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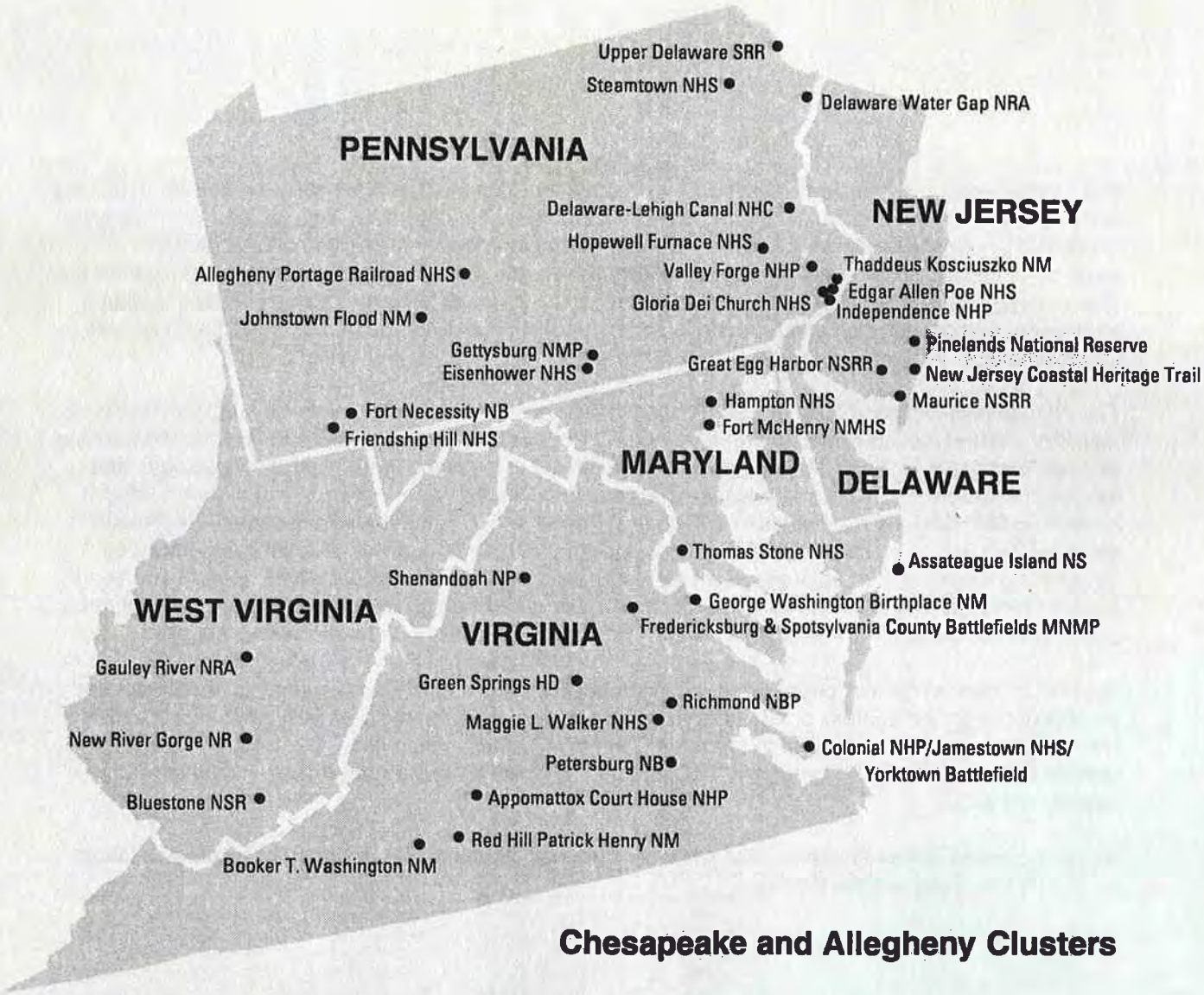

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A LEVEL I WATER QUALITY SURVEY OF FORT NECESSITY NATIONAL BATTLEFIELD, BRADDOCK'S GRAVE, AND JUMONVILLE GLEN

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TABLE OF CONTENTS

Section — Page Number

List of Figures v

List of Tables vii

Summary ix

Introduction 1

Sampling and Analytical Protocols 3

- Water Quality Parameters 4
- Sampling Strategy 4
- Sample Collection 8
- Analytical Procedures 8

Data Management and Archiving 11

Principle Investigators 13

Results and Discussion 15

- Fort Necessity (Main Unit) 15
- Braddock's Grave 15
- Jumonville Glen 33
- Relationship of Stream Discharge to Inorganic Water Quality Parameters 33
- Comparison to Pennsylvania Dept. of Environmental Protection Water Quality Criteria for High Quality Cold-Water Fisheries 35

Conclusion 41

Literature Cited 43

LIST OF FIGURES

Figure Page Number

Figure 1. Water quality survey station locations Fort Necessity National Battlefield 5

Figure 2. Water quality survey station locations..... 6

Figure 3. The relationship between alkalinity and discharge for all streams surveyed 36

Figure 4. The relationship between conductivity and discharge for all streams surveyed 37

Figure 5. The relationship between pH and discharge for all streams surveyed 38

Figure 6. The relationship between iron and discharge for all streams surveyed 39

Figure 7. The relationship between aluminum and discharge for all streams surveyed 40

LIST OF TABLES

Table Page Number

Table 1. Locations of water quality sampling stations in Fort Necessity, Braddock's Grave, and Jumonville Glen 3

Table 2. Water sampling timetable for selected parameters, FONE I Water Quality Survey 7

Table 3. Analytical methods employed in water quality analysis at Fort Necessity, Braddock's Grave, and Jumonville Glen sites 9

Table 4. Water quality parameters at station 1, unnamed tributary to Great Meadow Run 16

Table 5. Water quality parameters at station 2, unnamed tributary from ponds 17

Table 6. Water quality parameters at station 3, unnamed left fork tributary to Great Meadow Run 18

Table 7. Water quality parameters at station 4, unnamed tributary to Scott's Run at road culvert 19

Table 8. Water quality parameters at station 5, unnamed tributary to Scott's Run 20

Table 9. Water quality parameters at station 6, Indian Run above confluence with Great Meadow Run 21

Table 10. Water quality parameters at station 7, Great Meadow Run above confluence with Indian Run 22

Table 11. Water quality parameters at station 8, Great Meadow Run above stone bridge 23

Table 12. Water quality parameters at station 9, Great Meadow Run above confluence with tributary 24

Table 13. Water quality parameters at station 12, unnamed tributary to Scott's Run 25

Table 14. Water quality parameters at station 13, spring at head of Pond 1..... 26

Table 15. Water quality parameters at P1 (station 14), Pond 1 27

Table 16. Water quality parameters at P2 (station 15), Pond 2 28

Table 17. Water quality parameters at P3 (station 16), Pond 3 29

Table 18. Water quality parameters at P4 (station 17), Pond 4 30

Table 19. Water quality parameters at P5 (station 18), Pond 5 31

Table 20. Water quality parameters at station 10, Braddock's Run 32

Table 21. Water quality parameters at station 11, unnamed tributary to Dunbar Creek 34

Table 22. Selected water quality criteria for a HQ-CWF 35

SUMMARY

A Level I Water Quality Survey was conducted during calendar year 1999 on perennial and intermittent streams and small impoundments located at Fort Necessity National Battlefield (Main Unit) and two subunits, Braddock's Grave and Jumonville Glen (Fayette Co., PA). Streams were sampled seasonally at low and high flow periods while the impoundments were sampled seasonally. A total of 14 parameters – temperature, discharge (streams), total alkalinity, pH, specific conductance, dissolved oxygen, total iron, total aluminum, fecal coliforms, cadmium, chromium, copper, lead, and zinc were sampled routinely or at least once at each site over the course of this study. In addition, nutrients (nitrogen and phosphorus) were sampled once each year in the impoundments.

The behavior of water quality parameters analyzed in this yearlong survey of the three FONE National Park Units can best be explained as the result of the interaction of ambient precipitation, geology, atmospheric deposition of acids, and wildlife activity. In the streams, water quality parameters varied with flow. Most streams are episodically acidified to some degree. One stream, located in the Jumonville Glen Unit is chronically acidified. There is no evidence of pollution from development activities in the Park Units, mining activity, or point source discharges.

INTRODUCTION

The Fort Necessity National Battlefield and nearby units, Braddock's Grave and Jumonville Glen are located on Chestnut Ridge in Fayette County, Pennsylvania. Fort Necessity National Battlefield, the main unit, comprises 852 acres. Of these, 263 are fallow pasture, 517 deciduous forest, and 86 mostly non-native coniferous forest. Within its confines are 2 first-order streams, 1 second-order stream, and a number of intermittent watercourses. The northeast slope is drained by 3 perennial tributaries of the Youghiogheny River – Indian Run (order 1), Great Meadow Run (order 2), and an unnamed first-order tributary of Great Meadow run. In addition, a series of 5 impoundments ranging from 0.25 to 0.50 acres (maximum depth of 4 feet) fed by springs are drained by an intermittent stream emanating from the lowermost basin. This unnamed watercourse joins the unnamed tributary of Great Meadow Run approximately ¼ mile above its confluence with Great Meadow Run. The southwest slope on the Monongahela River watershed is drained by 3 intermittent unnamed tributaries of Scott's Run. Riparian vegetation consists largely of mixed mesophytic forest except for Indian Run and Great Meadow Run in the vicinity of Fort Necessity which are maintained as open meadow.

