Delaware Estuary Program Land Use and Nonpoint Pollution Study of the Delaware River Basin

DELAWARE
ESTUARY PROGRAM

DELEP Report #94-04
March, 1994

Penn State Environmental
Resources Research Institute

ER9406

LAND USE AND NONPOINT POLLUTION STUDY OF THE DELAWARE RIVER BASIN

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Prepared for the Delaware River Basin Commission

March 1994

PENNSTATE

ENVIRONMENTAL RESOURCES
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1. INTRODUCTION

The overall goal of this study was to contribute to the development of the Comprehensive Conservation and Management Plan for the Delaware Estuary by providing estimates of the changes in nonpoint source pollution loads that may result from corresponding changes in land use/cover within the Delaware River Basin. Earlier work associated with the Delaware Estuary Program and similar studies have already resulted in the compilation of water quality and flow data recorded by a number of monitoring stations in the basin. In this study, an attempt was made to analyze these data to develop an empirical model relating quantities of various nonpoint source pollutants entering the Estuary to the composition of land use/cover within the basin.

An evaluation of water quality and flow records was made to quantify the nonpoint source components of selected pollutants entering different segments of the Delaware River and to subsequently establish relationships between the quantity and composition of nonpoint source runoff and the amounts of land area devoted to different types of land use. These relationships were then evaluated along with projected changes in land use through the year 2020 to predict the impact of land use changes on runoff-derived loads to the Estuary. To aid in the above analyses, standard statistical modeling techniques were combined with the use of a geographic information system (GIS).

As originally envisioned, the study approach was based on several assumptions:

- Existing water quality archives would contain at least 8 stations, whose drainage areas jointly covered most of the Delaware River Basin, at which concentrations of nutrients and selected metals were measured with sufficient frequency that a significant number of measurements corresponded to high streamflow conditions.

- Daily flow data were available for the water quality stations.

- Seasonal and other factors influencing concentrations were small enough that statistically significant relationships between concentration and flow could be determined.

- Recent land use and land cover data for at least a sizable fraction of the Delaware River Basin would be available during the period of performance of the study to supplement existing data compiled by the USGS from aerial photography obtained during the 1970s.

- Data from all parts of the Basin are of equal importance.

Unfortunately, only the second of these assumptions proved valid; as a result, a major change in strategy was necessary midway through the study. As described below, this change in strategy involved reliance on the use of published loading coefficients rather than sampling data to predict nonpoint source pollutant loads for the basin at different dates.

2. METHODOLOGY

This study was comprised of four primary tasks. In the first task, available water quality and flow records, as well as digital map data for the basin, were reviewed and compiled. In the second phase, recent water quality and flow data were analyzed to determine current nonpoint source pollutant loadings for various subwatersheds corresponding to monitored stream segments. Subsequent to this, pollutant loads computed from the stream data were compared against computed loads derived via the use of published loading coefficients reported for a variety of pollutants for different land use/cover types. Finally, selected loading coefficients were used to predict nonpoint source pollutant loads for the year 2020 based upon projected changes in land use/cover. A detailed chronology of all activities undertaken as part of this study are provided in the quarterly project reports included in Appendix E.

2.1 Data Review and Compilation

2.1.1 Water Quality and Flow Data

In principal, water quality data collected over several years can be used to develop relationships between pollutant concentrations and water flow rates, which can then be combined with daily flow rate data to estimate annualized pollutant loadings, using procedures similar to those reported by Norman (1991) for the Ohio River Basin. By separating daily flow into base flow and the excess flow above base flow, the annualized loadings can be separated into base-flow and excess-flow components, where the latter is expected to contain most of the pollutants carried by runoff. If annualized loadings can be determined with sufficient accuracy for several different drainage basins having different relative proportions of land use and land cover types, it may be possible to utilize multivariate analysis to estimate the per-area runoff pollutant loadings for each type of land use/cover.

The original work plan for this study of nonpoint pollution in the Delaware River Basin sought to use the method outlined above. To this end, an attempt was made to find approximately ten drainage areas for which sufficient water quality and daily flow data were available, and which represented diverse land use/cover distributions. Because significant improvements in sewage treatment plants were completed during the mid-1980's, only measurements made in 1988 and later years were included.

The initial search for suitable monitoring stations relied on the CD-ROM surface water database distributed by EarthInfo, Inc., which purports to contain all data in the USGS WATSTORE database. However, the EarthInfo software for searching the CD-ROM data proved unreliable and, at times, very slow; there may also be errors in the actual data. As a result, the effort to use the CD-ROM was abandoned; instead, the printed "U.S.G.S. Water Resources Data" reports were consulted to identify candidate stations. These reports indicated that only one or two of the USGS stations within the Delaware Basin measured water quality more than six times per year, that metals were in most cases measured much less frequently, and pesticide residues and industrial organics were not measured on a regular basis at all.

After learning of these problems with the EarthInfo and USGS data, several people associated with the Delaware Estuary Program suggested additional sources of data. In particular, Sumner Crosby from the EPA Region 3 office retrieved a summary of all water quality monitoring stations in the Basin from the EPA STORET database. This revealed a number of stations, operated by the Pennsylvania Department of Environmental Resources (PA DER), which make monthly measurements of pollutants, including nutrients and metals, but whose data are not routinely entered into WATSTORE.

Nineteen water quality stations were selected for more detailed analysis, 13 operated by the PA DER and 6 recorded in the WATSTORE data base. With a few exceptions, these stations took samples at least 10 times a year and had drainage areas greater than 100 square miles. Water quality data for the PA stations were provided in computer-readable form by Tammy Schreffler of PA DER. Quality data for the remaining stations, and daily flow data for all stations, were obtained from the USGS National Water Data Exchange. The data were incorporated into a local database for further analysis.

Following discussions with Delaware Estuary Program personnel, it was decided to eliminate all stations on the Delaware and its tributaries above the fall line near Trenton. Stations in New Jersey were also eliminated from the later analysis steps because of their generally lower frequency of measurements. The seven stations retained through all analysis steps are listed in Table 1. More detailed information on sampling dates, flow rates and measured pollutant concentrations for these stations is provided in Appendix A. The locations of these stations are shown graphically in Figure 1.

Closer examination of the quality records from these stations showed that, in most cases, the majority of measurements of metal concentrations were reported as below the detection threshold of the analysis methods used. In addition, according to Ken Lanfear of the USGS, the method used for taking samples prior to 1992 often introduced significant contamination by metals. As a result, all published metals concentrations are suspect. Accordingly, it was decided to include only four metals, iron, lead, nickel, and zinc, in subsequent data analysis; and only with the understanding that results will be of very limited accuracy. The other pollutants selected for inclusion in the final analysis are total non-filterable residue (total suspended solids), total ammonia (NH3 + NH4), NO2, NO3, total phosphorus, total organic carbon, and total sulfate. Biological oxygen demand was not reported for these stations, and could not, therefore, be included in the analysis.

As evident from the tables in Appendix A, total N was not included in the sampling data; only total ammonia (NH_3 and NH_4), NO_2 and NO_3 were available. Accordingly, a decision was made to use NO_3 measurements as a surrogate for total N since on an annual basis, the total NO_3 load is generally believed to represent a significant portion of the total N load for a given watershed in this part of the country (A. McDonnell, pers. comm.). To avoid confusion, reference is made to the usage of total NO_3 values in the report where appropriate.

Table 1. Selected Water Quality Monitoring and Gauging Stations

Station code	Description	Location lat.	Location long.	Drainage Area(1)	Gauge(2) code	Gauge(2) dist.
WQN0101	Delaware R at Morrisville PA	40 13 09	74 46 42	6780	1463500	800ft
WQN0121	Neshaminy Cr at PA 213 br, Langhorne	40 10 26	74 57 26	210	1465500	0
WQN0113	Schuylkill R at T558 br, Berne	40 31 20	75 59 54	355	1470500	100ft
WQN0117	Tulpehocken Cr, T921 br, Bern Twp	40 22 08	75 58 46	211	1471000	0
WQN0111	Schuylkill R, Hanover St, Pottstown	40 14 30	75 39 05	1147	1472000	200ft
WQN0116	Perkiomen Cr nr PA 29	40 11 46	75 27 03	279	1473000	2.3mi
WQN0110	Schuylkill R, Falls Br, Philadelphia	40 01 00	75 11 52	1893	1474500	3.5mi

Notes:

(1) Drainage area is in square miles, at the flow gauging station.

(2) All flow gauges are USGS stations, at the indicated (approximate) distance from the water quality station.

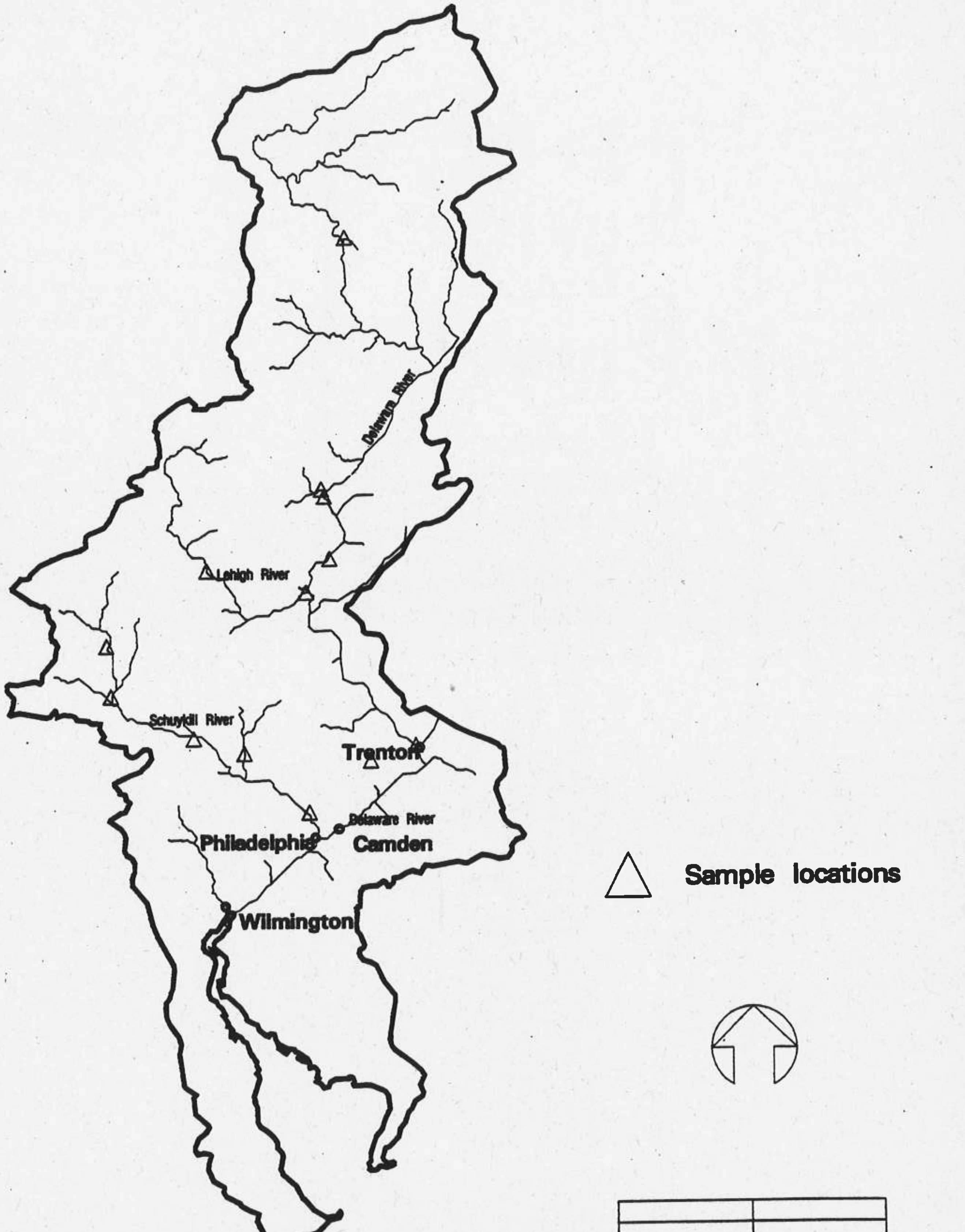

Fig 1. Monitoring Station Location

2.1.2 Digital Land Use/Cover Data

Digital land use/cover data available from the U.S. Geological Survey was obtained for the entire Delaware River Basin. This data was compiled via the interpretation of aerial photography dating from the mid-1970s to the early 1980s. The minimum mapping unit at which this data was compiled is approximately 16 hectares (40 acres) except for urban and some other intensive land use types, for which it is 4 hectares. All land use/cover delineations were made according to Level II of the Anderson classification system (see Table 2). Figure 2 depicts a land use/cover map produced for the entire basin based upon this data. As shown, Level II categories have been aggregated to Level I for the sake of simplicity.

Early in the project, an attempt was made to acquire land use/cover data more recent than the USGS data. Preliminary investigations indicated that newer data might be available from ongoing projects being conducted by both state and federal agencies in all four states included in the Delaware River Basin (Delaware, New Jersey, New York and Pennsylvania). However, due to budget cuts and project delays elsewhere, this turned out not to be the case. As a result, no other useful land use/cover data was available for use in this study. However, it was felt that in order to make meaningful evaluations of pollutant loads, it was imperative that the data for the land use/cover data set match fairly closely with that of the stream data used (circa 1990).

As an alternative, 1 km resolution land use/cover data developed for the entire country by the USGS EROS Data Center was acquired. The primary source of information for this data set is AVHRR (Advanced Very High Resolution Radiometer) imagery from the NOAA series of polar orbiting satellites, acquired during the 1989 to 1991 time period. During the initial classification procedure, this data was augmented via the use of a number of collateral data sets including ecoregion maps, generalized soil maps, climatic maps, and other similar physical resource maps.

Overall, the classification accuracy is considered to be fairly good. However, developed land categories (e.g., urban, commercial, residential, etc.) were not classified during the original data processing effort. This was not necessarily an oversight, but rather reflects the intended use of the data. It is anticipated to be used primarily for regional-scale ecological assessment and monitoring.

Table 2. Land use and land cover classification system for use with remote sensor data from Anderson, et al (1976)

Level I		Level II
1 Urban or Built-up Land	11	Residential
	12	Commercial and Services
	13	Industrial
	14	Transportation, Communications, and Utilities
	15	Industrial and Commercial Complexes
	16	Mixed Urban and Built-up Land
	17	Other Urban or Built-up Land
2 Agricultural Land	21	Cropland and Pasture
	22	Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
	23	Confined Feeding Operations
	24	Other Agricultural Land
3 Rangeland	31	Herbaceous Rangeland
	32	Shrub and Brush Rangeland
	33	Mixed Rangeland
4 Forest Land	41	Deciduous Forest Land
	42	Evergreen Forest Land
	43	Mixed Forest Land
5 Water	51	Streams and Canals
	52	Lakes
	53	Reservoirs
	53	Bays and Estuaries
6 Wetland	61	Forested Wetland
	62	Nonforested Wetland
7 Barren Land	71	Dry Salt Flats
	72	Beaches
	73	Sandy Areas Other than Beaches
	74	Bare Exposed Rock
	75	Strip Mines, Quarries, and Gravel Pits
	76	Transitional Areas
	77	Mixed Barren Land
8 Tundra	81	Shrub and Bruch Tundra
	82	Herbaceous Tundra
	83	Bare Ground Tundra
	84	Wet Tundra
	85	Mixed Tundra
9 Perennial Snow or Ice	91	Perennial Snowfields
	92	Glaciers

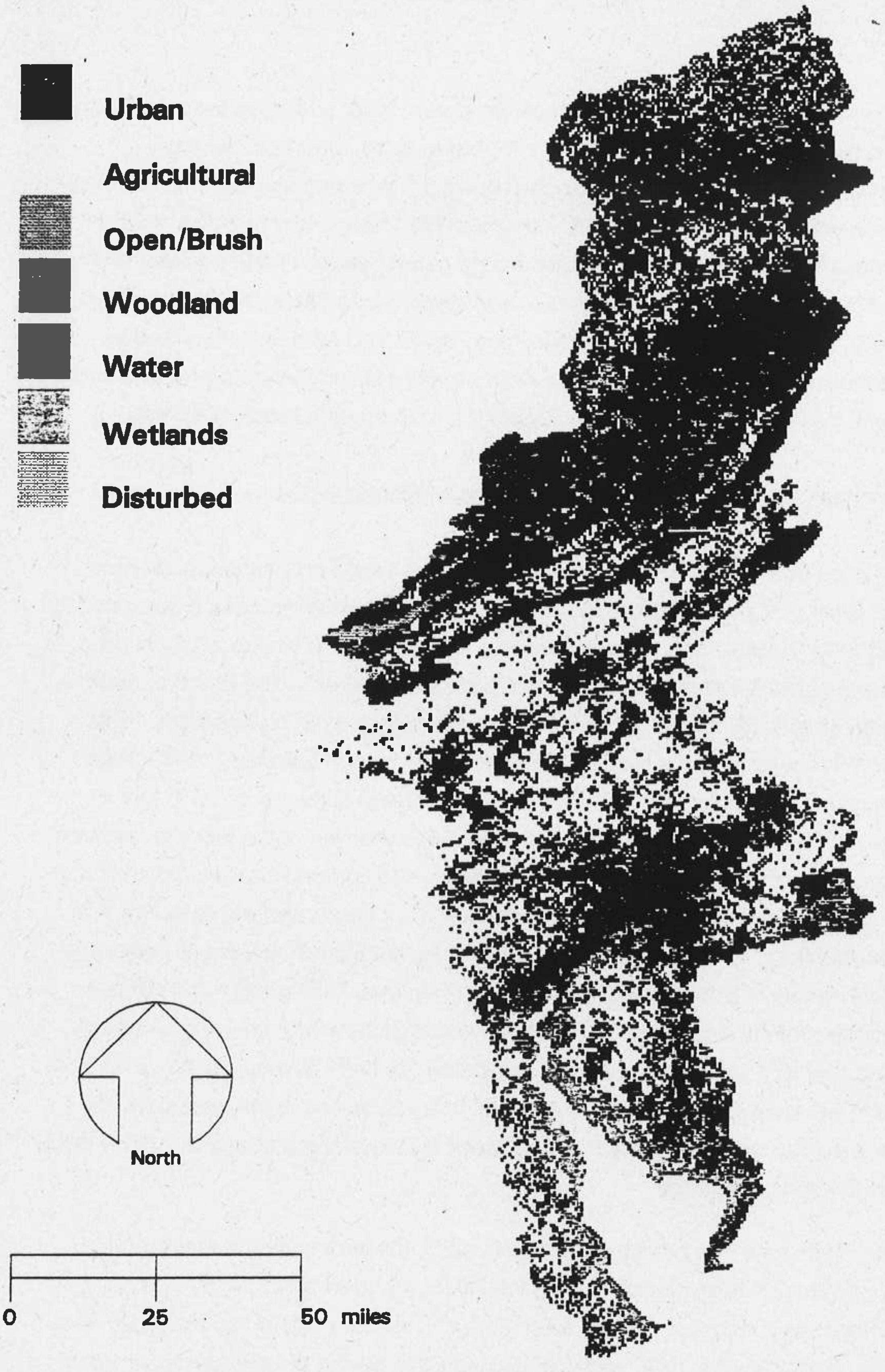

Fig 2. Landuse/cover from U.S.G.S.
Aggregated to Level I (ca 1978)

To overcome the lack of information on developed land, additional processing as part of this study was performed on the AVHRR data to "restore" this missing information. This was accomplished by performing the following steps. First, the 1980-vintage land use/cover data was overlaid onto the 1990 image to determine which of the "mis-classified" categories on the latter image corresponded most frequently with developed land categories on the former. Once identified, the most highly correlated categories that appeared to be adjacent to "true" developed land were recorded as such. Additionally developed land categories from the 1980 digital map were extracted and inserted into the 1990 digital map. Figure 3 shows the enhanced 1990 map.

2.2 Determination of Pollutant Loads from Compiled Stream Data

Daily base flow values for each day of the year at each flow gauge station were computed using a slightly modified version of the local minimum technique described by White and Sloto (1990). This technique uses a moving window whose width, in days, is twice the estimated duration of runoff after a precipitation event. The runoff duration is represented empirically as the 0.2 power of the drainage area in square miles. This width, which is rounded to the next higher odd integer, varied between 7 and 11 days for the gauging stations used in this study. The window is centered on each day in turn; whenever the daily average flow for the date at the center of the window is lower than for any other date within the window, the flow value is marked as a local minimum. On days for which the flow is a local minimum, the base flow is defined to be equal to the daily flow value. For days between local minima, the base flow value is computed by linear interpolation between the adjacent local minima. During extended periods (periods longer than the width of the moving window) of steadily increasing or steadily decreasing flow, the daily flow rates may sag below the base flow values obtained from the linear interpolation. To avoid having actual flow values below the base flow, the base flow obtained using interpolation is replaced by the actual average daily flow value whenever the latter is smaller.

Annual total flow was computed for each station by adding up the average total flow rates (in cubic feet per second) for each day of the year, and multiplying by the number of seconds in a day. Annual base flow was similarly computed using the base flow values, and annual excess flow was calculated by taking the difference between total flow and base flow. Totals were obtained only for calendar years 1988, 1989 and

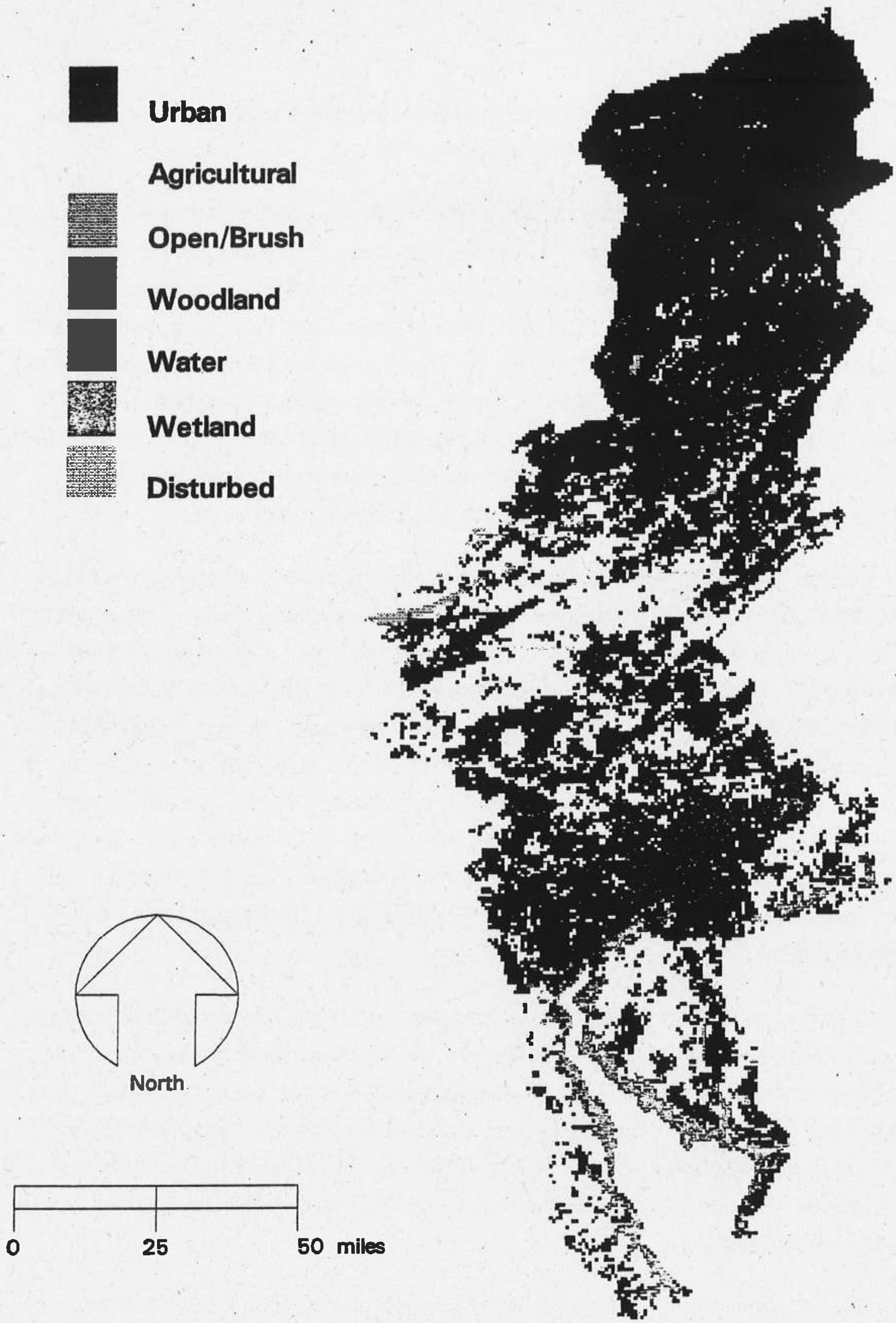

Fig 3. Generalized Landuse/cover for 1990

1990, since complete flow records for the last three months of 1991 at some stations were not yet available from the WATSTORE archive.

