Appendix A

Field Manual
Habitat Suitability Curve Transferability Testing for Pennsylvania Instream Flow Incremental Methodology Studies

A1.0 INTRODUCTION

The purpose of this study is to determine whether existing habitat suitability criteria (HSC) for brook trout and brown trout adults, juveniles, fry, and spawning are transferable to Pennsylvania Streams with wild trout populations and drainage areas of less than 100 square miles.

Bovee (1982) emphasizes that selection of the appropriate evaluation species for studies using the Instream Flow Incremental Methodology (IFIM) is important because all interpretations of environmental impacts hinge on the effect on the evaluation species. Habitat suitability criteria are used in the Physical Habitat Simulation System (PHABSIM) to evaluate effects on habitat for the evaluation species.

The work group of the Susquehanna River Basin Commission's (SRBC's) Instream Flow Subcommittee originally considered brook trout, brown trout, white sucker, blacknose dace, and slimy sculpin as possible evaluation species. Brook and brown trout were selected because they are the most recreationally and economically important species in the study streams. White sucker, blacknose dace, and slimy sculpin were originally considered because they can serve as forage species for trout. However, white sucker adults are tolerant of a variety of flow conditions and are not generally abundant in the smaller headwater trout streams. Only a limited number of HSC have been developed for blacknose dace and slimy sculpin. In light of the above, the work group has decided to focus only on brook and brown trout as evaluation species.

Work group representatives from the SRBC and PFBC reviewed existing brook and brown trout HSC for possible transferability testing. HSC examined included those that were cited by Raleigh and others (1986), Aceituno and others. (1985), Harris and others (1992), Jirka and Homa (1990), Normandeau Associates Inc. (1992), Bovee (1994), and Whelan (1994).

Combined HSC for brook and brown trout will be used for transferability testing. Testing will be performed on depth and mean column velocity HSC for fry, juveniles, and adults that were cited by Normandeau Associates Inc. (1992) and on Whelan's (1994) depth and mean column velocity HSC for spawning. Substrate and cover HSC for all life stages were developed by PFBC and SRBC staff for transferability testing. Nose velocity HSC are not being used for the Pennsylvania IFIM studies and will not be considered for transferability testing.

A2.0 SELECTION OF STREAMS FOR TRANSFERABILITY TESTING

Lanka and others (1987) cited that trout stream habitat in the Rocky Mountains is greatly influenced by drainage basin geomorphology. Similarly, Nelson and others (1992) found that trout distribution in the North Fork Humboldt River drainage area of northeastern Nevada is related to geologic district and land type association.

The physical and biological characteristics of wild trout streams vary greatly among physiographic regions in Pennsylvania, as well as between limestone and freestone streams. No one stream could be selected that contains all habitat types found in wild brook and brown trout streams in the Commonwealth. For this reason, transferability studies were planned to be performed on one stream from each of the following categories:

- Ridge and Valley Physiographic Region, limestone wild brown trout stream
- Ridge and Valley Physiographic Region, freestone wild brown trout stream
- Ridge and Valley Physiographic Region, freestone wild brook trout stream
- Unglaciated Plateau Physiographic Region, wild brown trout stream
- Unglaciated Plateau Physiographic Region, wild brook trout stream

Note: No limestone wild brook trout streams were identified in the Ridge and Valley Physiographic Region.

Commission staff questions whether the HSC will be transferable to all of the streams listed above. Without performing transferability studies on a variety of streams, this important question can not be answered.

To the extent possible, transferability testing will be performed on larger streams that have a drainage area of less than 100 square miles, large numbers of wild trout, excellent water quality and visibility, and good structural and hydraulic diversity. To facilitate trout identification during sampling, an attempt was made to select streams that did not contain significant numbers of more than one trout species.

SRBC and PFBC staff performed reconnaissance electrofishing on potential streams for transferability studies during May and June 1994. Based on the electrofishing results, the following streams were selected for transferability studies:

- Elk Creek, Centre County (Ridge and Valley Physiographic Region, limestone wild brown trout)
- Cherry Run, Centre and Union Counties (Ridge and Valley Physiographic Region, freestone wild brown trout)
- Little Fishing Creek, Centre County (Ridge and Valley Physiographic Region, freestone wild brook trout)
- Young Womans Creek, Clinton County (Unglaciated Plateau Physiographic Region, wild brown trout)
- Whitehead Run, Cameron County (Unglaciated Plateau Physiographic Region, wild brook trout)

Based on budget limitations, the Instream Flow Subcommittee Work Group decided in July 1994 to defer the proposed work on Elk Creek.

All of the selected streams have sections that are classified by the PFBC as 1994 Class A Wild Trout Waters. Electrofishing results indicate that brown trout are abundant in Elk Creek, Cherry Run, and Young Womans Creek. Brook trout are abundant in the study areas on Little Fishing Creek and Whitehead Run. Fry, juveniles, and adults were identified in all of the selected streams.

Commission staff believes that Elk Creek, Little Fishing Creek, and Young Womans Creek can be sampled using the combination of surface observations, underwater observations with snorkel diving gear, and electrofishing described below. Elk Creek and Young Womans Creek are larger streams where snorkel diving will be extensively used as a sampling technique. Because of its small size (8-10 feet wide), Little Fishing Creek will be sampled primarily by using surface observations and electrofishing equipment. However, snorkel observations may be possible in some locations in Little Fishing Creek. Cherry Run and Whitehead Run are small streams where surface observations and electrofishing will be the primary sampling methods.

Several other streams were sampled with electrofishing gear before Commission staff selected the five streams listed above. Possible alternative ridge and valley physiographic region, freestone wild brown trout streams that were sampled by Commission staff included Lost Creek in Juniata County, Wallace Run in Centre County, Swift Run in Mifflin County, Laurel Run in Union County, and the Lackawanna River in Lackawanna County.

Lost Creek was sampled on June 9, 1994, and was found to have excellent habitat diversity and water clarity. Although the stream contained good numbers of adult brown trout, relatively few juveniles and fry could be found. The stream also contained significant numbers of adult brook trout.

Wallace Run and Swift Run were sampled on June 20, 1994. Both streams were found to contain mixed populations of brook and brown trout. The ratio of brown trout to brook trout was about 60/40 in Wallace Run and about 50/50 in Swift Run. Wallace Run was found to have few fish.

Laurel Run was sampled on June 22, 1994, and found to have mixed populations of brook and brown trout. Extensive streambank shading made fish observations difficult.

The Lackawanna River near Archbald, Pa., was sampled on June 23, 1994. In this area, the stream is large enough to be sampled with snorkel gear and has good habitat diversity. However, the stream contained much trash and household debris, raising concerns for diver health and safety. The stream was found to contain mixed populations of brook, brown, and rainbow trout.

After considering the alternative streams listed above, Commission staff selected Cherry Run as the Ridge and Valley Physiographic Region, freestone wild brown trout stream for HSC transferability testing.

Reconnaissance electrofishing was performed on several streams before the wild brook trout study stream in the Unglaciated Plateau Physiographic Region could be selected. John Summerson Branch and Trout Run in Clinton County were sampled on May 19, 1994, but did not contain adequate numbers of trout for HSC transferability testing. Sampling in John Summerson Branch was performed near the mouth. Further discussion with the PFBC's area fishery manager indicated that trout are more abundant upstream. Accessibility to upstream areas of John Summerson Branch is a problem because the one dirt road to the area leads only to the mouth of the stream. Any further travel to upstream areas would have to be on foot.

On June 21, 1994, Commission staff sampled Grove Run in Cameron County, Montour Run in Clinton and Cameron Counties, and Whitehead Run in Cameron County. At the time of sampling, Grove Run contained good numbers of brook trout, but also contained many brown trout. Montour Run did not contain sufficient numbers of brook trout for HSC transferability testing. Sampling on Whitehead Run indicated that the stream has an excellent population of brook trout, is easily accessible, and has good habitat diversity and water clarity. Only a few isolated brown trout were identified during electrofishing activities. In light of the above, Whitehead Run was selected as the unglaciated plateau physiographic region, wild brook trout stream for HSC transferability testing.

A3.0 FIELD SAMPLING PROCEDURES

Commission staff will conduct the transferability studies using the general methodology described by Thomas and Bovee (1993). Microhabitat measurements will be taken at locations where undisturbed fish are observed and in randomly selected locations where fish are absent. Field data will be used to conduct a one-sided chi-square test to determine whether the HSC are transferable to the study streams.

The effectiveness of snorkel diving to make direct observations of undisturbed fish has been well documented (Bovee, 1986; Bovee and Zuboy, 1988). For this reason, snorkel diving will be used to the maximum extent possible in making fish observations for the transferability studies. However, not all habitat in Pennsylvania streams can be sampled using this method. A significant portion of the area in most wild brook trout streams and some wild brown trout streams is either too shallow to float a diver or difficult for a diver to approach without disturbing fish. For habitat types than cannot be effectively sampled with snorkel gear, surface observations and electrofishing will be used to identify fish locations.

For the purpose of this investigation, fry will be considered to be fish less than 2 inches in total length, juveniles to be 2 to 6 inches in total length, and adults to be 6 inches or more in total length. Spawning locations will be identified either by the presence of spawning fish or a redd. A plastic ruler will be carried by fish observers to assist in estimating length.

A minimum of four sampling trips will be made to each of the study streams during the course of a one-year period. The appropriate PFBC law enforcement regional office (Appendix A1) will be informed at least 24 hours in advance of each sampling trip as required under the SRBC's scientific collection permits.

Each trip to each stream is expected to require an average of one week of sampling effort. Life stages sampled during each of the four trips will be as follows:

- Adults and juveniles
- Adults and juveniles (different flow level than first sampling)
- Spawning (anticipated spawning in October for brook trout, November for brown trout)
- Fry (spring or early summer)

The two sampling trips for adults and juveniles are scheduled for July-August 1994. Sampling will not be performed during extreme low flows when habitat diversity is limited, or during extreme high flows when observations are difficult or dangerous. Depending on streamflow conditions, some of the sampling trips may need to be performed at a later date. In order to perform the required statistical analyses, microhabitat measurements for each trip and life stage will be made at 55 or more occupied locations and 200 or more unoccupied locations. A flow measurement at the downstream end of the sampling area will be taken on the first day of each sampling trip.

During the development of this field manual, a concern was raised that it may not be possible to identify the locations of 55 fish that are at least 6 inches long during each of the times that adult and juvenile brook trout are sampled at Little Fishing Creek and Whitehead Run. Growth rates vary from stream to stream, and brook trout in small streams such as these may be sexually mature before they are 6 inches long.

Bovee (1986) indicates that size class is a preferred means of HSC stratification because it is a more precise measurement than life stage or age group. If it is not possible to identify the locations of 55 fish that are 6 inches long during the full week of sampling and it is apparent from the data that a distinction can be made between adults and juveniles based on a length less than 6 inches, this lesser length will be noted and considered for the breakdown between juveniles and adults. The rationale for this modified breakdown will be documented in the trip notes prepared by the sampling team leader. This modified breakdown using the lesser length will only be considered as a last resort if 55 observations can not be made of fish that are at least 6 inches long. Every reasonable effort will be made to identify the locations of as many fish as possible that are at least 6 inches long.

Equal areas of all mesohabitat types will be sampled, regardless of which mesohabitat types are most abundant or have the greatest concentrations of fish. The locations of all undisturbed fish at each mesohabitat sampling site will be marked and appropriate data will be recorded. For example, if a stream has six mesohabitat types, equal areas of all six mesohabitat types will be sampled. If 55 occupied locations are identified in the first mesohabitat type sampled, equal areas of the remaining five mesohabitat types will still need to be sampled and microhabitat measurements will need to be recorded for occupied locations.

If two (non-spawning) fish are located within one foot of each other, they will be considered to be in the same location (IFIM cell) if all microhabitat measurement values are equal. If any one measurement (depth, velocity, substrate, or cover) is different, the fish will be considered to be in separate occupied locations.

The 200 or more unoccupied sampling locations will be distributed equally among all mesohabitat types. In the above example, at least 34 unoccupied locations would be sampled in each of the six mesohabitat types.

The appropriate equipment listed on Appendix A2 will be included on each field sampling trip. Electrofishing gear will only be needed to identify juvenile, adult, and fry locations and will not be used when making spawning observations.

Sampling will be performed by a three-man crew as specified below. The crew leader and at least one other crew member will be trained in cardiopulmonary resuscitation (CPR).

During field observations, a conscious effort will be made to avoid fish fright and investigator bias. Surface observation will be the first sampling method used to locate fish at each mesohabitat sampling site. The observer will wear camouflage clothing and the approach to the site will be made by moving in an upstream direction. If possible, the approach and observations will be made from the bank, using any available cover for the approach. Care will be taken not to cast shadows on the portion of stream to be sampled. Care also will be taken not to frighten fish into the sample site from either downstream or upstream areas. Observations will be made with the aid of polarized sunglasses and a pair of binoculars.

The observer will mark each fish location with a lead fishing sinker marked with a numbered piece of plastic surveyor's tape. The date, time, mesohabitat type, observation technique, marker tag number, fish species, length, and life stage will be entered on a copy of the data sheet shown as Appendix A3.

If the mesohabitat sampling site that was marked as per the above can also be sampled with snorkel gear, a nylon rope may be stretched through the length of the sampling site to assist the diver in moving upstream. This may be done with minimal disturbance to fish by fastening one end of the rope to an upstream anchor (rock, log, etc.) and attaching the other end of the rope to the handle of a plastic jug that is partially filled with water and floated downstream to the end of the sampling site.

Underwater observations will be made by a diver equipped with the snorkel sampling gear listed in Appendix A2. If fish were disturbed by the surface observations and setup procedures described above, at least one half hour will be allowed to pass before snorkel observations are begun.

The diver will carefully approach the downstream end of the sample site and move upstream in a zigzag fashion, sampling all habitat from bank to bank. When an undisturbed fish is observed, the diver will mark its location with a marker as described above. After each marker is positioned, the diver will roll his head out of the water and report the tag number, species, length, and life stage to an assistant on the bank of the stream. The assistant will enter the information on the same data sheet used for surface observations and also will record the date, time, mesohabitat type, and observation technique.

Using polarized sunglasses, the data recorder will also note any fish that are disturbed by the diver to ensure that their locations are not inadvertently counted. The data recorder also will assist the diver in site setup and equipment transport and will serve as the diver's "buddy" for safety purposes.

If the mesohabitat sampling site that was marked using surface observations can not be sampled with snorkel gear, electrofishing will also be used to identify the locations of undisturbed fish. Precautions will be made to avoid fright bias as described for surface observations. As with snorkel observations, electrofishing will be performed in a systematic manner, sampling at points from downstream to upstream and from bank to bank.

Electrofishing will be performed with a backpack DC shocker and two hand-held electrodes. For each point sampled, the electrodes will be carefully positioned and the current will then be switched on and the locations of fish identified. Fish will be netted with a dipnet or minnow seine if necessary for identification or measurement. Handling will be minimal and all fish will be safely returned to the water. Fish locations will be marked as described previously and appropriate notations will be made on the same data sheet used for surface observations.

After fish locations have been marked, the third crew member will measure and record water depth to the nearest 100th of a foot using a top setting rod equipped with a current meter. Water temperature in degrees centigrade at the fish location will also be measured and recorded. The number of cup rotations per unit of time (at least 40 seconds) will be recorded on the data sheet so that mean current velocity for each location can be calculated. If the water depth is less than 2.5 feet, one current meter reading will be taken at six tenths of the distance from the water surface to the stream bottom. If the water depth is greater than 2.5 feet, one current meter reading will be taken at two tenths and another reading will be taken at eight tenths of the distance from the water surface to the stream bottom. (The top setting rod is directly calibrated for setting the meter six tenths of the distance from the water surface to the stream bottom, but must be manually set for two tenths and eight tenths of the distance.) Mean column velocity will be calculated to the nearest 100th of a foot per second.

Before removing the fish location markers from the stream bottom, a random sampling procedure will be used to select locations that were unoccupied by fish. After measuring the width and length of the mesohabitat area sampled, the tape used for making the measurement will be left stretched in or along the length of the stream. A random number table will then be used to determine the distance that the first unoccupied location will be located from the downstream end of the sampling area. A die will then be rolled to determine the distance across the stream to sample. If a "1", "2", "3", "4", or "5" is rolled, sampling will be conducted 1/6, 2/6, 3/6, 4/6, or 5/6 of the distance from the left side of the stream to the right side when facing upstream. If a "6" is rolled, a second roll of the die will be made. If the number on this second roll is even, sampling will be performed along the right bank; if the number is odd, sampling will be performed along the left bank when facing upstream.

Additional unoccupied locations will be selected using the same methodology described above. Unoccupied locations will not be selected within one foot of an occupied location. Data will be collected and recorded on a copy of the field data sheet for unoccupied locations shown in Appendix A4.

For each field sampling trip, the field crew leader will prepare trip notes using the form shown in Appendix A5.

Field data sheets and trip notes will be submitted to the transferability study coordinator (Dave Heicher), who will perform one-sided chi-square tests described by Thomas and Bovee (1993) to determine HSC transferability.

Appendix A1

Pennsylvania Fish and Boat Commission
Law Enforcement Regional Offices

Pennsylvania Fish and Boat Commission
Law Enforcement Regional Offices

Northwest Region: P.O. Box 349, 1281 Otter Street, Franklin, PA 16323. (814) 437-5774

Butler, Clarion, Crawford, Erie, Forest, Lawrence, Mercer, Venango and Warren Counties

Southwest Region: R.R. #2, Box 39, Somerset, PA 15501-9311. (814) 445-8974

Allegheny, Armstrong, Beaver, Cambria, Fayettte, Green, Indiana, Somerset, Washington and Westmoreland Counties

Northeast Region: P.O. Box 88, Sweet Valley, PA 18656. (717) 477-5717

Bradford, Carbon, Columbia, Lackawanna, Luzerne, Monroe, Montour, Northumberland, Pike, Sullivan, Susquehanna, Wayne and Wyoming Counties

Southeast Region: P.O. Box 8, Elm, PA 17521. (717) 626-0228

Berks, Bucks, Chester, Delaware, Lancaster, Lehigh, Montgomery, Northampton, Philadelphia and Schuylkill Counties

Northcentral Region: P.O. Box 187 (Fishing Creek Rd.), Lamar, PA 16848. (717) 726-6056

Cameron, Centre, Clearfield, Clinton, Elk, Jefferson, Lycoming, McKean, Northumberland, Potter, Snyder, Tioga and Union Counties

Southcentral Region: 1704 Pine Rd., Newville, PA 17241 (717) 486-7087

Adams, Bedford, Blair, Cumberland, Dauphin, Franklin, Fulton, Huntingdon, Juniata, Lebanon, Mifflin, Northumberland, Perry and York Counties

Appendix A2

List of Equipment for IFIM Transferability Studies

List of Equipment for IFIM Transferability Studies

Surface Observations
polarized sunglasses
camouflage clothing
binoculars
6-inch plastic ruler

Underwater Observations with Snorkel Gear
mask with corrective lenses, if necessary
snorkel
two-piece, semi-dry diving suit
neoprene gloves and boots
wading shoes
two 100-ft nylon ropes
fishing sinkers
indelible marker
plastic surveyor's ribbon
mesh bag
plastic jug

Electrofishing
backpack DC shocker with probes
gasoline mixed with oil
hand-held collection net
4 ft. X 4 ft. seine
hip boots
chest-high waders

Microhabitat Measurements and Other
top-setting rod
measuring rod for depths greater than can be measured with top-setting rod
Price AA current meter
Pygmy current meter
stopwatch or wristwatch with stop mode
100 ft. cloth or fiberglass tape
field data sheets
topographic quads and location maps
thermometer marked in degrees centigrade
random number table
die

Appendix A3

Field Data Sheet for Occupied Locations, IFIM Transferability Studies

Field Data Sheet for Occupied Locations, IFIM Transferability Studies

Stream Name:

Crew Members:

Type of Flow Meter:

Observation Number	Date	Time	Mesohabitat Type	Observation Technique	Tag No.	Sp.	Length (inches)	Life Stage	Depth (ft)	Rotations/ Seconds	Velocity (ft/sec.)	Temp. (°C)	Substrate	Cover

Field Data Sheet for Occupied Locations, IFIM Transferability Studies—Continued

Observation Number	Date	Time	Mesohabitat Type	Observation Technique	Tag No.	Sp.	Length (inches)	Life Stage	Depth (ft)	Rotations/ Seconds	Velocity (ft/sec.)	Temp. (°C)	Substrate	Cover

CODES FOR FILLING IN DATA SHEET

Species

BK = Brook trout

BN = Brown trout

Mesohabitat Type (code & description to be filled in after preliminary field evaluation)

1 ____________________

2 ____________________

3 ____________________

4 ____________________

5 ____________________

6 ____________________

7 ____________________

8 ____________________

9 ____________________

10 ____________________

Life Stage

AD = Adult (6 inches or more)

JU = Juvenile (2 to 6 inches)

FR = Fry (less than 2 inches)

SP = Spawning fish

RD = Redd

Observation Technique

SU = Surface observation

UN = Underwater observation (snorkel)

EL = Electrofishing

Cover

1 = No cover

2 = Object at least 6 inches high and with a cross section horizontal measurement of at least 1 ft

3 = Undercut object along bank

4 = Aquatic vegetation

5 = Terrestrial vegetation < 1 ft high

Substrate

1 = Diameter of < 3 mm (silt, sand)

2 = Diameter of 3 mm - 64 mm

3 = Diameter of > 64 mm

APPENDIX A4

FIELD DATA SHEET FOR UNOCCUPIED LOCATIONS, IFIM TRANSFERABILITY STUDIES

Field Data Sheet for Unoccupied Locations, IFIM Transferability Studies

Stream Name:	Crew Members:
	Type of Flow Meter:

Observation Number	Date	Time	Mesohabitat Type	Depth (ft)	Rotations/ Seconds	Velocity (ft/sec.)	Temp. (°C)	Substrate	Cover

Field Data Sheet for Unoccupied Locations, IFIM Transferability Studies—Continued

Observation Number	Date	Time	Mesohabitat Type	Depth (ft)	Rotations/ Seconds	Velocity (ft/sec.)	Temp. (°C)	Substrate	Cover

CODES FOR FILLING IN DATA SHEET

Mesohabitat Type (code & description to be filled in after preliminary field evaluation)

1 __________

2 __________

3 __________

4 __________

5 __________

6 __________

7 __________

8 __________

9 __________

10 __________

Substrate

1 = Diameter of < 3 mm (silt, sand)
2 = Diameter of 3 mm - 64 mm
3 = Diameter of > 64 mm

Cover

1 = No cover
2 = Object at least 6 inches high and with a cross section horizontal measurement of at least 1 ft
3 = Undercut object along bank
4 = Aquatic vegetation
5 = Terrestrial vegetation < 1 ft high

APPENDIX A5

TRIP NOTES FOR IFIM TRANSFERABILITY STUDIES

Trip Notes for IFIM Transferability Studies

Trip dates: ______________________

Areas of each mesohabitat type sampled

Mesohabitat type, with detailed description	Area sampled (sq. ft.)
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	

Streamflow measurement on first day of sampling _____ cubic feet per second

Notes: (Describe stream and other field conditions, sampling and equipment problems, and other pertinent information.)