The Braddock's Grave and Jumonville Glen units comprising 24 and 26 acres respectively are largely forested and undeveloped. Braddock's Run, a first-order perennial headwater of Big Sandy Creek on the Monongahela watershed drains this unit, while an unnamed intermittent tributary of Dunbar Creek on the Youghiogheny River drainage is located within the boundaries of Jumonville Glen.

All streams are designated "High Quality Cold-Water Fisheries" (HQ-CWF) by the Pennsylvania Department of Environmental Protection (Pennsylvania Code, Title 25, Environmental Protection, 1996). Waters so designated must be suitable for the "maintenance and/or propagation of fish species including the family Salmonidae and additional flora and fauna which are indigenous to cold water habitat." As " special protection waters" (HQ designation) they fall into the category of "a stream or watershed which has excellent quality waters and environmental or other features that require special water quality protection".

In order to prepare a Level I Water Quality Inventory Plan (NPS-75) for the three units, existing water quality data was identified, short and long-term threats to water quality assessed, and a field survey of aquatic resources conducted. All steps were taken in conjunction with input from Connie Ranson of the National Park Service based at Fort Necessity. The field survey was undertaken on 19 and 22 May, 1998 in order to establish sampling stations and analyze for selected water quality parameters – pH, total alkalinity, specific conductance, and total iron. Site selection for The Level I Water Quality Inventory Plan was based on this initial survey. Water quality data is presented in Table 1 of the submitted document entitled, " Preliminary proposal: water quality survey of the Fort Necessity National Battlefield and associated units – Braddock's Grave and Jumonville Glen" (Kimmel, 1998).

Pre-existing water quality data on the parks and environs has been compiled and published by the NPS as Technical Report NPS/NRWRD/NRTR-97/131 dated July 1997and entitled, "Baseline water quality data, inventory and analysis, Fort Necessity National Battlefield". However, this compendium contains data from only one station within the Fort Necessity National Battlefield confines taken during a single sampling on 21 Aug., 1977 (p. 323). No data exists here for the Braddock's Grave or Jumonville Glen units nor for streams which flow into Park boundaries.

SAMPLING AND ANALYTICAL PROTOCOLS

Locations of Sampling Stations

Since most of the aquatic resources are located within park boundaries, outside threats to existing water quality are minimal except for development and possibly atmospheric deposition of acids. Southwestern Pennsylvania receives some of the most acidic precipitation in the United States. Locations of sampling stations are presented in Table 1 and Figures 1 and 2 and were selected to provide a comprehensive overview of selected water quality parameters at each of the 3 units. At Fort Necessity, Great Meadow Run and the unnamed tributary to Great Meadow Run arise outside of Park boundaries. Stations 8 and 9 within the Park were established to evaluate the effects of facilities development on water quality. The headwaters of Braddock's Run and the unnamed tributary to Dunbar Creek at the Braddock's Grave and Jumonville Glen units respectively also lie outside of Park boundaries on forested slopes and could be impacted by development.

Table 1. Locations of water quality sampling stations in Fort Necessity, Braddock's Grave, and Jumonville Glen.

Station	Location
1	unnamed tributary to Great Meadow Run (left fork facing upstream) above confluence of tributary from ponds (Lat: 39/48/36.33 Long: 79/34/55.30)
2	unnamed tributary from ponds above the confluence with left fork tributary to Great Meadow Run (Lat: 39/48/36.45 Long: 79/34/52.57)
3	unnamed left fork tributary to Great Meadow Run, 300 ft. Below confluence with tributary from ponds (Lat: 39/48/39.81 Long: 79/34/52.57)
4	unnamed tributary to Scott's Run at road culvert (Lat: 39/48/28.63 Long: 79/35/57.05)
5	unnamed tributary to Scott's Run (Lat: 39/48/38.19 Long: 79/35/59.94)
6	Indian Run above confluence with Great Meadow Run (Lat: 39/48/52.85 Long: 79/35/22.89)
7	Great Meadow Run above confluence with Indian Run (Lat: 39/48/54.46 Long: 79/35/22.57)
8	Great Meadow Run above stone bridge (Lat: 39/48/52.60 Long: 79/35/12.46)

9	Great Meadow Run above confluence with tributary along Rte. 40 (Lat: 39/48/51.11 Long: 79/34/57.70)
10	Braddock's Run (Lat: 39/49/58.93 Long: 79/36/04.76)
11	Unnamed tributary to Dunbar Creek at Jumonville Glen (Lat: 39/52/45.50 Long: 79/38/08.93)
P1	Pond (Lat: 39/48/32.85 Long: 79/35/16.96)
P2	Pond (Lat: 39/48/32.97 Long: 79/35/15.51)
P3	Pond (Lat: 39/48/34.59 Long: 79/35/13.91)
P4	Pond (Lat: 39/48/34.40 Long: 79/35/12.41)
P5	Pond (Lat: 39/48/34.47 Long: 79/35/17.60)
12	Unnamed tributary to Scott's Run (Lat: 39/48/01.67 Long: 79/33/55.45)
13	Spring at head of P1 (Lat: 39/48/32.73 Long 79/35/16.96)

Water Quality Parameters

Water quality parameters assessed in this survey included temperature, discharge, total alkalinity, pH, specific conductance, dissolved oxygen, total iron, total aluminum, nitrite nitrogen, nitrate nitrogen, total phosphorus, fecal coliforms, cadmium, chromium, copper, lead, and zinc. The first six are standard for a Level I Inventory. Iron was selected based on results from the preliminary field survey that showed the presence of this metal in all of the ponds and 8 of the 13 stream stations. Aluminum was added since it is a common element in Pennsylvania forest soils and can be leached into watercourses during acid runoff events. The combination of low pH and elevated aluminum concentrations can be toxic to aquatic life in the poorly buffered streams located at higher elevations in Pennsylvania. Nutrients, fecal coliforms, and the remaining metals were requested by the NPS.

Sampling Strategy

A comprehensive survey of selected water quality parameters was conducted during the 1999 calendar year at all 3 units. Because of the variation of significant water quality parameters (e.g. pH, total alkalinity, aluminum, and conductivity) with flow in streams subject to acid deposition, a seasonal sampling program directed toward high and low flow periods and maximum and minimum values was instituted in the perennial streams (Table 2). The intermittent streams were sampled seasonally along with a spring high flow aluminum determination. Total iron was also sampled seasonally since it can also

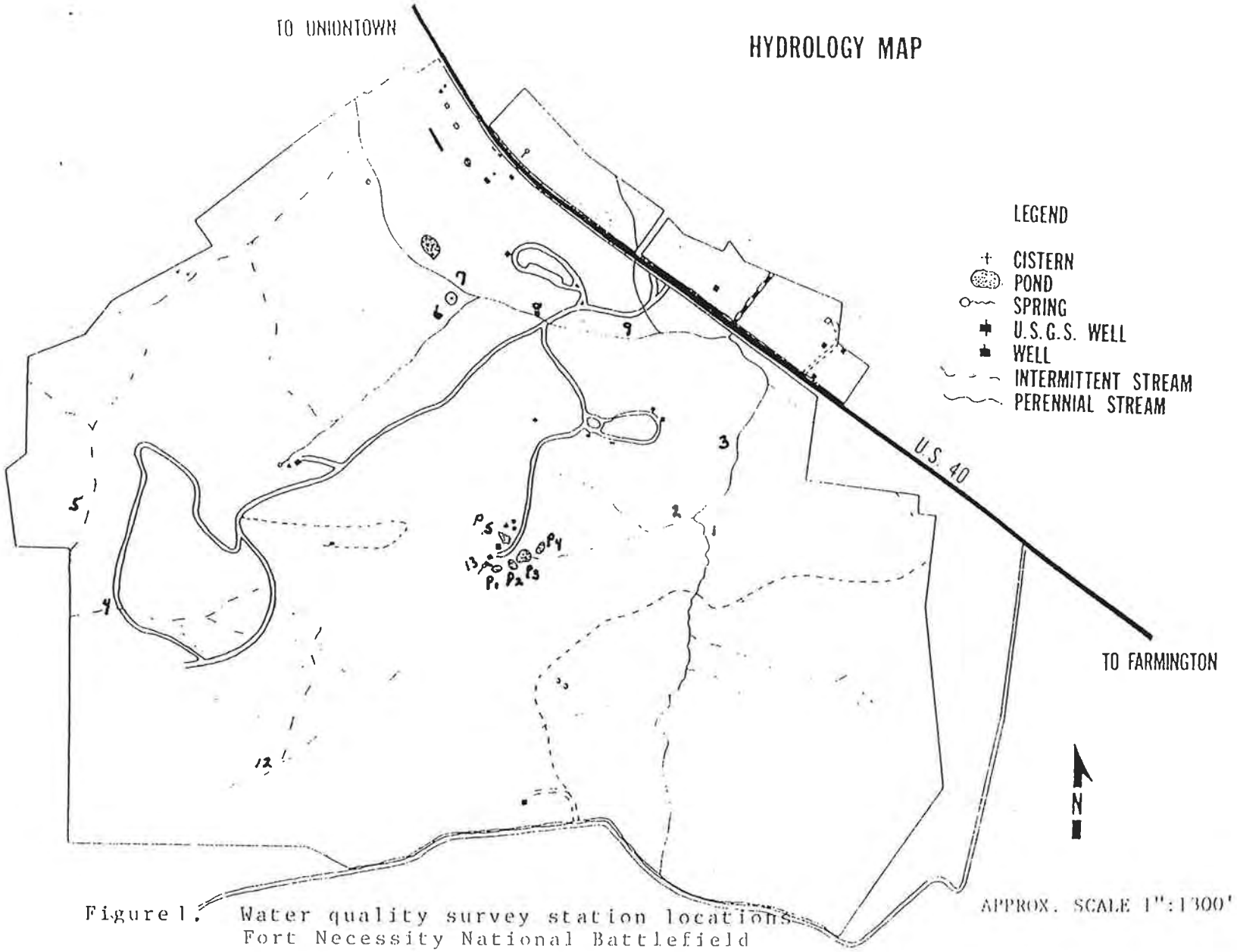

Figure 1. Water quality survey station locations
Fort Necessity National Battlefield