To help identify appropriate procedures for determining relations between pollutant concentrations and flow rates, for each station the concentrations of each pollutant were listed using several different sorting criteria: by sampling date, by sampling month, by instantaneous stream flow, and by flow above base flow. Concentrations of any given pollutant were found to vary widely at similar times of year and under similar flow conditions; variations by a factor of 2 or more were common, even when the stream flow was near base flow. No marked dependence of concentration on season or flow conditions was apparent; given the wide variations from measurement to measurement, however, such a dependence would be difficult to detect.

Several factors may contribute to the wide variation in concentrations under high flow conditions. For many of the streams involved, there is substantial resuspension of sediments under high flow conditions. Further, the amount of nonpoint pollutants carried by runoff may depend on the extent to which they have already been flushed from the land by heavy precipitation events in the recent past. Finally, a significant portion of the drainage area is upstream from flow-control reservoirs, which may affect results in two ways: 1) by releasing heavy flows in anticipation of precipitation, and 2) by serving as sediment traps after a precipitation event. Within the scope of the current study, it was not feasible to develop models relating sediment loads to resuspension effects, recent precipitation history, or reservoir releases, so no attempt was made to correct for them.

In view of the large variations of pollutant concentrations under similar conditions, only the mean concentration at low flow and a simple linear regression of concentration against flow were computed. All available measurements from January 1988 through September 1991 (the last month for which complete flow data records were obtained) were included in the computations. Concentration values flagged as below the limit of detectability were set to 0.71 times the limit value (i.e., the detectability limit divided by the square root of 2).

To compute the mean concentration at low flow, the criterion for low flow was set somewhat arbitrarily as any flow less than 1.3 times base flow. An average of 64% (range 40% to 78%) of the measurements at each station fell into the low flow category defined in this way. Of the remaining measurements, an average of 12% (range 8% to 22%) were taken under high flow conditions, defined as at least two times base flow; the remaining 23% (range 7% to 48%) were taken under medium flow conditions, defined as between 1.3 and 2.0 times base flow.

Two linear regressions were performed: concentration against excess flow (flow above base flow), and concentration against total flow. To give low and high flow measurements roughly equal total weighting in the regression computations, all measurements made under low flow conditions were given a weight of 0.2, versus 1.0 for the medium and high flow measurements.

The results show little difference in the goodness of fit, as measured by root-mean-square errors (RMSE), between the two types of regression method. The coefficients from the regression against excess flow were used for the subsequent calculations of annualized loadings. For example purposes, the regression results for one subwatershed are shown in Table 3. The results for the remaining subwatersheds analyzed are given in Appendix B. With few exceptions, the concentration at 2 times base flow predicted from the regression line does not differ very much from the mean concentration at low flow.

The regression results and mean concentrations for each station were used to compute the annual loadings for each pollutant at that station. For each day of the year, the excess stream flow was computed by subtracting the base flow from the average daily flow. For each pollutant, the regression slope was multiplied by the excess flow and added to the intercept value to estimate the pollutant's concentration on that day; these values were in turn multiplied by the total flow for the day to get the total pollutant mass for the day. The estimated total mass of each pollutant was summed for all the days of the year to get total annual pollutant loadings. To estimate the base flow component of the pollutant loadings, the base stream flow for each day was summed to get the total annual base stream flow. This annual base flow was then multiplied by the average pollutant concentrations at low flow to compute the base flow pollutant loadings. The difference between total loading and base-flow loading provides an estimate of pollutant loading associated with excess flow.

The results for the two stations for which loadings were also computed using land use cover coefficients, as described in the following section, are presented in Tables 4 and 5. Results for the remaining stations are included in Appendix C.

Table 3. Mean Concentration at Low Flow and Regression of Concentration Against Flow in Excess of Base Flow and Against Total Flow
Station WQN0111 -- Schuylkill River, Hanover St. Bridge, Pottstown, PA

Weighting of low flow values in regression computation: 0.20
Multiple of detectability limit to which values below limit were set: 0.71
Number of measurements in each flow range:
Low: 29 (< 1.30 times base flow)
Medium: 8 (>= 1.30 and < 2.00 times base flow)
High: 4 (>= 2.00 times base flow)

Notes:
1. There were fewer measurements for code 00530
2. Regression-line value for twice base flow is given under "2xBase"
3. Units of regression slope are units of parameter divided by cubic feet per second.

Parameter Code	Parameter Name	Units	Below Limit	Low Flow Conc Mean	Low Flow Conc Std Dev	Regress on Excess Flow I'cept	Regress on Excess Flow Slope	Regress on Excess Flow 2xBase	Regress on Excess Flow RMSE	Regress on Total Flow I'cept	Regress on Total Flow Slope	Regress on Total Flow 2xBase	Regress on Total Flow RMSE
00530	Resid	mg/l	8	7.0970	8.4344	11.396	2.09e-03	12.114	11.293	10.904	1.06e-03	11.633	11.461
00610	NH3/4	mg/l	0	.13172	.11745	.12890	2.09e-06	.12962	.09147	.12685	1.82e-06	.12810	.09146
00615	NO2	mg/l	0	.05466	.02403	.04712	-8.29e-06	.04426	.01787	.05466	-6.93e-06	.04990	.01719
00620	NO3	mg/l	0	3.2076	.54262	3.3545	6.51e-05	3.3769	.64633	3.1946	1.04e-04	3.2659	.63137
00665	P-tot	mg/l	0	.15207	.06799	.14387	-1.05e-05	.14026	.05618	.16988	-1.68e-05	.15831	.05148
00680	C-org	mg/l	0	3.0241	.58643	3.0982	-2.61e-04	3.0083	.58470	3.4728	-2.85e-04	3.2767	.49189
00945	SO4	mg/l	0	72.429	21.503	67.051	-9.98e-03	63.620	17.779	76.998	-8.74e-03	70.989	16.324
01045	Fe	ug/l	0	310.90	194.25	315.49	1.70e-01	373.96	280.28	251.75	9.74e-02	318.71	304.55
01051	Pb	ug/l	23	6.3933	15.391	5.6330	8.41e-05	5.6619	9.0717	6.2299	-2.61e-04	6.0505	9.0638
01067	Ni	ug/l	33	22.492	10.996	23.612	1.33e-03	24.070	15.183	25.796	-5.57e-04	25.413	15.232
01092	Zn	ug/l	6	18.880	7.9078	17.711	1.95e-03	18.380	8.7828	14.984	2.10e-03	16.426	8.4789

Table 4. Annual Loadings (kg/year) for Base, Excess, and Total Flow
Station WQN0101 -- Delaware River at Trenton Ave. Bridge, Morrisville PA
Flow Station: 01463500 -- Delaware River at Trenton NJ

Year Starting		00530 Resid	00610 NH3/4	00615 NO2	00620 NO3	00665 P-tot	00680 C-org	00945 SO4	01045 Fe	01051 Pb	01067 Ni	01092 Zn
88/01/01	Base	3.818e+07	3.202e+05	7.318e+04	4.947e+06	3.874e+05	1.391e+07	1.226e+08	9.335e+05	1.975e+04	1.153e+05	1.204e+05
	Excess	5.625e+07	1.834e+05	3.642e+04	2.899e+06	2.418e+05	1.123e+07	6.518e+07	1.693e+06	1.708e+04	5.757e+04	1.098e+05
	Total	9.444e+07	5.036e+05	1.096e+05	7.846e+06	6.292e+05	2.514e+07	1.877e+08	2.627e+06	3.683e+04	1.729e+05	2.302e+05
89/01/01	Base	5.622e+07	4.714e+05	1.077e+05	7.284e+06	5.704e+05	2.048e+07	1.804e+08	1.374e+06	2.908e+04	1.697e+05	1.773e+05
	Excess	7.665e+07	1.723e+05	2.613e+04	2.764e+06	2.323e+05	1.317e+07	5.960e+07	2.364e+06	2.042e+04	5.008e+04	1.461e+05
	Total	1.329e+08	6.437e+05	1.339e+05	1.005e+07	8.027e+05	3.365e+07	2.400e+08	3.738e+06	4.950e+04	2.198e+05	3.235e+05
90/01/01	Base	6.238e+07	5.230e+05	1.195e+05	8.081e+06	6.329e+05	2.272e+07	2.002e+08	1.525e+06	3.227e+04	1.883e+05	1.968e+05
	Excess	9.036e+07	2.454e+05	4.359e+04	3.904e+06	3.267e+05	1.669e+07	8.616e+07	2.756e+06	2.562e+04	7.448e+04	1.741e+05
	Total	1.527e+08	7.684e+05	1.631e+05	1.199e+07	9.596e+05	3.941e+07	2.863e+08	4.281e+06	5.789e+04	2.628e+05	3.709e+05
Average	Base	5.226e+07	4.382e+05	1.002e+05	6.771e+06	5.302e+05	1.904e+07	1.677e+08	1.278e+06	2.703e+04	1.578e+05	1.648e+05
	Excess	7.442e+07	2.004e+05	3.538e+04	3.189e+06	2.669e+05	1.370e+07	7.031e+07	2.271e+06	2.104e+04	6.071e+04	1.433e+05
	Total	1.267e+08	6.385e+05	1.355e+05	9.960e+06	7.972e+05	3.273e+07	2.380e+08	3.549e+06	4.807e+04	2.185e+05	3.082e+05

Table 5. Annual Loadings (kg/year) for Base, Excess, and Total Flow
Station WQN0111 -- Schuylkill River, Hanover St. Bridge, Pottstown, PA
Flow Station: 01472000 -- Schuylkill River at Pottstown, PA

Year Starting		00530 Resid	00610 NH3/4	00615 NO2	00620 NO3	00665 P-tot	00680 C-org	00945 SO4	01045 Fe	01051 Pb	01067 Ni	01092 Zn
88/01/01	Base	5.880e+06	1.091e+05	4.528e+04	2.657e+06	1.260e+05	2.505e+06	6.000e+07	2.576e+05	5.297e+03	1.863e+04	1.564e+04
	Excess	1.430e+07	9.149e+04	3.940e+03	2.416e+06	6.030e+04	1.185e+06	1.153e+07	7.612e+05	3.975e+03	1.985e+04	1.799e+04
	Total	2.018e+07	2.006e+05	4.922e+04	5.073e+06	1.863e+05	3.690e+06	7.153e+07	1.019e+06	9.271e+03	3.848e+04	3.363e+04
89/01/01	Base	8.938e+06	1.659e+05	6.884e+04	4.040e+06	1.915e+05	3.808e+06	9.122e+07	3.915e+05	8.052e+03	2.833e+04	2.378e+04
	Excess	1.751e+07	1.072e+05	9.921e+02	2.834e+06	6.550e+04	1.263e+06	9.073e+06	9.577e+05	4.653e+03	2.363e+04	2.174e+04
	Total	2.645e+07	2.731e+05	6.983e+04	6.874e+06	2.570e+05	5.072e+06	1.003e+08	1.349e+06	1.270e+04	5.195e+04	4.552e+04
90/01/01	Base	8.584e+06	1.593e+05	6.611e+04	3.880e+06	1.839e+05	3.658e+06	8.760e+07	3.760e+05	7.733e+03	2.720e+04	2.283e+04
	Excess	1.270e+07	9.593e+04	1.504e+04	2.520e+06	7.868e+04	1.617e+06	2.542e+07	5.996e+05	4.176e+03	1.967e+04	1.686e+04
	Total	2.128e+07	2.552e+05	8.115e+04	6.400e+06	2.626e+05	5.275e+06	1.130e+08	9.756e+05	1.191e+04	4.687e+04	3.969e+04
Average	Base	7.800e+06	1.448e+05	6.008e+04	3.525e+06	1.671e+05	3.324e+06	7.961e+07	3.417e+05	7.027e+03	2.472e+04	2.075e+04
	Excess	1.483e+07	9.820e+04	6.656e+03	2.590e+06	6.816e+04	1.355e+06	1.534e+07	7.729e+05	4.268e+03	2.105e+04	1.886e+04
	Total	2.264e+07	2.430e+05	6.673e+04	6.116e+06	2.353e+05	4.679e+06	9.495e+07	1.115e+06	1.129e+04	4.577e+04	3.961e+04

Because of the very large RMSE values in the regression computations, no attempt was made to deduce loadings for different land use/cover types using the differences in annual loadings per area for the different water quality stations. Instead, predicted total loadings were computed using the annual flow data, the estimated area of each land use type within the station's drainage area, and published values of per-area nonpoint loadings.

2.3 Comparison of Stream Data-Derived Nonpoint Source Pollutant Loads and Empirically Modeled Loads

As described above, annualized loads for selected pollutants were computed using recorded water quality and flow data. For the purposes of comparison and projection of future watershed loads, land use/cover-based loading coefficients were also used to compute loads for the year 1990.

Loading coefficients are useful mathematical constants that allow empirical modeling of nonpoint source pollutant loads generated by different land use/cover types within a watershed. These coefficients are normally expressed as event mean concentrations (e.g., in mg/l), but may also be expressed as release rates (e.g., lbs/acre).

For this study, event mean concentrations (EMC) were used since more published values of this type were available. An EMC is the average concentration of a water quality constituent over a given type of land use/cover during the course of a rainfall event. Although specific application may vary, for general usage, EMC values are multiplied by the surface water flow for a particular time period (e.g., a year) to compute the pollutant load for that time period.

Different sets of published EMC values were used to compute annual pollutant loads within the Delaware River Basin against which stream data-derived loads could be compared. These values, given by land use/cover type and source, are shown in Table 6. (Note that wide variations occur between coefficients from different sources. These variations are likely caused by different sets of underlying assumptions and environmental conditions.) The different loading coefficients were evaluated for the purpose of determining coefficients which best seemed to represent conditions in the basin. In essence, annual pollutant loads computed with different sets of loading

Table 6. Loading Coefficients Evaluated by Land Use/Cover Category.

Category	Source	Total N (mg/l)	Total P (mg/l)	TSS (mg/l)	Pb* (μg/l)	Zn* (μg/l)
Urban	(1)	0.167	0.009	277		
	(2)	1.28	0.62	388		
	(3)	2.10	0.37	166	0.0024	0.0183
	(4)	1.89	0.45	181		
Agriculture	(1)	2.60	0.24	201		
	(2)	2.08	0.30	201		
	(3)	1.56	0.36	201	0.0024	0.0183
	(4)	3.41	0.68	319		
Open/Brush	(1)	1.60	0.13	293		
	(2)	3.02	1.08	515		
	(3)	1.51	0.12	70	0.0024	0.0183
	(4)	2.19	0.29	224		
Woodland	(1)	0.19	0.006	39		
	(2)	0.51	0.033	39		
	(3)	0.83	0.06	39	0.0024	0.0183
	(4)	0.79	0.03	70		
Wetland	(1)	0.19	0.006	39		
	(2)	0.51	0.033	39		
	(3)	0.83	0.06	39	0.0024	0.0183
	(4)	0.79	0.03	39		
Barren	(1)	2.60	0.10	2200		
	(2)	3.90	0.35	2200		
	(3)	5.20	0.59	2200	0.0024	0.0183
	(4)	3.90	0.35	2200		

(1) Haith and Shoemaker (1987)
(2) Bedient et al. (1980)
(3) Newell et al. (1992)
(4) Average of values reported above as well as by U.S. EPA (1982), USGS (1990), NOAA (1987) and Winslow and Associates (1986)

*Note: Only one set of loading coefficients could be found for lead and zinc in the literature (3). In this case, the same value for each was applied to all land use/cover types coefficients were compared against similar loads computed with sampling data for the two sub-basins shown previously in Tables 4 and 5. Coefficients that produced close matches in terms of calculated loadings were considered to be more representative of conditions in the two sample sub-basins. The most representative sets of coefficients were then used to recompute loads for 1990 and to compute projected loads for the year 2020, thus providing a better basis of comparison between the two dates.

In comparing stream-derived versus coefficient-derived loads, it was felt that data generated only for those watersheds above the fall line (i.e., Trenton) should be used due to tidal influences on in-stream water quality readings in the lower part of the basin. The aggregated subwatersheds chosen for analysis were those within the Delaware River watershed above Trenton and the upper watershed of the Schuylkill River (see Figure 4). (Note: These subwatersheds coincide with those monitored by water quality stations WQN0101 and WQN0111.) The stream data-derived flows and loads for these two areas were shown previously in Tables 4 and 5. Note that values are given for base flow, excess flow (the amount of flow above baseflow), and total flow conditions.

In using loading coefficients, nonpoint source pollutant loads were derived by multiplying a given EMC for a pollutant type by that portion of the surface water runoff (e.g., excess flow) emanating from the corresponding land use/cover type. For example, if 70 percent of the watershed was comprised of forest land, then the EMC for forest land would be multiplied by a value representing 70 percent of the excess surface water flow.

Table 7 gives the combined pollutant loads for the two watersheds for 1990 as estimated using water quality and flow data (sampling) and various EMC values for land use/cover. Note that only values for total suspended solids (TSS), total nitrogen (TN), total phosphorus (TP), lead (Pb) and zinc (Zn) were computed. This is because published loading coefficients for water quality constituents other than those were difficult to find. As can be seen from this table, values computed using loading coefficients were reasonably close to stream-derived results for all constituents with the exception of total suspended solids, which was significantly higher. This overestimation may well have been caused by the sediment resuspension phenomenon discussed in Section 2.2. However, it should be recognized that stream-derived loadings may not be all that good given the suspect procedures used to collect water quality data in the first place.

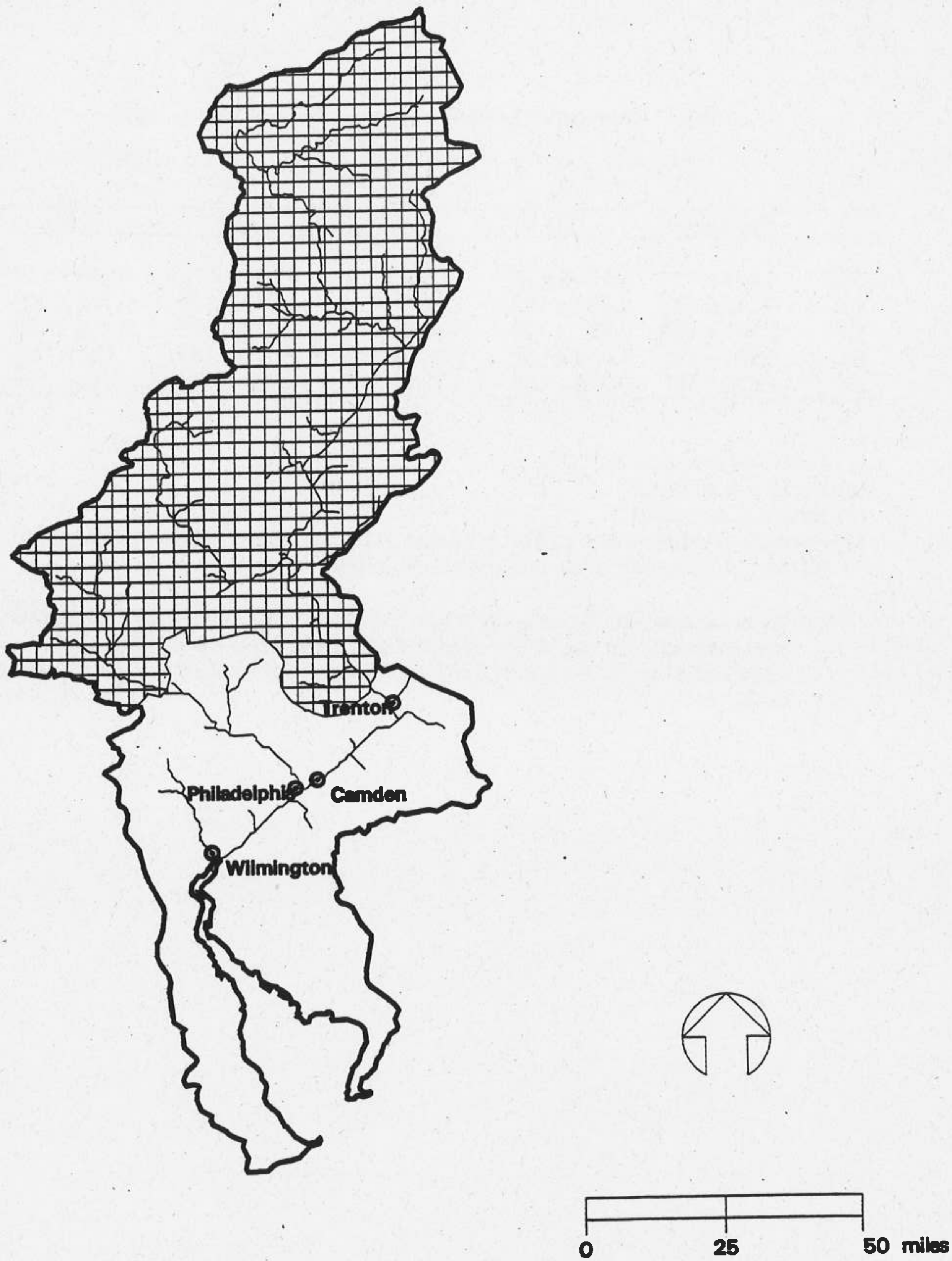

Fig 4. Aggregated subwatersheds selected for loading coefficient analyses

Table 7. Cumulative Load Comparisons (in Kg/Year) for 1990

	Sampling*	(1)	(2)	(3)	(4)
TSS	8.925×10^7	49.946×10^7	52.586×10^7	47.305×10^7	69.941×10^7
TN	6.118×10^6	3.668×10^6	4.293×10^6	4.848×10^6	6.752×10^6
TP	3.350×10^5	2.986×10^5	5.994×10^5	6.948×10^5	9.862×10^5
Pb	2.531×10^4	1.019×10^4	1.019×10^4	1.019×10^4	1.019×10^4
Zn	1.622×10^5	0.776×10^5	0.776×10^5	0.766×10^5	0.766×10^5

(1) Haith and Shoemaker (1987)
(2) Bedient et al. (1980)
(3) Newell et al. (1992)
(4) Average of values reported above as well as by U.S. EPA (1982), USGS (1990), NOAA (1987) and Winslow and Associates (1986)

*Note: In the case of TN, the value given for "sampling" only represents the cumulative load estimated for total NO_3. As described earlier, this value is believed to represent a significant part of the total nitrogen load for the basin on an annual basis.

As described earlier, the sets of loading coefficients which best appeared to represent conditions within the two subwatersheds were subsequently applied to the entire Delaware River Basin in order to compute and compare pollutant loads for 1990 and 2020. The loading coefficients selected for this purpose are those shown in Table 8. (References for each coefficient can be identified by matching values in the latter table with those given in Table 7.) As discussed in Section 2.1.1, flow data were only compiled for that part of the basin above the fall line. To compute surface water flow for the entire basin, a linear extrapolation of excess flow was made using the ratio between the area of the two watersheds evaluated and the area of the total basin. The total basin-wide pollutant loads for 1990 derived using this approach are given in Table 9. The procedures utilized for estimating similar loads for 2020 are discussed more fully in the following section.

2.4 Projection of Pollutant Loads for the Year 2020

In order to project pollutant loads for the year 2020, it was necessary to first estimate the distribution of land use/cover within the Delaware River Basin for that time period. This was accomplished by estimating the rates of changes between land use/cover types as depicted on the digital maps described earlier (i.e. representing the late 1970s and 1990), and extrapolating these changes to the year 2020.

Table 10 shows the rates of change within the entire basin for the generalized land use/cover categories between the time the USGS digital map was compiled and the time the AVHRR image (upon which the 1990 map was based) was generated. For the purposes of this exercise, it was assumed that the elapsed time between the two dates was 12 years. (This assumption is believed to be reasonable based upon our past experience with this type of data. Unfortunately, the exact date of compilation for the older land use/cover data is not known since USGS does not provide this information with each data set. In their description of this program [USGS, 1976], they state only that this particular mapping program was initiated in 1975 and scheduled for completion in 1982.) Using a linear rate of change as previously established for each category, the percent composition of land use/cover within the entire basin for the year 2020 was subsequently computed as also shown in Table 10.

