CONCLUSIONS

Despite the fact that flooding in fall 2011 prevented SRBC staff from collecting a second year of P95 data, the results of the Low Flow Monitoring Pilot Study provided useful information to guide future low flow monitoring efforts in the Susquehanna River Basin. Several biological metrics for macroinvertebrates, fish, and periphyton showed potential sensitivity to changes in flow. However, it is important to remember that this study compared only two points in time, making it impossible to separate seasonal and other factors as possible drivers for observed differences. It will require several years of sampling in both drought and normal flow years before relationships between flow and biological communities can be established.

FUTURE OF LOW FLOW MONITORING IN THE SUSQUEHANNA BASIN

SRBC established a basin-wide Low Flow Monitoring Network in 2012. The network consists of 19 stations in the Pennsylvania and New York portions of the Susquehanna River Basin (Figure 6). There are six stations located in the Northern Appalachian Plateau and Uplands, six in the North Central Appalachians ecoregions, and seven stations located in the Central Appalachian Ridges and Valleys ecoregion. The network focuses on forested streams in an attempt to isolate effects related to flow from anthropogenic impacts.

Eleven of the Low Flow Monitoring Network stations overlap with stations that are part of SRBC's Remote Water Quality Monitoring Network (RWQMN). The RWQMN stations are equipped with real-time data sondes that continuously record temperature, pH, conductance, dissolved oxygen, turbidity, and water depth. Water depth measurements can be used to establish a relationship with streamflow. SRBC staff installed InSitu, Inc. Level TROLL loggers to record temperature and water-depth at the other eight Low Flow Monitoring Network stations in June 2012. Having a continuous temperature and flow record will allow for a better correlation between these factors and biological communities.

SRBC staff will sample each station in the Low Flow Monitoring Network twice annually during the natural low flow period (June – September): once during a period of higher baseline flow (seasonal P50 or median flow) and again during a period of low flow characterized by the seasonal P95 flow. If streams never reach seasonal P95 flows, a second sampling round will still be conducted in September to document conditions during a "normal" baseline flow year. Should a prolonged drought occur in a given year, staff may conduct additional sampling to document potential impacts of extreme and sustained low flows on water quality and biological communities.

Data collection will closely follow the procedures outlined in the Low Flow Monitoring Pilot Study, including:

- Field water chemistry analysis, including temperature, pH, dissolved oxygen, and specific conductivity;
- Laboratory water quality analysis;
- Biological community data, including fish, macroinvertebrates, periphyton (algae), and the presence of any invasive species;
- Physical habitat data, including stream channel, stream bank, and riparian area conditions; and
- Streamflow measurements.