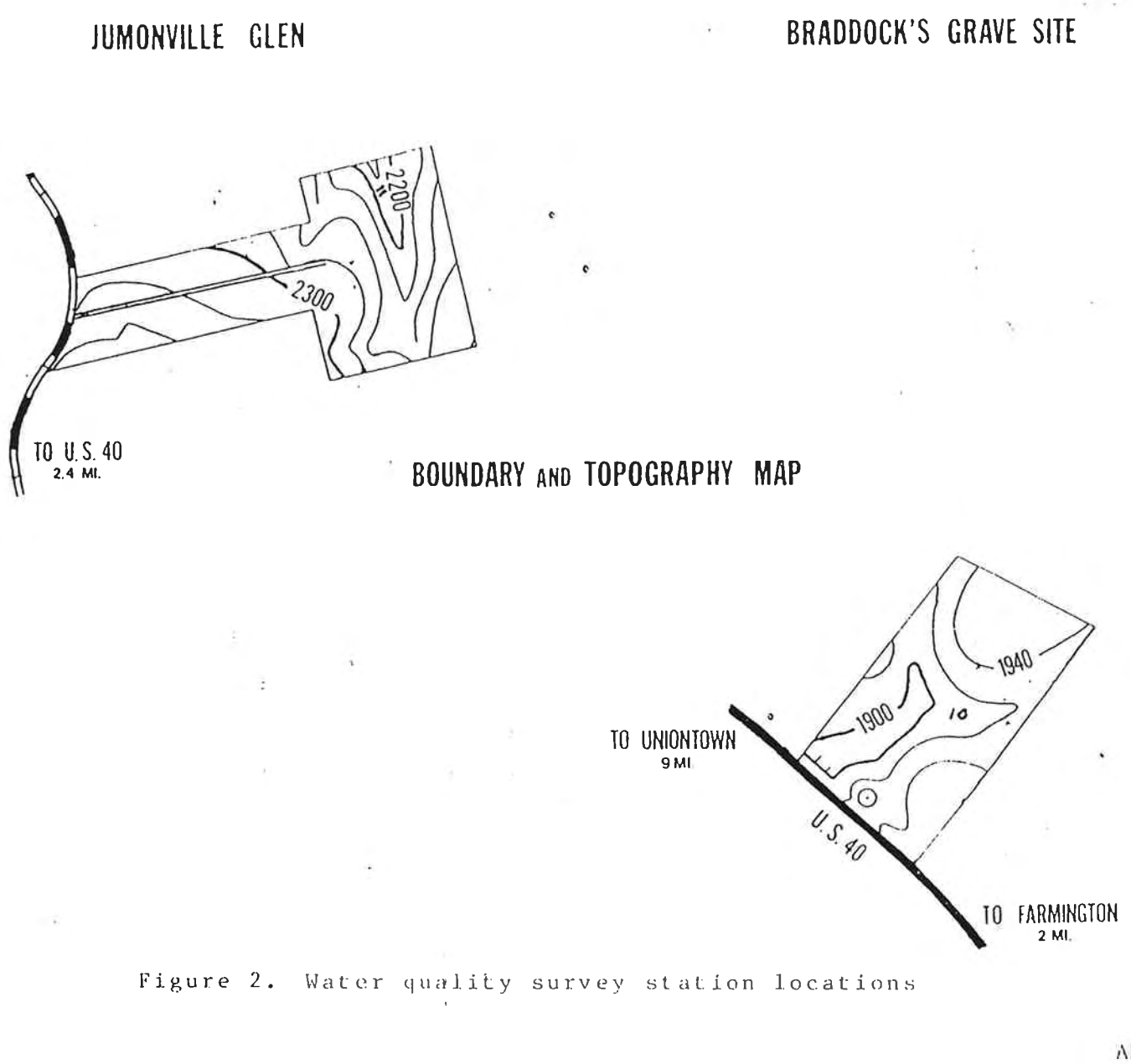

Figure 2. Water quality survey station locations

vary with stream discharge. Dissolved oxygen was sampled in the perennial streams only, spring, summer, and fall, and seasonally in all ponds (Table 2).

Table 2. Water sampling timetable for selected parameters, FONE Level I Water Quality Survey.

Station	pH	Conductivity	Alkalinity	DO	T	Flow	Fe	Al
1	A	A	A	C	A	A	A	A
2	B	B	B	-	B	B	B	D
3	A	A	A	C	A	A	A	A
4	B	B	B	-	B	B	B	D
5	B	B	B	-	B	B	B	D
6	A	A	A	C	A	A	A	A
7	A	A	A	C	A	A	A	A
8	A	A	A	C	A	A	A	A
9	A	A	A	C	A	A	A	A
10	A	A	A	C	A	A	A	A
11	B	B	B	-	B	B	B	D
12	B	B	B	-	B	B	B	D
13	B	B	B	-	B	B	B	D
P1	B	B	B	B	B	-	B	B
P2	B	B	B	B	B	-	B	B
P3	B	B	B	B	B	-	B	B
P4	B	B	B	B	B	-	B	B
P5	B	B	B	B	B	-	B	B

A = spring, summer, fall, winter; high and low flows

B = spring, summer, fall, winter

C = spring, summer, fall

D = spring; high flow

In addition, the following parameters were sampled at each station once during the course of this study: zinc, copper, cadmium, chromium, lead, and fecal coliform bacteria; nutrients (nitrogen and phosphorus) for the 5 ponds only.

Sample Collection

Stream discharge and water temperature was determined on-site. Five-hundred ml polyethylene bottles were used to collect samples for the determination of alkalinity, pH, and conductivity. Collected samples were transported under refrigeration to the laboratory at California University for analysis within 24 hours of collection. Acidified bottles (supplied by Geochemical Testing Laboratories) were used to collect samples for analyses of metals and transported to Geochemical Testing Laboratories for processing. Five-hundred ml polyethylene bottles were used to collect samples of nutrients and bacteria, and transported to Geochemical Testing Laboratories under refrigeration for processing within 24 hours of collection. Dissolved oxygen samples were collected, transferred to 300ml glass BOD bottles, fixed in the field (Winkler Method) and transported to the laboratory at California University for analysis. Ponds with sufficient depth were sampled with a Vertical Polycarbonate Water Bottle (WaterMark) at approximate mid-depth.

Analytical Procedures

Analytical methods are summarized in Table 3.

Table 3. Analytical methods employed in water quality analyses at Fort Necessity, Braddock's Grave, and Jumonville Glen sites.

Parameter	Methodology
Discharge	Flow Probe Hand Held Flowmeter (Forestry Suppliers Inc.)
Total Alkalinity (mg/l as $CaCO_3$)	titration*
Specific Conductance (uS/cm @ 25C)	Model 33 S-C-T Meter (Yellow Springs Instr.)
pH	Portable pH/mV/T Meter (Oakton)
Dissolved Oxygen (mg/l)	Azide Modification of the Winkler Method*
Total Iron (mg/l)	EPA-200.7**
Total Aluminum (mg/l)	EPA-200.7**
Cadmium (mg/l)	EPA-200.7**
Chromium (mg/l)	EPA-200.7**
Copper (mg/l)	EPA-200.7**
Lead (mg/l)	EPA-200.7**
Zinc (mg/l)	EPA-200.7**
Nitrite Nitrogen (mg/l)	SM 4500-NO_2-B**
Nitrate Nitrogen (mg/l)	EPA 353.2**
Total Phosphorus (mg/l)	EPA 365.3**
Fecal Coliform (colonies/100ml)	SM 18th 9222 D**

*Eaton, A.D., Clesceri, L.S., and A.E. Greenberg, eds. 1995. *Standard methods for the examination of water and wastewater*, ed. 19.APHA, AWWA, WEF

**performed by Geochemical Testing , Somerset, PA

DATA MANAGEMENT AND ARCHIVING

All water quality data collected over the course of this project has been entered into the Environmental Protection Agency's **STORET** water quality data base.

