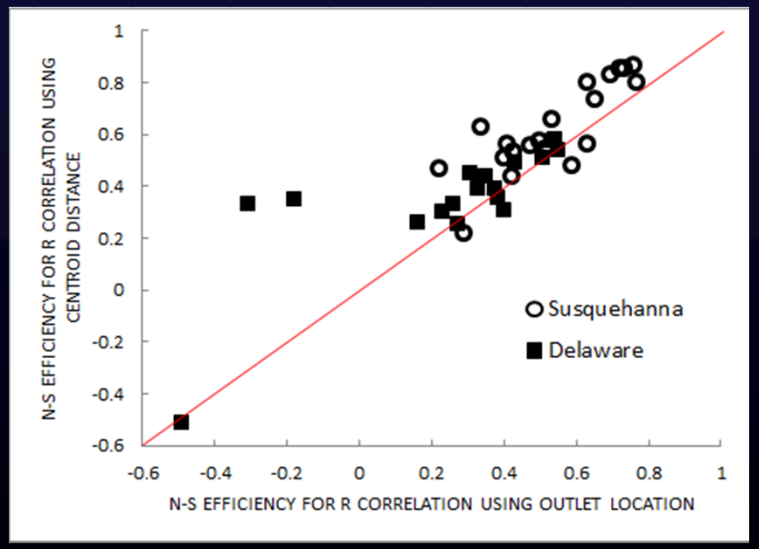
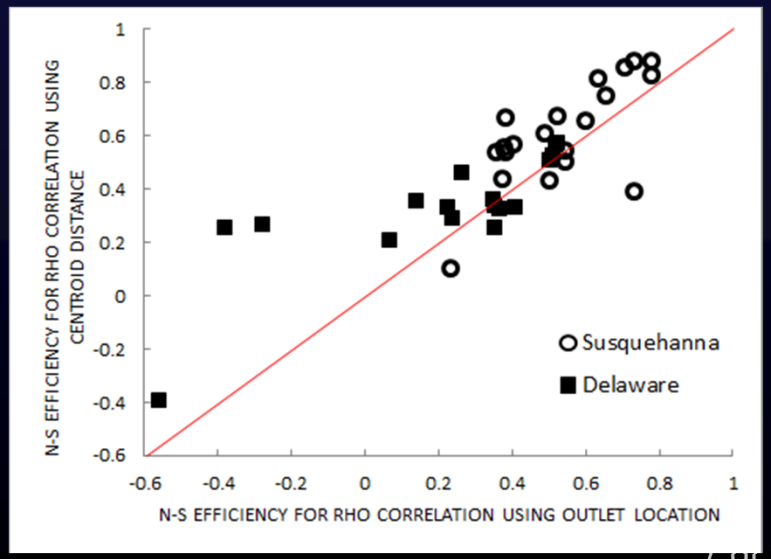
Pilot Basin Analysis -- Streamflow Correlation

- Log of streamflow vs. exceedance probabilities
  - Correlation of exceedance probabilities allows for zero values
  - No real difference in results between the correlations



- Correlation using distance between basin outlet vs. distance between basin centroid
  - Improvement when distance between basin centroid is used in correlations