Table 8. Representative Loading Coefficients by Land Use/Cover Category

Category	Total N	Total P	TSS	Pb	Zn
Urban	1.89	0.009	166	0.0024	0.0183
Agriculture	3.41	0.24	201	0.0024	0.0183
Open/Brush	2.19	0.13	70	0.0024	0.0183
Woodland	0.79	0.006	39	0.0024	0.0183
Wetland	0.79	0.006	39	0.0024	0.0183
Barren	3.90	0.10	2200	0.0024	0.0183

Table 9. Estimated Basin-wide Nonpoint Sources Pollutant Loads for 1990 (in Kg/Yr)

Constituent	Load
Total N	11.967×10^6
Total P	5.488×10^5
Total Suspended Solids	74.344×10^7
Lead	1.592×10^4
Zinc	1.214×10^5

As was done for 1990, the annual nonpoint source loads for various constituents were determined by multiplying the representative EMC for each pollutant (see Table 8) by the pro-rated surface water runoff for its corresponding land use/cover type. The resultant projected pollutant loads for 2020 are given in Table 11. In comparing this table with Table 10, it can be seen that decreases in nonpoint source pollutant loads are projected to occur by 2020 for three of the five constituents evaluated (TN, TP and TSS). This is primarily due to the anticipated decrease in agriculture (a major contributor of these pollutants) and a corresponding increase in woodland (a minor contributor of these pollutants). The projected changes in lead and zinc were statistically insignificant, primarily due to the fact that the same EMC value was used for all the land use/cover categories analyzed. As discussed in the next section; however, some of these changes may not be all that meaningful given the various short-comings identified with the data sets used.

3. DISCUSSION OF RESULTS

As described in this report, an approach was developed to determine estimates of pollutant loads originating from nonpoint sources within the Delaware River Basin. The approach entailed statistical analyses of in-stream water quality and flow data in conjunction with GIS-based analyses of land use/cover composition within the basin for two different time frames. The above analyses culminated in the projection of nonpoint source loadings to the Delaware Estuary for the year 2020.

The focus of this particular study was not necessarily to evaluate the dynamics of NPS pollution within small watersheds; rather it was to estimate NPS loads for the entire Delaware River Basin using available digital land use/cover data and representative water quality sampling data for large portions of the basin. The initial goal was to obtain a set of not more than a dozen water quality stations whose drainage areas jointly represented much of the basin. Stations with limited drainage areas were considered unlikely to help meet this criterion, and increased the likelihood of bias by point source pollution from, for example, badly managed intensive livestock operations.

Midway through the study, a major change in strategy was necessitated by the lack of sufficient water quality data. As described, this change in strategy involved reliance

Table 10. Land Use/Cover Distribution and Rates of Change by Year (in %)

	1978	1990	1978-1990 Change	2020	1990-2020 Change
Urban	11.68	13.86	(+2.18)	19.19	(+5.33)
Agriculture	36.01	31.44	(-4.57)	19.82	(-11.62)
Open/Brush	0.15	0.20	(+0.05)	0.32	(+0.12)
Woodland	46.97	50.17	(+3.20)	56.87	(+6.7)
Water	1.11	1.11	(0)	1.11	(0)
Wetlands	3.28	3.12	(-0.16)	2.70	(-0.42)
Barren	0.80	0.10	(-0.70)	0	
Total	100.00	100.00		100.00	

Table 11. Projected Nonpoint Source Pollutant Loads for the year 2020 (in Kg/Yr)

Constituent	Load
Total N	10.44×10^6
Total P	3.65×10^5
Total Suspended Solids	65.43×10^7
Lead	1.64×10^4
Zinc	1.25×10^5

on the use of published loading coefficients rather than sampling data to predict nonpoint source pollutant loads for the basin at different dates. In addition, the limited resolution of available land cover data (1 km for the only recent data obtainable) and the fact that each grid cell in these data represents the dominant, but not necessarily only, category for that grid cell, made it desirable to work with larger regions for which errors in individual grid cell values can be expected to average out.

Although the analytical methodology is believed to be generally sound, the study results may be somewhat suspect due to weaknesses in some of the data sets used. As described in Section 2.1, problems with integrity, frequency and quantity were encountered with all of the water quality data sets utilized. The flow data was usable to the extent that the algorithm used by USGS for filling data gaps, especially during winter months, is acceptable. Overall, these were the best data sets that could be found. Consequently, it is probably true that not enough "good" sample observations were available to support the types of statistical analyses conducted as part of this project.

Similarly, land use/cover projections for the year 2020 were based upon differences observed in two digital land use/cover maps that were not entirely compatible. The earlier map (circa late-1970's) was based on the interpretation of aerial photographs, and land use/cover was mapped at a spatial resolution of approximately 4 to 16 hectares. The 1990 map was based on the classification of AVHRR image data having a nominal spatial resolution of about 100 hectares (1 km x 1 km cells). Accordingly, it is probable that some of the observed differences between the two map dates were caused by differences in spatial resolution and format as well as by actual changes in land use/cover. However, given the data available, this approach was the most sound in assessing probable land use changes.

4. RECOMMENDATIONS FOR FURTHER STUDY/INVESTIGATION

Both of the approaches used in this study could provide significantly more accurate results if the quality of the input data and the models used to interpret them were improved. Specific recommendations for any future work in this area are as follows.

The accuracy of total loading estimates based on water quality and flow rate measurements could be improved by:

1. Increasing the frequency of measurements, with an emphasis on obtaining more measurements under high flow conditions. Ideally, samples should be collected daily, so that they could be analyzed for any date on which significant precipitation, reservoir release, or other significant events occurred. Unfortunately, current sampling protocols require carefully performing a series of steps to filter, acid stabilize, and chill each sample immediately after it is collected. As a result, automated sampling equipment which complies with these protocols is complex and expensive.

2. Using analytical techniques with lower detection thresholds, especially for metals. Current thresholds have often been chosen to detect concentrations above safe limits rather than to help estimate total loadings.

3. Measuring the same set of pollutants at all stations and for all samples. At present, different definitions of residue and suspended solids appear to be employed at different stations, organic chemicals are measured only occasionally, and many stations do not measure biological oxygen demand.

4. Developing and/or extracting from the published literature appropriate models for estimating the effects of sediment resuspension, controlled reservoir releases, time of year, rate of precipitation, and the time interval between successive precipitation events.

5. Compiling reported pollutant discharge data from all known point sources as an alternative method for estimating non runoff related pollutant loadings. It is unclear to what extent the release of data reported to the EPA and other agencies may be restricted by confidentiality requirements, nor how fully contributions from smaller polluters are being reported. Corrections would also be needed for effects such as sedimentation and filtering by wetlands.

6. Evaluating relative contributions of pollutants from point sources, ground water and atmospheric deposition via:

a. analysis of point discharge data that may be available from US EPA,

b. more frequent sampling of pollutants during base flow conditions, and

c. collection and analysis of rainfall samples distributed throughout the entire basin.

Estimates of pollutant loadings based on land use/cover types could be improved by:

1. Obtaining an up to date land use/cover data set for the entire Delaware River Basin compiled from a consistent set of aerial photography or satellite imagery. Such data may be available for the entire basin in the very near future. Potential sources of new land use/cover data include the following:

   a. Gap Analysis program being conducted by Penn State University for the U.S. Fish and Wildlife Service,

   b. recently completed mapping by the Delaware Valley Regional Planning Commission for nine counties in Pennsylvania and New Jersey, and

   c. Gap Analysis data being prepared for New York State by Cornell University.

2. Identifying or developing loading coefficients (particularly those for heavy metals) that better reflect land use/cover conditions in this part of the country.

3. Using soils, geological, and elevation data to permit adjusting loading coefficients for different land surface conditions. This would probably require an extensive literature search and perhaps further refining of existing models.

4. Assembling and analyzing precipitation data from all weather observation stations within the basin to permit adjusting runoff loadings for effects of rate of rainfall and the duration and spacing of precipitation events. This would require finding reliable techniques for estimating precipitation distributions at locations other than the observation stations, and finding or developing models for adjusting loading coefficients for precipitation intensity and duration.

5. Compiling existing data on rates of nonpoint pollution production, such as livestock numbers reported to the agricultural census and plans for erosion, pesticide, and fertilizer management submitted to the Soil Conservation Service and similar agencies. Models to estimate what fraction of these pollutants find their way into streams would need to be developed. Confidentiality policies may restrict distribution of some of these data.

5. REFERENCES

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Appendix A

Sampling Dates, Flow Rates and Measured Pollutant Concentrations for the Seven Monitoring Stations

Station WQN0110: Schuylkill R, Falls Br, Philadelphia

Flow Rates and Pollutant Concentrations

	Total flow cfs	Base flow cfs	Excess flow cfs	Ratio, excess to base	000530 Resid mg/l	000610 NH3/4 mg/l	000615 NO2 mg/l	000620 NO3 mg/l	000665 P-tot mg/l	000680 C-org mg/l	000945 SO4 mg/l	001045 Fe ug/l	001051 Pb ug/l	001067 Ni ug/l	001092 Zn ug/l
88/01/26	2520	1158	1362	1.18	22.0	0.490	0.034	3.71	0.240	3.50	45.0	278	4.0	25.0*	18.0
88/02/24	3580	2292	1288	0.56	4.0	0.380	0.030	3.27	0.180	2.90	41.0	586	4.0*	25.0*	55.0
88/03/31	2150	1585	565	0.36	12.0	0.210	0.050	2.59	0.190	3.70	51.0	228	4.0*	25.0*	10.0*
88/04/26	1280	1290	-10#	-0.01	2.0	0.340	0.076	2.34	0.290	3.70	66.0	289	4.0*	25.0*	19.0
88/05/31	2750	1434	1316	0.92	2.0	0.200	0.050	2.81	0.230	2.60	34.0	485	7.0	57.0	23.0
88/06/16	1100	1004	96	0.10	2.0*	0.240	0.084	3.64	0.330	3.10	63.0	230	4.0*	54.0	30.0
88/07/19	1600	1180	420	0.36	10.0	0.130	0.058	1.98	0.430	5.20	69.0	340	4.0	51.0	19.0
88/08/16	721	667	54	0.08	12.0	0.210	0.040	3.08	0.450	4.20	82.0	174	4.0*	65.0	20.0
88/09/15	1480	995	485	0.49	10.0	0.210	0.056	3.24	0.330	3.70	48.0	338	5.0	25.0*	12.0
88/10/13	858	589	269	0.46	12.0	0.290	0.080	3.66	0.490	3.70	72.0	181	4.0*	25.0*	22.0
88/11/15	1660	1140	520	0.46	2.0*	0.250	0.063	3.33	0.370	4.30	67.0	381	4.0*	32.0	42.0
88/12/13	975	900	75	0.08	2.0*	0.620	0.072	3.56	0.310	3.40	68.0	193	5.0	10.0*	22.0
89/01/26	1480	1410	70	0.05	2.0*	0.450	0.052	3.65	0.260	3.30	43.0	170	4.0*	25.0*	30.0
89/02/08	1230	1071	159	0.15	2.0*	0.290	0.068	3.56	0.300	3.40	57.0	185	4.0*	41.0	53.0
89/03/01	3110	1741	1369	0.79	10.0	0.260	0.048	3.34	0.200	3.30	45.0	283	5.0	25.0*	13.0
89/04/11	2930	2769	161	0.06	16.0	0.180	0.058	2.46	0.200	3.30	48.0	360	4.0	25.0*	10.0*
89/05/24	11700	5207	6493	1.25	52.0	0.150	0.050	2.37	0.220	3.20	44.0	1810	9.0	25.0*	25.0
89/06/15	3710	3650	60	0.02	4.0	0.160	0.054	2.85	0.200	3.30	46.0	622	6.0	25.0*	17.0
89/07/26	4680	2822	1858	0.66	16.0	0.110	0.034	2.74	0.190	3.00	58.0	357	9.0	58.0	20.0
89/08/16	7840	1340	6500	4.85	136.0	0.130	0.036	1.76	0.290	6.10	35.0	3080	10.0	41.0	10.0*
89/09/28	2380	1770	610	0.34	8.0	0.150	0.046	2.85	0.230	5.30	52.0	409	5.0	25.0*	11.0
89/10/25	3770	1187	2583	2.18	4.0	0.130	0.030	4.08	0.150	3.70	42.0	316	17.0	25.0*	23.0
89/11/14	1750	1693	58	0.03	16.0	0.100	0.044	3.52	0.230	3.50	68.0	199	16.0	25.0*	15.0
90/01/10	2670	1696	974	0.57	4.0	0.470	0.052	3.34	0.230	3.20	57.0	298	4.0	25.0*	30.0
90/02/26	3970	2182	1788	0.82	2.0*	0.220	0.044	3.35	0.130	3.30	52.0	472	4.0	38.0	21.0
90/04/16	4470	2620	1850	0.71	44.0	0.080	0.036	2.38	0.130	4.60	41.0	413	4.0*	25.0*	63.0
90/06/05	3160	2186	974	0.45	16.0	0.110	0.038	3.26	0.150	3.00	47.0	411	6.0	25.0*	27.0
90/07/26	881	727	154	0.21	2.0*	0.090	0.052	3.34	0.290	3.70	63.0	85	8.0	25.0*	12.0
90/08/23	3660	1260	2400	1.90	14.0	0.120	0.042	2.38	0.210	4.50	50.0	930	5.0	29.0	38.0
90/09/20	966	783	183	0.23	----	0.110	0.044	4.71	0.310	2.30	97.0	179	4.0*	25.0*	16.0
90/10/29	3020	2194	826	0.38	----	0.160	0.034	2.87	0.140	3.10	45.0	351	4.0*	25.0*	23.0
90/11/07	1540	1303	238	0.18	----	0.110	0.050	3.34	0.240	2.90	78.0	345	4.0*	25.0*	20.0
91/01/03	5520	4116	1404	0.34	----	0.110	0.024	3.61	0.100	2.40	39.0	453	4.0*	25.0*	22.0
91/01/15	4140	3217	923	0.29	----	0.170	0.036	3.35	0.130	3.00	39.0	394	4.0*	25.0*	24.0
91/02/25	2320	2158	162	0.07	----	0.150	0.048	3.58	0.130	2.70	60.0	164	4.0*	25.0*	20.0
91/03/21	3820	3379	441	0.13	----	0.130	0.038	2.62	0.130	2.80	58.0	212	4.0*	25.0*	10.0*
91/04/30	2830	1934	896	0.46	----	0.150	0.050	2.72	0.190	3.00	57.0	274	4.0*	25.0*	15.0
91/05/21	1910	1580	330	0.21	----	0.140	0.088	3.06	0.250	3.60	49.0	300	4.0*	25.0*	14.0
91/06/13	1430	753	677	0.90	----	0.260	0.102	4.01	0.330	4.10	85.0	419	5.0	25.0*	10.0*
91/07/24	780	484	296	0.61	----	0.230	0.080	3.55	0.460	4.40	87.0	95	4.0*	25.0*	15.0
91/08/27	587	392	195	0.50	----	0.100	0.056	2.18	0.380	4.30	69.0	170	4.0*	25.0*	10.0*
91/09/30	567	495	72	0.15	----	0.130	0.062	2.84	0.340	3.90	71.0	154	4.0*	25.0*	10.0

Notes: # Instantaneous flow was less than base flow derived from daily average flow.
* Measurement limit; data flagged as being below this limit.

Station WQN0101: Delaware R at Trenton Ave br, Morrisville PA

Flow Rates and Pollutant Concentrations

	Total flow cfs	Base flow cfs	Excess flow cfs	Ratio, excess to base	000530 Resid mg/l	000610 NH3/4 mg/l	000615 NO2 mg/l	000620 NO3 mg/l	000665 P-tot mg/l	000680 C-org mg/l	000945 SO4 mg/l	001045 Fe ug/l	001051 Pb ug/l	001067 Ni ug/l	001092 Zn ug/l
88/01/25	7890	5273	2618	0.50	4.0	0.170	0.004	1.67	0.060	2.60	24.0	153	4.0*	25.0*	10.0*
88/02/10	12900	8406	4494	0.53	2.0*	0.140	0.012	1.05	0.060	2.40	25.0	179	4.0*	25.0*	36.0
88/03/22	10800	9496	1304	0.14	2.0*	0.120	0.018	0.88	0.050	2.10	21.0	140	4.0*	26.0	30.0
88/04/05	13500	8099	5401	0.67	2.0*	0.130	0.026	0.90	0.060	2.30	21.0	170	4.0	33.0	33.0
88/05/18	8350	6789	1561	0.23	18.0	0.100	0.050	1.01	0.120	3.00	24.0	301	4.0*	43.0	52.0
88/06/06	9150	5826	3324	0.57	12.0	0.020	0.016	0.88	0.110	2.80	22.0	325	4.0*	28.0	10.0*
88/07/05	3360	3263	97	0.03	2.0*	0.090	0.030	1.37	0.130	3.40	53.0	183	4.0*	63.0	31.0
88/08/15	3880	3307	573	0.17	2.0*	0.060	0.024	1.22	0.140	3.20	27.0	98	4.0*	65.0	23.0
88/09/14	6430	4104	2326	0.57	14.0	0.110	0.050	1.57	0.120	3.20	30.0	443	10.0*	68.0	27.0
88/10/12	3080	3090	-10#	0.00	4.0	0.020	0.008	1.17	0.110	2.50	23.0	105	5.0	25.0*	10.0*
88/11/14	6040	5460	580	0.11	2.0*	0.050	0.014	1.01	0.100	3.50	20.0	244	4.0*	25.0*	26.0
88/12/12	5390	4060	1330	0.33	6.0	0.090	0.012	1.31	0.080	2.50	34.0	179	6.0	25.0*	42.0
89/01/25	4360	4010	350	0.09	4.0	0.280	0.028	1.54	0.070	3.00	30.0	125	4.0*	25.0*	26.0
89/02/09	4330	3635	695	0.19	10.0	0.200	0.022	1.39	0.080	3.20	24.0	97	4.0*	25.0*	27.0
89/03/02	7350	5455	1895	0.35	2.0	0.110	0.016	1.15	0.090	3.00	23.0	171	4.0*	25.0*	15.0
89/04/11	14300	12860	1440	0.11	4.0	0.080	0.016	0.90	0.060	2.80	24.0	272	4.0	25.0*	17.0
89/05/22	24500	23569	931	0.04	20.0	0.090	0.010	0.74	0.060	3.40	15.0	532	4.0*	25.0*	21.0
89/06/21	18800	18600	200	0.01	4.0	0.100	0.028	0.92	0.090	3.50	21.0	462	4.0*	25.0*	40.0
89/07/19	6120	6420	-300#	-0.05	2.0*	0.060	0.030	1.51	0.090	3.00	27.0	196	4.0*	25.0*	19.0
89/08/16	8610	4605	4005	0.87	66.0	0.150	0.038	1.26	0.190	6.10	24.0	2070	10.0	25.0*	25.0
89/09/18	5560	3896	1664	0.43	12.0	0.070	0.038	1.59	0.160	3.00	29.0	312	6.0	25.0*	21.0
89/09/25	14600	4390	10210	2.33	16.0	0.070	0.018	1.08	0.090	5.50	25.0	730	5.0	25.0*	25.0
89/10/25	24800	8744	16056	1.84	6.0	0.040	0.006	0.96	0.070	5.20	19.0	581	7.0	25.0*	61.0
89/11/30	9580	6646	2934	0.44	2.0*	0.050	0.010	1.09	0.060	2.70	24.0	91	5.0	25.0*	14.0
89/12/20	11400	4050	7350	1.81	18.0	0.300	0.018	1.70	0.100	3.80	28.0	83	11.0	25.0*	10.0*
90/01/24	11800	10233	1567	0.15	14.0	0.110	0.016	1.12	0.100	2.90	24.0	213	5.0	25.0*	22.0
90/02/20	19700	17233	2467	0.14	36.0	0.030	0.006	0.92	0.050	2.50	21.0	229	16.0	64.0	25.0
90/03/19	17000	10512	6488	0.62	10.0	0.040	0.016	0.97	0.060	3.10	23.0	322	11.0	25.0*	20.0
90/04/26	9580	9354	226	0.02	4.0	0.020*	0.010	0.76	0.050	2.80	22.0	142	6.0	25.0*	14.0
90/05/15	33800	10002	23798	2.38	30.0	0.050	0.010	0.74	0.090	3.10	17.0	891	6.0	25.0*	38.0
90/06/14	8250	8060	190	0.02	10.0	0.040	0.010	1.02	0.070	2.70	27.0	256	4.0*	25.0*	23.0
90/07/19	10100	4419	5681	1.29	4.0	0.050*	0.008	0.81	0.100	4.10	22.0	709	6.0	25.0*	32.0
90/08/13	12000	5250	6750	1.29	40.0	0.020	0.012	0.93	0.110	4.10	23.0	887	8.0	10.0*	43.0
90/09/04	6040	4940	1100	0.22	2.0	0.020*	0.006	0.85	0.070	3.10	28.0	213	6.0	25.0*	36.0
90/10/29	13700	6138	7562	1.23	----	0.030	0.004	0.84	0.050	3.70	21.0	306	4.0	25.0*	45.0
90/11/15	21300	6933	14367	2.07	----	0.040	0.004	0.75	0.060	3.80	19.0	478	4.0*	25.0*	40.0
90/12/26	33100	17754	15346	0.86	----	0.050	0.004	0.92	0.050	3.00	21.0	376	6.0	25.0*	46.0
91/01/15	11800	10900	900	0.08	----	0.060	0.008	1.20	0.060	2.20	27.0	179	4.0*	16.0	34.0
91/02/05	9360	9250	110	0.01	----	0.020*	0.012	1.22	0.050	2.20	28.0	121	4.0*	32.0	50.0
91/03/27	18900	11492	7408	0.64	----	0.050	0.010	0.76	0.050	2.50	17.0	181	4.0*	25.0*	25.0
91/04/18	10700	8910	1790	0.20	----	0.020	0.018	1.04	0.040	2.40	21.0	224	4.0*	25.0*	53.0
91/05/20	6170	6130	40	0.01	----	0.040	0.016	1.00	0.090	3.50	20.0	142	4.0*	25.0*	10.0
91/06/20	4190	3688	502	0.14	----	0.020	0.016	1.10	0.110	3.10	27.0	166	4.0*	25.0*	16.0
91/07/18	3200	3200	0	0.00	----	0.050	0.010	0.74	0.110	2.90	29.0	109	4.0*	25.0*	10.0*
91/08/20	4530	2653	1877	0.71	----	0.030	0.012	0.98	0.120	3.00	33.0	94	4.0*	25.0*	10.0*
91/09/10	2870	2617	253	0.10	----	0.020	0.012	0.91	0.110	3.00	30.0	85	4.0*	25.0*	10.0*

Notes: # Instantaneous flow was less than base flow derived from daily average flow.
* Measurement limit; data flagged as being below this limit.