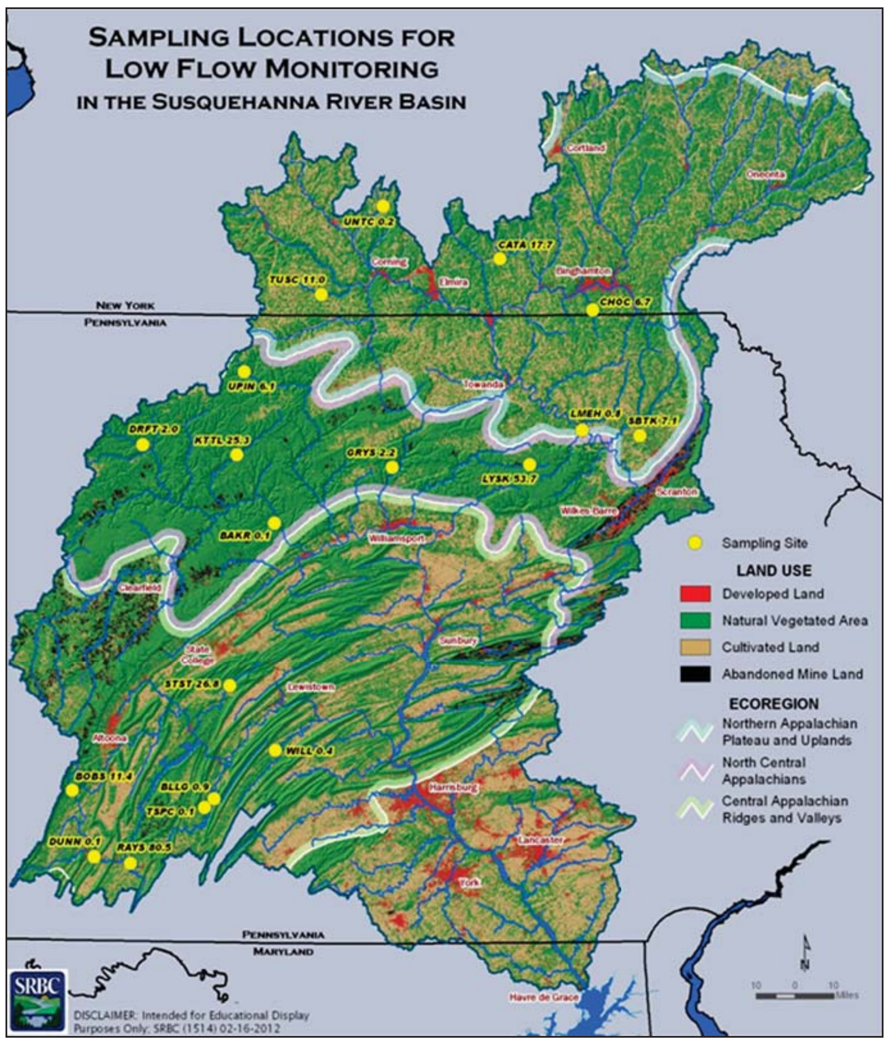


Figure 6. Location of the Low Flow Monitoring Network Stations in the Susquehanna River Subbasin

Commission staff measuring flow at Buffalo Creek, Perry, Co., Pa., during baseline flow in 2010.

These data will be used to characterize "normal" conditions during baseline flow and low flow, as well as to compare water quality and biological communities associated with different flows. Data collected as part of the newly established Low Flow Monitoring Network will be used to advise management decisions regarding low flow mitigation and passby flows associated with surface water withdrawals, and to improve knowledge of changes associated with naturally occurring low flow conditions.

REFERENCES

Apse, C., M. DePhilip, J. Zimmerman, and M.P Smith. 2008. Developing Instream Flow Criteria to Support Ecologically Sustainable Water Resource Planning and Management. The Nature Conservancy, Harrisburg, Pennsylvania.

Armitage, P.D. and G.E. Petts. 1992. Biotic score and prediction to assess the effects of water abstractions on river macroinvertebrates for conservation purposes. Aquatic Conservation: Marine and Freshwater Ecosystems 2:1-17.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841/B-99/002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Barbour, M.T., J.B. Stribling, and J.R. Karr. 1995. Multimetric approach for establishing biocriteria and measuring biological condition. Chapter 6 in Biological assessment and criteria: tools for water resource planning and decision making, W.S. Davis and T.P. Simon, eds. (pp. 63-77). CRC Press, Boca Raton, Florida.

Biggs, B.J.F., D.G. Goring, and V.I. Nikora. 1998. Subsidy and stress responses of stream periphyton to gradients in water velocity as a function of community growth form. Journal of Phycology 34:598-607.

Biggs, B.J.F. and M.E. Close. 1989. Periphyton biomass dynamics in gravel bed rivers: the relative effects of flow and nutrients. Freshwater Biology 22:209-231.

Boulton, A.J. 2003. Parallels and contrasts in the effects of drought on stream macroinvertebrates assemblages. Freshwater Biology 48:1173-1185.

Boulton, A.J. and P.S. Lake. 1990. The ecology of two intermittent streams in Victoria, Australia. I. Multivariate analyses of physicochemical features. Freshwater Biology 24:123-141.

Buchanan, T.J. and W.P. Somers. 1969. Discharge measurements at gaging stations. U.S. Geological Survey Techniques of Water Resources Investigations, Book 3, Chapter A8, Washington, D.C.