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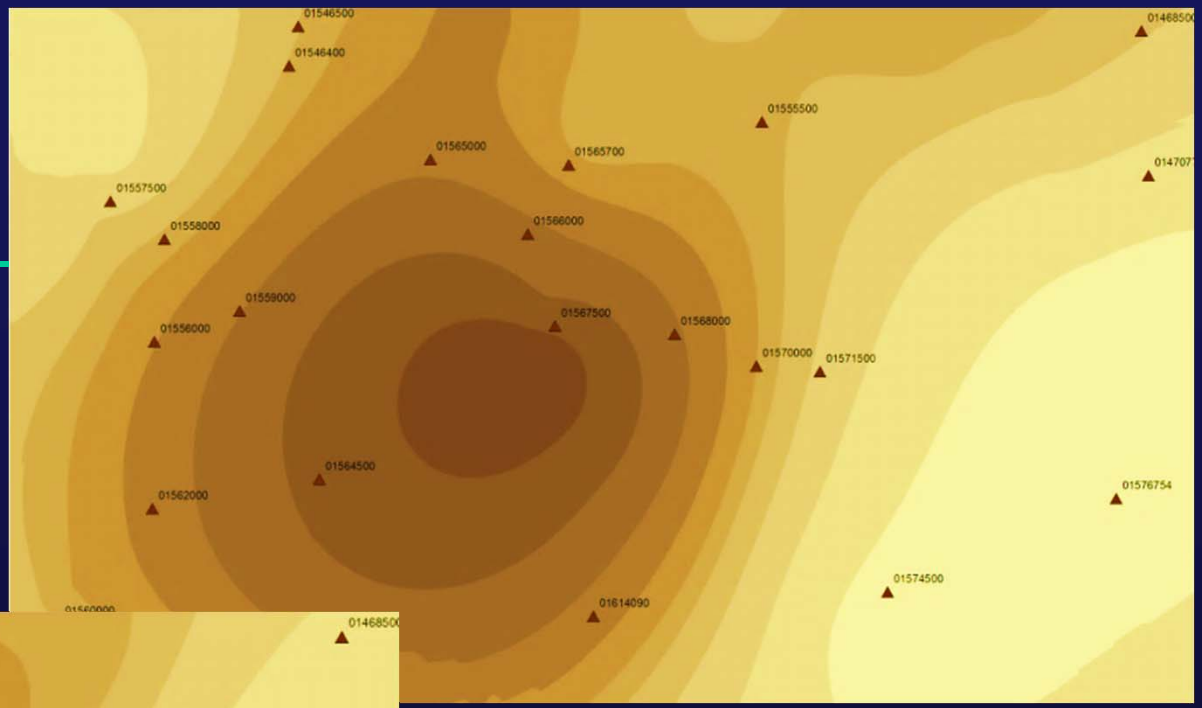
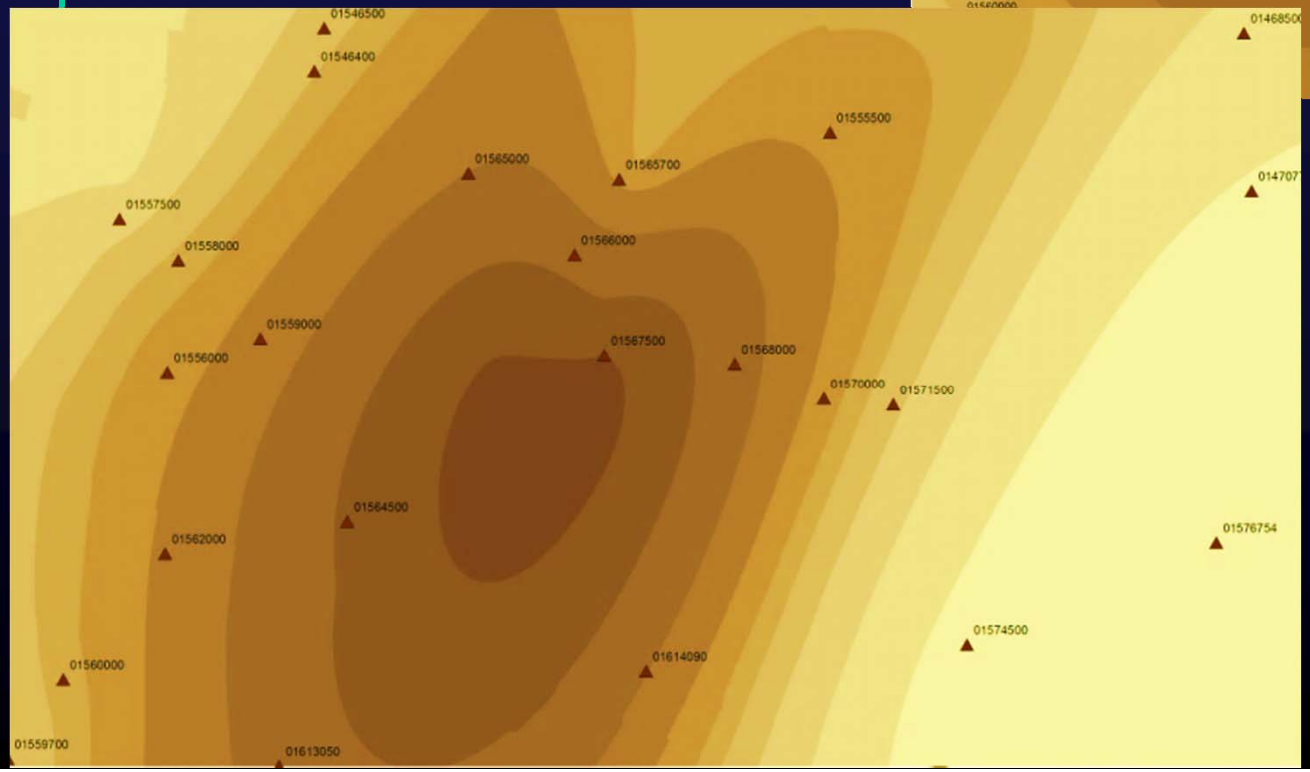
Example of Anisotropy (directional variation)

