# Report as of FY2007 for 2006WV79B: "Systematic determination of water resource data & information management needs in West Virginia (WRI-81)"

## Publications

Project 2006WV79B has resulted in no reported publications as of FY2007.

## Report Follows

# Systematic Determination of Water Resource Data & Information Management Needs in WV Final Report

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By Richard Herd, Alyse Marie Schrecongost & Jennifer Fulton

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WV Water Research Institute
West Virginia University
150 Evansdale Drive
Morgantown, WV 26505

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# Abstract

The nation and world are rapidly recognizing the value of water resources and becoming aware of the changing use, climate, and precipitation trends that affect supply, quality, and frequencies of peaks and dips in resource stocks and flows. Unfortunately, state and federal government agencies are simultaneously disinvesting in the streamgaging and groundwater monitoring well networks that provide the data foundation upon which nearly all US water resource research and management rests. West Virginia's history of flooding and drought, as well as its water resource abundance and location relative to eastern seaboard population centers, lends it to being a state with a particular stake in collecting quality information about water resource trends. This report is an institutional review of how water resource data is collected and managed with an emphasis on security of long term water resource trend data. The report also provides a tool for and results from an interagency participatory streamgage prioritization exercise designed and conducted in cooperation with the WV Gaging Council.

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# Executive Summary

The streamgage and groundwater monitoring well network in West Virginia has been threatened by consistent funding shortages for almost 15 years. Moreover, our gages with long-term histories of data collection – those upon which we most rely for evaluating patterns today against historical trends – are often among those that suffer during cutbacks. Ten years of peakflow values from a stream gage is the generally accepted minimum requirement for development of a flood probability estimate (Cleaves & Doheny, 2000). Our lost ability to relate more complex current weather and water events to past patterns severely weakens our ability to understand and manage our most important state resource – freshwater. Heightened public awareness just after severe flooding can often result in periodic windfalls of network funding, but the lost years of data or changed new locations of the re-funded gages significantly undermines the value of the historical trend data. Also, these gages may be replaced with funding to monitor real-time stages for floodwarning and recreational use, but without sufficient funding to collect, store and present that data to the public in a way that preserves it as trends in flow data.

Insecure gage and well funding results in lost water resource data. This, in turn, results in lost analysis and therefore lost or mismanaged opportunities over time. Ending data collection at gages with years of historical record removes the possibility of conducting reliable research and analysis now and in the future; the data will not exist to support important research or decisions about climate change, bridge sizes, road design, building codes, factory locations, and flood management infrastructure (USGS, 1998). Economic development opportunities are lost, and a lack of information results in mismanaged resources.

Moreover, when WV agencies' budget cuts reduce gage and well network state funding, the USGS Federal-State Cooperative Water Program (CWP) is forced to cut back its matching funds accordingly, doubling the loss to the network. Annual funding cuts that started in the late 80s and continue today, cost WV tens of thousands of dollars in lost wages as personnel from multiple state agencies, organizations, and research institutes invest time and effort into scrambling, year after year, to negotiate complex coverage of funding gaps or to decide where data collection effort must end.[1] An interagency council that exists to manage this annual crisis, unfunded, has even turned to seek private charitable donations to cover basic state operations of gaging operations – an expensive and unreliable endeavor. Members of the WV Gaging Council travel to meet four to five times a year in addition to fulfilling inter-meeting efforts. Time taken for these activities is time taken away from agencies' other duties and goals.

[1] This estimate is based on wage estimates for those attending quarterly WV Gaging Council meetings and conducting related work in between meetings. The estimate quickly surpassed $20,000 without including time used to conduct legislative and interagency negotiations.

The 2004 Statewide Flood Report and the 2006 Water Resources Protection Act Report both underscored the importance of reinvesting in reliable water resource information collection and management. Requests from the state legislature to identify flood and drought prone areas and to estimate water supply and demand balances remained largely inconclusive in the final reports, in great part due to the lack of available historical streamgage and groundwater monitoring well data needed to conduct these analyses. Much of the analysis that was provided in the report had to be based on 30 year trend data from 1964-1994 because of the severe drop in the number of gages with significant data history after the gaging network budget cuts that ran from 1994-1997.

For this report, an interagency participatory survey was developed to assess and prioritize streamgaging needs and priorities in the state. The survey, or prioritization tool, which targeted members of the WV Gaging Council, reflected the challenge of coordinating diverse stakeholders to identify their agencies' priorities in the gage network. Asked to rank WV's river Basins in order from 1-8 based on how well each watershed was covered by the gaging network, respondents revealed many opposing perspectives on gage network resources and gaps; one basin alone was ranked $4^{th}$, $7^{th}$, $8^{th}$, and $2^{nd}$ by four responding agencies.

From the survey, the existing gage stations received an average rating of 3.184, using a scale of 1-4 (not useful:1, critically important 4). Looking at ratings of just the United States Geological Survey's (USGS) National Streamflow Information Program (NSIP) gages (prioritized for receiving guaranteed federal funding), state agencies rated these gages at an average of 3.476, indicating better agreement among agencies for the importance of the core set of NSIP gages. Selecting the highest rated gages on the survey would help define a second set of WV-core gages identified to receive secure state funding annually if WV had a program similar to the federal NSIP program. As stated earlier, such a list would be preliminary and would then have to be discussed by primary stakeholders.

The prioritization tool was used for analysis of streamgage priorities only. Because of the small number of groundwater monitoring wells N=8, it was not useful to prioritize them – though funding for even those eight is threatened annually.[2] A separate analysis is necessary of where groundwater monitoring wells are necessary for sound water resource management in West Virginia. For the 2006 Water Resource Protection Act Report, WVDEP conducted a preliminary review of groundwater monitoring well needs and identified notably important gaps in the western regions of the state in particular (WVDEP, 2006).

[2] This absence of a groundwater monitoring network in WV should be cause for concern among public decision makers in WV. WV has monitoring wells despite the approximately 33 billions of gallons of groundwater extracted annually in the state for public and private uses. By comparison, Maryland has 141 wells, Delaware 96, Pennsylvania 65, Virginia 256, and Ohio 140. (WVDEP, 2006)

## Acronyms

COE – US Army Corps of Engineers
CWP - USGS Federal-State Cooperative Water Program
NSIP – National Streamflow Information Program
OWRC - Ohio Water Resources Council
USGS – United States Geological Survey
WRPA – Water Resource Protection Act
WVCA – WV Conservation Agency
WVDNR – WV Department of Natural Resources
WVDEP – WV Department of Environmental Protection

# 1. Introduction

This report provides an institutional overview and analysis of the state gaging network limitations related to providing adequate and reliable streamflow data for the diverse group of public and private users that rely on that network to meet their organizations' objectives. The report also provides a participatory gage prioritization tool to support gage network resource allocation decisions, and it presents preliminary results from an initial application of that tool among state agencies and organizations actively involved in the WV Gaging Council, an organization with a mission to "*ensure that reliable water resources gaging data are available to meet the needs of the State's varied stakeholders*".

This report addresses the problem of insufficient, inconsistent, and unevenly distributed streamflow monitoring efforts that fail to provide adequate information for governments, academia, or private interests to assess, manage, and/or develop the state's valuable and extensive water resources.

A primary challenge to consistent and adequate provision of streamflow data is the institutional separation among the many and diverse users of gage data, the funders of that data collection, and the managers of the data (Cleaves, 1998). Table 2 describes primary types of gage data, the users, and the funders of a gaging network.

The United States Geological Survey (USGS) manages the vast majority of the state's real time and historical water resource data through its Federal-State Cooperative Water Program – a program which provides federal matching funds for states' investments in their water gaging networks and related water science research and analysis.

In West Virginia, USGS Federal-State Cooperative Water Program funds are matched by a quilt of different state agencies' contributions which vary year by year. Each year, the WV USGS office must invest weeks of staff time into accounting for promised contributions from each agency, comparing expected contributions with total anticipated costs of managing the gaging network, and then making additional solicitations, network cuts, and negotiations among agencies accordingly. Each agency has an incentive to default on their financial responsibility if other agency/agencies will cover the shortfall in order to protect the data (a traditional Prisoners' Dilemma game or Tragedy of the Commons[3]).

The lack of secure gage and groundwater monitoring well funding results in lost water resource data.[4] These annual data fluctuations result in weakened analytical capacity and

[3] The Prisoner's Dilemma is a more detailed analysis of another well known management problems called the Tragedy of the Commons. In both of these situations, individual agents have an incentive to "free ride" or shirk their responsibility and can reasonably expect other agents or stakeholders to continue contributing enough to maintain the common good, at least for the short or medium term. This Tragedy of the Commons is considered a tragedy because, without a change in institutional design, the commons are eventually abused/abandoned by all to a degree that makes the common pool resource unusable or beyond reasonable restoration costs.

[4] This absence of a groundwater monitoring network in WV should be cause for notable concern among public decision makers. WV has only 8 groundwater monitoring wells despite the approximately 33

therefore foregone or mismanaged economic and public safety opportunities over time. The trend of ending data collection at gages with years of historical record removes the possibility of conducting reliable research and analysis now and in the future (Figure 1); the data will not exist to support important research or decisions about climate change, bridge sizes, road design, building code design, factory locations, and flood management infrastructure (USGS, 1998). For example, ten years of peakflow values from a stream gage is the generally accepted minimum requirement for development of a flood probability estimate (Cleaves & Doheny, 2000).

Moreover, when WV state agencies' budget cuts result in reduced funds for gages and wells, the USGS Federal-State Cooperative Water Program is forced to cut back its matching funds accordingly, doubling the losses to the networks. Annual funding insecurity costs tens of thousands of dollars in lost wages as personnel from multiple state agencies, organizations, and research institutes invest time and effort into scrambling, year after year, to negotiate complex coverage of funding gaps or to decide where data collection effort must end.[5] An interagency council that exists to manage this annual crisis, unfunded, has even turned to seek private charitable donations to cover basic state operations of gaging infrastructure – an expensive and unreliable endeavor which is akin to asking private businesses to make charitable donations for state road maintenance. Members of the WV Gaging Council travel to meet four to five times a year in addition to fulfilling inter-meeting efforts. Time taken for these activities is time taken away from agencies' other duties and goals.

The 2004 Statewide Flood Report and 2006 Water Resources Protection Act Report underscored the importance of reinvesting in reliable water resource information collection and management. Requests from the state legislature to identify flood and drought prone areas and to estimate water supply and demand balances remain largely unmet, in great part due to the lack of available historical gage and well data with which to conduct these analyses. Moreover, both reports underscored the importance of preserving and supplementing the state streamgaging network and making specific recommendations for streamgages. The WRPA report also underscored the link between ground water monitoring data and analysis of streamflow data as critical for facilitating development of the state's energy and industrial sectors, planning around population growth, and protecting water supply (Table 1). State contributions to building and protecting reliable water monitoring networks must acknowledge the importance of this link.

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billions of gallons of groundwater extracted annually in the state for public and private uses. By comparison, Maryland has 141 wells, Delaware 96, Pennsylvania 65, Virginia 256, and Ohio 140. (WVDEP, 2006)

[5] This estimate is based on wage estimates for those attending quarterly WV Gaging Council meetings and conducting related work in between meetings. The estimate quickly surpassed $20,000 without addressing much of the time used to conduct legislative and interagency negotiations.