Bunn, S.E. and A.H. Arthington. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management 30:492-507.

Campbell, E.J. 2012. Lower Susquehanna River Subbasin Survey: A Water Quality and Biological Assessment, April – July 2011. Susquehanna River Basin Commission (Publication No. 282), Harrisburg, Pennsylvania.

Campbell, E.J. 2011. Juniata River Subbasin Survey: A Water Quality and Biological Assessment, April – July 2010. Susquehanna River Basin Commission (Publication No. 274), Harrisburg, Pennsylvania.

Carlisle, D.M., M.R. Meador, S.R. Moulton II, and P.M. Ruhl. 2007. Estimation and application of indicator values for common macroinvertebrate genera and families of the United States. Ecological Indicators 7:22-33.

Chow, V.T. 1959. Open-channel hydraulics. McGraw-Hill Book Co., New York, New York.

Cortes, R.M.V., M.T. Ferreira, S.V. Oliveira, and D. Oliveira. 2002. Macroinvertebrate community structure in a regulated river segment with different flow conditions. River Research and Applications 18:367-382.

DePhilip, M. and T. Moberg. 2010. Ecosystem Flow Recommendations for the Susquehanna River Basin. The Nature Conservancy, Harrisburg, Pennsylvania.

Dewson, Z.S., A.B.W. James, and R.G. Death. 2007a. A review of the consequences of decreased flow for instream habitat and macroinvertebrates. Journal of the North American Benthological Society 26:401-415.

REFERENCES

_____. 2007b. Invertebrate community responses to experimentally reduced discharge in small streams of different water quality. Journal of the North American Benthological Society 26:754-766.

Dewson, Z.S., R.G. Death, and A.B.W. James. 2003. The effect of water abstractions on invertebrate communities in four small North Island streams. New Zealand Natural Sciences 28:51-65.

Englund, G. and B. Malmqvist. 1996. Effects of flow regulation, habitat area and isolation on the macroinvertebrate fauna of rapids in north Swedish rivers. Regulated Rivers: Research and Management 12:433-445.

Evans-White, M.A., W.K. Dodds, and M.R. Whiles. 2003. Ecosystem significance of crayfishes and stonerollers in a prairie stream: functional differences between co-occurring omnivores. Journal of the North American Benthological Society 22:423-441.

Freeman, M.C. and P.A. Marcinek. 2006. Fish assemblage responses to water withdrawals and water supply reservoirs in Piedmont streams. Environmental Management 38:435-450.

Gorman, O.T. and J.R. Karr. 1978. Habitat structure and stream fish communities. Ecology 59:507-515.

Guy, H.P. and V.W. Norman. 1969. Field Methods for Measurement of Fluvial Sediment. U.S. Geological Survey Techniques of Water Resources Investigation, Book 3, Chapter C2 and Book 5, Chapter C1, Washington, D.C.

Hakala, J.P. and K.J. Hartman. 2004. Drought effect on stream morphology and brook trout (Salvelinus fontinalis) populations in forested headwater streams. Hydrobiologia 515:203-213.

Hart, D.D. and C.M. Finelli. 1999. Physical-biological coupling in streams: the pervasive effects of flow on benthic organisms. Annual Review of Ecology and Systematics 30:363-395.

Hem, J.D. 1970. Study and Interpretation of the Chemical Characteristics of Natural Water. 2nd edition. Geological Survey Water-Supply Paper 1473. United States Department of the Interior. United States Government Printing Office, Washington, D.C.

Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution. The Great Lakes Entomologist 20:31-39.

Humphries, P. and D.S. Baldwin. 2003. Drought and aquatic ecosytems: an introduction. Freshwater Biology 48:1141-1146.

James, D.A., J.W. Wilhite, and S.R. Chipps. 2010. Influence of drought conditions on brown trout biomass and size structure in the Black Hills, South Dakota. North American Journal of Fisheries Management 30:791-798.

Lake, P.S. 2003. Ecological effects of perturbation by drought in flowing waters. Freshwater Biology 48:1161-1172.