APPENDIX B

TRANSFERABILITY STUDY TEST RESULTS

Table B1. One-Sided Chi-Square Tests for Habitat Suitability Criteria Transferability, Cherry Run, Brown Trout

Life Stage/Test Parameters	1st Data Set	2nd Data Set	1 & 2 Combined
Cherry Run, Adult Brown Trout			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	0	0	0
b, occupied usable cells	5	20	25
c, unoccupied optimum cells	0	1	1
d, unoccupied usable cells	3	12	15
N, total number of cells	8	33	41
T, test statistic	Not applicable	-1.260	-1.266
Transferable? (T>1.6449)	Not applicable	No	No
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	5	20	25
b, occupied unsuitable cells	58	51	109
c, unoccupied suitable cells	3	13	16
d, unoccupied unsuitable cells	201	199	400
N, total number of cells	267	283	550
T, test statistic	2.631	5.007	5.678
Transferable? (T>1.6449)	Yes	Yes	Yes
Cherry Run, Juvenile Brown Trout			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	0	1	1
b, occupied usable cells	50	60	110
c, unoccupied optimum cells	1	4	5
d, unoccupied usable cells	89	142	231
N, total number of cells	140	207	347
T, test statistic	-0.748	-0.470	-0.812
Transferable? (T>1.6449)	No	No	No
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	50	61	111
b, occupied unsuitable cells	11	5	16
c, unoccupied suitable cells	90	146	236
d, unoccupied unsuitable cells	114	66	180
N, total number of cells	265	278	543
T, test statistic	5.196	3.832	6.299
Transferable? (T>1.6449)	Yes	Yes	Yes

NOTE: For the above, optimum habitat was assumed to have a suitability index of 0.8 or more, and suitable habitat was assumed to have a suitability index of 0.1 or more.

Table B1. One-Sided Chi-Square Tests for Habitat Suitability Criteria Transferability, Cherry Run, Brown Trout—Continued

Life Stage/Test Parameter	1st Data Set	2nd Data Set	1 & 2 Combined
Cherry Run, Brown Trout Spawning			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	32		
b, occupied usable cells	13		
c, unoccupied optimum cells	22		
d, unoccupied usable cells	15		
N, total number of cells	82		
T, test statistic	1.107		
Transferable? (T>1.6449)	No		
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	45		
b, occupied unsuitable cells	12		
c, unoccupied suitable cells	37		
d, unoccupied unsuitable cells	173		
N, total number of cells	267		
T, test statistic	8.902		
Transferable? (T>1.6449)	Yes		
Cherry Run, Brown Trout Fry			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	6		
b, occupied usable cells	67		
c, unoccupied optimum cells	76		
d, unoccupied usable cells	124		
N, total number of cells	273		
T, test statistic	-4.751		
Transferable? (T>1.6449)	No		
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	73		
b, occupied unsuitable cells	2		
c, unoccupied suitable cells	200		
d, unoccupied unsuitable cells	12		
N, total number of cells	287		
T, test statistic	1.034		
Transferable? (T>1.6449)	No		

NOTE: For the above, optimum habitat was assumed to have a suitability index of 0.8 or more, and suitable habitat was assumed to have a suitability index of 0.1 or more.

Table B2. One-Sided Chi-Square Tests for Habitat Suitability Criteria Transferability, Little Fishing Creek, Brook Trout

Life Stage/Test Parameter	1st Data Set	2nd Data Set	1 & 2 Combined
Little Fishing Creek, Adult Brook Trout			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	0	0	0
b, occupied usable cells	17	20	37
c, unoccupied optimum cells	0	0	0
d, unoccupied usable cells	3	7	10
N, total number of cells	20	27	47
T, test statistic	Not applicable	Not applicable	Not applicable
Transferable? (T>1.6449)	Not applicable	Not applicable	Not applicable!
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	17	20	37
b, occupied unsuitable cells	44	56	100
c, unoccupied suitable cells	3	7	10
d, unoccupied unsuitable cells	205	205	410
N, total number of cells	269	288	557
T, test statistic	6.918	5.906	9.005
Transferable? (T>1.6449)	Yes	Yes	Yes
Little Fishing Creek, Juvenile Brook Trout			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	0	1	1
b, occupied usable cells	47	77	124
c, unoccupied optimum cells	0	0	0
d, unoccupied usable cells	95	102	197
N, total number of cells	142	180	322
T, test statistic	Not applicable	1.147	1.257
Transferable? (T>1.6449)	Not applicable	No	No
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	47	78	125
b, occupied unsuitable cells	17	16	33
c, unoccupied suitable cells	95	102	197
d, unoccupied unsuitable cells	113	110	223
N, total number of cells	272	306	578
T, test statistic	3.888	5.717	6.948
Transferable? (T>1.6449)	Yes	Yes	Yes

NOTE: For the above, optimum habitat was assumed to have a suitability index of 0.8 or more, and suitable habitat was assumed to have a suitability index of 0.1 or more.

Table B2. One-Sided Chi-Square Tests for Habitat Suitability Criteria Transferability, Little Fishing Creek, Brook Trout—Continued

Life Stage/Test Parameter	1st Data Set	2nd Data Set	1 & 2 Combined
Little Fishing Creek, Brook Trout Spawning			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	26		
b, occupied usable cells	27		
c, unoccupied optimum cells	8		
d, unoccupied usable cells	2		
N, total number of cells	63		
T, test statistic	-1.801		
Transferable? (T>1.6449)	No		
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	53		
b, occupied unsuitable cells	8		
c, unoccupied suitable cells	10		
d, unoccupied unsuitable cells	198		
N, total number of cells	269		
T, test statistic	13.310		
Transferable? (T>1.6449)	Yes		
Little Fishing Creek, Brook Trout Fry			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	10		
b, occupied usable cells	58		
c, unoccupied optimum cells	91		
d, unoccupied usable cells	115		
N, total number of cells	274		
T, test statistic	-4.368		
Transferable? (T>1.6449)	No		
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	68		
b, occupied unsuitable cells	7		
c, unoccupied suitable cells	206		
d, unoccupied unsuitable cells	6		
N, total number of cells	287		
T, test statistic	-2.328		
Transferable? (T>1.6449)	No		

NOTE: For the above, optimum habitat was assumed to have a suitability index of 0.8 or more, and suitable habitat was assumed to have a suitability index of 0.1 or more.

Table B3. One-Sided Chi-Square Tests for Habitat Suitability Criteria Transferability, Young Womans Creek, Brown Trout and Combined Brook/Brown Fry

Life Stage/Test Parameter	1st Data Set	2nd Data Set	1 & 2 Combined
Young Womans Creek, Adult Brown Trout			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	4	2	6
b, occupied usable cells	55	49	104
c, unoccupied optimum cells	0	0	0
d, unoccupied usable cells	86	82	168
N, total number of cells	145	133	278
T, test statistic	2.449	1.807	3.060
Transferable? (T>1.6449)	Yes	Yes	Yes
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	59	51	110
b, occupied unsuitable cells	22	5	27
c, unoccupied suitable cells	86	82	168
d, unoccupied unsuitable cells	121	128	249
N, total number of cells	288	266	554
T, test statistic	4.776	6.918	8.125
Transferable? (T>1.6449)	Yes	Yes	Yes
Young Womans Creek, Juvenile Brown Trout			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	2	1	3
b, occupied usable cells	51	59	110
c, unoccupied optimum cells	16	12	28
d, unoccupied usable cells	187	161	348
N, total number of cells	256	233	489
T, test statistic	-1.042	-1.532	-1.833
Transferable? (T>1.6449)	No	No	No
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	53	60	113
b, occupied unsuitable cells	2	1	3
c, unoccupied suitable cells	203	173	376
d, unoccupied unsuitable cells	22	37	59
N, total number of cells	280	271	551
T, test statistic	1.458	3.164	3.324
Transferable? (T>1.6449)	No	Yes	Yes

NOTE: For the above, optimum habitat was assumed to have a suitability index of 0.8 or more, and suitable habitat was assumed to have a suitability index of 0.1 or more.

Table B3. One-Sided Chi-Square Tests for Habitat Suitability Criteria Transferability, Young Womans Creek, Brown Trout and Combined Brook/Brown Fry —Continued

Life Stage/Test Parameter	1st Data Set	2nd Data Set	1 & 2 Combined
Young Womans Creek, Brown Trout Spawning			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	34		
b, occupied usable cells	10		
c, unoccupied optimum cells	5		
d, unoccupied usable cells	3		
N, total number of cells	52		
T, test statistic	0.888		
Transferable? (T>1.6449)	No		
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	44		
b, occupied unsuitable cells	20		
c, unoccupied suitable cells	8		
d, unoccupied unsuitable cells	202		
N, total number of cells	274		
T, test statistic	11.599		
Transferable? (T>1.6449)	Yes		
Young Womans Creek, Brook/Brown Trout Fry			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	19		
b, occupied usable cells	59		
c, unoccupied optimum cells	75		
d, unoccupied usable cells	122		
N, total number of cells	275		
T, test statistic	-2.161		
Transferable? (T>1.6449)	No		
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	78		
b, occupied unsuitable cells	11		
c, unoccupied suitable cells	197		
d, unoccupied unsuitable cells	22		
N, total number of cells	308		
T, test statistic	-0.595		
Transferable? (T>1.6449)	No		

NOTE: For the above, optimum habitat was assumed to have a suitability index of 0.8 or more, and suitable habitat was assumed to have a suitability index of 0.1 or more.

Table B4. One-Sided Chi Square Tests for Habitat Suitability Criteria Transferability, Young Womans Creek, Brook Trout

Life Stage/Test Parameter	1st Data Set	2nd Data Set	1 & 2 Combined
Young Womans Creek, Adult Brook Trout			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells		3	
b, occupied usable cells		51	
c, unoccupied optimum cells		0	
d, unoccupied usable cells		82	
N, total number of cells		136	
T, test statistic		2.158	
Transferable? (T>1.6449)		Yes	
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells		54	
b, occupied unsuitable cells		5	
c, unoccupied suitable cells		82	
d, unoccupied unsuitable cells		128	
N, total number of cells		269	
T, test statistic		7.123	
Transferable? (T>1.6449)		Yes	
Young Womans Creek, Juvenile Brook Trout			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells		3	
b, occupied usable cells		54	
c, unoccupied optimum cells		14	
d, unoccupied usable cells		200	
N, total number of cells		271	
T, test statistic		-0.354	
Transferable? (T>1.6449)		No	
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells		57	
b, occupied unsuitable cells		1	
c, unoccupied suitable cells		214	
d, unoccupied unsuitable cells		53	
N, total number of cells		325	
T, test statistic		3.361	
Transferable? (T>1.6449)		Yes	

NOTE: For the above, optimum habitat was assumed to have a suitability index of 0.8 or more, and suitable habitat was assumed to have a suitability index of 0.1 or more.

Table B5. One-Sided Chi-Square Tests for Habitat Suitability Criteria Transferability, Whitehead Run, Brook Trout

Life Stage/Test Parameter	1st Data Set	2nd Data Set	1 & 2 Combined
Whitehead Run, Adult Brook Trout			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	0	2	2
b, occupied usable cells	11	22	33
c, unoccupied optimum cells	0	0	0
d, unoccupied usable cells	13	24	37
N, total number of cells	24	48	72
T, test statistic	Not applicable	1.445	1.475
Transferable? (T>1.6449)	Not applicable	No	No
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	11	24	35
b, occupied unsuitable cells	48	36	84
c, unoccupied suitable cells	13	24	37
d, unoccupied unsuitable cells	197	184	381
N, total number of cells	269	268	537
T, test statistic	2.965	5.065	5.807
Transferable? (T>1.6449)	Yes	Yes	Yes
Whitehead Run, Juvenile Brook Trout			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	0	1	1
b, occupied usable cells	58	90	148
c, unoccupied optimum cells	0	1	1
d, unoccupied usable cells	129	155	284
N, total number of cells	187	247	434
T, test statistic	Not applicable	0.387	0.468
Transferable? (T>1.6449)	Not applicable	No	No
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	58	91	149
b, occupied unsuitable cells	3	7	10
c, unoccupied suitable cells	129	156	285
d, unoccupied unsuitable cells	81	52	133
N, total number of cells	271	306	577
T, test statistic	5.003	3.694	6.346
Transferable? (T>1.6449)	Yes	Yes	Yes

NOTE: For the above, optimum habitat was assumed to have a suitability index of 0.8 or more, and suitable habitat was assumed to have a suitability index of 0.1 or more.

Table B5. One-Sided Chi-Square Tests for Habitat Suitability Criteria Transferability, Whitehead Run, Brook Trout—Continued

Life Stage/Test Parameter	1st Data Set	2nd Data Set	1 & 2 Combined
Whitehead Run, Brook Trout Spawning			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	22		
b, occupied usable cells	40		
c, unoccupied optimum cells	13		
d, unoccupied usable cells	40		
N, total number of cells	115		
T, test statistic	1.273		
Transferable? (T>1.6449)	No		
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	62		
b, occupied unsuitable cells	3		
c, unoccupied suitable cells	53		
d, unoccupied unsuitable cells	157		
N, total number of cells	275		
T, test statistic	10.019		
Transferable? (T>1.6449)	Yes		
Whitehead Run, Brook Trout Fry			
Optimum Versus Usable Test Parameter			
a, occupied optimum cells	6		
b, occupied usable cells	45		
c, unoccupied optimum cells	15		
d, unoccupied usable cells	153		
N, total number of cells	219		
T, test statistic	0.603		
Transferable? (T>1.6449)	No		
Suitable Versus Unsuitable Test Parameter			
a, occupied suitable cells	51		
b, occupied unsuitable cells	6		
c, unoccupied suitable cells	168		
d, unoccupied unsuitable cells	44		
N, total number of cells	269		
T, test statistic	1.762		
Transferable? (T>1.6449)	Yes		

NOTE: For the above, optimum habitat was assumed to have a suitability index of 0.8 or more, and suitable habitat was assumed to have a suitability index of 0.1 or more.

APPENDIX C

FIELD DATA COLLECTION PROBLEMS

C1.0 GENERAL DISCUSSION OF FIELD DATA COLLECTION PROBLEMS

1. In some cases, study sites were selected without considering influences of aquatic vegetation, or effects of human activities. Sites should be free of human activities to the extent possible.

2. At some sites, benchmarks were not established on a permanent structure when the CDS was collected.

3. In some cases, end pin reference points and benchmark points were not clearly differentiated.

4. Field data sheets for some sites showed inadequate description of benchmarks and reference marks. The description should include the type of marking (PK nail, paint spot, etc.), type and size of object benchmark is located on (12" birch, large rock), and a general location (left bank 10 ft from edge of water, between run and riffle).

5. Partial data set

   a. In some cases, data sheets did not describe the benchmark used for the survey.

   b. In some cases, end pin elevations were not surveyed. These elevations are necessary to resolve elevation inconsistencies among data sets.

   c. Elevations of end pins and water surfaces were not computed in the field to check for errors.

   d. In some instances, transect location appears to be based on proximity to the other transects, rather than representativeness. The importance of transect selection can not be over stressed, considering a single transect represents a mesohabitat for an entire stream segment.

6. Four streams in the Maryland Piedmont appear not to be in dynamic equilibrium, and actively adjusting stream bed or banks. The channel changes are more apparent and extreme than observed elsewhere. Changes in flows, resulting from withdrawals from these streams, may alter substrate, and affect fishery habitat. Effects of changing substrate were not considered in this study (C. Spaur, U.S. Army Corps of Engineers, written communication 9/20/95, and oral communication 10/27/97). The data for the Maryland Piedmont streams should be used cautiously pending further evaluation of these effects.

C2.0 SPECIFIC STREAM DATA COLLECTION PROBLEMS

Stream Name	Segment	Problems
Black Ash Run (Luzerne County)	1	Eliminated, no trout observed. Owner said stream becomes dry in summer.
Broad Run (Franklin County)	1	Eliminated from study because site was located too close to segment 2 site.
Broad Run (Franklin County)	2	Changed to segment 1 when original segment 1 was eliminated. A permanent benchmark was not established at the site when the CDS was collected. The original run transect was not satisfactory for low flow work, so it was relocated upstream. The original riffle transect was skewed across the stream, resulting in a sloping stream bottom. Returning crews had difficulty locating the tail pin at the skewed riffle transect.
Cedar Run (Centre County)	1	Aquatic vegetation may have affected velocity measurements.
Dunlap Run (Clearfield County)	1	Leaf accumulation affected water surface elevation, possibly due to very narrow stream.
First Mine Branch (Baltimore County)	1	Possible influence of old mill works on site.
Fowler Hollow Run (Perry County)	1	Original site was located within segment 2 because of inaccurate existing mapping. Site was relocated upstream to the midpoint of segment 1. The use of a hand-held Global Positioning System (GPS) receiver would have eliminated this problem.
Georgetown Branch (Bedford County)	1	Stream eliminated because of no trout reproduction.
Gillis Falls (Carroll County)	1	Forested wetlands above bankfull elevation may influence hydraulics at high flow. Small mill dams may have been present in the past. Stream is presently cutting through mill pond deposits, resulting in potential channel instability.
Gillis Falls (Carroll County)	2	Possible anomalous quantity of gravel for this stream.
Greene Branch (Baltimore County)		Large volume of fine grained micaceous sediment, may be result of accelerated erosion of uplands due to human activities.
Kase Run (Montour County)	1	Stream eliminated because of no trout reproduction.

Stream Name	Segment	Problems
Lanigan Branch (Elk County)	1	Gated access road, unable to gain access.
Laurel Run (Juniata County)	2	Eliminated from study due to poor access.
Letort Spring Run (Cumberland County)	1	Vegetation upstream of the run transect caused unusual column velocities at some verticals, necessitating measuring column velocities at 0.2, 0.6 and 0.8 times the depth. Original transect relocated a short distance because of vegetation affecting velocity measurements.
Letort Spring Run (Cumberland County)	2	Original transect located in reach with split channel. Transect re-located downstream. Seasonal variations in vegetation downstream from transect may have caused seasonal variations in depth/velocity/discharge relationships.
Little Fishing Creek (Clinton County)	1	Skewed riffle transect resulted in sloping stream bottom and water surface.
Meyers Run (Centre County)	1	Leaf accumulation affected water surface elevation, possibly due to very narrow stream.
Piney Run (Carroll County)		Stream appears to be cutting through mill pond deposits, and streambank is unstable. Forested wetlands in vicinity of site at and above top of bank may influence hydraulics at high flows.
Sicily Run (McKean County)	1	Gated access road, unable to gain access.
Sugar Camp Run (Jefferson County)	1	Eliminated, water quality could not support a natural trout population.
Third Mine Branch (Baltimore County)		Water depths seem to have changed substantially at run site on different visits, probably due to erosion and deposition of bed materials. Stream appears to be cutting through mill pond deposits, and streambank is unstable. Forested wetlands in vicinity of site at and above bankfull may influence hydraulics at high flows.
Three Square Hollow (Cumberland County)	1	Stream eliminated because of no trout reproduction.
Upper Stimpson Run (Clinton County)	1	Eliminated, no trout or other fish observed.
Wapwallopen Creek (Luzerne County)	5	Eliminated from study due to poor access.