**Table 1 Comparison of groundwater monitoring resources regionally in absolute and relative numbers.** Figures in this table for wells are from the USGS website (June 2006).

| State | Groundwater Monitoring Wells | Counties with Monitoring Wells / Total Counties | State Sq. Miles |
|---|---|---|---|
| Pennsylvania | 68 | 66/67 | 45,888 |
| Ohio | 100+ | 83/89 | 44,828 |
| Virginia | 47 | 26/95 | 42,769 |
| Maryland | 10 | 6/24 | 12,407 |
| West Virginia | 7 | 3/55 | 24,231 |

Some stakeholders only need real-time gage data for immediate decisions (recreation companies, vacationers, flood emergency response agencies, etc.). For these users, moving gages for temporary convenience or taking them off line during budget crises does not a pose a significant problem. For many others, the value of a year or two of gage data is exponentially more valuable if it can be compared with historical trend data collected at that site over time. Therefore, losing state gages that have been providing historical data for decades is the loss of much more than a year or two of data. Evaluating data over time allows us to recognize and respond to changing weather and hydrology trends – predicting and preventing where damage is likely to occur rather than just reacting event by event. Gaps in data cannot be recovered later when budgets are more robust. In fact, these gaps permanently weaken our ability to make informed, safe, and/or economically proactive decisions in all facets of the state's pubic, private, and research sectors. Mark Anderson, Director of the South Dakota Water Science Center states, "If you have a discontinuity of a couple of years even, you lose part of the substantial investment that's been made in the period of record (of that gage). It's like you're squandering the investment of your predecessors."

Historical streamgage data gaps present an obstacle for two important state goals – sustainable economic development and protection of the citizens of West Virginia. To sustainably attract and locate industries that require use of WV's significant water resources requires an understanding of the extent of water supplies in the state as well as historical patterns of drought and flooding, dynamic relationships among landuse, groundwater, and surface water supplies in various regions of the state. This information is also critical for the recreation economy, and environmental standards are established based analysis of streamflow trends over time. For private and public service engineers to safely design roads, bridges, factories, and developments requires historical water trend data that can be analyzed to safely anticipate future trends in water resource behavior. As well, premier research at our state's universities in disciplines such as engineering, forestry and agriculture, chemistry and geology, and even in economics and political science frequently requires an accurate analysis of water resource supply dynamics that can only be provided if historical and contemporary streamflow data are collected and archived responsibly and consistently from the same stream locations.

## *1.1. Streamgaging in the United States & West Virginia*

The national network of streamgages expends some $120 million annually to run about 7,400 gauges, down from a peak of 8,221 in 1968. Each gauge costs, on average, $13,500 to run per year. These costs include capital investments, operation and maintenance of

the gage itself, monitoring and cleaning incoming data from gages and providing that data to the public through various web interfaces, among other costs (Schwartz, 2006). As budget cuts have affected the national network of gages, so too has WV's network suffered significant losses in the early 80s and again in the mid-90s (Figure 1 & 2).

Losses of gages with valuable historical data collection periods are exceptionally alarming (Figure 3). In 2006, 216 gages were on the chopping block across 26 states' networks. On the list of cuts was a gage in Kentucky with 98 years of data, in Hawaii with 87 years, and in Illinois with 97 years.

Between 1994 and 1997, WV lost nearly 20 stream gages with significant histories of gage data. Losses like this in WV and in many other states through the country have prompted USGS to secure funding for a core set of gages through the National Streamflow Information Program, which collect data that cannot be compromised with budget and political fluctuations at federal, state, and local levels (Figure 3).

> "The National Streamflow Information Program (NSIP) has been formulated by the U.S. Geological Survey (USGS) to create a stable, federally funded *base network* of streamgages and to enhance the information derived from this network with intensive data collection during major floods and droughts, periodic regional and national assessments of streamflow characteristics, enhanced streamflow information delivery to customers, and methods development and research." (Water Science and Technology Board, 2004)

This base network of streamgages is designed to meet five minimum federal streamflow information goals, namely, (1) interstate and international agreements, (2) flow forecasts, (3) river basin outflows, (4) long-term monitoring using benchmark (sentinel) watersheds, and (5) water quality.

Robin G. Middlemis-Brown, director of the Geological Survey's Iowa Water Science Center, said he was especially sorry to see a gauge go offline that had been providing data on the Des Moines River in Iowa for 87 years. "If you don't know your past, you can't tell your future," Mr. Middlemis-Brown said. "It's like going blind, slowly" (Schwartz, 2006). While the NSIP serves to protect the core data needs of the nation, with over 800 different state and local funding partners, juggling donors' fluctuating commitments to "keep states from going blind" becomes almost a full time job for state network coordinators.

Over the past ten years in West Virginia, funding crises have arisen nearly every year (Evaldi, 2006). In 1996, the state defaulted on providing its share of matching funds to the USGS Cooperative Water Program. The next year, the Legislature filled the gap when flooding raised public concern. In 1998, funds are used to address flood warning problems – shifting resources to realtime stage data monitoring. Three years of stability were followed by a $200,000 cut by one single agency, which again caused USGS to cut back on its federal matching contribution.

In 2003, state agencies met informally to pool funding resources and cover the funding gap left by the $200,000 cut. This interagency scramble occurred again in 2004 and in 2005. Agencies willing to step up to fill gaps realize that each agency faces the prisoner's dilemma to not contribute or to contribute less than the gage network is worth. Other agencies value the gage data regardless and are willing to increase contributions if possible to prevent data losses.

This repeating scenario, in part, prompted agencies to develop the WV Gaging Council – Council members' existence rely significantly on maintaining a stable and adequate water monitoring network. Founding Council member organizations included the following agencies and organizations: U.S. Geological Survey, U.S. Army Corps of Engineers, National Oceanic and Atmospheric Administration, WV Department of Environmental Protection, WV Division of Natural Resources, WV Conservation Agency, WV Division of Homeland Security and Emergency Management, NOAA, WV Department of Transportation, WV Water Research Institute, West Virginia Rivers Coalition, Michael Baker Corporation, and the Canaan Valley Institute.

While the Council mission and objectives are somewhat broader, Council members collaborate primarily on closing funding gaps for supporting the streamgage and monitoring well networks. The Council indirectly serves to help each agency identify and involve itself with the network funding problem - ideally this would generate greater commitment and reduce the agencies' willingness to free ride[6]. Accordingly, most Council agencies seem to be successful at negotiating among themselves to fill funding gaps.

The separation between gage information users and gage information funders/managers is important at two levels. At the state agency level, contributors have an incentive to step back and let the other agencies manage alone. At the public level, the gage information is valuable to many other public users (academics, engineering firms, the recreation industry, etc.). The Council's interest in public fundraising is intended to address that gap by allowing more direct and indirect users of gage data to help support the network that produces that data.

[6] Free riding is a term from economic game theory that describes scenarios when an agent faces a perverse incentive to not contribute a "fair share" to maintain a jointly used resource (common pool resources) if other actors are likely to continue contributing and providing the good. The danger in this scenario is not that one agent will free ride, but rather that the example creates an unfair scenario, reducing others' interest in contributing.

