Report for 2005WV52B: West Virginia Water Resources Inventory and Assessment

Publications

- There are no reported publications resulting from this project.

Report Follows

West Virginia Water Resources Inventory and Assessment

West Virginia Water Resource Protection Act Water Resources Inventory and Assessment

WV Water Research Institute

Submitted to

United States Geological Survey
Tamara Vandivort, WV Water Research Institute

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ABBREVIATIONS AND ACRONYMS

CEGAS	Center for Environmental, Geotechnical and Applied Sciences
CVI	Canaan Valley Institute
HUC	Hydrological Unit Code
IMS	Information Management System
MU	Marshall University
NCDC	National Climate Data Center
NFIP	National Flood Insurance Program
NWS	National Weather Service
OES	Office of Emergency Services
PDSI	Palmer Drought Severity Index
USGS	United States Geological Survey
WRI	West Virginia Water Research Institute
WRPA	Water Resource Protection Act
WVDA	WV Department of Agriculture
WVDEP	WV Department of Environmental Protection
WVU	West Virginia University

1 Introduction

In March 2004 the West Virginia Legislature adopted Senate Bill 163, the Water Resources Protection Act, which recognizes the need to inventory, assess and evaluate the State's water resources for present and future use and enjoyment and protection of the environment. The Legislature recognized for the first time, in statute, that the state's water resources are vital and essential for preserving and promoting the quality of life and economic vitality of the state. The Act calls for a one-time, limited assessment of the ***quantity*** of the state's water resources. It provides for: claiming and protecting state waters for the use and benefit of its citizens; evaluating the nature and extent of its water resources; and identifying activities that impede the beneficial uses of the resource. This is the first statewide initiative to compile and analyze the disparate water quantity related data and information from multiple public agencies, universities and private sources.

The legislation requires the Secretary of the West Virginia Department of Environmental Protection (WVDEP) to inventory, assess and evaluate the State's water resources and propose a strategy for water quantity management. The Secretary is to accomplish this mission by soliciting the assistance and cooperation of federal and state agencies and universities who have management responsibility and research capabilities related to state water resources and report to the Legislature by December, 2006.

The objective of this project was to provide technical support to the WVDEP in identifying, collecting, assessing, reconciling and analyzing the State's water resources to fulfill the mandate of the Act. To accomplish this objective the Water Resource Institute at West Virginia University (WVWRI) and the Center for Environmental, Geotechnical and Applied Sciences (CEGAS) at Marshall University formed a program management entity titled the ***West Virginia Center for Water Resource Management*** (Center). The Center, under the co-direction of Dr. Paul Ziemkiewicz (WVWRI) and Dr. Tony Szwilski (CEGAS) utilized internal funding sources to assist DEP in addressing the higher priority information and research needs (for WVWRI, USGS 104 (b) funds were utilized). Research priorities were determined in a joint effort between Center and WVDEP representatives.

While internal funding was used for the first of this two year project, additional work for the second year was to be funded by state or private funds. A small additional grant of USGS 104 (b) funds was solicited by and allocated to WVWRI to undertake a state-wide and inter-agency monitoring stream gage and groundwater well needs assessment and prioritization project. Provision of funding was discussed by the Water Resources Committee of the Legislature in December, but no funds were allocated by the end of the legislative session. As a result, some of the tasks have not been completed.

This report provides the status efforts and results of WVWRI findings relating to the project elements assigned by WVDEP to WVWRI and shown in Table 1. Our key conclusions to date, however, can be summarized briefly.

Our research efforts generated three key findings that are important for WVDEP efforts to recommend a state water quantity management program. The first is that historical land and water resource monitoring data are insufficient to reliably answer the research questions outlined in Table 1. Unfortunately, this is not a problem of past data collection gaps but rather current and growing problems in maintaining the state's water data collection infrastructure. Much of this report focuses not on providing definite answers. Rather, it is an evaluation and illustration of what data exist and where there are critical data gaps with respect to the research questions outlined in the WRPA.

The second notable issue is that water resource evaluation and planning require significant input at the local and regional levels; state-level datasets and regulatory efforts cannot capture important dynamic and location-specific information flows and on-going resource management practices (formal or informal, and often qualitative rather than quantitative). Eastern and mid-Atlantic states' water resource management programs increasingly consist of both a state-level water resource data monitoring program and county or watershed-based water resource management and planning programs.

Finally, domestic and international trends in water resource planning all support the concept of integrated water resource management (IWRM). Land use, water quality, and water quantity must be studied as interrelated systems. Additionally, science, policy, law, economics, and the social contexts are all part of any water resource management question, but such interdisciplinary analysis requires quantitative data and trend analysis as a foundation. Technical, science-based information can lose important significance if taken outside of economic or policy context.

This report first outlines the **research questions** that identified in the Act and allocated to WVWRI. The second section outlines our **research strategy or methodology**. The third section reviews the **results** of our research with commentary on data gaps and other shortfalls mentioned above. This section first covers issues of flooding, followed by a section on drought and low flow issues, and then one on water conservation issues. In both the flood and drought sections, information available to the state is presented, and mapped when possible. In each case, preliminary findings are detailed to illustrate data gaps. Finally, a list of presentations and papers is presented at the end of the report.

Table 1 Highest priority project elements addressed by WVWRI to assist DEP in meeting the requirements of SB 163

Element 4: Historical and Current Conditions That Indicate Low Flow and Flood / Drought Conditions.

4.1 Identify areas of concern regarding historical or current conditions that indicate low flow conditions or where drought or flood has occurred or is likely to occur that threatens the beneficial use of the surface water and groundwater

4.2 Examine historical conditions that may exacerbate flooding

4.3 Map drought and flood prone areas

Element 5: Evaluate Current or Potential In-Stream or Off-Stream Uses that Contribute to or are Likely to Exacerbate Natural Flow Conditions to the Detriment of the Water Source.

Element 9: Practices to Reduce Water Withdrawals.

9.1 Past and present conservation techniques that will reduce water use in industrial commercial and residential sectors

2 Methodology

The following work plan for WVWRI Water Resource Protection Act 163 is based on our intended research methodology. As the project progressed, the methodology was altered based on time, data, and funding short falls. These are discussed in the **Results** section of this report.

Element 4: Historical and Current Conditions That Indicate Low Flow and Flood/Drought Conditions.

Approach: *Flood and drought metrics will be developed and applied to historical data to determine areas that are drought and flood prone. Drought and flood threats to the beneficial use of surface and groundwater will be discussed qualitatively based on published and collected cases that are illustrative of impact on various uses.*

4.1 IDENTIFY AREAS OF CONCERN REGARDING HISTORICAL OR CURRENT CONDITIONS THAT INDICATE LOW FLOW CONDITIONS OR WHERE A DROUGHT OR FLOOD HAS OCCURRED OR IS LIKELY TO OCCURE THAT THREATENS THE BENEFICAIL USE OF SURFACE AND OR GROUNDWATER

4.1.1 ***Drought Metrics****: 5-factor index (precipitation, soil moisture, groundwater, streamflow, reservoir levels) for assessment of 3 severity levels of drought (watch, warning, emergency) to be developed that could serve as drought indicator and applied to historical data to determine drought-prone areas. Coordinates with neighboring states' approaches (PA, VA).*

4.1.1.1 Precipitation

A. Obtain NOAA precipitation data for all sites in West Virginia with 30 year or more period of record.
B. Determine the number of drought occurrences and duration of occurrence at each station based on the Pennsylvania precipitation deficit table.
C. Plot station locations in the GIS.
D. Use precipitation deficit to map the extent of drought in the state for one occurrence by month to illustrate drought monitoring relevance.
E. Compare incidence of drought as determined in item B above to historical drought declarations.

4.1.1.2 Stream Flow

A. Obtain (hourly) stream flow data from all gages USGS gages in West Virginia with a 30-year or greater period of record.
B. Obtain all historic percentile data for these same gages.
C. Plot stations in the GIS and assign counties to gage data
D. Create percentile data for these gages where it is absent.
E. Use percentile data to map at least one drought statewide.
F. Compare incidence of drought as mapped in D to historical drought declarations and precipitation deficit data generated in 4.1.1.1.
G. Compare drought flows against available 7Q10 flows.