Station WQN0121: Neshaminy Cr at PA 213 br, nr Langhorne

Flow Rates and Pollutant Concentrations

	Total flow cfs	Base flow cfs	Excess flow cfs	Ratio, excess to base	000530 Resid mg/l	000610 NH3/4 mg/l	000615 NO2 mg/l	000620 NO3 mg/l	000665 P-tot mg/l	000680 C-org mg/l	000945 SO4 mg/l	001045 Fe ug/l	001051 Pb ug/l	001067 Ni ug/l	001092 Zn ug/l
88/01/25	228	237	-9#	-0.04	8.0	0.720	0.024*	2.97	0.32	3.8	46.0	278	4.0*	25.0*	10.0*
88/02/10	213	186	27	0.15	2.0	0.430	0.032	3.05	0.31	4.0	45.0	250	4.0*	25.0*	22.0
88/03/22	140	138	2	0.01	6.0	0.020	0.048	3.25	0.32	4.3	46.0	265	4.0	25.0*	20.0
88/04/05	171	147	24	0.16	12.0	0.040	0.076	2.34	0.42	4.7	46.0	268	6.0	25.0*	15.0
88/05/18	258	235	23	0.10	16.0	0.130	0.070	2.79	0.41	4.8	43.0	624	5.0	60.0	10.0*
88/06/06	150	148	2	0.02	24.0	0.050	0.024	2.84	0.32	4.0	35.0	613	5.0	25.0*	10.0*
88/07/05	44	40	4	0.10	8.0	0.080	0.030	2.39	0.43	5.5	55.0	282	5.0	34.0	11.0
88/08/16	48	48	0	0.00	22.0	0.070	0.028	0.67	0.41	10.2	49.0	174	12.0	34.0	26.0
88/09/14	163	77	86	1.11	12.0	0.030	0.010	1.79	0.47	4.3	37.0	270	7.0	92.0	35.0
88/10/12	35	30	5	0.17	8.0	0.030	0.010	4.39	0.76	5.2	50.0	87	7.0	28.0	10.0*
88/11/14	276	77	200	2.61	20.0	0.020	0.016	4.06	0.67	5.9	45.0	2910	8.0	25.0*	28.0
88/12/12	109	90	19	0.21	2.0	0.240	0.030	3.84	0.32	3.6	48.0	858	14.0	25.0*	44.0
89/01/25	174	130	44	0.34	10.0	0.020	0.024	3.85	0.28	3.3	38.0	244	4.0*	25.0*	30.0
89/02/09	109	116	-7#	-0.06	20.0	0.020	0.026	3.93	0.29	3.7	44.0	183	6.0	25.0*	10.0*
89/03/02	213	185	28	0.15	10.0	0.040	0.046	0.28	0.27	3.0	37.0	492	4.0*	25.0*	18.0
89/04/10	356	361	-5#	-0.01	2.0	0.040	0.016	2.14	0.14	3.8	36.0	341	7.0	25.0*	10.0*
89/05/22	132	328	-196#	-0.60	2.0	0.050	0.016	2.88	0.14	3.6	39.0	333	5.0	25.0*	10.0*
89/06/21	265	282	-17#	-0.06	2.0*	0.090	0.010	3.14	0.17	3.2	32.0	288	4.0*	25.0*	19.0
89/07/19	251	247	4	0.02	4.0	0.040	0.012	2.89	0.21	4.6	35.0	396	4.0	25.0*	24.0
89/08/16	681	524	157	0.30	170.0	0.130	0.034	1.47	0.39	8.8	21.0	7100	24.0	28.0	23.0
89/09/25	290	287	3	0.01	4.0	0.070	0.032	2.74	0.20	4.1	40.0	495	4.0*	25.0*	10.0*
89/10/25	412	170	242	1.43	10.0	0.060	0.050	2.85	0.17	4.5	34.0	1060	8.0	25.0*	10.0*
89/11/30	258	152	106	0.70	8.0	0.030	0.014	2.37	0.18	4.2	37.0	218	5.0	25.0*	10.0*
89/12/20	82	93	-11#	-0.12	4.0	0.040	0.034	4.59	0.37	4.0	52.0	133	9.0	25.0*	44.0
90/01/24	301	304	-3#	-0.01	14.0	0.030	0.022	2.40	0.19	4.1	35.0	240	6.0	25.0*	10.0
90/02/20	208	192	16	0.09	34.0	0.020*	0.038	3.59	0.11	3.0	41.0	202	4.0	25.0*	10.0*
90/03/19	255	128	127	0.99	16.0	0.030	0.068	2.59	0.21	6.0	35.0	394	6.0	25.0*	42.0
90/04/26	204	192	12	0.06	2.0*	0.020*	0.038	1.98	0.15	4.0	37.0	263	4.0*	25.0*	11.0
90/05/15	419	379	40	0.11	46.0	0.090	0.044	1.83	0.20	6.3	29.0	1890	6.0	25.0*	21.0
90/06/14	125	130	-5#	-0.04	2.0*	0.050	0.018	3.15	0.13	3.3	38.0	190	4.0*	25.0*	10.0
90/07/19	65	56	9	0.16	4.0	0.060	0.010	1.82	0.25	5.2	37.0	177	8.0	25.0*	10.0*
90/08/13	165	165	0	0.00	16.0	0.020	0.010	1.75	0.21	4.7	58.0	432	6.0	25.0*	29.0
90/09/04	76	74	2	0.03	2.0*	0.020*	0.012	2.11	0.31	3.7	48.0	206	4.0*	25.0*	24.0
90/10/29	69	65	5	0.07	----	0.040	0.006	2.10	0.27	4.2	47.0	213	4.0*	25.0*	24.0
90/11/15	94	81	13	0.16	----	0.100	0.012	2.89	0.24	4.7	41.0	278	4.0*	25.0*	21.0
90/12/26	369	280	89	0.32	----	0.100	0.016	2.18	0.21	4.7	34.0	754	4.0*	25.0*	21.0
91/01/15	470	491	-21#	-0.04	----	0.100	0.024	2.75	0.14	3.4	36.0	480	4.0*	25.0*	19.0
91/02/05	248	252	-4#	-0.02	----	0.020*	0.026	3.23	0.17	3.2	36.0	301	4.0*	25.0*	32.0
91/03/27	335	356	-21#	-0.06	----	0.040	0.018	2.05	0.19	4.6	32.0	299	4.0*	25.0*	10.0*
91/04/18	207	165	42	0.26	----	0.020	0.046	2.59	0.22	4.4	38.0	246	4.0*	25.0*	41.0
91/05/20	115	104	11	0.10	----	0.040	0.034	3.60	0.30	3.5	49.0	177	4.0*	25.0*	10.0*
91/06/20	150	61	89	1.46	----	0.100	0.022	1.74	0.27	4.8	41.0	369	4.0*	25.0*	11.0
91/07/18	66	49	17	0.34	----	0.050	0.022	1.28	0.23	4.0	40.0	202	4.0*	25.0*	10.0*
91/08/20	1300	55	1245	22.64	----	0.320	0.034	0.78	1.16	9.5	26.0	25100	42.0	143.0	117.0
91/09/10	44	42	2	0.04	----	0.030	0.018	2.64	0.24	4.0	53.0	322	4.0*	25.0*	10.0*

Notes: # Instantaneous flow was less than base flow derived from daily average flow.
* Measurement limit; data flagged as being below this limit.

Station WQN0113: Schuylkill R at T558 br, Berne

Flow Rates and Pollutant Concentrations

	Total flow cfs	Base flow cfs	Excess flow cfs	Ratio, excess to base	000530 Resid mg/l	000610 NH3/4 mg/l	000615 NO2 mg/l	000620 NO3 mg/l	000665 P-tot mg/l	000680 C-org mg/l	000945 SO4 mg/l	001045 Fe ug/l	001051 Pb ug/l	001067 Ni ug/l	001092 Zn ug/l
88/01/28	391	359	32	0.09	4.0	0.230	0.012	1.27	0.080	1.50	85.0	349	5.0	25.0*	33.0
88/02/29	608	535	73	0.14	2.0*	0.200	0.012	1.07	0.080	1.40	87.0	304	4.0*	25.0*	32.0
88/03/23	490	440	50	0.11	2.0*	0.140	0.014	0.85	0.060	1.40	83.0	328	13.0	25.0*	36.0
88/04/21	360	336	24	0.07	2.0*	0.090	0.020	1.04	0.090	1.80	98.0	301	5.0*	25.0*	27.0
88/05/23	2340	440	1900	4.31	4.0	0.070	0.010	1.09	0.090	1.50	43.0	781	6.0	58.0	64.0
88/06/16	309	286	23	0.08	2.0*	0.030	0.014	0.99	0.050	1.90	132.0	208	4.0*	62.0	26.0
88/07/06	192	160	32	0.20	10.0	0.020	0.008	0.09	0.090	2.40	156.0	91	4.0*	33.0	10.0*
88/07/12	188	156	32	0.20	2.0	0.090	0.020	1.34	0.100	2.70	155.0	143	4.0	26.0	10.0*
88/08/16	170	150	20	0.13	10.0	0.050	0.010	1.11	0.160	3.00	180.0	105	4.0*	49.0	25.0
88/09/22	206	215	-9#	-0.04	16.0	0.040	0.006	1.33	0.080	2.90	119.0	166	4.0*	41.0	28.0
88/10/31	174	132	42	0.32	8.0	0.070	0.016	1.72	0.090	2.40	126.0	200	4.0*	25.0*	18.0
88/11/22	1640	327	1313	4.01	2.0*	0.090	0.012	2.00	0.080	2.40	38.0	715	4.0*	25.0*	42.0
88/12/15	275	230	45	0.20	2.0*	0.260	0.040	1.30	0.070	1.50	116.0	295	6.0	25.0*	58.0
89/01/19	515	309	206	0.67	2.0*	0.150	0.012	1.53	0.130	1.60	51.0	366	4.0	46.0	40.0
89/02/02	309	313	-4#	-0.01	24.0	0.170	0.016	1.15	0.090	2.10	87.0	352	4.0	25.0*	28.0
89/03/15	474	461	13	0.03	2.0	0.140	0.016	1.54	0.070	2.20	126.0	408	6.0	25.0*	29.0
89/04/26	316	289	27	0.09	----	----	----	----	----	----	----	384	4.0	25.0*	36.0
89/05/31	783	810	-27#	-0.03	4.0	0.120	0.022	0.86	0.050	1.60	149.0	288	4.0*	25.0*	42.0
89/06/20	908	920	-12#	-0.01	2.0*	0.050	0.020	1.19	0.060	1.60	96.0	589	4.0*	36.0	47.0
89/07/19	1290	687	603	0.88	4.0	0.080	0.014	1.49	0.080	2.30	78.0	752	7.0	25.0*	42.0
89/08/17	263	273	-10#	-0.04	26.0	0.020	0.008	1.44	0.060	2.70	231.0	283	5.0	25.0*	49.0
89/09/25	225	247	-22#	-0.09	2.0	0.060	0.020	1.41	0.070	2.80	223.0	192	4.0*	25.0*	32.0
89/10/25	810	251	559	2.22	6.0	0.070	0.012	1.79	0.050	2.50	104.0	512	5.0	25.0*	35.0
89/11/14	351	371	-20#	-0.05	24.0	0.040	0.024	1.21	0.060	1.80	131.0	332	4.0*	25.0*	20.0
89/12/06	380	317	63	0.20	12.0	0.250	0.014	1.09	0.060	1.50	133.0	328	4.0*	25.0*	56.0
90/01/03	410	364	46	0.13	18.0	0.320	0.016	1.59	0.110	2.10	79.0	1090	7.0	25.0*	55.0
90/02/01	2200	1458	742	0.51	12.0	0.090	0.008	1.51	0.050	1.50	50.0	36	4.0*	25.0*	29.0
90/03/06	549	485	64	0.13	4.0	0.110	0.008	1.33	0.040	1.60	73.0	300	4.0*	25.0*	53.0
90/05/23	930	857	73	0.08	26.0	0.090	0.016	1.81	0.030	1.30	90.0	----	----	----	----
90/06/07	523	494	29	0.06	22.0	0.090	0.018	1.01	0.050	2.40	119.0	62	4.0*	25.0*	43.0
90/07/18	366	190	176	0.92	2.0*	0.020*	0.018	1.37	0.060	2.00	120.0	83	3.0	4.0*	16.0
90/08/15	360	272	88	0.32	10.0	0.040	0.012	1.16	0.080	4.10	128.0	443	2.0	10.0	16.0
90/09/12	208	208	0	0.00	----	0.040	0.006	1.09	0.060	1.60	192.0	34	2.0	9.0	16.0
90/10/10	190	198	-8#	-0.04	----	0.060	0.004	1.28	0.080	2.70	156.0	154	2.0*	11.0	18.0
90/11/07	575	522	53	0.10	----	0.080	0.016	0.97	0.040	1.70	129.0	20	4.0*	12.0	23.0
90/12/06	2750	503	2247	4.47	----	0.060	0.006	1.29	0.030	1.80	39.0	627	3.0	15.0	44.0
91/01/02	1670	1198	472	0.39	----	0.120	0.008	1.40	0.030	1.20	61.0	403	2.0	17.0	60.0
91/02/05	540	540	0	0.00	----	0.240	0.014	1.18	0.050	1.50	138.0	330	2.0*	26.0	73.0
91/03/06	1470	592	878	1.48	----	0.020*	0.014	1.31	0.050	1.60	68.0	398	2.0	6.0	11.0
91/04/11	547	564	-17#	-0.03	----	0.050	0.024	0.93	0.040	1.70	165.0	363	2.0	22.0	24.0
91/05/15	840	575	265	0.46	----	0.090	0.040*	0.89	0.092	3.00	91.0	1330	9.0	15.0	39.0
91/06/18	213	213	0	0.00	----	0.050	0.040*	1.16	0.057	2.60	219.0	199	2.0	12.0	11.0
91/07/17	152	140	12	0.09	----	0.040	0.040*	1.00	0.054	2.50	256.0	76	2.0	8.0	8.0
91/08/08	99	107	-8#	-0.07	----	0.030	0.040*	1.21	0.068	2.70	336.0	97	3.0	13.0	10.0
91/09/05	147	107	40	0.37	----	0.020	0.040*	1.24	0.073	2.40	280.0	69	1.0	11.0	8.0

Notes: # Instantaneous flow was less than base flow derived from daily average flow.
* Measurement limit; data flagged as being below this limit.

Station WQN0117: Tulpehocken Cr, T921 br, Bern Twp

Flow Rates and Pollutant Concentrations

	Total flow cfs	Base flow cfs	Excess flow cfs	Ratio, excess to base	000530 Resid mg/l	000610 NH3/4 mg/l	000615 NO2 mg/l	000620 NO3 mg/l	000665 P-tot mg/l	000680 C-org mg/l	000945 SO4 mg/l	001045 Fe ug/l	001051 Pb ug/l	001067 Ni ug/l	001092 Zn ug/l
88/01/28	166	157	9	0.06	6.0	0.320	0.030	5.69	0.150	2.50	32.0	281	4.00*	25.0*	10.0*
88/03/23	423	199	224	1.13	4.0	0.150	0.036	5.02	0.120	3.10	27.0	172	4.00*	25.0*	10.0*
88/05/23	2810	243	2567	10.56	16.0	0.180	0.046	3.47	0.180	3.40	19.0	1070	6.00	52.0	28.0
88/06/14	192	191	1	0.01	2.0*	0.060	0.064	4.56	0.110	2.70	22.0	207	4.00*	34.0	10.0*
88/07/06	118	115	3	0.03	4.0	0.090	0.078	5.06	0.130	2.60	25.0	10*	4.00*	25.0*	10.0*
88/08/11	118	118	0	0.00	2.0*	0.020	0.012	2.63	0.120	2.30	30.0	180	4.00	25.0*	10.0*
88/09/28	109	102	7	0.07	4.0	0.040	0.130	4.27	0.120	2.60	34.0	287	4.00*	46.0	13.0
88/10/18	69	71	-2#	-0.03	16.0	0.060	0.070	3.89	0.160	3.10	33.0	84	4.00*	25.0*	10.0*
88/11/15	177	138	40	0.29	2.0*	0.140	0.077	3.55	0.100	3.80	25.0	44	4.00*	25.0*	10.0*
88/12/20	130	132	-2#	-0.02	2.0*	0.130	0.040	5.28	0.080	2.50	28.0	93	4.00*	25.0*	10.0*
89/01/10	363	180	183	1.02	4.0	0.170	0.044	5.04	0.060	2.50	10.0*	156	4.00*	25.0*	10.0*
89/02/22	796	193	603	3.12	26.0	0.100	0.036	5.04	0.090	3.20	25.0	676	4.00*	45.0	22.0
89/03/22	313	252	61	0.24	2.0*	0.080	0.034	4.81	0.050	3.10	27.0	126	4.00*	25.0*	10.0*
89/05/22	646	650	-4#	-0.01	12.0	0.180	0.038	4.80	0.110	3.10	24.0	523	4.00*	25.0*	10.0*
89/06/21	441	485	-44#	-0.09	2.0*	0.170	0.072	5.74	0.110	2.30	23.0	266	4.00*	25.0*	10.0*
89/07/17	1180	572	608	1.06	10.0	0.170	0.090	5.23	0.060	2.70	20.0	400	4.00*	25.0*	10.0*
89/08/30	156	134	22	0.17	2.0*	0.140	0.174	5.64	0.110	2.30	25.0	138	4.00*	25.0*	10.0*
89/09/27	170	152	18	0.12	6.0	0.150	0.080	5.00	0.130	2.90	34.0	196	4.00*	25.0*	22.0
89/10/30	294	284	10	0.04	2.0*	0.190	0.066	5.98	0.130	2.90	25.0	165	4.00*	25.0*	14.0
89/12/18	174	170	4	0.02	18.0	0.110	0.040	7.22	0.090	2.10	33.0	159	4.00*	25.0*	14.0
90/01/31	2140	612	1528	2.50	16.0	0.230	0.034	5.29	0.120	3.60	28.0	978	4.00	25.0*	58.0
90/02/22	322	323	-1#	0.00	2.0*	0.080	0.028	6.26	0.090	3.10	29.0	251	4.00*	25.0*	33.0
90/03/26	253	233	20	0.09	14.0	0.040	0.034	6.26	0.070	2.70	29.0	156	4.00*	25.0*	49.0
90/04/25	232	232	0	0.00	2.0*	0.100	0.044	4.80	0.070	3.40	31.0	254	4.00	25.0*	10.0
90/05/22	275	241	34	0.14	2.0*	0.120	0.050	5.03	0.080	2.60	28.0	395	4.00*	32.0	14.0
90/06/21	223	203	20	0.10	24.0	0.140	0.076	5.00	0.110	3.30	32.0	603	5.00	25.0*	19.0
90/07/26	101	95	6	0.07	2.0*	0.200	0.162	5.16	0.110	2.50	24.0	104	4.00*	25.0*	10.0*
90/08/30	156	104	52	0.50	13.0	0.100	0.096	4.26	0.100	2.80	30.0	235	4.00*	25.0*	10.0*
90/09/19	121	121	0	0.00	----	0.070	0.070	4.29	0.090	1.10	30.0	146	4.00*	25.0*	10.0*
90/10/25	901	309	592	1.92	----	0.130	0.056	3.81	0.070	3.50	33.0	148	4.00*	25.0*	10.0*
90/11/27	129	131	-2#	-0.02	----	0.100	0.048	5.52	0.100	2.90	34.0	73	4.00*	25.0*	35.0
90/12/20	423	429	-6#	-0.01	----	0.070	0.036	5.28	0.050	2.90	29.0	159	4.00*	25.0*	10.0*
91/01/16	689	608	81	0.13	----	0.100	0.028	6.26	0.070	1.70	29.0	248	4.00*	25.0*	10.0*
91/02/21	395	350	46	0.13	----	0.050	0.030	6.50	0.030	1.60	29.0	203	4.00*	25.0*	10.0*
91/03/21	395	378	17	0.05	----	0.050	0.046	5.75	0.070	1.40	33.0	83	4.00*	25.0*	10.0*
91/04/24	308	222	86	0.39	----	0.040	0.046	5.76	0.070	2.20	32.0	293	4.00*	25.0*	10.0*
91/05/16	401	194	207	1.07	----	0.080	0.054	5.03	0.070	2.50	33.0	397	4.00*	58.0	10.0*
91/06/13	188	100	88	0.89	----	0.130	0.112	5.70	0.100	2.90	34.0	752	4.00*	25.0*	10.0*
91/07/11	110	116	-6#	-0.05	----	0.090	0.096	3.30	0.120	2.30	31.0	544	4.00*	30.0	10.0*
91/08/15	52	59	-7#	-0.12	----	0.110	0.092	4.51	0.180	2.60	32.0	386	4.00*	25.0*	19.0
91/09/11	153	38	115	3.03	----	0.400	0.194	2.96	0.120	2.90	10.0*	647	4.00*	25.0*	10.0*

Notes: # Instantaneous flow was less than base flow derived from daily average flow.
* Measurement limit; data flagged as being below this limit.

Station WQN0111: Schuylkill R, Hanover St br, Pottstown

Flow Rates and Pollutant Concentrations

	Total flow cfs	Base flow cfs	Excess flow cfs	Ratio, excess to base	000530 Resid mg/l	000610 NH3/4 mg/l	000615 NO2 mg/l	000620 NO3 mg/l	000665 P-tot mg/l	000680 C-org mg/l	000945 SO4 mg/l	001045 Fe ug/l	001051 Pb ug/l	001067 Ni ug/l	001092 Zn ug/l
88/02/23	3470	1920	1550	0.81	12.0	0.250	0.022	3.94	0.150	2.60	38.0	701	5.0*	25.0*	23.0
88/03/21	1450	1400	50	0.04	20.0	0.270	0.056	2.60	0.130	2.70	57.0	223	4.0*	25.0*	19.0
88/05/25	4720	1178	3542	3.01	24.0	0.150	0.028	2.61	0.160	2.60	48.0	1320	10.0	34.0	16.0
88/08/24	587	608	-21#	-0.03	2.0*	0.040	0.056	2.58	0.240	3.70	82.0	180	4.0*	56.0	23.0
88/09/21	753	711	42	0.06	2.0*	0.170	0.102	2.76	0.210	3.10	----	478	4.0*	51.0	20.0
88/10/20	408	471	-63#	-0.13	24.0	0.070	0.090	3.21	0.270	3.40	103.0	92	4.0*	25.0*	16.0
88/11/15	1010	903	107	0.12	2.0*	0.190	0.090	3.06	0.170	3.20	69.0	302	4.0*	43.0	33.0
88/12/06	1070	1050	20	0.02	2.0	0.330	0.065	3.54	0.150	2.80	51.0	152	4.0*	25.0*	27.0
89/01/19	1880	861	1019	1.18	2.0*	0.280	0.038	3.83	0.110	2.60	36.0	225	4.0*	79.0	10.0*
89/02/27	2000	1068	932	0.87	8.0	0.210	0.038	3.35	0.120	3.50	45.0	315	6.0	25.0*	10.0*
89/03/23	1800	1779	21	0.01	6.0	0.190	0.048	3.10	0.050	3.70	45.0	215	4.0*	25.0*	10.0*
89/04/26	1140	985	155	0.16	----	----	----	----	----	----	----	310	5.0	25.0*	30.0
89/05/31	2220	2380	-160#	-0.07	2.0	0.140	0.058	3.09	0.120	2.50	71.0	365	4.0*	25.0*	13.0
89/07/25	1840	2110	-270#	-0.13	2.0*	0.060	0.050	3.00	0.120	2.50	65.0	301	4.0*	25.0*	10.0*
89/08/28	660	757	-97#	-0.13	2.0	0.100	0.030	3.60	0.170	3.40	101.0	88	4.0*	25.0*	11.0
89/09/27	1350	946	404	0.43	8.0	0.100	0.046	3.34	0.160	3.90	92.0	303	6.0	25.0*	34.0
89/10/26	2150	840	1310	1.56	18.0	0.100	0.038	4.32	0.100	3.00	45.0	406	4.0*	25.0*	15.0
89/11/30	1320	1069	251	0.23	6.0	0.140	0.038	3.59	0.120	3.10	72.0	157	5.0	25.0*	16.0
90/02/14	2650	2298	352	0.15	2.0*	0.170	0.042	3.52	0.060	2.10	44.0	257	4.0*	25.0*	14.0
90/03/27	1600	1388	212	0.15	4.0	0.110	0.058	3.33	0.070	2.70	55.0	187	4.0*	25.0*	22.0
90/04/25	1540	1527	13	0.01	2.0*	0.070	0.070	2.57	0.080	2.90	63.0	820	4.0	25.0*	37.0
90/05/23	2190	2173	17	0.01	16.0	0.130	0.056	2.58	0.080	2.10	62.0	475	8.0	25.0*	20.0
90/06/28	984	1000	-16#	-0.02	2.0*	0.040	0.060	3.57	0.140	3.00	91.0	205	6.0	25.0*	15.0
90/07/23	912	649	263	0.41	42.0	0.050	0.038	3.35	0.150	3.50	75.0	260	5.0	26.0	15.0
90/08/27	1110	833	277	0.33	12.0	0.040	0.016	3.38	0.120	2.90	67.0	237	9.0	25.0*	15.0
90/09/24	792	699	93	0.13	----	0.030	0.026	3.01	0.110	2.20	70.0	184	89.0	25.0*	20.0
90/10/17	1110	1100	10	0.01	----	0.040	0.038	3.11	0.130	3.30	48.0	1010	4.0	25.0*	11.0
90/11/28	1090	1056	34	0.03	----	0.090	0.050	3.34	0.170	3.20	82.0	279	4.0	25.0*	27.0
90/12/26	5890	2988	2903	0.97	----	0.080	0.016	3.61	0.080	2.00	33.0	661	4.0	25.0*	34.0
91/01/22	3630	1880	1750	0.93	----	0.130	0.026	4.08	0.070	1.90	35.0	362	4.0	25.0*	35.0
91/02/28	1500	1500	0	0.00	----	0.100	0.044	4.32	0.070	2.20	69.0	360	4.0*	25.0*	27.0
91/03/21	2660	1833	827	0.45	----	0.050	0.032	4.33	0.060	1.80	58.0	211	5.0	25.0*	13.0
91/04/18	1420	1345	75	0.06	----	0.060	0.052	3.58	0.100	2.60	83.0	283	4.0*	25.0*	32.0
91/05/23	1260	1144	116	0.10	----	0.070	0.060	3.57	0.190	2.70	65.0	383	4.0	46.0	18.0
91/06/11	753	625	128	0.21	----	0.030	0.018	3.06	0.220	3.60	103.0	270	4.0*	25.0*	23.0
91/07/01	578	497	81	0.16	----	0.050	0.032	2.08	0.270	4.20	117.0	431	4.0*	25.0*	15.0
91/08/29	406	386	20	0.05	----	0.020	0.030	4.57	0.260	3.70	122.0	194	4.0*	25.0*	10.0*
91/09/26	920	344	576	1.68	----	0.120	0.066	1.89	0.250	3.60	61.0	1230	6.0	28.0	19.0

Notes: # Instantaneous flow was less than base flow derived from daily average flow.
* Measurement limit; data flagged as being below this limit.