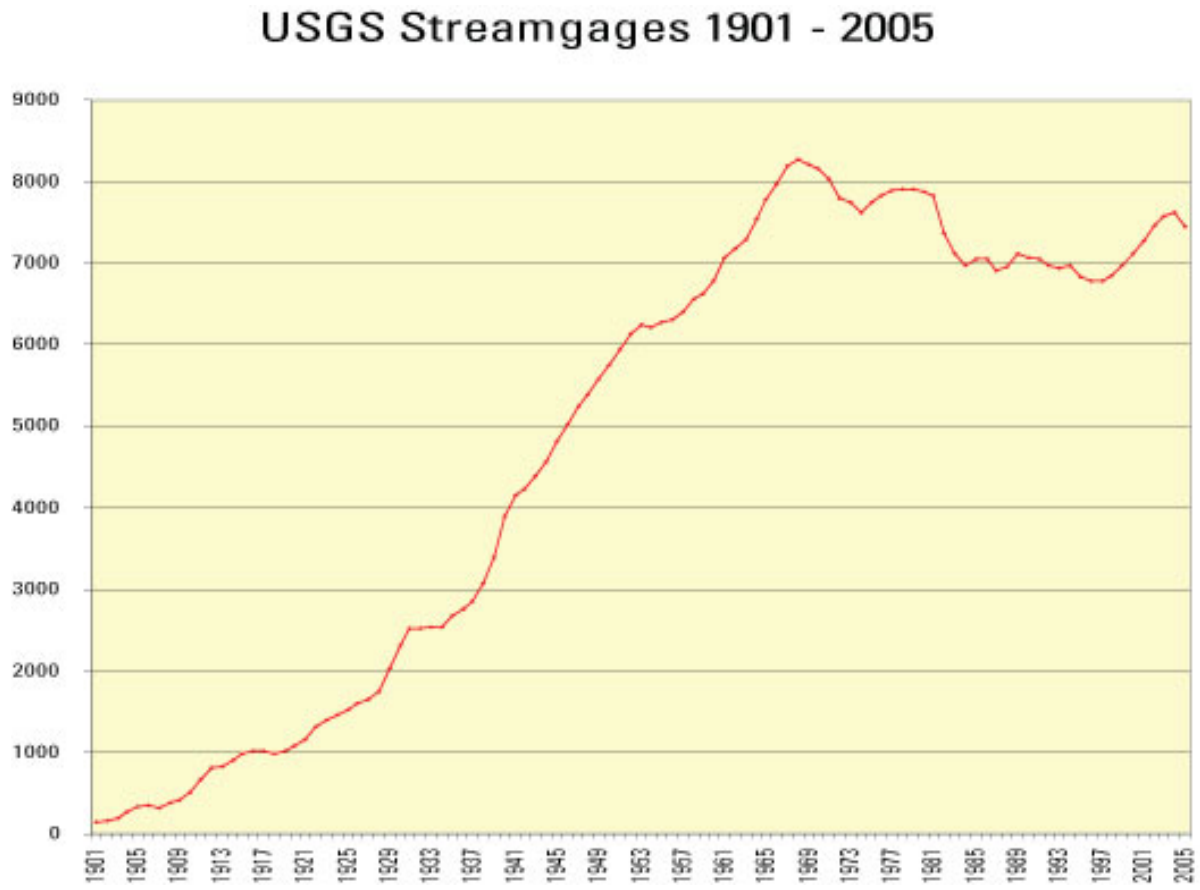


**Figure 1 Total streamgages (stage and discharge) managed by USGS from 1901-2005, Source: USGS NSIP.**

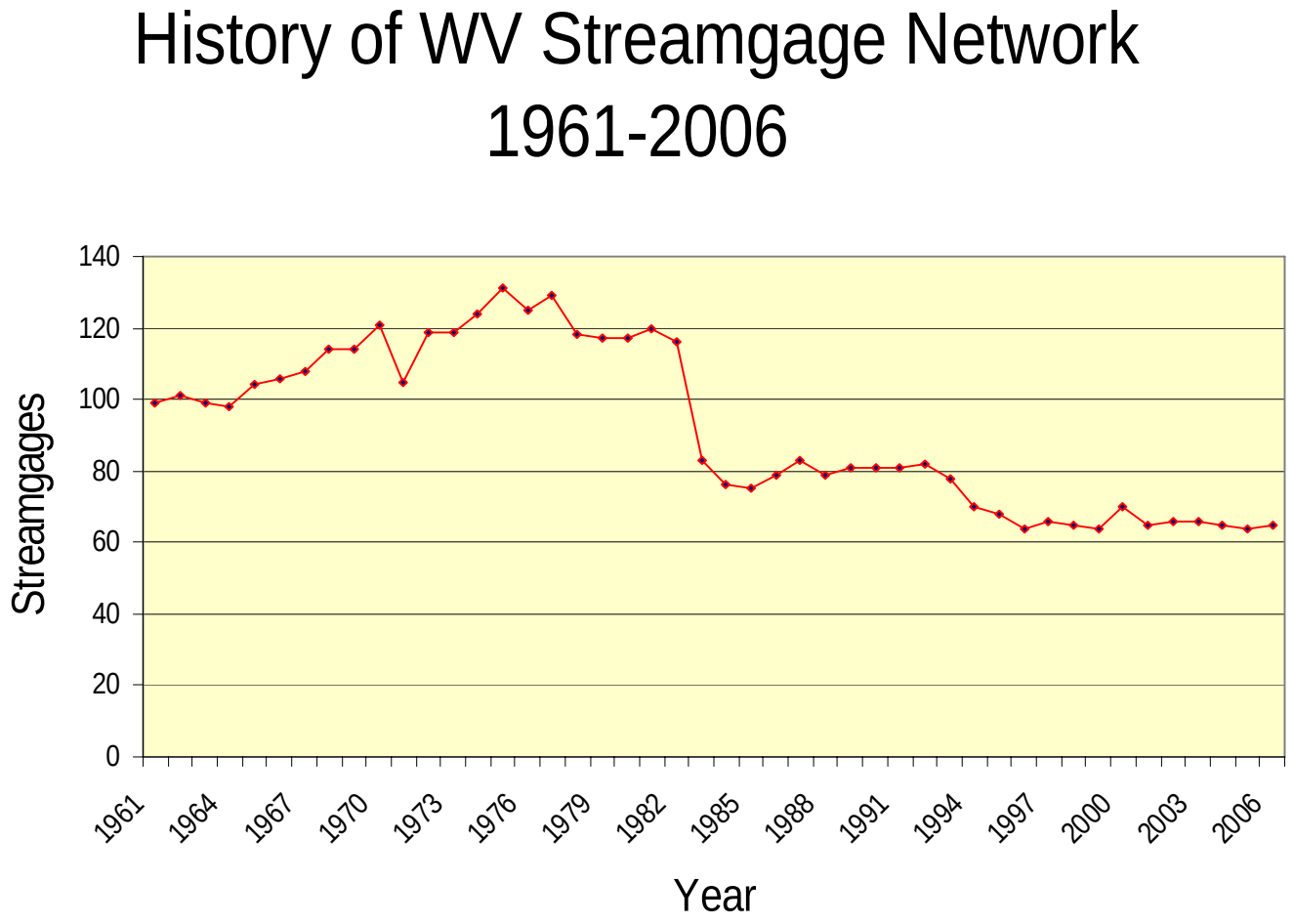


**Figure 2 History of WV streamgage network reflects decline in effective data collection capacity. Source: USGS, WV Office.**

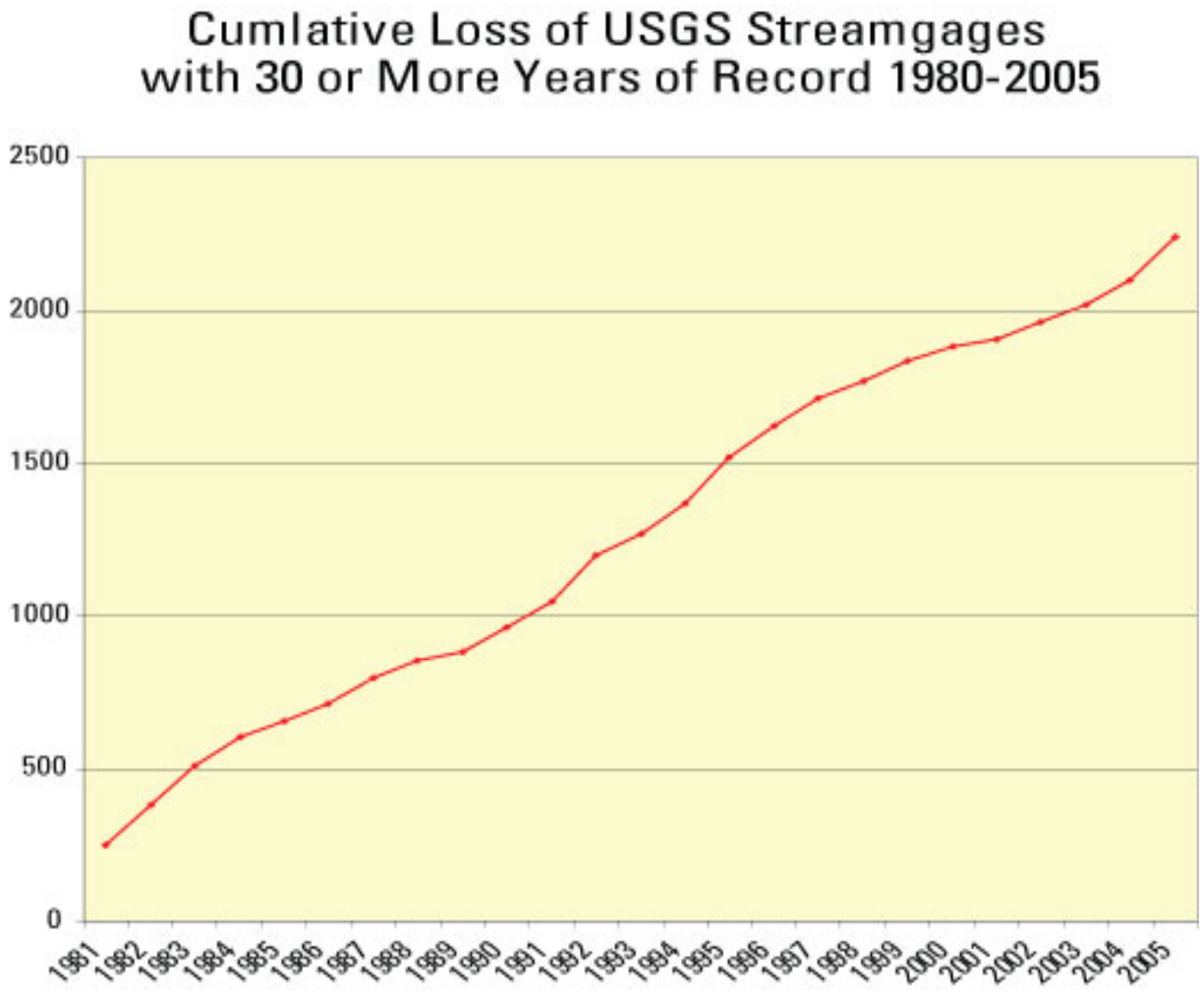


**Figure 3 Number of "long record" streamgages (those with 30 years or more of historical data) that have been de-funded and no longer report data for historical trends. Source: USGS NSIP.**

**Table 2 Taxonomy of WV stream gage data, uses, users, and funding sources**

| Primary types of gage data | Uses of gage data | Primary users that rely on gage information | Offices that annually coordinate to provide funding, installation, operations, maintenance, and public information sharing services in WV |
|---|---|---|---|
| **STREAM** | | | |
| **Real-time stage data** (how high the water is currently relative to a fixed benchmark) | > Flood warning systems<br>> Transportation advisories<br>> Recreation | > Governmental and non-governmental emergency flood response agencies<br>> Citizens/Businesses potentially affected by flooding<br>> Citizens/Businesses frequently accessing streams<br>> Recreational users of waters (fishermen, boaters, etc)<br>> Recreation-based service providers | > US Geological Survey (operator/funding agency)<br>> US Army Corps of Engineers (operator/funding agency)<br>> National Weather Service (operator)<br>> WV Office of Homeland Security / Emergency Services (operator/funding agency)<br>> Department of Natural Resources (funding agency)<br>> WV Conservation Agency (funding agency)<br>> WV Department of Transportation (funding agency)<br>> WV Department of Environmental Protection (funding agency)<br>>American Whitewater (funding agency, limited)<br>> Private companies (funding agency, limited) |
| **Historical stage and flow data** (realtime data from cleaned and archived over life of the gage which provides stage information as well as flow volume) | > Private, federal, state, and academic research of historical climate, landuse, and water supply trends.<br>> Planning, designing, managing public or private water use systems.<br>> Mapping & managing floodplains.<br>> Designing bridges and roads.<br>> Managing water rights.<br>> Establishing safe pollutant discharge control limits.<br>> Siting and design of mining/energy development projects | > Federal agencies and research institutes<br>> State agencies (DEP, Division of Highways, Department of Natural Resources, etc.)<br>>Engineering firms<br>> WVU/MU and other research institutes | |
| **Water quality data** (quality data collected at a stage and flow gage which is usually associated with a specific water use goal and/or pollutant presence/threat) | > Monitoring env conditions and protecting aquatic habitat. | > WVU/MU and other research institutes<br>> DEP/EPA/NPDES permittees<br>> Public water supply providers | |

Gaging Council time that has been invested into fundraising among private firms with interests in local water quality has been unsuccessful to date. Promotional fundraising materials have been in the development phase for approximately two years. This is possibly in part due to the absence of a paid staffer for the organization and possibly in part because of the undefined nature of how contributions would be managed. There seem to be a few primary approaches to how private donations might serve the gage network.

1. Donations could support specific gages located in a donor's watershed. This would make them marketable, but would also make data collection at that point subject to the private party's continued charitable contribution.
2. A list of "high priority" gages could be put up for "adoption." High priority could be used to refer to gages that are most critical to the state based on average interagency rating, years in service, gages that are threatened to lose funding, or gages that are most critical for flood warning, etc. "Adoption" could mean that the business funds the gage O&M costs, the average costs, or just the fixed costs of installation and/or a necessary upgrade. This again makes gages more marketable from year to year, but also creates a pattern of unreliable funding flows.
3. Funds could be solicited to provide general operating funds to the Council and/or to the USGS, COE, or other agencies that incur operating costs for gage and gage data management. This option may create a more sustainable flow of funds

Two formidable challenges related to each of these approaches remain. One is the time commitment needed to see them through effectively - identifying potential donors, soliciting funds, and providing the public relations assistance or other follow up needed to retain private donors year after year. Without staff funded to work on this issue specifically, the commitment can quickly become overwhelming. The second challenge is the remaining problem of not being able to secure continuity of the donations year after year and, again, the time commitment associated with trying to.

## *1.2. Surrounding states*

West Virginia's neighboring states have not faced the same challenges in maintaining their long term network stability. This section is a brief description of some of the more interesting elements of neighboring programs that have helped bridge the institutional gaps that have lead to WV gaging losses and shortfalls.

**OHIO**: The Ohio Water Resources Council (OWRC - http://www.dnr.state.oh.us/owrc/goals.htm) was chartered by the state legislature in 2001 to facilitate interagency cooperation and public private partnerships to help stabilize the state gaging network. As a result, significant cuts made to the network in the 80's have all been recovered and the state tends toward gaining gages rather than cutting them (Mangus, 2007).

Ohio seems to have tackled the tragedy of the commons problem through formal institutional arrangements and informal investment in creating an atmosphere of interagency investment and cooperation. Codified in Ohio Revised Code Section 1521.19 the OWRC is recognized by the state as being a critical public organization that is necessary for the proper management of their water resources. Nine partner agencies and the governor's office make up the council. Each agency is represented by a deputy director with significant decision making authority and the "departments of agriculture, development, environmental protection, health, natural resources, and transportation shall transfer moneys to the fund *in equal amounts* via intrastate transfer voucher"; additional agencies or private organizations may contribute as well but are not mandated to do so. Twenty private and non-profit organizations make up the Council's advisory board including major industrial and environmental stakeholders in the state.