4.1.1.3 Groundwater

A. Obtain (daily) water level data from USGS operated wells.
B. Obtain all historic percentile data for these same wells.
C. Plot stations in the GIS and assign counties to gage data based on USGS regions.
D. Create percentile data for these wells where it is absent.
E. Use percentile data to map at least one drought statewide.
F. Compare incidence of drought as mapped in D to historical drought declarations, precipitation deficit data generated in 4.1.1.1, and stream flow data generated in 4.1.1.3
G. Identify mine discharges and natural springs, or ground water based public water supplies that may be used to augment the water well data.

4.1.1.4 Soil Moisture

A. Obtain historical (Weekly) Palmer Drought Index data from NOAA
B. Plot stations in the GIS and assign counties to the index data
C. Map Palmer data for at least one drought statewide.
D. Compare incidence of Palmer drought index with the other indices previously generated.

4.1.1.5 Drinking Water Supplies/Reservoirs

A. Identify lakes or reservoirs used to supply public water supply systems.
B. Obtain water level records and stage storage data from selected water supplies in each of the States climatic regions.
C. Create percentile ranking on the reservoir storage volume.
D. Map reservoir data for at least one drought statewide.
E. Compare reservoir index with other drought indices previously generated.

4.1.2 ***Drought Implications*** *for Beneficial Use – these reports will primarily be qualitative analyses based on illustrative published and collected case studies.*

4.1.2.1 Recreational fishing
4.1.2.2 Swimming
4.1.2.3 Aquatic habitat
4.1.2.4 Recreational boating
4.1.2.5 Transportation
4.1.2.6 Electric power generation (Lake Lynn, Albright, Glen Ferris)
4.1.2.7 Water Supply
4.1.2.8 Effects of water use restrictions

4.1.3. ***Flood Metrics -*** *Comparison of Various Flood Indicators and Declaration Data*

A. Perform a frequency analysis on the number of counties where OES has declared flood emergencies.
B. Analyze precipitation data to determine percent-exceeded level that correlates with flood declaration.
C. Analyze precipitation record to determine indicated flooding frequency and compare these data to incidence of flood declaration.
D. Analyze hydrograph data to determine the percent-exceeded level that correlates with flooding.

E. Compare precipitation and hydrograph methods; determine if some watersheds have lower or higher flooding thresholds.

4.1.3 ***Flood Implications*** *for Beneficial Use – qualitative research and collected case reviews*

A. Transportation
B. Water Intakes
C. Sewer Systems / Combined Sewer Overflow
D. Channel Alterations
E. Impacts on ground water
F. Surface water quality

4.2 EXAMINE HISTORIC CONDITIONS THAT MAY EXACERBATE FLOODING.

4.2 Historic Conditions that May Exacerbate Flooding

A. Summarize findings from State Flood Report and other state and academic flood research

4.3 MAP DROUGHT AND FLOOD PRONE AREAS.

4.3 Map Drought and Flood Prone Areas

4.3.1 Mapping Drought Prone Areas

A. Utilize precipitation deficit mapping to identify areas of historic sub-normal precipitation.
B. Utilize occurrences of stream flow below the 90 (or other) percentile to generate drought frequency mapping.
C. Utilize soil-mapping techniques to identify drought susceptible soils.

4.3.2 Mapping Flood Prone Areas

A. Generate map of flooding based on historic OES flood declarations.
B. Generate and evaluate percentile stream flow data to determine suitability of method for flood mapping. If suitable generate flood frequency mapping.
C. Assemble digital FEMA floodplain maps and compare percentile streamflow data to flood plain maps.

Element 5: Evaluate Current or Potential In-Stream or Off-Stream Uses that Contribute to or are Likely to Exacerbate Natural Flow Conditions to the Detriment of the Water Source.

Approach: Changes in flow volume and/or velocity may have adverse effects on the volume and quality of water in streams or groundwater supplies. For example, dams tend to reduce peak flows while securing minimum flows. Controlled dams also eliminate the natural variability of flow on which riparian flora and fauna can rely. Development including buildings, roads, and other impermeable surfaces exacerbate high flow conditions and minimize or eliminate ground-water recharge. Other land use modifications including mining, timbering, and farming change the rainfall – runoff – infiltration relationships for large land areas within the State thus changing natural peak flow and low flow conditions in the receiving streams and aquifers. Consumptive uses must be identified and the degree to which they diminish stream flow identified. The timing and conditionality of non-consumptive water use is also important

5.1 Dams

A. Utilizing DEP survey, permit files and reservoir GIS mapping identify reservoirs that provide water for consumptive use.
B. Obtain facility-operating data.
C. Quantify water consumption by watershed.

5.2 Intake / Users

A. Obtain data from DEP survey and select water users to identify quantity concerns related to drought, flood, and growth policy.
B. Utilize these data to identify water quantity problems on a statewide basis.
C. Impact of significant users exempt from the DEP survey where there is a low-flow impact on ground or surface water (e.g. mining, drilling, quarrying, water bottling facilities, agriculture). Scenario analysis/evaluation.

5.3 Land use

A. Obtain historic land use maps in digital format and evaluate these maps for changes in land use over time. Specifically, for changes in forest acreage, mining acreage, agricultural acreage, open water, and impervious surface area by watershed.
B. Evaluate these results for implications to changes that may be to the detriment of the water resource.

Element 9: Practices to Reduce Water Withdrawals: Review the past and present conservation techniques that will reduce water use in industrial, commercial and household sectors.

Approach: Review Federal, State, and Local statutes to identify any rules that may address water conservation techniques or practices (voluntary or mandatory). Agencies would include but not be limited to: Environmental Protection Agency, Department of Energy, Department of Agriculture, Monongalia County Commission, West Virginia Public Service Commission, West Virginia Development Office, West Virginia Department of Environmental Protection, local public service districts and/or utility boards.

3 Results

3.1 FLOODING

Objective. The Water Resource Protection Act (WRPA) research elements related to flooding entail the identification and mapping of historically flood-prone areas of the state (Elements 4.1, 4.3), the anthropogenic factors exacerbating flood conditions (4.2), and areas in which high flows negatively affect beneficial uses (4.1).

Floods are seemingly easy events to define and identify. In West Virginia, however, no uniform and accepted definition exists to facilitate event tracking, thus complicating attempts to evaluate flooding events and trends in the state. Floods can be defined as when flow exceeds bankfull, when flows expand beyond 100-year flood plains, or when flows begin to threaten human safety and property. As well, flood "proneness" can vary by frequency, severity, and economic impact. Additional complexities include the differences between natural flood patterns, flash flooding, and human-exacerbated flood flows (e.g. from sedimentation, inappropriate land use practices), and human-exacerbated flood damages (e.g. inappropriate and uninsured development in floodplain).

The State of West Virginia has funded significant research on flooding over the past few years. The Flood Advisory Technical Taskforce Report, the State Flood Plan, and the State All-Hazards Plan are key resources for analysis of flooding in West Virginia. These reports provide the foundation for flood analysis requested in Element 4.

Three findings stand out among the others in this section. The first is that one-time-event-driven research projects will continue to produce incomplete and potentially misleading findings until more resources are invested in expanding maintaining our state's water monitoring infrastructure. Monitoring infrastructure is necessary if trends, anomalies, and problem areas are to be identified and evaluated within historical context. Streamflow data are monitored and recorded in 50 of the state's 159 watersheds (10 digit HUCs). Twenty-four of the state's counties are not represented by a single stream gage.

The second important finding is that the US Corps of Engineers (USACE) Statewide Flood Report and the State All-Hazards Mitigation Plan both comprehensively address the flood-related research questions outlined in the Water Resource Protection Act (taking into consideration the stream flow data). This report references those findings and adds some new information, but the original reports should be referenced for more complete flooding information, specifically relative to Element 4.2, "Conditions that exacerbate flooding."

Finally, framing the question around "impacts on beneficial use" was important. However, this aspect of the question can only be addressed generally. To address these issues in a detailed manner, they must be evaluated on a watershed basis, which would require significant local participation and feedback at the information gathering stages.

3.1.1 Conditions that indicate where flooding has or is likely to occur

Elements 4.1, 4.3

This section presents four approaches to identifying and mapping areas where flooding has or is likely to occur. These are as follow: 1) identify existing flood monitoring data; 2) identify indirect indicators of flood events (insurance damages); 3) conduct statistical analysis on historical stream flow data; 4) model land and stream characteristics that are likely to contribute to flood events. The four approaches are used because of the paucity of direct flood monitoring data and lack of a consistent definition of flooding.