Station WQN0116: Perkiomen Cr at T325 br, Lwr Providence Twp

Flow Rates and Pollutant Concentrations

	Total flow cfs	Base flow cfs	Excess flow cfs	Ratio, excess to base	000530 Resid mg/l	000610 NH3/4 mg/l	000615 NO2 mg/l	000620 NO3 mg/l	000665 P-tot mg/l	000680 C-org mg/l	000945 SO4 mg/l	001045 Fe ug/l	001051 Pb ug/l	001067 Ni ug/l	001092 Zn ug/l
88/02/24	492	471	21	0.04	2.0*	0.180	0.022	2.40	0.140	3.4	29.0	281.0	4.0*	25.0*	12.0
88/03/31	246	188	58	0.31	4.0	0.020	0.018	1.16	0.120	4.5	35.0	187.0	4.0*	25.0*	10.0*
88/04/27	132	137	-5#	-0.04	10.0	0.050	0.028	1.07	0.110	5.0	23.0	166.0	4.0*	25.0*	10.0*
88/05/25	593	208	385	1.86	10.0	0.060	0.030	1.61	0.170	4.6	39.0	584.0	4.0*	33.0	10.0*
88/07/14	52	52	0	0.01	2.0	0.050	0.016	0.74	0.150	5.1	33.0	155.0	4.0*	34.0	10.0*
88/08/24	52	56	-4#	-0.07	2.0*	0.030	0.020	1.58	0.220	5.1	46.0	172.0	4.0*	61.0	17.0
88/09/21	78	76	2	0.03	2.0*	0.050	0.008	1.15	0.140	4.7	37.0	309.0	4.0*	51.0	15.0
88/10/31	78	81	-3#	-0.04	10.0	0.020*	0.010	1.41	0.100	5.3	40.0	145.0	4.0*	25.0*	10.0*
88/11/15	202	144	58	0.40	2.0*	0.020*	0.016	1.52	0.140	5.7	39.0	444.0	4.0*	25.0*	10.0*
88/12/06	186	173	13	0.08	12.0	0.110	0.016	2.80	0.110	3.6	35.0	378.0	4.0*	25.0*	23.0
89/01/19	3530	159	3371	21.25	2.0*	0.110	0.022	2.88	0.100	3.5	28.0	260.0	4.0*	42.0	14.0
89/02/27	378	214	164	0.77	2.0*	0.130	0.020	2.88	0.120	4.1	34.0	217.0	4.0*	25.0*	10.0*
89/04/26	178	172	6	0.03	----	----	----	----	----	----	----	147.0	4.0	25.0*	37.0
89/05/31	260	247	13	0.05	4.0	0.110	0.022	1.63	0.140	5.1	31.0	222.0	4.0*	25.0*	10.0*
89/07/25	160	162	-2#	-0.01	6.0	0.040	0.010	1.44	0.120	4.5	34.0	191.0	10.0	25.0*	29.0
89/08/28	91	84	7	0.08	2.0*	0.050	0.010	1.09	0.080	4.7	13.0	149.0	4.0*	25.0*	10.0*
89/09/27	593	351	242	0.69	16.0	0.090	0.014	1.44	0.150	7.3	29.0	672.0	4.0	25.0*	37.0
89/10/26	295	184	111	0.60	4.0	0.060	0.014	2.04	0.100	4.7	32.0	228.0	6.0	25.0*	22.0
89/11/30	255	159	96	0.60	10.0	0.020*	0.012	1.58	0.070	4.0	34.0	197.0	5.0	25.0*	16.0
89/12/26	132	134	-2#	-0.01	16.0	0.040	0.018	3.61	0.080	3.4	41.0	110.0	4.0*	25.0*	13.0
90/02/14	435	394	41	0.10	2.0*	0.090	0.018	2.36	0.090	3.6	26.0	258.0	4.0*	25.0*	13.0
90/03/27	223	195	28	0.14	2.0*	0.020*	0.016	1.55	0.080	3.6	34.0	130.0	5.0	25.0*	10.0*
90/04/25	206	212	-6#	-0.03	2.0*	0.020*	0.034	1.27	0.060	4.0	33.0	107.0	4.0*	25.0*	10.0*
90/05/23	232	230	2	0.01	6.0	0.020*	0.024	1.87	0.100	3.4	34.0	264.0	4.0*	25.0*	16.0
90/06/28	156	152	4	0.02	10.0	0.020	0.008	1.51	0.080	3.8	44.0	168.0	5.0	25.0*	15.0
90/07/23	135	123	12	0.09	42.0	0.040	0.012	1.46	0.100	5.2	34.0	251.0	7.0	25.0*	14.0
90/08/27	185	185	0	0.00	12.0	0.020*	0.008	1.40	0.100	4.1	33.0	178.0	6.0	25.0*	17.0
90/09/24	158	103	55	0.54	----	0.020	0.020	1.78	0.110	2.9	34.0	235.0	4.0*	25.0*	10.0*
90/10/17	168	172	-4#	-0.02	----	0.020*	0.010	1.20	0.110	5.3	32.0	233.0	10.0	25.0*	10.0*
90/11/28	124	111	13	0.12	----	0.020*	0.012	1.62	0.060	3.9	38.0	160.0	4.0*	25.0*	10.0*
90/12/26	517	330	187	0.57	----	0.070	0.016	2.03	0.130	4.9	29.0	685.0	4.0*	25.0*	22.0
91/01/22	497	442	55	0.12	----	0.070	0.014	2.17	0.090	3.3	24.0	659.0	15.0	25.0*	10.0*
91/02/28	231	230	2	0.01	----	0.020	0.018	1.78	0.050	2.9	34.0	204.0	4.0	25.0*	18.0
91/03/21	426	361	65	0.18	----	0.020*	0.016	1.66	0.080	4.3	38.0	339.0	4.0*	25.0*	10.0*
91/04/18	322	223	99	0.44	----	0.020	0.020	1.08	0.050	4.1	32.0	224.0	4.0*	71.0	19.0
91/05/23	124	136	-12#	-0.09	----	0.060	0.030	1.59	0.150	3.4	35.0	275.0	4.0*	25.0*	10.0*
91/06/03	133	151	-18#	-0.12	----	0.030	0.028	1.51	0.290	4.6	35.0	353.0	5.0	40.0	13.0
91/07/01	106	114	-8#	-0.07	----	0.030	0.012	0.65	0.150	12.9	36.0	94.0	4.0*	25.0*	10.0*
91/08/29	119	109	10	0.09	----	0.020	0.012	0.80	0.110	3.8	36.0	236.0	4.0*	25.0*	10.0*
91/09/26	336	96	240	2.49	----	0.080	0.018	1.13	0.220	4.3	33.0	949.0	4.0*	25.0*	11.0

Notes: # Instantaneous flow was less than base flow derived from daily average flow.
* Measurement limit; data flagged as being below this limit.

Appendix B

Mean Pollutant Concentrations and Regression Results

WQN0101 -- Delaware R at Trenton Ave br, Morrisville PA

Mean Concentration at Low Flow and Regression of Concentration Against Flow in Excess of Base Flow and Against Total Flow

Weighting of low flow values in regression computation: 0.20
Multiple of detectability limit to which values below limit were set: 0.71
Number of measurements in each flow range:
Low: 24 (< 1.30 times base flow)
Medium: 14 (>= 1.30 and < 2.00 times base flow)
High: 8 (>= 2.00 times base flow)
Notes: 1. There were fewer measurements for code 00530
2. Regression-line value for twice base flow is given under "2xBase"

Parameter			Below	Low Flow Conc		Regress on Excess Flow				Regress on Total Flow			
Code	Name	Units	Limit	Mean	Std Dev	I'cept	Slope	2xBase	RMSE	I'cept	Slope	2xBase	RMSE
00530	Resid	mg/l	8	8.0647	9.0891	9.5347	7.09e-04	11.389	15.181	8.5522	4.01e-04	10.649	15.429
00610	NH3/4	mg/l	4	.07011	.06179	.09007	-1.80e-06	.08535	.06353	.10064	-1.64e-06	.09204	.06302
00615	NO2	mg/l	0	.01742	.01001	.02032	-7.49e-07	.01836	.01085	.02363	-5.98e-07	.02050	.01064
00620	NO3	mg/l	0	1.0642	.22312	1.2051	-2.10e-05	1.1501	.25915	1.3180	-1.83e-05	1.2221	.24538
00665	P-tot	mg/l	0	.08375	.02796	.09626	-1.52e-06	.09228	.03355	.11193	-1.91e-06	.10192	.03115
00680	C-org	mg/l	0	2.9125	.41464	3.0267	5.35e-05	3.1669	.90421	3.1425	1.53e-05	3.2226	.94598
00945	SO4	mg/l	0	25.542	6.8067	26.936	-4.82e-04	25.674	4.2309	29.435	-4.14e-04	27.270	3.8244
01045	Fe	ug/l	0	201.42	107.37	267.27	2.26e-02	326.50	383.77	262.26	1.07e-02	318.11	395.69
01051	Pb	ug/l	26	3.8800	2.7224	4.7031	9.32e-05	4.9471	2.6385	4.5475	5.45e-05	4.8326	2.6560
01067	Ni	ug/l	36	25.448	15.691	24.231	-4.59e-04	23.031	12.021	25.247	-2.87e-04	23.742	12.086
01092	Zn	ug/l	7	25.679	13.137	20.079	1.29e-03	23.456	12.436	15.286	9.60e-04	20.309	12.261

WQN0121 -- Neshaminy Cr at PA 213 br, nr Langhorne

Mean Concentration at Low Flow and Regression of Concentration Against
Flow in Excess of Base Flow and Against Total Flow

Weighting of low flow values in regression computation: 0.20
Multiple of detectability limit to which values below limit were set: 0.71
Number of measurements in each flow range:
Low: 35 (< 1.30 times base flow)
Medium: 5 (>= 1.30 and < 2.00 times base flow)
High: 5 (>= 2.00 times base flow)
Notes: 1. There were fewer measurements for code 00530
2. Regression-line value for twice base flow is given under "2xBase"

Parameter			Below	Low Flow Conc		Regress on Excess Flow				Regress on Total Flow			
Code	Name	Units	Limit	Mean	Std Dev	I'cept	Slope	2xBase	RMSE	I'cept	Slope	2xBase	RMSE
00530	Resid	mg/l	4	16.433	31.978	10.592	5.30e-02	12.831	21.794	-10.84	1.11e-01	-1.488	18.380
00610	NH3/4	mg/l	4	.08591	.13286	.05452	1.91e-04	.06259	.09291	.02174	2.06e-04	.03918	.09125
00615	NO2	mg/l	1	.02763	.01608	.02637	9.24e-06	.02677	.01663	.02443	1.13e-05	.02538	.01655
00620	NO3	mg/l	0	2.6591	.89942	2.6541	-1.33e-03	2.5981	.88736	2.8510	-1.32e-03	2.7391	.89226
00665	P-tot	mg/l	0	.27200	.12317	.24241	7.18e-04	.27275	.13694	.16083	6.28e-04	.21394	.17498
00680	C-org	mg/l	0	4.4343	1.4481	4.2647	4.28e-03	4.4456	1.0311	3.6539	4.19e-03	4.0078	1.1012
00945	SO4	mg/l	0	41.543	7.8316	40.321	-1.22e-02	39.807	5.6859	43.261	-1.62e-02	41.895	4.9167
01045	Fe	ug/l	0	553.60	1163.2	-554.2	1.97e+01	278.39	1352.9	-3439.	1.95e+01	-1788.	2049.2
01051	Pb	ug/l	20	5.3840	4.1455	3.3329	3.01e-02	4.6034	3.0951	-1.066	2.98e-02	1.4523	3.8918
01067	Ni	ug/l	38	20.471	8.0429	17.936	9.47e-02	21.938	19.176	5.7244	8.80e-02	13.164	22.484
01092	Zn	ug/l	16	17.151	10.941	14.517	7.85e-02	17.834	12.456	3.8879	7.47e-02	10.207	15.141

WQN0113 -- Schuylkill R at T558 br, Berne

Mean Concentration at Low Flow and Regression of Concentration Against
Flow in Excess of Base Flow and Against Total Flow

Weighting of low flow values in regression computation: 0.20
Multiple of detectability limit to which values below limit were set: 0.71
Number of measurements in each flow range:
Low: 31 (< 1.30 times base flow)
Medium: 9 (>= 1.30 and < 2.00 times base flow)
High: 5 (>= 2.00 times base flow)
Notes: 1. There were fewer measurements for code 00530
2. Regression-line value for twice base flow is given under "2xBase"

Parameter			Below	Low Flow Conc		Regress on Excess Flow				Regress on Total Flow			
Code	Name	Units	Limit	Mean	Std Dev	I'cept	Slope	2xBase	RMSE	I'cept	Slope	2xBase	RMSE
00530	Resid	mg/l	9	9.7509	9.2744	8.0506	-2.92e-03	7.7385	6.2471	7.5810	-9.02e-04	7.3880	6.4242
00610	NH3/4	mg/l	2	.10667	.08191	.08613	-1.08e-05	.08497	.05697	.08190	-1.03e-06	.08168	.05738
00615	NO2	mg/l	5	.01677	.00790	.01742	-5.08e-06	.01688	.00630	.01933	-4.60e-06	.01834	.00609
00620	NO3	mg/l	0	1.1613	.29253	1.2979	8.30e-05	1.3068	.30284	1.2817	5.94e-05	1.2944	.30384
00665	P-tot	mg/l	0	.06863	.02521	.07433	-9.31e-06	.07333	.02531	.08149	-1.23e-05	.07886	.02412
00680	C-org	mg/l	0	2.0400	.53141	2.2680	-2.93e-04	2.2367	.64870	2.4750	-3.68e-04	2.3963	.60975
00945	SO4	mg/l	0	144.63	59.627	136.32	-6.03e-02	129.86	52.813	161.39	-5.72e-02	149.15	47.307
01045	Fe	ug/l	0	272.37	199.13	320.30	2.02e-01	341.89	289.95	279.20	1.47e-01	310.66	295.19
01051	Pb	ug/l	19	3.6103	2.1867	3.5593	3.11e-04	3.5926	2.1582	3.4710	2.53e-04	3.5251	2.1581
01067	Ni	ug/l	22	21.467	11.671	17.517	4.99e-03	18.051	13.235	17.004	3.10e-03	17.667	13.390
01092	Zn	ug/l	2	31.740	16.635	27.239	1.14e-02	28.458	15.173	22.391	1.10e-02	24.741	14.409

WQN0117 -- Tulpehocken Cr, T921 br, Bern Twp

Mean Concentration at Low Flow and Regression of Concentration Against Flow in Excess of Base Flow and Against Total Flow

Weighting of low flow values in regression computation: 0.20
Multiple of detectability limit to which values below limit were set: 0.71
Number of measurements in each flow range:
Low: 29 (< 1.30 times base flow)
Medium: 3 (>= 1.30 and < 2.00 times base flow)
High: 9 (>= 2.00 times base flow)
Notes: 1. There were fewer measurements for code 00530
2. Regression-line value for twice base flow is given under "2xBase"

Parameter			Below	Low Flow Conc		Regress on Excess Flow				Regress on Total Flow			
Code	Name	Units	Limit	Mean	Std Dev	I'cept	Slope	2xBase	RMSE	I'cept	Slope	2xBase	RMSE
00530	Resid	mg/l	12	5.7638	6.6424	7.7138	4.62e-03	7.8893	6.8518	6.9021	4.08e-03	7.2120	6.9001
00610	NH3/4	mg/l	0	.11034	.06105	.12970	3.05e-05	.13087	.08069	.12578	2.51e-05	.12768	.08107
00615	NO2	mg/l	0	.06362	.03804	.07438	-1.60e-05	.07377	.04156	.07961	-1.82e-05	.07823	.04076
00620	NO3	mg/l	0	5.1048	.99072	5.0017	-4.06e-04	4.9863	.87925	4.9912	-2.34e-04	4.9734	.90205
00665	P-tot	mg/l	0	.10138	.03298	.08838	2.53e-05	.08934	.02911	.08692	1.79e-05	.08828	.03077
00680	C-org	mg/l	0	2.5828	.58960	2.6644	4.12e-04	2.6801	.43168	2.6011	3.55e-04	2.6281	.43764
00945	SO4	mg/l	2	28.966	3.5475	26.932	-2.34e-03	26.843	7.8700	27.134	-1.76e-03	27.000	7.9118
01045	Fe	ug/l	1	219.35	145.96	273.22	3.37e-01	286.04	201.11	222.76	2.88e-01	244.65	211.01
01051	Pb	ug/l	36	2.9945	.47940	2.7244	1.05e-03	2.7643	.41086	2.5783	8.80e-04	2.6452	.47462
01067	Ni	ug/l	34	20.198	6.5428	20.744	9.06e-03	21.088	11.732	20.009	6.75e-03	20.522	12.169
01092	Zn	ug/l	27	12.752	10.120	8.9138	1.26e-02	9.3926	10.702	6.3387	1.19e-02	7.2400	10.354

WQN0111 -- Schuylkill R, Hanover St br, Pottstown

Mean Concentration at Low Flow and Regression of Concentration Against Flow in Excess of Base Flow and Against Total Flow

Weighting of low flow values in regression computation: 0.20
Multiple of detectability limit to which values below limit were set: 0.71
Number of measurements in each flow range:
Low: 26 (< 1.30 times base flow)
Medium: 8 (>= 1.30 and < 2.00 times base flow)
High: 4 (>= 2.00 times base flow)
Notes: 1. There were fewer measurements for code 00530
2. Regression-line value for twice base flow is given under "2xBase"

Parameter			Below	Low Flow Conc		Regress on Excess Flow				Regress on Total Flow			
Code	Name	Units	Limit	Mean	Std Dev	I'cept	Slope	2xBase	RMSE	I'cept	Slope	2xBase	RMSE
00530	Resid	mg/l	8	5.7462	7.1493	10.301	3.03e-03	11.342	11.193	10.647	1.12e-03	11.414	11.521
00610	NH3/4	mg/l	0	.10840	.07635	.10923	1.58e-05	.11465	.07496	.10316	9.44e-06	.10965	.07539
00615	NO2	mg/l	0	.05276	.01989	.04754	-9.02e-06	.04444	.01532	.05369	-6.64e-06	.04912	.01501
00620	NO3	mg/l	0	3.2136	.53780	3.3637	5.88e-05	3.3839	.64909	3.1964	1.02e-04	3.2665	.63496
00665	P-tot	mg/l	0	.14800	.06591	.14490	-1.24e-05	.14063	.05422	.17175	-1.76e-05	.15964	.04948
00680	C-org	mg/l	0	2.9840	.55330	3.1384	-2.91e-04	3.0382	.57392	3.5115	-2.95e-04	3.3088	.48391
00945	SO4	mg/l	0	74.583	21.560	71.079	-1.31e-02	66.587	16.604	80.675	-9.92e-03	73.856	15.620
01045	Fe	ug/l	0	315.42	202.93	277.91	1.98e-01	346.09	278.78	243.00	9.95e-02	311.39	311.23
01051	Pb	ug/l	20	6.8185	16.482	5.9151	-1.32e-04	5.8698	9.2639	6.7402	-4.38e-04	6.4393	9.2434
01067	Ni	ug/l	30	22.558	11.441	23.755	1.14e-03	24.146	15.469	26.637	-8.58e-04	26.047	15.462
01092	Zn	ug/l	5	19.627	8.0875	17.847	1.82e-03	18.471	8.9543	15.122	2.02e-03	16.514	8.6602

WQN0116 -- Perkiomen Cr at T325 br, Lwr Providence Twp

Mean Concentration at Low Flow and Regression of Concentration Against Flow in Excess of Base Flow and Against Total Flow

Weighting of low flow values in regression computation: 0.20
Multiple of detectability limit to which values below limit were set: 0.71
Number of measurements in each flow range:
Low: 28 (< 1.30 times base flow)
Medium: 9 (>= 1.30 and < 2.00 times base flow)
High: 3 (>= 2.00 times base flow)
Notes: 1. There were fewer measurements for code 00530
2. Regression-line value for twice base flow is given under "2xBase"

Parameter			Below	Low Flow Conc		Regress on Excess Flow				Regress on Total Flow			
Code	Name	Units	Limit	Mean	Std Dev	I'cept	Slope	2xBase	RMSE	I'cept	Slope	2xBase	RMSE
00530	Resid	mg/l	10	7.7744	9.5049	7.1651	-1.52e-03	7.0183	6.6488	7.4081	-1.44e-03	7.1314	6.6663
00610	NH3/4	mg/l	10	.04458	.03842	.04730	2.08e-05	.04930	.03546	.04221	2.30e-05	.04664	.03465
00615	NO2	mg/l	0	.01674	.00710	.01735	1.65e-06	.01751	.00536	.01702	1.68e-06	.01734	.00536
00620	NO3	mg/l	0	1.6044	.62560	1.6009	3.79e-04	1.6375	.52681	1.5182	3.99e-04	1.5951	.51809
00665	P-tot	mg/l	0	.11444	.04939	.12154	-3.28e-06	.12122	.04512	.12258	-4.12e-06	.12179	.04508
00680	C-org	mg/l	0	4.5185	1.7930	4.6273	-2.96e-04	4.5987	1.3151	4.6702	-2.67e-04	4.6187	1.3188
00945	SO4	mg/l	0	33.630	6.5101	33.810	-1.70e-03	33.646	4.4059	34.263	-1.96e-03	33.885	4.3427
01045	Fe	ug/l	0	226.21	112.02	349.32	1.58e-04	349.33	227.90	344.77	9.50e-03	346.61	227.79
01051	Pb	ug/l	27	4.3614	2.8633	3.7880	-3.30e-04	3.7562	1.8613	3.8267	-2.78e-04	3.7730	1.8662
01067	Ni	ug/l	33	21.857	10.795	22.650	5.77e-03	23.206	13.694	21.612	5.62e-03	22.696	13.731
01092	Zn	ug/l	19	12.550	7.2940	13.947	2.58e-04	13.972	8.4007	13.628	8.14e-04	13.785	8.3800

WQN0110 -- Schuylkill R, Falls Br, Philadelphia

Mean Concentration at Low Flow and Regression of Concentration Against
Flow in Excess of Base Flow and Against Total Flow

Weighting of low flow values in regression computation: 0.20
Multiple of detectability limit to which values below limit were set: 0.71
Number of measurements in each flow range:
- Low: 17 (< 1.30 times base flow)
- Medium: 20 (>= 1.30 and < 2.00 times base flow)
- High: 5 (>= 2.00 times base flow)

Notes: 1. There were fewer measurements for code 00530
2. Regression-line value for twice base flow is given under "2xBase"

Parameter			Below	Low Flow Conc		Regress on Excess Flow				Regress on Total Flow			
Code	Name	Units	Limit	Mean	Std Dev	I'cept	Slope	2xBase	RMSE	I'cept	Slope	2xBase	RMSE
00530	Resid	mg/l	7	5.7100	6.0003	-3.074	1.35e-02	3.5890	17.610	-8.677	8.04e-03	-0.717	21.936
00610	NH3/4	mg/l	0	.21294	.13775	.22483	-1.46e-05	.21762	.10898	.24355	-1.24e-05	.23131	.10772
00615	NO2	mg/l	0	.05682	.01542	.05512	-3.87e-06	.05321	.01640	.06102	-3.58e-06	.05747	.01547
00620	NO3	mg/l	0	3.2647	.54678	3.2488	-1.50e-04	3.1745	.55992	3.3369	-9.37e-05	3.2441	.56844
00665	P-tot	mg/l	0	.25824	.08226	.27151	-1.67e-05	.26325	.10090	.31605	-2.16e-05	.29469	.09197
00680	C-org	mg/l	0	3.3000	.45633	3.5456	1.20e-04	3.6050	.83649	3.7584	-1.60e-05	3.7425	.85646
00945	SO4	mg/l	0	62.118	14.568	60.462	-4.51e-03	58.228	12.571	65.718	-3.65e-03	62.099	11.780
01045	Fe	ug/l	0	250.29	123.01	44.424	3.36e-01	210.68	253.48	-104.2	1.94e-01	88.064	380.80
01051	Pb	ug/l	22	4.2988	3.2506	3.4837	1.12e-03	4.0369	2.7045	3.1254	6.02e-04	3.7217	2.9137
01067	Ni	ug/l	32	23.403	14.668	23.042	1.31e-03	23.693	13.061	23.347	4.75e-04	23.818	13.177
01092	Zn	ug/l	6	19.776	10.550	21.709	4.18e-04	21.916	13.565	19.591	8.62e-04	20.445	13.439

Appendix C.

