ENVIRONMENTAL STUDIES
IN THE VICINITY OF THE
SUSQUEHANNA STEAM ELECTRIC STATION

2008
WATER QUALITY
BENTHIC MACROINVERTEBRATES
FISHES

Prepared by

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2008 ANNUAL REPORT

Enclosed is a copy of "Environmental Studies in the Vicinity of the Susquehanna Steam Electric Station, 2008 Water Quality, Benthic Macroinvertebrates, and Fishes" prepared by Ecology III, Inc. for PPL Susquehanna, LLC. The purpose of this report was to assess the environmental impact of the Susquehanna Steam Electric Station on the Susquehanna River water quality, benthic macroinvertebrates, and relative abundance of fishes. This was done by evaluating 2008 results and by comparing preoperational and operational data.

If you have any questions regarding this report, please contact us.

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INTRODUCTION

PPL Susquehanna, LLC (PPL) contracted Ecology III, Inc. to conduct nonradiological monitoring of the Susquehanna River in the vicinity of the Susquehanna Steam Electric Station (Susquehanna SES) in 2008. The Susquehanna SES is a nuclear power station with two boiling water reactors, each with a net electrical generating capacity of approximately 1,230 megawatts. It is located on a 2,355-acre site in Salem Township, Luzerne County, 5 miles northeast of Berwick, Pennsylvania. Approximately 716 acres of mostly undeveloped and recreational lands owned by PPL are located on the east side of the Susquehanna River in Conyngham and Hollenback Townships. PPL owns 90 percent of the station and the Allegheny Electric Cooperative, Inc. owns 10 percent.

The objective of the nonradiological environmental monitoring program is to assess the impact of operating the Susquehanna SES on the Susquehanna River water quality and relative abundance of fishes. This was accomplished in 2008 by comparing data at control and indicator stations and by evaluating results of preoperational (1971-1982) and operational (1983-2008) studies (Ichthyological Associates 1972, Ichthyological Associates, Inc. 1973-1985, Ecology III, Inc. 1986-2008). In addition, benthic macroinvertebrate samples were collected in 2008. Monitoring was done at sites within a control station (SSES) upriver from the Susquehanna SES river intake structure and indicator station (Bell Bend) downriver from the discharge diffuser.

To more objectively assess the impact of operating the Susquehanna SES on the Susquehanna River, a statistical procedure called BACI (Before-After:Control-Impact) analysis was applied to preoperational and operational fishes monitoring data.

This report presents results of water quality, benthic macroinvertebrate, and fishes studies.

WATER QUALITY

PROCEDURES

Water quality of the Susquehanna River relative to operation of the Susquehanna SES was monitored throughout 2008 at four locations (Table 1, Fig. 1). Susquehanna River water samples were collected quarterly at SSES (control) and Bell Bend (indicator). In addition, water samples were also collected quarterly from the cooling tower blowdown of the Susquehanna SES. River flow and temperature were monitored continuously at the Environmental Laboratory (Table 2).

Most of the water sample parameters were analyzed by the Chemical Laboratory at the PPL System Facilities Center, Hazleton, Pennsylvania. This laboratory has state accreditation with the Pennsylvania Department of Environmental Protection (PADEP, 2006), identified as Lab #40-00568 (www.dep.state.pa.us). Water temperature and dissolved oxygen were measured by Ecology III personnel and river level was recorded with the SSES data (Table 2). PPL Susquehanna, LLC personnel provided data for Susquehanna River water withdrawal and blowdown discharge.

RESULTS AND DISCUSSION

River Flow, River Water Withdrawal, and River Temperature

In 2008, Susquehanna River flow was above the 47-year average for January, February, March, and December, and below average for the remaining months (Fig. 2). The annual precipitation data at Avoca, PA (about 30 miles upriver from the Susquehanna

SES) was 43.25 inches. This was the ninth highest annual total on record since 1951 (www.erh.noaa.gov/bgm/climate/avp.shtml, accessed 19 and 25 February 2009).

Daily mean river flow ranged from 897 to 124,000 cubic feet per second (cfs; Table 3). March had the second highest monthly mean flow in the past 48 years. Luzerne County was under a drought watch issued by PADEP from 6 August 2007 to 11 January 2008 (www.srbc.net/hydrologic/drought_center.htm link: Pennsylvania Department of Environmental Protection Drought Center, accessed 2 March 2009). Cumulatively, an estimated 519 billion cubic feet of water flowed through this section of the Susquehanna River during 2008 (Fig. 3). This was the 17th highest flow in the last 48 years.

Susquehanna SES river water withdrawal of river flow ranged from 0.03% on 9 and 10 March to 8.33% on 27 September (Fig. 4). Daily river water withdrawal of the plant was ≤2% of river flow for two-thirds of 2008. River water withdrawal equaled or exceeded 4% of river flow on 55 days last year.

River temperature was monitored throughout the year. The hourly minimum river temperature of 0.4 C occurred nine times in 2008 in the months of January, February and December. The hourly maximum river temperature of 30.1 C occurred at 1400 h on 21 July. Daily mean river temperature ranged from 0.5 C on numerous days in January, February and December to 28.3 C on 20 and 21 July (Table 4). April had the warmest monthly mean river temperature on record since 1974 and September was the third warmest in 35 years. River temperature was above average every month except March, May, November and December.

River Water Quality at the Susquehanna SES

Control and indicator data were compared to PADEP water quality criteria (2008; Table 5). The parameters with published water quality criteria include alkalinity, ammonia nitrogen, chloride, dissolved oxygen, fluoride, total and dissolved iron, manganese, nitrogen (nitrate), pH, sulfate, temperature and total dissolved solids. In 2008, Susquehanna River water met the published criteria at both the control and indicator sampling sites (Table 6). The total iron concentration for the October sample exceeded 1.5 mg/L because the sample was collected during an elevated river flow following an extended period of low flow. This did not technically violate the criterion at this concentration because it is based on a 30-day average. Still, this relatively high iron concentration is reflective of the legacy of anthracite coal mining upstream from the power plant in the Wyoming Valley and Mocanaqua regions.

Overall, the water quality of this section of the Susquehanna River continues to improve. There have been significant decreases over time in certain indicators of abandoned mine discharge such as total iron and sulfate concentrations (Table 7, Fig. 5), and Ecology III, Inc. has long reported the biotic recovery in the river associated with these improvements.

Blowdown

Blowdown is river water used in the nuclear power plant cooling cycle that is discharged back to the river. It has elevated conductivity and dissolved solids concentrations because of evaporative loss from the cooling towers (9,700-27,900

gallons/minute during 2008 operation). In 2008, the daily average blowdown discharge rate to the river ranged from 3,680-12,000 gallons/minute.

Control and Indicator Site Comparisons

Control and indicator water quality data were similar on most of the sampling dates during 2008 (Table 6). The dilutive effect of high river flow tends to equalize values at the control and indicator sites. Slightly higher values of total mineral solids (TMS) at the indicator site are possibly due in part to the elevated concentrations of solids in the blowdown. Most of the water taken from the river for plant operation is evaporated in the cooling process and the remaining cooling water returned to the river subsequently contains concentrated mineral solids. This is evident when TMS values of the blowdown are compared to the control and indicator TMS results (Tables 8 and 9). It has been previously demonstrated that TMS concentrations at SSES are the best predictor of TMS concentrations at Bell Bend at most river flows. In addition, it has been confirmed that if operation of the Susquehanna SES is to influence the water quality at the indicator site, then the probability of that occurring should be greatest at low river flows (Ecology III, Inc. 2008).

Conclusion

Susquehanna River flow exceeded the 47-year average during four months in 2008 and was below average for the remaining months. The maximum river water withdrawal of river flow by Susquehanna SES was 8.3% on 27 September. On most days during 2008,

however, river water withdrawal was ≤2% of river flow. Exceptionally warm river temperatures were recorded for April and September.

Water quality data demonstrated that river samples met the published criteria for 13 common parameters. Overall, water quality of this section of the Susquehanna River continues to improve.

Our data analyses demonstrate that effects of the operation of Susquehanna SES on water quality of the Susquehanna River will likely occur at the lowest range of river flows. This is reasonable because the dilutive power of the river against plant discharge would then be minimized. For a variable such as TMS, this is further amplified because low river flows naturally increase TMS concentrations of the river water *before* it enters Susquehanna SES, resulting in some of the most concentrated discharge occurring during these periods.

BENTHIC MACROINVERTEBRATES

PROCEDURES

Benthic macroinvertebrates were collected from the Susquehanna River in June. Ecology III scuba divers collected two samples at each of two sampling sites, a control site (SSES I) upriver from the intake of Susquehanna SES and at an indicator site (Bell Bend IV) downriver from the intake (Fig. 1). Both of these sites correspond to historic benthos sampling locations in the river that were last routinely sampled by Ecology III in 1994 (Ecology III, Inc. 1995).

The sampling methodology followed the procedures used previously for macroinvertebrates. A dome suction sampler was lowered from a boat to the river bottom and was positioned by a diver in an undisturbed area of river substrate. The diver vacuumed the substrate inside the dome for five minutes and the organisms and sediments drawn from the dome were collected in a 216-micron mesh net. The net was removed from the dome, returned to the boat, and then a new net was attached to the dome and the entire procedure was repeated in a different area.

Samples were returned to the laboratory and the organisms and sediments in the nets were washed into tubs using tap water. Excess water was poured off through an 841-micron mesh sieve and the samples were placed in one-gallon plastic jugs and fixed with 100% isopropanol. All four samples were transported to Normandeau Associates, Inc. where the organisms in the samples were separated into orders and subsequently identified to genus. The density of organisms per square meter was estimated by

multiplying the organisms in each taxon by 6.13, the conversion factor for the 0.163 m^2 dome.

RESULTS AND DISCUSSION

The overall densities and proportions of organisms in the 2008 samples generally approximated those previously measured in the Susquehanna River (Tables 10 through 13; Ecology III, Inc. 1995, 2007). Overall, the density of organisms at SSES was higher than densities reported at that site since 1990 (Table 14). This was due largely to greater numbers of Trichopterans in the genera *Cheumatopsyche*, *Hydropsyche*, and *Macrostemum*, Coleopterans in the genera *Optioservus* and *Stenelmis*, and Dipterans of the genus *Chironomidae*. Oligochaetes comprised 24% of one of the samples taken at the Bell Bend site. Also at Bell Bend since 1990, a greater density of Crustaceans was observed due to Amphipods, as were Dipterans because of the numbers of Chironomids. Coleopterans comprised the greatest proportion of macroinvertebrates collected at SSES, while Dipterans were the largest proportion at Bell Bend (Table 15).