Appendix D

Hydrologic Computations for Selected Watersheds

D1.0 INTRODUCTION

General aspects of the hydrologic computations are described in section 5.5. The hydrologic computations for certain streams, where complex geology, withdrawals, or WWTP flows complicated the hydrology, are described in this appendix.

D2.0 STUDY SITES ON MONOCACY CREEK, NORTHAMPTON COUNTY

The hydrology for the study sites on Monocacy Creek is complicated by the fact that part of the watershed is underlain by shale rock, and part is underlain by limestone rock. These different rock types have different hydrologic characteristics. The study sites on Monocacy Creek are located in limestone areas.

U.S. Geological Survey (USGS) has operated a stream gage on Monocacy Creek at Bethlehem since 1949. Wood and others (1972) estimate there is an unmeasured underflow at the Monocacy Creek gage of 12 cfs on an average annual basis.

The hydrology for the three study sites was estimated by using the flow data collected at the study sites and the daily flow at the gage on the same date to solve water balance equations. Water balance equations basically show that the amount of water coming into the study site equals the amount of water leaving the study site. The water balance equations were used to estimate the flows from each type of geology for the date on which the complete data set (CDS) was collected. The observed daily flow at the gage was adjusted by adding the average underflow at the gage, and then water balance equations were written for each study site to account for streamflows contributed by each type of geology, and the underflow bypassing that site. Then flows for each type of geology were converted to unit flow (cubic feet per second per square mile, csm) rates, and used to estimate hydrology for the study sites. For the purpose of writing the water balance equations, the gage was considered as a fourth study site.

The water balance equations used in this study had the general form that the water coming into the study site was equal to the streamflow leaving the upstream segment, plus the runoff and spring flow generated in the study segment, minus any underflow bypassing the study site. These equations can be represented mathematically as:

$$\sum rL_i * AL_i + \sum rS_i * AS_i + \sum S_i - \sum U_i = Q_n \quad \text{(D1)}$$

where:

- $\sum$ = the summation operator;
- $*$ = the multiplication operator;
- rL_i = the runoff rate from the limestone part of the i^{th} segment;
- rS_i = the runoff rate from the shale part of the i^{th} segment;
- AL_i = the area of the i^{th} segment underlain by limestone;
- AS_i = the area of the i^{th} segment underlain by shale;
- U_i = the incremental underflow bypassing the i^{th} study site;
- S_i = the spring flow in the i^{th} study segment;
- Q_n = the streamflow measured at the n^{th} study site for a specific measurement.

In these equations, the summations are for all the study sites contributing flow to the n^{th} study site.

The underflow at the gage probably varies with flow rate, but the only data available regarding that underflow is the average daily flow of 12 cfs (Wood and others, 1972). Because of the lack of data, the underflow was assumed to be constant at 12 cfs. The sum of the underflows passing the respective study sites should equal 12 cfs, resulting in the following water balance equation:

$$\sum U_i = 12 \text{ cfs} \quad \text{(D2)}$$

For Monocacy Creek, the spring flow terms were assumed to be zero, since there are no significant springs in this watershed (Flippo, 1974). Therefore, these equations need to be solved for the runoff rates from the different rock types, and the amount of underflow bypassing the respective study site. However, there are four segments, each with two values of runoff and an underflow, resulting in five equations and 12 unknown variables. To reduce the number of unknowns, the runoff rates for each rock type were assumed equal for each segment, and the shale runoff rates were set to zero for segments where shale is not present. This results in five equations and six unknown variables. To solve the equations, another unknown variable had to be assumed. Most of the watershed above study site 1 is underlain by shale, and only a small part is underlain by limestone. Therefore, it was assumed that negligible underflow would bypass this study site. Because of this assumption, and because the variables of greatest interest are the runoff rates for the different rock types, the underflow from segment 1 was assumed to be zero.

These equations were written in matrix form in the Excel spreadsheet program, and solved using the matrix functions in Excel.

The solution is summarized in Table D1. In this table, the unit runoff rates (csm) for each rock type are shown in the first two rows of the second column. The flow rates for each rock type (column 1 multiplied by drainage area in that rock type), the underflow, and the total flow for each study site are shown in the remaining columns. The underflow is the total amount of underflow bypassing the respective study site. For example, at the time the CDS was collected, the underflow at study site 2 is estimated to be 22.83 cfs, while the underflow at sites 3 and 4 are estimated as 17.06 and 11.99 cfs, respectively, based on the assumptions used to solve the water balance equations. The estimated streamflow in row 4 is the sum of the runoff and underflow.

Table D1. Summary of Monocacy Creek Flows for Complete Data Set

Water Balance Component	Unit Flow Rate (csm)	Flow Rate Site 1 (cfs)	Flow Rate Site 2 (cfs)	Flow Rate Site 3 (cfs)	Flow Rate Site 4 (cfs)
Runoff from shale	0.75	5.63	10.99	10.99	10.99
Runoff from limestone	1.84	1.79	36.03	49.28	54.98
Accumulated underflow	—	0	-22.83	-17.06	-11.99
Estimated total streamflow	—	7.42	24.19	43.21	53.98
Measured streamflow	—	7.41	24.20	43.20	54.00

Conceptually, the estimated underflow could be assumed constant for all flow conditions, but that assumption is probably unrealistic, considering the underflow has been estimated using only one field data set. The variation of underflow rates with streamflow was estimated by assuming that the underflow is a constant percentage (or ratio) of the streamflow. The ratio of underflow bypassing each study site for the CDS was estimated by dividing the amount of underflow by the measured flow at each study site. Then the measured flow at the site was adjusted to estimate the amount of flow that would have occurred in the absence of the underflow. To make the adjustment, the underflow was computed by multiplying the measured flow by the underflow ratio and adding the underflow to the measured flow. The computations and the resulting flow at the study site(s) are shown in Table D2.

Table D2. Summary of Monocacy Creek Underflow Estimates

Study Site	Measured Flow (cfs)	Accumulated Underflow * (cfs)	Accumulated Underflow Ratio *	Adjusted Flow (cfs)
1	7.41	0	0	7.41
2	24.20	-22.80	-0.942	47.00
3	43.20	-17.06	-0.394	60.25
4	54.00	-11.99	-0.221	65.96

* Minus sign indicates underflow bypassing study site.

The procedure used to compute the necessary hydrology for the Monocacy Creek study sites included the following steps:

- Jordan Creek at Schnecksville (L. Taylor, SRBC, oral communication; C. Wood, USGS, oral communication) was used to represent the runoff from the part of the Monocacy Creek watershed underlain by shale;
- Flow rates for Jordan Creek at selected probabilities of exceedance were tabulated and converted to unit flow rates (csm), and then multiplied by the drainage area at the Monocacy Creek gage underlain by shale;
- Flow rates at the Monocacy Creek gage were tabulated at the same selected probabilities of exceedance, and adjusted by adding the underflow, estimated by multiplying the actual flow by the underflow ratio (0.221) at the gage;
- The flow rates for areas underlain by shale were subtracted from the adjusted Monocacy Creek gage flow rates to obtain the flow rates for areas underlain by limestone;
- The flow rates at the gage for the areas underlain by limestone were converted to unit flow rates (csm), and then multiplied by the drainage area of each study site underlain by limestone to obtain the corresponding flow for that rock type and study site;
- For each study site, the Jordan Creek unit flow rates (csm) were multiplied by the area underlain by shale, and added to the corresponding flow rates for the areas underlain by limestone, to estimate the total flow rate for that study site, neglecting the underflow;
- For each study site, the unadjusted total flow rates were adjusted using the accumulated underflow ratio shown in Table D2.

D3.0 STUDY SITES ON BUSHKILL CREEK, NORTHAMPTON COUNTY

Bushkill Creek is adjacent to Monocacy Creek, and has similarly mixed shale and limestone geology. The study sites on Bushkill Creek also are located in limestone.

The flows for the Bushkill Creek study sites were computed by multiplying the unit flow rates (csm) for each rock type, determined as described for Monocacy Creek, by the drainage area of Bushkill Creek underlain by the respective rock type, and summing the products. Flow values for study site 2 were adjusted by adding 3.57 cfs to represent the average daily net import to the segment discharged by the Nazareth WWTP (S. Runkle, Pa. Dept. of Environmental Protection, oral communication).

D4.0 STUDY SITES ON CEDAR CREEK, LEHIGH COUNTY

The hydrology of the Cedar Creek Basin is complicated by varying rock types, the discharge of Schantz Spring to the watershed, and the fact that the City of Allentown withdraws most of the flow of Schantz Spring for water supply (Wood and others, 1972).

Because only about 20 percent of the Cedar Creek Watershed is underlain by freestone (Wood and others, 1972), the watershed was assumed to be entirely underlain by limestone. Schantz Spring is located within the Cedar Creek Watershed, but most of the drainage area contributing to Schantz Spring is in adjacent surface water basins (Wood and others, 1972).

The adjusted drainage area for Cedar Run was determined by subtracting the portion of the drainage area of Schantz Spring within the Cedar Creek drainage area (2.15 square miles) (Wood and others 1972) from the drainage area at the study site (11.58 square miles).

Although the amount of spring flow reaching Cedar Creek probably varies with the total spring flow, the only data readily available is the average daily flow estimated as 1.6 mgd (2.48 cfs) (Wood and others, 1972).

The unadjusted flow for Cedar Creek was computed by multiplying the unit flow rates (csm) for the limestone area, as determined for Monocacy Creek, by the adjusted drainage area for Cedar Run at the study site. Then these flows were adjusted by adding the part of the Schantz Spring flow that reaches Cedar Run.

D5.0 STUDY SITE ON NANCY RUN, BERKS COUNTY

Nancy Run is entirely underlain by limestone rock. The necessary hydrology was determined by multiplying the adjusted unit flow rates (csm) for areas underlain by limestone, determined for the Monocacy Creek gage (section D2.0), by the drainage area at the Nancy Run study site.

D6.0 STUDY SITE ON TROUT CREEK, LEHIGH COUNTY

About 55 percent of the Trout Creek Watershed is within the Reading Prong physiographic subprovince. The Reading Prong is underlain by metamorphic rocks, which have very different hydrology compared to the limestone or shale areas.

Furnace Creek near Robesonia is the only gage available to represent flows from the metamorphic rocks. This gage has short records (1983-93), and is affected by water supply withdrawal from a small reservoir. Based on withdrawal data for 5 years during the period 1983 to 1990 (T. Denslinger, Pa. DEP, oral communication), the average daily withdrawal was estimated as 0.66 cfs, with a standard deviation of 0.11 cfs.

To obtain the hydrology for Trout Creek, the flow rates for Furnace Creek were tabulated, adjusted for the estimated average daily withdrawal, and multiplied by the appropriate ratio of drainage areas to obtain the flows from the metamorphic rocks on Trout Creek. The adjusted unit flow rates for areas underlain by limestone determined for Monocacy Creek (section D2.0) were multiplied by the drainage area of Trout Creek underlain by limestone rocks, and added to the flow rates from the metamorphic rocks to obtain flow rates at the study site.

D7.0 STUDY SITE ON SPRING CREEK, BERKS COUNTY

The geology of the Spring Creek Watershed is very complex, because part of the watershed is underlain by metamorphic rocks, part is underlain by limestone, and part is underlain by shale.

The flow rates for the limestone rock were estimated from the flow rates for areas underlain by limestone determined for Monocacy Creek, (section D2.0). The flow rates for areas underlain by metamorphic rocks were estimated using the flow rates at the Furnace Creek gage, adjusted for the effect of the water supply withdrawal (section D6.0). The flow rates for the area underlain by shale rocks were estimated using the unit flow rates for Jordan Creek at Schnecksville. The flow rates for each type of geology were determined using a ratio of drainage areas, and then summed to obtain total flow rates.

D8.0 STUDY SITES ON LETORT SPRING RUN, CUMBERLAND COUNTY

The hydrology of Letort Spring Run is complicated by at least 16 springs in the limestone strata on the watershed (Barrick, 1977). While there are no specific flow data to estimate the drainage area for these springs, it is likely the ground-water divide does not coincide with the surface water divide (L. Taylor, SRBC, oral communication).

USGS has operated a stream gage near the mouth of the watershed since 1976. Several flow measurements were made at other locations in the watershed by USGS in calendar years 1990 (Loper and others, 1991) and 1991 (Durlin and Schaffstall, 1992). Since these measurements were made at locations other than the sites measured for this study, the USGS data were used only to check the procedures developed.

The first study site is located a short distance upstream from the watercress beds at Bonny Brook. The second study site is located downstream from the Harmony Hall Road bridge, east of the Army War College. For the purpose of estimating the hydrology, an additional study site was assumed at the USGS gage. Based on a map prepared by Barrick (1977), the springs appear to occur only in the first two segments.

After several trials at estimating the annual flow duration at the study sites, the five sets of flow measurements available for the study sites were used to solve the water balance equations (equation D1), similar to the solution for Monocacy Creek. However, this watershed is entirely underlain by limestone, and therefore, the first two terms in equation D1 become one term. Also, the springs are assumed to be important factors in the hydrology, although Flippo (1974) does not show any significant springs in this watershed. Therefore, the unknown variables in the equations are the runoff rates for each segment and the spring flow rates for segments 1 and 2. In effect, the flow data at the study sites and the equations are used to partition the observed flow rates at the gage into flow components at the study sites.

The measured flow at the gage was assumed to be represented by the daily flow on the same day the measurements were made.

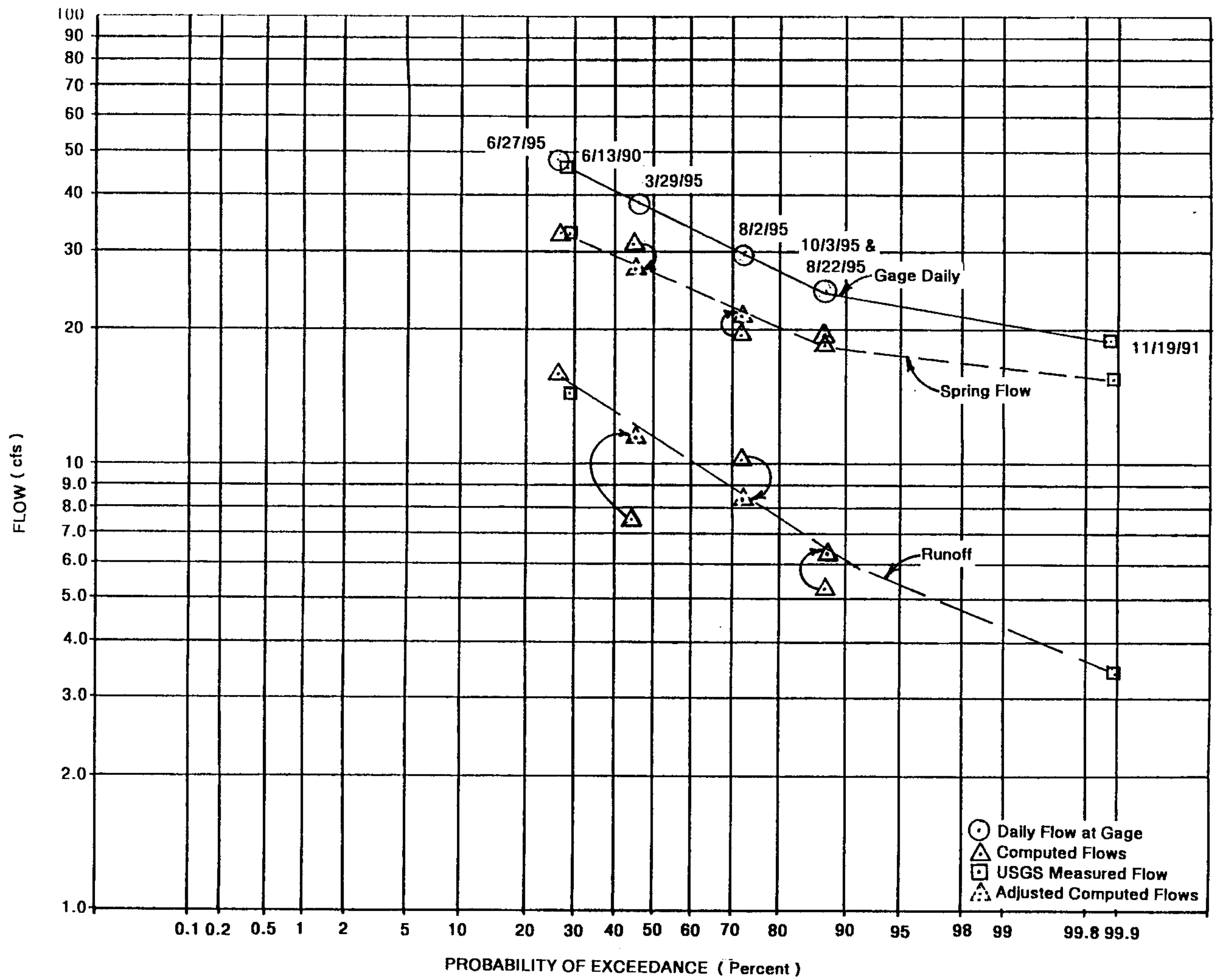


Figure D1. Letort Spring Run Flow Duration at Stream Gage

These equations were solved for each of the five flow measurements. For each measurement, there are three equations and five unknown variables. The number of unknown variables was reduced by assuming the runoff rates (csm) were the same for each segment.

The solutions for each event were tabulated along with the probability of exceedance of the daily flow rate at the gage. This tabulation showed inconsistencies among events, probably due to the assumptions involved.

For each event, the estimated runoff and spring flows, and observed flows at the gage were plotted on log-normal probability paper, and then fitted by eye, as shown in Figure D1. For the measurement taken on March 29, 1995, the water balance calculation apparently overestimates the spring flow and underestimates the runoff, compared to the trend of the other measurements, so the computed values were adjusted to obtain the best fit and maintain the total flow, as shown by arrows and dashed symbols in the figure. For the measurement taken on August 2, 1995, the water balance calculation appears to underestimate the spring flow and overestimate the runoff, so similar adjustments were made, as shown in the figure. Note the adjusted values plot very close to the eye-fit line. Also, note that measurements made on August 22, 1995, and October 3, 1995, were identical at the gage, but the computed spring flow and runoff values were slightly different. Minor adjustments were made to these flows so that they coincide.

The flow duration for the gage and the measured flows at each site were plotted on log-normal probability paper, as shown in Figure D2. Note the measurements made at both study sites on June 27, 1995, are anomalous, compared to the other measurements. This is probably due to significant rainfall at the time of this measurement, which violates the steady-state assumption implicit in the water balance calculations. For that reason, the measurement was ignored. The remaining measurements were again fitted by eye.

These curves were extrapolated to higher and lower flows as follows. The flow duration curve for study site 2 parallels the gage curve within the range of the measured flows (probabilities of exceedance between 45 percent and 87 percent). The curve was extrapolated to lower flows by assuming the two lines remain parallel, which implies a constant percentage difference between the gage flow and the study site 2 flow. To allow for increased runoff between study site 2 and the gage at higher flows, a straight line extrapolation was assumed for flows greater than the measured flows (probabilities less than 45 percent).

For study site 1, the measurements do not follow the expected pattern, especially if the June 27, 1995, measurement is included, but the eye-fit line through those points between 45 percent and 87 percent probability seems reasonable. A straight line extrapolation to probabilities less than 45 percent was assumed. The curve was extrapolated to probabilities greater than 87 percent by assuming a constant difference between the gage flows and the site 1 flows.

The necessary hydrology at the Letort Spring Run study sites was determined using the flow duration curves, shown in Figure D2, as follows:

- The flows at the gage were determined from the gage record;
- The probability of those flows at the gage was determined from the gage flow duration curve; and
- The flows at the study sites were computed by summing the runoff and spring flows for the respective segment.