3.1.1.1 Direct flood monitoring data

West Virginia monitors the threat of flooding in the state on a real-time basis based on precipitation (iFLOWS program) but invests little in maintaining flood records after the immediate threat at hand disappears. The **State Office of Emergency Services** and **the National Climate Data Center** are two agencies that maintain a historical record of flooding in the state (Figures 1 and 2).

Unfortunately, each agency has different criteria and methodology for measuring flooding and, therefore, analysis of their data indicates contradictory flood-prone areas as well as dramatically different perspectives on flooding frequency. OES data are based on official emergency declarations, while NCDC data reflects a variety of sources including staff observations, citizen phone calls, and newspaper clippings. OES floods are limited to the most severe cases that warranted FEMA intervention. In determining areas that are "flood-prone," however, based on the Figures 1 and 2, there appears to be a difference between areas that are prone to frequent floods (NCDC, Figure 2) and areas that are prone to severe floods (OES, Figure 1).

NCDC also provides the state's only historical record of flash flooding in the state (Figure 3). This is not necessarily an accurate representation of actual flash flooding events. A quick glance of the low estimated number of flash floods over the past 10 years, particularly in southern counties such as Mingo, Wyoming, and McDowell Counties warrants concern over the meaningfulness of these numbers. Flash flooding numbers are based in part on predictions of heavy rainfall that generate flash flood warnings. These warnings are then noted as actual events if newspapers or citizen/employee calls verify that flash flooding did occur in the county.

The rate of flash flood verifications to flash flood events is not uniform across all counties. As a result, the total numbers by county are erroneous, as are the indicators of relative flash flooding problems among different regions of the state. Finally, because these numbers have only been tracked for ten years, it is not possible to identify trends such as increased or decreased flooding in watersheds or counties.