The OWRC convened an interagency gaging prioritization workgroup in 2007. The workgroup provided agencies with a list of gages by basin with their various attributes and the primary uses of the gage data. Agencies then worked together to select a process for allocating each gage points. This process differs from our approach because the participating agencies were asked to come up with common criteria that were important to the state network rather than those specific to their own agency. Their ranking categories included data quality/duration, public safety, environmental concerns, health and economic concerns, and project support. WV USGS has a copy of the OH workgroup tool, or it can be requested from James Mangus, jpmangus@usgs.gov.

**MARYLAND**: The Maryland Water Monitoring Council has been working to develop an approach to maintaining an efficient state stream-gaging network in Maryland since 1995 (http://mddnr.chesapeakebay.net/MWMC). The 24 Council members come from stakeholder agencies and organizations in the private, non-profit, academic/research, and public sectors. The Council tackles a broad set of water issues through its workgroups and committees including a Data Management Committee, Groundwater Monitoring Workgroup, Monitoring and Assessment Committee, and a Programmatic Coordination Committee. The Council has a paid staff and also funding resources to convene and fund interagency workgroups and studies.

The Council's Stream-Gage Committee convened a workshop in 1997, after losing several gages to funding cuts. The task of the workshop was to investigate the status of stream gaging in Maryland and the issues related to continued operation and needed growth of the current network. The focus was on two specific aspects of stream gaging: "the representativeness of the principal physical characteristics of Maryland watersheds, and an inventory of streamflow data users and their applications." This process included a survey of over 500 streamgage data and a series of workgroup discussion meetings to inform the survey design and final report content which was published three years later (Cleaves & Doheny, 2000). The Maryland process essentially allowed the workgroup staff to prioritize gages for each main gage data use separately first and then examine the overlaps and gaps respectively.

**KENTUCKY**: While Maryland and Ohio have exemplary scenarios to follow, the political reality of funding for water projects in states with a Great Lake or a Chesapeake Bay asset is not necessarily something that WV can follow. Kentucky is in more of a similar position as WV and is facing some of the same problems. Kentucky convened a Water Gaging Council about a year after the WV Council was established. They also worked with their Water Research Institute to set up a mechanism to accept private funds through the University of Kentucky.

In KY as well, efforts to raise funds from the private sector fizzled and the USGS continues to cobble together funding year to year based on state and local agencies' annual willingness and ability to contribute to the network. In the case of KY, the past couple of years have not posed significant problems, and so the Council is all but dissolved as of 2007 (Griffin, 2007). The new ability of USGS to accept private funds directly as of 2006 further undermined the Council's nascent *raison d'etre*.

### *1.3. Another alternative: Legislative funding in Georgia*

An alternative to the patchwork quilts of state, local and private funding efforts that states have traditionally used is being attempted by Georgia's legislature, which funds the entire gaging network through a line item within the Environmental Protection Division's budget (A J-C, 2006).

The Georgia Water Science Center counts 44 cooperative partners in its WCP. But in Georgia these agencies provide programmatic support and planning input, they are not primarily responsible for funding monitoring gages. The cooperative relationship however, makes it easier for the organizations to organize amongst themselves and mobilize. The Georgia State Legislature tried to cut funding for the state's CWP matching contribution in 2006 – nearly $800,000 for the network and other water monitoring associated costs. This threat made for an easy and effective way for all water data managers and users to coordinate with one another and voice their concerns and express the importance of the network to the public and private sectors and to the environment – the funding was quickly and fully restored to the budget in its final draft (News&Views, 2006).

## 2. Experimental Methods

This work was conducted in the following four phases: 1) background research about the issues of gage network funding and stability and general Gaging Council survey; 2) development and beta test of gage prioritization tool in Monongahela River Basin; 3) survey of Gaging Council members with revised gage prioritization tool covering entire state; 4) data analysis. The methodology for each is described below.

There are various methodologies used to evaluate stream gage networks and the relative value of individual gaging stations. The two primary and interrelated approaches are 1) statistical analysis to determine the value of the network and individual gages for the purposes of running regional regressions to estimate flow patterns at ungaged sites (e.g.

entropy analysis, generalized least squares) and 2) qualitative evaluation of use, characteristics, and overall value of gages within the network (Markus et al., 2003).

Developing a single statistical analysis would require a narrow definition of the use of or objective for the gage network data. Statistical analyses could be a useful complementary approach used by each individual agency to help them identify the most important gages for their specific agency goals and objectives. A qualitative survey approach, at the interagency level however, helps to find the common ground among agencies for gage network evaluation, allowing each agency to provide input based on their own goals and objectives.

The principles of integrated natural resource management (INRM) contributed to the choice of survey design methodology and the choice to use a survey rather than a model to prioritize stream gages within the network. Integrating survey respondents into the design of the survey is critical to allowing a collective and collaborative design process that removes some of the survey designer-survey participant imbalance. This approach is based on a long history of literature about common-pool resource problem solving among parties with diverse interests, particularly as it applies to natural resource management decision making.

The streamgage network is largely managed by USGS, COE, and the Dept of Homeland Security. Each of these agencies has diverging objectives from the others, and other agencies that contribute to the gage network funding have additional priorities and objectives. This survey approach allowed each agency to determine what gages are priorities for that agency – using their own appropriate model, best guess, political weights, population weights, or combination of these strategies. The outcome of the survey is not meant to be a final answer for which gage should be funded/cut first, but rather the final prioritization worksheet should serve as a departing point on which future *discussions* can be based as funding ebbs and flows affect how many gages can be funded.

## *2.1. Background Research*

Background literature research was conducted according to standard literature review methods. In addition to research of academic literature, a search of agency, non-profit and popular literature was conducted to help identify and understand the nature of the gage funding and prioritization problem. The first introduction of the project to the Gaging Council coincided with the Council's independent initiation of a discussion of developing a tool to prioritize gages among the member agencies; the foundation of this survey tool was based on the design elements provided by that discussion and further refined by survey participants themselves. Interviews were conducted with members of the Gaging Council in small focus groups and on an individual basis to acquire feedback on and refinement of the gaging prioritization tool design. A letter of intent and survey were sent to all Council members describing the intended approach and requesting feedback on the nature of their agencies' use of gage data (Appendix 1).

## 2.2. Draft Prioritization Tool and Beta Test

Descriptive gage characterization information was developed for each gage within the Monongahela River Basin. This river basin was selected for its diversity of land and water use trends and the variation in population density throughout the basin. A basin map was distributed with gage locations noted over a map layer of streams and major incorporated cities. Information was provided for each gage in two categories – information about the specific gage itself and information about the drainage area that the gage served. These two categories of characteristics are listed below.

**Gage station characteristics:**

- Gage name
- If stage or discharge data collected
- Water quality equipped
- Temperature equipped
- Telemetry type
- Upgrades recommended by Statewide Flood Plan
- Current O & M agency responsible
- Past years of archived data
- If funding is supplemented by private funds

**Drainage area characteristics:**

- 8-Digit HUC
- % Drainage that is forested
- % Drainage that is urban
- Drainage area upstream from gage ($km^2$)
- County served
- County population
- County population density

Three beta testers were selected to fill out and comment on the draft prioritization tool. Each respondent was given a fixed quantity of points to allocate among the listed watershed gages (more points indicating greater need for that gage). An option was provided for the respondent to allocate points to a new/proposed gage if the respondent feels a particular area is under-covered or to allocate points for an upgrade of an existing gage. For each gage, the respondent was asked to also rank gage use by importance.

Methodology for watershed landcover analysis for each gage coverage area can be found in Appendix 2.

## 2.3. Final Prioritization Tool and Survey

The final tool was revised based on the Beta testing comments. Comments returned indicated that distributing a fixed number of total points for all gages or even by basin was too difficult and we adopted the suggestion that each gage be ranked rather than allocated points; each gage was to be ranked on a scale of 1-4. Each gage was listed for each 8-HUC with gage and area served characteristics; Flood Plan-suggested gages were listed by HUC, but without the gage characterization information. In addition to the information in the Beta survey, gages were listed by Basin and by 8 digit HUC. Additional service area characteristics were figured as follow in red:

About the drainage area:

- 8 Digit HUC
- 10 Digit HUC
- 12 Digit HUC
- % Drainage that is forested, 12 Digit HUC and cumulative drainage
- % Drainage that is urban, 12 Digit HUC and cumulative drainage
- Drainage area upstream from gage ($km^2$)
- County served
- County population
- County population density
- County population growth rate 1986-2000

Additionally, respondents had the opportunity in the revised survey to rank the state's eight river basins by how well (or deficiently) they were covered by gage sites. Respondents were also asked to suggest areas/streams where new gages should be installed or former gages re-installed/brought back on-line. Finally, respondents were asked to categorize the primary and secondary nature of their agencies' use of gage data. These options were categorized into the following three categories: 1) historical discharge data; 2) historical discharge data and water quality data; 3) realtime stage data only. Within each main category of data type, respondents identified how they used each category of data, e.g. 7Q10 for water quality management, emergency flood management, recreation, etc.

**Responses:** Council member response rate was quite positive. Seven of the ten active member agencies responded to the survey.[7] Unfortunately, the member agency representing recreation and citizen action and the agency primarily focused on flood hazard mitigation and response are two of the agencies that did not respond. Because they were the only representatives from those categories, the analysis cannot be expected to reflect all interests on the Council without further follow up with missing agencies.

Surveys were sent out to the Gaging Council by the council administrator at the time from the Water Research Institute. A third presentation and question session was conducted at the following two Council meeting (in person and by conference call respectively), a reminder email was re-sent with the survey tool, and phone calls were made to each of the Council member representatives at least once to increase the initially low response rate.

Surveys were not all completed in their entirety or in the same manner possibly due to unclear instructions being and/or time constraints of respondents. This primarily affected

[7] A survey was not filled out on behalf of the WV Water Research Institute by decision, though in hindsight, it seems that WVWRI should have filed a response based on the critical importance of gages to the many WVWRI-affiliated professors and their academic departments.
Throughout the 14 month period of this project, Canaan Valley Institute and the Division of Highways did not attend any Gaging Council meetings and so lack of response on the survey was expected.
Division of Homeland Security and Emergency Management, unfortunately, was the one agency with a very salient stake in the gaging program that did not respond to the survey.

the results of the Basin Prioritization tool was intended to order basins in order from 1 to 8 based on how well they are gaged relative to one another. Some respondents used the 1-8 scale as a rating rather than an ordinal rank. Full results are in Appendix 3.

## 3. Analysis

Survey analysis was conducted by simply averaging each gage's rankings from all responding agencies. Averages are presented directly. Averages were also to be weighted by basin prioritization rank; however responses were submitted inconsistently in methodology and cannot be used in this manner. The basin prioritization exercise asked each respondent how well they thought each of eight WV river basins were covered by the streamgage network, ranking them in order from best to worst. The results of this simple analysis are compared with the National Streamflow Information Program's selection of critical WV gages which are currently guaranteed federal funding for a permanent set of core streamgages that will be uncompromised by fluctuating funding from state and local partners, allowing state partners to focus on the remaining gages in the network.

## 4. Results and Discussion

This gage prioritization tool was designed to be a starting point for further interagency streamgage prioritization discussions rather than a final conclusive answer to where investments and/or cuts should be made in the network.