Correlation map without anisotropy

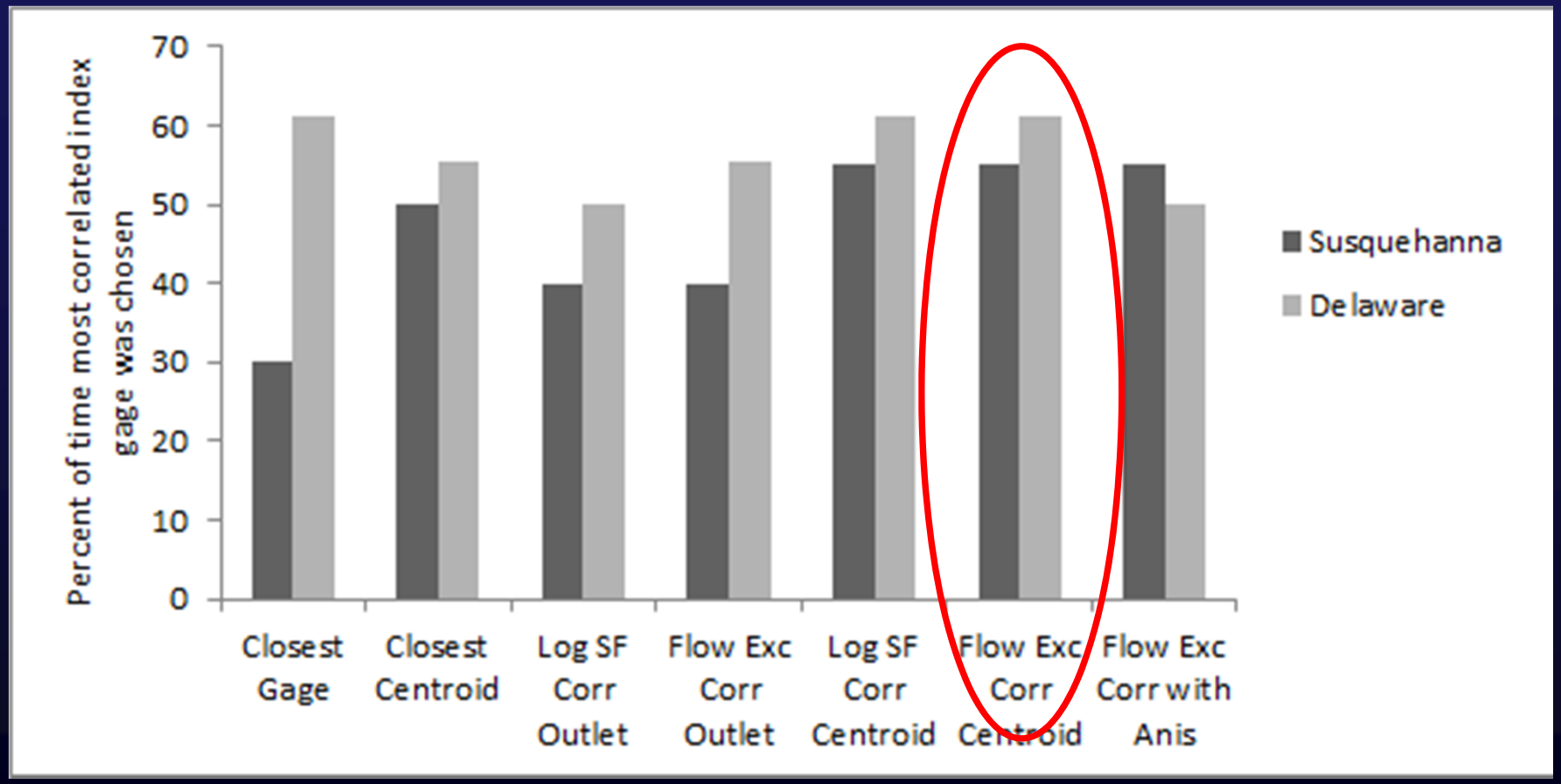


Correlation map with anisotropy



Result:
no overall improvement in gage selection

Comparison of possible improvements to map correlation method and traditional distance methods



Correlation of flow exceedances using centroid distance was chosen for use with the map correlation method in PA

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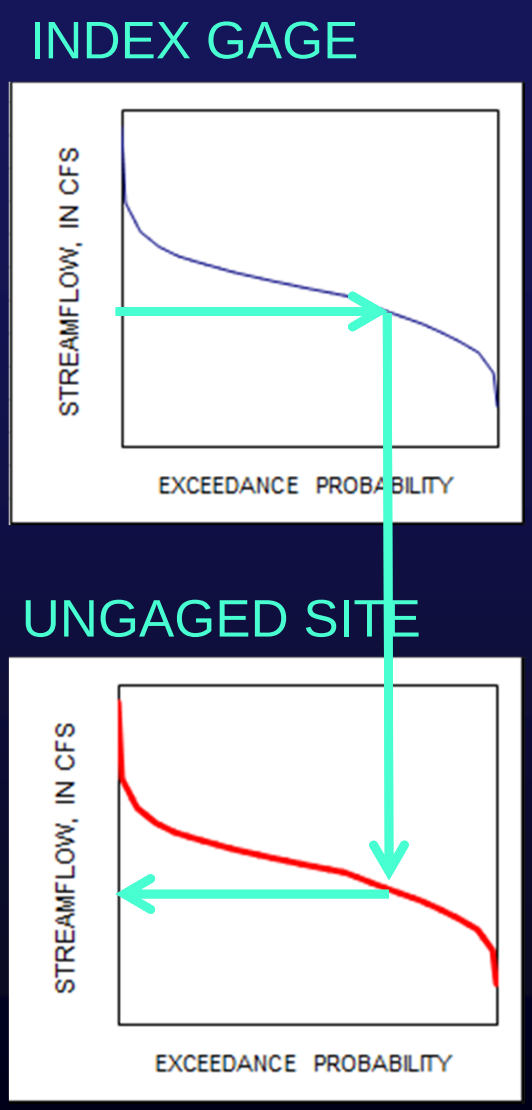
Overview of QPPQ Approach

Estimates streamflow at ungaged site by equating daily flow durations

1. Selects index gage
2. Determines flow exceedances from index gage for selected period
3. Equates the exceedances at the ungaged and index gage site
4. Fills in hydrograph at ungaged site using dates and exceedances from index gage



Source: modified from S.A. Archfield

Estimating Flow Duration Curve using Regression Equations

- Statewide basin-characteristic-derived regression equations developed for
  - P99.9944, P99, P95, P90, P85, P80, P70, P60, P50, P40, P30, P20, P15, P10, P5, P1, P.0056
- Developed using WLS
- Significant basin characteristics: drainage area, longitude, depth to bedrock, drainage run-off number, maximum daily temperature, mean annual precipitation, percent urban, percent carbonate bedrock
- Standard errors of prediction range from 11% to 93%