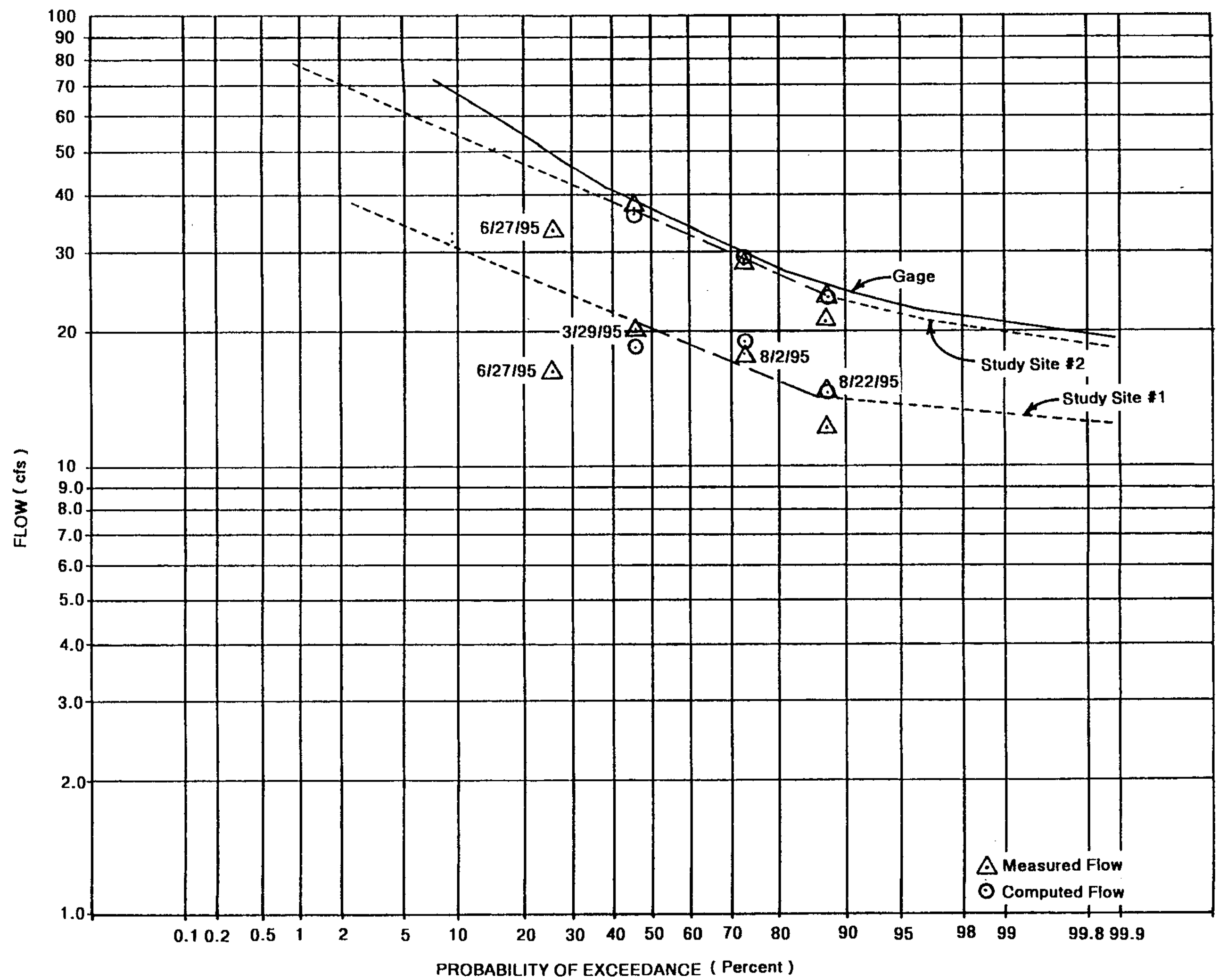


Figure D2. Letort Spring Run Flow Duration for Study Sites and Stream Gage

The runoff rates were obtained from Figure D1, converted to unit flow rates (csm), and plotted on log-normal probability paper, as shown in Figure D3. These runoff rates were used to determine runoff rates for Trindle Spring Run, Big Spring Creek, and Falling Spring Run, which were believed to have similar runoff characteristics.

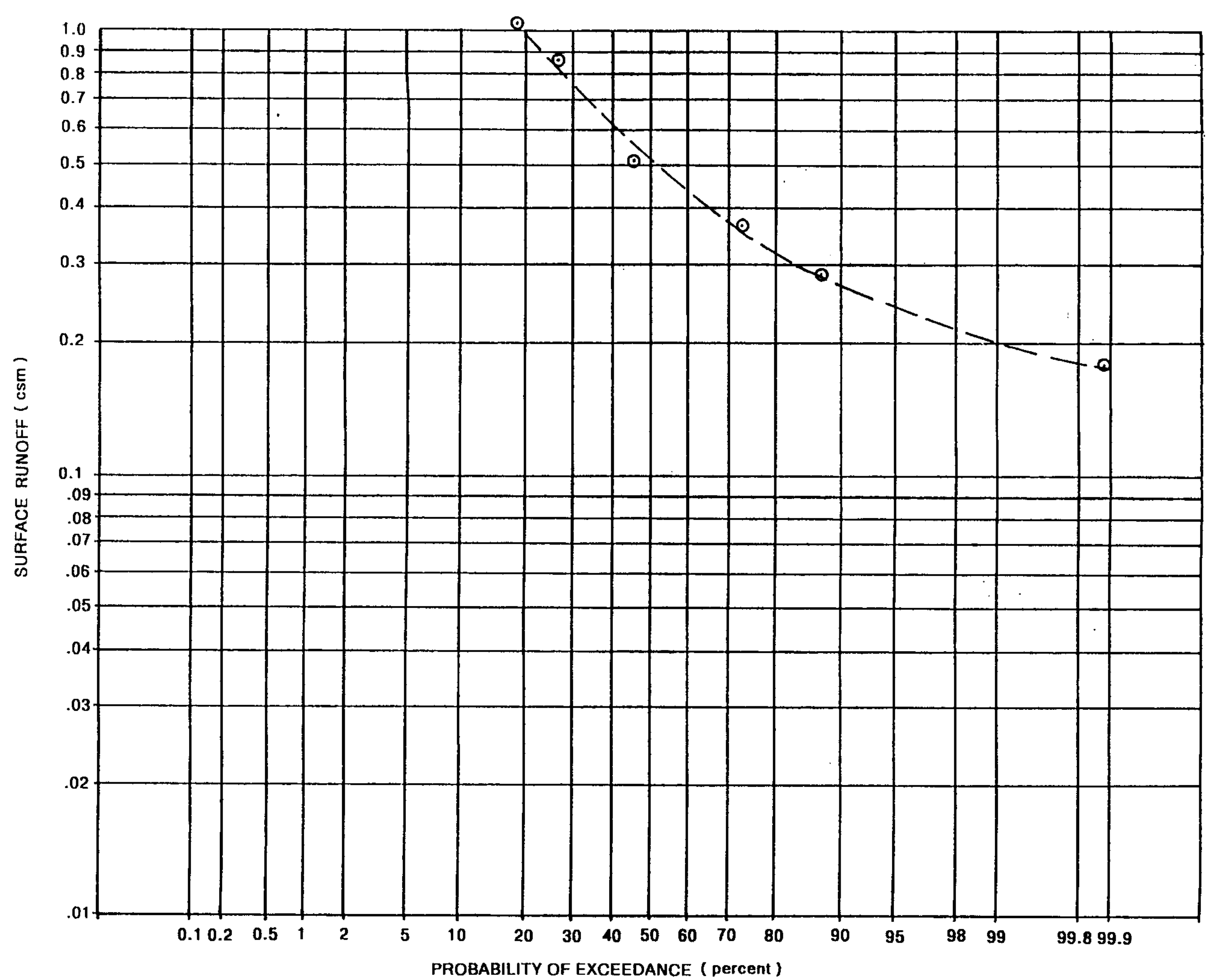


Figure D3. Letort Spring Run Flow Duration for Runoff Only

D9.0 STUDY SITE ON TRINDLE SPRING RUN, CUMBERLAND COUNTY

USGS measured Trindle Spring Run flows on June 13, 1990 (Loper and others, 1991), and November 18, 1991 (Durlin and Schaffstall, 1992), at a location close to the study site. These flow measurements range from 12 to 21 cfs, and did not appear to have any relationship to flows at nearby gages. For that reason, and the fact that the drainage area at the USGS site is about 8 percent less than the drainage area at the site used in this study, the USGS measurements were not used to develop hydrology.

Flippo (1974) shows two springs on the Trindle Spring Run Watershed, Trindle Spring and Silver Spring, and shows two sets of flow measurements for each spring. For Trindle Spring, the measured flow on November 6, 1970, was 960 gpm (2.14 cfs); the measured flow on November 11, 1971, was 730 gpm (1.63 cfs). For Silver Spring, the flows measured on the same dates were 1,690 gpm (3.77 cfs) and 1,890 gpm (4.21 cfs), respectively. Flippo (1974) estimates the median flow rates for Trindle Spring and Silver Spring as 850 gpm (1.89 cfs) and 1,900 gpm (4.23 cfs), respectively. Because the absolute variation in the measured flow rates is small, and no additional data are available, the spring flow rate was assumed constant at the sum of the median values.

The annual flow duration curve was estimated by multiplying the unit runoff rates (csm) for Letort Spring Run, as shown in Figure D3**,** by the drainage area at the site, and adding the spring flow.

Annual mean and median flows, seasonal flow duration, and median monthly time series were estimated as follows:

- The appropriate flow values were determined from the Letort Spring Run gage data;
- The probability of those flows was determined from the Letort Spring Run gage flow duration curve;
- The runoff rates for Letort Spring Run were determined from Figure D3 at the same probability; and
- The runoff rates were multiplied by the site drainage area and the median spring flows were added to obtain Trindle Spring Run flows.

D10.0 STUDY SITE ON BIG SPRING CREEK, CUMBERLAND COUNTY

The hydrology of Big Spring Creek is complicated by a large spring (Big Spring) near the headwaters, and upstream of the study site. Becher and Root (1981) estimate Big Spring diverts between 5 and 10 percent of the flow of the adjacent Yellow Breeches Creek. Flippo (1974) shows nine measurements of Big Spring flows that range from 7,500 gpm (16.7 cfs) to 13,900 gpm (31.0 cfs). He estimates the maximum spring flow as 15,000 gpm. (33.5 cfs), and the minimum spring flow as 6,000 gpm. (13.4 cfs). The USGS measured the spring flow on June 14, 1990 (Loper and others, 1991), and November 20, 1991 (Durlin and Schaffstall, 1992). The flow rate was 24 cfs on both dates. An additional measurement was made for this study on January 27, 1995. Because the spring flow data shows wide variation, the spring flow could not be assumed constant, as for Trindle Spring Run.

Gage flow data are the only information available to estimate the probability of the measured spring flows. The probability of exceedance of the spring flow was assumed to be equal to the probability of the streamflow on the same date at one or more nearby gages, Conodoguinet Creek near Hogestown, Yellow Breeches Creek near Camp Hill, or Letort Spring Run near Carlisle.

Initial attempts to estimate the probability of the spring flows by using probabilities of the flows for these gages, produced uncertain results. Further comparisons of flows based on these three gages showed flows based on Letort Spring Run gage data were closest to the observed flows at the study site.

The nine spring flows shown by Flippo (1974), the spring flow value collected for this study, and the probability of exceedance are summarized in Table D3. These data were plotted on log-normal probability paper, as shown in Figure D4**.**

The six spring flow values for the months of June through October plot around a straight line (Figure D4), which increases with decreasing probability. The four spring flow values for the months of November and January also plot around a straight line, but flows decrease with decreasing probability, and are significantly less than the summer and early fall data. This suggests that season affects the spring flows, but the data are insufficient to confirm that conclusion. Since the behavior of the late fall and winter data is anomalous and unexplainable, it was ignored in subsequent analyses. The summer and early fall curve was used in estimating the probability of the spring flows to synthesize a flow duration curve for the study site.

After several unsuccessful attempts, the following procedure was developed to estimate the flow duration curve for Big Spring Creek:

- Multiply the Letort Spring Run runoff rates (csm) (Figure D3) by the drainage area at the Big Spring Creek study site;
- Add assumed spring flow rates that ranged from 23 cfs at 98 percent probability of exceedance to 32.8 cfs at 20 percent probability of exceedance, as shown in Figure D4; and
- Plot the resulting flow duration curve and the measured flows at the study site, assuming the probabilities of the measured flows are the same as the probabilities of the flows at the Letort Spring Run gage on the same date.

Comparison of the measured flows at the Big Spring Creek study site with the flow duration curve showed reasonable agreement and better fit than other approaches, so this flow duration curve was adopted.

The necessary hydrology at the study site was determined from this flow duration by using flows and probabilities for the Letort Spring Run gage.

Table D3. Big Spring Creek, Cumberland County, Spring Flow Data and Concurrent Flows at Nearby Gages

Spring Flow Data		Conodoguinet		Yellow Breeches		Letort Spring Run	
Date	Spring cfs	Flow cfs	Exceedance Probability percent	Flow cfs	Exceedance Probability percent	Flow cfs	Exceedance Probability percent
06/09/44	31.00	313	51				
07/07/44	28.77	360	45				
08/17/49	26.76	113	90				
08/20/65	24.08			92	99.3		
01/13/67	16.73			139	78		
01/17/67	18.29			148	74		
10/16/67	22.97	102	93	120	88.4		
10/05/71	26.76	152	78.8	145	75.3		
11/11/71	25.42	290	54.4	202	53.2		
01/27/95	16.49	894	16	493	11.7	66	10.75

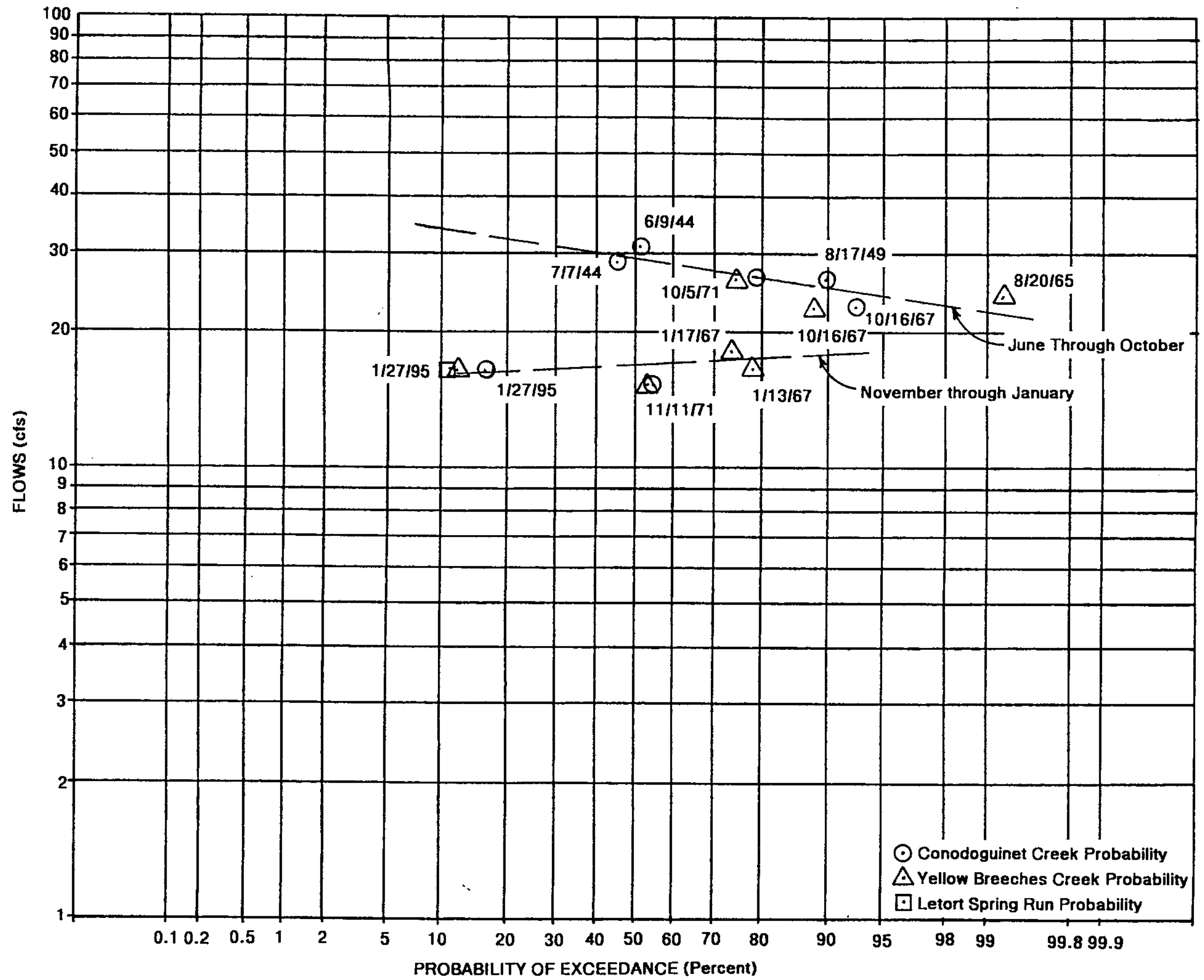


Figure D4. Big Spring Creek, Cumberland County, Flow Duration for Spring Flow

D11.0 STUDY SITE ON FALLING SPRING RUN, FRANKLIN COUNTY

There are two springs on the Falling Spring Run Watershed that are very close together and a short distance upstream from the study site. Flippo (1974) shows two spring flow measurements that are nearly equal. Because of the limited spring flow data available, additional spring flow measurements were made as part of three of the five data sets collected at the study site. The site and spring flow measurements are summarized in Table D4**.**

Table D4. Summary of Flow Measurements for Falling Spring Run

Measurement Date	Site Flow (cfs)	Spring Flow (cfs)	Letort Spring Run Flow (cfs)	Letort Probability (percent)
07/14/94	23.33	—	37	51
11/02/94	19.34	—	38	48
11/09/94	14.08	12.14	31	70
08/02/95	15.90	7.11	29	75
10/04/95	13.58	5.51	26	84

After several unsuccessful trials, the following procedure was used to determine the site flow duration curve.

- The site flows were plotted versus probability of exceedance of the corresponding gage flows for both Letort Spring Run near Carlisle and Conodoguinet Creek near Hogestown;
- The corresponding spring flows were plotted on the same graph, using the same probabilities;
- The spring flow measurements given by Flippo (1974) were plotted on the same graph, with the probability of exceedance determined from the concurrent Conodoguinet Creek flows, as shown in Figure D5. (Conodoguinet Creek was used to determine probability of exceedance for plotting these measurements, because the Letort Spring Run gage was not in operation at the time); and
- Curves were fitted to the site flows and spring flows by eye.

This plot shows the site measurements are reasonably consistent, with the exception of the July 14, 1994, measurement. That measurement was assumed to be incorrect, and was ignored for the purpose of developing hydrology. The spring flow measurements also fit reasonably well, with the exception of the November 9, 1994, and November 10, 1971, measurements reported by Flippo (1974).

Considering the natural complexity of the system and the scarcity of data to allow resolution of the complexity, this appears to be the best flow duration curve at the study site.

The necessary hydrology at the Falling Spring Run study site was determined in the same manner as for Trindle Spring Run.

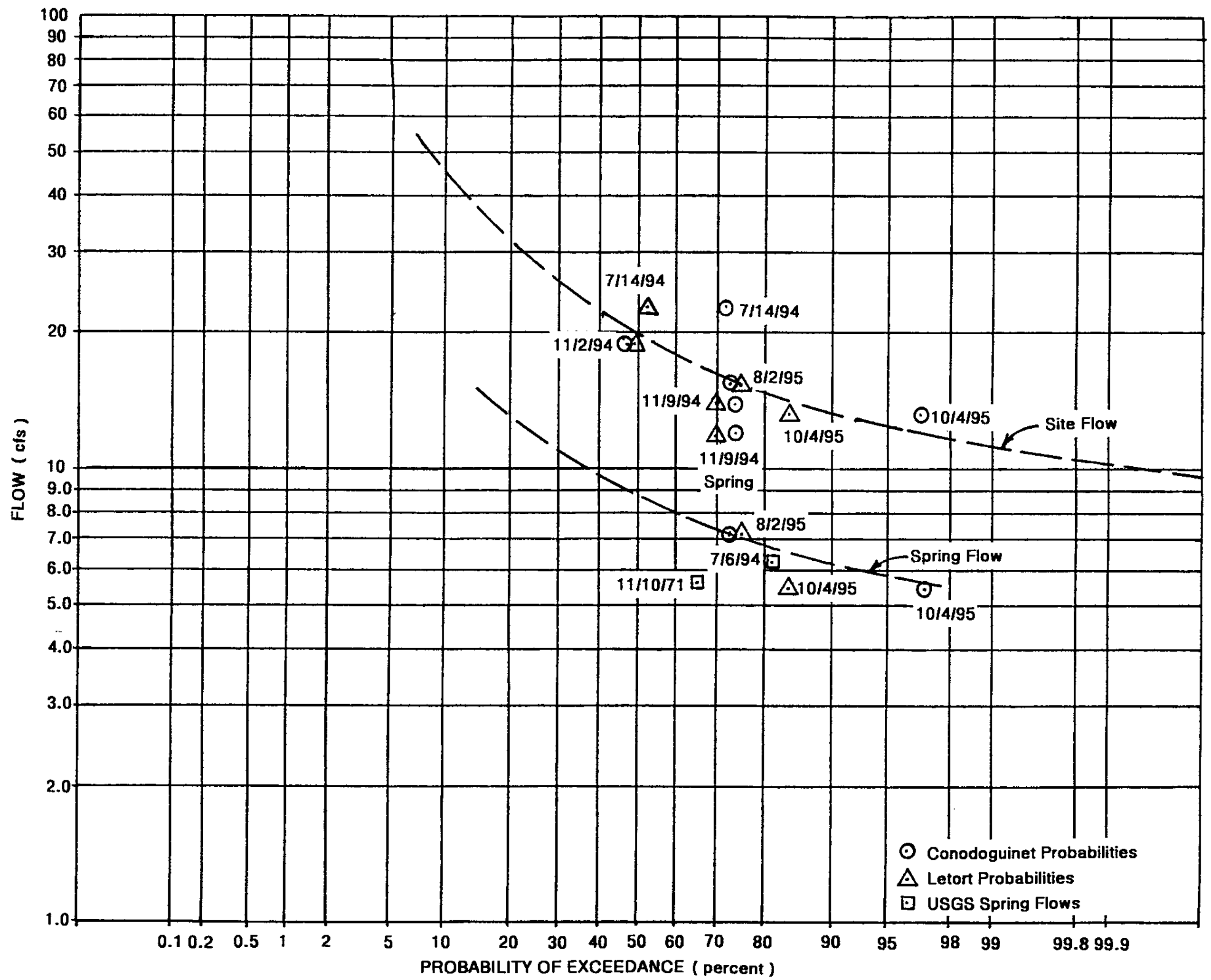


Figure D5. Falling Spring Run Flow Durations for Study Site and Springs

D12.0 STUDY SITES ON SPRING CREEK, CENTRE COUNTY

Five study segments are located in the Spring Creek Watershed, Cedar Run, and four segments on the main stem of Spring Creek. A drainage area ratio was applied to the Houserville gage data to estimate hydrology for Cedar Run and Spring Creek study sites 1 and 2. The hydrology for Spring Creek study sites 3 and 4 is complicated by springs and a WWTP flow.