The results of this survey reflect the diversity of perspectives on where investments/cuts should be made. While full results of this survey tool are in Appendix 3, the table below reveals some of the complexities in attempting to make interagency decisions on resource allocation for the gaging network. By the end of the survey it became clearer to the authors and the respondents that some important information was missing. One respondent suggested that the gage characteristics chart also have information regarding the relative 'flooding/drought' problems experienced in the area. Another respondent suggested including the physiographic regions as a layer on the map or a column in the spread sheet.

The average gage station rank was 3.184. Looking at ratings of just the NSIP gages that are prioritized by the federal USGS program, state agencies ranked these gages at an average of 3.476, indicating better agreement among agencies for the core set of NSIP gages. Using average station rank across agencies would be a first step in determining a secondary set of core gages to receive secure state funding annually. As stated earlier, such a list would be preliminary and would then have to be discussed by primary stakeholders.

Table 2 compares the average ratings for gage stations within each basin with the respondents' rank of gage network coverage adequacy (intended to determine which basins are perceived to require the most overall investment and attention relative to where their current network coverage status). It illustrates, perhaps first and foremost, the

problems with the perhaps excessive complexity of the survey tool or lack of clarity of instructions. Two agencies did not respond to this portion of the survey and two other agencies of the seven did not order the basins, but rather scored them on a scale of 1-8, resulting in multiple basins receiving the same score. Because we were only looking for order, we averaged the five agencies' responses to this question despite the two approaches reflected.

We expected to find that basins identified as having poor coverage overall (low basin rank), would also have high average ratings for each gage station. This was based on the assumption that if coverage were considered poor in a basin, then every gage in that basin would matter a lot; if existing coverage were considered to be very good, then some gages may be less important than those in critical watersheds. The cells highlighted in this table indicate significant exception to this assumption.

Interestingly, there was significant disparity among agencies regarding how satisfied each was with network coverage of basins. For example, DNR ranked Kanawha Basin as having the worst network coverage (1) while USGS ranked it as 7$^{th}$ best out of 8. Both USGS and DNR ranked the Ohio as having poor network coverage (1 and 2 respectively). And while DNR and WVCA generally agreed on their ranking of the Kanawha's coverage (1 and 2 respectively), they were almost directly opposed on their rank of the Ohio's coverage (2 and 8 respectively).

We expected that in the basins that are judged to be most lacking in gage coverage would also be the basins with higher average gage rate scores. This assumed that if there is insufficient coverage at the start (too few gages), then the gages that were in place would be ranked more consistently as 4's (very important). Those basins judged to have adequate network coverage already would have had lower average gage rankings – more 2s and 3s. The tables below indicate that this expectation was not met.

The following tables show a simple prioritization of gage stations, by basin, based on survey responses. The average rating given to gages by responding agencies for each basin is highlighted and used as a breaking point to offer a definition for "high priority" gages – at least for the purposes of the following tables.

**Table 3 Ordering of Basin's Gage Network Coverage Adequacy (1-Worst coverage, 8 - Best coverage) compared with average rate of importance for gages within each basin (1: least important, 4 most important). Basins ranked as having least adequate network coverage (Kanawha, Ohio) did not have gage stations that were, on average, ranked as most important to agencies (4).**

| | Ordering of Network Coverage Adequacy (1-8) Worst coverage=1; Best coverage=8 | | | | | | |
|---|---|---|---|---|---|---|---|
| **Rank of network coverage adequacy from worst to best** | **NWS** | **COE** | **USGS** | **DNR** | **WVCA** | **Basin coverage rank/rate average** | **Average rating of gage stations in each basin** |
| 1. Kanawha | 4 | 8 | 7 | 1 | 2 | **4.4** | **3.1** |
| 2. Ohio | 8 | 4 | 1 | 2 | 8 | **4.6** | **3.2** |
| 3. Guyandotte | 5 | 8 | 3 | 4 | 4 | **4.8** | **3.5** |
| 4. Potomac | 7 | 8 | 8 | 3 | 1 | **5.4** | **3.3** |
| 5. Twelvepole | 7 | 6 | 2 | 6 | 7 | **5.6** | **3.5** |
| 6. Monongahela | 4 | 8 | 6 | 8 | 3 | **5.8** | **3.5** |
| 7. Big Sandy | 8 | 8 | 4 | 7 | 5 | **6.4** | **3.1** |
| 8. Little Kanawha | 8 | 8 | 5 | 5 | 6 | **6.4** | **3.4** |

**Table 4 Ranking of basins by Agency and average gage rating by basin.**

| | NWS | | COE | | DNR | | WVCA | |
|---|---|---|---|---|---|---|---|---|
| **BASIN** | Basin Rank | Ave Gage Rate | Basin Rank | Ave Gage Rate | Basin Rank | Ave Gage Rate | Basin Rank | Ave Gage Rate |
| 1. Kanawha | 4 | 3.2 | 8 | 2.6 | 7 | 2.7 | 2 | 2.9 |
| 2. Ohio | 8 | 4.0 | 4 | 3.8 | 1 | 3.3 | 8 | 2.3 |
| 3. Guyandotte | 5 | 3.3 | 8 | 3.6 | 3 | 2.9 | 4 | 3.1 |
| 4. Potomac | 7 | 3.6 | 8 | 2.2 | 8 | 3.4 | 1 | 3.4 |
| 5. Twelvepole | 7 | 3.5 | 6 | 3.8 | 2 | 3.3 | 7 | 3.3 |
| 6. Monongahela | 4 | 3.2 | 8 | 3.4 | 6 | 3. 5 | 3 | 3.0 |
| 7. Big Sandy | 8 | 3.7 | 8 | 2.4 | 4 | 1.7 | 5 | 2.9 |
| 8. Little Kanawha | 8 | 3.6 | 8 | 3.0 | 5 | 3.7 | 6 | 3.4 |

**Table 5 Ohio Basin priority gages**

| Basin | Gage Name | Ave Rate |
|---|---|---|
| Ohio Mainstem | Ohio River at Willow Island Lock & Dam, WV | **3.8** |
| Wheeling Creek | Wheeling Creek at Elm Grove, WV | **3.7** |
| Ohio Mainstem | Ohio River at Pike Island Lock & Dam, WV (Lower) | **3.3** |
| Ohio Mainstem | Ohio River at Point Pleasant, WV | **3.3** |
| AVE | | 3.2 |
| Ohio Mainstem | Ohio River at Hannibal Lock & Dam, WV | **3.2** |
| Ohio Mainstem | Ohio River at Belleville Lock & Dam, WV | **3.2** |
| Ohio Mainstem | Ohio River at Huntington, WV | **3.2** |
| Ohio Mainstem | Ohio River at Robert C. Byrd Lock & Dam, WV | **3.2** |
| Ohio Mainstem | Ohio River at Racine Lock & Dam, WV | **3.0** |
| Ohio Mainstem | Ohio River at Parkersburg, WV | **3.0** |
| Wheeling Creek | Kings Creek at Weirton, WV | **2.8** |
| Ohio Mainstem | Ohio River at Wheeling, WV | **2.8** |

**Table 6 Potomac Basin priority gages**

| Basin | Gage Name | Ave Rate |
|---|---|---|
| Potomac | South Fork South Branch Potomac River at Brandywine, WV | **3.7** |
| Potomac | North Fork South Branch Potomac River at Cabins, WV | **3.7** |
| Potomac | Cacapon River near Great Cacapon, WV | **3.7** |
| Potomac | Opequon Creek near Martinsburg, WV | **3.7** |
| Potomac | South Branch Potomac River near Springfield, WV | **3.5** |
| Potomac | South Branch Potomac River near Moorefield, WV | **3.5** |
| Potomac | South Fork South Branch Potomac River near Moorefield, WV | **3.5** |
| Potomac | South Branch Potomac River near Petersburg, WV | **3.5** |
| Potomac | South Branch Potomac River at Franklin, WV | **3.5** |
| Potomac | Shenandoah River at Millville, WV | **3.5** |
| AVE RATE | | 3.3 |
| Potomac | Patterson Creek near Headsville, WV | **3.2** |
| Potomac | Stony River near Mount Storm, WV | **3.0** |
| Potomac | North Branch Potomac River at Barnum, WV | **2.8** |
| Potomac | Potomac River at Paw Paw, WV | **2.8** |
| Potomac | Potomac River at Shepherdstown, WV | **2.8** |
| Potomac | Waites Run near Wardensville, WV | **2.7** |
| Potomac | Potomac River at Harpers Ferry, WV | **2.5** |

**Table 7 Guyandotte Basin priorities**

| Basin | Gage Name | Ave Rate |
|---|---|---|
| Guyandotte | Guyandotte River at Logan, WV | **3.8** |
| Guyandotte | Guyandotte River at Branchland, WV | **3.8** |
| Guyandotte | Guyandotte River at Man, WV | **3.7** |
| Guyandotte | Guyandotte River below R.D. Bailey Dam, WV | **3.7** |
| AVE | | 3.5 |
| Guyandotte | Guyandotte River near Baileysville, WV | **3.2** |
| Guyandotte | Guyandotte River at Pineville, WV | **3.2** |
| Guyandotte | Clear Fork at Clear Fork, WV | **3.0** |

**Table 8 Big Sandy Basin priorities**

| Basin | Gage Name | Ave Rate |
|---|---|---|
| Big Sandy | Tug Fork at Matewan, WV | **3.7** |
| Big Sandy | Tug Fork at Williamson, WV | **3.3** |
| Big Sandy | Tug Fork at Kermit, WV | **3.2** |
| Big Sandy | Tug Fork at Welch, WV | **3.2** |
| AVE | | 3.1 |
| Big Sandy | Tug Fork at Litwar, WV | **3.0** |
| Big Sandy | Dry Fork at Beartown, WV (Bradshaw) | **3.0** |
| Big Sandy | Panther Creek near Panther, WV | **2.3** |

**Table 9 Little Kanawha Basin priorities**

| Basin | Gage Name | Ave Rate |
|---|---|---|
| Little Kanawha | Little Kanawha River at Palestine, WV (Elizabeth) | **4.0** |
| Little Kanawha | Little Kanawha River at Glenville, WV | **3.7** |
| Little Kanawha | Little Kanawha River at Burnsville, WV | **3.7** |
| Little Kanawha | Little Kanawha River near Wildcat, WV | **3.5** |
| AVE | | 3.4 |
| Little Kanawha | Little Kanawha River at Grantsville, WV | **3.3** |
| Little Kanawha | West Fork Little Kanawha River at Rocksdale, WV | **3.2** |
| Little Kanawha | West Fork Little Kanawha River at Creston, WV | **2.5** |

**Table 10 Twelvepole Basin priorities**

| Basin | Gage Name | Ave Rate |
|---|---|---|
| Twelvepole | Twelvepole Creek below Wayne, WV | **3.8** |
| Twelvepole | East Fork Twelvepole Creek below East Lynn Dam, WV | **3.7** |
| Twelvepole | East Fork Twelvepole Creek near Dunlow, WV | **3.5** |
| AVE | | 3.5 |
| Twelvepole | Beech Fork below Beech Fork Dam, WV | **3.0** |