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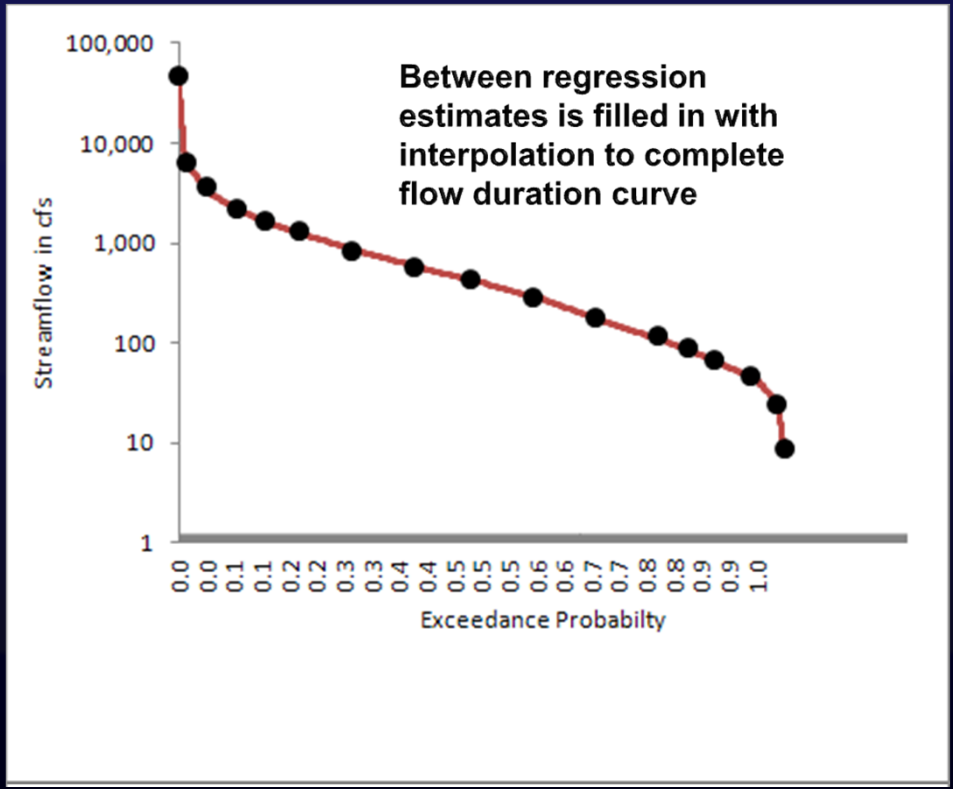
Estimating Flow Duration Curve using Regression Equations – con't

- 17 points along flow duration curve are determined from regression equations
- Remaining flow duration curve filled in using interpolation