LeFevre, S.R. 2005. Juniata Subbasin Survey: A Water Quality and Biological Assessment, June – November 2004. Susquehanna River Basin Commission (Publication No. 240), Harrisburg, Pennsylvania.

Lytle, D.A. and N.L. Poff. 2004. Adaptation to natural flow regimes. Trends in Ecology and Evolution 19:94-100.

McIntosh, M.D., M.E. Benbow, and A.J. Burky. 2002. Effects of stream diversion on riffle macroinvertebrate communities in a Maui, Hawaii stream. River Research and Applications 18:569-581.

McKay, S.F. and A. J. King. 2006. Potential ecological effects of water extractions in small, unregulated streams. River Research and Applications 22:1023-1037.

Mecklenburg, D.E. and A.D. Ward. 2005. STREAM modules: spreadsheet tools for river evaluation, assessment and monitoring. In: D'Ambrosio, J.L., editor. Self-sustaining solutions for streams, wetlands and watersheds. ASAE, St. Paul, Mn. Available from: http://www.dnr.state.oh.us/Portals/12/water/streammorphology/08-09-18%20stream%20morphology%20webpage/Information/ASAE%20STREAM%Modules%paper.doc.

Merritt, R.W. and K.W. Cummins (eds). 2008. An Introduction to the Aquatic Insects of North America (4th edition). Kendall/Hunt, Dubuque, Iowa.

Omernik, J.M. 1987. Aquatic Ecoregions of the Conterminous United States. U.S. Geological Survey, Reston, Virginia.

PADEP. 2012. A Benthic Macroinvertebrate Index of Biotic Integrity for Wadeable Freestone Riffle-Run Streams in Pennsylvania. Harrisburg, Pennsylvania.

_____. 2009. An Index of Biological Integrity for "True" Limestone Streams. Harrisburg, Pennsylvania.

Paul, M.J. 2012. Evaluation of nutrients as a stressor of aquatic life in Wissahickon Creek, Pa. Prepared for U.S. Environmental Protection Agency, Region 3, Philadelphia, Pa., by Tetra Tech Inc., Owings Mills, Maryland.

Plafkin, J.L., M.T. Barbour, D.P. Kimberly, S.K. Gross, and R.M. Hughes. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. EPA 440/4-89/001. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Poff, N.L. and J.K.H. Zimmerman. 2010. Ecological responses to altered flow regimes: a literature review to inform the science and management of environmental flows. Freshwater Biology 55:194-205.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. BioScience 47:769-784.

Pusey, B.J., A.H. Arthington, and M.G. Read. 1993. Spatial and temporal variation in fish assemblage structure in the Mary River, south-east Queensland: the influence of habitat structure. Environmental Biology of Fishes 37:355-380.

Rader, R.B. and T.A. Belish. 1999. Influence of mild to severe flow alterations on invertebrates in three mountain streams. Regulated Rivers: Research and Management 15:353-363.

Richards, C., R.J. Haro, L.B. Johnson, and G.E. Host. 1997. Catchment and reach-scale properties as indicators of macroinvertebrate species traits. Freshwater Biology 37:219-230.

Riseng, C.M., M.J. Wiley, and R.J. Stevenson. 2004. Hydrologic disturbance and nutrient effects on benthic community structure in Midwestern US streams: a covariance structure analysis. Journal of the North American Benthological Society 23:309-326.

Schlosser, I.J. 1982. Fish community structure and function along two habitat gradients in a headwater stream. Ecological Monographs 52:395-414.

Suren, A.M., B.J.F. Biggs, C. Kilroy, and L. Bergey. 2003a. Benthic community dynamics during summer low-flows in two rivers of contrasting enrichment: 1. Periphyton. New Zealand Journal of Marine and Freshwater Research 37:53-70.

Suren, A.M., B.J.F. Biggs, M.J. Duncan, L. Bergey, and P. Lambert. 2003b. Benthic community dynamics during summer low-flows in two rivers of contrasting enrichment: 2. Invertebrates. New Zealand Journal of Marine and Freshwater Research 37:71-83.