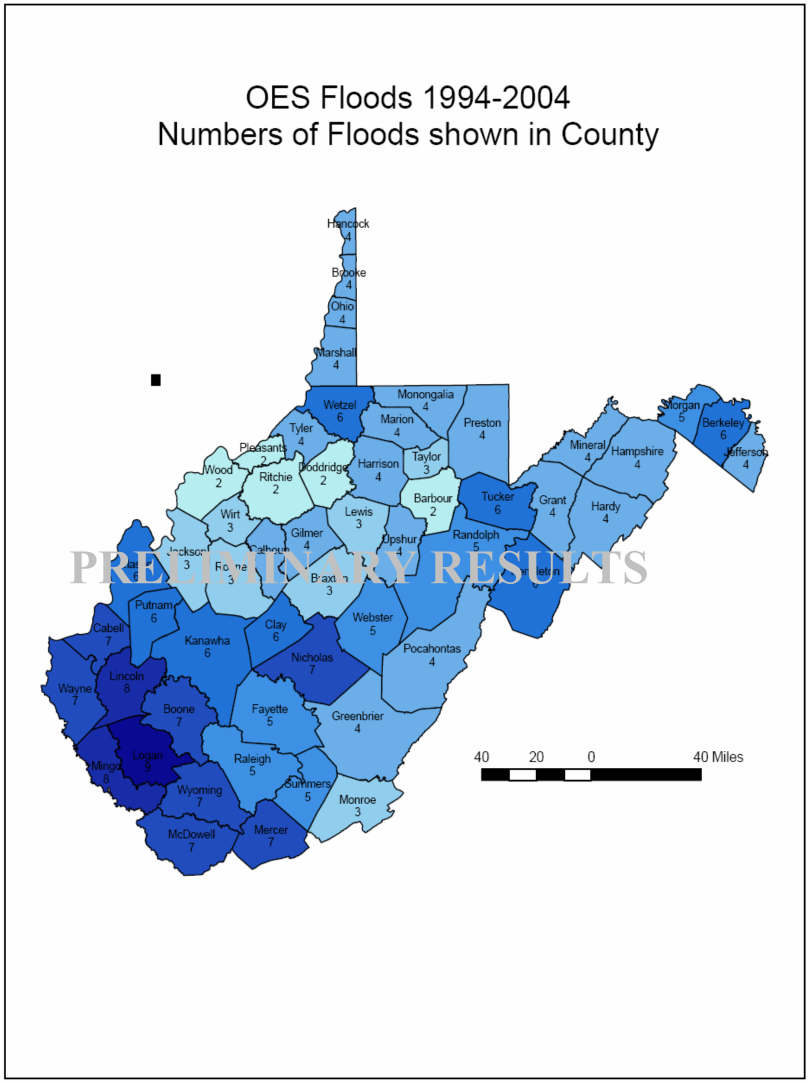


Figure 1 Floods 1994-2004, OES

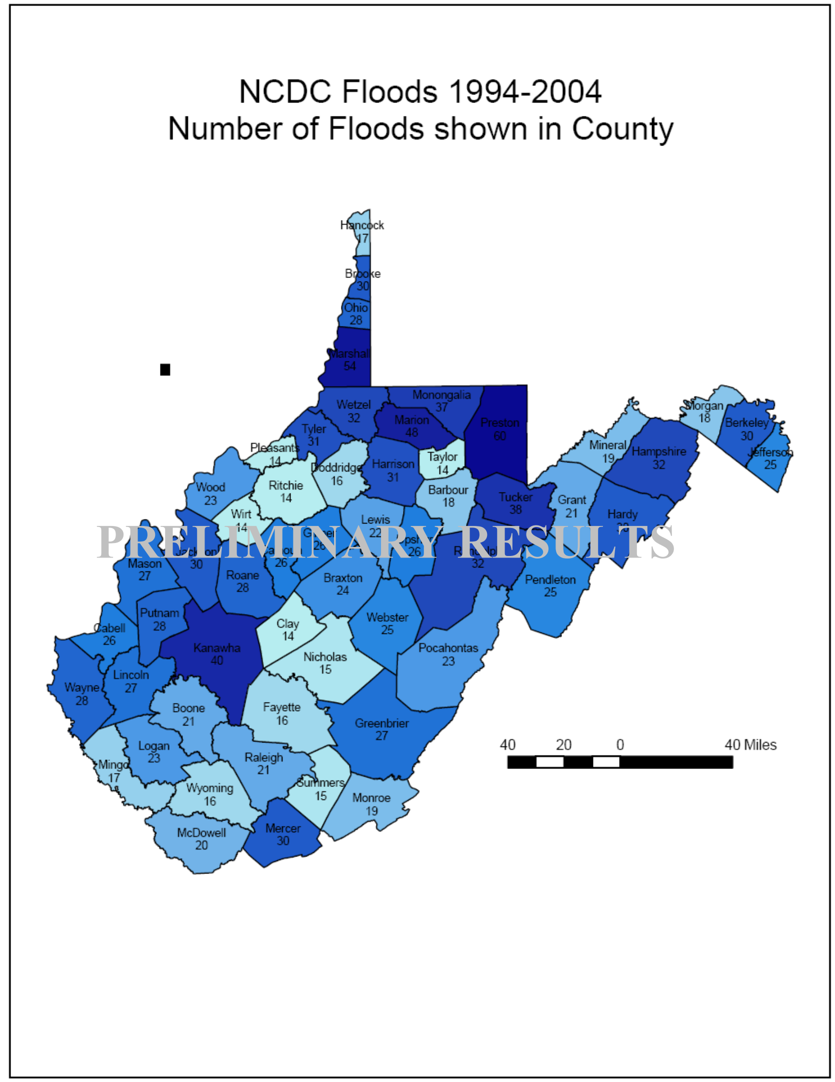


Figure 2 Floods 1994-2004, NCDC

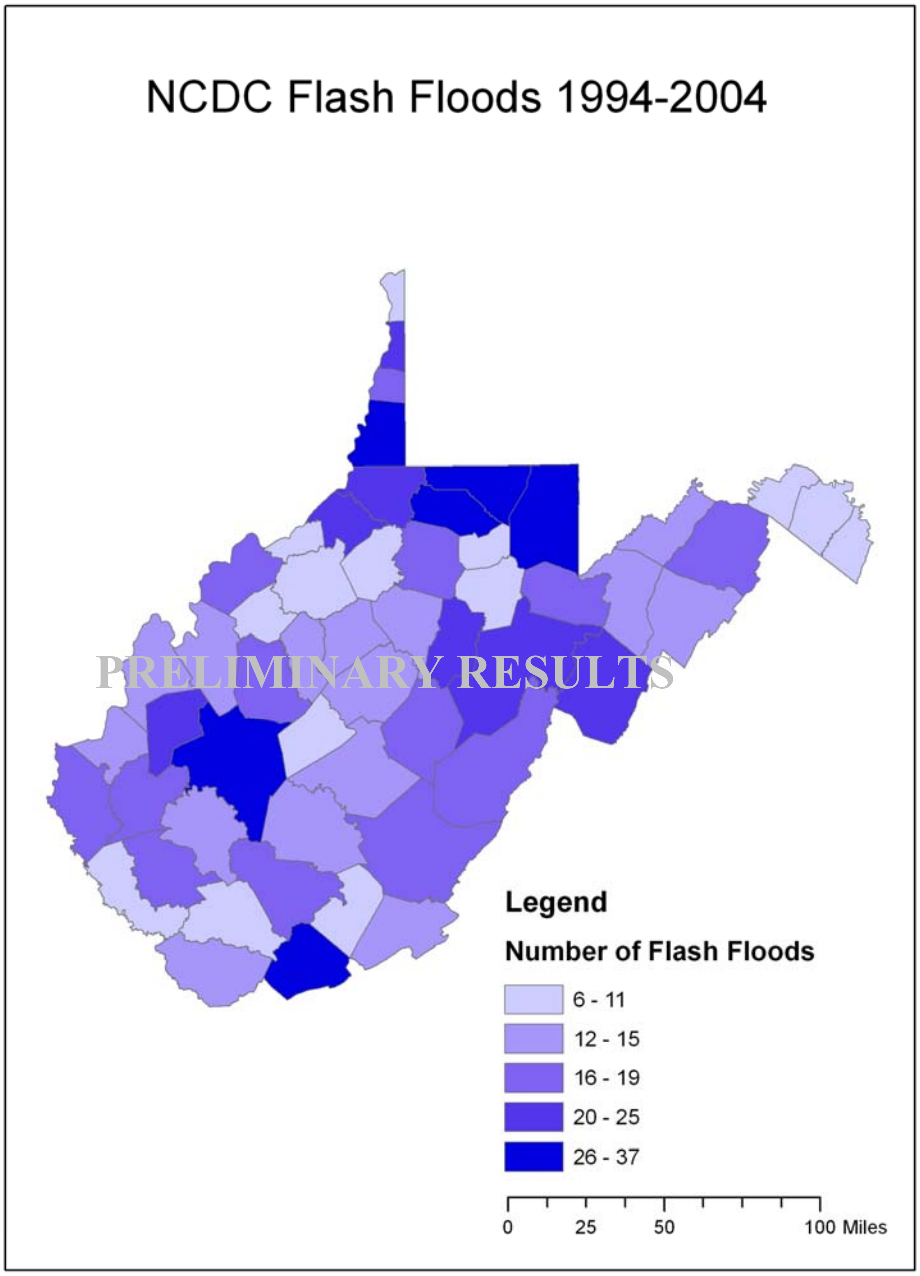


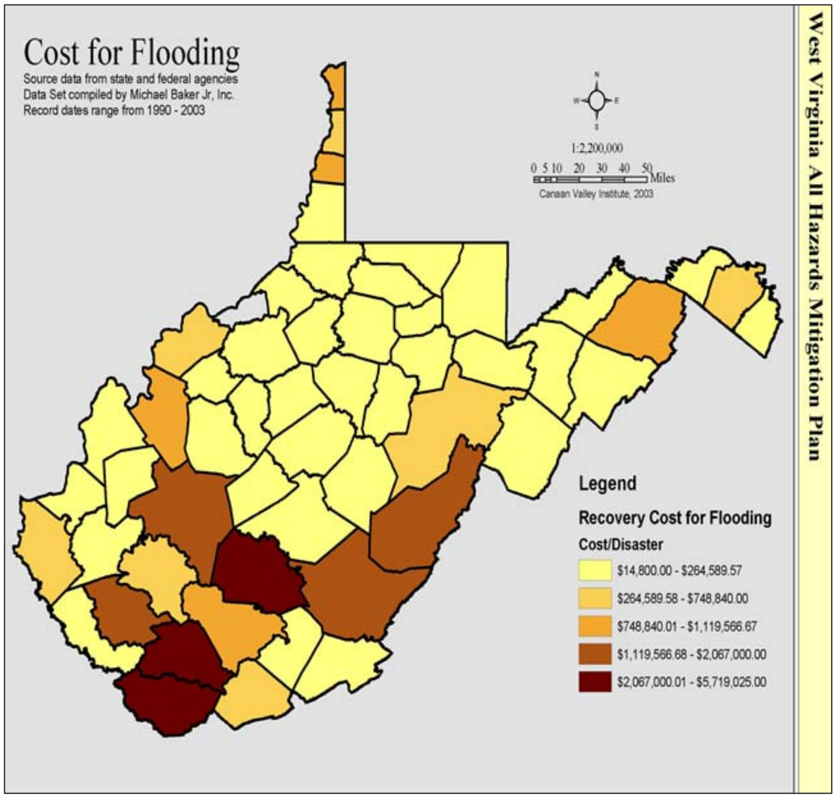
Figure 3 Flash Floods 1994-2004, NCDC

3.1.1.2 Indirect flood monitoring data

One approach to measuring the incidence of flooding and, in particular, economic impacts of flood events is to evaluate the costs of flood damages. The State All-Hazards Report used this approach by evaluating National Flood Insurance Program (NFIP) payment trends. The maps below (Figure 4) illustrate relative scale of payments as well as recurrence rates of claims.

The cost estimates reflect only damage to properties insured by the NFIP. As a result, the distribution of claims and damages paid by this program reflects the distribution of flooding in the state skewed by the uneven distribution of NFIP coverage. According to the OES, NFIP coverage rates of floodplain structures range from 10-90% across the state (mean coverage is only 34% per county).

For the final report, pending data availability, we would like to include a map that illustrates NFIP coverage rates relative to number of floodplain structures. This would help to identify some of the insurance coverage disparity biases across counties that now appear to be flood cost differences.



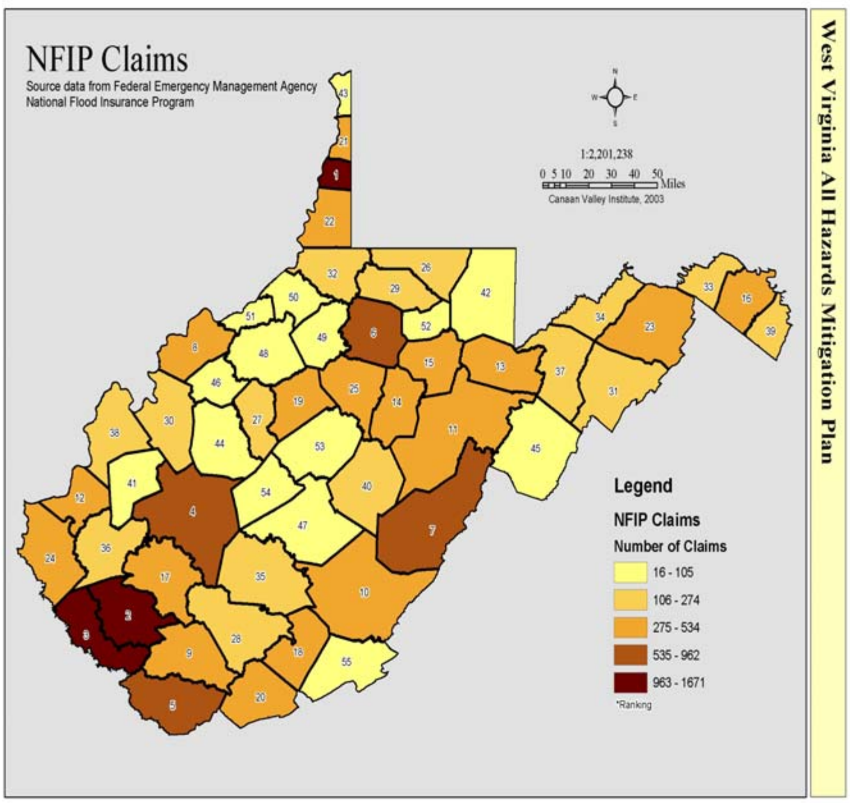


Figure 4 National Flood Insurance Program Payments, 1990-2003

3.1.1.3 Statistical analysis of stream flows

It is reasonable to imagine that streamflow gages would be good indicators of flood events. Flows on ungaged low order stream (smaller streams) cannot reliably be linked to gaged flows on higher order streams (larger rivers). While the USGS is working to develop a methodology to link small stream flows to monitored behavior on high order gaged streams, the model accuracy will be limited by lack of land use data in many areas. Furthermore, the model may be successful at detecting regular floods on low-order streams but will not predict tributary flash flooding. Detecting unreported flash floods, given the paucity of stream gage stations and limited historical detailed meterological data, will be challenging well into the future. For the short term, attention can be directed to improving the methodology of collecting and tracking flood and flash flood reports to the NCDC.