USGS operates three continuous record stream gages on this watershed. Pertinent data for these gages are shown in Table D5.

Table D5. Gages in Spring Creek Watershed, Centre County

Gage Location	Period of Record	Period of Record Used	Drainage Area (sq. mi.)
Spring Creek at Houserville	1985-date	1985-94	58.5
Spring Creek near Axemann	1941-date	1985-94	87.2
Spring Creek at Milesburg	1967-date		142.0

The study site for Spring Creek segment 2 is located just upstream from the Houserville gage. The study site for segment 4 is located just upstream from the Axemann gage. The University Area Joint Authority wastewater treatment plant discharges 6.98 cfs, as an annual average, just downstream from the Houserville gage. The treatment plant began operations in 1985.

Flippo (1974) shows flow measurements for nine springs in the Spring Creek Watershed. Five springs are located on the main stem of Spring Creek upstream of the Axemann gage (study sites 2, 3, and 4). The spring flow rates are summarized by study segment in Table D6. Only flow rates measured in November 1971 are shown, because that is the only consistent set of data.

Table D6. Spring Flow Rates of Spring Creek Watershed, Centre County
Source: Flippo (1974)

Study Segment	Spring Flow Rate Within Segment (gpm)		Spring Flow Rate Within Segment (cfs)	
	November 1971	Median	November 1971	Median
2	3,240	3,500	7.22	7.80
3	4,080	4,000	9.09	8.91
4	3,930*	4,000*	8.76*	8.91*
Downstream from study area	19,290	23,400	42.98	52.13

* No measurement for Bellefonte Fish Hatchery Spring in 1971 and no estimate of median flow; not included in the spring flow total for this reach.

The initial hydrology was based on data for the Milesburg gage. However, as shown in Table D6, more than half the total spring flow enters downstream from the Axemann gage and upstream from the Milesburg gage. Because the Milesburg gage is not representative of the flow regime in the study segments, only the Houserville and Axemann gages were used to estimate hydrology for the study sites.

Due to the effects of the WWTP discharge, only the period of record for the Axemann gage corresponding to the period of record for the Houserville gage was used in estimating flows for study sites 3 and 4, using the following procedure:

- The annual flow duration relationships for the Houserville and Axemann gages were tabulated for selected probabilities;
- The WWTP flow and the total spring flow between the Houserville and Axemann gages were added to the Houserville flows, and compared to the corresponding flows at the Axemann gage, which showed that:

    - For 95 and 90 percent probabilities of exceedance, the flow at Axemann was overestimated by small amounts;
    - For probabilities less than, or equal to 75 percent, the Axemann flows were underestimated by amounts that increased with increasing flow;

- The water balance at the Axemann gage was maintained by
    - Reducing the spring flow rate at the 95 percent probability of exceedance by about 6 percent to match the Axemann data; and
    - Assuming the differences between the observed and estimated flows at the Axemann gage for probabilities less than, or equal to, 75 percent were due to runoff from the intervening area and converting those differences to unit rates (csm);

- Flow duration relationships for study sites 3 and 4 were estimated by adding the Houserville flow, the average daily WWTP flow, the appropriate spring flow (Table D6)**,** and the appropriate runoff, based on the runoff rates (csm) multiplied by the appropriate intervening area.

The necessary hydrology at study sites 3 and 4 was computed by: determining a flow at the Houserville gage; interpolating in the annual flow duration table for the Houserville gage to obtain the probability of exceedance for that flow; and interpolating in the annual flow duration table for the site at the same probability to determine the corresponding flow at the site.

D13.0 STUDY SITES ON PENNS CREEK, CENTRE COUNTY

Three study sites are located on Penns Creek. The first is a short distance downstream from Penn's Cave, which complicates the hydrology for these sites. Although the actual cave flow was not measured during this study, the cave flow was probably a large part of the measured flow at study site 1. The effect of the cave flow dissipates as the drainage area increases.

Flippo (1974) shows two flow measurements for Penn's Cave. The first measurement was made on August 13, 1944; the flow was 4,700 gpm (10.47 cfs). The second measurement was made on November 15, 1971; the flow was 3,420 gpm (7.62 cfs). He estimates the median flow rate as 4,000 gpm (8.9 cfs). The CDS flow at study site 1 was 9.17 cfs, slightly greater than the median cave flow. Efforts to contact the operators of the Penn's Cave recreation facility to obtain additional cave flow data were unsuccessful.

The annual flow duration at the study sites were initially estimated using flow data for the study sites and the flow duration table for the Penns Creek gage. The topographic and geologic maps show different topography and geology for segment 1, compared to the remainder of the watershed upstream from the USGS gage on Penns Creek at Penns Creek. For that reason, the watershed upstream from the gage was divided into an area upstream from study site 1 and an area between study site 1 and the gage.

The cave flow at the time of the CDS measurement was estimated as greater than, or equal to, 4.2 cfs, but the corresponding upper bound could not be determined. Comparison of the two measurements of cave flow (Flippo, 1974) with the flows at the Penns Creek gage on the same date showed that the cave flow has been at least as great as 10.47 cfs. However, the probability of that flow could not be determined, because the cave flow measurements decrease with increasing flow at the gage.

The flow duration analysis for the Penns Creek gage resulted in 20 bins (21 boundary flow values) over the range between 100 percent and 10.73 percent probability of exceedance. The gage flow rates range from 21 cfs at 100 percent probability to 929 cfs at 10.73 percent probability. The maximum cave flow is greater than, or equal to, about 10.5 cfs, based on available measurements. The cave flow is less than 9.0 percent of the gage flow at 116 cfs, which is exceeded 74.59 percent of the time. Also, the drainage area above site 1 is about 5 percent of the drainage area at the gage. It appears that, for probabilities of exceedance less than 74.59 percent, most of the flow at the gage comes from runoff from the area between study site 1 and the gage. Also, for the drainage area above site 1, and for the same probabilities, most of the flow was assumed to come from the cave.

Several trials showed that a unique solution was not possible. Therefore, the cave flow and unit runoff rates for the drainage area upstream from site 1 were computed by trial and error to balance to the gage flow rates. The final trial assumed the cave flow was 6.5 cfs at 74.59 percent probability, which resulted in a unit runoff rate of 0.177 csm for the drainage area above site 1. The cave flows were constant at 6.5 cfs for probabilities greater than, or equal to, 74.59 percent, and the unit runoff rates were computed to balance the flows at the gage. For probabilities less than 74.59 percent, unit runoff rates for study site 1 were increased proportionately to the streamflow at the gage, and the cave flow rates were computed to balance the flows at the gage. The resulting cave flow is 11.1 cfs at 10.73 percent probability, which is only slightly greater than the maximum measured cave flow of 10.47 cfs (Flippo, 1974). This solution balances the observed flows at the gage within about 0.15 percent for all probability levels.

Subsequent studies during development of the regional hydrology (section 6.6.3) showed that data for the gage on Spring Creek at Houserville was more representative of the hydrology for the drainage area on Penns Creek underlain by limestone. About 10 percent of the total drainage area of the Penns Creek Watershed at the gage is underlain by limestone.

To synthesize flow duration at the study sites, the cave flows were determined as described above. The estimated cave flows were subtracted from the flows at the Penns Creek gage, to estimate the runoff from the freestone drainage area. For each study site and certain selected probabilities, the runoff from the area underlain by limestone rock was estimated by multiplying the corresponding flow value at the Houserville gage by the ratio of site drainage area underlain by limestone to drainage area at the Houserville gage. The runoff from the area underlain by freestone rock was estimated by multiplying the estimated runoff at the gage by the ratio of drainage area underlain by freestone to the drainage area at the Penns Creek gage. Then the respective flows from the cave, and runoff from limestone, and freestone were summed to estimate the flow at each study site.

D14.0 STUDY SITE ON HONEY CREEK, MIFFLIN COUNTY

Honey Creek is a tributary of Kishacoquillas Creek. The study site is located a short distance upstream from the confluence of Honey Creek with Kishacoquillas Creek, and just downstream from

Alexander Cavern. USGS operated a continuous record stream gage on Kishacoquillas Creek at Reedsville between 1940 to 1970, and 1984 to 1985. The gage was located just downstream from the mouth of Honey Creek.

The hydrology of Honey Creek is complicated by the fact that the cavern contributes a variable flow rate, and most of the drainage area upstream from the cavern is underlain by shale rock. Topographic maps show Honey Creek is perennial for much of its length upstream from the cavern, but becomes intermittent in the vicinity of the cavern. For that reason, Honey Creek was assumed to flow underground, for most of the range of flows, in the vicinity of the cavern. The topographic maps also show Kishacoquillas Creek upstream from the mouth of Honey Creek is a relatively large stream, and that streams in that part of the watershed are generally perennial.

Flippo (1974) shows a single measurement of the flow from the cavern, which was 14,600 gpm (32.5 cfs). He also estimates the median flow from Alexander Cavern as 14,000 gpm (32 cfs). The flow duration for the Reedsville gage shows flows as low as 13 cfs. If the cavern were the only source of flow at the gage at the time of the lowest flow, the low flow from the cavern must be less than, or equal to, 13 cfs. Because it is likely that the drainage area upstream from Honey Creek is contributing part of that low flow, the cavern flow was probably less than 13 cfs under this low flow condition. This reasoning implies the flow from the cavern decreases very rapidly with decreasing flows less than the median cavern flow. Therefore, the flow from the cavern appears to be highly variable and dependent on surface runoff from the watershed above the cave, and could not be easily estimated. For these reasons, it was assumed the study site hydrology was dependent primarily on runoff, and the effect of the cavern on storage and the time distribution of flow at the study site could be ignored.

The following procedure was used to develop flow duration at the site.

- The flow at the gage on the date of the completed data set measurement was partitioned into a flow from Honey Creek above the study site and a flow from the rest of the watershed. The resulting water balance equation is:

  $$Q_G = Q_S + Q_R = r_S * A_S + r_R * A_R \quad \text{(D3)}$$

  where:
  Q_G = the observed flow at the gage;
  Q_S = the flow from Honey Creek above the study site, including Alexander Cavern;
  Q_R = the flow from the rest of the watershed above the gage;
  r_S = a runoff rate from Honey Creek above the study site, including Alexander Cavern;
  A_S = the drainage area above the study site;
  r_R = the runoff rate from the remainder of the watershed;
  A_R = the area of the remainder of the watershed;

- The flow rate at the study site was 18.68 cfs (0.20 csm) when the CDS was collected on February 10, 1995; the daily flow at the gage on the same date was 58 cfs (0.35 csm).
- The ratio of the runoff rate (csm) at the site to the runoff rate (csm) at the gage was computed as 0.56, and then rounded to 0.60, resulting in an effective runoff rate from the watershed upstream from the study site equal to 0.212 csm for the CDS measurement;
- The continuity equation was solved for the runoff rate from the rest of the watershed (0.532 csm);

- The annual flow duration curve at the site was computed from the flow duration at the gage by assuming the unit flow rates (csm) at the site were 60 percent of the corresponding unit flow rates for the rest of the watershed; and
- Flows at the site were determined from the site flow duration curve by assuming the probability of exceedance at the site was the same as the probability of exceedance at the gage.

D15.0 STUDY SITE ON LONG HOLLOW RUN, MIFFLIN COUNTY

Long Hollow Run enters the Juniata River just east of Mt. Union. It is formed in a narrow, steep-sided valley, and the stream is formed on a narrow outcrop of limestone. About 20 percent of the watershed is underlain by limestone rocks. This stream apparently is not a typical limestone stream.

Initially, hydrology was computed for this stream based on data for the USGS gage on Kishacoquillas Creek at Reedsville. The flow measurements showed the estimated flows were too high. Second, the annual flow duration at the site was computed using data for the USGS gage on the Frankstown Branch Juniata River at Williamsburg (L. Taylor, SRBC, oral communication). Comparison of the estimated flows to the measured flows showed the former were too high by a factor of about 2. There is no obvious reason (e.g., split channel, sinkholes) for the flows at the study site to be so low (L. Baker and L. Boar, PFBC, oral communication, July 17, 1995). The measured flows at the study site seemed to fit the site flow duration curve, based on data for the USGS gage on Dunning Creek at Belden. Dunning Creek at Belden has only small amounts of limestone (Shaw, 1974), and has very low flows compared to other limestone streams used in this study. During development of regional hydrology, Bixler Run at Loysville was selected instead, because the geology of the Bixler Run Watershed was similar to the geology of Long Hollow Run, and to simplify the delineation of hydrologic regions.

D16.0 STUDY SITES ON BOILING SPRING RUN, BLAIR COUNTY, AND POTTER CREEK, BEDFORD COUNTY

Boiling Spring Run flows north into Beaverdam Creek, which combines with other streams to form the Frankstown Branch Juniata River. The stream is located in a narrow valley between Dunning Mountain to the east and high hills to the west.

Initially, hydrology for Boiling Spring Run was based on data for the gage on Dunning Creek at Belden. However, as noted previously, there is little limestone on the Dunning Creek Watershed, and the measured flows were too high, compared to the annual flow duration based on Dunning Creek. Hydrology also was computed based on data for the gage on Frankstown Branch Juniata River at Williamsburg (L. Taylor, SRBC, oral communication). The resulting flow duration seemed reasonable, compared to the flow measurements. However, during the development of regional hydrology, Bixler Run at Loysville was selected instead. The reasons were the relative size of the Frankstown Branch and Boiling Spring Run Watersheds, the mixed geology of the Frankstown Branch Watershed, and the similarity of the geology of Bixler Run to the geology of Boiling Springs Run. Data for the Bixler Run gage was used in the impact analysis.

Potter Creek begins on the east side of Dunning Mountain and flows southeast into Yellow Creek, which is a tributary of the Raystown Branch Juniata River. The New Enterprise quadrangle map shows two springs in this watershed. Flippo (1974) does not show any data for these springs; therefore, they were assumed to be insignificant.

The hydrology for this study site was initially based on data for the USGS gage on the Frankstown Branch Juniata River at Williamsburg. However, the measurements for Potter Creek were too high, compared to the flow duration curve, so that gage was not used. The final hydrology for Potter Creek was based on data for the gage on Spring Creek at Houserville.

The differences in the hydrology of these two watersheds were considered in the regionalization of hydrology and impact analysis.

D17.0 STUDY SITES ON WAPWALLOPEN CREEK AND SALEM CREEK, LUZERNE COUNTY, AND MUGSER RUN AND EAST BRANCH RAVEN CREEK, COLUMBIA COUNTY

Wapwallopen Creek is affected by a water supply withdrawal from Crystal Lake, which is located in the headwaters of the watershed, and the return flows from the Mountaintop Joint Authority WWTP, which is located between study sites 2 and 3. The average daily water supply withdrawal is about 1.2 mgd (1.86 cfs) (S. Runkle, Pa. DEP, oral communication), and the average daily WWTP flow is 2.4 mgd (3.7 cfs). The minimum release from Crystal Lake is 0.378 cfs when the inflow exceeds that amount; otherwise the release equals the inflow. There also is an intermittent, small importation to Crystal Lake from the Delaware River Basin, which was considered insignificant.

USGS has operated a gage on Wapwallopen Creek at Wapwallopen since 1919. Initially, hydrology for Wapwallopen Creek was based on adjusting the observed flow duration at the gage for the effects of the water withdrawal and WWTP flows. However, it was determined this led to zero, and even negative flows for some months. The hydrology was revised to utilize the period of record prior to 1979, when the WWTP began operating. The flows for each study site were computed by drainage area ratio. The minimum release from Crystal Lake was ignored, but the WWTP flow was added to the flows for sites 3 and 4 to obtain the current hydrology.

The hydrology for Salem Creek, Mugser Run and East Branch Raven Creek were estimated by applying a drainage area ratio to the Wapwallopen Creek data for the period-of-record prior to 1979.

D18.0 STUDY SITE ON RED RUN, CAMBRIA COUNTY

Red Run is affected by a water supply withdrawal, which is 242,000 gpd (0.38 cfs). The natural hydrology was estimated by drainage area ratio, using the data for the USGS gage on Blacklick Creek at Josephine. The water supply withdrawal was subtracted from the natural hydrology to estimate the existing hydrology.

APPENDIX E

THE PENNSYLVANIA-MARYLAND INSTREAM FLOW STUDY IMPACT ANALYSIS PROGRAM

E1.0 INTRODUCTION

The Pennsylvania/Maryland Instream Flow Study Impact Analysis Program is designed to estimate the potential impact of water withdrawals on trout habitat in cold-water streams. This analysis considers the study region in which the stream is found, the hydrology of the stream, the drainage area, the distance from the headwaters to the point of withdrawal, and the fish species composition in the stream. The program utilizes fishery habitat information, developed for specific study streams using the Instream Flow Incremental Methodology (IFIM). It is designed to predict the effects of a withdrawal on any stream that has not been studied, based on the average of the effects on studied streams in the same study region.

The computer program is written in Microsoft™ Excel 7.0 spreadsheet format. The minimum system requirements are an IBM™ compatible computer, with an 80486 processor; Microsoft™ Windows 95 operating system; and Microsoft™ Excel 5.0 program.

The Impact Analysis Program includes the detailed analysis and preliminary analysis programs, which are closely related. There are three main differences between these programs:

1. The detailed analysis program provides in-depth analysis of the effects of withdrawals on flows and habitat in terms of Renormalized Minimum Weighted Usable Area (RMWUA). The preliminary analysis program provides only a general overview of impacts of a proposed withdrawal over a range of potential passby flows. As a result, the output from the preliminary analysis program is much less detailed than the detailed analysis program.

2. The detailed analysis program allows the input of any passby flow, and the passby flows can vary seasonally. The preliminary analysis program automatically uses 13 different passby flows, ranging from 0 to 60 percent ADF, in 5 percent ADF increments. These flows cannot vary seasonally.

3. The two programs use different algorithms to compute average seasonal impacts to RMWUA.

There are a variety of ways to evaluate impacts to trout habitat using the various outputs produced from these programs. The detailed analysis program is designed to estimate average impacts on median monthly flow, or RMWUA, for a particular type of fishery on a monthly, seasonal, and annual basis. It also calculates changes in monthly, seasonal, and annual duration of flow and RMWUA. The program estimates the average impact on streamflow, or RMWUA, given the hydrology, drainage area, average daily flow, and species composition of a particular site, based on the streams studied in the specific class. The duration analyses are presented in tabular format but can also be graphed. The preliminary analysis program only estimates changes in seasonal and annual average RMWUA, and seasonal and annual median RMWUA, resulting from a given withdrawal combined with the preselected passby flows. Outputs such as duration analyses of the effects of withdrawal on flow and habitat are not computed in the preliminary analysis program. The abbreviated format of the preliminary analysis program allows a general evaluation of the effect of a wide range of passby flows for any given withdrawal, while reducing the run time necessary to analyze the same number of passby flows with the detailed analysis program.

The program also can perform analyses for other time steps (e.g., annual, daily) provided that hydrologic data file limits are not exceeded.

E2.0 DATA NEEDS AND CALCULATION METHODS

E2.1 Detailed Analysis Program

The detailed analysis program requires:

1. The natural median monthly flows for a period of years for the site from which the withdrawal is proposed (project stream). These flows should be synthesized using the regional hydrology procedures described in section 6.6.3.

2. The proposed withdrawal and passby flows for the project stream for each season. The proposed withdrawal and passby flows are entered in units of either cfs, csm, mgd, or percent ADF. The withdrawal and passby flow information can vary with season. One combination of withdrawal and passby flow must be entered for each season for each run.

3. Other required data such as the stream name, distance from the headwaters to the taking point, the study region, drainage area, and ADF at the taking point, and the trout species (brook, brown, or combined) to be considered.

4. The appropriate RMWUA versus flow tables, based on the study region. Tables for the Ridge and Valley Freestone, Ridge and Valley Limestone, and Unglaciated Plateau study regions are presently included in the program. Tables for the 12 study streams in the Piedmont Upland study region also are included.

The detailed analysis program:

1. Converts all median monthly flows to percent ADF.

2. Modifies the existing flow record for the effect of withdrawals and passby flows so that predictions of impacts on flow and habitat can be based on comparison of the existing (unimpacted by the proposed withdrawal) flow and habitat and the flow and habitat available as affected by the proposed withdrawal.

3. Converts the flows in the RMWUA versus flow tables for each study site in that class of streams to percent ADF, so that flow values for the project stream and each of the study streams can be directly related to each other.

4. Determines the stream segment class, based on length of stream.

5. Develops unimpacted and impacted median monthly RMWUA tables for each study stream, using the unimpacted and impacted median monthly flow tables for the project stream and the RMWUA versus flow relationships for each of the study streams.