Another noteworthy finding in 2008 was the relative paucity of Asian clams (*Corbicula* spp.) in the benthos samples. In 2007, Asian clams were collected in all four dome samples that were taken; *Corbicula* spp. comprised almost 18% of the organisms collected in one dome at Bell Bend. In the 2008 samples, however, Asian clams were collected in only one of the domes at Bell Bend and at low numbers. This volatility in Asian clam density between sites and years continues to suggest that the vicinity of Susquehanna SES still approximates a northern edge of this biofouling mollusk in the Susquehanna River.

FISHES

PROCEDURES

Electrofishing

Electrofishing samples were collected once each month in May, June, July, August and October in 2008. Sampling was done at four sites, and each site was approximately 1,100-yards long and parallel to the river shoreline. These sites have been consistently sampled by boat electrofishing since 1976. Two sites were located upriver from the Susquehanna SES river intake structure along each bank of the river, and two sites were downriver from the intake (referred to as SSES and Bell Bend locations, respectively; Table 16, Fig. 1).

The 18-foot electrofishing boat was outfitted with a 5-KW generator (direct current). Electrical output was controlled by a variable-voltage pulsator, with a target of 5-6 amps delivered to the water.

During sampling the boat was driven downstream parallel to the shoreline, usually within 30 feet of the riverbank. For both safety purposes and sampling efficiency electrofishing was done at river levels less than 493.1 feet above mean sea level (msl; equivalent to 10.1 feet) as measured at the Environmental Laboratory. Sampling was done in the evening and began about one hour after sunset. Two observers stood in the bow of the boat and identified and counted fish during each sample. Data were recorded using a cassette tape recorder.

Seining

Shoreline fishes were collected by seine during June and August. Sampling was done when river levels were less than 490.2 feet above msl (equivalent to 7.2 feet at the Environmental Lab). Similar to the electrofishing sampling sites, two shoreline seine sites were above the Susquehanna SES river intake structure and two were below (Table 16, Fig. 1). High water interrupted seining at the SSES sites in October.

To seine, one end of the 25-foot bag seine (0.25-inch mesh) was kept stationary on the riverbank while the other end was extended about 20 feet into the river or as far as depth of the water allowed. The seine was then pulled upriver and onto shore. Two hauls were made in the same location at each site and the catches from both hauls were combined and considered one unit of effort. Captured fish were placed in 10% formalin in the field and returned to the laboratory. After at least two weeks in the formalin, the fish were rinsed with water, identified, and enumerated before final preservation in 40% isopropyl alcohol.

Statistical Analysis

A statistical analysis known as the Before-After:Control-Impact (BACI), was applied to the electrofishing (1976-2008) and seining data (1978-2008; Ecology III, Inc. 1990). Twenty species or categories of fish were analyzed from the electrofishing data, as were 12 species from the seining data. These species or groups were chosen based on their abundance during the years before Susquehanna SES operation.

Two different electrofishing data sets were analyzed. The first set included all months sampled by electrofishing through the years, and is referred to as the All Data set.

The second set, named the Summer Data set, included only the months from June through October to reflect the reduced monitoring effort in place since1986. The seining data set analyzed by the BACI represents all of the months sampled by this method through the years.

RESULTS AND DISCUSSION

Electrofishing

Electrofishing at the SSES and Bell Bend locations in 2008 resulted in the observation of 2,377 fish of 19 species (Tables 17 through 19). The total numbers of fish collected above and below the SSES intake and discharge for the year were generally similar. Differences in monthly totals between upriver vs. downriver sites ranged from as few as 63 fish in July to as many as 81 fish in August. Comparatively, the range of monthly sample sizes (maxima minus minima) between the east and west banks was 33 fish at SSES and 35 at Bell Bend. Maximum monthly sample sizes occurred during October at SSES (380) and August at Bell Bend (373).

Smallmouth bass was the most abundant species overall observed at SSES and Bell Bend in 2008 (28% and 29% of the totals, respectively). Smallmouth bass and walleye together represented 44% of the fish observed at SSES and 52% of those at Bell Bend. Smallmouth bass was also the most abundant species during most months at both SSES and Bell Bend, with the exception of northern hog sucker in August at SSES and walleye in August and October at Bell Bend.

Seventeen species were observed at SSES as were 19 at Bell Bend. Species richness in monthly samples ranged from 12 to 13 at SSES and 10 to 15 at Bell Bend. Sucker and sunfish species dominated richness in all months during 2008.

Seining

Seining at the SSES and Bell Bend locations in 2008 resulted in the capture of 2,618 fish of 14 species (Tables 17 and 20). Spotfin shiner was the most abundant species captured at both SSES and Bell Bend, representing 33% and 80% of the total collections, respectively. Spotfin shiner, spottail shiner, and white sucker comprised 74% of the fishes collected at SSES and 98% of those collected at Bell Bend.

Similar to previous years, the number of fishes captured at SSES was a fraction (44%) of those collected at Bell Bend. This disparity between the upriver and downriver locations was most evident during the August sample when over five times as many fish were captured at Bell Bend. This may reflect increasing habitat differences between the sites. For example, the SSES location on the west bank of the river has had increasing amounts of emergent vegetation. Thick vegetation during certain water levels at this site sometimes presents an obstacle that can affect seining efficiency. Moreover, this location is also the deepest of the four sites.

Thirteen species were collected at SSES and 9 species were captured at Bell Bend. At both stations, species in the minnow and sunfish families predominated.

BACI Results: Electrofishing

Of the 20 species or categories of fish that were tested with the BACI analysis, nine species from the All Data set and eight species from the Summer Data set showed significant differences in the numbers of fishes above versus below the power plant discharge ($P \leq 0.05$, Table 21). Species in the All Data set that indicated decreases in abundance below the power plant discharge included quillback, white sucker, northern hog sucker, shorthead redhorse, muskellunge, rock bass, smallmouth bass, and unidentified fish. Brown bullhead was also significantly different; however, its numbers significantly increased at Bell Bend compared to the upriver sites. The Summer Data set demonstrated decline or increase in all of the same species except white sucker.

BACI Results: Seining

The results of the 12 seined species tested by BACI analysis indicated that spotfin shiner was marginally significant ($P=0.086$). The point estimates for this species indicate that more spotfins were collected at the downriver sites vs. upriver.

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Table 1

Descriptions of water quality sampling sites in the vicinity of the Susquehanna SES, 2008.

SITE	LOCATION
Susquehanna SES Environmental Laboratory	West bank of the Susquehanna River: 1,620 feet (ft) upriver from the Susquehanna SES intake structure, sensors for river depth and temperature are located on river bottom within 100 ft of the bank
SSES (control)	Susquehanna River: 750 ft upriver from the center of the Susquehanna SES intake structure, 130 ft from the west bank
Blowdown	Since November 1996: Susquehanna SES Cooling Tower Blowdown Discharge Line 2S7 automatic composite sampler (ACS) about 750 feet downstream from the cooling tower basin, 0.1 air miles NNE from the stand-by gas treatment vent at 44200/N34117 (PA Grid System) December 1990-October 1996: 6S7 ACS at the Susquehanna SES sewage treatment plant about 2,880 feet downstream from the cooling tower basin
Bell Bend (indicator)	Susquehanna River: 2,260 ft downriver from the Susquehanna SES discharge diffuser, 130 ft from the west bank

Table 2

Water quality parameters and methods of analyses utilized by the Susquehanna SES Environmental Laboratory, 2008.

PARAMETER	METHOD	REFERENCE [a]
River depth (ft)	Seven-day continuous recording from an Acco Bristol, Model No. G500-15 bubbler-type water level gauge.	ACCO (1971)
River level (ft above msl)	$Level = Depth + 482.96$	Soya (1991)
River flow (cfs)	Insert river level into the appropriate regression equation. At level <486.0 ft, $\log flow = -0.0525(level)^2 + 51.478501(level) - 12612.85672$ At level ≥486.0 ft, $flow = 319.96989(level)^2 - 3093316.24395(level) + 74753300$	Soya (1991)
Temperature (°F)	Constant monitor of river temperature: Seven-day continuous recording from a Yokogawa AX 102-1-2 temperature recorder.	Omega (2001) Yokogawa (2003)
(°C)	River and blowdown temperature of samples collected: Calibrated, mercury-filled thermometer. Method 2550 B. Convert Fahrenheit to Celsius for tabulation: $^{\circ}C = (^{\circ}F - 32) \div 1.8$ or $\frac{^{\circ}C}{^{\circ}F - 32} = 5/9$	APHA (1995) [b] Internet site
Dissolved oxygen (mg/L)	Membrane electrode. Method 4500-O G.	APHA (1995)

[a] Listed in references cited.
[b] http://mathforum.org/library/drmath/view/58393.html. Accessed: 19 February 2009.

Table 3

Daily mean flow (cfs) of the Susquehanna River at the Susquehanna SES Environmental Laboratory, 2008.