**Table 11 Monongahela Basin prioritization**

| Basin | Gage Name | Ave Rate |
|---|---|---|
| Monongahela | Cheat River at Highway 50 near Rowlesburg, WV | **4.0** |
| Monongahela | Dry Fork at Hendricks, WV | **4.0** |
| Monongahela | Tygart Valley River near Dailey, WV | **4.0** |
| Monongahela | Blackwater River at Davis, WV | **3.8** |
| Monongahela | Buckhannon River at Alton, WV | **3.8** |
| Monongahela | Cheat River near Parsons, WV | **3.8** |
| Monongahela | Middle Fork River at Audra, WV | **3.8** |
| Monongahela | Shavers Fork below Bowden, WV | **3.8** |
| Monongahela | Tygart Valley River at Belington, WV | **3.8** |
| Monongahela | Tygart Valley River at Philippi, WV | **3.8** |
| Monongahela | West Fork River at Weston, WV | **3.8** |
| Monongahela | Buckhannon River at Buckhannon, WV | **3.7** |
| Monongahela | Buckhannon River at Hall, WV | **3.7** |
| Monongahela | Blackwater River near Davis, WV | **3.5** |
| Monongahela | Cheat River at Albright, WV | **3.5** |
| Monongahela | Cheat River below Lake Lynn Dam, WV | **3.5** |
| Monongahela | Dry Fork at Gladwin, WV | **3.5** |
| Monongahela | Dry Fork at Job, WV | **3.5** |
| Monongahela | Middle Fork River at Ellamore, WV | **3.5** |
| Monongahela | Shavers Fork near Cheat Bridge, WV | **3.5** |
| Monongahela | Three Fork Creek near Grafton, WV | **3.5** |
| Monongahela | Tygart Lake Outflow near Grafton, WV | **3.5** |
| Monongahela | Tygart Valley River at Valley Head, WV | **3.5** |
| Monongahela | West Fork River at Butcherville, WV | **3.5** |
| Monongahela | West Fork River at Enterprise, WV | **3.5** |
| Monongahela | West Fork River below Stonewall Jackson Dam, WV | **3.5** |
| AVE | | 3.5 |
| Monongahela | Big Sandy Creek at Rockville, WV | **3.3** |
| Monongahela | West Fork River at Walkersville, WV | **3.3** |
| Monongahela | West Fork River near Mount Clare, WV (Clarksburg) | **3.3** |
| Monongahela | Buffalo Creek at Barrackville, WV | **3.2** |
| Monongahela | Deckers Creek at Morgantown, WV | **3.2** |
| Monongahela | Monongahela River at Morgantown Lock & Dam, WV | **3.2** |
| Monongahela | Shavers Fork at Bemis, WV | **3.2** |
| Monongahela | Tygart Valley River at Colfax, WV | **3.2** |
| Monongahela | Middle Fork River at Adolph, WV | **3.0** |
| Monongahela | Tygart Valley River near Elkins, WV | **3.0** |
| Monongahela | Tygart Valley River at Millcreek | **2.8** |
| Monongahela | Sand Run near Buckhannon, WV | **2.7** |
| Monongahela | Glady Fork at Evenwood, WV | **2.5** |

**Table 12 Kanawha Basin prioritization**

| Basin | Gage Name | Ave Rate |
|---|---|---|
| Kanawha | Elk River at Queen Shoals, WV | **4.0** |
| Kanawha | Greenbrier River at Hilldale, WV | **3.8** |
| Kanawha | New River at Hinton, WV | **3.8** |
| Kanawha | Elk River below Sutton Dam, WV | **3.8** |
| Kanawha | Bluestone River near Pipestem, WV | **3.7** |
| Kanawha | Greenbrier River at Buckeye, WV | **3.7** |
| Kanawha | Gauley River above Belva, WV | **3.7** |
| Kanawha | Gauley River below Summersville Dam, WV | **3.7** |
| Kanawha | Gauley River nearr Craigsville, WV | **3.7** |
| Kanawha | Kanawha River at Kanawha Falls, WV | **3.7** |
| Kanawha | Elk River below Webster Springs | **3.7** |
| Kanawha | Kanawha River at Lock 6 at Charleston, WV | **3.7** |
| Kanawha | Elk River at Clay, WV | **3.5** |
| Kanawha | Coal River at Tornado, WV | **3.5** |
| Kanawha | Cranberry River near Richwood, WV | **3.3** |
| Kanawha | Kanawha River at London Lock & Dam, WV | **3.3** |
| Kanawha | Elk River near Frametown, WV | **3.3** |
| Kanawha | Greenbrier River at Alderson, WV | **3.2** |
| Kanawha | New River at Thurmond, WV | **3.2** |
| Kanawha | Meadow River near Mount Lookout, WV | **3.2** |
| Kanawha | Williams River at Dyer, WV | **3.2** |
| Kanawha | Kanawha River at Marmet Lock & Dam, WV | **3.2** |
| Kanawha | Big Coal River at Ashford, WV | **3.2** |
| AVE | | 3.1 |
| Kanawha | Gauley River at Camden-on-Gauley, WV | **3.0** |
| Kanawha | Clear Fork at Whitesville, WV | **3.0** |
| Kanawha | Greenbrier River at Renick, WV | **2.8** |
| Kanawha | Greenbrier River at Durbin, WV | **2.8** |
| Kanawha | New River below Hawks Nest Dam, WV (The Drys) | **2.8** |
| Kanawha | Kanawha River at Southside Bridge at Charleston, WV | **2.8** |
| Kanawha | Greenbrier River at Caldwell, WV | **2.7** |
| Kanawha | Piney Creek at Raleigh, WV | **2.7** |
| Kanawha | Knapp Creek at Minnehaha Springs, WV | **2.5** |
| Kanawha | Right Fork Holly River at Gurdian | **2.5** |
| Kanawha | Left Fork Holly River near Replete, WV | **2.5** |
| Kanawha | Fourpole Creek near Huntington | **2.5** |
| Kanawha | Hurricane Creek at Hurricane, WV | **2.5** |
| Kanawha | Greenbrier River at Ronceverte, WV | **2.3** |
| Kanawha | Greenbrier River at Clover Lick, WV | **2.3** |
| Kanawha | Peters Creek at Lockwood, WV | **2.3** |
| Kanawha | Kanawha River at Railroad Bridge at Charleston, WV | **2.3** |
| Kanawha | Anthony Creek at Blue Bend, WV | **2.0** |

# 5. Conclusions & recommendations

West Virginia does not border the great lakes or the Chesapeake Bay, so state funding is more challenging to secure in any scenario or under any institutional design, but its contribution to the Ohio River and Bay drainage are not insignificant. Furthermore, though the significance may not be as apparent to the public eye as other such large water bodies that affect multiple economic sectors of interstate regions, WV's water resources are equally critical to our state's short and long term economic stability and the vitality of its character as the Chesapeake Bay is to Maryland's economy. As WV's leadership angles the state to focus on energy production and to promote our state as one with abundant natural resources to serve its own citizens *and* the many major population centers that lie within a day's travel of the state, understanding our resources – monitoring and predicting resource patterns - is critical. These goals are impossible to achieve sustainably or responsibly for the benefit of future citizens of the state without building plans on a foundation of reliable water resource monitoring data.

West Virginia's stream gaging network has been in steady decline over the past twenty years. In 1975, WV had 131 streamgages. Funding cuts in 1983 and again in 1994 resulted in two compounding sharp drops in the number of gaging stations collecting continuous data on the state's water resource trends. Cuts continued through 2007 costing the state in lost analytical and management capacity, as well as time lost while agencies are forced to patchwork together stopgap agreements each year.

This report recommends that members of the West Virginia Gaging Council and other key stakeholders work with local, county, state, federal, academic, and non-governmental stakeholder agencies to identify a core set of streamflow gages that are *de minimus* necessary for accurately characterizing West Virginia's streamflow resources and for evaluating regional hydrologic conditions *over time* as well as hydrologic responses of streams to geological, physiographical, and land-use change, and to climate variability (gages that are priority to WV, above and beyond the NSIP gages in WV that are already guaranteed federal funding). This effort may want to use the results in this study as an initial foundation for discussion. Alternatively, the tool produced for this study may be used with the suggested revisions and additional feedback from other respondents.

It is recommended that the cost of upgrading and maintaining this core WV network be guaranteed adequate state budget funding annually in coordination with the USGS Cooperative Partnership program. Funding flexibility should be available for the additional gages which are needed temporarily. One option would be that the funds go directly to the WV Conservation Agency or to WVDEP or another state agency directly and then be transferred to the USGS or other monitoring programs.

It is recommended that the Gaging Council continue to convene to carry out the other purposes listed in its mission even past an immediate funding crisis. These meetings reduce some of the pressure on USGS to maintain multiple bilateral relationships by

facilitating a network of communications among agencies with a shared interest in water resource management – despite the variation in specific uses.

Finally, while we were unable to acquire a draft of formal documents describing the partnership between Georgia's Environmental Protection Division and its USGS Water Science Center in time for this report, it is recommended that follow up steps be taken to learn more about how various states are guaranteeing funding through legislative budget allocations. This institutional funding arrangement realigns interests among tax paying stakeholders and public agencies that are otherwise funded by the public to provide services to the public so that they are benefited by cooperating with one another rather than annually facing costly divisions over budget cuts and allocations and shell games.

Documents that arrive to the WV Water Research Institute regarding additional state programs will be shared with the WV Gaging Council via email (namely information on funding programs in Georgia and Michigan). A copy of the Ohio and WV gaging network prioritization tools are available upon request.

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## 7. Student support, Notable achievements or awards.

One graduate student in WVU's Fisheries and Wildlife program contributed to the mapping and data collection efforts used to develop the gage prioritization tool.

# Appendix 1 – Letter of Intent to Gaging Council and Preliminary Questionnaire

**MEMORANDUM**

To: West Virginia Water Gaging Council Members

From: Alyse Schrecongost, Program Coordinator

Date: May 15, 2006

Re: Preliminary survey about your agency's use of stream monitoring data in West Virginia.

In an attempt to fulfill requirements of the West Virginia Water Resource Protection Act 2004, a proposal, *Systematic Determination of Water Resource Data and Information Management Needs in West Virginia*, was developed by West Virginia Water Research Institute personnel and submitted to USGS to address the following problems:

1. Insufficient and unevenly distributed water resource monitoring data to support effective water resource assessment and management.
2. Inaccessibility of existing data stemming from the diversity of agencies and methods used to collect, store, and analyze water resource data and information.

The results of this project will include: 1) a statewide evaluation of existing water quantity and quality monitoring data sources; and 2) a participatory and credible, interagency spatial analysis of critical monitoring data gaps prioritized by importance to state agencies and other principal users. The final project report will supplement the West Virginia Department of Environmental Protection Water Resource Protection Act final report submitted to the West Virginia Legislature in December of 2006 as part of an on-going comprehensive effort to evaluate state water resource balances.

In order to fulfill not only the obligations to the USGS and the State, but to address needs raised by the West Virginia Water Gaging Council, we have developed a preliminary survey intended to learn more about your use of stream monitoring data in West Virginia. This enclosed survey is intended to be used to develop a system for monitoring gage and well prioritization. This survey will help us develop a tool for quantitatively identifying gaging investment priorities (approach outlined below). We are interested both in your survey feedback and your feedback on our planned approaches to developing a system for gage prioritization. A separate approach will be developed for well prioritization after the stream gage phase is underway.

**Prioritization Approach Outline:**

1. Survey Gaging Council members and select other relevant stakeholder organizations and agencies with open-ended survey tool developed by Liz Garland (Attachment 1; hypothetical responses Attachment 2) to determine general uses of gage and well data. ***Please complete this step by June 1. Comments on prioritization strategy welcome at this time as well.***

2. This qualitative survey information will be collected and used to inform a final report and to inform the field selection for a quantitative survey instrument that will allow agency representatives prioritize gage data needs.