6. Estimates the average monthly, seasonal, and annual RMWUA, both with and without the withdrawal, for each study stream, using the RMWUA values from the tables developed in step 5. Seasonal averages for each study stream are computed from all the individual monthly values in the period of record for each study stream. Thus, if there are three months in the season, and 50 years in the period of record, the average seasonal RMWUA for that particular season would be calculated using 150 values.

7. Estimates the average change and average percent change in RMWUA for each month, season, and year, for each study stream in the appropriate class of streams, based on the flows for the project stream.

8. Computes the average monthly, seasonal, and annual impact of the withdrawal on RMWUA for the project stream by averaging all the individual monthly, seasonal and annual outputs for all the study streams in the stream class (steps 5 and 6 above) across years and then across streams (stream variation method). Standard deviations and 95 percent confidence intervals also are calculated for the average data sets. For example, if there are 19 study streams in a particular class of streams, the average impact to RMWUA in March would be calculated from the average of the 19 average March impacts, one from each of the 19 study streams, and the sample size used in the confidence interval calculation would be 19.

9. Computes the average monthly, seasonal, and annual impact of the withdrawal on RMWUA for the project stream by averaging all the individual monthly, seasonal and annual outputs for all the study streams in the stream class (steps 5 and 6 above) across streams and then across years (yearly variation method). Standard deviations and 95 percent confidence intervals also are calculated for this case. The sample size used to compute standard deviations and confidence intervals is equal to the number of years of record used to develop the hydrology for the stream.

10. Develops a table of average median monthly RMWUAs by averaging all the corresponding individual median monthly values from the individual RMWUA tables for each study stream in the stream class. The size of the resulting table of RMWUAs will be 12 months times the number of years in the estimated hydrology for the project stream.

11. Computes duration analyses of flow and RMWUA with and without the withdrawal, using the table described in step 8. Monthly duration analyses use all the monthly values for each month in the period of record. Seasonal duration analyses use all the monthly values from each season. Thus, if there are three months in a season and 20 years in the period of record, 60 values would be used in the seasonal duration analysis. Annual duration analyses use all the monthly values in the table. Thus, if there are 20 years in the period of record, 240 values would be used in the annual duration analysis.

The differences between the stream variation method and the yearly variation method generally appear in the values of standard deviations and confidence limits. The averages should be similar.

E2.2 Preliminary Analysis Program

Data entry for the preliminary analysis program is identical to that of the detailed analysis program, except that passby flows are not entered. The program automatically estimates the impacts of the proposed withdrawal with 13 preset passby flows. The program performs the following data manipulations and calculations:

1. Develops unimpacted and impacted median monthly RMWUA tables for each study stream, using the same process described in steps 1-4 for the detailed analysis program.

2. Estimates the average seasonal and average annual RMWUA, both with and without the withdrawal, for each study stream, using the RMWUA values from the tables developed in step 1. First, the RMWUA values for the months in a season are averaged, resulting in one

seasonal value for each year. Then, the seasonal averages for each year for each study stream are averaged across years to obtain a seasonal average for each study stream. Thus, if there are three months in a season, three values are averaged for each year, for each stream, to obtain a seasonal average for the year. Then, if there are 50 years in the period of record, 50 values (one seasonal value per year) are averaged to derive the seasonal average. This differs from the algorithm used to derive seasonal averages in the detailed analysis program. (See step 5 above for the detailed analysis program.) The difference is that the preliminary analysis program first averages the months in each season in each year to derive seasonal averages for each year. It then averages each of these seasonal values for the entire period of record. The detailed analysis program skips this first step. Consequently, the results may be slightly different.

3. Estimates the average percent change in seasonal and annual RMWUA for each study stream in the appropriate class of streams using the flows from the project stream.

4. Estimates the average seasonal and annual impact of the withdrawal on RMWUA for the project stream by averaging all the individual seasonal and annual outputs from all the study streams in the stream class (steps 2 and 3 above).

5. Estimates the median seasonal and annual RMWUA, with and without the withdrawal, and the absolute and percentage change in median RMWUA. The same process described in steps 2-4 above is used, except that the median of the RMWUA values in each year in the period of record is determined for each study stream, and not the average as in step 2. This is a different algorithm than is used in the detailed analysis program, where the median values can be derived from the duration analysis described in steps 8 and 9 of the detailed analysis program. As a result, the answers will likely be slightly different from those calculated using the detailed analysis program.

E3.0 PROGRAM INSTALLATION

This program includes two files, **PA-MD Instream Flow Study.XLS** and **Output.XLT**, which are distributed on two 3.5 inch floppy diskettes, and requires at least 15 MB of free hard drive space. The two files must be installed on the hard drive in the Excel directory in a folder named **PA-MD IF Study.** If the folder does not already exist, it will be created automatically. The files are compressed, and will automatically decompress to the folders listed above.

To install, place floppy disk 1 into the computer, access the file on the disk, double click on the file **Pa-Md IF STUDY**, and follow the instructions on the screen. Do not change the **unzip to** location during installation, because the file is programmed to unzip to the correct folders.

E4.0 PROGRAM LAUNCH, INPUT, OUTPUT, AND OPERATION

To launch the program, open the file **C:\EXCEL\Pa-Md IF STUDY\PA-MD Instream Flow Study.XLS**. The program will open to the Main Menu for the Detailed Analysis and Preliminary Analysis Programs, shown in Figure E1. There are four buttons on this screen. The button labeled “Info: Getting Started” leads to an introductory screen that provides information regarding use of the program. The “Detailed Analysis Program” or “Preliminary Analysis Program” buttons lead to the respective programs.

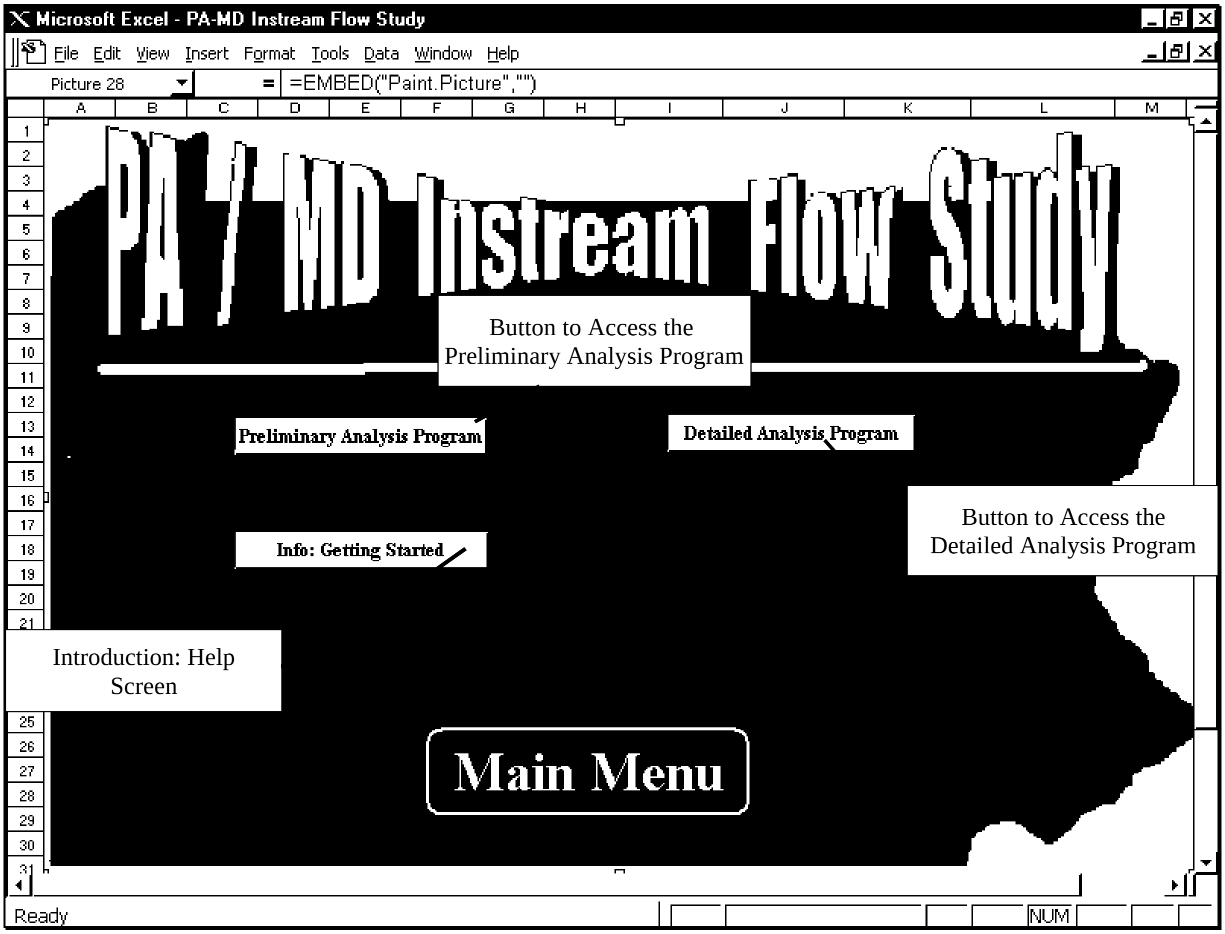


Figure E1. Instream Flow Impact Analysis Program Main Menu

E4.1 Detailed Analysis Program

E4.1.1 Input data

To access the Detailed Analysis Program, press the Detailed Analysis Program button on the Main Menu (Figure E1). The Streamflow Data Form, shown in Figure E2, appears automatically. Enter the median monthly flow time series for the study site in this table. If hydrologic data has been previously entered in the program, press the Clear Monthly Medians button to clear the data file, before entering new data. Hydrologic data can be entered either from the keyboard, or by pasting data from a previously computed file, but must be in units of cubic feet per second (cfs). Be sure to copy only the years and flow values, without any headings or other description. The analysis programs can handle up to 75 years of hydrologic data.

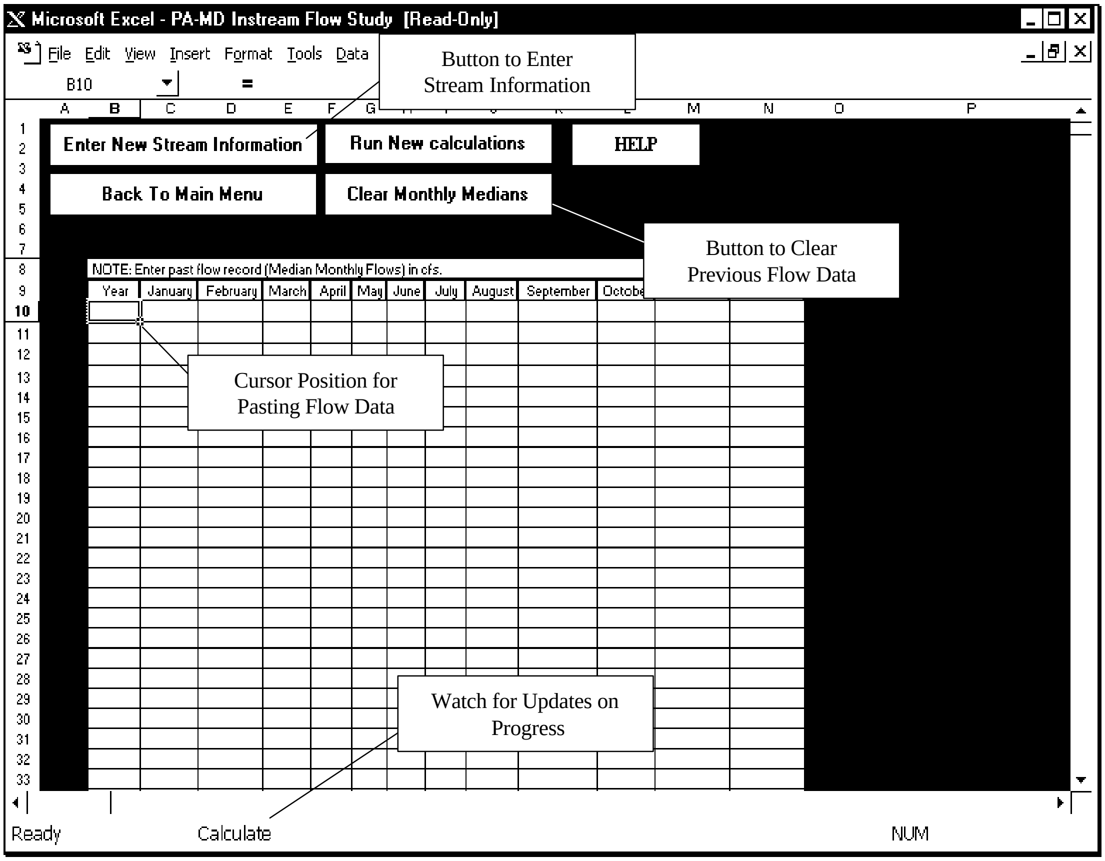


Figure E2. Streamflow Data Form

When the hydrologic data have been entered, press the Enter New Stream Information button to display the Stream Information dialog box shown in Figure E3. This dialog box is used to enter information regarding the project stream. Use the TAB key to scroll between data fields.

Enter the name of the project stream in the first data field. In this dialog box there are three list boxes that allow the user to pick the relevant information from a previously defined list, rather than typing it into a box. The Distance from Headwaters to Taking Point is selected in the first list box. The distance is divided into 5-mile increments, so that the options are 0-5.0 miles, 5.1-10.0 miles, 10.1-15.0 miles, 15.1-20.0 miles, and greater than 20.1 miles. Simply select the appropriate category for the project stream from the list. Because there are no study streams longer than 20.0 mi. at this time, selection of that category results in an error message.

The Study Region is selected from the next list box. The study region may be either Ridge and Valley Limestone, Ridge and Valley Freestone, or Unglaciated Plateau. Although RMWUA data for the Piedmont study streams are included in the data file, studies are incomplete, and hydrology is not provided at this time. Therefore, the Piedmont study stream data should not be utilized at this time.

The trout species and type of population present in the project stream are selected in the third list box. The following options are allowed: wild brook trout; wild brown trout; wild combined brook and brown trout; stocked adult brook trout; stocked adult brown trout; stocked adult combined brook and brown trout; stocked fingerling brook trout; stocked fingerling brown trout; and stocked

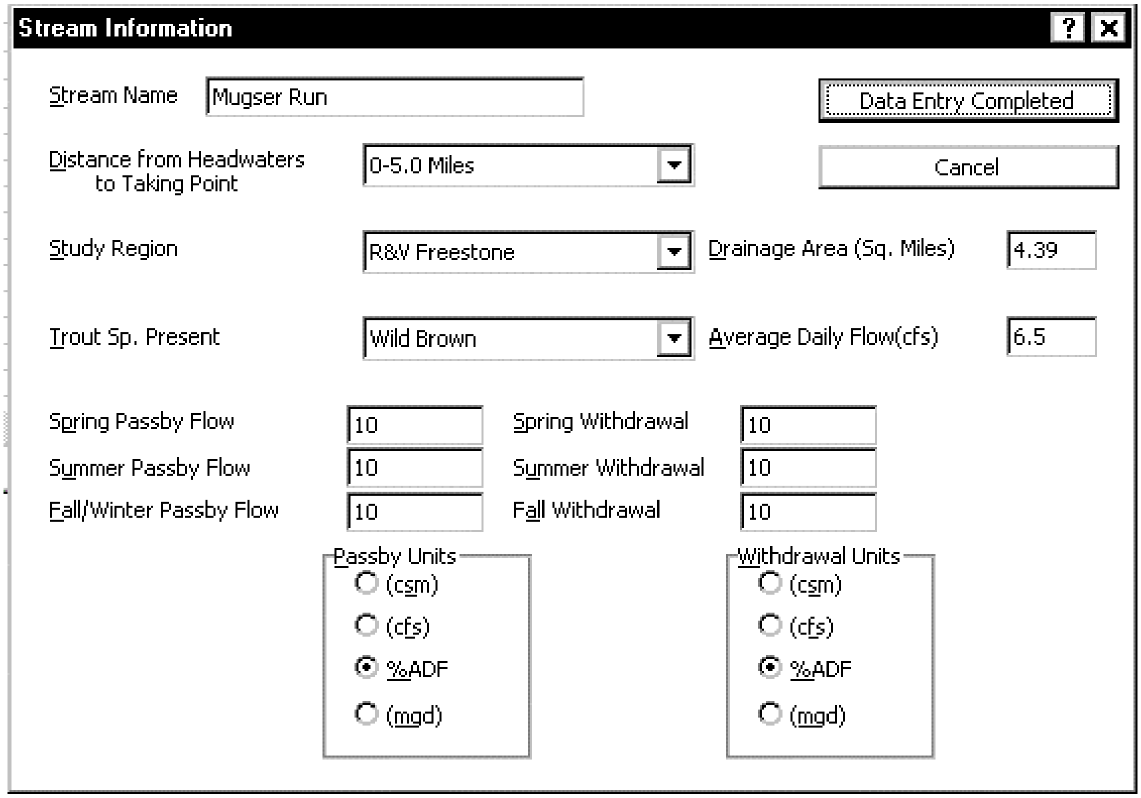


Figure E3. Detailed Analysis Program Stream Information Dialog Box

fingerling combined brook and brown trout. The differences in the evaluation of wild and stocked populations are described in section 6.6.2.1.

After completing the three list boxes, enter the drainage area at the site of the withdrawal, the corresponding average daily flow, and the passby and withdrawal flow rates for each season, in the respective boxes. Then press the box for the appropriate units for both withdrawal and passby flows. Note that the average daily flow must be entered in units of cfs, but the withdrawal and passby flows can be entered in several alternative units. The program automatically converts all flow data to percent ADF.

The Cancel button on this dialog box clears all new stream information and returns control to the flow data input screen (Figure E2).

Once this information is entered, press the Data Entry Completed button to return to the streamflow data screen (Figure E2). Then press the Run New Calculations button at the top of that screen to run the detailed analysis program**.** This program may take several minutes to compute the results depending on the computer's processor speed, and the number of streams in the class. Check the status bar at the bottom left corner to see the progress. Experience shows that with a Pentium 133 mhz processor, the computations require about 45 seconds for each combination of withdrawal and passby flow.

E4.1.2 Output table structure and interpretation

When the computations are complete, the output table will be displayed. The table includes buttons that control program operation, the input data, and the output data. The output data includes three main sections, the stream variation section, the duration analysis section, and the yearly variation section, as shown schematically in Figure E4. The first and third sections summarize the RMWUA computations for the respective methods described in the Data Needs and Computations section of this appendix. The duration analysis section summarizes duration analyses of flow and RMWUA, which do not depend on the method used to summarize the computations.