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	30000	10300	13100	40200	14400	5020	3460	5020	1940	3230	9910	6490
2	28100	19200	11900	58600	13500	5020	3230	4480	1940	3000	8470	8470
3	24600	26300	11900	66700	12300	4480	3000	4210	2140	2350	7780	12700
4	19700	28100	14900	58600	12300	4480	3000	3710	1940	1750	7450	14900
5	17200	25200	64800	51800	13500	4740	2770	3710	1570	1750	7450	13100
6	16200	35900	121000	52600	14900	4210	2770	3960	1570	1750	7120	11100
7	17200	99800	90900	47800	14000	3960	2560	4210	1940	1750	6490	10300
8	22900	120000	92000	40900	12700	3960	2560	5020	1750	1750	5880	9180
9	32600	85500	124000	35200	11900	3960	2560	4480	2140	1570	5590	7780
10	41600	63900	110000	31300	11900	3960	2140	4210	2350	1390	5300	8120
11	47000	46200	83400	27500	11500	3960	1940	3960	2140	1210	5300	10700
12	56800	32600	66700	26300	10300	3960	1940	4210	1940	1210	5300	25700
13	56000	28100	51800	26300	9910	3460	1940	4480	1940	1210	5020	40900
14	47000	29400	40900	26300	9180	3230	2560	5020	2140	1210	4740	35200
15	38000	25200	37300	24600	8470	3000	3230	5300	2140	1390	4480	26900
16	31900	23500	48500	21800	7780	3460	3000	5300	2140	1210	5020	24000
17	26900	20700	52600	18700	10700	3460	3000	4740	1750	996	9180	30600
18	22300	26300	42400	15500 [a]	11900	3460	3460	4210	1570	897	14400	33900
19	19200	50200	36600	14200	12300	3710	3460	3960	1570	897	13500	29400
20	17200	55100	56000	13100	12300	3710	3230	3460	1390	897	11100	24000
21	14400	41600	95300	12200	11900	3710	2770	3230	1570	996	9180	20200
22	13100	28800	78300	11200	11500	3710	2770	3000	1570	996	7450	17700
23	11100	22900	57700	10500	9910	4210	3460	3000	1570	1210	6800	16700
24	10300	19700	43900	10300	8820	4210	6800	2770	1390	996	6180	15300
25	10300	18700	35200	9910	8120	3960	10700	2770	1210	996	5880	19700
26	8820	17700	29400	8820	7780	3710	10300	2560	1210	1750	5590	22900
27	9180	18700	25700	8470	7120	3230	11100	2140	996	3230	6180	27500
28	9180	17200	25700	9540	7120	3230	9180	2350	1210	4740	6490	28800
29	8120	14400	37300	13100	6490	3460	6800	1940	1750	9180	6800	46200
30	8820		39500	14900	5590	3960	6490	1940	1940	11900	6490	58600
31	9180		31300		5020		6180	1940		11500		51000
MEAN	23400	36200	53900	26900	10500	3890	4270	3720	1750	2550	7220	22800

[a] Calculated 18-23 April flows using USGS data.

Table 4

Daily mean temperature (C) of the Susquehanna River at the Susquehanna SES Environmental Laboratory, 2008.

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	-- [a]	1.3	1.4	--	14.3	20.9	24.8	26.6	23.3	18.9	8.0	3.1
2	--	1.2	1.8	--	14.1	21.2	25.1	26.5	23.8	17.8	8.0	3.1
3	--	1.0	2.8	6.5	14.3	21.5	24.9	26.0	24.4	16.4	8.1	2.9
4	--	1.3	3.8	6.1	14.8	21.6	24.3	25.9	25.0	15.8	8.5	3.2
5	0.5	1.8	3.3	6.2	15.5	21.9	24.2	26.1	25.2	15.8	9.2	3.0
6	0.8	2.6	2.1	6.4	16.0	22.4	24.5	26.4	24.8	15.7	10.1	2.3
7	2.1	2.6	2.3	6.9	16.6	23.9	25.3	25.8	24.5	15.5	10.7	1.8
8	3.1	2.0	2.7	7.9	17.3	25.3	26.3	25.3	24.1	15.3	11.0	0.8
9	4.3	1.9	2.3	9.2	16.7	27.0	25.9	24.6	23.1	16.3	10.7	0.8
10	4.6	1.9	2.1	10.3	15.9	27.7	26.5	24.0	22.1	16.4	9.9	1.9
11	4.6	1.0	2.2	11.3	15.5	27.7	26.5	23.1	21.8	16.5	9.0	2.8
12	4.8	0.5	2.5	12.0	14.9	27.4	26.8	23.0	21.1	16.8	8.7	3.1
13	4.4	0.5	3.0	12.1	14.8	27.3	26.6	23.3	21.9	16.7	8.5	2.1
14	4.2	0.6	3.6	11.4	15.8	27.3	26.7	24.1	22.8	17.1	8.8	1.7
15	3.8	0.7	4.1	10.9	16.7	27.1	26.3	24.3	23.1	17.7	9.6	2.3
16	3.6	0.9	4.4	11.1	16.4	26.5	26.7	24.1	21.9	17.5	9.7	3.1
17	3.0	1.0	4.2	11.8	15.4	25.1	27.0	24.4	21.7	16.5	8.5	2.8
18	2.7	1.9	3.9	12.9	14.9	23.5	27.4	24.8	21.3	15.2	7.4	2.7
19	2.5	2.0	4.1	14.2	14.0	22.8	27.8	24.5	20.3	14.1	6.3	2.1
20	1.7	1.5	4.7	15.0	13.2	22.4	28.3	24.2	20.1	13.2	5.5	1.5
21	0.5	1.1	4.0	15.7	13.3	22.5	28.3	24.0	20.2	12.4	4.6	1.1
22	0.5	0.9	3.7	16.7	13.6	23.2	28.0	24.3	20.1	11.4	3.5	0.5
23	0.5	0.6	3.9	17.6	14.1	24.1	26.5	24.6	20.0	10.9	2.9	0.5
24	0.5	0.8	4.1	18.3	14.9	24.2	25.4	25.1	20.1	10.4	2.5	0.5
25	0.5	1.3	4.5	18.2	16.0	24.3	24.7	24.7	19.7	11.1	2.9	0.7
26	0.5	1.7	5.0	18.6	17.5	24.5	24.9	24.2	19.1	11.4	3.2	0.9
27	0.5	2.1	--	18.6	19.2	24.4	25.3	23.8	19.2	11.1	3.3	1.2
28	0.6	1.5	--	17.4	19.7	24.8	25.1	22.8	19.2	10.2	3.1	1.9
29	0.8	1.0	--	16.3	19.3	24.8	25.4	22.7	19.3	8.5	3.1	2.7
30	1.2		--	15.1	19.7	24.9	25.8	22.9	19.1	8.0	2.9	2.8
31	1.2		--		20.3		26.4	23.1		7.6		2.6
MEAN	2.1	1.4	3.3	12.7	16.0	24.4	26.1	24.5	21.7	14.1	6.9	2.0

[a] Equipment Failure

Table 5

Pennsylvania Department of Environmental Protection specific water quality criteria for the Susquehanna River in the vicinity of the Susquehanna SES, 2008.

PARAMETER	UNIT	PERIOD	CRITERIA		AVERAGE
			Minimum	Maximum	
Alkalinity as CaCO3	mg/L		20		
Ammonia Nitrogen	mg/L			4.56	
Chloride	mg/L			250	
Dissolved Oxygen	mg/L		4.0		
		Daily Average	5.0		
Fluoride	mg/L	Daily			2.0
Iron Total	mg/L	30-Day			1.5
Dissolved	mg/L			0.3	
Manganese	mg/L			1.0	
	ug/L			1000	
Nitrite plus Nitrate as N	mg/L			10	
pH			6.0	9.0	
Sulfate	mg/L			250	
Temperature	C	January 1-31		4.4	
		February 1-29		4.4	
		March 1-31		7.8	
		April 1-15		11.1	
		April 16-30		14.4	
		May 1-15		17.8	
		May 16-31		22.2	
		June 1-15		26.7	
		June 16-30		28.9	
		July 1-31		30.6	
		August 1-15		30.6	
		August 16-31		30.6	
		September 1-15		28.9	
		September16-30		25.6	
		October 1-15		22.2	
		October 16-31		18.9	
		November 1-15		14.4	
		November 16-30		10.0	
		December 1-31		5.6	
Total Dissolved Solids	mg/L	Monthly		750	500

Table 6

Water quality data collected quarterly from the Susquehanna River and the Susquehanna SES blowdown, 2008. River sites were SSES (control) and Bell Bend (indicator). Analyses were performed by the PPL Chemical Laboratory, Hazleton, PA. N.D. = Not Detected

PARAMETER	UNITS	SSES	BLOW DOWN	BELL BEND	SSES	BLOW DOWN	BELL BEND
Date		2/28/2008	2/28/2008	2/28/2008	5/22/2008	5/22/2008	5/22/2008
Time		717	557	734	712	751	708
River level	ft	491.0			489.6		
Temperature	C	1.2	12.2	1.2	12.9	16.6	12.9
Dissolved oxygen	mg/L	21.3	13.9	21.8	11.7	10.6	11.5
pH, lab		7.78	8.52	7.74	7.94	8.79	7.9
Conductivity, lab	µmho	241	617	239	256	835	258
Total alkalinity	mg/L	45	114	45	61	202	61
Phenolphthalein alkalinity	mg/L	0	4	0	0	13	0
Total suspended solids	mg/L	<4.0	33.6	5.6	7.6	57.3	6
Ammonia as N	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	N.D.
Silicon dioxide	mg/L	4.57	12.3	4.63	1.1	5.28	1.1
Bicarbonate as CaCO3	mg/L	45	106	45	61	176	61
Carbonate as CO3	mg/L	0	4.8	0	0	15.6	0
Chloride	mg/L	31.1	85.2	30.8	24.9	99.2	25.4
Fluoride	mg/L	<0.10	<0.20	<0.10	0.06	0.24	0.06
Nitrate as NO3	mg/L	3.1	9.1	3.1	1.3	6.1	1.4
Nitrate ion as N	mg/L	0.7	2.1	0.7	0.3	1.4	0.3
Phosphorus as PO4	mg/L	0.187	1.715	0.181	0.147	3.914	0.202
Sulfate	mg/L	21.2	58.7	20.6	26	90.9	26.1
Aluminum, dissolved	ug/L	N.D.	<100	N.D.	N.D.	<100	N.D.
Aluminum, total	ug/L	163	690	156	<100	736	106
Barium, total	ug/L	26	75	26	31	117	32
Calcium, dissolved	mg/L	22	57.9	21.8	24.3	83.5	24.6
Calcium, total	mg/L	22.1	58.6	21.8	24.6	86	24.9
Copper, dissolved	ug/L	<20	N.D.	N.D.	N.D.	N.D.	N.D.
Copper, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Iron, dissolved	mg/L	0.18	0.37	0.17	0.09	0.23	0.09
Iron, total	mg/L	0.66	2.21	0.66	0.62	2.8	0.62
Magnesium, dissolved	mg/L	4.6	12.1	4.54	5.74	19.2	5.94
Magnesium, total	mg/L	4.66	12.4	4.58	5.81	20	5.85
Manganese, dissolved	ug/L	82	42	77	39	26	39
Manganese, total	ug/L	85	147	82	112	353	112
Nickel, total	ug/L	N.D.	N.D.	N.D.	N.D.	<10	N.D.
Potassium, dissolved	mg/L	1.19	3.24	1.14	1.44	4.74	1.55
Potassium, total	mg/L	1.21	3.3	1.17	1.46	4.94	1.46
Silver, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sodium, dissolved	mg/L	17.2	47.5	17	14.8	56.7	15.2
Sodium, total	mg/L	17.2	47.9	17.1	14.8	57.6	14.9
Strontium, total	ug/L	81	206	80	94	337	94
Vanadium, total	ug/L	<10	<10	<10	N.D.	<10	<10
Zinc, dissolved	ug/L	<20	<20	<20	<20	<20	<20
Zinc, total	ug/L	<20	<20	<20	<20	<20	N.D.
Beryllium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cadmium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Chromium, total	ug/L	N.D.	N.D.	N.D.	N.D.	<10	N.D.
Lead, total	ug/L	N.D.	<5	N.D.	N.D.	<5	N.D.
Thallium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Arsenic, total	ug/L	<1.0	1.4	<1.0	<1.0	2.3	<1.0
Selenium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Antimony, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Total mineral solids	mg/L	132.04	354.44	130.65	136.16	486.55	137.85
Calcium hardness (C)	mg/L	54.9	144.6	54.4	60.7	208.5	61.4
Total hardness (C)	mg/L	74.4	197	73.3	85.4	297	86.3

Table 6 (cont.)