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RESULTS AND DISCUSSION

All aquatic resources were sampled according to the schedule presented in Table 2 and summarized in Tables 4 – 21. Calendar year 1999 was atypical for precipitation in southwestern Pennsylvania culminating in a severe drought which lasted throughout the summer and early fall months. During this period, the intermittent streams and some classified as perennial were reduced to disconnected small pools or dried up completely. The combination of stream discharge, bedrock geology, and acid deposition was the principal governor of the behavior of the inorganic water quality parameters in the streams (Tables 4 – 14, 20 –21). In the ponds (Tables 15 – 19), basin geology and acid deposition were paramount. No evidence exists for point-source discharges of pollutants into streams or ponds in any of the 3 Park units surveyed.

Fort Necessity (Main Unit)

Great Meadow Run, its unnamed tributaries and Indian Run, along with unnamed tributaries to Scott's Run and the 5 ponds (Tables 4-19) are underlain by formations of the Conemaugh Group (Hickock and Moyer, 1973). Strata consist of shales, sandstones, thin limestones, and coalbeds. While no commercial mining has been documented here, the consistent presence of elevated iron and aluminum at low-flows is the likely signature of groundwater emanating from the coal seams. Base-flow conditions also produce elevations of alkalinity (limestone) and conductivity. Levels of pH are governed by varying combinations of groundwater and surface runoff. Trace metals (Cd, Cr, Cu, Pb, and Zn) are low to below limits of detection. Dissolved oxygen varies inversely with temperature. High fecal coliform densities are the likely result of wildlife and waterfowl.

Iron and aluminum are also present in all 5 ponds with concentrations varying seasonally. Concentrations of trace metals are similar to those of the streams. Total alkalinity varies directly with conductivity. Levels of pH are influenced by groundwater, surface runoff, and photosynthetic activity. Dissolved oxygen varies seasonally with temperature and photosynthesis. Nutrient levels are low (possibly incorporated into algal biomass) and coliform densities are related to wildlife and waterfowl activity patterns.

Braddock's Grave

The watershed of Braddock's Run is underlain by formations of the Allegheny Group featuring shale, sandstones, clay, thin limestone and coal seams (Hickock and Moyer, 1973). Groundwater from the limestone and coal seams, again, likely generate alkalinity, iron, and aluminum (Table 20) but the behavior of these metals is somewhat anomalous with no clear pattern between discharge and concentration. Levels of pH here are circumneutral and stable. Trace metal concentrations are low and similar to the Fort Necessity (Main Unit) levels. High fecal coliform densities are consistent with wildlife populations.

Table 4. Water quality parameters at station 1, unnamed tributary to Great Meadow Run

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	7/30/99	9/22/99	10/5/99	11/3/99
Discharge	CFS	3.93	0.50	1.02	6.10	0.01	nf	0.04	2.03
pH		6.05	5.56	6.57	6.26	6.66	nf	6.46	5.44
Conductivity	uS/cm @ 25 degrees C	33.00	32.20	36.40	32.40	75.00	nf	45.90	37.50
Alkalinity	mg/l	5.00	8.00	7.00	5.00	15.00	nf	10.00	5.00
Dissolved Oxygen	mg/l	nd	nd	nd	8.40	5.00	nf	nd	8.00
Temperature	degrees Celsius	6.0	4.0	12.0	13.5	24.0	nf	11.0	9.0
Total Iron	mg/l	0.31	0.29	0.56	1.02	2.73	nf	4.26	0.60
Total Aluminum	mg/l	0.45	0.37	0.59	1.15	3.33	nf	6.58	0.72
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nf	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nf	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nf	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nf	nd	nd
Zinc	mg/l	nd	nd	nd	0.037	nd	nf	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	>2000	nf	nd	nd

nd = not determined
nf = no flow

Table 5. Water quality parameters at station 2, unnamed tributary from ponds

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	7/30/99	9/22/99	10/5/99	11/3/99
Discharge	CFS	2.04	nd	nd	3.22	nd	nf	nd	1.25
pH		6.30	nd	nd	6.31	nd	6.21	nd	5.96
Conductivity	uS/cm @ 25 degrees C	35.20	nd	nd	34.60	nd	97.20	nd	46.90
Alkalinity	mg/l	10.00	nd	nd	7.00	nd	30.00	nd	14.00
Temperature	degrees Celsius	5.0	nd	nd	14.0	nd	12.0	nd	9.0
Total Iron	mg/l	0.46	nd	nd	<0.05	nd	13.20	nd	0.87
Total Aluminum	mg/l	nd	nd	nd	0.66	nd	nd	nd	nd
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd	nd
Zinc	mg/l	nd	nd	nd	0.031	nd	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	nd	nd	TNC	nd

nd = not determined
nf = no flow
TNTC = Too Numerous to Count

Table 6. Water quality parameters at station 3, unnamed left fork tributary to Great Meadow Run									
Parameter	**Unit**	**1/23/99**	**2/16/99**	**4/3/99**	**4/24/99**	**7/30/99**	**9/22/99**	**10/5/99**	**11/3/99**
Discharge	CFS	4.55	0.86	0.90	10.00	0.03	nf	0.17	3.08
pH		5.97	5.87	6.60	6.57	6.99	6.71	6.31	5.86
Conductivity	uS/cm @ 25 degrees C	33.00	33.30	39.50	33.50	78.00	79.50	42.80	38.40
Alkalinity	mg/l	5.00	8.00	7.00	7.00	21.00	52.00	15.00	6.00
Dissolved Oxygen	mg/l	nd	nd	nd	8.80	6.50	nd	nd	9.60
Temperature	degrees Celsius	5.0	4.0	12.0	14.0	24.0	12.0	12.0	9.0
Total Iron	mg/l	0.34	0.29	0.67	0.63	4.90	1.52	3.59	1.81
Total Aluminum	mg/l	0.39	0.28	0.78	0.65	3.77	0.16	5.57	1.96
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd	nd
Zinc	mg/l	nd	nd	nd	0.029	nd	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	>2000	nd	nd	nd

nd = not determined
nf = no flow

Table 7. Water quality parameters at station 4, unnamed tributary to Scott's Run at road culvert

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	7/30/99	9/22/99	10/5/99	11/3/99
Discharge	CFS	1.11	nd	nd	1.54	nd	nf	nd	0.21
pH		6.39	nd	nd	6.36	nd	6.98	nd	5.86
Conductivity	uS/cm @ 25 degrees C	30.80	nd	nd	34.60	nd	249.10	nd	41.00
Alkalinity	mg/l	5.00	nd	nd	7.00	nd	148.00	nd	7.00
Temperature	degrees Celsius	7.0	nd	nd	11.0	nd	11.0	nd	9.5
Total Iron	mg/l	0.09	nd	nd	0.11	nd	1.35	nd	0.16
Total Aluminum	mg/l	nd	nd	nd	0.11	nd	nd	nd	nd
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd	nd
Zinc	mg/l	nd	nd	nd	0.023	nd	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	nd	nd	TNC	nd

nd = not determined
nf = no flow
TNC = Too Numerous to Count

Table 8. Water quality parameters at station 5, unnamed tributary to Scott's Run

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	7/30/99	9/22/99	10/5/99	11/3/99
Discharge	CFS	1.25	nd	nd	3.06	nd	nf	nd	0.78
pH		6.42	nd	nd	6.37	nd	6.70	nd	5.91
Conductivity	uS/cm @ 25 degrees C	33.00	nd	nd	32.40	nd	95.40	nd	68.20
Alkalinity	mg/l	7.00	nd	nd	7.00	nd	48.00	nd	0.00
Temperature	degrees Celsius	8.0	nd	nd	11.0	nd	14.0	nd	9.0
Total Iron	mg/l	0.26	nd	nd	0.28	nd	0.58	nd	0.50
Total Aluminum	mg/l	nd	nd	nd	0.22	nd	nd	nd	nd
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd	nd
Zinc	mg/l	nd	nd	nd	0.019	nd	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	nd	nd	TNC	nd

nd = not determined
nf = no flow
TNC = Too Numerous to Count

Table 9. Water quality parameters at station 6, Indian Run above confluence with Great Meadow Run

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	7/30/99	9/22/99	10/5/99	11/3/99
Discharge	CFS	1.43	0.20	1.05	6.11	0.01	nf	0.03	0.84
pH		6.58	6.21	6.52	6.49	6.52	6.69	6.36	5.88
Conductivity	uS/cm @ 25 degrees C	41.80	42.20	43.70	40.00	90.00	147.50	53.00	50.20
Alkalinity	mg/l	7.00	11.00	9.00	9.00	11.00	68.00	16.00	10.00
Dissolved Oxygen	mg/l	nd	nd	nd	10.40	6.20	nd	nd	8.40
Temperature	degrees Celsius	7.0	5.0	9.5	10.0	20.0	10.0	11.0	9.0
Total Iron	mg/l	1.63	0.17	0.48	0.72	3.74	0.29	0.64	0.43
Total Aluminum	mg/l	1.70	0.17	0.45	0.79	3.84	0.20	0.90	0.39
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd	nd
Zinc	mg/l	nd	nd	nd	0.011	nd	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	>2000	nd	nd	nd

nd = not determined
nf = no flow

Table 10. Water quality parameters at station 7, Great Meadow Run above confluence with Indian Run