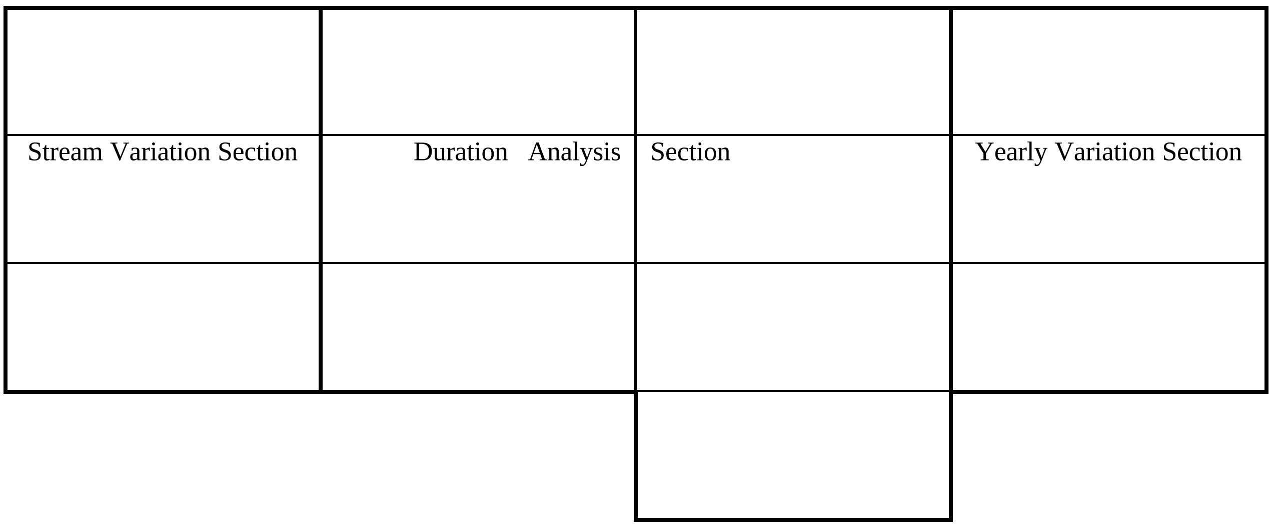
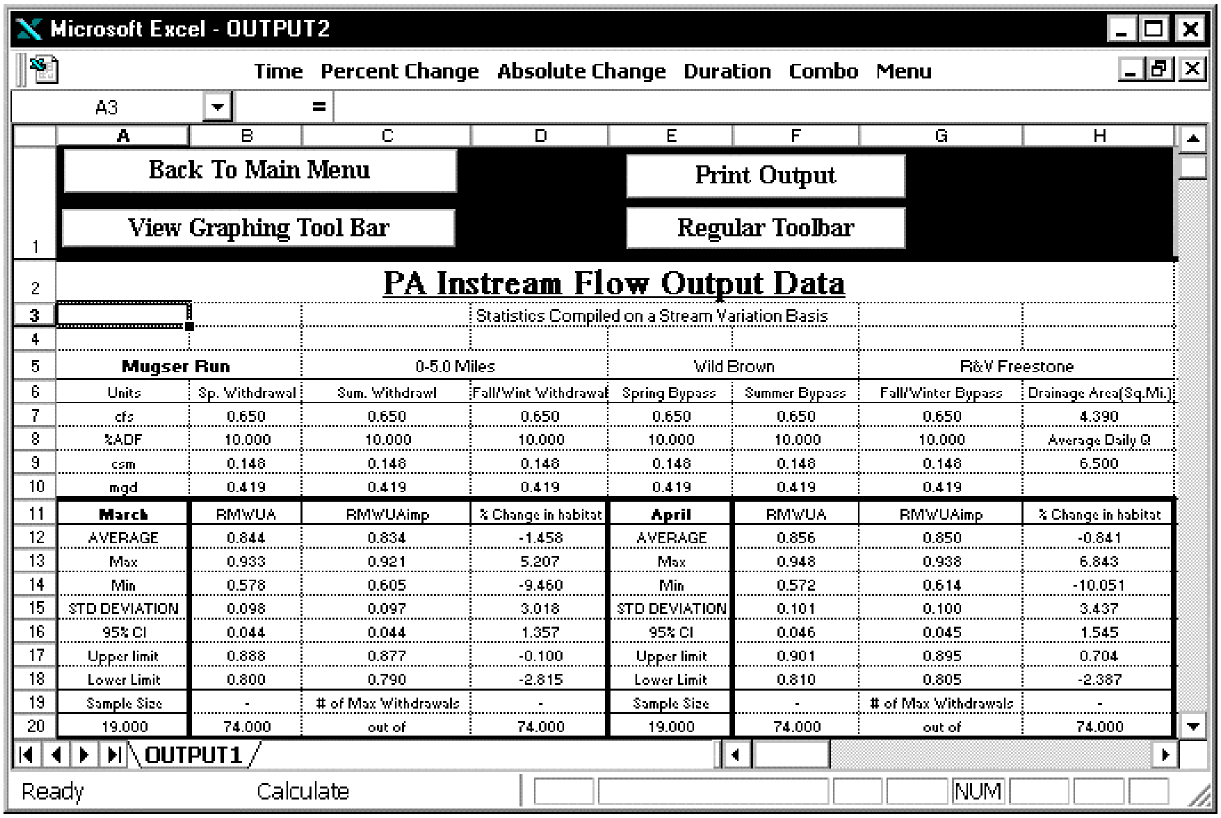


Figure E4. Schematic of Output Table Sections

The stream variation and the yearly variation sections of the output table are essentially identical in form. The first six lines of output show the input data, including seasonal withdrawals and passby flows. The remainder of these sections is divided into groups of 10 lines for each month, and the table is split vertically so that two months are included in each group of 10 lines. The first month shown is March, because it is the beginning of the spring season.

A sample of the monthly part of the stream variation section of the output table is shown in Figure E5. A summary explanation of the monthly output data included in this part of the table is shown in Table E1. Similar seasonal, combined monthly and annual statistics also are provided.



PA Instream Flow Output Data

	A	B	C	D	E	F	G	H
3				Statistics Compiled on a Stream Variation Basis				
4								
5	**Mugser Run**		0-5.0 Miles		Wild Brown		R&V Freestone	
6	Units	Sp. Withdrawal	Sum. Withdrawl	Fall/Wint Withdrawal	Spring Bypass	Summer Bypass	Fall/Winter Bypass	Drainage Area(Sq.Mi.)
7	cfs	0.650	0.650	0.650	0.650	0.650	0.650	4.390
8	%ADF	10.000	10.000	10.000	10.000	10.000	10.000	Average Daily Q
9	csm	0.148	0.148	0.148	0.148	0.148	0.148	6.500
10	mgd	0.419	0.419	0.419	0.419	0.419	0.419	
11	**March**	RMWUA	RMWUAimp	% Change in habitat	**April**	RMWUA	RMWUAimp	% Change in habitat
12	AVERAGE	0.844	0.834	-1.458	AVERAGE	0.856	0.850	-0.841
13	Max	0.933	0.921	5.207	Max	0.948	0.938	6.843
14	Min	0.578	0.605	-9.460	Min	0.572	0.614	-10.051
15	STD DEVIATION	0.098	0.097	3.018	STD DEVIATION	0.101	0.100	3.437
16	95% CI	0.044	0.044	1.357	95% CI	0.046	0.045	1.545
17	Upper limit	0.888	0.877	-0.100	Upper limit	0.901	0.895	0.704
18	Lower Limit	0.800	0.790	-2.815	Lower Limit	0.810	0.805	-2.387
19	Sample Size	-	# of Max Withdrawals	-	Sample Size	-	# of Max Withdrawals	-
20	19.000	74.000	out of	74.000	19.000	74.000	out of	74.000

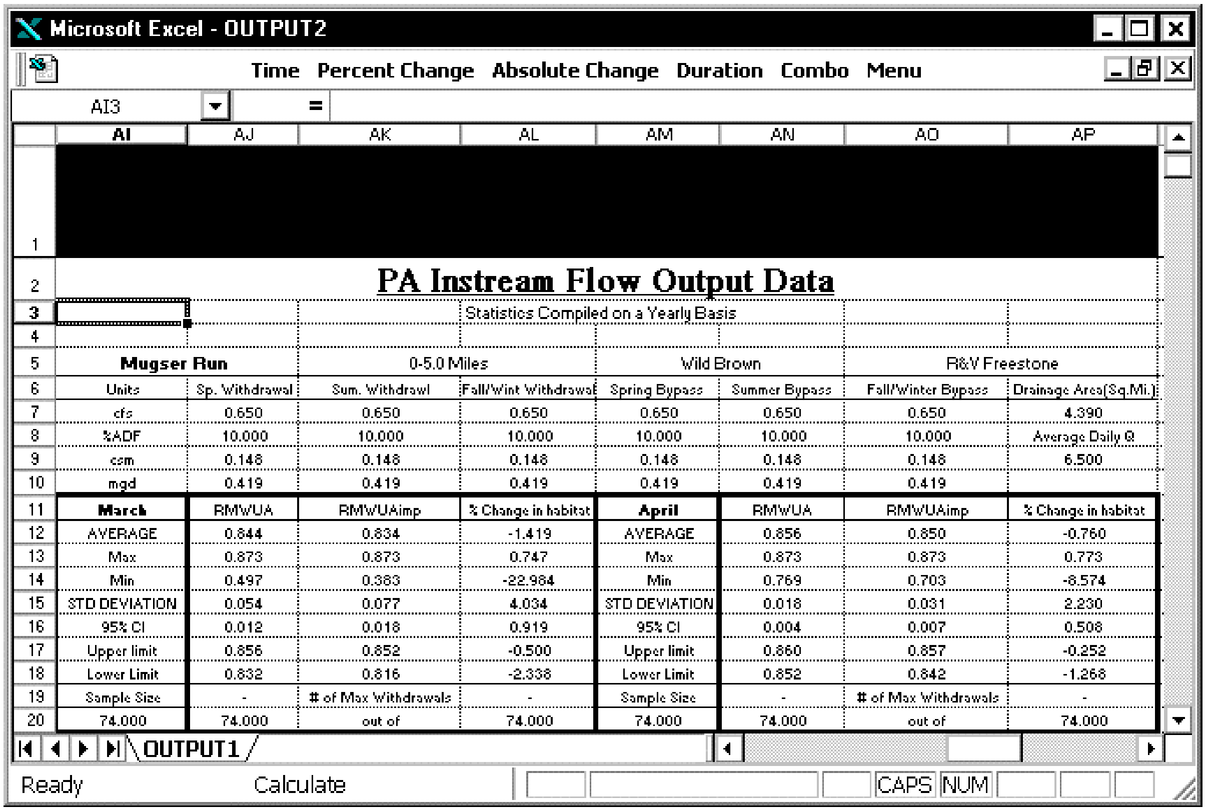
Figure E5. Sample Detailed Analysis Program Output Table, Stream Variation Method

Table E1. Explanation of Monthly RMWUA Statistics, Stream Variation Method

[Month]	RMWUA (Natural Conditions)	RMWUAimp (Impacted Conditions)	%Change in Habitat
AVERAGE	Average of average habitat (RMWUA) values, one for each study stream, for month shown	Average of average habitat (RMWUAimp) values, one for each study stream, for month shown	Average of values described below*
Max	Maximum of average habitat (RMWUA) values, one for each study stream, for month shown	Maximum of average habitat (RMWUAimp) values, one for each study stream, for month shown	Maximum of values described below*
Min	Minimum of average habitat (RMWUA) values, one for each study stream, for month shown	Minimum of average habitat (RMWUAimp) values, one for each study stream, for month shown	Minimum of values described below*
STD DEVIATION	Standard deviation of average habitat (RMWUA) values, one for each study stream, for month shown	Standard deviation of average habitat (RMWUAimp) values, one for each study stream, for month shown	Standard Deviation of values described below*
95% CI	95th Percentile Confidence Interval of the average habitat RMWUA values, one for each study stream, for month shown	95th Percentile Confidence Interval of the average habitat RMWUA values, one for each study stream, for month shown	95th Percentile Confidence Interval of percent change in habitat.
Upper Limit	Upper limit of the 95% confidence band	Upper limit of the 95% confidence band	Upper limit of the 95% confidence band
Lower Limit	Lower limit of the 95% confidence band	Lower limit of the 95% confidence band	Lower limit of the 95% confidence band
Sample Size	**# of Max Withdrawals**		
Number of study streams in region	Number of years over period-of-record in which entire withdrawal is available in month shown	**out of**	Number of years over period-of-record in which month shown occurs

*For a given month, for each study stream, the model calculates a percent change in habitat value for each year of record. An average for the period-of-record is then calculated for each stream by averaging the yearly values. These averages across years are averaged across streams, and the result is shown in the first row. The maximum, minimum, standard deviation, and confidence interval across streams are shown in the appropriate rows.

A sample of the monthly part of the yearly variation section of the output table is shown in Figure E6. A summary of the output data included in the yearly variation section is shown in Table E2. Similar statistics are provided for the spring, summer, and fall/winter seasons and for combined monthly and yearly periods.



Microsoft Excel - OUTPUT2

Time Percent Change Absolute Change Duration Combo Menu

PA Instream Flow Output Data

Statistics Compiled on a Yearly Basis

Mugser Run		0-5.0 Miles		Wild Brown		R&V Freestone	
Units	Sp. Withdrawal	Sum. Withdrawl	Fall/Wint Withdrawal	Spring Bypass	Summer Bypass	Fall/Winter Bypass	Drainage Area(Sq.Mi.)
cfs	0.650	0.650	0.650	0.650	0.650	0.650	4.390
%ADF	10.000	10.000	10.000	10.000	10.000	10.000	Average Daily Q
csm	0.148	0.148	0.148	0.148	0.148	0.148	6.500
mgd	0.419	0.419	0.419	0.419	0.419	0.419	
March	RMWUA	RMWUAimp	% Change in habitat	**April**	RMWUA	RMWUAimp	% Change in habitat
AVERAGE	0.844	0.834	-1.419	AVERAGE	0.856	0.850	-0.760
Max	0.873	0.873	0.747	Max	0.873	0.873	0.773
Min	0.497	0.383	-22.984	Min	0.769	0.703	-8.574
STD DEVIATION	0.054	0.077	4.034	STD DEVIATION	0.018	0.031	2.230
95% CI	0.012	0.018	0.919	95% CI	0.004	0.007	0.508
Upper limit	0.856	0.852	-0.500	Upper limit	0.860	0.857	-0.252
Lower Limit	0.832	0.816	-2.338	Lower Limit	0.852	0.842	-1.268
Sample Size	-	# of Max Withdrawals	-	Sample Size	-	# of Max Withdrawals	-
74.000	74.000	out of	74.000	74.000	74.000	out of	74.000

OUTPUT1

Ready Calculate CAPS NUM

Figure E6. Sample Detailed Analysis Program Output Table, Yearly Variation Method

Table E2. Explanation of Monthly RMWUA Statistics, Yearly Variation Method

[Month]	RMWUA (Normal Conditions)	RMWUAimp (Impacted Conditions)	% Change in Habitat
AVERAGE	Average of average habitat (RMWUA) values, one for each year in period-of-record, for month shown	Average of average habitat (RMWUAimp) values, one for each year in period-of-record, for month shown	Average of values described below*
Max	Maximum of average habitat (RMWUA) values, one for each year in period-of-record, for month shown	Maximum of average habitat (RMWUAimp) values, one for each year in period-of-record, for month shown	Maximum of values described below*
Min	Minimum of average habitat (RMWUA) values, one for each year in period-of-record, for month shown	Minimum of average habitat (RMWUAimp) values, one for each year in period-of-record, for month shown	Minimum of values described below*
STD DEVIATION	Standard deviation of average habitat (RMWUA) values, one for each year in period-of-record, for month shown	Standard deviation of average habitat (RMWUAimp) values, one for each year in period-of-record, for month shown	Standard Deviation of values described below*
95% CI	95^{th} Percentile Confidence Interval of average habitat (RMWUA) values, one for each year in period-of-record, for	95^{th} Percentile Confidence Interval of average habitat (RMWUAimp) values, one for each year in period-of-record,	95^{th} Percentile Confidence Interval of values described below*
Upper Limit	Upper Limit of the 95% confidence band	Upper Limit of the 95% confidence band	Upper Limit of the 95% confidence band
Lower Limit	Lower limit of the 95% confidence band	Lower limit of the 95% confidence band	Lower limit of the 95% confidence band
Sample Size	**# of Max Withdrawals**		
Number of times month shown occurs in period-of-record	Number of years over period-of-record in which entire withdrawal is available in month shown	**out of**	Number of years month shown occurs in period-of-record

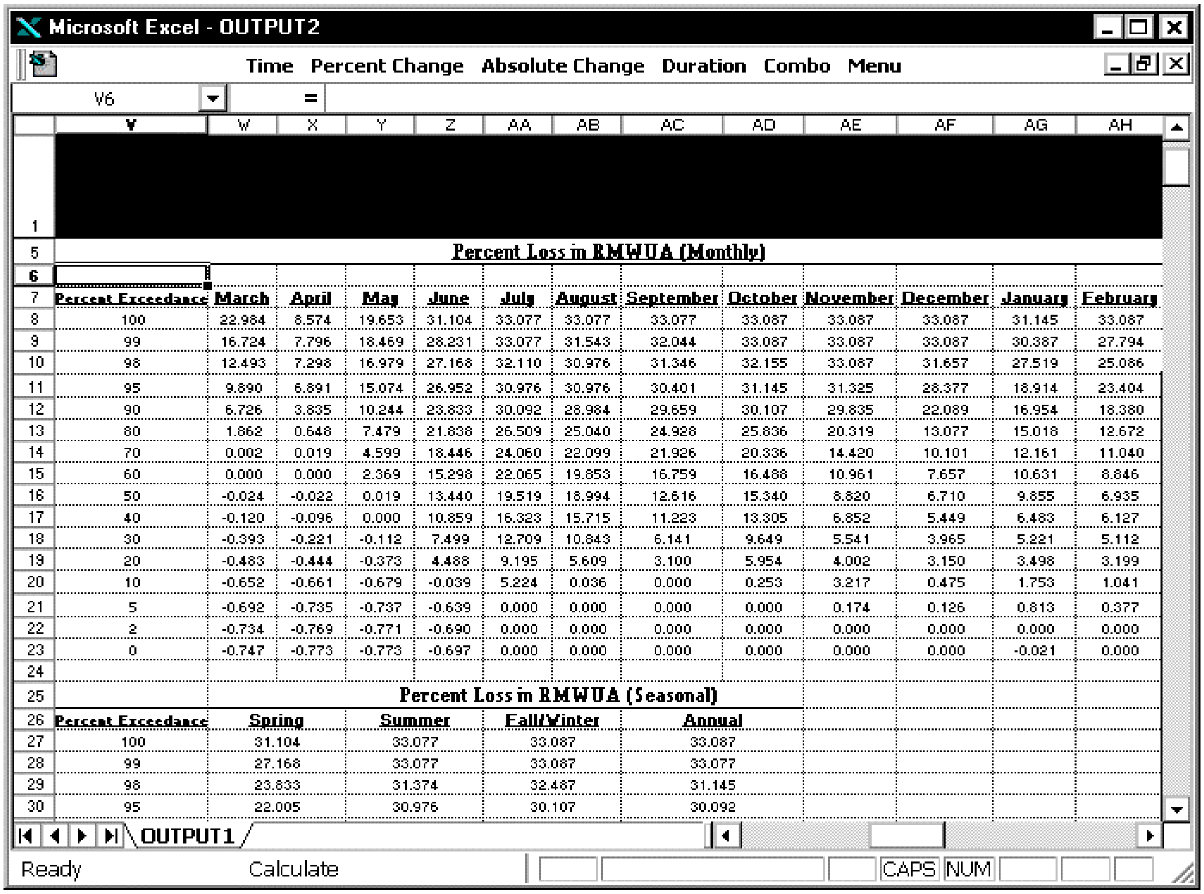
*For a given month, for each year in the period-of-record, the average natural and average impacted RMWUA values are calculated from the monthly natural and impacted RMWUA values for each study stream. A percent change in habitat value is then calculated for each year from the difference between the average natural and average impacted RMWUA values. The average, maximum, minimum, standard deviation, confidence interval, and limits of confidence band of those yearly values are then reported in the output in the respective rows.

The duration analysis section of the output table includes five parts, as shown schematically in Figure E7. Each column of data is calculated independently; thus, the flow duration can not be estimated from the RMWUA duration, and vice versa.

Duration Table of Unimpacted and Impacted Monthly Median Flows	Duration Table of Percent Loss in RMWUA (Monthly, Seasonal, and Annual) (Figure E8)
Duration Table of Unimpacted and Impacted Monthly RMWUAs	Duration Table of Actual Loss in RMWUA (Monthly, Seasonal, and Annual)
Seasonal and Annual Duration Table of Unimpacted and Impacted Flows and RMWUA	Duration Table of Percent Loss in Flow (Monthly, Seasonal, and Annual)
	Duration Table of Actual Loss in Flow (Monthly, Seasonal, and Annual)

Figure E7. Schematic of Duration Analysis Section of Output Table

A sample RMWUA duration table is shown in Figure E8. The other duration tables have a similar form. Each section of the duration table is printed on a separate page. Each page includes one subsection shown in Figure E7, and the pages are printed in column order.



Percent Loss in RMWUA (Monthly)

Percent Exceedance	March	April	May	June	July	August	September	October	November	December	January	February
100	22.984	8.574	19.653	31.104	33.077	33.077	33.077	33.087	33.087	33.087	31.145	33.087
99	16.724	7.796	18.469	28.231	33.077	31.543	32.044	33.087	33.087	33.087	30.387	27.794
98	12.493	7.298	16.979	27.168	32.110	30.976	31.346	32.155	33.087	31.657	27.519	25.086
95	9.890	6.891	15.074	26.952	30.976	30.976	30.401	31.145	31.325	28.377	18.914	23.404
90	6.726	3.835	10.244	23.833	30.092	28.984	29.659	30.107	29.835	22.089	16.954	18.380
80	1.862	0.648	7.479	21.838	26.509	25.040	24.928	25.836	20.319	13.077	15.018	12.672
70	0.002	0.019	4.599	18.446	24.060	22.099	21.926	20.336	14.420	10.101	12.161	11.040
60	0.000	0.000	2.369	15.298	22.065	19.853	16.759	16.488	10.961	7.657	10.631	8.846
50	-0.024	-0.022	0.019	13.440	19.519	18.994	12.616	15.340	8.820	6.710	9.855	6.935
40	-0.120	-0.096	0.000	10.859	16.323	15.715	11.223	13.305	6.852	5.449	6.483	6.127
30	-0.393	-0.221	-0.112	7.499	12.709	10.843	6.141	9.649	5.541	3.965	5.221	5.112
20	-0.483	-0.444	-0.373	4.488	9.195	5.609	3.100	5.954	4.002	3.150	3.498	3.199
10	-0.652	-0.661	-0.679	-0.039	5.224	0.036	0.000	0.253	3.217	0.475	1.753	1.041
5	-0.692	-0.735	-0.737	-0.639	0.000	0.000	0.000	0.000	0.174	0.126	0.813	0.377
2	-0.734	-0.769	-0.771	-0.690	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	-0.747	-0.773	-0.773	-0.697	0.000	0.000	0.000	0.000	0.000	0.000	-0.021	0.000

Percent Loss in RMWUA (Seasonal)

Percent Exceedance	Spring	Summer	Fall/Winter	Annual
100	31.104	33.077	33.087	33.087
99	27.168	33.077	33.087	33.077
98	23.833	31.374	32.487	31.145
95	22.005	30.976	30.107	30.092

Figure E8. Sample Duration Analysis Table

4.1.3 Graphics

The output table screens (Figures E5 and E6) automatically show the graphics menu tool bar. The output can be displayed graphically by pressing one of the graphics menu shortcuts.