3. Descriptive gage characterization sheets will be developed for each gage (on-line and off-line gages) within two adjacent demonstration 8-Digit HUC watersheds (see preliminary list characterization fields in Excel WS 1, Attachment 3). A watershed map will be distributed with gage locations noted over a map layer of streams and incorporated cities. ***Suggestions for trial watersheds welcome by June 1.***

4. A trial quantitative survey will be conducted among Council members to prioritize gage investments within the trial watershed. Each respondent will be given a fixed quantity of points to allocate among watershed gages. An option will be provided for the respondent to allocate points to a new/proposed gage if the respondent feels a particular area is under-covered or to allocate points for an upgrade of an existing gage. For each existing or proposed gage, the respondent will be asked to also rank gage use by importance (see model survey in Excel WS 2, Attachment 4). ***Suggestions on how to rank investment on upgrades as opposed to installing basic gages welcome.***

5. For trial survey, respondents will also be asked to critique survey instrument design and offer suggestions for revisions.

6. Survey results will be aggregated and gages will be mapped with a progressive color scale to indicate resulting priorities (with a specific legend value). Proposed gages will also be mapped and addressed in a discussion section of an interim report.

7. Critiques and suggestions will be addressed in Council meetings. Council members will comment on whether prioritizations should be conducted by watershed or at a state level. Additional stakeholders will be identified to participate in survey. Final survey will be conducted, analyzed, and will inform a final report.

Thank you in advance for taking the time to review the enclosed documents and to provide responses to the initial survey (Attachment 1). I will be at the June 1, 2006 meeting of the Gaging Council and can address any questions you may have at that time. However, if you wish to contact me before then, feel free to call me at 304-293-2867 x5418 or email me at amschrecongost@mail.wvu.edu. I look forward to discussing this further with you on June 1.

**Please respond to the following questions. For reference, see hypothetical example of responses for the US Army Corps (Attachment 2).**

*What type of user do you represent/serve?*

*What is your interest in gage or gage data?*

*What is the geographic scope of your need (location characteristics)?*

*Do you need real time data, historical data, recent historical data, etc?*

*What is the most ideal format for gage data for your use?*

*What parameters are most important to you?*

**Please let us know if you would like an electronic copy of this information.**
**Please return responses to:**

Alyse Schrecongost
West Virginia Water Research Institute
150 Evansdale Drive
PO Box 6064
Morgantown, WV 26501
304.293.2867 x5418
amschrecongost@mail.wvu.edu

# Appendix 2 - Watershed land cover analysis methodology

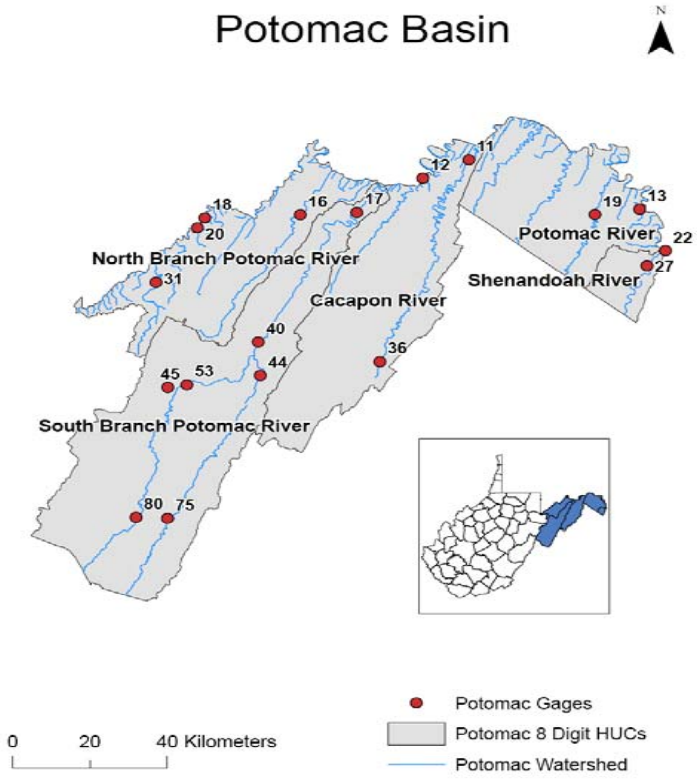
Watershed land cover attributes were calculated for each stream gage using West Virginia Gap Analysis (WV-GAP) land classification data (Yuill et al. 2000). The WV-GAP source data were acquired from multiple 30-meter Landsat imagery obtained from 1992-1994 and field checked with videography. The raster representation of this data includes cell counts for 25 land cover types across the state.

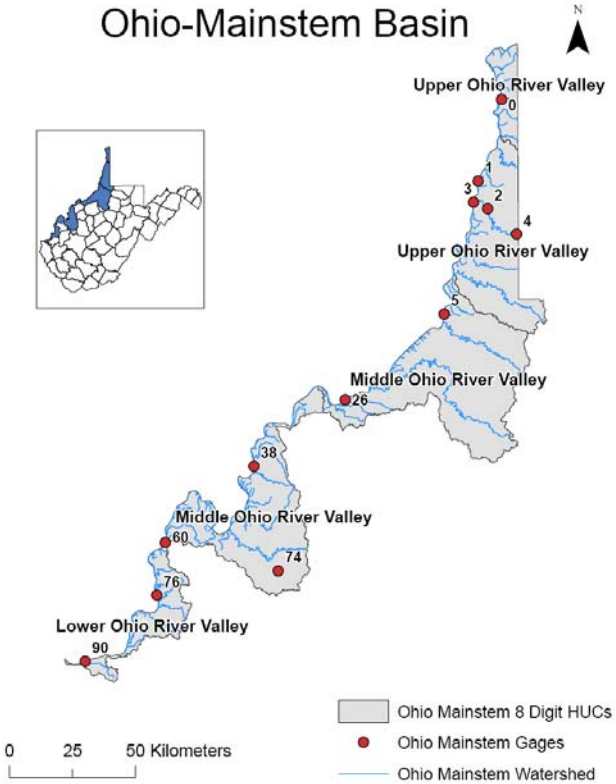
Using the Spatial Analyst function in ArcMap (ESRI 2005), a new raster dataset was created in which the 25 land cover types were reclassified into two types: forested and nonforested. The "forested" classification included the following land cover types: woodland, conifer plantation, floodplain forest, forested wetland, cove hardwood forest, diverse/mesophytic hardwood forest, hardwood/conifer forest, oak dominant forest, mountain hardwood forest, mountain hardwood/conifer forest, and mountain conifer forest. Forested cells in the raster were given a value of one, while the nonforested cells were assigned a value of zero. This reclassification process was then repeated for urban and nonurban land cover types. The "urban" classification included light intensity urban, moderate intensity urban, and intensive urban land cover types.

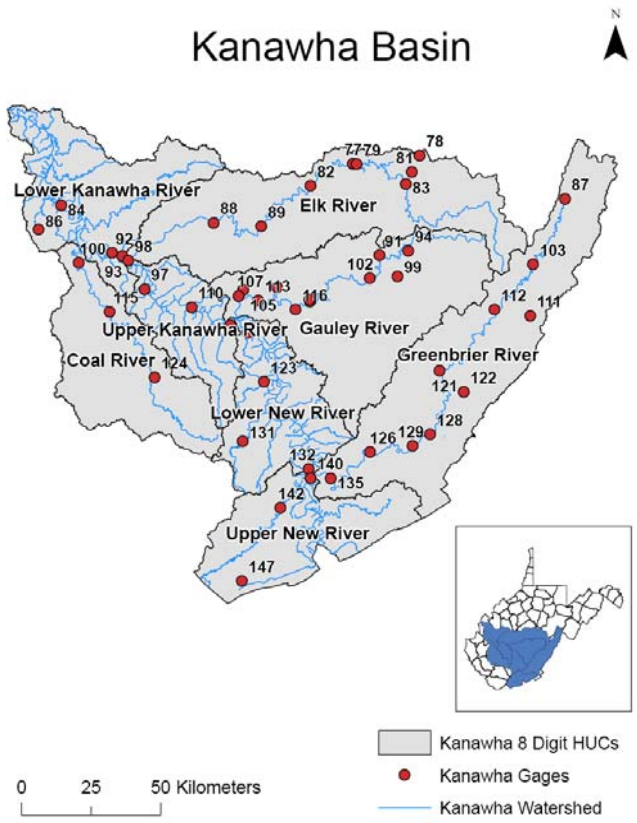
Using the zonal statistics feature of Spatial Analyst, the sum of the forested/urban cells as well as a total cell count was calculated for each 12-digit Hydrologic Unit Code (HUC) watershed. The result was a count of the total number of cells, the total number of forested cells, and the total number of urban cells for each 12-digit watershed in the state. Land cover values for each 12-digit watershed were then accumulated in a downstream direction using the Twelve Digit Hydrologic Unit Code Accumulator Program (Strager and Strager 2006) in ArcView 3.3 (ESRI 2002). In 12-digit watersheds that contained stream gages, the cumulative sum of the forested and urban cells were each divided by the total cumulative cell count for the watershed and multiplied by 100 to determine the cumulative percent of the gage watershed that was classified as forested or urban.

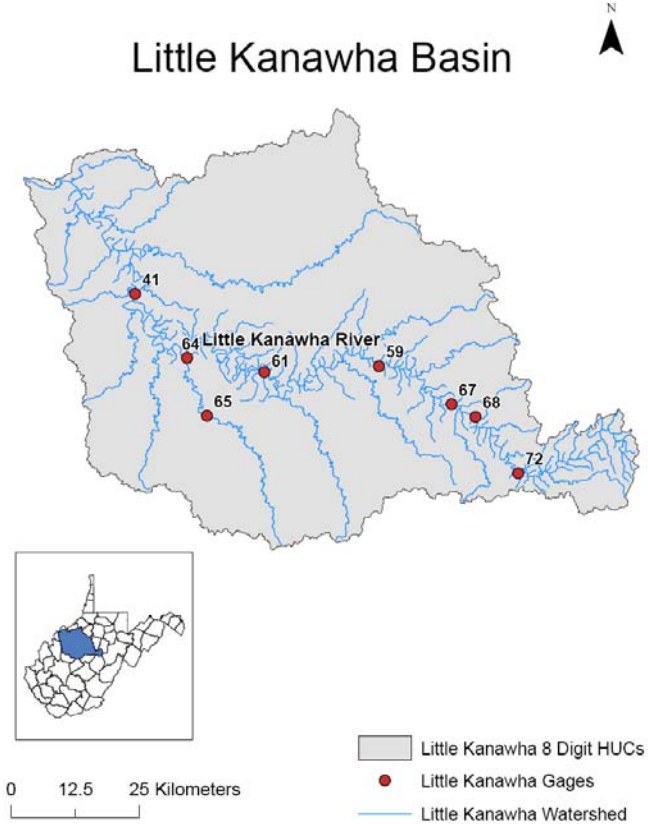
This watershed accumulation process allows for the examination of watershed processes at multiple scales (Strager et al. *In Review*). Streams can be impacted by local (within a 12-digit HUC) influences as well as watershed scale (cumulative 12-digit HUC) factors. As an alternative to static watershed delineations, the accumulation of small sub-watersheds provides information on both local and watershed scale influences.