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	7/30/99	9/22/99	10/5/99	11/3/99
Discharge	CFS	16.03	1.27	4.48	18.55	0.19	0.06	0.53	8.39
pH		6.72	6.49	7.00	7.22	7.05	7.03	6.74	6.08
Conductivity	uS/cm @ 25 degrees C	73.70	124.30	83.20	81.00	160.00	190.80	114.20	79.30
Alkalinity	mg/l	10.00	13.00	15.00	16.00	30.00	60.00	27.00	19.00
Dissolved Oxygen	mg/l	nd	nd	nd	8.80	5.60	nd	nd	6.80
Temperature	degrees Celsius	7.0	6.0	13.0	12.0	22.0	10.0	12.0	8.5
Total Iron	mg/l	0.69	0.41	0.45	0.70	0.92	0.59	0.87	0.84
Total Aluminum	mg/l	0.82	0.36	0.31	0.59	0.63	<0.10	0.94	0.57
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd	nd
Zinc	mg/l	nd	nd	nd	0.041	nd	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	740	nd	nd	nd

nd = not determined
nf = no flow

Table 11. Water quality parameters at station 8, Great Meadow Run above stone bridge

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	7/30/99	9/22/99	10/5/99	11/3/99
Discharge	CFS	11.40	1.33	3.06	19.05	0.19	0.07	0.69	7.50
pH		6.74	6.45	6.98	6.81	7.17	7.00	6.74	6.18
Conductivity	uS/cm @ 25 degrees C	68.20	115.50	82.20	64.80	158.00	206.70	131.60	80.50
Alkalinity	mg/l	10.00	15.00	15.00	12.00	32.00	63.00	28.00	18.00
Dissolved Oxygen	mg/l	nd	nd	nd	10.80	6.00	nd	nd	9.20
Temperature	degrees Celsius	7.0	5.0	11.0	10.0	21.0	10.0	12.0	8.5
Total Iron	mg/l	1.21	0.39	0.38	0.74	1.04	0.48	0.79	1.14
Total Aluminum	mg/l	1.49	0.38	0.27	0.55	0.77	<0.10	0.88	1.11
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd	nd
Zinc	mg/l	nd	nd	nd	0.021	nd	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	810	nd	nd	nd

nd = not determined
nf = no flow

Table 12. Water quality parameters at station 9, Great Meadow Run above confluence with tributary

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	7/30/99	9/22/99	10/5/99	11/3/99
Discharge	CFS	11.60	1.36	3.54	20.06	0.23	0.06	0.59	8.66
pH		6.74	6.50	6.93	6.71	7.34	6.86	6.72	6.14
Conductivity	uS/cm @ 25 degrees C	68.20	124.30	85.30	55.10	185.00	203.50	119.30	79.40
Alkalinity	mg/l	12.00	16.00	16.00	10.00	32.00	55.00	32.00	20.00
Dissolved Oxygen	mg/l	nd	nd	nd	10.00	6.90	nd	nd	10.00
Temperature	degrees Celsius	7.0	5.0	9.5	10.0	23.0	12.0	12.0	8.5
Total Iron	mg/l	1.50	0.37	0.36	0.54	1.01	0.70	0.74	0.98
Total Aluminum	mg/l	1.83	0.37	0.26	0.50	0.87	0.15	0.85	0.92
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd	nd
Zinc	mg/l	nd	nd	nd	0.023	nd	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	960	nd	nd	nd

nd = not determined
nf = no flow

Table 13. Water quality parameters at station 12, unnamed tributary to Scott's Run

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	7/30/99	9/22/99	10/5/99	11/3/99
Discharge	CFS	0.91	nd	nd	4.37	nd	nf	nd	1.05
pH		6.50	nd	nd	6.58	nd	6.91	nd	5.85
Conductivity	uS/cm @ 25 degrees C	31.90	nd	nd	32.40	nd	95.40	nd	38.40
Alkalinity	mg/l	5.00	nd	nd	5.00	nd	35.00	nd	8.00
Temperature	degrees Celsius	7.0	nd	nd	11.5	nd	11.0	nd	8.0
Total Iron	mg/l	0.11	nd	nd	<0.05	nd	0.31	nd	0.21
Total Aluminum	mg/l	nd	nd	nd	<0.10	nd	0.14	nd	nd
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd	nd
Zinc	mg/l	nd	nd	nd	<0.005	nd	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	nd	nd	TNC	nd

nd = not determined
nf = no flow
TNC = Too Numerous to Count

Table 14. Water quality parameters at station 13, spring at head of Pond 1

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	7/30/99	9/22/99	10/5/99	11/3/99
Discharge	CFS	1.20	nd	nd	1.09	nd	nf	nd	0.36
pH		6.24	nd	nd	6.32	nd	nf	nd	5.82
Conductivity	uS/cm @ 25 degrees C	31.90	nd	nd	32.40	nd	nf	nd	38.40
Alkalinity	mg/l	5.00	nd	nd	0.50	nd	nf	nd	5.00
Temperature	degrees Celsius	7.0	nd	nd	11.0	nd	nf	nd	9.5
Total Iron	mg/l	0.78	nd	nd	0.19	nd	nf	nd	0.14
Total Aluminum	mg/l	nd	nd	nd	0.18	nd	nf	nd	nd
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nf	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nf	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nf	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nf	nd	nd
Zinc	mg/l	nd	nd	nd	0.023	nd	nf	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	nd	nf	nd	30

nd = not determined
nf = no flow

Table 15. Water quality parameters at P1, Pond 1

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	8/9/99	9/22/99	10/5/99
pH		6.20	nd	nd	6.20	7.07	nd	6.22
Conductivity	uS/cm @ 25 degrees C	33.00	nd	nd	43.20	69.40	nd	63.20
Alkalinity	mg/l	3.00	nd	nd	5.00	10.00	nd	25.00
Dissolved Oxygen	mg/l	7.00	nd	nd	10.00	7.60	nd	6.00
Temperature	degrees Celsius	9.0	nd	nd	13.0	27.0	nd	11.0
Total Iron	mg/l	0.12	nd	nd	0.10	6.65	nd	3.24
Total Aluminum	mg/l	<0.10	nd	nd	<0.10	0.16	nd	0.14
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd
Zinc	mg/l	nd	nd	nd	0.009	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	650	nd	nd
Nitrite	mg/l	nd	nd	nd	nd	<0.05	nd	nd
Nitrate	mg/l	nd	nd	nd	nd	<0.05	nd	nd
Phosphorus	mg/l	nd	nd	nd	nd	0.40	nd	nd

nd = not determined

Table 16. Water quality parameters at P2, Pond 2								
Parameter	**Unit**	**1/23/99**	**2/16/99**	**4/3/99**	**4/24/99**	**8/9/99**	**9/22/99**	**10/5/99**
pH		6.15	nd	nd	6.43	8.35	nd	6.56
Conductivity	uS/cm @ 25 degrees C	29.70	nd	nd	34.60	42.80	nd	30.60
Alkalinity	mg/l	4.00	nd	nd	6.00	15.00	nd	16.00
Dissolved Oxygen	mg/l	10.00	nd	nd	10.00	8.60	nd	9.60
Temperature	degrees Celsius	4.0	nd	nd	13.0	27.5	nd	15.5
Total Iron	mg/l	0.17	nd	nd	0.22	1.99	nd	1.11
Total Aluminum	mg/l	<0.10	nd	nd	<0.10	<0.10	nd	<0.10
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd
Zinc	mg/l	nd	nd	nd	0.019	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	10	nd	nd
Nitrite	mg/l	nd	nd	nd	nd	<0.05	nd	nd
Nitrate	mg/l	nd	nd	nd	nd	<0.05	nd	nd
Phosphorus	mg/l	nd	nd	nd	nd	<0.10	nd	nd

nd = not determined

Table 17. Water quality parameters at P3, Pond 3

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	8/9/99	9/22/99	10/5/99
pH		6.53	nd	nd	6.77	9.06	nd	6.84
Conductivity	uS/cm @ 25 degrees C	35.20	nd	nd	48.60	56.10	nd	56.10
Alkalinity	mg/l	5.00	nd	nd	10.00	28.00	nd	32.00
Dissolved Oxygen	mg/l	10.00	nd	nd	10.40	8.60	nd	10.00
Temperature	degrees Celsius	5.5	nd	nd	15.0	28.5	nd	17.0
Total Iron	mg/l	0.25	nd	nd	0.28	0.88	nd	0.37
Total Aluminum	mg/l	<0.10	nd	nd	0.10	<0.10	nd	<0.10
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd
Zinc	mg/l	nd	nd	nd	0.018	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	<10	nd	nd
Nitrite	mg/l	nd	nd	nd	nd	<0.05	nd	nd
Nitrate	mg/l	nd	nd	nd	nd	<0.05	nd	nd
Phosphorus	mg/l	nd	nd	nd	nd	<0.10	nd	nd