An expanded view of the graphics menu tool bar is shown in Figure E9. When any of the buttons (except Menu) is selected, the dropdown box shown in Figure E9 under "Percent Change" appears, which allows selection of graphs of RMWUA or flow. The "Percent Change", "Absolute Change", and "Duration" menu choices also provide options (not shown here) to graph either monthly, seasonal, or annual data. The "Time" button graphs the appropriate time series of absolute change in RMWUA or flow caused by the withdrawal. The "Percent Change" button graphs the difference in RMWUA, or flow, expressed as a percentage of the unimpacted values for a specified period, across years, versus probability of exceedance in percent. The specified period may be a particular month, or season, or all the annual values. The "Absolute Change" button produces the same graphs for the absolute change in RMWUA, or flow. The "Duration" button graphs the probability of exceedance (duration) of median monthly RMWUA, or flow, for the entire record used, for both unimpacted and impacted conditions. The Combo button combines similar graphs for different combinations of withdrawal and passby flow. Simply press the appropriate menu item to create a graph of that variable on a separate output sheet.

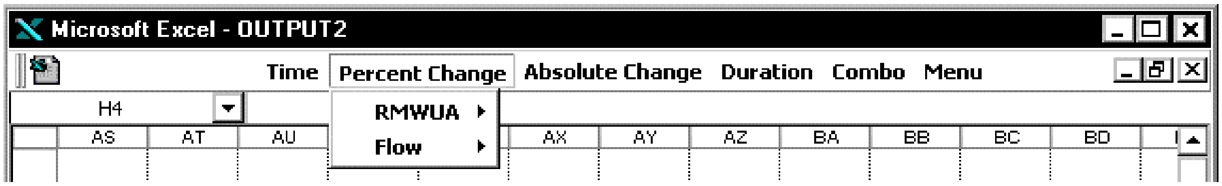


Figure E9. Graphical Output Menu Bar

Graphs of similar items can be overlaid by pressing the combo menu item. This is particularly useful when evaluating impacts of different combinations of withdrawal and passby flow on the same stream. Two different combinations can be plotted on one graph.

To create a combo graph, run the Detailed Analysis Program with both desired combinations of withdrawal and passby flow, and save the output files. After completing each program run, create the individual graphs, leave both charts open, write down the name of the file (e.g., Chart 7 and Chart 9), but do not save them. Then overlay them by pressing "Combo" on the Graphical Output Menu Bar, and then press the “Create Overlay Chart" command that appears immediately below the Combo menu item. The Overlay Graphs dialog box shown in Figure E10 appears. The numbers of the charts to be overlaid (e.g., Chart 7 and Chart 9) can be selected by scrolling each of the list boxes shown. Then press the Create Chart button to create the combined graph.

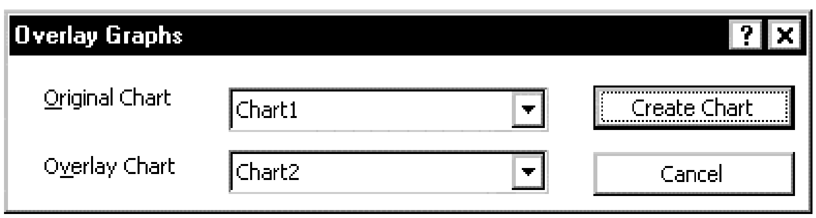


Figure E10. Graph Overlay Dialog Box

E4.1.4 Operation

The output spans many pages, and is most easily analyzed after it is printed. To print the output, press the Print Output button on the Output Data screen shown in Figure E5. The printout of the output table is 13 pages long.

The output table is calculated from an Excel template. The filename for the template is OUTPUTx, where x is a number. If the output from a particular run is not saved in a separate file, it will be overwritten by a subsequent run. To save the output for a particular run for further analysis, change the graphics tool bar on the output screen (Figure E5) to a regular tool bar by pressing the Regular Tool Bar button. Then press the File/Save As command on the toolbar, and enter an appropriate filename in the dialog box that appears. To save graphics, press the Window menu item on the regular toolbar, and select the chart to be saved from the list of open files. Then press the File/Save As command and enter the file name.

After completing a run of either program, close the output file. To close the detailed analysis program output file, press the *lower* close button (lower X shown in upper right corner of Figure E8). Control is transferred to the Streamflow Data Form (Figure E2). If the upper icon is pressed, the entire program will be closed, and control will be transferred to the WINDOWS START screen. Be sure to close the file before exiting the program. There may be problems with subsequent runs if the upper icon is pressed without closing the output file.

The information, as summarized in this program, is different than that contained in the Preliminary Analysis Program, as described in the Data Needs and Calculation Methods section of this appendix.

E4.2 Preliminary Analysis Program

The monthly median time series data is entered in the Preliminary Analysis Program, in the same manner as for the Detailed Analysis Program. This data entry screen differs from the corresponding screen for the detailed analysis program (Figure E2) only in that this data entry screen includes a button called View Last Output that can be used to view the output from a previous run. The data entry part of the data entry screens are identical.

When the streamflow data has been entered, press the Enter New Stream Information button to display the stream data entry dialog box shown in Figure E11. The data is entered in this form in the same manner as for the Detailed Analysis Program. The data entry forms are similar, except that passby flows are not entered for this program. After entering these data, press the Data Entry Complete button to return to the flow data entry screen (Figure E2). Then press the Run New Calculations button on that screen to run the Preliminary Analysis Program. This program will take several minutes to compute the results. Check the status bar at the bottom left corner of the screen to see progress. Run time depends on the computer processor speed and number of streams in the class.

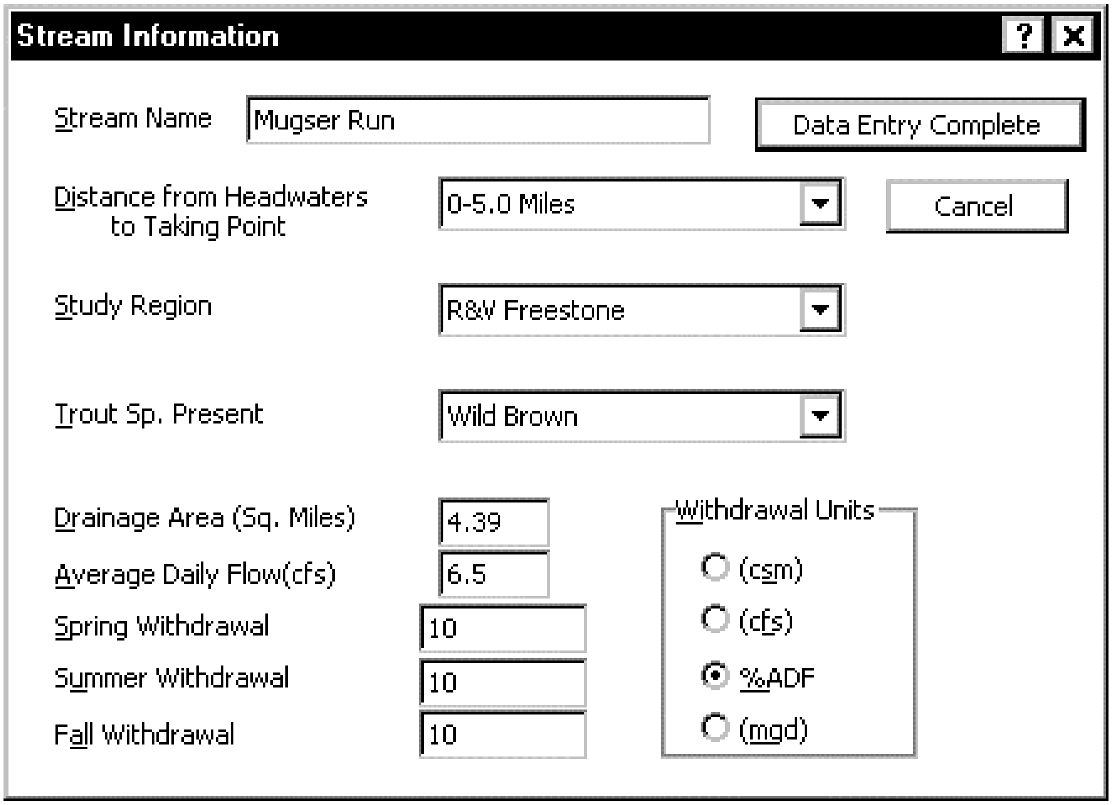
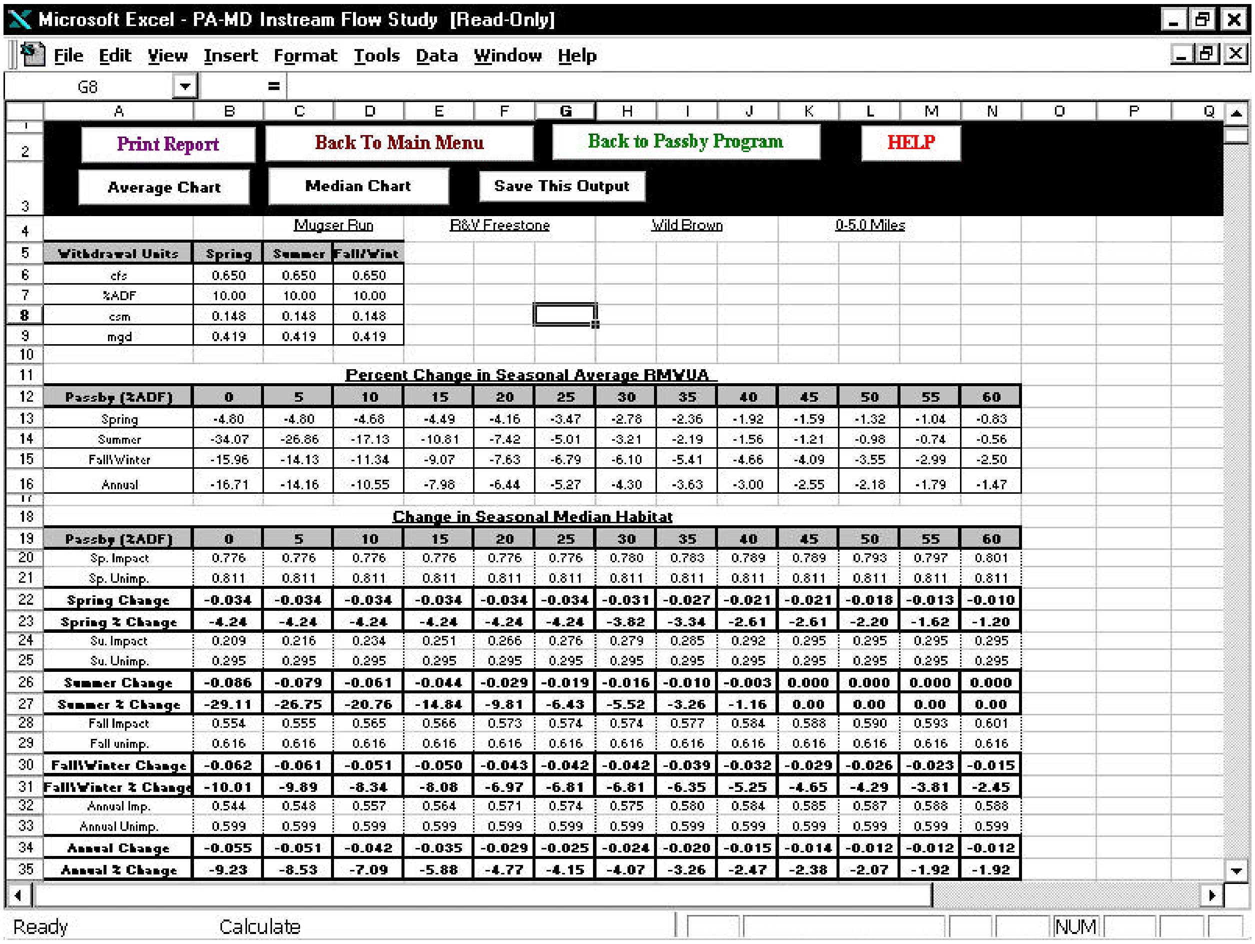


Figure E11. Preliminary Analysis Program Stream Information Dialog Box

When the calculations are completed, an output table similar to that shown in Figure E12 will appear. The table shows the impacts of the specified withdrawal in terms of percent change in seasonal average habitat, as well as absolute and percent change in median seasonal habitat.



Withdrawal Units	Spring	Summer	Fall/Wint
cfs	0.650	0.650	0.650
%ADF	10.00	10.00	10.00
csm	0.148	0.148	0.148
mgd	0.419	0.419	0.419

Percent Change in Seasonal Average RMWUA

Passby (%ADF)	0	5	10	15	20	25	30	35	40	45	50	55	60
Spring	-4.80	-4.80	-4.68	-4.49	-4.16	-3.47	-2.78	-2.36	-1.92	-1.59	-1.32	-1.04	-0.83
Summer	-34.07	-26.86	-17.13	-10.81	-7.42	-5.01	-3.21	-2.19	-1.56	-1.21	-0.98	-0.74	-0.56
Fall\Winter	-15.96	-14.13	-11.34	-9.07	-7.63	-6.79	-6.10	-5.41	-4.66	-4.09	-3.55	-2.99	-2.50
Annual	-16.71	-14.16	-10.55	-7.98	-6.44	-5.27	-4.30	-3.63	-3.00	-2.55	-2.18	-1.79	-1.47

Change in Seasonal Median Habitat

Passby (%ADF)	0	5	10	15	20	25	30	35	40	45	50	55	60
Sp. Impact	0.776	0.776	0.776	0.776	0.776	0.776	0.780	0.783	0.789	0.789	0.793	0.797	0.801
Sp. Unimp.	0.811	0.811	0.811	0.811	0.811	0.811	0.811	0.811	0.811	0.811	0.811	0.811	0.811
Spring Change	**-0.034**	**-0.034**	**-0.034**	**-0.034**	**-0.034**	**-0.034**	**-0.031**	**-0.027**	**-0.021**	**-0.021**	**-0.018**	**-0.013**	**-0.010**
Spring % Change	**-4.24**	**-4.24**	**-4.24**	**-4.24**	**-4.24**	**-4.24**	**-3.82**	**-3.34**	**-2.61**	**-2.61**	**-2.20**	**-1.62**	**-1.20**
Su. Impact	0.209	0.216	0.234	0.251	0.266	0.276	0.279	0.285	0.292	0.295	0.295	0.295	0.295
Su. Unimp.	0.295	0.295	0.295	0.295	0.295	0.295	0.295	0.295	0.295	0.295	0.295	0.295	0.295
Summer Change	**-0.086**	**-0.079**	**-0.061**	**-0.044**	**-0.029**	**-0.019**	**-0.016**	**-0.010**	**-0.003**	**0.000**	**0.000**	**0.000**	**0.000**
Summer % Change	**-29.11**	**-26.75**	**-20.76**	**-14.84**	**-9.81**	**-6.43**	**-5.52**	**-3.26**	**-1.16**	**0.00**	**0.00**	**0.00**	**0.00**
Fall Impact	0.554	0.555	0.565	0.566	0.573	0.574	0.574	0.577	0.584	0.588	0.590	0.593	0.601
Fall unimp.	0.616	0.616	0.616	0.616	0.616	0.616	0.616	0.616	0.616	0.616	0.616	0.616	0.616
Fall\Winter Change	**-0.062**	**-0.061**	**-0.051**	**-0.050**	**-0.043**	**-0.042**	**-0.042**	**-0.039**	**-0.032**	**-0.029**	**-0.026**	**-0.023**	**-0.015**
Fall\Winter % Change	**-10.01**	**-9.89**	**-8.34**	**-8.08**	**-6.97**	**-6.81**	**-6.81**	**-6.35**	**-5.25**	**-4.65**	**-4.29**	**-3.81**	**-2.45**
Annual Imp.	0.544	0.548	0.557	0.564	0.571	0.574	0.575	0.580	0.584	0.585	0.587	0.588	0.588
Annual Unimp.	0.599	0.599	0.599	0.599	0.599	0.599	0.599	0.599	0.599	0.599	0.599	0.599	0.599
Annual Change	**-0.055**	**-0.051**	**-0.042**	**-0.035**	**-0.029**	**-0.025**	**-0.024**	**-0.020**	**-0.015**	**-0.014**	**-0.012**	**-0.012**	**-0.012**
Annual % Change	**-9.23**	**-8.53**	**-7.09**	**-5.88**	**-4.77**	**-4.15**	**-4.07**	**-3.26**	**-2.47**	**-2.38**	**-2.07**	**-1.92**	**-1.92**

Figure E12. Sample Preliminary Analysis Program Output Table

The output table is a single sheet with three sections that summarize the input and output data. Withdrawal rates for each season are displayed in the first section, in several different units. The percent change in seasonal *average* RMWUA is displayed in the second section for all three seasons, and annually. The seasonal *median* unimpacted and impacted RMWUA, and the percent change in seasonal RMWUA, for each of the preset passby flows (percent ADF) are displayed in the third section for each season, and annually. The unimpacted and impacted RMWUA values are shown, along with the percentage change.

To print the output table, press the Print Report button on the Passby Program output screen (Figure E12). To save this output table to a file, press the Save This Output button to display a pop-up menu, which allows entry of a name for the file. If the file is not saved, it will be overwritten by the next program run.

The output can be displayed graphically by pressing either the Average Chart or the Median Chart buttons on the output screen. The Average Chart button produces a graph of the seasonal average RMWUA versus passby flow, with one curve for each season. The Median Chart button produces a similar graph of seasonal median RMWUA versus passby flow. Both graphs will be printed automatically.

To close the preliminary analysis program output, press either the Back to Main Menu button or the Back to Passby Program button on the output screen (Figure E12). If the first button is pressed, control is transferred to the Main Menu (Figure E1). If the second button is pressed, control will be transferred to the passby program streamflow data input screen, which is identical to the Streamflow Data Form, shown in Figure E2.

The information contained in the report can be used to determine feasible passby flows for each season. The impacts of feasible combinations of withdrawal and passby flow should be evaluated using the detailed analysis program.

Key to Study Sites Shown on Plate 1

Stream Name	Number
Bear Run	1
Big Fill Run, Seg. 1	2
Big Fill Run, Seg. 2	3
Big Run	4
Fowler Hollow, Seg. 1	6
Fowler Hollow, Seg.2	7
Green Creek, Seg. 1	9
Green Creek, Seg. 2	10
Green Creek, Seg. 3	11
Horning Run	12
Kansas Valley Run	13
Laurel Run (Juniata)	15
Mile Run	16
Mugser Run, Seg. 1	17
Mugser Run, Seg.2	18
Rapid Run, Seg. 1	19
Rapid Run, Seg. 2	20
Rapid Run, Seg. 3	21
Salem Creek	22
Sand Spring Run	23
Swift Run	24
Vanscoyoc Run	26
Wapwallopen Creek, Seg. 1	27
Wapwallopen Creek, Seg. 2	28
Wapwallopen Creek, Seg. 3	29
Wapwallopen Creek, Seg. 4	30
Antes Creek	31
Big Spring Creek	32
Boiling Spring Run	33
Bushkill Creek, Seg. 1	34
Bushkill Creek, Seg. 2	35
Cedar Creek (Lehigh)	36
Cedar Run (Centre)	37
Cedar Run (Cumberland)	38
Falling Spring Run	39
Honey Creek	40
Letort Creek, Seg. 1	41
Letort Creek, Seg. 2	42
Lick Creek	43
Little Fishing Creek	44
Long Hollow Run	45
Monocacy Creek, Seg. 1	46
Monocacy Creek, Seg. 2	47
Monocacy Creek, Seg. 3	48
Nancy Run	49
Penns Creek, Seg. 1	50
Penns Creek, Seg. 2	51
Penns Creek, Seg. 3	52
Potter Creek	53

Stream Name	Number
Spring Creek (Berks)	54
Spring Creek, Seg. 1	55
Spring Creek, Seg. 2	56
Spring Creek, Seg. 3	57
Spring Creek, Seg. 4	58
Trindle Spring Run	59
Trout Creek	60
Beech Run	61
Benner Run	62
Bloomster Hollow	63
Cherry Run	64
Coke Oven Hollow	65
Cush Creek, Seg. 1	66
Cush Creek, Seg. 2	67
Dunlap Run	68
E. Br. Spring Creek, Seg.2	70
Fall Creek, Seg. 1	71
Fall Creek, Seg. 2	72
Findley Run	73
Lower Two Mile Run, Seg. 1	74
Lower Two Mile Run, Seg. 2	75
Lyman Run	76
McClintock Run	77
McEwen Run	78
Meyers Run	79
Mill Run	80
Red Run	82
Seaton Run	83
Strange Hollow	84
Tannery Hollow	85
Warner Brook	86
Whites Creek, Seg. 1	88
Whites Creek, Seg. 2	89
E. Br. Raven Creek	90
Granville Run	91
Laurel Run (Huntingdon)	92
Baisman Run	93
Basin Run, Seg. 1	94
Basin Run, Seg. 2	95
Cooks Branch	96
First Mine Branch	97
Gillis Falls, Seg. 1	98
Gillis Falls, Seg. 2	99
Greene Branch	100
Norris Run	101
Piney Run	102
Third Mine Branch	103
Timber Run	104