Stoddard, J.L., D.P. Larsen, C.P. Hawkins, R.K. Johnson, and R.H. Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications 16:1267-1276.

USEPA. 2007. National River and Stream Assessment Field Operations Manual. EPA-841-B-07-009. Washington, D.C.

Walters, A.W. and D.M. Post. 2011. How low can you go? Response of aquatic insect communities to low flow disturbance. Ecological Applications 21:163–174.

_____. 2008. An experimental disturbance alters fish size structure but not food chain length in streams. Ecology 89:3261-3267.

Welsh, E.B., J.M. Jacoby, R.R. Horner, and M.R. Seeley. 1988. Nuisance biomass levels of periphytic algae in streams. Hydrobiologia 157:161-168.

Wills, T.C., E.A. Baker, A.J. Nuhfer, and T.G. Zorn. 2006. Response of the benthic macroinvertebrate community in a northern Michigan stream to reduced summer streamflows. River Research and Applications 22:819-836.

Winemiller, K.O. and K.A. Rose. 1992. Patterns of life-history diversification in North American fishes: implications for population regulation. Canadian Journal of Fisheries and Aquatic Sciences 49:2196-2218.

APPENDIX A

Station Names, Location Descriptions, Geographic Coordinates, and Drainage Areas for Low Flow Monitoring Pilot Study Stations