Afore mentioned limitations considered, stream gage analysis was conducted on all gages with at least 30 years of data in the state (where watersheds crossed state boundaries and there were no gages in WV, gages were used from neighboring states). These data were compared with the period of record available for each gage to determine the statistical 5, 10, 50, and 100-year flood flows and the frequency of their occurrences over the past 30 years. The maps below (Figure 5) indicate relative flooding frequencies among different gages for two of the calculated levels of flood severity (percent time in a 10-50 year flood and percent time in >100 year flood).

Information in the maps of Figures 5 and 6 should be interpreted with caution. Gage station flow analysis **cannot** be extrapolated to indicate flooding trends by watershed or county because of the problems with relating gaged and ungaged streamflow behavior within a watershed (described above). Furthermore, the interpretive value of these maps is limited due to extensive gage funding cuts in 1994. Many gages were taken off-line in 1995, so analysis was conducted on those gages with a 30-year period from 1964-1994. As a result, no 100-year or greater floods appear to have occurred in McDowell County over the past 30 years according the maps in Figure 5. Yet, the county suffered two 500-year floods since 2000. Watersheds that currently have real time or “on-line” flow monitoring gages are shown in Figure 7.

The final approach to gage data collection as an indicator of flooding was to combine National Weather Service (NWS) flood stage (height) estimates with USGS flow data by using ratings tables (flow to height conversion equations). Flood heights have been established by NWS agents’ trips to each gage station in which they identified a local flood stage based on community input regarding the flow height at which floodwaters would begin to cause a threat to lives or property. Using USGS ratings curves, we determined what flow would raise the river to the NWS flood stage. Then, using historical USGS flow data, we produced a statistical analysis of historical flow data to determine the flood stage recurrence interval (how often flows would reach flood stage heights).

The results are mapped in Figure 6. There are clearly problems with the inputs to this analysis since some gages appear to experience flood stage exceedence every year or two while others have recurrence intervals that indicate thousands of years between floods. Without making site visits to and analyses of each gage station, it is not possible to determine whether data inaccuracies lie with the stage heights recorded or with the ratings curves provided by the USGS.

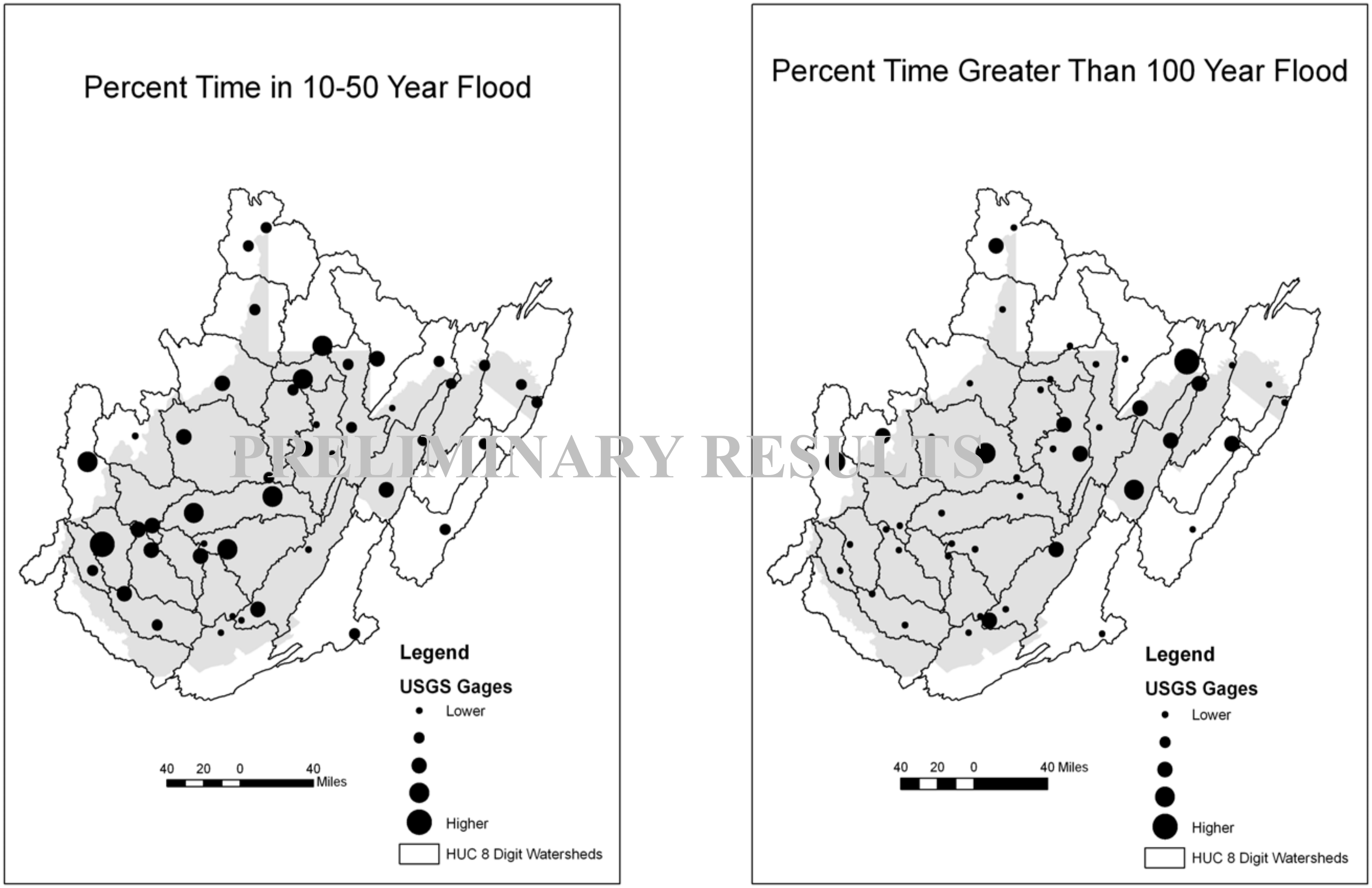


Figure 5 Relative indicator of flood frequencies among relevant gage stations, 1965-1994