PARAMETER	UNITS	SSES	BLOW DOWN	BELL BEND	SSES	BLOW DOWN	BELL BEND
Date		8/28/2008	8/28/2008	8/28/2008	10/30/2008	10/30/2008	10/30/2008
Time		723	841	714	800	714	753
River level	ft	486.6			489.7		
Temperature	C	22.9	24	22.9	7.6	16.8	7.8
Dissolved oxygen	mg/L	8.5	8	8.3	14.6	6.9	14.6
pH, lab		7.92	8.9	7.96	7.94	8.8	7.92
Conductivity, lab	µmho	385	995	393	339	992	343
Total alkalinity	mg/L	89.5	232	88.5	83.5	220	79.1
Phenolphthalein alkalinity	mg/L	0	23.6	0	0	17.6	0
Total suspended solids	mg/L	6.8	14.6	4.8	25.3	49	24.6
Ammonia as N	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon dioxide	mg/L	1.79	5.88	1.8	1.49	4.46	1.46
Bicarbonate as CaCO3	mg/L	89.5	185	88.5	83.5	185	79.1
Carbonate as CO3	mg/L	0	28.3	0	0	21.1	0
Chloride	mg/L	39.6	123	41.3	39.8	130	39.8
Fluoride	mg/L	0.1	0.29	0.1	0.09	0.27	0.09
Nitrate as NO3	mg/L	0.9	3.3	0.9	1.4	4.9	1.4
Nitrate ion as N	mg/L	0.2	0.7	0.2	0.3	1.1	0.3
Phosphorus as PO4	mg/L	0.199	3.571	0.319	0.445	4.564	0.512
Sulfate	mg/L	43	127	44.6	21.9	104	22.4
Aluminum, dissolved	ug/L	N.D.	<100	N.D.	<100	<100	<100
Aluminum, total	ug/L	<100	232	<100	381	675	397
Barium, total	ug/L	37	99	35	44	95	44
Calcium, dissolved	mg/L	34.8	98.7	35.3	31.1	90.7	31.7
Calcium, total	mg/L	38.4	100	35.9	31.6	92.7	32.2
Copper, dissolved	ug/L	N.D.	N.D.	N.D.	<20	N.D.	N.D.
Copper, total	ug/L	N.D.	<20	N.D.	N.D.	<20	N.D.
Iron, dissolved	mg/L	0.02	0.06	<0.02	0.1	0.07	0.1
Iron, total	mg/L	0.57	1.37	0.5	2.07	4.24	2.13
Magnesium, dissolved	mg/L	9.61	26.9	9.75	6.91	24.2	7.08
Magnesium, total	mg/L	10.6	27.5	9.94	7.1	25	7.28
Manganese, dissolved	ug/L	7	9	5	29	13	26
Manganese, total	ug/L	152	368	133	276	639	281
Nickel, total	ug/L	<10	<10	N.D.	<10	<10	N.D.
Potassium, dissolved	mg/L	2.14	5.89	2.26	2.22	6.57	2.33
Potassium, total	mg/L	2.4	5.94	2.31	2.32	6.71	2.39
Silver, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sodium, dissolved	mg/L	24.8	74.3	25.4	23.1	77.6	23.9
Sodium, total	mg/L	27.2	75.1	25.5	23.2	78.5	23.8
Strontium, total	ug/L	187	470	175	100	427	103
Vanadium, total	ug/L	<10	<10	N.D.	N.D.	<10	<10
Zinc, dissolved	ug/L	<20	N.D.	<20	<20	N.D.	N.D.
Zinc, total	ug/L	N.D.	<20	<20	N.D.	<20	N.D.
Beryllium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cadmium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Chromium, total	ug/L	N.D.	<10	N.D.	N.D.	<10	N.D.
Lead, total	ug/L	N.D.	N.D.	N.D.	N.D.	<5	N.D.
Thallium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Arsenic, total	ug/L	<1.0	2.6	<1.0	1.5	3.2	1.3
Selenium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Antimony, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Total mineral solids	mg/L	210.36	604.61	214.43	178.02	574.44	177.53
Calcium hardness (C)	mg/L	86.9	246.5	88.1	77.7	226.5	79.2
Total hardness (C)	mg/L	140	363	131	108	334	110

Table 7

Total iron concentrations from the Susquehanna River at the SSES sampling site, 1975-2008. Samples were collected monthly from 1975 through 1996 and quarterly from 1997 through 2008. Analyses were performed by the PPL Chemical Laboratory, Hazleton, PA.

YEAR	NO. SAMPLES Collected	NO. SAMPLES <1.50 mg/L	% SAMPLES <1.50 mg/L	ANNUAL MEAN
1975	12	2	16.7	3.55
1976	12	3	25.0	3.08
1977	11	5	45.5	1.71
1978	12	5	41.7	1.48
1979	12	5	41.7	3.13
1980	12	5	41.7	1.74
1981	12	9	75.0	1.31
1982	12	7	58.3	2.37
1983	11	6	54.5	1.41
1984	12	4	33.3	1.71
1985	12	5	41.7	1.61
1986	12	7	58.3	1.82
1987	12	8	66.7	1.96
1988	12	7	58.3	1.28
1989	12	9	75.0	1.45
1990	12	10	83.3	1.41
1991	12	10	83.3	0.98
1992	12	12	100.0	0.92
1993	12	8	66.7	1.55
1994	11	8	72.7	1.46
1995	12	12	100.0	0.89
1996	12	9	75.0	1.42
1997	4	4	100.0	0.55
1998	4	4	100.0	0.65
1999	4	4	100.0	0.60
2000	4	4	100.0	0.70
2001	4	4	100.0	0.74
2002	4	4	100.0	0.62
2003	4	3	75.0	1.43
2004	4	3	75.0	0.94
2005	4	4	100.0	0.57
2006	4	4	100.0	0.62
2007	4	3	75.0	2.00
2008	4	3	75.0	0.98

Table 8

Comparison of total mineral solids (TMS) concentrations from the Susquehanna River and the Susquehanna SES blowdown, 2008. River sites were SSES (control) and Bell Bend (indicator).

DATE	SSES		BLOWDOWN		BELL BEND	DIFFERENCE
	Flow (cfs)	tms (mg/L)	Flow (cfs)	tms (mg/L)	tms (mg/L)	BELL BEND - SSES tms (mg/L)
28 Feb	17200	132.0	19.8	354.4	130.6	-1.4
22 May	11500	136.2	21.3	486.6	137.8	1.6
28 Aug	2350	210.4	26.5	604.6	214.4	4.0
30 Oct	11900	178.0	25.1	574.4	177.5	-0.5

Table 9

Comparison of annual average total mineral solids (TMS) concentrations from the Susquehanna River and the Susquehanna SES blowdown, 1991-2008. River sites were SSES (control) and Bell Bend (indicator).

YEAR	SSES		BLOWDOWN		BELL BEND	DIFFERENCE
	Flow (cfs)	tms (mg/L)	Flow (cfs)	tms (mg/L)	tms (mg/L)	BELL BEND - SSES tms (mg/L)
1991	12600	197.3	14.6	711.8	203.7	6.4
1992	13400	155.3	7.5	600.3	156.4	1.1
1993	23700	202.8	13.1	636.2	204.4	1.6
1994	19200	174.9	13.9	660.9	175.3	0.4
1995	10200	196.7	12.9	643.9	198.8	2.1
1996	24000	151.8	19.5	438.4	152.6	0.8
1997	6490	239.0	16.9	787.7	248.6	9.6
1998	11200	242.2	19.2	649.3	247.9	5.7
1999	9120	204.1	11.2	585.1	212.0	7.9
2000	21200	160.4	12.6	449.5	163.5	3.1
2001	7190	180.2	20.8	572.5	183.9	3.7
2002	12200	136.2	17.7	523.4	142.5	6.3
2003	26900	131.3	18.7	459.0	132.5	1.2
2004	12200	134.1	18.3	446.6	136.3	2.2
2005	13500	157.1	16.2	583.9	165.4	8.3
2006	14400	137.6	17.9	522.8	138.0	0.4
2007	20810	145.7	20.4	455.1	147.9	2.2
2008	10700	164.1	23.2	505.0	165.1	1.0
MEAN	14900	172.8	16.4	568.4	176.4	3.6

Table 10

Number, density (no/m^2), and percent total of benthic macroinvertebrates collected with a dome sampler at SSES I (replicate 1) on the Susquehanna River, June 2008.