nd = not determined

Table 18. Water quality parameters at P4, Pond 4

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	8/9/99	9/22/99	10/5/99
pH		6.73	nd	nd	6.51	6.98	nd	6.44
Conductivity	uS/cm @ 25 degrees C	41.80	nd	nd	45.40	70.40	nd	60.20
Alkalinity	mg/l	7.00	nd	nd	10.00	23.00	nd	35.00
Dissolved Oxygen	mg/l	11.00	nd	nd	10.40	10.00	nd	9.20
Temperature	degrees Celsius	6.0	nd	nd	17.0	27.0	nd	12.0
Total Iron	mg/l	0.39	nd	nd	0.22	4.41	nd	1.78
Total Aluminum	mg/l	0.21	nd	nd	0.11	0.27	nd	0.22
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd
Zinc	mg/l	nd	nd	nd	0.008	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	280	nd	nd
Nitrite	mg/l	nd	nd	nd	nd	<0.05	nd	nd
Nitrate	mg/l	nd	nd	nd	nd	<0.05	nd	nd
Phosphorus	mg/l	nd	nd	nd	nd	<0.10	nd	nd

nd = not determined

Table 19. Water quality parameters at P5, Pond 5

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	8/9/99	9/22/99	10/5/99
pH		5.56	nd	nd	6.33	8.12	nd	5.87
Conductivity	uS/cm @ 25 degrees C	45.10	nd	nd	54.00	51.00	nd	52.00
Alkalinity	mg/l	2.00	nd	nd	9.00	15.00	nd	13.00
Dissolved Oxygen	mg/l	10.50	nd	nd	12.40	10.00	nd	10.40
Temperature	degrees Celsius	9.0	nd	nd	17.0	26.0	nd	11.5
Total Iron	mg/l	0.21	nd	nd	0.16	4.36	nd	0.96
Total Aluminum	mg/l	0.22	nd	nd	0.15	0.12	nd	0.17
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd
Zinc	mg/l	nd	nd	nd	0.014	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	110	nd	nd
Nitrite	mg/l	nd	nd	nd	nd	<0.05	nd	nd
Nitrate	mg/l	nd	nd	nd	nd	<0.05	nd	nd
Phosphorus	mg/l	nd	nd	nd	nd	0.10	nd	nd

nd = not determined

Table 20. Water quality parameters at station 10, Braddock's Run

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	7/30/99	9/22/99	10/5/99	11/3/99
Discharge	CFS	9.60	0.75	2.27	8.12	0.02	nf	0.31	2.21
pH		6.64	6.44	6.78	6.36	6.97	6.52	6.82	6.16
Conductivity	uS/cm @ 25 degrees C	55.00	90.20	64.50	37.80	122.00	121.90	112.20	68.20
Alkalinity	mg/l	5.00	12.00	12.00	9.00	20.00	43.00	22.00	7.00
Dissolved Oxygen	mg/l	nd	nd	nd	9.20	6.00	nd	nd	9.00
Temperature	degrees Celsius	9.0	6.5	14.0	15.5	24.0	12.0	12.0	9.0
Total Iron	mg/l	2.12	0.38	0.80	0.57	1.65	0.40	1.16	0.88
Total Aluminum	mg/l	2.42	0.28	0.50	0.40	0.87	0.15	1.14	0.90
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nd	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nd	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nd	nd	nd
Zinc	mg/l	nd	nd	nd	0.033	nd	nd	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	800	nd	nd	nd

nd = not determined
nf = no flow

Jumonville Glen

The stream here is an unnamed tributary to Dunbar Creek on the Youghiogheny River drainage. Rocks of the Pocono Group – sandstones, conglomerate, with some sandy shale predominate in this watershed. Streams emanating from these acidic formations exhibit little buffering capacity and are typically episodically or permanently acidified, or both (Sharpe, et. al., 1984, 1987). Such is the most probable scenario here. Levels of pH below 5.0 and 0 total alkalinity (Table 21) are the likely result of this combination of acid deposition and geology. Again, trace metals are consistent with those of the other 2 Park Units.

Relationship of stream discharge to inorganic water quality parameters

Figures 3 – 7 are plots of stream discharge versus total alkalinity, conductivity, pH, iron, and aluminum, all parameters which were sampled more than once and data for all streams combined. The acidic runoff from acid deposition erodes alkalinity as discharge increases (Figure 3). Conductivity also varies inversely with flow as ions become diluted (Figure 4). The relationship of discharge to pH is not clearcut although the trend line is slightly downward (Figure 5). This is likely a result of the high base-flow alkalinities and attendant buffering capacities of most of these streams. Episodically-acidified streams typically have little buffering capacity and pH varies inversely with flow (Sharpe, 1983, 1987). The depression of total iron concentrations with increasing discharge indicates that iron is present in the groundwater and is diluted as flow increases (Figure 6). The trend line for total aluminum is elevated as would be expected under episodic acidification, however most of the points are clustered around base-flow measurements (Figure 7). It seems likely that more of the aluminum enters from the groundwater than is mobilized from the soils.

Table 21. Water quality parameters at station 11

Parameter	Unit	1/23/99	2/16/99	4/3/99	4/24/99	7/30/99	9/22/99	10/5/99	11/3/99
Discharge	CFS	0.71	nd	nd	0.87	nd	nf	nd	0.21
pH		4.85	nd	nd	4.61	nd	nf	nd	3.84
Conductivity	uS/cm @ 25 degrees C	35.20	nd	nd	34.60	nd	nf	nd	35.80
Alkalinity	mg/l	0.00	nd	nd	0.00	nd	nf	nd	0.00
Temperature	degrees Celsius	9.5	nd	nd	11.0	nd	nf	nd	8.0
Total Iron	mg/l	0.07	nd	nd	0.59	nd	nf	nd	0.05
Total Aluminum	mg/l	nd	nd	nd	0.43	nd	nf	nd	nd
Cadmium	mg/l	nd	nd	nd	<0.005	nd	nf	nd	nd
Chromium	mg/l	nd	nd	nd	<0.01	nd	nf	nd	nd
Copper	mg/l	nd	nd	nd	<0.01	nd	nf	nd	nd
Lead	mg/l	nd	nd	nd	<0.05	nd	nf	nd	nd
Zinc	mg/l	nd	nd	nd	0.034	nd	nf	nd	nd
Fecal Coliform	colonies/100ml	nd	nd	nd	nd	nd	nf	nd	<10

nd = not determined
nf = no flow

Comparison to Pennsylvania Dept. of Environmental Protection water quality criteria for High Quality Cold-Water Fisheries

Water quality criteria for a HQ-CWF consistent with parameters evaluated in this study are presented in Table 22.

Table 22. Selected water quality criteria for a HQ-CWF.

Parameter	Criterion
Dissolved Oxygen	minimum of 7.0 mg/l
Aluminum	a
Iron	daily average 1.5 mg/l as total iron
Alkalinity	20 mg/l except where natural conditions are less
Bacteria	b
N (Nitrite + Nitrate)	10 mg/l as N
pH	6 - 9

a = bioassay required
b = requires multiple samples for geometric mean

For the most part, dissolved oxygen levels in the streams meet the criterion. The several instances where levels are below minimum occur at times of extreme low flows due to the drought and are, therefore, natural. While no attempt was made here to obtain daily averages of total iron, the high values are consistent with the underlying geology and there is no evidence of commercial mining. Base-flow alkalinities are governed by geological factors. Declines with increasing discharge are consistent with acid deposition. Nitrogen levels in ponds are low and meet the criterion. Most pH values meet the criterion with exceptions, again, best explained by acid deposition. The unnamed tributary to Dunbar Creek at Jumonville Glen is acidified to the extent that viable fish populations are unlikely.