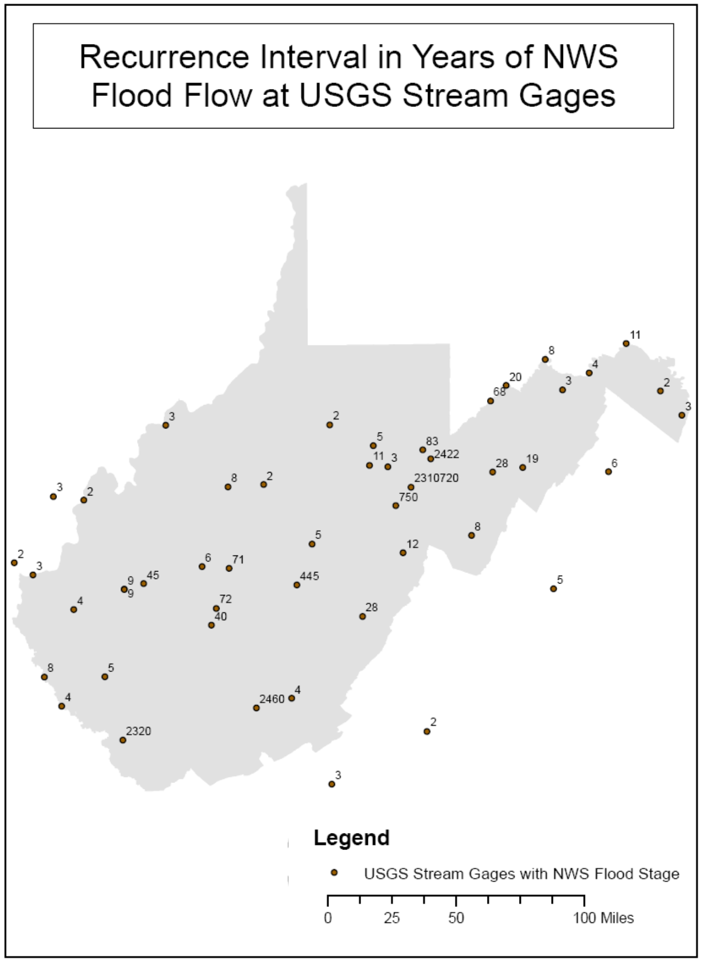


Figure 6 Recurrence Intervals for NWS-Defined Floods

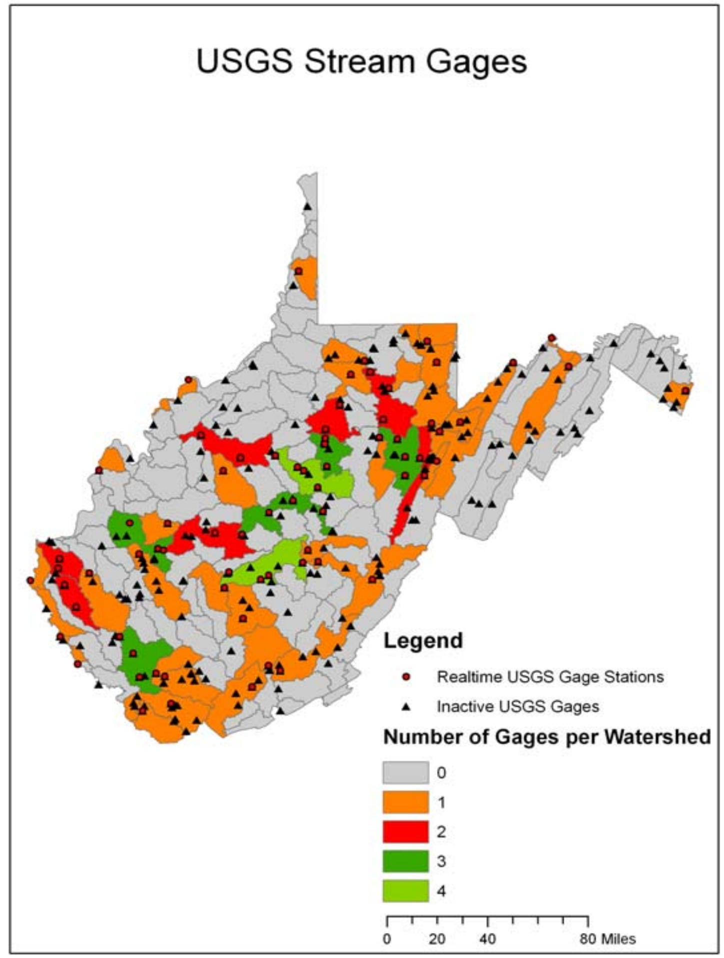


Figure 7 Watersheds with Active USGS Stream stations

3.1.1.4 Modeled Flooding Risk Factors

The Water Research Institute intended to model flood vulnerability by watershed at the 10-digit HUC level. While data quality constraints would have limited the reliability of the map generated, development of such a general model would important for future efforts, in anticipation of comprehensive state water planning efforts. Had funding been made available, the model would have integrated flood-related factors including the following:

- Slope/Topography
- Land use/imperviousness
- Stream sinuosity/Vegetative cover
- Soil type
- Storage capacity/wetlands
- Watershed area

3.1.2 Factors that Exacerbate Flooding (Element 4.2)

As noted earlier, a great deal of state-funded work has recently been completed in West Virginia on flooding. The "West Virginia Statewide Flood Report" was written by a Task Force of experts from various State and Federal agencies responding to the governor's call to address the increasing number of devastating floods in the State. The Report notes that flooding has affected all 32 major watersheds and all 55 counties of West Virginia. USGS work on flood trends, valley fill impacts, and the Flood Advisory Task Force report are additional important and publicly funded reports that address flood issues in the state. Findings from these reports will be summarized for the bulk of our response to this task in the final report to the state.

Factors reviewed in the state report of primary importance include the following:

- Precipitation and Runoff
- Floodplain Development
- Resource Extraction (mining, timbering, natural gas exploration, etc.)
- Valley Fill
- Mine Subsidence and "Blowouts"
- Water Transfers
- Dams
- Channel Restrictions
- Insufficient Flood Prevention

3.2 DROUGHT

Objective. *Drought analysis is to a) determine areas where historical drought and low-flow conditions have threatened beneficial uses of water (Task 4.1) and b) map drought-prone areas of the state (Task 4.3).*

The same complexities make flood events difficult to define and map also plague the issues of drought and low flow. Many of these complexities are discussed in section 3.2. The variety of drought definitions that exist introduces some of the variety of factors at play in drought analysis. Four drought definitions are often used to discern various sources and effects: meteorological, hydrological, agricultural, and socioeconomic (Table 1). With the exception of meteorological drought, differentiating between natural and anthropogenic causes of water scarcity is difficult to impossible. Consumptive resource use, interbasin transfers and landuse change are among many factors that can exacerbate dry meteorological conditions and cause supply-demand imbalance.

Droughts affect people, the economy, and the environment differently depending on the event's stage, severity, timing, and spatial impact. Agricultural productivity is affected when the soil moisture becomes too low for optimal plant development. This can result from a short-term precipitation deficit. Diminished flow in major navigable rivers is one of the last impacts of a long-term drought. These rivers have large watersheds that may extend beyond the meteorological drought; also the base flow of rivers is sustained by groundwater discharge, which is not strongly influenced by short-term precipitation deficits.
Conditions that indicate where low flow conditions have or are likely to occur (Elements 4.1, 4.3)

Meteorological Drought - a measured departure of precipitation from normal and the duration of a dry period for a given geographic area.
Hydrological Drought - amount of surface and groundwater relative to normal levels as measured by streamflow, snowpack, and lake, reservoir and groundwater levels. There is usually a delay between lack of precipitation and reduced water levels in streams, lakes and reservoirs. It can occur from a persistent meteorological drought *and/or* unsustainable withdrawal and consumptive use rates.
Agricultural Drought - inadequate soil moisture for a particular crop at a particular time. Factors include precipitation, ground water/reservoir levels, evapotranspiration, weather conditions, accessible irrigation technology, crop variety and stage of growth, soil type, and relative availability of water/moisture in prior growing stages.
Socioeconomic Drought - physical water shortages affect the health, well being, and quality of life of the people. Measurements integrate consumption patterns, production technologies, and resource management practices with natural climatological patterns.

Table 2 Types of Drought

3.2.1 Existing Drought Indicators

The National Climate Data Center (NCDC), Office of Emergence Services (OES) and the WV Department of Agriculture (WVDA) each use different systems for drought declaration. Mapping the history of these declarations serves primarily to illustrate inconsistency in the states' current capacity to evaluate and address water scarcity problems. OES and NCDC droughts are mapped (Figures 8 & 9) for period of record (POR). NCDC declarations are based on a variety of information sources including weather reports, local calls and newspaper stories. OES drought declarations are based only on events that require FEMA payments. WVDA drought declaration history is based on payments made to farmers due to agricultural droughts declared by WV, bordering states, or the Federal Department of Agriculture. Data on these droughts are available in discontinuous intervals over the past two decades making a mapped analysis unreliable.

Upon review of the existing maps, it is evident that there are contradictions among data sources and indicators. An important interim finding is that more data collection and investment in reliable data analysis methodologies is necessary to produce reliable indicators of drought prone areas. Furthermore, a standardized approach to local-level data collection is likely to be the best source of information for the impact of low flows and drought on beneficial uses as well for identifying anthropogenic factors.