GROUP Taxon	No.	24-Jun No./m^2	% Total
CRUSTACEA			
Amphipoda	3	18	0.1%
PLECOPTERA			
Neoperla sp.	1	6	0.0%
EPHEMEROPTERA			
Anthopotamus sp.	96	589	3.3%
Caenis sp.	36	221	1.3%
Ephoron sp.	360	2,209	12.5%
Isonychia sp.	4	25	0.1%
Leucrocuta sp.	96	589	3.3%
Stenonema sp.	4	25	0.1%
TRICHOPTERA			
Cheumatopsyche sp.	216	1,325	7.5%
Chimarra sp.	88	540	3.1%
Ithytrichia sp.	3	18	0.1%
Hydropsyche sp.	80	491	2.8%
Macrostemum sp.	152	933	5.3%
COLEOPTERA			
Dineutus sp.	7	43	0.2%
Optioservus sp.	112	687	3.9%
Stenelmis sp.	1,109	6,804	38.5%
DIPTERA			
Chironomidae	196	1,202	6.8%
MOLLUSCA			
Goniobasis sp.	1	6	0.0%
Musculium sp.	244	1,497	8.5%
Pisidium sp.	8	49	0.3%
OTHER			
Prostoma sp.	1	6	0.0%
Tricladida	60	368	2.1%
TOTAL	2,877	17,650	100.0%

Table 11

Number, density (no/m^2), and percent total of benthic macroinvertebrates collected with a dome sampler at SSES I (replicate 2) on the Susquehanna River, June 2008.

GROUP Taxon	No.	24-Jun No./m^2	% Total
OLIGOCHAETA			
Unidentified	11	67	0.2%
CRUSTACEA			
Amphipoda	15	92	0.3%
PLECOPTERA			
Acroneuria sp.	1	6	0.0%
Isoperla sp.	1	6	0.0%
Pteronarcys sp.	1	6	0.0%
EPHEMEROPTERA			
Anthopotamus sp.	256	1,571	5.7%
Baetis sp.	8	49	0.2%
Caenis sp.	16	98	0.4%
Ephoron sp.	83	509	1.9%
Isonychia sp.	24	147	0.5%
Leucrocuta sp.	112	687	2.5%
Stenonema sp.	8	49	0.2%
TRICHOPTERA			
Ceraclea sp.	32	196	0.7%
Cheumatopsyche sp.	480	2,945	10.7%
Chimarra sp.	112	687	2.5%
Protoptila sp.	32	196	0.7%
Hydropsyche sp.	320	1,963	7.1%
Macrostemum sp.	368	2,258	8.2%
Neureclipsis sp.	8	49	0.2%
COLEOPTERA			
Dineutus sp.	5	31	0.1%
Optioservus sp.	224	1,374	5.0%
Psephenus sp.	1	6	0.0%
Stenelmis sp.	1,666	10,221	37.2%
DIPTERA			
Chironomidae	384	2,356	8.6%
Simulium sp.	6	37	0.1%
MOLLUSCA			
Goniobasis sp.	2	12	0.0%
Musculium sp.	192	1,178	4.3%
Pisidium sp.	4	25	0.1%
OTHER			
Acariformes	1	6	0.0%
Prostoma sp.	3	18	0.1%
Tricladida	101	620	2.3%
TOTAL	4,477	27,466	100.0%

Table 12

Number, density (no/m^2), and percent total of benthic macroinvertebrates collected with a dome sampler at Bell Bend IV (replicate 1) on the Susquehanna River, June 2008.

GROUP Taxon	24-Jun No.	 No./m^2	 % Total
OLIGOCHAETA			
Unidentified	35	215	3.0%
CRUSTACEA			
Amphipoda	57	350	4.9%
Decapoda	7	43	0.6%
Isopoda	1	6	0.1%
PLECOPTERA			
Neoperla sp.	1	6	0.1%
EPHEMEROPTERA			
Anthopotamus sp.	120	736	10.2%
Baetis sp.	4	25	0.3%
Caenis sp.	4	25	0.3%
Ephoron sp.	7	43	0.6%
Leucrocuta sp.	28	172	2.4%
Paraleptophlebia sp.	4	25	0.3%
Stenonema sp.	24	147	2.0%
Tricorythodes sp.	21	129	1.8%
TRICHOPTERA			
Ceraclea sp.	6	37	0.5%
Cheumatopsyche sp.	48	294	4.1%
Hydropsyche sp.	4	25	0.3%
Lepidostoma sp.	1	6	0.1%
Macrostemum sp.	1	6	0.1%
Neureclipsis sp.	3	18	0.3%
COLEOPTERA			
Optioservus sp.	1	6	0.1%
Psephenus sp.	3	18	0.3%
Stenelmis sp.	115	706	9.8%
DIPTERA			
Chironomidae	450	2,761	38.3%
MOLLUSCA			
Ferrissia sp.	9	55	0.8%
Musculium sp.	192	1,178	16.4%
Physa sp.	8	49	0.7%
Pisidium sp.	4	25	0.3%
OTHER			
Alloeocoela	2	12	0.2%
Sialis sp.	9	55	0.8%
Tricladida	5	31	0.4%
TOTAL	1,174	7,202	100.0%

Table 13

Number, density (no/m^2), and percent total of benthic macroinvertebrates collected with a dome sampler at Bell Bend IV (replicate 2) on the Susquehanna River, June 2008.

GROUP		24-Jun	
Taxon	No.	No./m2	% Total
OLIGOCHAETA			
Unidentified	480	2,945	24.0%
CRUSTACEA			
Amphipoda	204	1,252	10.2%
PLECOPTERA			
Neoperla sp.	2	12	0.1%
EPHEMEROPTERA			
Anthopotamus sp.	160	982	8.0%
Caenis sp.	8	49	0.4%
Ephoron sp.	23	141	1.1%
Leucrocuta sp.	32	196	1.6%
Stenonema sp.	8	49	0.4%
TRICHOPTERA			
Cheumatopsyche sp.	5	31	0.2%
Lepidostoma sp.	1	6	0.0%
Neureclipsis sp.	2	12	0.1%
COLEOPTERA			
Dineutus sp.	4	25	0.2%
Stenelmis sp.	124	761	6.2%
DIPTERA			
Chironomidae	744	4,564	37.1%
MOLLUSCA			
Ferrissia sp.	2	12	0.1%
Corbicula sp.	4	25	0.2%
Musculium sp.	168	1,031	8.4%
Pisidium sp.	8	49	0.4%
OTHER			
Alloeocoela	10	61	0.5%
Sialis sp.	6	37	0.3%
Tricladida	9	55	0.4%
TOTAL	2,004	12,294	100.0%

Table 14

Comparative densities of organisms/m^2 in dome samples collected from the Susquehanna River at SSES I and Bell Bend IV from 1990-1994 and 2007-2008. The 2008 data used for this comparison represented the dome sample at each site from the greatest overall density (minus Oligochaetes).

SSES I

Taxon	1990	1991	1992	1993	1994	2007	2008
Crustacea	6	25	0	12	6	583	92
Plecoptera	110	104	0	43	6	86	18
Ephemeroptera	2384	4359	570	5595	589	3209	3110
Trichoptera	1661	2322	1771	3083	785	883	8294
Coleoptera	1067	2029	1231	785	840	3472	11632
Diptera	993	552	392	361	110	644	2393
Mollusca	503	160	754	0	18	1521	1215
Other	48	6	42	24	24	1196	644
Total	6772	9557	4760	9903	2378	11594	27398

Bell Bend IV

Taxon	1990	1991	1992	1993	1994	2007	2008
Crustacea	0	0	0	12	6	607	1252
Plecoptera	49	0	0	6	18	12	12
Ephemeroptera	925	2526	301	2066	324	2841	1417
Trichoptera	208	447	196	110	428	295	49
Coleoptera	1006	601	257	337	214	1416	786
Diptera	687	643	325	1398	404	1301	4564
Mollusca	441	275	220	49	79	3601	1117
Other	55	30	24	61	18	281	153
Total	3371	4522	1323	4039	1491	10354	9350

Table 15

Comparative proportions of organisms in dome samples collected from the Susquehanna River at SSES I and Bell Bend IV from 1990-1994 and 2007-2008. The 2008 data used for this comparison represented proportions of the dome sample at each site with the greatest overall density (minus Oligochaetes).

SSES I

Taxon	1990	1991	1992	1993	1994	2007	2008
Crustacea	0.1	0.3	0.0	0.1	0.3	5.0	0.3
Plecoptera	1.6	1.1	0.0	0.4	0.3	0.7	0.1
Ephemeroptera	35.2	45.6	12.0	56.5	24.8	27.7	11.4
Trichoptera	24.5	24.3	37.2	31.1	33.0	7.6	30.3
Coleoptera	15.8	21.2	25.9	7.9	35.3	29.9	42.5
Diptera	14.7	5.8	8.2	3.6	4.6	5.6	8.7
Mollusca	7.4	1.7	15.8	0.0	0.8	13.1	4.4
Other	0.7	0.1	0.9	0.2	1.0	10.3	2.4
Total	100	100	100	100	100	100	100

Bell Bend IV

Taxon	1990	1991	1992	1993	1994	2007	2008
Crustacea	0.0	0.0	0.0	0.3	0.4	5.9	13.4
Plecoptera	1.5	0.0	0.0	0.1	1.2	0.1	0.1
Ephemeroptera	27.4	55.9	22.8	51.2	21.7	27.4	15.2
Trichoptera	6.2	9.9	14.8	2.7	28.7	2.8	0.5
Coleoptera	29.8	13.3	19.4	8.3	14.4	13.7	8.4
Diptera	20.4	14.2	24.6	34.6	27.1	12.6	48.8
Mollusca	13.1	6.1	16.6	1.2	5.3	34.8	11.9
Other	1.6	0.7	1.8	1.5	1.2	2.7	1.6
Total	100	100	100	100	100	100	100

Table 16

Descriptions of electrofishing (EL) and seining (SN) sites at SSES and Bell Bend on the Susquehanna River, 2008.

SITE	LOCATION
	SSES (Control)
EL-1	East bank, 426 feet upriver from gas-line crossing to 1,082 feet upriver from a point opposite the center of the Susquehanna SES intake structure
EL-2	West bank from gas-line crossing to a point 820 feet upriver from the center of the Susquehanna SES intake structure
SN-1	East bank, 1,837 feet upriver from a point opposite the center of the Susquehanna SES intake structure (33 feet upriver from the mouth of Little Wapwallopen Creek)
SN-2	West bank, 1,312 feet upriver from the center of the Susquehanna SES intake structure (328 feet downriver from the boat dock at the Susquehanna SES Environmental Laboratory)
	BELL BEND (Indicator)
EL-3	East bank, 1,279 feet downriver from a point opposite the Susquehanna SES intake structure to a point 1,640 feet upriver from the mouth of Wapwallopen Creek
EL-4	West bank, 1,246 feet downriver from the Susquehanna SES intake structure (558 feet downriver from the discharge diffuser) to a point near the southeastern boundary of PPL's Wetlands Nature Area
SN-3	East bank, 8,528 feet (1.6 miles) downriver from a point opposite the Susquehanna SES intake structure, at the launching ramp of the Berwick Boat Club
SN-4	West bank, 4,264 feet (0.8 miles) downriver from the Susquehanna SES intake structure, near the southeastern boundary of PPL's Wetlands Nature Area

Table 17

Fish species that were observed while electrofishing or collected by seining at SSES and Bell Bend on the Susquehanna River, 2008. Names of fishes and order of listing conform to Nelson et al. (2004).