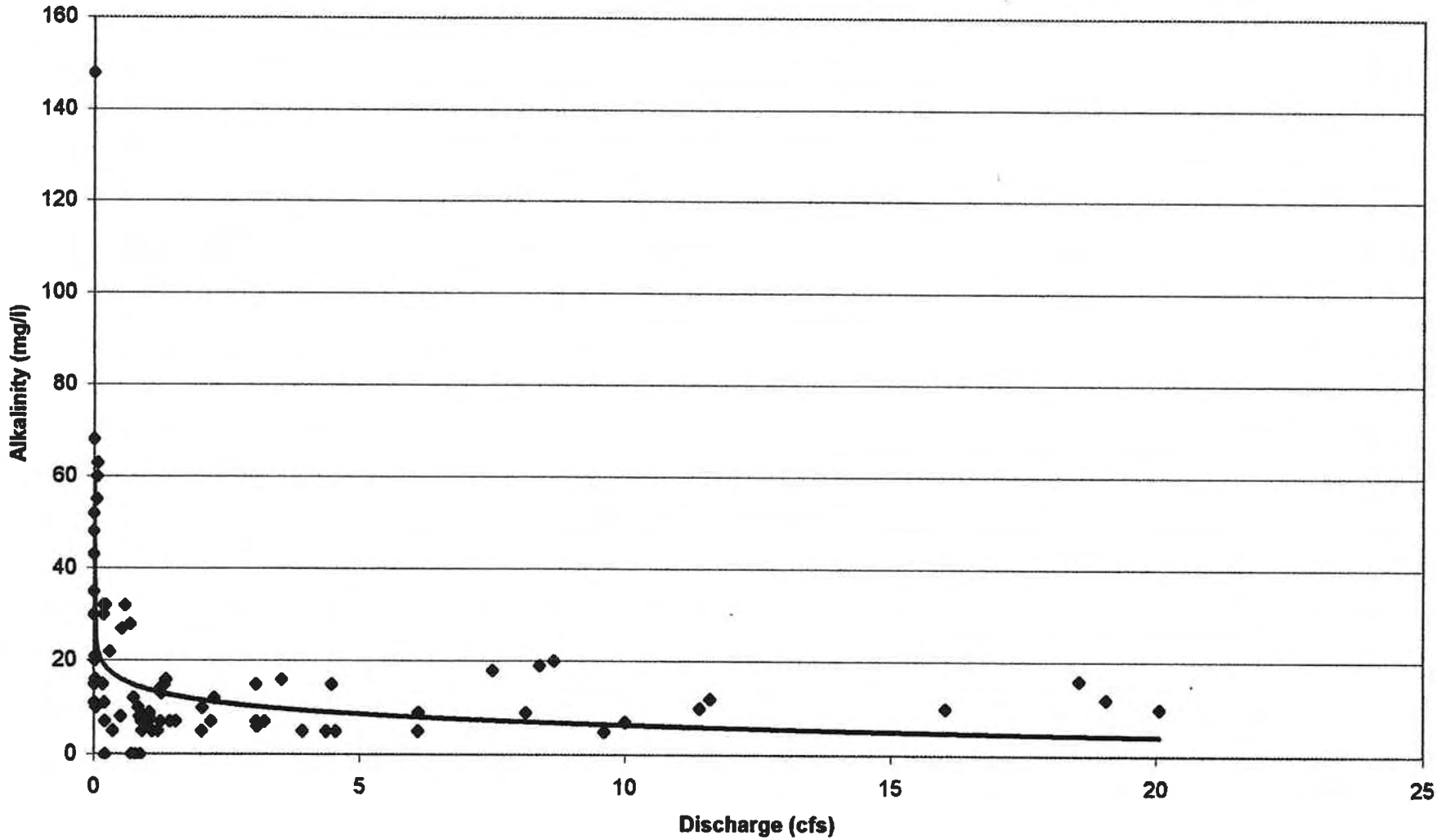

Figure 3. The relationship between alkalinity and discharge for all streams surveyed

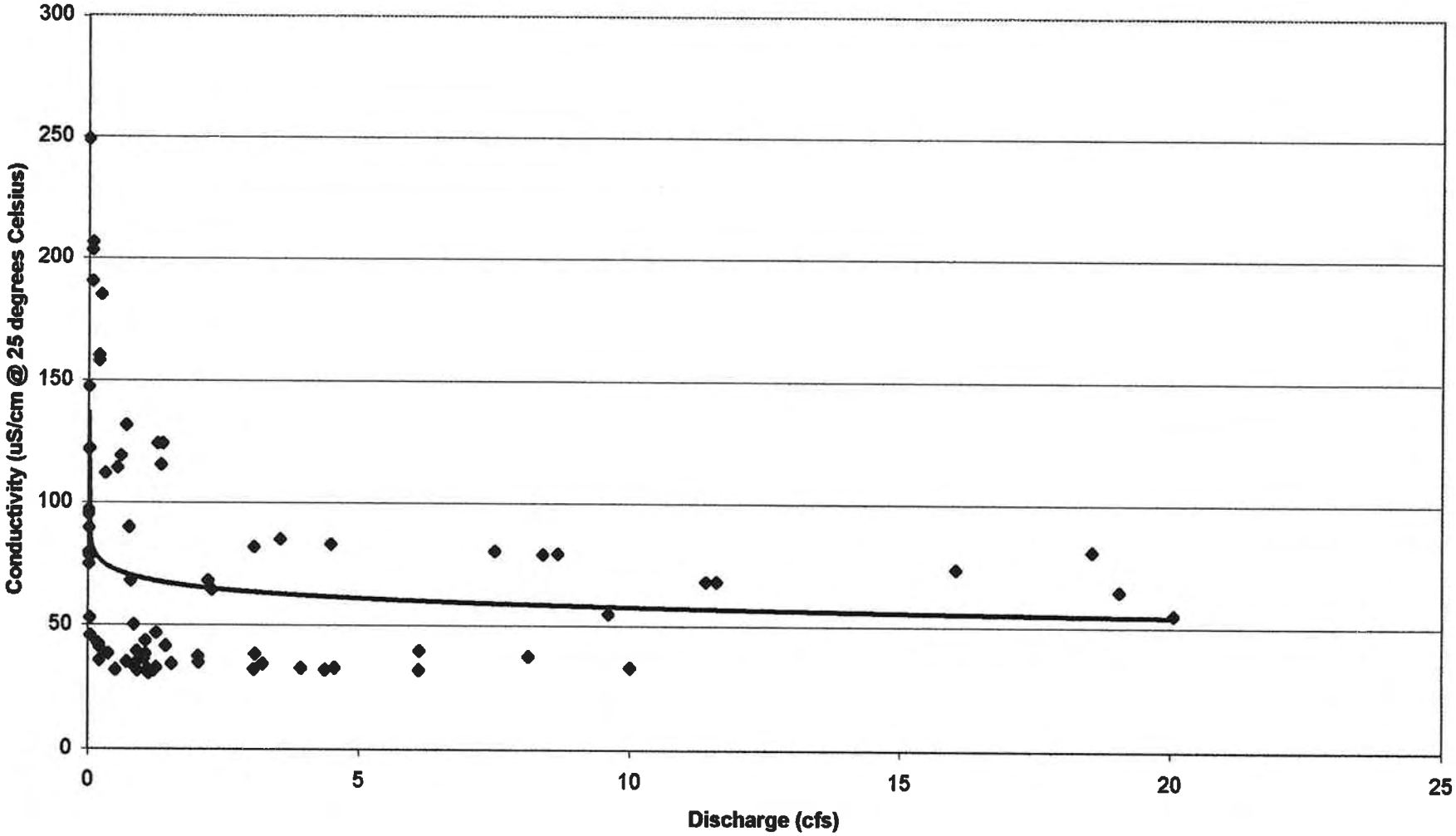

Figure 4. Relationship between conductivity and discharge for all streams surveyed