  - Log-linear interpolation
  - Log-log interpolation



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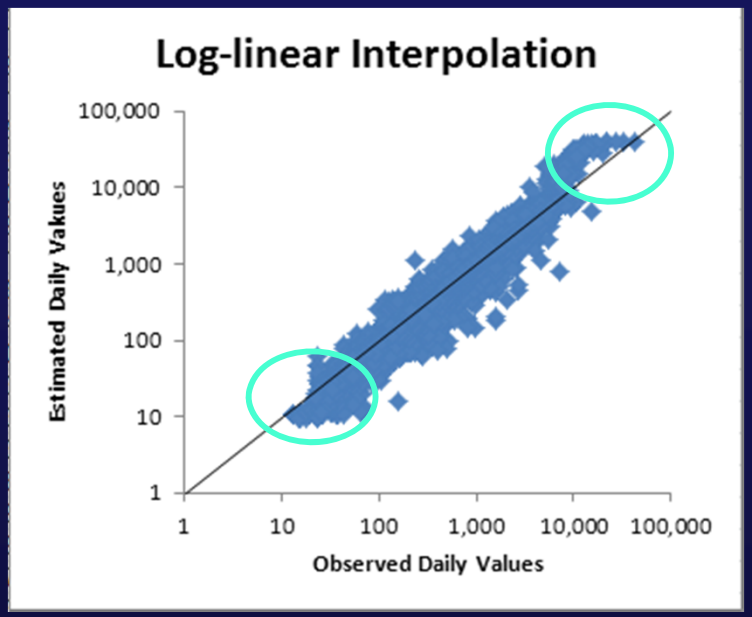
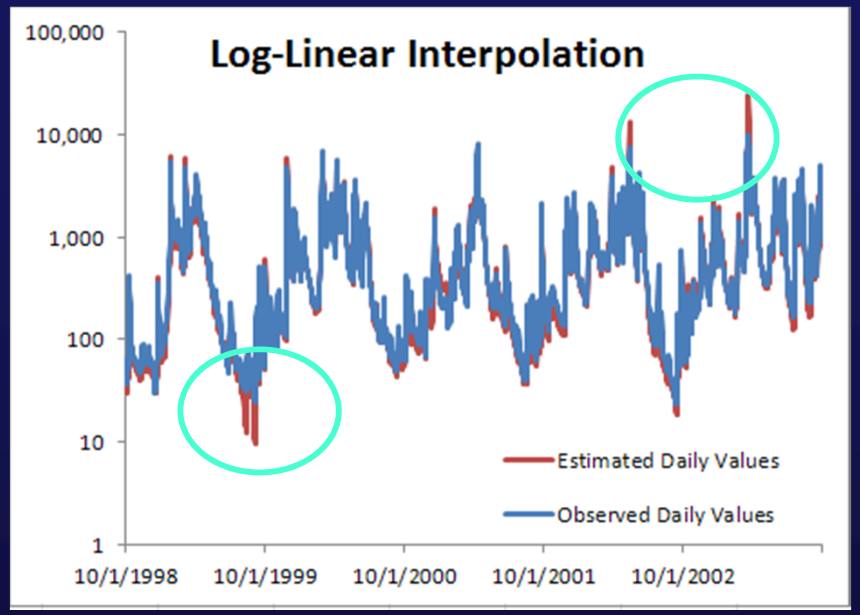
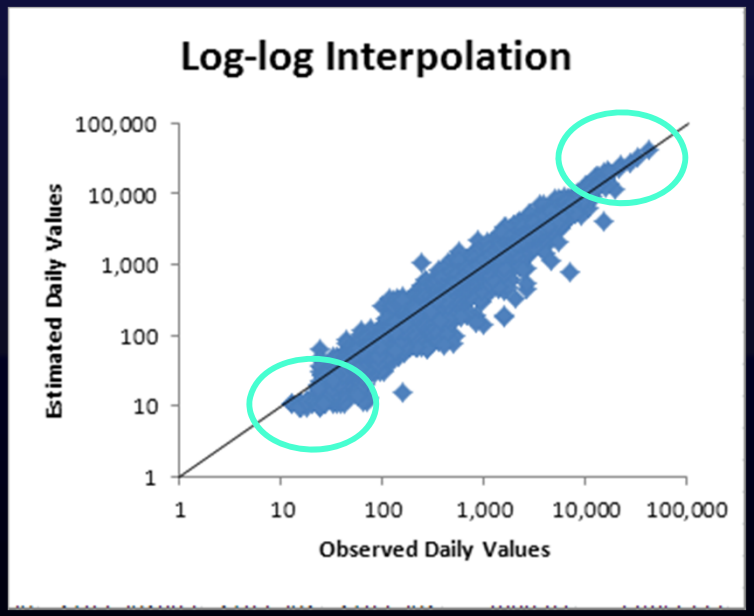
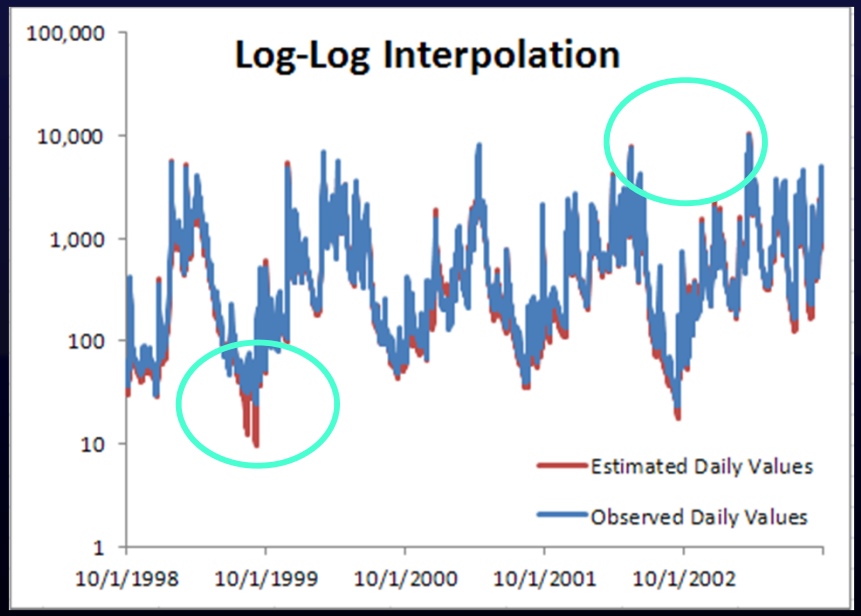
Interpolation Between Exceedances