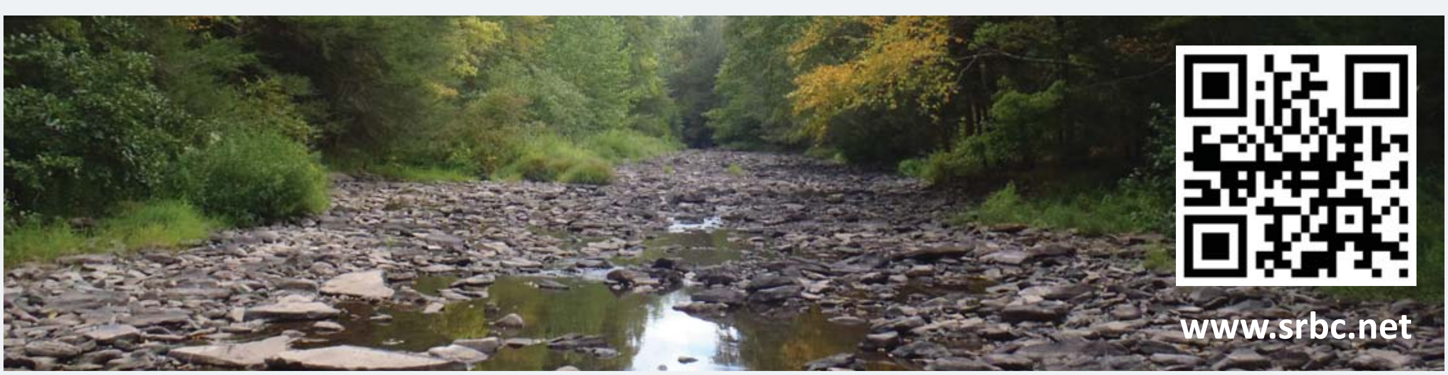
Station Name	Location Description	Latitude	Longitude	Drainage Area (m^2)
AUGH 17.2	Aughwick Creek downstream of Three Springs Creek and Rt. 994 near Pogue, Huntingdon Co.	40.21542	-77.92717	203.9
BLLG 0.9	Blacklog Creek along T599 upstream of Rockhill and Orbisonia, Huntingdon Co.	40.24054	-77.89502	66.4
BLLG 4.6	Blacklog Creek upstream of Peterson Road Bridge, upstream of Shade Creek, Huntingdon Co.	40.23172	-77.8633	34.1
BOBS 0.9	Bobs Creek at tractor crossing, near Reynoldsdale, Bedford Co.	40.15096	-78.54532	64.1
BUFF 0.4	Buffalo Creek upstream of SR 1007 (Fairground Road) covered bridge, near Newport, Perry Co.	40.48906	-77.15807	67.3
BUFR 0.4	Buffalo Run upstream of Route 31/96 bridge in Manns Choice, Bedford Co.	40.00201	-78.59735	24.2
CANO 5.1	Canoe Creek, upstream of Canoe Creek State Park, along SR 1011, Blair Co.	40.52815	-78.25041	8.6
CRKD 0.3	Crooked Creek upstream of SR 3033 bridge in Huntingdon, Huntingdon. Co.	40.48039	-78.02143	26.9
DUNN 0.1	Dunning Creek near mouth upstream SR 1001, near Bedford, Bedford Co.	40.02433	-78.47794	196.4
FRNK 18.9	Frankstown Branch Juniata River at USGS gage in Williamsburg, Blair Co.	40.46309	-78.20009	289.3
GTRC 2.9	Great Trough Creek upstream of T370 bridge near Newburg, Huntingdon Co.	40.28637	-78.12104	71.5
HONY 0.2	Honey Creek near mouth in Reedsville, Mifflin Co.	40.66347	-77.59253	93.6
JACK 2.9	Jacks Creek upstream SR 2004 east of Lewistown, Mifflin Co.	40.61305	-77.53219	57
JUNR 34.0	Juniata River at Route 35 bridge in Mifflintown, Juniata Co.	40.56889	-77.40067	2838
JUNR 47.0	Juniata River at Route 103 bridge upstream of Kishacoquillas Creek in Lewistown, Mifflin Co.	40.59352	-77.57842	2518.4
JUNR 63.6	Juniata River on both sides of the island at bridge in McVeytown, Mifflin Co.	40.49817	-77.73621	2454.8
JUNR 84.6	Juniata River at bridge in Mapleton, Huntingdon Co.	40.3946	-77.93979	2026.8
JUNR 94.9	Juniata River at 4th Street bridge in Huntingdon, Huntingdon Co.	40.48258	-78.01178	846.2
KISH 5.5	Kishacoquillas Creek in Jacks Mountain gap near Burnham, Mifflin Co.	40.65472	-77.58333	163
LJUN 3.8	Little Juniata River at SR 4004 bridge in Barree, Huntingdon Co.	40.58703	-78.10042	335.2
NBLA 1.4	North Branch Little Aughwick Creek upstream T457 bridge near Burnt Cabins, Fulton Co.	40.09193	-77.90921	18
RAYS 80.5	Raystown Branch Juniata River upstream of Greys Run east of Everett, Bedford Co.	40.00466	-78.30017	546
SHAV 17.0	Shaver's Creek downstream of Route 26 in Penn State Experimental Forest, Huntingdon Co.	40.69245	-77.8949	3.9
SHOB 0.4	Shobers Run along Business Route 220 downstream of Bedford Springs, Bedford Co.	39.99889	-78.50361	16.3
SIDE 0.1	Sideling Hill Creek at mouth near Maddensville, Huntingdon Co.	40.13057	-77.95726	96.7
STST 26.8	Standing Stone Creek at SR 1023 bridge near McAlevys Fort, Huntingdon Co.	40.65185	-77.82278	34
TIPT 3.0	Tipton Run along SR 4023 near Tyrone, Blair Co.	40.65534	-78.3281	15.6
TSPC 0.1	Three Springs Creek upstream of T341 near Pogue, Huntingdon Co.	40.20794	-77.94091	30.9
TUSC 0.6	Tuscarora Creek near mouth at Route 75/Route 333 bridge in Port Royal, Juniata Co.	40.52816	-77.39193	269.5
WILL 0.4	Willow Run near mouth at T305 bridge near McCullochs Mills, Juniata Co.	40.41852	-77.59602	10.5

Susquehanna River Basin Commission

Protecting Your Watershed for Today and Tomorrow

Maintaining natural flow regimes is critical to conserving the native biodiversity of freshwater systems.

Flood damage reduction and low flow mitigation planning are ongoing priorities of the Susquehanna River Basin Commission.



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