COMMON NAME	SCIENTIFIC NAME
Carps and Minnows	Cyprinidae
Spotfin shiner	*Cyprinella spiloptera*
Common carp	*Cyprinus carpio*
Cutlips minnow	*Exoglossum maxillungua*
Golden shiner	*Notemigonus crysoleucas*
Spottail shiner	*Notropis hudsonius*
Bluntnose minnow	*Pimephales notatus*
Fallfish	*Semotilus corporalis*
Suckers	Catostomidae
Quillback	*Carpiodes cyprinus*
White sucker	*Catostomus commersonii*
Northern hog sucker	*Hypentelium nigricans*
Shorthead redhorse	*Moxostoma macrolepidotum*
North American Catfishes	Ictaluridae
Yellow bullhead	*Ameiurus natalis*
Channel catfish	*Ictalurus punctatus*
Pikes	Esocidae
Northern pike	*Esox lucius*
Muskellunge	*Esox masquinongy*
Sunfishes	Centrarchidae
Rock bass	*Ambloplites rupestris*
Redbreast sunfish	*Lepomis auritus*
Green sunfish	*Lepomis cyanellus*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Smallmouth bass	*Micropterus dolomieu*
White crappie	*Pomoxis annularis*
Perches	Percidae
Tessellated darter	*Etheostoma olmstedi*
Banded darter	*Etheostoma zonale*
Yellow perch	*Perca flavescens*
Walleye	*Sander vitreus*

Table 18

Number, mean, and percent total of fish observed while electrofishing at SSES on the Susquehanna River, 2008.

SPECIES	19 May				27 Jun				31 Jul				28 Aug				8 Oct				OVERALL	
	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	Mean	% Total
Common carp	2	0	1.0	1.9	3	2	2.5	3.1	3	3	3.0	2.9	3	4	3.5	2.4	5	1	3.0	1.6	2.6	2.3
Fallfish	1	1	1.0	1.9	0	1	0.5	0.6	0	0	0.0	0.0	0	9	4.5	3.1	0	1	0.5	0.3	1.3	1.1
Quillback	3	2	2.5	4.9	8	1	4.5	5.5	7	3	5.0	4.8	11	0	5.5	3.8	45	2	23.5	12.4	8.2	7.2
White sucker	1	1	1.0	1.9	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0.2	0.2
Northern hog sucker	6	0	3.0	5.8	6	8	7.0	8.6	15	6	10.5	10.1	17	57	37.0	25.3	13	68	40.5	21.3	19.6	17.1
Shorthead redhorse	7	3	5.0	9.7	4	2	3.0	3.7	2	1	1.5	1.4	3	4	3.5	2.4	5	4	4.5	2.4	3.5	3.1
Sucker spp.	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.5	0.5	0	0	0.0	0.0	0	0	0.0	0.0	0.1	0.1
Channel catfish	0	2	1.0	1.9	2	0	1.0	1.2	1	6	3.5	3.4	4	0	2.0	1.4	14	4	9.0	4.7	3.3	2.9
Northern pike	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.5	0.3	0.1	0.1
Muskellunge	1	0	0.5	1.0	1	0	0.5	0.6	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0.2	0.2
Pike spp.	0	0	0.0	0.0	0	0	0.0	0.0	1	0	0.5	0.5	0	0	0.0	0.0	0	0	0.0	0.0	0.1	0.1
Rock bass	1	6	3.5	6.8	9	19	14.0	17.2	5	6	5.5	5.3	11	21	16.0	11.0	9	11	10.0	5.3	9.8	8.6
Redbreast sunfish	0	0	0.0	0.0	0	0	0.0	0.0	2	0	1.0	1.0	0	0	0.0	0.0	0	0	0.0	0.0	0.2	0.2
Green sunfish	0	0	0.0	0.0	1	0	0.5	0.6	2	1	1.5	1.4	1	2	1.5	1.0	0	0	0.0	0.0	0.7	0.6
Pumpkinseed	0	0	0.0	0.0	0	0	0.0	0.0	1	0	0.5	0.5	1	0	0.5	0.3	1	0	0.5	0.3	0.3	0.3
Bluegill	0	0	0.0	0.0	1	0	0.5	0.6	1	0	0.5	0.5	1	1	1.0	0.7	0	1	0.5	0.3	0.5	0.4
Smallmouth bass	13	16	14.5	28.2	45	11	28.0	34.4	54	37	45.5	44.0	45	9	27.0	18.5	52	42	47.0	24.7	32.4	28.3
Sunfish spp.	0	0	0.0	0.0	2	4	3.0	3.7	0	2	1.0	1.0	3	3	3.0	2.1	0	1	0.5	0.3	1.5	1.3
Yellow perch	0	3	1.5	2.9	2	1	1.5	1.8	0	1	0.5	0.5	5	0	2.5	1.7	4	5	4.5	2.4	2.1	1.8
Walleye	9	9	9.0	17.5	6	6	6.0	7.4	9	17	13.0	12.6	19	26	22.5	15.4	48	33	40.5	21.3	18.2	15.9
Fish (unidentified)	8	8	8.0	15.5	8	10	9.0	11.0	12	8	10.0	9.7	22	10	16.0	11.0	6	4	5.0	2.6	9.6	8.4
TOTAL	52	51	51.5		98	65	81.5		115	92	103.5		146	146	146.0		202	178	190.0		114.5	

Table 19

Number, mean, and percent total of fish observed while electrofishing at Bell Bend on the Susquehanna River, 2008.

SPECIES	19 May				27 Jun				31 Jul				28 Aug				8 Oct				OVERALL	
	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	Mean	% Total
Common carp	3	5	4.0	4.6	1	1	1.0	2.0	2	5	3.5	2.6	2	1	1.5	0.8	2	8	5.0	3.2	3.0	2.4
Golden shiner	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.5	0.3	0.1	0.1
Fallfish	2	2	2.0	2.3	0	0	0.0	0.0	0	3	1.5	1.1	1	1	1.0	0.5	1	0	0.5	0.3	1.0	0.8
Quillback	4	3	3.5	4.0	0	4	2.0	4.0	4	1	2.5	1.9	2	0	1.0	0.5	9	2	5.5	3.5	2.9	2.4
White sucker	0	2	1.0	1.1	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0.2	0.2
Northern hog sucker	1	6	3.5	4.0	11	0	5.5	11.1	6	5	5.5	4.1	32	6	19.0	10.2	23	23	23.0	14.6	11.3	9.2
Shorthead redhorse	0	0	0.0	0.0	0	0	0.0	0.0	1	2	1.5	1.1	0	1	0.5	0.3	1	1	1.0	0.6	0.6	0.5
Sucker spp.	0	0	0.0	0.0	0	1	0.5	1.0	0	0	0.0	0.0	0	2	1.0	0.5	0	0	0.0	0.0	0.3	0.2
Channel catfish	0	0	0.0	0.0	3	0	1.5	3.0	3	6	4.5	3.3	2	3	2.5	1.3	0	1	0.5	0.3	1.8	1.5
Northern pike	0	1	0.5	0.6	0	0	0.0	0.0	1	0	0.5	0.4	0	1	0.5	0.3	0	0	0.0	0.0	0.3	0.2
Muskellunge	1	0	0.5	0.6	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0.1	0.1
Pike spp.	1	1	1.0	1.1	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.5	0.3	0.3	0.2
Rock bass	7	4	5.5	6.3	7	4	5.5	11.1	4	1	2.5	1.9	23	16	19.5	10.5	18	21	19.5	12.4	10.5	8.5
Redbreast sunfish	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.5	0.4	0	1	0.5	0.3	0	0	0.0	0.0	0.2	0.2
Green sunfish	0	0	0.0	0.0	0	0	0.0	0.0	0	3	1.5	1.1	1	11	6.0	3.2	0	0	0.0	0.0	1.5	1.2
Pumpkinseed	0	0	0.0	0.0	1	0	0.5	1.0	1	2	1.5	1.1	4	1	2.5	1.3	0	0	0.0	0.0	0.9	0.7
Bluegill	0	0	0.0	0.0	0	0	0.0	0.0	2	7	4.5	3.3	8	11	9.5	5.1	1	0	0.5	0.3	2.9	2.4
Smallmouth bass	36	23	29.5	33.7	15	10	12.5	25.3	88	46	67.0	49.6	32	37	34.5	18.5	22	49	35.5	22.5	35.8	29.1
White crappie	0	0	0.0	0.0	1	0	0.5	1.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0.1	0.1
Sunfish spp.	1	1	1.0	1.1	0	3	1.5	3.0	7	14	10.5	7.8	6	14	10.0	5.4	0	1	0.5	0.3	4.7	3.8
Yellow perch	0	2	1.0	1.1	14	0	7.0	14.1	3	4	3.5	2.6	11	8	9.5	5.1	12	7	9.5	6.0	6.1	5.0
Walleye	22	20	21.0	24.0	5	5	5.0	10.1	11	15	13.0	9.6	53	62	57.5	30.8	43	49	46.0	29.2	28.5	23.1
Fish (unidentified)	12	15	13.5	15.4	9	4	6.5	13.1	11	11	11.0	8.1	11	9	10.0	5.4	9	10	9.5	6.0	10.1	8.2
TOTAL	90	85	87.5		67	32	49.5		144	126	135.0		188	185	186.5		141	174	157.5		123.2	

Table 20

Number, mean, and percent total of fish captured by seining at SSES and Bell Bend on the Susquehanna River, 2008.