Log-linear interpolation: Hooks at ends









Log-log interpolation: Upper end is smoothed out

PA Baseline Streamflow Calculator

- Based on code developed by Archfield (2009) for the MA Safe Yield Estimator
- Converted code to VB.NET
- Region basin characteristics downloaded from StreamStats or entered manually
- Uses map correlation method to select index gage
- Returns daily values for period from 1960-2008, flow exceedances for period, and summary report
- Currently in testing phase
- Resulting daily values must be adjusted manually for water use

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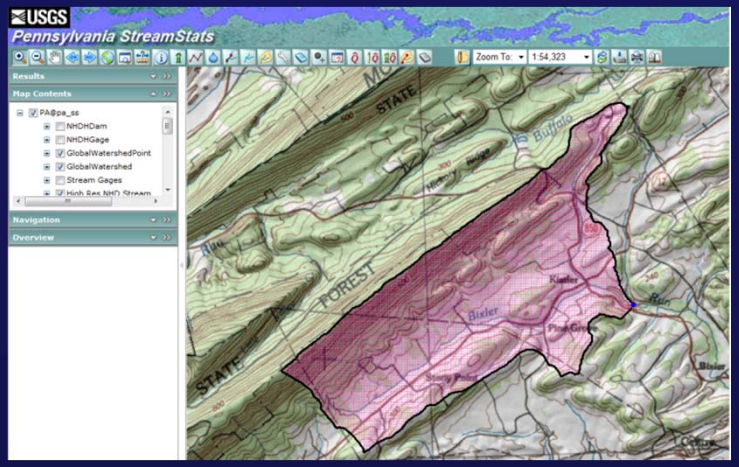
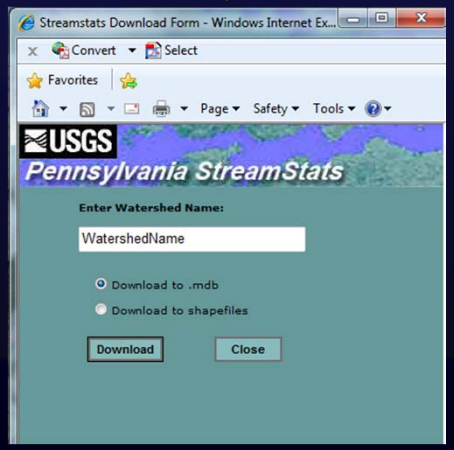
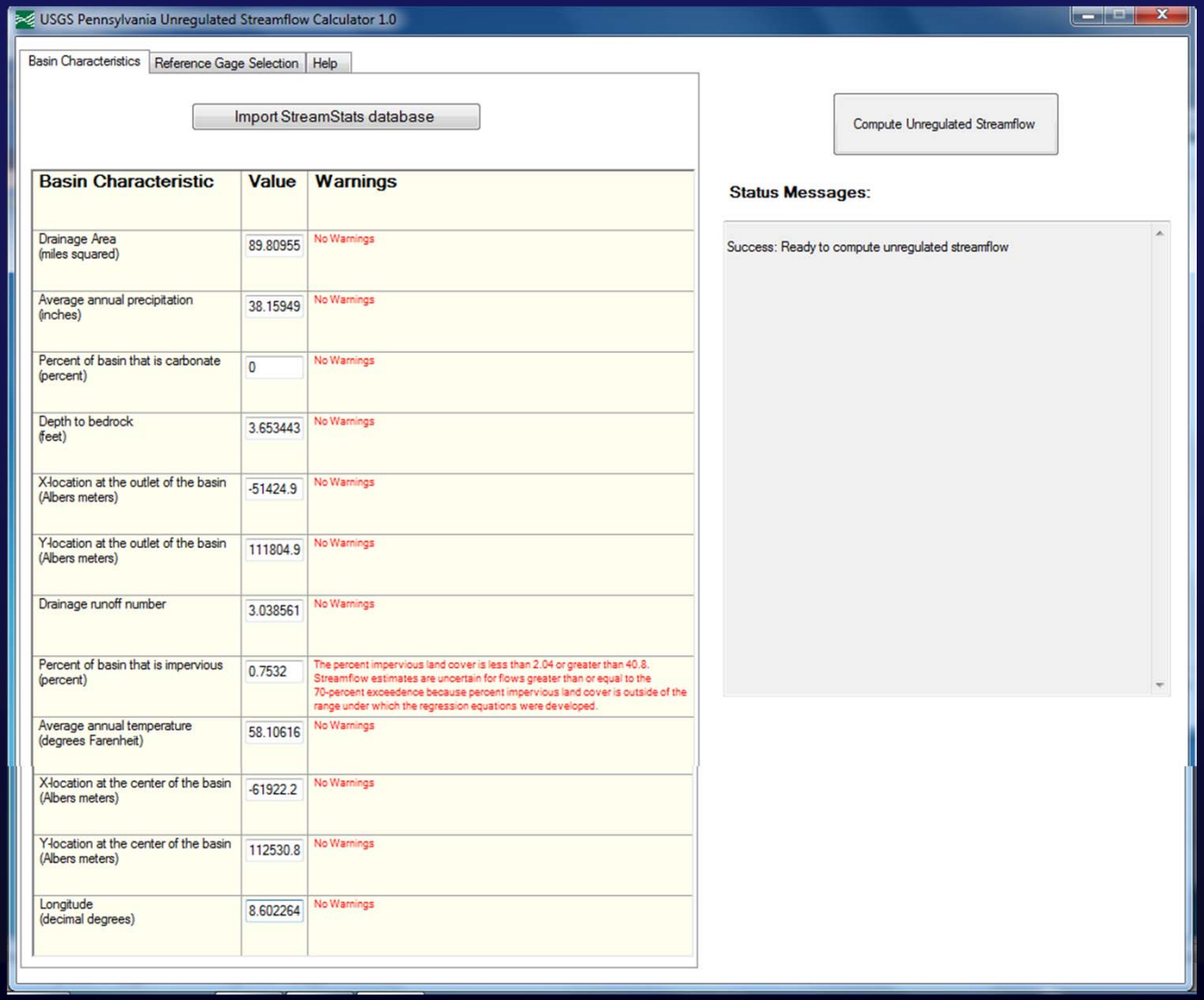
PA Baseline Streamflow Calculator







Basin Characteristic	Value	Warnings
Drainage Area (miles squared)	89.80955	No Warnings
Average annual precipitation (inches)	38.15949	No Warnings
Percent of basin that is carbonate (percent)	0	No Warnings
Depth to bedrock (feet)	3.653443	No Warnings
X-location at the outlet of the basin (Albers meters)	-51424.9	No Warnings
Y-location at the outlet of the basin (Albers meters)	111804.9	No Warnings
Drainage runoff number	3.038561	No Warnings
Percent of basin that is impervious (percent)	0.7532	The percent impervious land cover is less than 2.04 or greater than 40.8. Streamflow estimates are uncertain for flows greater than or equal to the 70-percent exceedence because percent impervious land cover is outside of the range under which the regression equations were developed.
Average annual temperature (degrees Farenheit)	58.10616	No Warnings
X-location at the center of the basin (Albers meters)	-61922.2	No Warnings
Y-location at the center of the basin (Albers meters)	112530.8	No Warnings
Longitude (decimal degrees)	8.602264	No Warnings

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Reference Streamgage Report

Information related to the reference streamgage.

Streamgage code	Streamgage number	Streamgage name
01559700	01559700	Sulphur Springs Creek near Manns Choice, PA

Basin Characteristic	Value for the reference streamgage	Value at the ungaged site	Relative percent difference
Drainage area, in miles squared	5.28	89.81	177.79
Average annual precipitation, in inches	39.02	38.16	2.23
Percent of basin with carbonate rock	1.73	0.00	200.00
Depth to bedrock, in feet	4.04	3.65	9.97
Drainage runoff number	3.10	3.04	
Percent of basin that is impervious land cover	5.60	0.75	152.58
Average annual temperature, in degrees Farenheit	58.17	58.11	0.11
Outlet X-location, in PA Albers, meters	-52866.44	-51424.90	
Outlet Y-location, in PA Albers, meters	108723.26	111804.90	
Longitude, in decimal degrees	78.62	78.60	
Distance between ungaged site and reference streamgage, in miles	2.11		

Correlation of streamflow between ungaged site and reference streamgage	1.00

Reference streamgages most-correlated with the ungaged site

Reference streamgages most-correlated with the ungaged site	Correlation
01559700 Sulphur Springs Creek near Manns Choice, PA	1.000
01560000 Dunning Creek at Belden, PA	0.936
03078000 Casselman River at Grantsville, MD	0.909
03039200 Clear Run near Buckstown, PA	0.908
01566000 Tuscarora Creek near Port Royal, PA	0.901

- **Compares basin characteristics from reference gage and ungaged location**
- **Lists the top 5 most highly correlated reference gages**