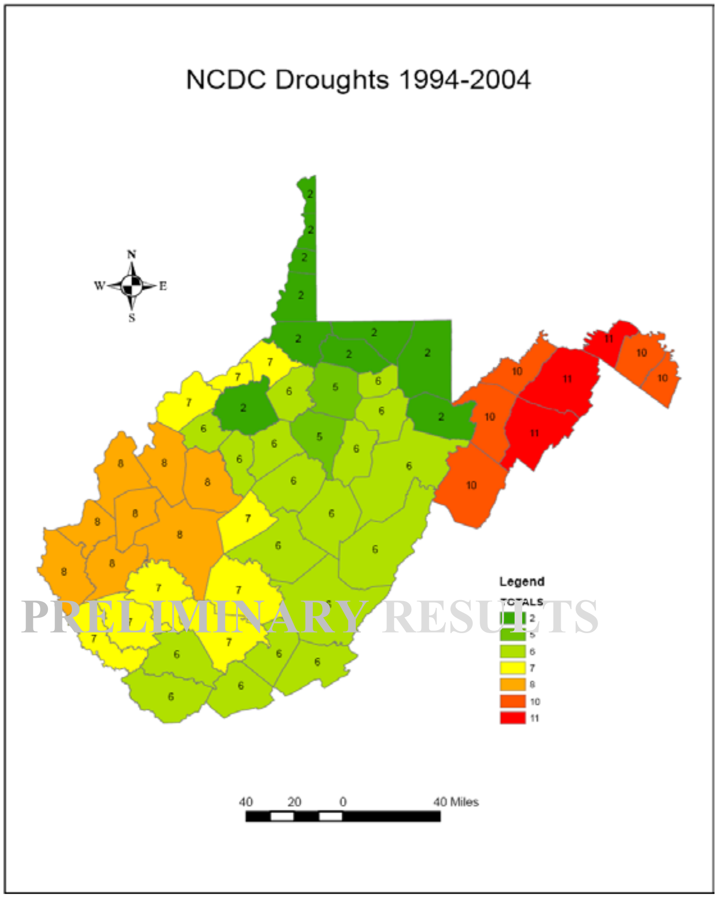
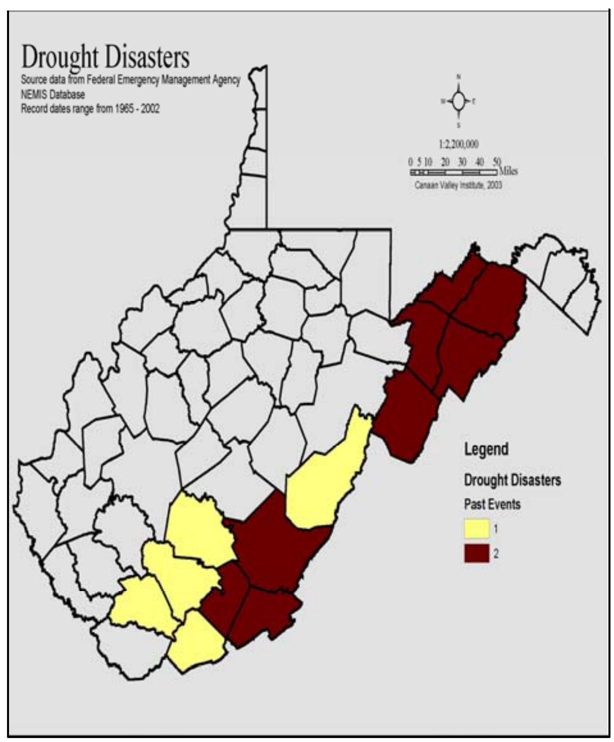


Figure 9 NCDC Reported Droughts 1994-2004

Figure 8 OES Reported Droughts 1965-2002



3.2.2 Alternative Approach: Drought Severity Index

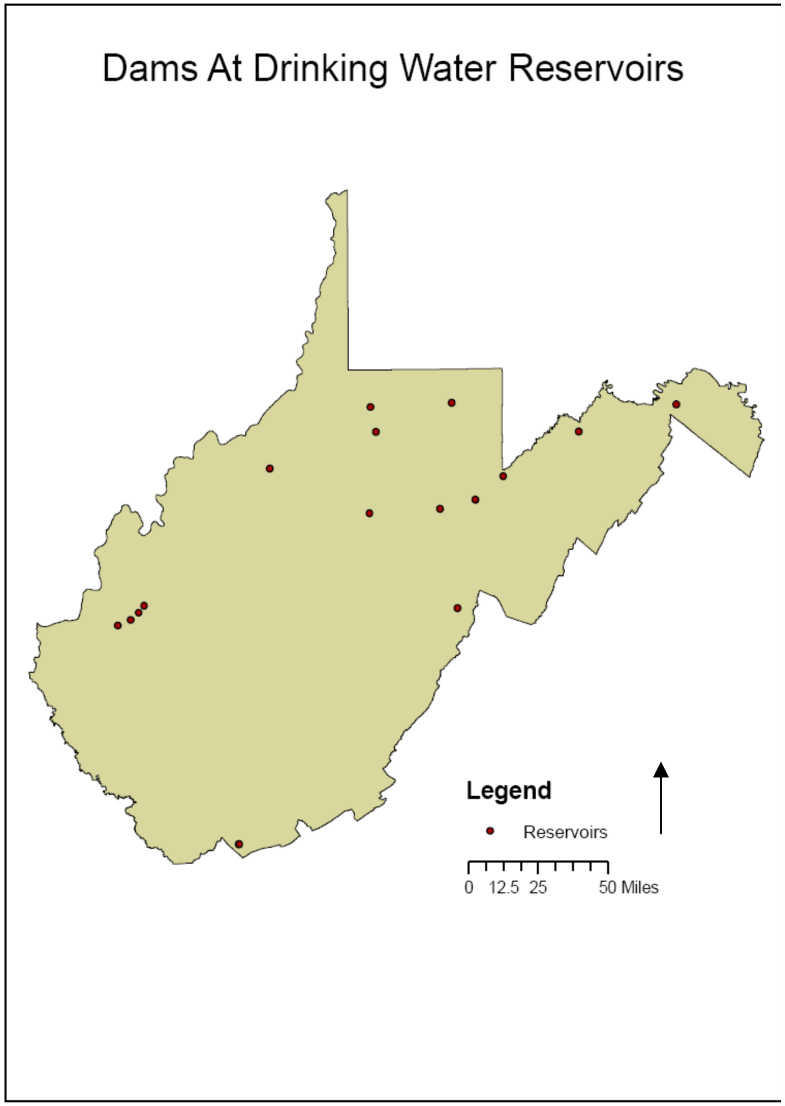
Drought monitoring trends in a region are generally based on an index of multiple drought indicators. An index of multiple drought indicators is useful because water resources are affected differently given the severity, timing, and duration of a drought and differences across topographies and geological contexts can also play a role in drought.

Looking to neighboring states' models, most rely on five indicators - precipitation, streamflow, soil moisture, groundwater, and reservoir levels - to comprehensively determine drought conditions. For WV, we combine only three indicators in an index to provide a snapshot of historically drought-prone areas including precipitation, streamflows, and the Palmer Drought Severity Index (PDSI – soil moisture). Groundwater and public water supply reservoir levels should be included as additional index variables, but the number of gages and period of record for existing gages are insufficient to support a reliable analysis (Figures 10 and 11).

The three-factor index does not necessarily provide a reliable indicator of relative drought-prone areas in the state. The model does, however, demonstrate the objective standard for WV. Pennsylvania and other neighboring states use drought indices both as a tool for historical record keeping as well as an on-going drought monitoring mechanism (http://www.dep.state.pa.us/dep/subject/hotopics/drought/). As a monitoring mechanism, the index allows state officials to declare drought watches, drought warnings, and drought emergencies in different regions of the state depending on the severity of drought in that area. A standardized set of voluntary and mandatory conservation practices are automatically announced and implemented under each category. With a standardized procedure for declaring drought at different levels of severity, agencies are better able to balance physical resource needs with political pressures when declaring droughts and suggesting conservation practices.

The following maps (10 & 11) illustrate why groundwater and reservoir data cannot be used for WV drought monitoring. These are followed by maps that illustrate the remaining three drought indicators (soil moisture – Figure 12; precipitation – Figure 13; and streamflow – Figure 14). Finally, the equation used to calculate state index values is presented with an explanation of methodology and resulting maps.

The results of the application of the multifactor index at the county and watershed level are illustrated in Figures 13 &14. It is evident from these figures that the areas affected by historical drought severity and frequency differs based on spatial-unit boundaries.