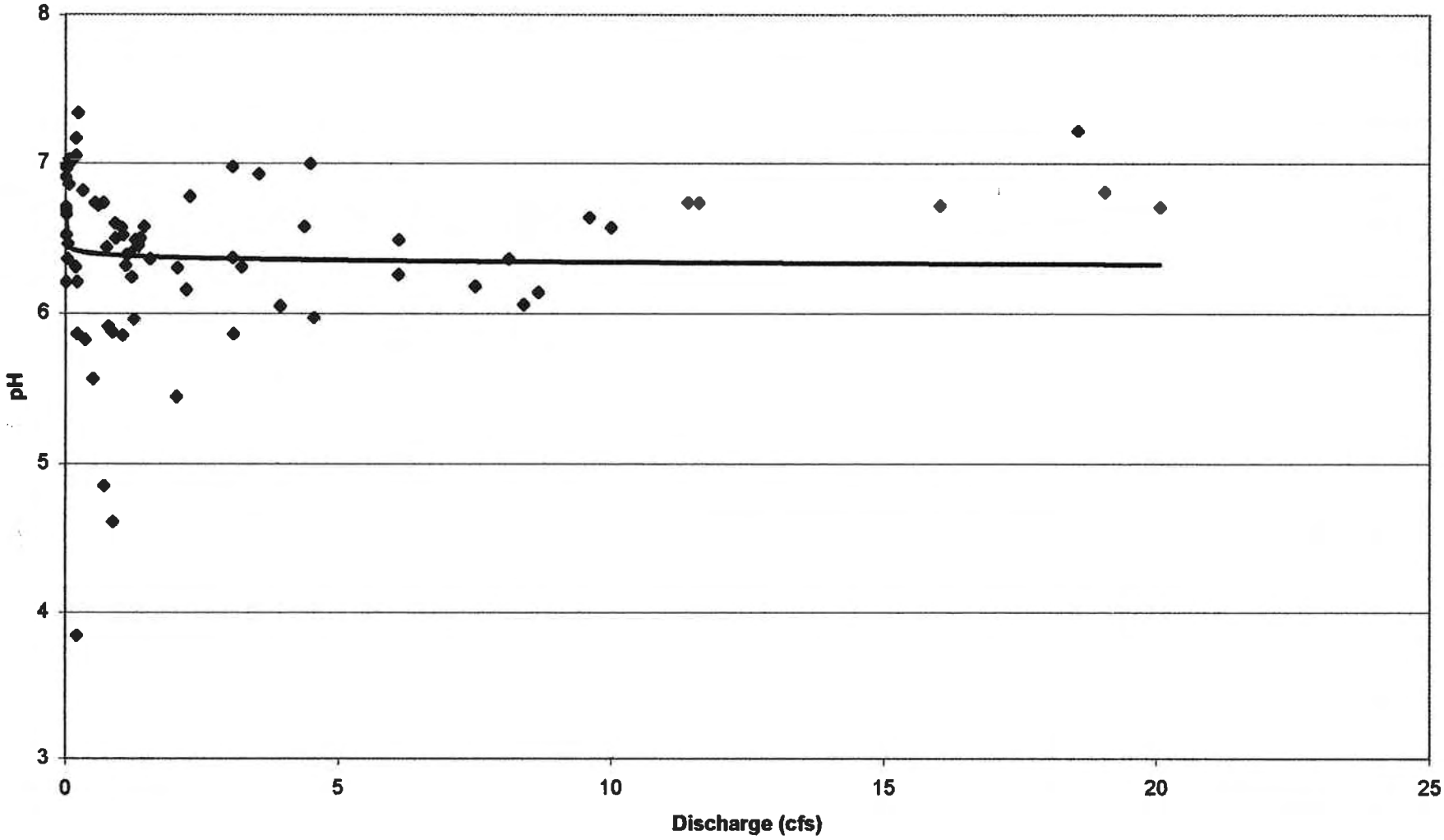

Figure 5. The relationship between pH and discharge for all streams surveyed

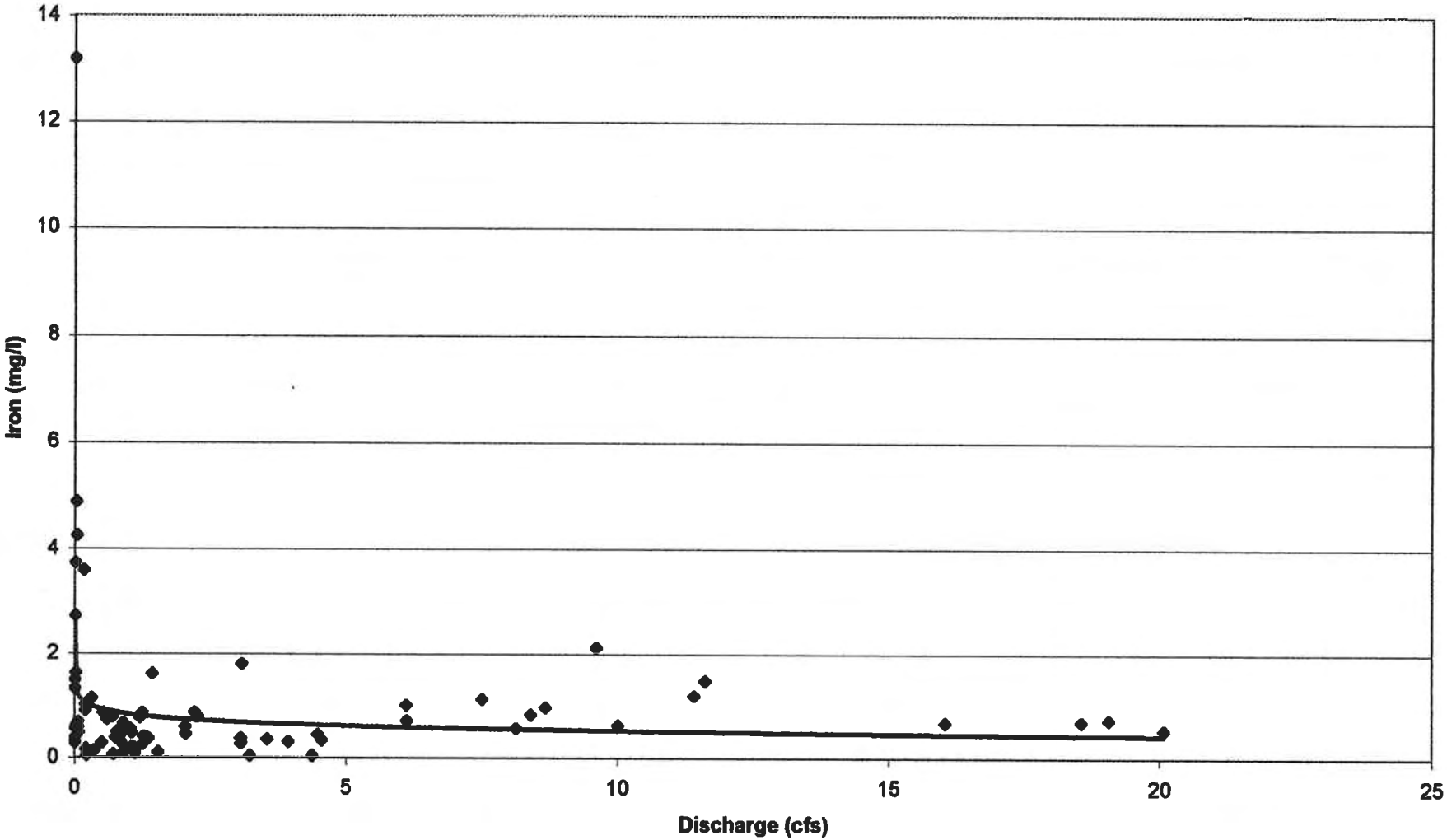

Figure 6. The relationship between iron and discharge for all streams surveyed

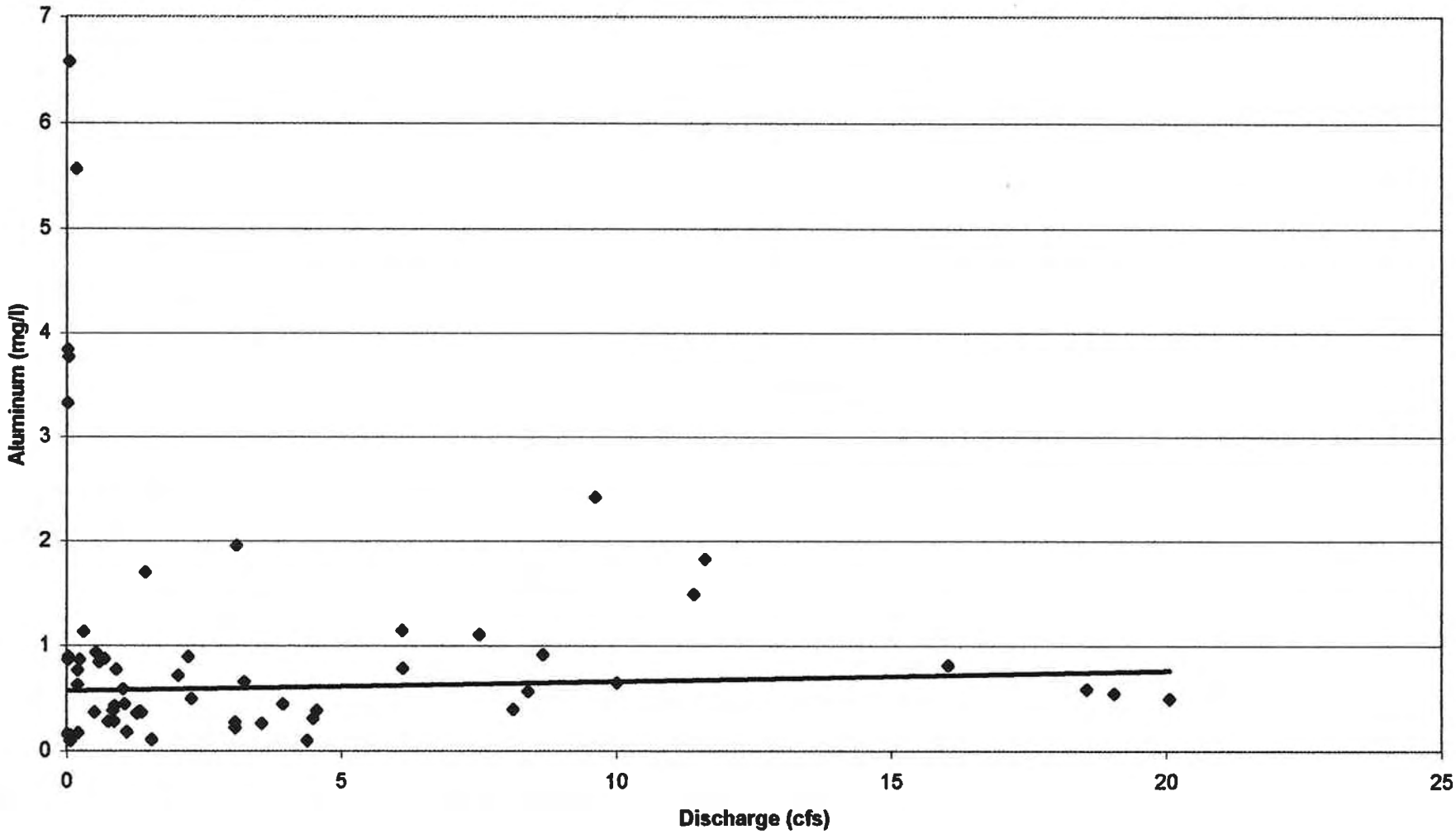

Figure 7. The relationship between aluminum and discharge for all streams surveyed

CONCLUSION

The behavior of water quality parameters sampled in this yearlong survey of the three FONE Park Units can best be explained as the result of the interaction of ambient precipitation, geology, acid deposition, and wildlife activity. There is no evidence of pollution from development activities in the parks, mining activity, or point-source discharges.

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