Annual Pollutant Loadings from Water Quality Data

WQN0101 -- Delaware R at Trenton Ave br, Morrisville PA

Annual Loadings (kg/year) for Base, Excess, and Total Flow

Flow Station: 01463500 -- DELAWARE RIVER AT TRENTON NJ

Year Starting		00530 Resid	00610 NH3/4	00615 NO2	00620 NO3	00665 P-tot	00680 C-org	00945 SO4	01045 Fe	01051 Pb	01067 Ni	01092 Zn
88/01/01	Base	3.867e+07	3.362e+05	8.354e+04	5.103e+06	4.016e+05	1.397e+07	1.225e+08	9.659e+05	1.861e+04	1.220e+05	1.231e+05
	Excess	5.599e+07	2.092e+05	3.430e+04	2.915e+06	2.388e+05	1.132e+07	6.469e+07	1.672e+06	1.797e+04	5.723e+04	1.103e+05
	Total	9.467e+07	5.454e+05	1.178e+05	8.019e+06	6.404e+05	2.529e+07	1.872e+08	2.638e+06	3.657e+04	1.793e+05	2.334e+05
89/01/01	Base	5.694e+07	4.950e+05	1.230e+05	7.514e+06	5.913e+05	2.056e+07	1.803e+08	1.422e+06	2.739e+04	1.797e+05	1.813e+05
	Excess	7.829e+07	1.755e+05	1.682e+04	2.552e+06	2.143e+05	1.346e+07	5.621e+07	2.376e+06	2.159e+04	4.888e+04	1.514e+05
	Total	1.352e+08	6.705e+05	1.398e+05	1.007e+07	8.056e+05	3.403e+07	2.365e+08	3.798e+06	4.898e+04	2.286e+05	3.327e+05
90/01/01	Base	6.318e+07	5.492e+05	1.365e+05	8.337e+06	6.561e+05	2.282e+07	2.001e+08	1.578e+06	3.040e+04	1.994e+05	2.012e+05
	Excess	9.121e+07	2.665e+05	3.610e+04	3.782e+06	3.131e+05	1.694e+07	8.364e+07	2.748e+06	2.703e+04	7.346e+04	1.779e+05
	Total	1.544e+08	8.157e+05	1.726e+05	1.212e+07	9.692e+05	3.975e+07	2.837e+08	4.326e+06	5.742e+04	2.728e+05	3.790e+05
Average	Base	5.293e+07	4.602e+05	1.143e+05	6.985e+06	5.497e+05	1.912e+07	1.676e+08	1.322e+06	2.547e+04	1.670e+05	1.685e+05
	Excess	7.517e+07	2.171e+05	2.907e+04	3.083e+06	2.554e+05	1.391e+07	6.818e+07	2.265e+06	2.219e+04	5.986e+04	1.465e+05
	Total	1.281e+08	6.772e+05	1.434e+05	1.007e+07	8.051e+05	3.302e+07	2.358e+08	3.587e+06	4.766e+04	2.269e+05	3.150e+05

WQN0121 -- Neshaminy Cr at PA 213 br, nr Langhorne

Annual Loadings (kg/year) for Base, Excess, and Total Flow

Flow Station: 01465500 -- NESHAMINY CREEK NEAR LANGHORNE, PA.

Year Starting		00530 Resid	00610 NH3/4	00615 NO2	00620 NO3	00665 P-tot	00680 C-org	00945 SO4	01045 Fe	01051 Pb	01067 Ni	01092 Zn
88/01/01	Base	2.020e+06	1.056e+04	3.396e+03	3.269e+05	3.343e+04	5.451e+05	5.106e+06	6.805e+04	6.618e+02	2.516e+03	2.108e+03
	Excess	1.399e+07	5.276e+04	5.935e+03	6.499e+04	2.037e+05	1.616e+06	2.873e+06	4.562e+06	7.566e+03	2.486e+04	2.056e+04
	Total	1.601e+07	6.332e+04	9.331e+03	3.918e+05	2.371e+05	2.161e+06	7.980e+06	4.630e+06	8.227e+03	2.738e+04	2.267e+04
89/01/01	Base	3.039e+06	1.589e+04	5.109e+03	4.917e+05	5.030e+04	8.200e+05	7.682e+06	1.024e+05	9.956e+02	3.785e+03	3.172e+03
	Excess	2.453e+07	9.180e+04	9.368e+03	-9.330e+03	3.529e+05	2.689e+06	3.231e+06	8.185e+06	1.337e+04	4.363e+04	3.609e+04
	Total	2.757e+07	1.077e+05	1.448e+04	4.824e+05	4.032e+05	3.509e+06	1.091e+07	8.288e+06	1.437e+04	4.741e+04	3.926e+04
90/01/01	Base	2.213e+06	1.157e+04	3.721e+03	3.581e+05	3.663e+04	5.971e+05	5.594e+06	7.454e+04	7.250e+02	2.757e+03	2.309e+03
	Excess	1.080e+07	4.100e+04	5.005e+03	1.008e+05	1.589e+05	1.306e+06	2.959e+06	3.442e+06	5.791e+03	1.917e+04	1.585e+04
	Total	1.301e+07	5.257e+04	8.726e+03	4.589e+05	1.955e+05	1.903e+06	8.553e+06	3.517e+06	6.516e+03	2.193e+04	1.815e+04
Average	Base	2.424e+06	1.267e+04	4.075e+03	3.922e+05	4.012e+04	6.540e+05	6.127e+06	8.165e+04	7.941e+02	3.019e+03	2.530e+03
	Excess	1.644e+07	6.185e+04	6.770e+03	5.215e+04	2.385e+05	1.870e+06	3.021e+06	5.396e+06	8.910e+03	2.922e+04	2.417e+04
	Total	1.887e+07	7.452e+04	1.084e+04	4.444e+05	2.786e+05	2.524e+06	9.148e+06	5.478e+06	9.705e+03	3.224e+04	2.670e+04

WQN0113 -- Schuylkill R at T558 br, Berne

Annual Loadings (kg/year) for Base, Excess, and Total Flow

Flow Station: 01470500 -- SCHUYLKILL RIVER AT BERNE, PA.

Year Starting		00530 Resid	00610 NH3/4	00615 NO2	00620 NO3	00665 P-tot	00680 C-org	00945 SO4	01045 Fe	01051 Pb	01067 Ni	01092 Zn
88/01/01	Base	2.615e+06	2.861e+04	4.498e+03	3.115e+05	1.841e+04	5.471e+05	3.879e+07	7.305e+04	9.683e+02	5.758e+03	8.513e+03
	Excess	4.488e+05	1.404e+04	1.531e+03	3.225e+05	1.212e+04	3.657e+05	2.694e+06	1.616e+05	9.222e+02	6.101e+03	1.113e+04
	Total	3.064e+06	4.265e+04	6.028e+03	6.340e+05	3.052e+04	9.128e+05	4.149e+07	2.347e+05	1.890e+03	1.186e+04	1.965e+04
89/01/01	Base	4.296e+06	4.700e+04	7.389e+03	5.117e+05	3.024e+04	8.988e+05	6.372e+07	1.200e+05	1.591e+03	9.458e+03	1.398e+04
	Excess	-5.964e+04	1.333e+04	7.172e+02	3.688e+05	1.151e+04	3.451e+05	-8.428e+06	2.150e+05	1.068e+03	7.622e+03	1.434e+04
	Total	4.237e+06	6.033e+04	8.106e+03	8.805e+05	4.175e+04	1.244e+06	5.530e+07	3.351e+05	2.659e+03	1.708e+04	2.832e+04
90/01/01	Base	4.655e+06	5.092e+04	8.005e+03	5.544e+05	3.276e+04	9.738e+05	6.904e+07	1.300e+05	1.723e+03	1.025e+04	1.515e+04
	Excess	8.250e+05	1.723e+04	2.294e+03	3.606e+05	1.487e+04	4.501e+05	9.508e+06	1.636e+05	1.023e+03	6.457e+03	1.154e+04
	Total	5.480e+06	6.815e+04	1.030e+04	9.150e+05	4.763e+04	1.424e+06	7.855e+07	2.936e+05	2.747e+03	1.670e+04	2.669e+04
Average	Base	3.855e+06	4.218e+04	6.631e+03	4.592e+05	2.714e+04	8.066e+05	5.719e+07	1.077e+05	1.427e+03	8.488e+03	1.255e+04
	Excess	4.047e+05	1.486e+04	1.514e+03	3.506e+05	1.283e+04	3.870e+05	1.258e+06	1.801e+05	1.005e+03	6.727e+03	1.234e+04
	Total	4.260e+06	5.704e+04	8.145e+03	8.098e+05	3.997e+04	1.194e+06	5.844e+07	2.878e+05	2.432e+03	1.521e+04	2.489e+04

WQN0117 -- Tulpehocken Cr, T921 br, Bern Twp

Annual Loadings (kg/year) for Base, Excess, and Total Flow

Flow Station: 01471000 -- TULPEHOCKEN CREEK NEAR READING, PA.

Year Starting		00530 Resid	00610 NH3/4	00615 NO2	00620 NO3	00665 P-tot	00680 C-org	00945 SO4	01045 Fe	01051 Pb	01067 Ni	01092 Zn
88/01/01	Base	8.875e+05	1.699e+04	9.796e+03	7.860e+05	1.561e+04	3.977e+05	4.460e+06	3.377e+04	4.611e+02	3.110e+03	1.963e+03
	Excess	1.152e+06	1.496e+04	5.451e+03	4.291e+05	1.062e+04	2.873e+05	2.296e+06	5.699e+04	3.525e+02	2.783e+03	2.009e+03
	Total	2.039e+06	3.195e+04	1.525e+04	1.215e+06	2.623e+04	6.850e+05	6.756e+06	9.076e+04	8.136e+02	5.893e+03	3.973e+03
89/01/01	Base	1.309e+06	2.505e+04	1.444e+04	1.159e+06	2.302e+04	5.864e+05	6.577e+06	4.980e+04	6.799e+02	4.586e+03	2.895e+03
	Excess	1.731e+06	2.195e+04	7.506e+03	6.064e+05	1.564e+04	4.184e+05	3.242e+06	8.762e+04	5.232e+02	4.145e+03	3.102e+03
	Total	3.040e+06	4.700e+04	2.195e+04	1.765e+06	3.866e+04	1.005e+06	9.819e+06	1.374e+05	1.203e+03	8.731e+03	5.998e+03
90/01/01	Base	1.222e+06	2.340e+04	1.349e+04	1.083e+06	2.150e+04	5.477e+05	6.143e+06	4.652e+04	6.351e+02	4.283e+03	2.704e+03
	Excess	8.009e+05	1.181e+04	5.596e+03	3.998e+05	8.206e+03	2.351e+05	2.147e+06	3.446e+04	2.624e+02	2.036e+03	1.181e+03
	Total	2.023e+06	3.521e+04	1.909e+04	1.482e+06	2.971e+04	7.828e+05	8.290e+06	8.098e+04	8.975e+02	6.319e+03	3.885e+03
Average	Base	1.139e+06	2.181e+04	1.258e+04	1.009e+06	2.004e+04	5.106e+05	5.727e+06	4.337e+04	5.920e+02	3.993e+03	2.521e+03
	Excess	1.228e+06	1.624e+04	6.184e+03	4.785e+05	1.149e+04	3.136e+05	2.562e+06	5.969e+04	3.794e+02	2.988e+03	2.097e+03
	Total	2.367e+06	3.805e+04	1.876e+04	1.488e+06	3.153e+04	8.242e+05	8.288e+06	1.031e+05	9.714e+02	6.981e+03	4.618e+03

WQN0111 -- Schuylkill R, Hanover St br, Pottstown

Annual Loadings (kg/year) for Base, Excess, and Total Flow

Flow Station: 01472000 -- SCHUYLKILL RIVER AT POTTSTOWN, PA.

Year Starting		00530 Resid	00610 NH3/4	00615 NO2	00620 NO3	00665 P-tot	00680 C-org	00945 SO4	01045 Fe	01051 Pb	01067 Ni	01092 Zn
88/01/01	Base	4.760e+06	8.981e+04	4.371e+04	2.662e+06	1.226e+05	2.472e+06	6.179e+07	2.613e+05	5.649e+03	1.869e+04	1.626e+04
	Excess	1.664e+07	1.232e+05	1.837e+03	2.401e+06	5.478e+04	1.113e+06	4.005e+06	8.278e+05	3.456e+03	1.932e+04	1.766e+04
	Total	2.140e+07	2.131e+05	4.555e+04	5.064e+06	1.774e+05	3.586e+06	6.579e+07	1.089e+06	9.105e+03	3.801e+04	3.392e+04
89/01/01	Base	7.237e+06	1.365e+05	6.644e+04	4.047e+06	1.864e+05	3.758e+06	9.393e+07	3.972e+05	8.587e+03	2.841e+04	2.472e+04
	Excess	2.064e+07	1.500e+05	-1.766e+03	2.815e+06	5.827e+04	1.168e+06	-1.012e+06	1.047e+06	3.957e+03	2.294e+04	2.129e+04
	Total	2.788e+07	2.865e+05	6.468e+04	6.862e+06	2.447e+05	4.926e+06	9.292e+07	1.444e+06	1.254e+04	5.134e+04	4.601e+04
90/01/01	Base	6.950e+06	1.311e+05	6.381e+04	3.887e+06	1.790e+05	3.609e+06	9.021e+07	3.815e+05	8.247e+03	2.728e+04	2.374e+04
	Excess	1.400e+07	1.123e+05	1.372e+04	2.513e+06	7.521e+04	1.579e+06	2.137e+07	6.349e+05	3.898e+03	1.935e+04	1.667e+04
	Total	2.095e+07	2.434e+05	7.753e+04	6.399e+06	2.542e+05	5.188e+06	1.116e+08	1.016e+06	1.214e+04	4.663e+04	4.041e+04
Average	Base	6.316e+06	1.191e+05	5.799e+04	3.532e+06	1.627e+05	3.280e+06	8.197e+07	3.467e+05	7.494e+03	2.479e+04	2.157e+04
	Excess	1.709e+07	1.285e+05	4.597e+03	2.576e+06	6.275e+04	1.287e+06	8.120e+06	8.366e+05	3.770e+03	2.053e+04	1.854e+04
	Total	2.341e+07	2.477e+05	6.259e+04	6.108e+06	2.254e+05	4.566e+06	9.009e+07	1.183e+06	1.126e+04	4.533e+04	4.011e+04

WQN0116 -- Perkiomen Cr at T325 br, Lwr Providence Twp

Annual Loadings (kg/year) for Base, Excess, and Total Flow

Flow Station: 01473000 -- PERKIOMEN CREEK AT GRATERFORD, PA.

Year Starting		00530 Resid	00610 NH3/4	00615 NO2	00620 NO3	00665 P-tot	00680 C-org	00945 SO4	01045 Fe	01051 Pb	01067 Ni	01092 Zn
88/01/01	Base	1.074e+06	6.160e+03	2.313e+03	2.217e+05	1.581e+04	6.244e+05	4.647e+06	3.126e+04	6.027e+02	3.020e+03	1.734e+03
	Excess	8.496e+05	1.483e+04	3.652e+03	4.048e+05	2.114e+04	7.538e+05	5.646e+06	6.364e+04	5.908e+02	5.849e+03	2.616e+03
	Total	1.924e+06	2.099e+04	5.965e+03	6.265e+05	3.696e+04	1.378e+06	1.029e+07	9.489e+04	1.194e+03	8.869e+03	4.350e+03
89/01/01	Base	1.503e+06	8.616e+03	3.235e+03	3.101e+05	2.212e+04	8.733e+05	6.500e+06	4.372e+04	8.429e+02	4.224e+03	2.426e+03
	Excess	1.084e+06	2.262e+04	5.298e+03	6.026e+05	2.967e+04	1.044e+06	7.860e+06	9.009e+04	8.106e+02	8.730e+03	3.723e+03
	Total	2.587e+06	3.124e+04	8.534e+03	9.127e+05	5.179e+04	1.917e+06	1.436e+07	1.338e+05	1.654e+03	1.295e+04	6.149e+03
90/01/01	Base	1.487e+06	8.526e+03	3.202e+03	3.068e+05	2.189e+04	8.642e+05	6.432e+06	4.326e+04	8.341e+02	4.180e+03	2.400e+03
	Excess	7.849e+05	2.339e+04	5.048e+03	5.997e+05	2.660e+04	9.117e+05	6.935e+06	8.211e+04	6.946e+02	8.725e+03	3.427e+03
	Total	2.272e+06	3.191e+04	8.249e+03	9.065e+05	4.849e+04	1.776e+06	1.337e+07	1.254e+05	1.529e+03	1.290e+04	5.827e+03
Average	Base	1.355e+06	7.767e+03	2.917e+03	2.795e+05	1.994e+04	7.873e+05	5.860e+06	3.941e+04	7.599e+02	3.808e+03	2.187e+03
	Excess	9.062e+05	2.028e+04	4.666e+03	5.357e+05	2.581e+04	9.031e+05	6.813e+06	7.861e+04	6.987e+02	7.768e+03	3.255e+03
	Total	2.261e+06	2.805e+04	7.583e+03	8.152e+05	4.575e+04	1.690e+06	1.267e+07	1.180e+05	1.459e+03	1.158e+04	5.442e+03

WQN0110 -- Schuylkill R, Falls Br, Philadelphia

Annual Loadings (kg/year) for Base, Excess, and Total Flow

Flow Station: 01474500 -- SCHUYLKILL RIVER AT PHILADELPHIA, PA.

Year Starting		00530 Resid	00610 NH3/4	00615 NO2	00620 NO3	00665 P-tot	00680 C-org	00945 SO4	01045 Fe	01051 Pb	01067 Ni	01092 Zn
88/01/01	Base	6.472e+06	2.413e+05	6.440e+04	3.700e+06	2.927e+05	3.740e+06	7.040e+07	2.837e+05	4.872e+03	2.652e+04	2.241e+04
	Excess	7.071e+07	1.192e+05	2.764e+04	2.054e+06	1.490e+05	3.785e+06	2.888e+07	1.867e+06	9.169e+03	2.748e+04	2.145e+04
	Total	7.718e+07	3.605e+05	9.204e+04	5.754e+06	4.417e+05	7.525e+06	9.928e+07	2.150e+06	1.404e+04	5.400e+04	4.386e+04
89/01/01	Base	1.054e+07	3.932e+05	1.049e+05	6.028e+06	4.769e+05	6.094e+06	1.147e+08	4.622e+05	7.938e+03	4.321e+04	3.652e+04
	Excess	1.202e+08	1.489e+05	3.383e+04	2.712e+06	1.883e+05	5.566e+06	3.467e+07	3.143e+06	1.468e+04	4.105e+04	3.117e+04
	Total	1.307e+08	5.421e+05	1.387e+05	8.740e+06	6.652e+05	1.166e+07	1.494e+08	3.606e+06	2.262e+04	8.426e+04	6.769e+04
90/01/01	Base	9.257e+06	3.452e+05	9.212e+04	5.293e+06	4.187e+05	5.350e+06	1.007e+08	4.058e+05	6.970e+03	3.794e+04	3.206e+04
	Excess	8.623e+07	1.513e+05	3.517e+04	2.591e+06	1.889e+05	4.712e+06	3.682e+07	2.280e+06	1.128e+04	3.414e+04	2.675e+04
	Total	9.549e+07	4.966e+05	1.273e+05	7.884e+06	6.076e+05	1.006e+07	1.375e+08	2.686e+06	1.825e+04	7.208e+04	5.881e+04
Average	Base	8.758e+06	3.266e+05	8.715e+04	5.007e+06	3.961e+05	5.061e+06	9.527e+07	3.839e+05	6.593e+03	3.589e+04	3.033e+04
	Excess	9.237e+07	1.398e+05	3.221e+04	2.452e+06	1.754e+05	4.687e+06	3.346e+07	2.430e+06	1.171e+04	3.422e+04	2.646e+04
	Total	1.011e+08	4.664e+05	1.194e+05	7.459e+06	5.715e+05	9.749e+06	1.287e+08	2.814e+06	1.830e+04	7.011e+04	5.679e+04

Appendix D

List of Contacts for DRB Nonpoint Pollution Study

List of Contacts for DRB Nonpoint Pollution Study

US EPA

Region 2, Marine & Wetlands Protection Branch
26 Federal Plaza, New York, NY 10278, 212-264-5170 (FAX 212-264-4690)

Robert Nyman, project manager, 212-264-5565

Eric A. Stern, oceanographer

Region 3
(FAX 215-597-1850)

Bob Tudor (215-597-9977)
Coordinator for Delaware Estuary Program.

Steve Hammel (215-597-9977)
Independent contractor helping Bob Tudor draft nonpoint part of Estuary report.

Mindy Lemoine (215-597-3697)

Roy Denmark

Sumner Crosby (215-597-3424, FAX 215-597-8541)
GIS specialist, director for water management.
Has located extensive PA water quality records in STORET.

Environmental Services Division
839 Bestgate Rd., Annapolis, MD 21401, 301-266-9180 (FAX 410-573-2698)

Marria O'Malley Walsh

Delaware River Basin Commission

P.O. Box 7360, West Trenton, NJ 08628, 609-883-9500

David P. Pollison, P.E., Planning Branch

Tod Kratzer

Warren Huff
Suggested Patricia Cummins, NJ DEPE, is aware of all GIS activities in NJ.

Dick Albert

Seymour P. Gross, ext. 236
Provided information on water quality measurements for Estuary.

Tim Lazaro
Contact for DRBC estuary measurments entered into STORET.

Delaware Valley Regional Planning Commission

Bourse Bldg., 21 S. Fifth St., Philadelphia, PA 19106

Bill Greene (215-592-1800)
Reported that new landuse based on 1990 flights (1200 ft) for four NJ and five PA counties will be available by 1 Sept. 1993. Will supply data to us.

USGS

DE District

Robert Simmons (302-734-2506)
Reported Lillian Maclin at Towson office handles water quality archiving.

MD/DE Office
Towson, 410-828-1535

Lillian Maclin
Responsible for archiving water quality data.

NJ District
810 Bear Tavern Rd., West Trenton, NJ 08628, 609-771-3900

Eric Evenson (ext. 3902)
Willing to help with problems with WATSTORE data.

Curtis Price
Provided watershed boundaries for NJ.

Ed Pustay, hydrologist

Dan Vaulpel (ext. 0065)
Possible source of water quality data.

NY District, 518-472-3663

Yvonne Baezsky, hydrologist, GIS specialist

Reported Andy Cohen is handling landuse work.

Andy Cohen

Developing new landuse coverage for entire state, in coordination with SCS; coverage for DRB area not yet planned.

Patricia Murray, 518-472-7176

Responsible for water monitoring and WATSTORE interface.

PA District
Lemoyne, 717-730-6900

Scott Hoffman

<u>National Water Data Exchange</u>

Reston, VA, 703-648-5000, FAX 648-5704

Carol Lewis (ext. 5676)

Can provide tapes containing WATSTORE records selected using criteria we specify. Did initial search yielding 3 stations on DR main stem.

Ed Pickering (ext. 5664)

Don Dominick (ext. 5671)

Ken Lanfear (ext. 6852)

Reported that metal measurements prior to 1992 have serious contamination problems.

<u>National Park Service</u>

Mid-Atlantic Region

John Karish (209B Ferguson, PSU, 865-7974), regional scientist

Delaware Water Gap N. P.
Milford, PA, 717-296-6952

Beth Johnson

Provided copies of water quality reports from Scenic Rivers program.

US Fish & Wildlife Service

Delaware Estuary Program, Bombay Hook NWCR
R.D. 1, Box 146-A, Smyrna, DE 19977, 302-653-9152

David Stout

NJ DEPE

Patricia Cummins (609-984-2243), GIS Coordinator
Suggested Curtis Price, USGS, as source of watershed boundaries.
Provided information on current status of landuse redo.
Suggested Office of State Planning could provide population projections.

James Mumman (609-292-1623), Adminstrator, Water Monitoring Management
Can provide PCS data for NJ.

Larry Thornton (via 609-292-1623)
May help with GIS contacts.

NY Environment Agency (exact name?)

Fred VanAustine (518-457-7470), GIS coordinator
May have watershed boundaries for NY.
Suggested USGS as best source of water quality data.
Suggested Equalization Assessment Office for property and landuse data.

PA DER

Tammy Schreffler (717-783-3638)
STORET contact for surface water program.

Rod Kime (717-783-3638)
Working with surface water program GIS.

Charles Rehm (215-832-6065)
Chief, Planning Section, Water Quality Management

James Walsh (717-787-2529)
PA coordinator for Delaware Estuary Program

DE Division of Water Resources

Rick Truett (302-739-4691)
Provided watershed boundaries and landuse data.
Landuse currently being updated -- completion mid-1993.

New Castle, DE

David Roca (302-731-7670)
Has extensive water quality data for local area.