SPECIES	5 Jun				26 Aug				OVERALL	
	East	West	Mean	% Total	East	West	Mean	% Total	Mean	% Total
SSES										
Spotfin shiner	205	24	114.5	40.5	33	3	18.0	15.0	66.3	32.9
Cutlips minnow	1	0	0.5	0.2	0	0	0.0	0.0	0.3	0.1
Spottail shiner	9	60	34.5	12.2	0	4	2.0	1.7	18.3	9.1
Bluntnose minnow	2	0	1.0	0.4	21	6	13.5	11.3	7.3	3.6
Fallfish	0	0	0.0	0.0	3	0	1.5	1.3	0.8	0.4
White sucker	65	193	129.0	45.7	0	0	0.0	0.0	64.5	32.0
Yellow bullhead	0	0	0.0	0.0	1	0	0.5	0.4	0.3	0.1
Pike spp.	0	2	1.0	0.4	0	0	0.0	0.0	0.5	0.2
Rock bass	0	1	0.5	0.2	36	8	22.0	18.3	11.3	5.6
Green sunfish	0	0	0.0	0.0	23	12	17.5	14.6	8.8	4.3
Bluegill	0	0	0.0	0.0	19	48	33.5	27.9	16.8	8.3
Smallmouth bass	0	1	0.5	0.2	0	1	0.5	0.4	0.5	0.2
Tessellated darter	2	0	1.0	0.4	7	12	9.5	7.9	5.3	2.6
Banded darter	0	0	0.0	0.0	3	0	1.5	1.3	0.8	0.4
TOTAL	284	281	282.5		146	94	120.0		201.3	
BELL BEND										
Spotfin shiner	11	227	119.0	43.6	1165	56	610.5	96.4	364.8	80.5
Spottail shiner	6	27	16.5	6.0	6	13	9.5	1.5	13.0	2.9
Bluntnose minnow	2	3	2.5	0.9	3	2	2.5	0.4	2.5	0.6
White sucker	112	153	132.5	48.5	0	0	0.0	0.0	66.3	14.6
Rock bass	0	0	0.0	0.0	4	1	2.5	0.4	1.3	0.3
Green sunfish	0	0	0.0	0.0	1	0	0.5	0.1	0.3	0.1
Bluegill	0	0	0.0	0.0	2	4	3.0	0.5	1.5	0.3
Tessellated darter	2	1	1.5	0.5	0	9	4.5	0.7	3.0	0.7
Walleye	2	0	1.0	0.4	0	1	0.5	0.1	0.8	0.2
TOTAL	135	411	273.0		1181	86	633.5		453.3	

Table 21

P-values for fish species deemed significant by the BACI analysis, 1976-2008 ($\alpha = 0.05$). Columns depict the p-values associated with the two temporal categories of data analyzed; All Data represents all months sampled, Summer Data denotes samples collected from June through October, *ns* indicates that a species was not significant in that data set.

SPECIES	ALL DATA	SUMMER DATA
Quillback	0.012	0.003
White sucker	0.031	*ns*
Northern hog sucker	0.002	0.020
Shorthead redhorse	<0.001	<0.001
Brown bullhead*	0.005	0.046
Muskellunge	<0.001	0.003
Rock bass	0.002	0.009
Smallmouth bass	0.047	0.002
Unidentified fish	0.015	<0.001

*Brown bullhead numbers increased at Bell Bend relative to those collected at SSES.

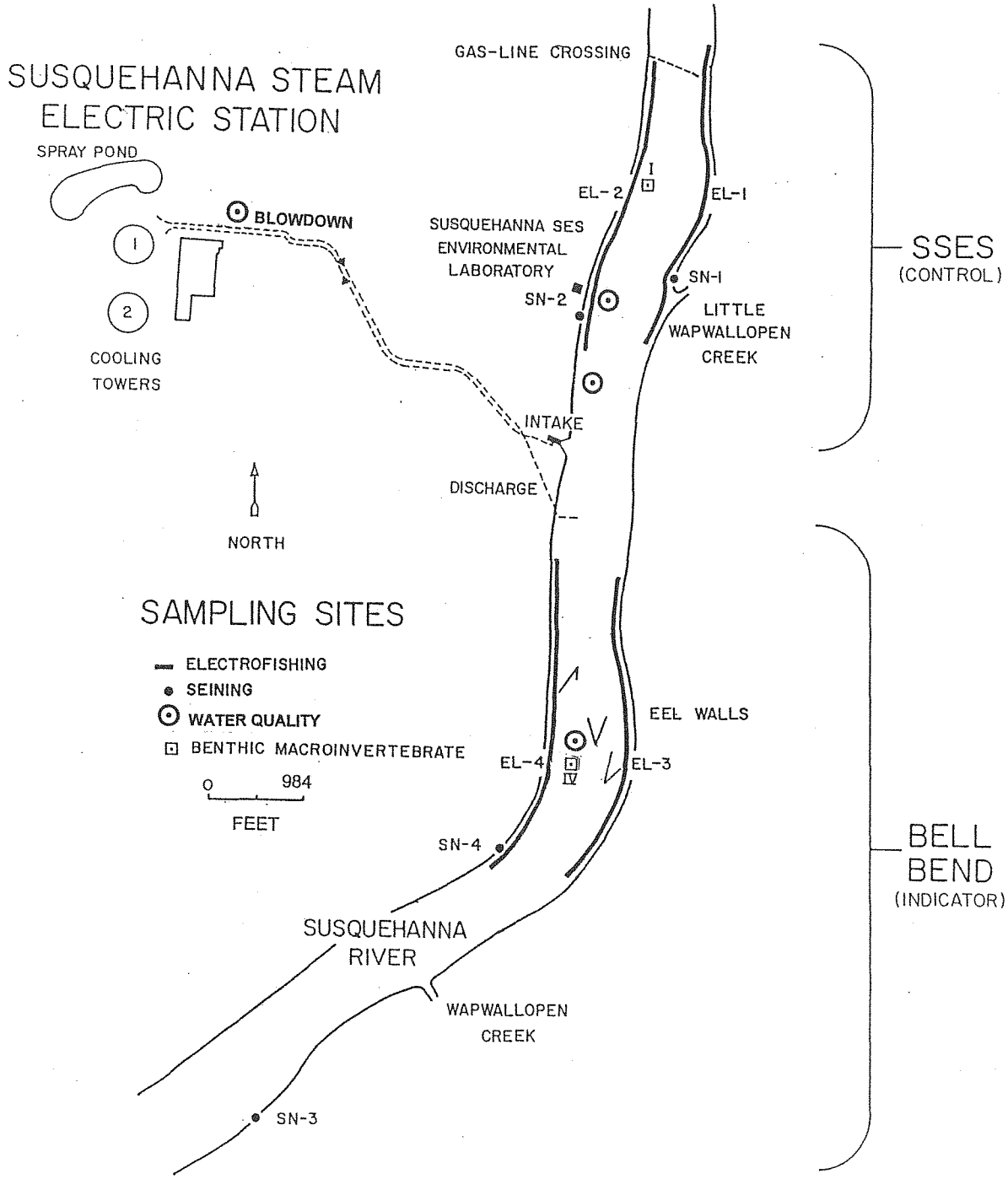

Fig. 1

Sampling sites for water quality, benthic macroinvertebrates, electrofishing (EL), and seining (SN) at SSES and Bell Bend on the Susquehanna River, 2008.

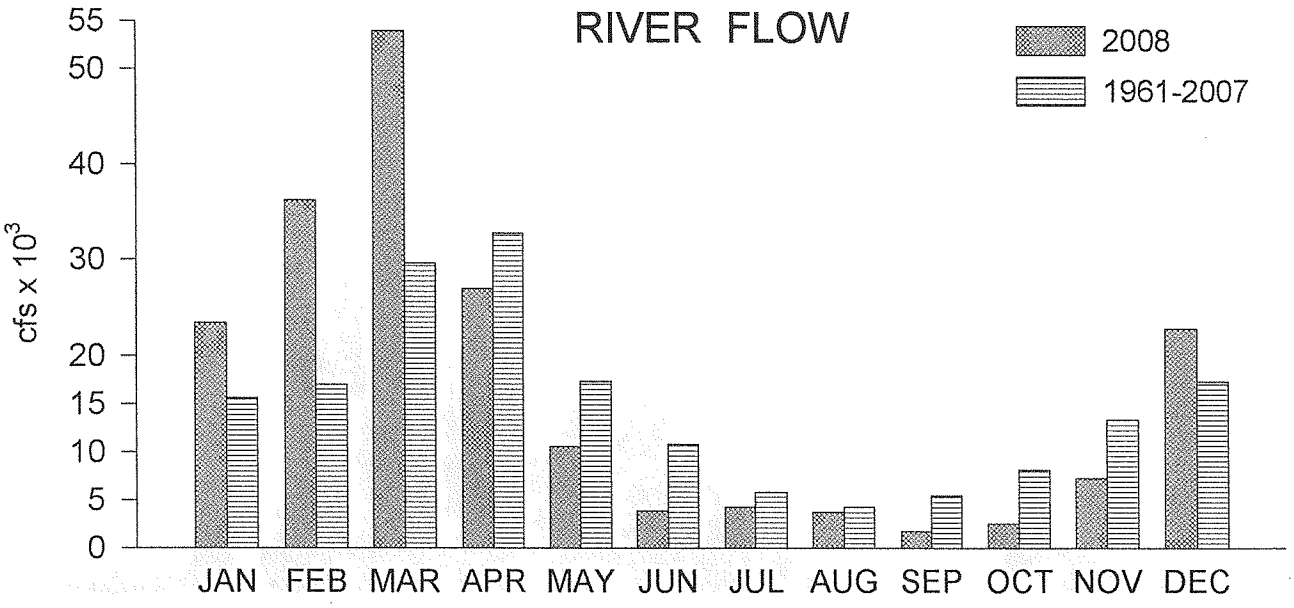

Fig. 2

The 2008 monthly mean flow of the Susquehanna River at the Susquehanna SES Environmental Laboratory compared to the 47-year (1961-2007) mean. The means were calculated from U.S. Geological Survey and Environmental Laboratory data.