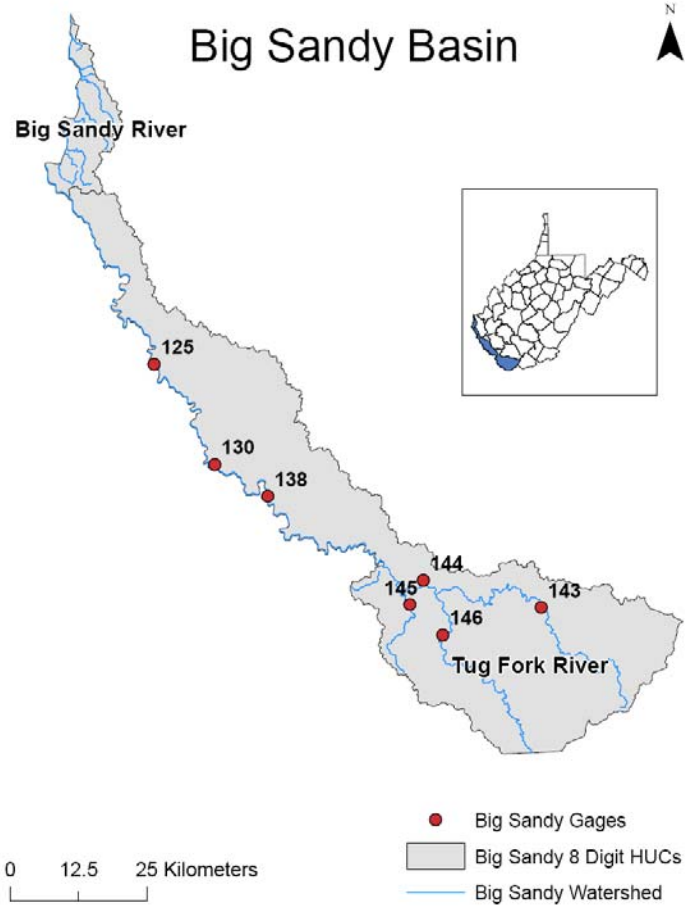
## Appendix 3 – River basin maps of streamgages rated

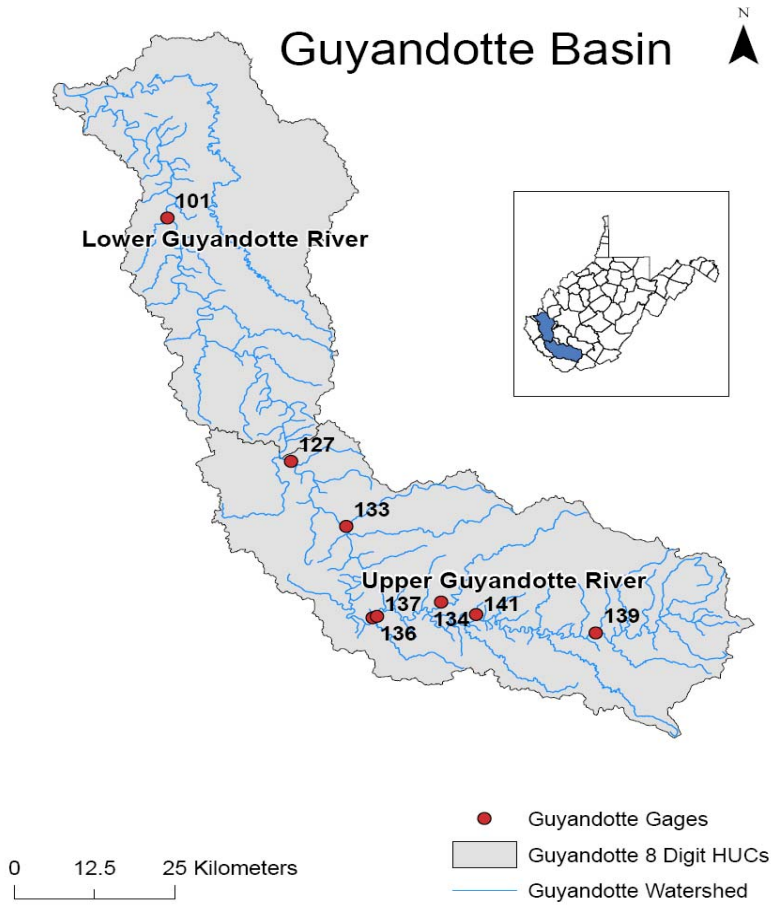


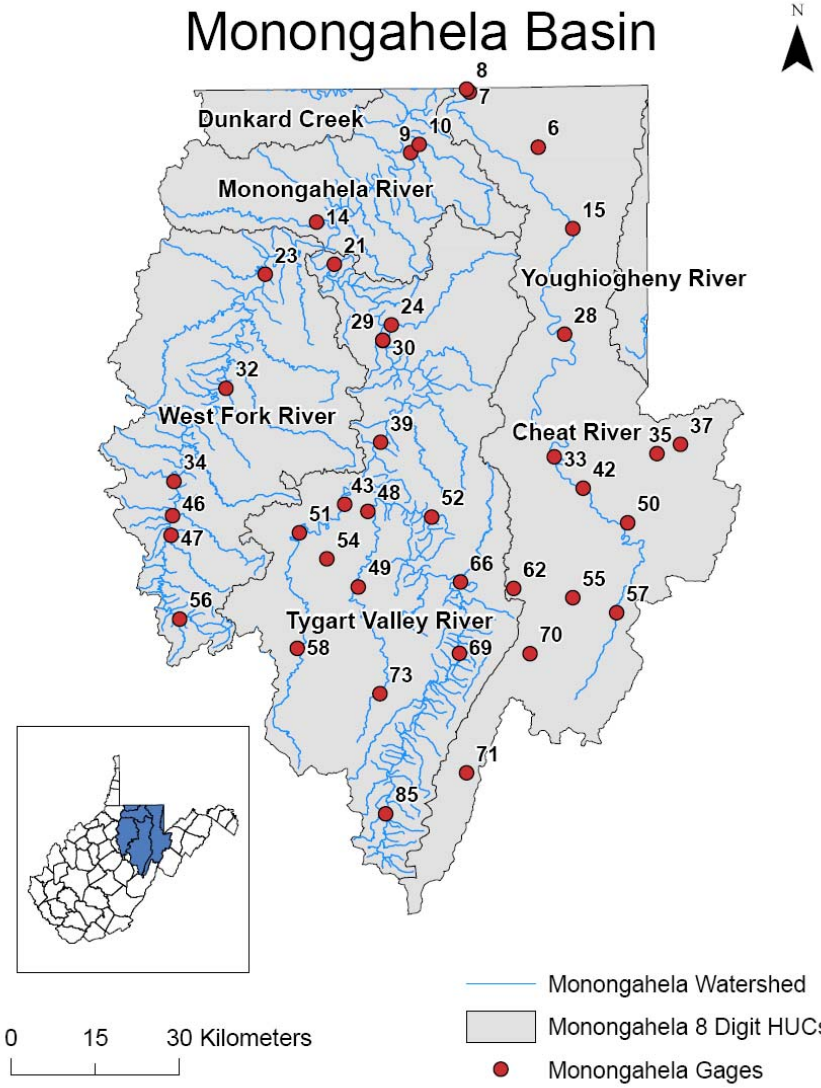



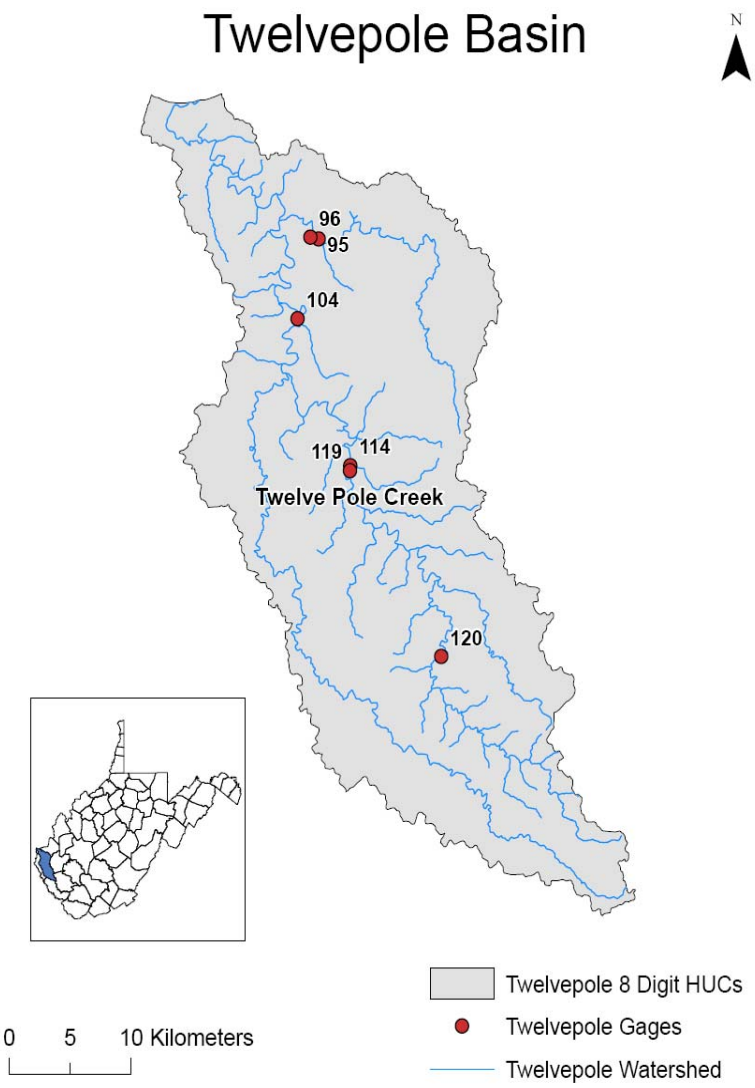

Kanawha Basin
N
Lower Kanawha River
Elk River
Upper Kanawha River
Gauley River
Greenbrier River
Coal River
Lower New River
Upper New River
78
77-79
81
82
83
87
84
86
88
89
92
98
100
93
97
91
94
103
102
99
115
110
107
113
105
116
112
111
124
123
121
122
128
131
126
129
132
140
135
142
147
0 25 50 Kilometers
Kanawha 8 Digit HUCs
Kanawha Gages
Kanawha Watershed


Little Kanawha Basin
N
Little Kanawha River
41
64
61
59
67
68
65
72
0 12.5 25 Kilometers
Little Kanawha 8 Digit HUCs
Little Kanawha Gages
Little Kanawha Watershed


Big Sandy Basin
N
Big Sandy River
125
130
138
144
145
143
146
Tug Fork River
0 12.5 25 Kilometers
Big Sandy Gages
Big Sandy 8 Digit HUCs
Big Sandy Watershed


Guyandotte Basin
N
101
Lower Guyandotte River
127
133
Upper Guyandotte River
137
134
141
139
136
0 12.5 25 Kilometers
Guyandotte Gages
Guyandotte 8 Digit HUCs
Guyandotte Watershed


Monongahela Basin
N
Dunkard Creek
Monongahela River
Youghiogheny River
West Fork River
Cheat River
Tygart Valley River
8
7
9
10
6
15
14
21
23
24
29
30
28
32
39
35
37
33
42
34
43
48
52
50
46
51
54
47
49
66
62
55
57
56
70
58
69
73
71
85
0 15 30 Kilometers
Monongahela Watershed
Monongahela 8 Digit HUCs
Monongahela Gages


Twelvepole Basin
N
96
95
104
119
114
Twelve Pole Creek
120
0 5 10 Kilometers
Twelvepole 8 Digit HUCs
Twelvepole Gages
Twelvepole Watershed