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Data Tables

Streamflow at the ungaged site.			*Streamflow at the reference streamgage.*		
Exceedence Probability	Streamflow, in cubic feet per second	Streamflow, in cubic feet per second per mile	Exceedence Probability	Streamflow, in cubic feet per second	Streamflow, in cubic feet per second per mile
5.5869E-05	40285.70	53.29	5.5869E-05	18700.00	91.22
0.000111738	39889.88	52.76	0.000111738	17600.00	85.85
0.000167607	39489.89	52.24	0.000167607	12400.00	60.49
0.000223476	39093.91	51.71	0.000223476	10000.00	48.78
0.000279345	38701.90	51.19	0.000279345	9610.00	46.88
0.000335214	38313.82	50.68	0.000335214	7670.00	37.41
0.000391083	37929.64	50.17	0.000391083	7660.00	37.37
0.000446952	37549.30	49.67	0.000446952	7660.00	37.37
0.000502821	37172.78	49.17	0.000502821	7110.00	34.68
0.00055869	36800.03	48.68	0.00055869	6800.00	33.17
0.000614559	36431.03	48.19	0.000614559	6600.00	32.20
0.000670429	36065.72	47.71	0.000670429	6370.00	31.07
0.000726298	35704.07				
0.000782167	35346.06				
0.000838036	34991.63				
0.000893905	34640.75				
0.000949774	34293.40				

Streamflow at the ungaged site.			*Streamflow at the reference streamgage.*		
Date	Streamflow, in cubic feet per second	Streamflow, in cubic feet per second per mile	Date	Streamflow, in cubic feet per second	Streamflow, in cubic feet per second per mile
10/1/1959	629.09	0.83	10/1/1959	140.00	0.68
10/2/1959	773.08	1.02	10/2/1959	170.00	0.83
10/3/1959	292.16	0.39	10/3/1959	50.00	0.24
10/4/1959	214.59	0.28	10/4/1959	29.00	0.14
10/5/1959	178.17	0.24	10/5/1959	22.00	0.11
10/6/1959	147.97	0.20	10/6/1959	18.00	0.09
10/7/1959	147.93	0.20	10/7/1959	18.00	0.09
10/8/1959	214.56	0.28	10/8/1959	29.00	0.14
10/9/1959	564.92	0.75	10/9/1959	127.00	0.62
10/10/1959	501.56	0.66	10/10/1959	110.00	0.54
10/11/1959	307.87	0.41	10/11/1959	55.00	0.27
10/12/1959	251.30	0.33	10/12/1959	38.00	0.19
10/13/1959	219.17	0.29	10/13/1959	30.00	0.15
10/14/1959	214.52	0.28	10/14/1959	29.00	0.14
10/15/1959	206.82	0.27	10/15/1959	27.00	0.13
10/16/1959	206.78	0.27	10/16/1959	27.00	0.13
10/17/1959	188.87	0.25	10/17/1959	24.00	0.12

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PA Baseline Streamflow Calculator Report

Pennsylvania Unimpacted Streamflow Calculator

Summary Report by: julrich Date: 5/24/11

Index-gage site name: 01564500 Aughwick Creek near Three Springs, PA
Correlation coefficient: 0.97

Basin characteristics	Index-gage site	Ungaged site	Unit	Percent difference
Drainage area	205.00	756.00	miles squared	114.67
Mean basin elevation	38.29	38.00	feet	0.76
Average annual precipitation	4.46	14.00	inches	103.36
Open water	3.93	4.30	percent of basin	8.89
Maximum monthly temperature	3.04	3.06	degrees Celsius	0.00
Wetlands	12.07	15.00	percent of basin	21.65
Sand and gravel deposits	58.95	57.80	percent of basin	1.97

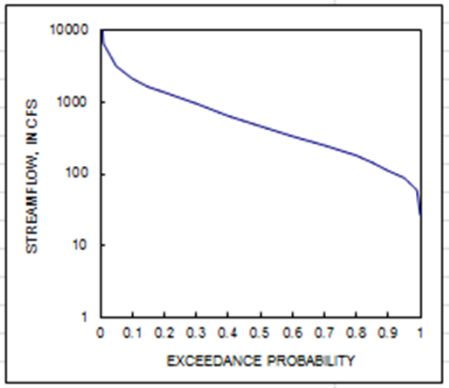

Figure 1. Flow-duration curves in cubic feet per second.

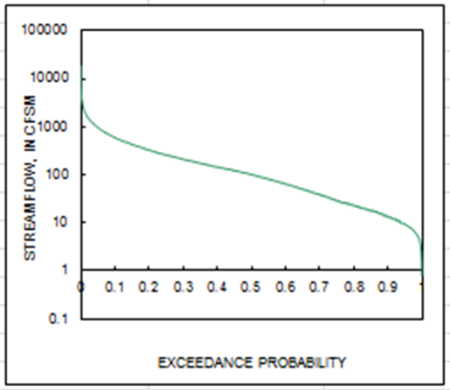

Figure 2. Flow-duration curves in cubic feet per second per mile.

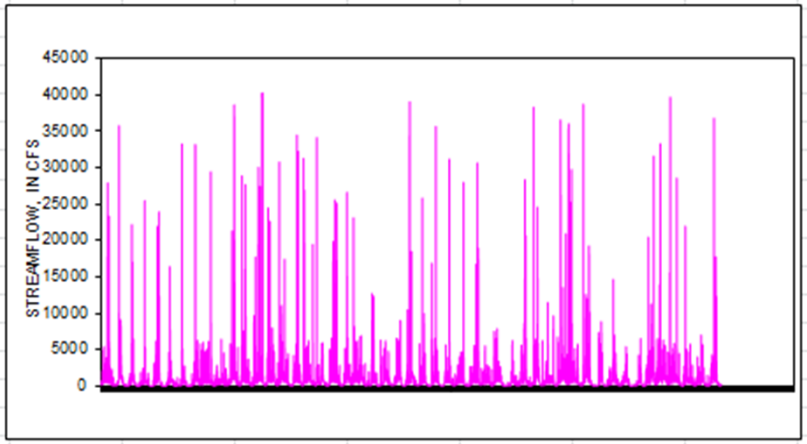

Figure 3. Hydrographs in cubic feet per second.