USDA Soil Conservation Service

Elbert Wells (215-696-0468), Project Leader, Del. Estuary Program
Interested in nonpoint source pollutants entering estuary; concerned about likely low accuracy of our results.

DE Dept. of Agriculture

Mike McGreff (302-739-4811), compiling landuse/cover
Provided additional information on 1984 landuse classification.
1992 revision based on aerial photos, release scheduled for mid-1993.

NJ Council on Affordable Housing

Art Bernard (609-292-3000)
Outlined current landuse classification project, suggested Kev Airola could provide more details.

NJ Office of State Planning

Jim Reilly (609-292-7156), population projections
Sent description of projection model.
Offered to run model for us, using our choice of parameters.

Paul Gottleib
Did programming for population model.

NY Equalization Assessment Office

Jim Dunne (518-473-4216)
Sent 1986 assessment data.

NY Dept. of Economic Development

State Data Center
(518)424-6005

Leonard Gaines
Someone in this office sent county population projections.

Bob Scardamalia

Rutgers University

Cook College Remote Sensing Center

Kev Airola (908-932-9631)
Compiling land cover classification for NJ from March 1991 TM imagery for NJ Council on Affordable Housing. Collapsing categories to builtup/non-builtup. Because of risks of litigation, cannot release data in forseeable future.

University of Delaware

Jonathan Sharp (FAX 302-645-4007)

Widener University

John Davis (215-499-4063, FAX 215-499-4059)

Appendix E

Quarterly Progress Reports

Delaware River Basin Nonpoint Pollution Study

Quarterly Progress Report

July through September, 1992

SUMMARY

Our efforts have focused on data acquisition (Phase 1 of the "Scope of Services"). For water quality data, we have attempted to locate all stations at which at least 20 water parameters were measured routinely (at least four times per year) from 1988 to 1990. Because toxic metals are of particular interest for urban runoff, we made a separate search for stations which routinely monitored one or more metals. The only database in which we have thus far found station data meeting our preliminary search criteria, WATSTORE, yielded 32 stations. However, most are located on tributaries in New Jersey (26 stations, many of them a long distance upstream from their confluence with the Delaware). Of the remaining 6 stations, 5 are on the main stem of the Delaware; the only station on a major tributary in Pennsylvania (the Schuylkill River at Philadelphia) has no WATSTORE entries after mid-1989. In addition, most of the stations do not routinely measure toxic metals and organics and few take measurements more than 4 to 6 times per year. As a result, our original goal of analyzing pollutant constituent flows from at least 8 sub-basins will be very difficult to achieve.

We have obtained digitized watershed boundaries for the parts of the DRB in Delaware, New Jersey, and Pennsylvania. We expect to find a suitable source for New York.

Digital landuse/landcover data at 1:250,000 scale, generally based on aerial surveys from the mid-1970's, are available for the entire basin. We have also obtained a somewhat more recent coverage (1984) for Delaware. Updated coverages are currently being compiled for all of Pennsylvania, and have recently been completed for three of the most urban New Jersey counties in the DRB. Updated coverage for Delaware, the rest of New Jersey and for the New York part of the DRB apparently will not be available in time to be used in the current study.

Rough projections of landuse change are available for Pennsylvania. New Jersey operates a computerized population projection model, and has offered to run projections for us using parameters of our choice; landuse changes must then be inferred by associating population growth with landuse conversion from forest/agricultural to urban. We have received population projections through 2010 and real estate assessment data for New York counties. We have not yet located projections of either population or landuse changes for Delaware.

WORK ACCOMPLISHED

To initiate the study effort, we reviewed the proposed study plan to identify the data sets which would be required and, for water quality data, the criteria to be used for selecting stations. We concluded that four types of data will be needed: water composition and flow rate, watershed boundaries, land use, and projections of land use change.

In an effort to locate available data in these four categories, we contacted a number of people in state and federal agencies, who in turn suggested other contacts. Our working list of contacts is included as Attachment 1.

Our data acquisition activities are discussed below for each of the data types in turn.

Water Monitoring Data

For determining the runoff-related component of pollution, measurements must be available for a number of different dates, some of them when stream flow has increased following rainfall or snow melt. To give a reasonable chance of finding high flow events, our initial screening of stations required at least 8 measurement dates during the years 1988 to 1990.

Since a signature of urban runoff is the presence of various metals, we also tried to screen out stations at which these components were not measured routinely. We found that many of the stations measure only a limited number of components, concentrating on parameters such as pH, turbidity, nutrients, and bacteria. To have a reasonable chance of finding measurements of a variety of other pollutants, such as heavy metals and organics, our initial screening ignored stations which measured fewer than about 20 components on each date.

The most extensive source of water monitoring data proved to be the USGS WATSTORE database, which we accessed using the search software and CDROM version of the data distributed by EarthInfo, Inc. The initial search yielded 32 stations meeting the search criteria. To make sure that we did not overlook any stations recording toxic metals, we also tried an alternate search, looking for all stations recording at least one heavy metal; no additional stations were found.

We gradually became aware that there are a number of problems with the EarthInfo CDROM and/or software. Stream flow (discharge rate) data are omitted from the CDROM for all stations after early 1989. Comparison with WATSTORE data obtained directly from the National Water Data Exchange (NAWDEX) for two of the stations showed that stream flow had in fact been measured after this date. This comparison also showed that some heavy metal observations were omitted from the EarthInfo CDROM. In addition, our EarthInfo searches sometimes returned data for stations and time periods outside those specified by the search criteria. Although the EarthInfo data have been helpful for our initial screening, it is clear that we will need to go directly to the WATSTORE data for definitive records. Accordingly, we will use NAWDEX facilities for additional searches and retrievals.

We also reviewed the annotated bibliography in the report "Status and Trends of Toxic Pollutants in the Delaware Estuary"; unfortunately, none of the stations listed in this bibliography reported more than 5 samples during the 1988-1990 period. In addition, we reviewed data for the DR segment between Hancock, NY (where the river divides into E and W branches) and the Delaware Water Gap, included in the reports "Findings of the 19xx Scenic Rivers Water Quality Monitoring Program"; although an extensive series of measurements are reported, they do not include toxic metals or organics. These data do include, however, rain gauge data at a number of stations, which may help us infer stream flows.

We have not yet definitively determined whether the STORET database contains additional stations which meet the selection criteria, but at present it seems unlikely.

Of the 32 stations found to date which do satisfy our initial search criteria, 5 are located on the main stem of the river. Of the remainder, 26 are on tributaries in New Jersey, often a considerable distance upstream from their entry into the Delaware. Only one station, at the mouth of the Schuylkill, is located on a Pennsylvania tributary; measurements were not recorded for this station after mid-1989. At almost all of these stations, measurements were taken only 4 to 6 times a year, so there will probably be only a very small number of measurements taken during conditions of high stream flow. At only a few of these stations were dissolved metals recorded routinely, although as noted above this may partly reflect problems in the EarthInfo data. Data searches for additional stations are continuing; however, it currently appears we will have at most 3 or 4 stations which provide the range and frequency of measurements needed for the type of analysis we originally planned.

Watershed Boundaries

Watershed boundaries have been compiled separately for each of the states in the DRB. Details for each state are given below.

Delaware:

The Division of Water Resources has digitized boundaries from 7.5 minute quads, in ARC/INFO format; Rick Truett has sent these to us.

New Jersey:

The USGS (West Trenton) has digitized watershed boundaries from 1:24,000 topographic maps for the entire state. Curtis Price has sent these to us, in ARC/INFO format.

New York:

Watershed boundaries for about 40% of the state have been digitized from 1:24000 quads, in cooperation with the Soil Conservation Service, but there are no immediate plans to do the Delaware Basin area. Digitized hydrologic unit maps at 1:500000 are probably available; the NY portion of the DRB is divided into 3 hydrologic units.

Pennsylvania:

ORSER has adequate data, in ARC/INFO format.

Landuse/Landcover

The USGS digital landuse products are available for the entire DRB. These are based on aerial photography dating mainly from the mid-1970's. The minimum mapping unit is 16 ha (40 acres) except for urban and some other intensive-use landuse types, for which it is 4 ha. Newer and/or higher resolution surveys are currently underway in all states but New York.

Delaware:

Data at a 10 acre mapping unit were compiled by Earth Satellite Corp. from IR-enhanced aerial photos in 1984, using an Anderson-type of classification, with main emphasis on wetlands. Significant landuse changes have occurred since. New data are currently being compiled from photos -- the target date for completion of general landuse data is summer 1993. Rick Truett of the Division of Water Resources has sent us the 1984 data.

New Jersey:

The GIS coordinator for the NJ DEPE, Pat Cummins, reports that landuse/landcover for the entire state is being redone at a 1 ha mapping unit, using 29 categories similar to Anderson level 2. Of the counties in the DRB, only Burlington, Mercer, and Camden counties have been completed; Glouscester is in progress, but may not be done in time for use in the current study. The three completed counties do include much of the most heavily urbanized areas around Trenton and Camden. Not yet started are Salem & Cumberland counties (lower Estuary and Bay) and Hunterdon, Warren, & Sussex (from N of Trenton to NY line).

A separate landuse classification effort, based on Landsat TM imagery, is underway at Rutgers University under contract to the NJ Council on Affordable Housing. However, Kev Airola of Rutgers believes any release of these data to other agencies will not be permitted for some time; since one of their intended uses is in mandatory allocation of low-cost housing units to the various towns and municipalities, a process which may spark protest and litigation.

New York:

Fred VanAustine (NY GIS coordinator) was not aware of any recent landuse/landcover data for the Delaware Basin. Counties in the DRB are most of Delaware and Sullivan, part of Orange, and a small part (well up in the Catskills) of Ulster.

Pennsylvania:

In conjunction with the EMAP project, an EPA contractor is redoing the entire state. The target date for completion of classification is January, 1993.

Population Projections

Delaware:

No information.

New Jersey:

Jim Reilly and Paul Gottleib at the Office of State Planning have a very sophisticated program to project population for each municipality in the state given either statewide or county-by-county overall population totals. Parameters include whether or not the state plan is implemented, various factors affecting trends such as marriage rates and family size, income based on trends in type of employment, etc. The model takes the total number of people, aggregates them into households including distribution of household incomes, and fits the households into the available land. Jim will happily run the model for us with whatever parameters we request -- but the model may not be useful beyond 2010.

One outcome of their playing with this model was a very high correlation between population and total highway lane miles -- which might in turn correlate with highway runoff pollution.

New York:

The Department of Economic Development state data center has sent us population projection data by county.

The State Equalization Assessment Office has sent county assessment data as of 1986; 1989 data are in preparation. Standardized statewide data sets extend back only a few years.

Pennsylvania:

ORSER has projections from the PA nonpoint pollution potential study carried out for the PA DER. These projections are based on an observed linear relation between total assessed value of urban real estate (adjusted for inflation and common market ratios) and urban area.

WORK PLANNED

Our top priority is to complete our search for additional water quality data, and identify measurements taken under high stream flow conditions.

If, as now appears likely, we are unable to identify additional stations having extensive series of data, our original plan to try and isolate a number of subbasins having different landuse characteristics will not be feasible. A major rethinking of strategy will be needed. This will require meeting with DRBC personnel.

We will continue acquisition and, as necessary, reformatting of the GIS data coverages.

Delaware River Basin Nonpoint Pollution Study

Quarterly Progress Report

October through December, 1992

SUMMARY

Our efforts have continued to focus on data acquisition (Phase 1 of the "Scope of Services"). We discovered that the search performed for us by NAWDEX of the WATSTORE and STORET databases apparently used the wrong search parameters, since no stations were found in Pennsylvania or Delaware. With the generous help of Sumner Crosby of EPA Region 3 and John Davis of Widener University, we have now identified about 50 additional stations which measure water quality approximately once a month.

We have acquired the USGS LUDA landuse/landcover data (compiled during the mid-1970's) for the entire Delaware Basin. We are currently determining the proportion of each type of landuse and total area of the drainage basin for each of the potentially usable monitoring stations. We anticipate making a final selection of stations by the end of January.

Examination of the measurement summaries for the candidate stations indicates that, with relatively few exceptions, the majority of metal concentration measurements are reported as being at or below the detection threshold. In addition, the USGS has now determined that their standard technique for collecting water samples has been prone to contamination which makes all metal concentrations reported prior to 1992 of doubtful accuracy. Although we still plan to include metals in our analyses, any conclusions will be of limited validity.

Toxic organics appear to be measured at most once per year at all but a very few stations. Accordingly, we have concluded it is not feasible to include organics in our analysis.

We have learned that the new landuse/landcover data for Pennsylvania, which was to be compiled as an extension to the EPA EMAP program, will not be released for the Delaware Basin part of the state in the near future. As a result, recent landuse/landcover will be available only for Delaware and part of New Jersey.

WORK ACCOMPLISHED

We continued our efforts to locate and acquire the data needed for the study.

Water Monitoring Data

During our initial search for usable water quality data, we had written to NAWDEX requesting a summary of all WATSTORE and STORET water quality data for the Delaware River Basin recorded from 1988 through 1990. We received back a short list containing only a few stations on the Delaware River. It has subsequently become apparent that the wrong parameters were entered for the search. As a result, we were misled into believing that the STORET records did not contain data beyond that available from the USGS WATSTORE database.

We had also attempted to search the water quality data distributed on CDROM by EarthInfo, which purported to include all the USGS WATSTORE records. However, it had become clear that the CDROM data were far from complete, omitting some samples and observations for some stations. Accordingly, we went directly to the published "U.S.G.S. Water Resources Data" compilations to identify potentially usable stations. Although this enabled us to characterize the data available at each station with greater confidence, it did not increase the number of stations found.

Based on this search, we identified about 10 stations which contained at least marginally suitable records. A few stations were on the main stem of the Delaware; most of the others were on minor tributaries in New Jersey, with limited drainage areas. Only one station was found on a major tributary in Pennsylvania. In addition, most of the USGS measurements are taken only 4 to 6 times a year, so the number of measurements coinciding with high discharge rates is likely to be very limited. We were also informed by Ken Lanfear of USGS that the method used for taking samples prior to 1992 often introduced significant contamination by metals, with the result that all published metals concentration data are highly suspect.

In response to our discussion of water quality data problems in our first quarterly progress report, David Pollison sent us summaries of measurements made by the DRBC in the Estuary, in most cases at monthly intervals or more frequently. Because all these stations are tidal, however, direct measurement of river flow rates is very difficult, and substantial mixing occurs, so that the effects of runoff pulses become very difficult to detect and interpret.

In view of our continuing problems locating suitable data, Robert Nyman set up a conference call with a number of people familiar with water quality measurements in the Basin. During this call, it became obvious that our original NAWDEX search had missed large numbers of potentially usable stations in Pennsylvania and Delaware. Subsequent to this conference call, John Davis of Widener University sent us a list of stations in northern Delaware for which daily flow data are also available, and Sumner Crosby of EPA Region 3 provided us with summary printouts for all stations in the Delaware Basin at which water quality measurements were made during 1988 through 1990.

We have now identified about 50 additional stations at which nutrients, and in most cases also metals, were measured at regular intervals, typically once a month. We are in the process of superimposing the locations of these stations and the nearest flow-rate gauging stations on watershed and land/use landcover maps to determine the approximate drainage area and proportions of different landuse types for each station. Although it is clear than many of the stations have limited drainage areas, there are also several which drain larger areas, so we now anticipate being able to follow our original plan of using data from about 10 stations representing sizable drainage areas with diverse landuse/landcover characteristics. We expect to complete this analysis and make our final selection of stations by the end of January.

During the conference call, several people pointed out that a large proportion of measurements of metals concentrations are reported as being at or below detectability limits. Our review of the station summaries provided by Sumner Crosby confirms this. Accordingly, it will probably be difficult to extract meaningful relationships between metals concentrations and stream discharge rates, even if the contamination problems reported by the USGS are not present in the measurements by state agencies in Pennsylvania and Delaware. However, it is probably still worthwhile to go ahead and perform the analysis; if nothing else, we may be able to infer what improvements in detection sensitivity would be needed to permit meaningful studies in the future. As is the case for the USGS data, the Pennsylvania and Delaware stations do not, in general, measure toxic organics on a regular basis. Accordingly, organics will not be included in the study. Appendix A provides a preliminary list of the water quality parameters which will be included.

Watershed Boundaries

We now have watershed boundary data, at varying resolutions, for Delaware, New Jersey, and Pennsylvania. Since we expect that the monitoring stations to be selected will subdivide the New York part of the Basin into at most 2 drainage areas, hydrologic unit boundaries will probably provide sufficient resolution.

Since many monitoring stations are not located at the outflow point of a standard watershed, some manual digitization of boundaries between the areas drained by different monitoring stations may be necessary.

Landuse/Landcover

We have received USGS LUDA landuse/landcover data for the entire Basin, which are based on imagery acquired mainly during the mid-1970's. We have also received coverage for all of Delaware, updated to 1984. We had hoped to obtain updated data for the Pennsylvania part of the Basin, but have recently been informed that is now not expected to be released in time for use in the current study. We still expect to be able to get recently updated coverage for Burlington, Mercer, and Camden counties in New Jersey, but need to verify whether it is in fact ready for release. As indicated in our last quarterly report, updated coverage for New York and the rest of New Jersey will apparently not be available.

Because recent data are available for only a small part of the Basin, most of the analysis will have to rely on the old LUDA data. For most monitoring stations having large drainage areas, changes in land use/landcover since the LUDA data were compiled are likely to have occurred only in a small fraction of the total area, and may partially cancel out. Of the areas currently undergoing rapid urbanization, however, current landuse will be depicted with reasonable accuracy only in the Camden to Trenton corridor of New Jersey and, to a lesser extent, the Wilmington suburban fringe; landuse distributions for the Philadelphia suburbs will be seriously out of date. Unfortunately, the monitoring stations within the recently reclassified part of New Jersey measure nutrients only 6 times per year, and metals much less frequently; this will make it more difficult to detect and characterize nonpoint pollution associated with urban landuse.

Population Projections

We have taken no further action to locate or acquire additional population projection data.

WORK PLANNED

Phase 1 -- Data Acquisition

We will complete the superposition of monitoring station locations on the landuse and watershed boundary GIS layers, and determine approximate areas and landuse distributions for each of the candidate monitoring stations. We will then select approximately 10 stations for detailed analysis.

Once this selection is completed, full water quality and discharge rate data sets will be requested for the selected stations.

We will also complete our acquisition of supporting GIS data by verifying the availability of the updated landuse/landcover data for New Jersey, requesting it from the appropriate agency, and entering it into our GIS data base.

Phase 2 -- Development of Mass Balances

For each of the selected monitoring stations, we will tabulate the concentrations of all the selected constituents and the corresponding flow rate for each date on which measurements were taken. In most cases, this flow rate will represent a daily average value rather than instantaneous flow. We will also tabulate daily average discharge rates for each day of the year for each year from 1988 through 1991; when daily discharge data are not recorded at the water quality monitoring site, we will use data from a nearby flow gauging station.

Initially, a simple linear regression of concentration against discharge rate will be performed for each constituent at each station, and the probable errors in the regression coefficients will be determined. If there are sufficient measurements under conditions of high flow (which will not usually be the case), an attempt will be made to identify non-linearities in the concentration-flow relationships and to identify seasonal changes in them.

Using the resulting relationships between concentration and discharge rate, we will estimate the concentration of each constituent on each day of each year during the study period. The estimated concentration will be converted to daily total loading by multiplying it by the average discharge rate for the day and the number of seconds in the day. The daily total loadings will be summed to compute annual total loadings.

To estimate the runoff-related component of the annual loadings, the loading calculations will be repeated using only that part of the daily discharge which is above the baseline flow. We will determine the baseline flow for each station by examining the hydrograph to identify those days which are associated with runoff events, and drawing a smooth curve through the remaining data. Obviously, this procedure will be somewhat subjective -- it may prove desirable to draw more than one curve, representing "higher" and "lower" estimates of baseline flow, and do the computation of runoff-related loadings for each such curve.

Phase 3 -- Relating Nonpoint Pollutants to Landuse

For each of the selected monitoring stations, we will use watershed boundary data to delineate the area drained by the station. As noted above, the boundaries between drainage areas may not fully coincide with the watershed boundaries. For such cases, we will manually add the approximate dividing lines between drainage areas with the help of other data sources, such as digital hydrology data and hardcopy topographic maps.

We will then superimpose the drainage area boundaries on the digital land use data and determine the amount of land in each drainage area in each of the five categories urban, agricultural, forest, extractive/other, and water. Multivariate statistical methods will then be used to try to infer a relation between annual nonpoint loadings and landuse distribution.

APPENDIX A

Preliminary
1 Dec. 1992

Parameters to be Included in Annualized Mass Balances

CODE	NAME
61	DISCHARGE, INSTANTANEOUS STREAM (CUBIC FEET PER SECOND)
300	OXYGEN, DISSOLVED (MG/L)
500	SOLIDS, RESIDUE ON EVAPORATION AT 105 DEG C. TOTAL (MG/L) (or ditto at 180 DEG C., code 70300)
610	NITROGEN, AMMONIA, TOTAL (MG/L AS N)
615	NITROGEN, NITRITE, TOTAL (MG/L AS N)
620	NITROGEN, NITRATE, TOTAL (MG/L AS N)
625	NITROGEN, AMMONIA PLUS ORGANIC, TOTAL (MG/L AS N)
630	NITROGEN, NITRITE PLUS NITRATE, TOTAL (MG/L AS N)
665	PHOSPHOROUS, TOTAL, (MG/L AS P)
915	CALCIUM, WATER, DISSOLVED, (MG/L AS CA)
935	POTASSIUM, WATER, DISSOLVED, (MG/L AS K)
945	SULFATE, WATER, DISSOLVED, (MG/L AS S04)
1000	ARSENIC, WATER, DISSOLVED, (UG/L)
1025	CADMIUM, WATER, DISSOLVED, (UG/L)
1030	CHROMIUM, WATER, DISSOLVED, (UG/L)
1040	COPPER, WATER, DISSOLVED, (UG/L)
1046	IRON, WATER, DISSOLVED, (UG/L)
1049	LEAD, WATER, DISSOLVED, (UG/L)
1065	NICKEL, WATER, DISSOLVED, (UG/L)
1090	ZINC, WATER, DISSOLVED, (UG/L)
71890	MERCURY, WATER, DISSOLVED, (UG/L)

Notes:

1. Some stations do not report ammonia, nitrite, and nitrate separately.

2. For several of the metals, some stations report total rather than dissolved quantities.

Delaware River Basin Nonpoint Pollution Study
Quarterly Progress Report
January through March, 1993

SUMMARY

We have continued to have difficulties acquiring water quality and flow data in digital format. We have successfully obtained 1988 through 1992 water quality data for 18 sites, with drainage areas representing diverse distributions of land use, and entered it into a database. However, the USGS WATSTORE daily flow database recently became corrupted, and had not yet been fully restored as of the end of March. As a result, we have been unable to retrieve all the date needed to compute base flow for each station; this, in turn, has precluded the derivation of the relations between flow rate and pollutant concentration needed for compiling mass balances.

Software for entering data from STORET and WATSTORE retrievals into our database has been developed, together with low-level routines to support data analysis and report generation. This has enabled us to determine that, at most sites, at least two or three sets of water quality measurements were taken under conditions of relatively high stream flow, with flow rates at least twice the rates for the immediately preceding and following sampling dates. It now appears that it will be possible to establish statistically meaningful relationships between flow rate and concentration for at least some metals and nutrients.

We have completed ingest of watershed boundaries and the USGS LUDA land use/land cover data into our GIS database. Because final selection of the water-quality monitoring sites still depends on successful retrieval of daily flow data, we have not yet compiled quantitative land use/land cover distributions for the area drained by each monitoring station.

As the result of the repeated delays in obtaining the needed water quality and flow data, we are now at least three months behind our original schedule.

WORK ACCOMPLISHED

Water Monitoring Data

We identified about 30 stations in the Delaware River Basin at which water quality was measured routinely and for which daily flow measurements were available from the same or a nearby site. We located each station on a map of land use/land cover, and visually characterized the drainage area as to approximate proportions of forest, agricultural, and urban land use. We also obtained the published drainage area for each USGS daily flow station.

We then used several criteria to eliminate about one-third of the candidate stations. In general, stations with drainage areas less than about 100 square miles were eliminated; the one station not so eliminated, on Raccoon Creek in New Jersey, appears to drain a rapidly urbanizing area which may have unique characteristics. Most of the PA DER monitoring stations measured a number of different nutrients and metals about once a month; stations with less frequent or less comprehensive measurements were eliminated if other stations draining areas of similar geographic and land use characteristics were available. One station was eliminated because flow gauge records were available for only a limited period of time. The 21 water quality stations left after this selection process are listed in Attachment 1.