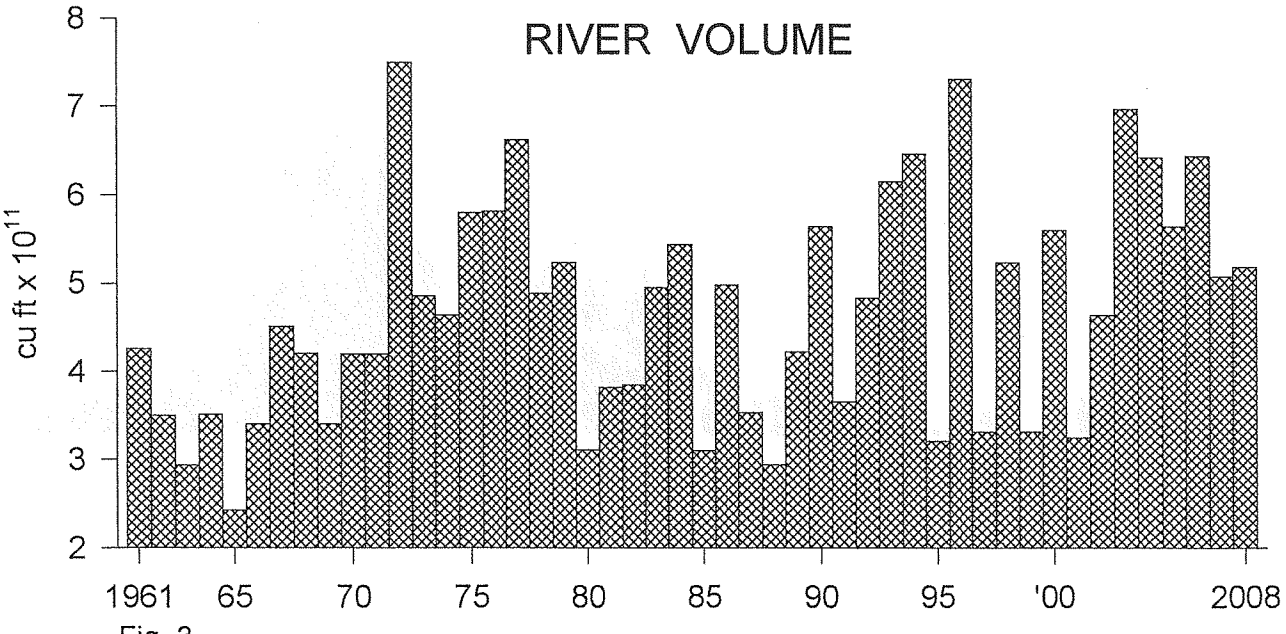

Fig. 3

Volume of Susquehanna River flow at the Susquehanna SES Environmental Laboratory, 1961-2008. The volumes were calculated from U.S. Geological Survey and Environmental Laboratory data.

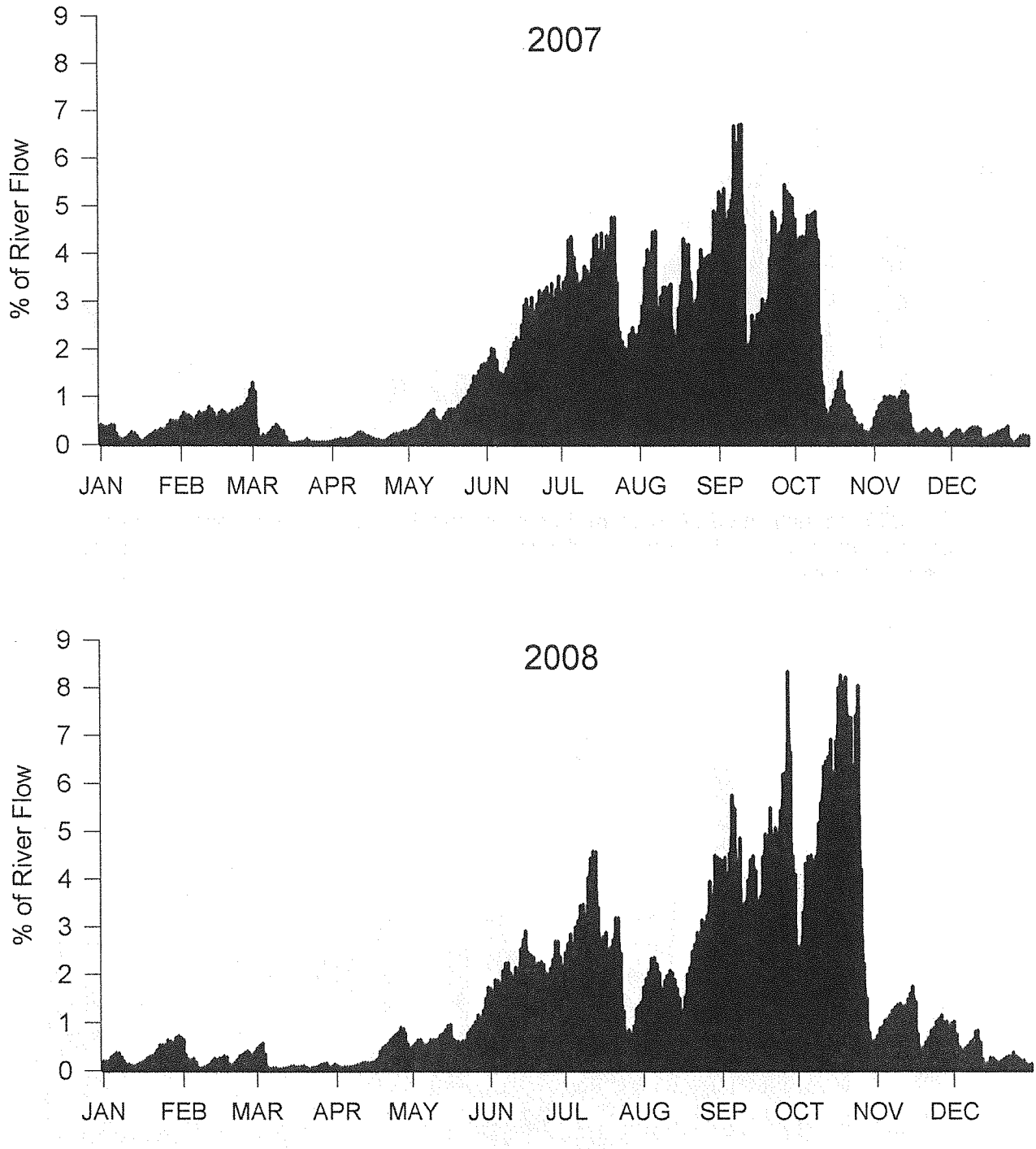

Fig. 4

Daily Susquehanna River water withdrawal by Susquehanna SES, 2007-2008.

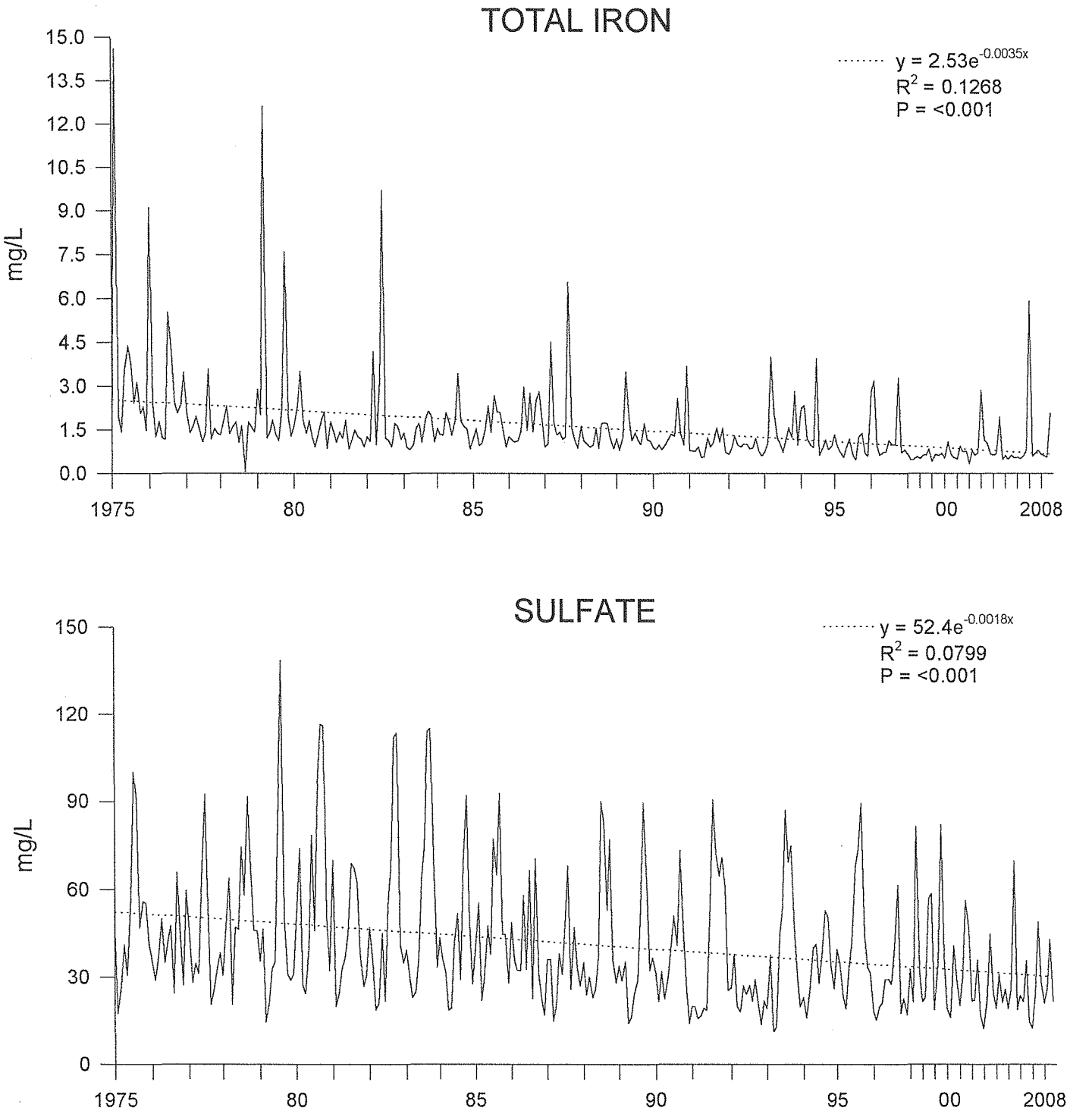

Fig. 5

Total iron and sulfate of the Susquehanna River at the SSES sampling site, 1975-2008. Samples were collected monthly 1975-1996 and quarterly 1997-2008. Analyses were performed by the PPL Chemical Laboratory, Hazleton, PA.