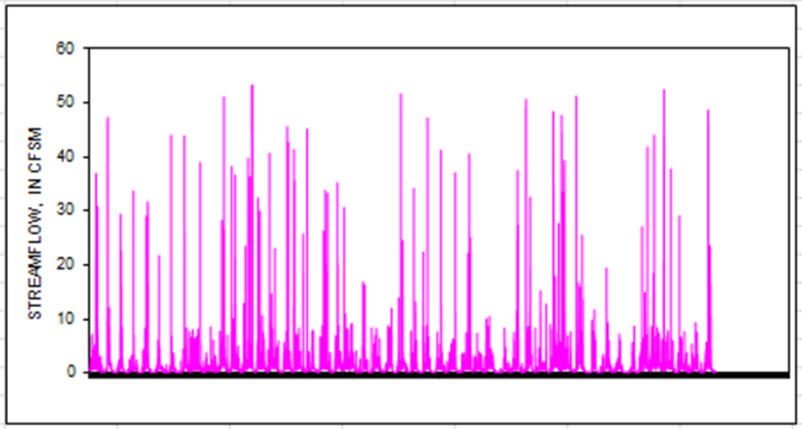

Figure 4. Hydrographs in cubic feet per second per mile.

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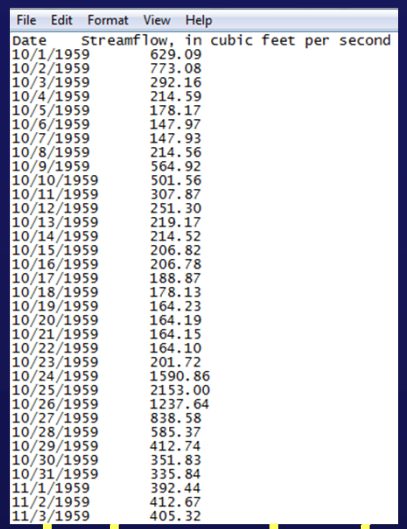
Uses of PA Baseline Streamflow Calculator

- Assess streamflow correlation between gaged stream and ungaged stream
- Select reference streamgage
- Estimate daily flows at ungaged location
  - Daily flows can be entered as input into many different statistical software packages
    - Frequency statistics such as 7Q10
    - Non-interpretive statistics such as monthly and annual flow exceedances; means



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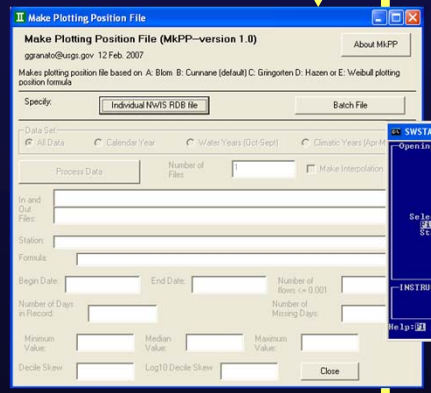
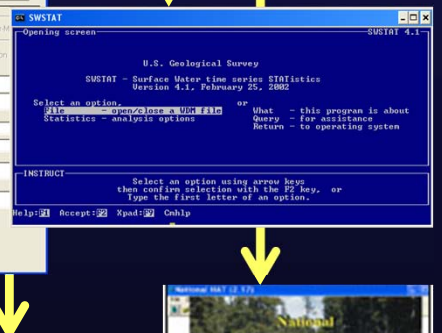
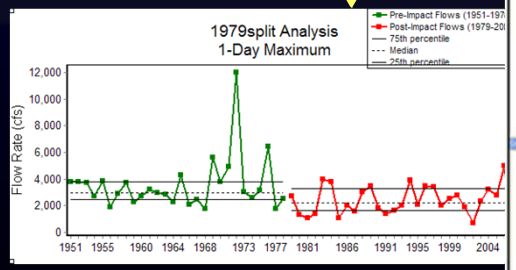
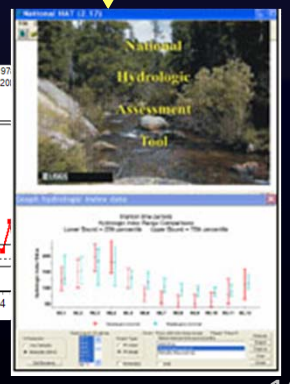
Date	Streamflow, in cubic feet per second
10/1/1959	629.09
10/2/1959	773.08
10/3/1959	292.16
10/4/1959	214.59
10/5/1959	178.17
10/6/1959	147.97
10/7/1959	147.93
10/8/1959	214.56
10/9/1959	564.92
10/10/1959	501.56
10/11/1959	307.87
10/12/1959	251.30
10/13/1959	219.17
10/14/1959	214.52
10/15/1959	206.82
10/16/1959	206.78
10/17/1959	188.87
10/18/1959	178.13
10/19/1959	164.23
10/20/1959	164.19
10/21/1959	164.15
10/22/1959	164.10
10/23/1959	201.72
10/24/1959	1590.86
10/25/1959	2153.00
10/26/1959	1237.64
10/27/1959	838.58
10/28/1959	585.37
10/29/1959	412.74
10/30/1959	351.83
10/31/1959	335.84
11/1/1959	392.44
11/2/1959	412.67
11/3/1959	405.32









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Thank you

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