Of these 21 stations, two are USGS stations at which measurements were made only about 4 times per year and which are within a short distance of PA DER monitoring stations: we plan to consolidate the data from these USGS stations with that from the nearby PA DER stations. Another four of the 21 stations recorded measurements only about six times per year, and at three of these stations only nutrients were measured. We will include these stations in subsequent analyses only if several sets of measurements were acquired under high water flow conditions, since otherwise it will be not be possible to derive statistically meaningful relationships between concentrations and flow rates. For one station, on Brandywine Creek in Brandywine Park, Wilmington, we currently only have hard copy data: we will include this station in our analyses only if we succeed in retrieving the data from STORET in digital format.

We obtained data in computer-readable format for all the selected USGS water quality stations from the WATSTORE database: the search and retrieval was performed for us by NAWDEX. Tammy Schreffler of PA DER retrieved data for DER monitoring stations for us from STORET. NAWDEX also attempted to retrieve daily flow data: however, we found that data for water year 1990 were omitted for most of the stations. After further discussions with NAWDEX personnel, we learned that they had discovered that part of the daily flow database had become corrupted. Restoration of the database is in progress: as of March 29, there were still some stations for which 1990 data were still not accessible. Database restoration should be completed in the near future.

We have written software to ingest the data retrieved from WATSTORE and STORET and convert it to a standard binary data structure designed to simplify subsequent analysis. We have also written some support subroutines to facilitate data manipulation for statistical analysis.

In retrospect, we should have arranged for our own STORET account at the start of this study, and spent the time needed to learn the search and retrieval software. Although the personnel at NAWDEX and PA DER, together with Sumner Crosby at EPA Region 3, have been very helpful, it would have been much faster to initiate searches and retrievals ourselves, especially when supplementary retrievals have proved desirable.

Watershed Boundaries

Since a number of the monitoring stations are not at the outflow points of subwatersheds, some additional digitization from printed maps will be needed to fully delineate the drainage area for each station. We have deferred doing this additional digitization until we are certain which stations will be used.

Land Use/Land Cover

The USGS LUDA land use/land cover data and more recent (mid-1980's) data for Delaware have been entered into ARC/INFO coverages. The LUDA data were used for our preliminary, qualitative characterization of the relative proportions of forest, agricultural, and urban land use for each drainage area.

We have not yet obtained copies of the new land use/land cover data for the three counties in New Jersey for which it is available. Unfortunately, it now appears that almost all the monitoring stations which recorded sufficient data for meaningful statistical analysis are in Pennsylvania; accordingly, the more recent data from New Jersey and Delaware will be of limited value in deriving relationships between land use and nonpoint pollutant loadings.

Relations between Flow and Pollutant Loadings

Due to the lack of complete daily flow data, we have not yet been able to develop baseline flow rates for each station. We have examined the discharge rates reported for the dates on which samples were taken and the corresponding concentrations of selected pollutants, however. For most stations, there appear to be at least two or three samples taken when the discharge rate was at least twice that for the immediately preceding and following sample dates. We expect that these samples will correspond to flow conditions substantially above the smoothed baseline flow, so it should be possible to derive statistically meaningful relations between concentrations and flow rates.

As noted in a previous report, a large proportion of measurements for most metals were reported as being at or below the measurement thresholds, making analysis of relations between concentrations and flow rates very difficult. For iron, manganese, and zinc, however, this is less of a problem at most stations, so statistical analysis may be feasible. The only nutrient component for which a high proportion of threshold values are reported is nitrite.

WORK PLANNED

Phase 1 -- Data Acquisition

We expect restoration of the WATSTORE daily flow data to be completed by the end of April. Once all the required data are retrievable, we will enter the daily flow data into our database.

We also hope to acquire the updated landuse/landcover data for New Jersey.

Phase 2 -- Development of Mass Balances

We plan to develop mass balance data using the procedures outlined in the "Work Planned" section of our previous quarterly report (for October through December, 1992).

In addition to computing regressions of concentration against total stream flow, we will also try regressions using only the flow in excess of smoothed base flow rates, and also using the ratio of total flow to base flow. If either of these alternatives gives consistently lower residual errors, it will be adopted as the standard procedure.

Phase 3 -- Relating Nonpoint Pollutants to Landuse

We plan to carry out the work described in our previous quarterly report.

Attachment 1

12 April 1993

Water Quality Monitoring and Gauging Stations

Station code	Description	Location lat.	Location long.	Drainage Area(1)	Gauge(2) code	Gauge(2) dist.	Notes (3)
WQN0185	Delaware R. Callicoon NY. SR1020 br	41 45 54	75 03 12	1820	1427510	0.6mi	
WQN0137	Brodhead Cr .5 mi US from SR2028 br	40 59 59	75 08 54	259	1442500	600ft	
WQN0176	Delaware R at Stroudsburg	40 58 42	75 08 10	3850	1440200	3.5mi	
01443500	Paulins Kill at Blairstown NJ	40 58 44	74 57 15	126	1443500	0	(4)
WQN0148	Delaware R at RR spur to PP&L plant	40 47 20	75 06 58	4535	1446500	3.1mi	
WQN0125	Lehigh R at PA 873 br. Walnutport	40 45 11	75 36 11	889	1451000	0.3mi	
WQN0123	Lehigh R at Third St br. Easton	40 41 12	75 12 32	1359	1454700	1.8mi	
01463500	Delaware R at Trenton NJ	40 13 18	74 46 42	6780	1463500	0	(5)
WQN0101	Delaware R at Morrisville PA	40 13 09	74 46 42	6780	1463500	800ft	
01467000	N Br Rancocas Cr at Pemberton NJ	39 58 10	74 41 05	118	1467000	0	(4)
WQN0121	Neshaminy Cr at PA 213 br	40 10 26	74 57 26	210	1465500	0	
WQN0113	Schuylkill R at T558 br. Berne	40 31 20	75 59 54	355	1470500	100ft	
WQN0117	Tulpehocken Cr. Bern Twp. T602 cov br	40 22 08	75 58 46	211	1471000	0	
WQN0111	Schuylkill R. Hanover St. Pottstown	40 14 30	75 39 05	1147	1472000	200ft	
WQN0116	Perkiomen Cr at PA 29	40 11 46	75 27 03	279	1473000	2.3mi	
WQN0110	Schuylkill R. Falls Br. Philadelphia	40 01 00	75 11 52	1893	1474500	3.5mi	
01474500	Schuylkill R. Fairmount Dam. Phila	39 58 00	75 11 20	1893	1474500	0	(6)
01477120	Raccoon Cr near Swedesboro NJ	39 44 28	75 15 33	27	1477120	0	(4)
WQN0105	Brandywine Cr .25 mi from PA 100 br	39 51 14	75 35 48	287	1481000	1.1mi	
104011	Brandywine Cr. Brandyw. Pk. foot br	39 45 32	75 33 15	314	1481500	1.3mi	(7)
01411500	Maurice R at Norma NJ	39 29 42	75 04 38	112	1411400	0	(8)

Notes:

(1) Drainage area is in square miles. at the flow gauging station.

(2) All flow gauges are USGS stations. at the indicated (approximate) distance from the water quality station.

(3) Except as noted. nutrients and metals were measured at each station 10 to 12 times per year. from 1988 through 1992.

(4) Only about 6 measurements per year. nutrients only.

(5) Only 4 measurements per year: data will be combined with data for WQN0101.

(6) Only 4 measurements per year: data will be combined with data for WQN0110.

(7) Currently only hard-copy data obtained: metals measured only about 6 times per year.

(8) Only about 6 measurements per year.

Delaware River Basin Nonpoint Pollution Study

Quarterly Progress Report

April through June, 1993

SUMMARY

We obtained corrected and updated daily flow data for the nearest flow gauge to each of the water quality monitoring stations previously selected for detailed analysis, and determined daily base flow values using a variant of the local minimum method. For each of 13 stations having monthly measurements of nutrients and metals, we tabulated pollutant concentrations for each measurement date. To help reveal possible correlations, three additional sets of tables were compiled, sorting the measurement by decreasing flow above base flow, decreasing total flow, and month of year. No obvious trends or correlations were apparent. In particular, for any given station, concentrations often varied by a factor of 2 or more for roughly equal flow rates, under both low flow and high flow conditions. For most metals, a high proportion of measurements were reported as below the measurement threshold.

We assembled mid-1970's landuse data (from USGS LUDA files), digital elevation model (DEM) data at 100 meter horizontal resolution, and USGS 8-digit watershed boundaries for the entire Delaware River Basin. Using the DEM data, we delineated the drainage area for each quality measurement station, and then tabulated the area of each landuse type within each drainage area. It now appears that more recent, higher resolution landuse data will be available for four New Jersey counties and five Pennsylvania counties draining into the tidal river.

During a meeting with representatives of the Delaware Estuary Program, it was concluded that for a number of reasons, including the lack of comprehensive recent landuse data, insufficient water quality measurements under high flow conditions, and major errors introduced by sediment resuspension during high flow events and the presence of flow-control dams upstream from a number of the monitoring stations, our original approach is not technically viable. Accordingly, we have developed a modified scope of work which will estimate runoff-related loadings by combining the best available landuse data with published estimates of pollutant runoff per unit area for each type of landuse. The estimates of pollutant loadings which can be derived from water quality monitoring data will now be used primarily to provide a check on the reasonableness of the runoff loadings derived from the landuse data.

WORK ACCOMPLISHED

Water Monitoring Data

We contacted the USGS branch offices responsible for daily flow data in each of the four states in the Delaware River Basin to determine the status of water year 1990 entries, which had become corrupted in the WATSTORE database. For two states, data for all stations had already been reentered; for the other two states, we provided a list of the stations we needed and the necessary updates were made within a few days. USGS then provided us with updated average daily flow data for all stations from October, 1987 to the present.

Data for all stations was complete through September, 1991. For water year 1992, however, there were some data gaps at some flow gauging stations which the USGS offices had not yet filled using their standard algorithms for estimating the missing values. Rather than trying to fill the gaps ourselves, we decided to limit our initial data analysis for each station to the period for which gap-free flow data are currently available. For our final analyses, it may be better to use an identical time period for all stations. This would require ending with water year 1991. To get as many quality measurements as possible, we may want to extend the coverage period back to include water year 1987, giving us data for five full years.

To determine daily base flow values, we wrote simple software to implement a slightly modified version of the local minimum technique described by White and Sloto (1990). This technique uses a moving window whose width, in days, depends on the drainage area of the gauging station. The window is centered on each day in turn; whenever the daily average flow for the date at the center of the window is lower than for any other date within the window, the flow value is marked as a local minimum. On days for which the flow is a local minimum, the base flow is defined to be equal to the daily flow value. For days between local minima, the base flow value is computed by linear interpolation between the adjacent local minima. During extended periods (periods longer than the width of the moving window) of steadily increasing or steadily decreasing flow, the daily flow rates may sag below the base flow values obtained from the linear interpolation. To avoid having actual flow values below the base flow, our version of the technique replaces the base flow obtained using interpolation by the actual average daily flow value whenever the latter is smaller.

The standard version of the local minimum algorithm uses a moving window whose width is twice the estimated duration of runoff after a precipitation event, given empirically as the 0.2 power of the drainage area in square miles; this yields windows from 7 to 11 days wide. Our modified version permits multiplying this window size by an arbitrary constant and/or adding a constant to it (with the result rounded to an odd integer). We initially determined daily base flow values at all stations using the standard window width. When we examined the results, we found a number of occasions on which the computed excess flow (measured average daily flow minus base flow) was small although the daily flow was much greater than the flows a week earlier and a week later; i.e., a pulse of heavy flow persisted for a period longer than the window width. Accordingly, we repeated the base flow calculations after multiplying the default window width values by 2. The two sets of base flow values have been designated "highbase" and "lowbase", respectively.

Relations between Flow and Pollutant Loadings

We tabulated concentrations of total ammonia, nitrite, nitrate, total phosphorous, total organic carbon, sulfate, iron, lead, manganese, nickel, and zinc for 13 stations in PA for which they had been measured approximately once per month. The initial set of tables were sorted chronologically, by date of measurement. To help reveal possible correlations between flow rate or time of year, three additional sets of tables were compiled, sorting the measurements by decreasing value of flow above base flow, decreasing total flow, and month of year.

With two exceptions, iron and manganese, no obvious trends or correlations were apparent from casual inspection of the tabulated data. In particular, for any given station, concentrations often varied by a factor of 2 or more for roughly equal flow rates, under both low flow and high flow conditions. At some stations, but not at others, the highest concentrations of iron and manganese tended to occur under high excess flow conditions. At most stations, the large proportion of measurements of the other metals flagged as below measurement threshold rendered trend analysis especially difficult.

For most stations, roughly two-thirds of the measurements were taken for instantaneous flow rates not more than 50% above the low value of baseflow. Although concentrations vary widely from one such measurement date to the next, there are enough of these measurements (20 to 30) at each station to provide a reasonable approximation of the distribution function of concentration values under low to moderate flow conditions. Hence the mean of the measured concentrations for each pollutant at a given station under these conditions should be a statistically meaningful approximation to the mean concentration for all days having low to moderate flow. This should remain true even when a significant municipal sewage system upgrade or other change in point source loadings occurred during the years covered by the measurements, so long as the sampling frequency remained constant.

The distribution of concentration measurements made under high flow conditions, on the otherhand, may, at best, represent only a very poor approximation of the total distribution for high flow conditions. At least three factors contribute to this: the much smaller number of measurements made under high flow conditions, the fact that some high flow events may represent controlled release from reservoirs in anticipation of heavy precipitation, and the dependence of the amount of pollutants carried by runoff upon how recently the land surface was flushed by an earlier precipitation event.

Accordingly, while it should be possible to obtain fairly accurate estimates of annual mass loadings associated with stream base flows, it will be much more difficult to estimate total loadings and the loading components associated with the component of flow above base flow.

<u>Watershed and Drainage Boundaries</u>

We have extracted the 8-digit watershed boundaries for the Basin from the USGS data set for the entire U.S. and reprojected it into UTM Zone 18. We have a higher resolution set of watershed boundaries for New Jersey, provided by Curtis Price, but have not yet merged these data with the USGS 8-digit watersheds.

Because most of the water quality monitoring stations are not located at the outflow point of a watershed, we also acquired 3-arcsecond USGS digital elevation model (DEM) data covering all of the Basin except the southernmost part of the Bay. After merging these data sets and reprojecting them to UTM Zone 18 at 100 meter horizontal resolution, we used ARC/INFO drainage network software to delineate the drainage area of each of the water quality stations.

There are numerous minor differences, and one or two major ones, in the watershed boundaries derived from the DEM data and those in the USGS data set for the U.S. The minor differences may reflect the fact that the USGS boundaries were digitized from 1:250000 scale maps which provide limited detail for smaller streams. We are still investigating the major discrepancies -- we plan to make comparisons with 1:100000 digital hydrology data and perhaps with 1:24000 topographic maps.

Landuse/Landcover

We have merged the mid-1970's landuse data sets (from USGS LUDA files) for the Delaware Basin into a single coverage and reprojected it to UTM Zone 18. Using these data, we have compiled the area of each landuse type for the drainage area of each monitoring station.

We have been informed by Bill Greene of the Delaware Valley Regional Planning Commission that high resolution landuse data sets, based on aerial photography acquired in 1990, will soon be available for the more heavily urbanized parts of the lower Basin, probably by the beginning of September. The counties covered are Mercer, Burlington, Camden, and Gloucester in New Jersey and Bucks, Montgomery, Philadelphia, Delaware, and Chester in Pennsylvania.

Revision of Scope of Work

We briefly discussed the status of the nonpoint pollution study at the May meeting of the Scientific and Technical Advisory Committee for the Delaware Estuary Program, describing the problems encountered. As a result, we met with a smaller group of people in June to try to redefine study objectives and determine what was technically feasible within the constraints of the available data.

In addition to the problems associated with limited measurements of pollutant concentrations under high flow conditions, it was pointed out during these meetings that two additional factors complicate the derivation of nonpoint runoff loadings from high flow concentration data. First, high stream flow frequently causes resuspension of sediments, which in some cases contain pollutants coming primarily from point sources. Second, many of the quality monitoring stations are downstream from flow control reservoirs, so that high flow events may reflect reservoir releases in anticipation of heavy precipitation.

In order to obtain meaningful estimates of nonpoint loadings, therefore, it was agreed that we should rely primarily on published estimates of per-acre pollutant loadings for different types of landuse. Total nonpoint loadings will be computed by determining total area of each landuse type and multiplying by the per-acre nonpoint loading values. Although we will also compute rough estimates of loadings in excess of base loadings using the monitoring station data, these results will be used primarily to verify that the values derived from landuse data are giving reasonable results, and possibly to help identify problems.

During the meetings, it also became apparent that the primary immediate application of the results from the current study will be in the region adjacent to the Delaware Estuary. Accordingly, it was agreed that we should focus on monitoring stations in the lower Basin. To this end, we have dropped from further study all monitoring stations above the fall line near Trenton; they will be replaced by a few stations, having smaller drainage areas and/or less extensive lists of pollutants monitored, from the lower Basin.

In view of the numerous changes to our original research plans, we drafted a modified scope of work and list of deliverables. After review by another meeting of Delaware Estuary Program representatives, this modified scope of work will become the basis for all further work under the current contract.

To accommodate the delays in data acquisitions and the changes in the work plan, we have asked for a no-cost contract extension until December, 1993.

WORK PLANNED

We are scheduled to meet with representatives of the Delaware Estuary Program in early July to review the modified scope of work. Once these modifications are agreed upon, we will continue work in accord with them.

REFERENCE

White, Kirk E. and Ronald A. Sloto, 1990, "Base-Flow-Frequency Characteristics of Selected Pennsylvania Streams", U.S. Geological Survey (Water-Resources Investigations Report 90-4160), Harrisburg, PA.

Delaware River Basin Nonpoint Pollution Study

Quarterly Progress Report

July through September, 1993

SUMMARY

Work continued on the basis of the "Revised Scope of Services."

Bill Greene of the Delaware Valley Regional Planning Commission informed us that, as of September 30, they did not expect to release the new land use data for the nine NJ and PA counties bordering the Estuary until early or mid November. This is too late to use these data for the current study. The planned update of State of Delaware land use has also been postponed, due to funding problems.

As an alternative, we have acquired the 1 km land use data set covering the entire U.S. which was compiled by the USGS EROS Data Center. These data will be useful for estimating the amount of each type of land use in the Delaware Basin as a whole and in the drainage areas of water quality monitoring stations. Because they are at a much coarser resolution than the mid-1970s LUDA data, however, it will be difficult to use them as a basis for determining changes in land use and projecting future land use patterns.

WORK ACCOMPLISHED

We met with Delaware Estuary Program personnel in early July to finalize the revised scope of services for the nonpoint pollution study. Our efforts are now focussed on producing the deliverables called for in the revised scope of services.

Watershed and Drainage Boundaries

The USGS 8-digit watershed boundary data were used to develop a mask for defining the boundaries of the Delaware River Basin on other data sets. As noted in our previous quarterly report, these boundaries exhibit significant discrepancies from those inferred from the USGS 100 meter digital elevation model (DEM) data using the ARC/INFO GRID software. Part of the discrepancy results from the coarse resolution (1:250000) of the maps from which the USGS compiled the watershed boundaries. In addition, however, the accuracy of the DEM data are insufficient to permit accurate delineation of watershed boundaries in regions where the divide between two watersheds is not marked by a well defined ridge.

We also used the ARC/INFO GRID software to extract stream locations from the DEM data. In areas where the terrain is nearly level, such as southern New Jersey, the software yielded numerous spurious water channels; we suspect that this reflects both limitations in DEM accuracy and an overly simplified software algorithm. In hillier regions, stream channels inferred from the DEMs were often displaced from their true location. We believe this is at least partly because segments of the narrower streams often pass between two adjacent 100-meter grid points, with the result that the DEM data sets report the elevation of points well up on the stream banks, and perhaps at the top of the vegetation canopy, rather than the lower elevation at the stream itself.

Landuse/Landcover Data

At the request of Mindy Lemoine, we generated large scale maps depicting the LUDA landuse data with superimposed major streams. Comparison of LUDA data compiled for different 1 x 2 degree map sheets showed significant discontinuities across sheet boundaries. For example, south of 40 degrees latitude in the Philadelphia suburbs the photointerpreter made extensive differentiation between the different Anderson Level 2 categories of urban and suburban landuse; north of this latitude, the (presumably different) photointerpreter tended to lump all urban and suburban land into a single urban category. Similarly, there are often discontinuities in agricultural and forest classifications across sheet boundaries. For this reason, we have collapsed the Anderson Level 2 categories into about 7 classes.

Using the USGS LUDA data and the boundaries of drainage areas for the water quality monitoring stations which we had previously derived from the 100 meter (DEM) data,. we made a preliminary tabulation of the different types of land use in the drainage area for each water quality monitoring station. For the different drainage areas, urban land use categories ranged from roughly 5% of the area to more than 60%; agricultural land uses varied from about 20% up to 65%; and forest ranged from about 10% to 70%.

As of September 30, Bill Greene of the Delaware Valley Regional Planning Commission (DVRPC) estimates that the new land use data sets for four counties in New Jersey and five counties in Pennsylvania will not be ready for release until early or mid November. Although he did not say so explicitly, I gather that the reviews of the preliminary data by the counties revealed software problems whose solution has contributed to the delay. I also learned from Mike McGreff of the Delaware Department of Agriculture that the planned update of land use for Delaware has been postponed due to lack of funding.

Accordingly, recent high-resolution land use data will not be available for any part of the Basin in time to be used in the current study. Because of the rapid urbanization of the nine counties covered by the new DVRPC data, extrapolation from the mid-1970's LUDA data on the basis of population changes will be of limited value.

As an alternative, we have acquired the new 1 km resolution land use/land cover data set for the entire U.S. which has been developed by the USGS EROS Data Center in consultation with the EPA. The primary source of information for this data set is the AVHRR imagery from the NOAA series of polar orbiting satellites, acquired during the 1989 to 1991 time period. We have been informed that geographic information from other sources was also used to aid in the interpretation of the satellite imagery.

Since the 1 km resolution of this data set is coarser than the 200 to 400 meter resolution of the LUDA data, comparison of the two data sets for individual 1 km cells will not be particularly meaningful. The 1 km data should be usable, however, for estimating the distribution of landuse types over larger regions, such as the drainage areas of monitoring stations.

Because of the incompatibility in scale between the LUDA and EDC data, we do not recommend using the latter as the basis for extrapolation of landuse patterns out to the year 2020. We believe that such extrapolations could be made with significantly greater accuracy after the DVRPC data become available.

Pollutant Loadings

We have received a copy of the final report for the Galveston Bay nonpoint pollution study and are reviewing the references therein to develop figures for nonpoint runoff to be expected from different types of landuse. In general, for any given pollutant the published estimates vary over a wide range. Within the scope of our current study, it is not possible to do the extensive data retrieval and analysis that would be needed to take into account soil properties and precipitation patterns.

As an alternative, we plan to use two or more different sets of published nonpoint loading coefficients to generate estimates of total nonpoint loadings for the drainage areas of each of the water quality monitoring stations for which we have adequate data sets, using the EDC landuse data to determine the amount of each land use type in each drainage area. These results will be compared with the (very rough) estimates of high-flow related loadings for each monitoring station; these comparisons may provide a basis for choosing between the alternative sets of loading coefficients.

We have given further thought to the determination of total nitrogen, since this is not reported explicitly for the PA DER monitoring stations. We plan to use the sum of N from NO3, NO2, and ammonia as an estimate of total N; data for organic nitrogen are not available. In most cases, NO3 contributes substantially more than 90% of total N, so we expect errors from this method to be small compared to other error sources.

We have also considered trying to adjust the pollutant concentrations measured under high flow conditions to take into account reservoir release and precipitation events. Because sediment resuspension is likely to account for a large proportion of total loadings under high flow conditions, and in the absence of good models to adjust for this resuspension and also to model the dependence of pollutant flushing on time of year and on the time since the last previous major precipitation event, we have concluded that the substantial effort needed to assemble adequate precipitation and reservoir release data can be better spent on searching the literature for landuse-related nonpoint loading data.

We have reviewed a number of additional water quality monitoring stations in New Jersey which were initially screened out because metals were not measured regularly. Unfortunately, these stations in general report only six measurements per year, so we have decided to continue to focus on the previously selected stations at which monthly measurements were made.

WORK PLANNED

We plan to complete development and generation of the items listed under "Deliverables" in the Revised Scope of Services, with one exception. As mentioned above, we do not believe that trying to project land use patterns to 2020 on the basis of the 1 km EDC land use data is worthwhile.

As an alternative, we will look into the feasibility of creating a map, using grid cells which are 2 km or larger in size, showing roughly how land use has changed between the mid-1970s LUDA data and the 1990 EDC data. The usefulness of this map will depend, in part, on the extent to which the EDC land use categories are consistent with the LUDA categories.

We plan to complete a draft final report by the end of November, 1993.