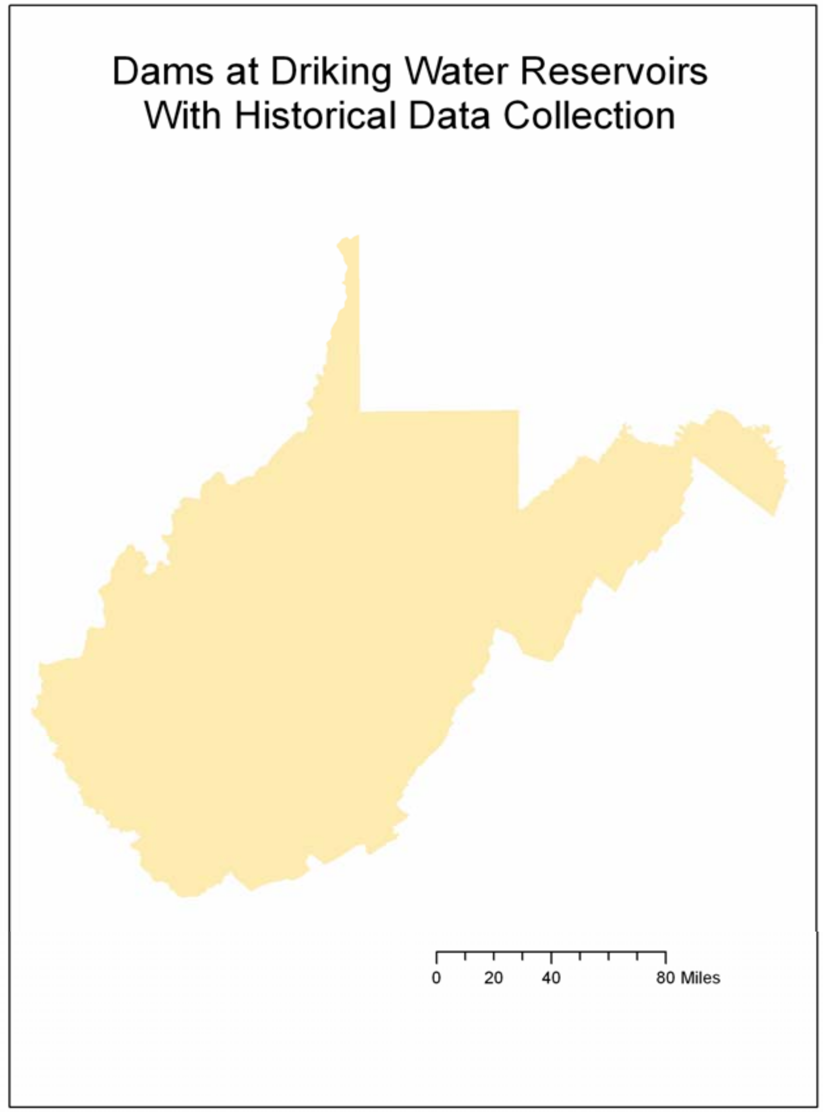


Figure 10 Public water supply reservoirs with monitoring data collection capacity
This indicator is used in surrounding state, but is not used in the drought index for this report because of lack of data.

Figure 11 USGS Groundwater Monitoring Stations
Two of the five remaining monitoring wells are slated to be turned off this year due to federal budget cuts. This indicator is not used in our index.

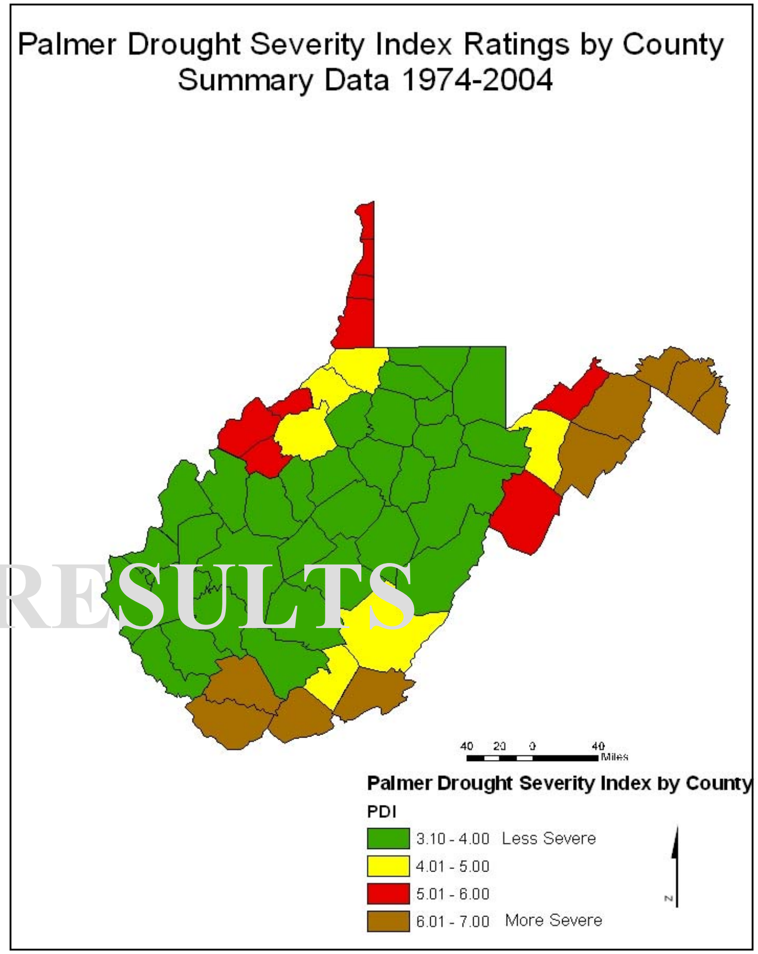


Figure 12 Soil Moisture Drought Indicator (PDSI)
This indicator is used in our index.

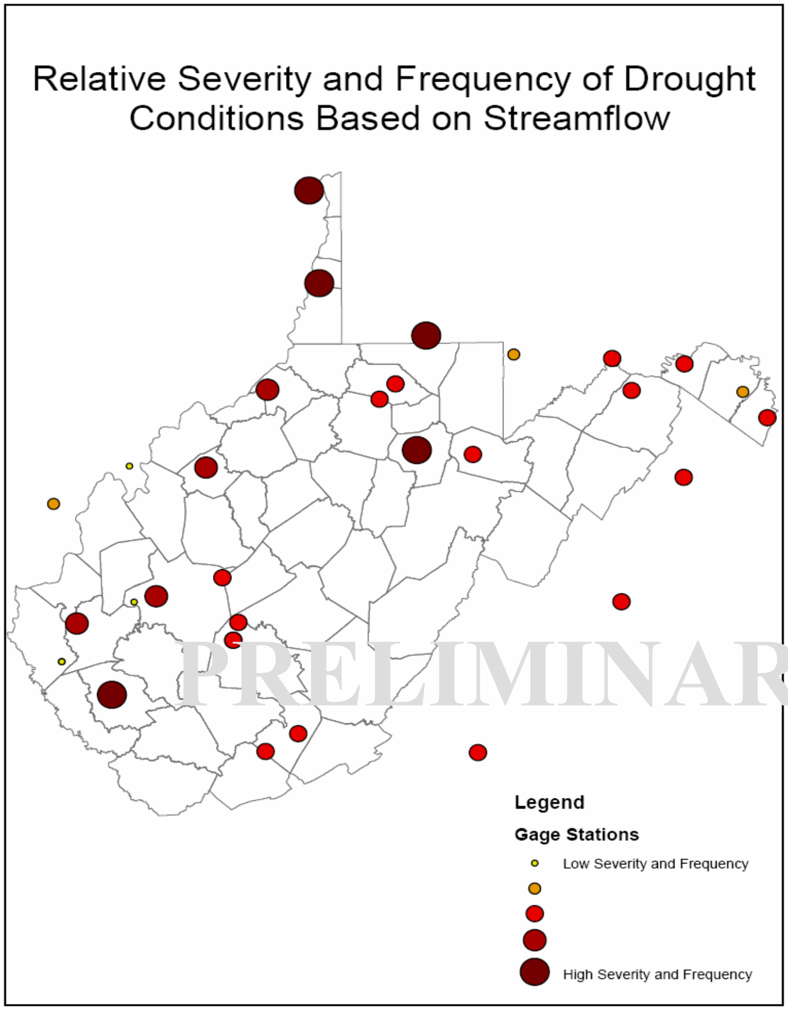


Figure 13 Streamflow Drought Indicator
State coverage by stream gages, particularly gages with 30-years of historical data, is not good. Data collected above were used in the index calculations, though it is not recommended that a stream gage point be used as an indicator of flow patterns for its own watershed or neighboring watersheds.

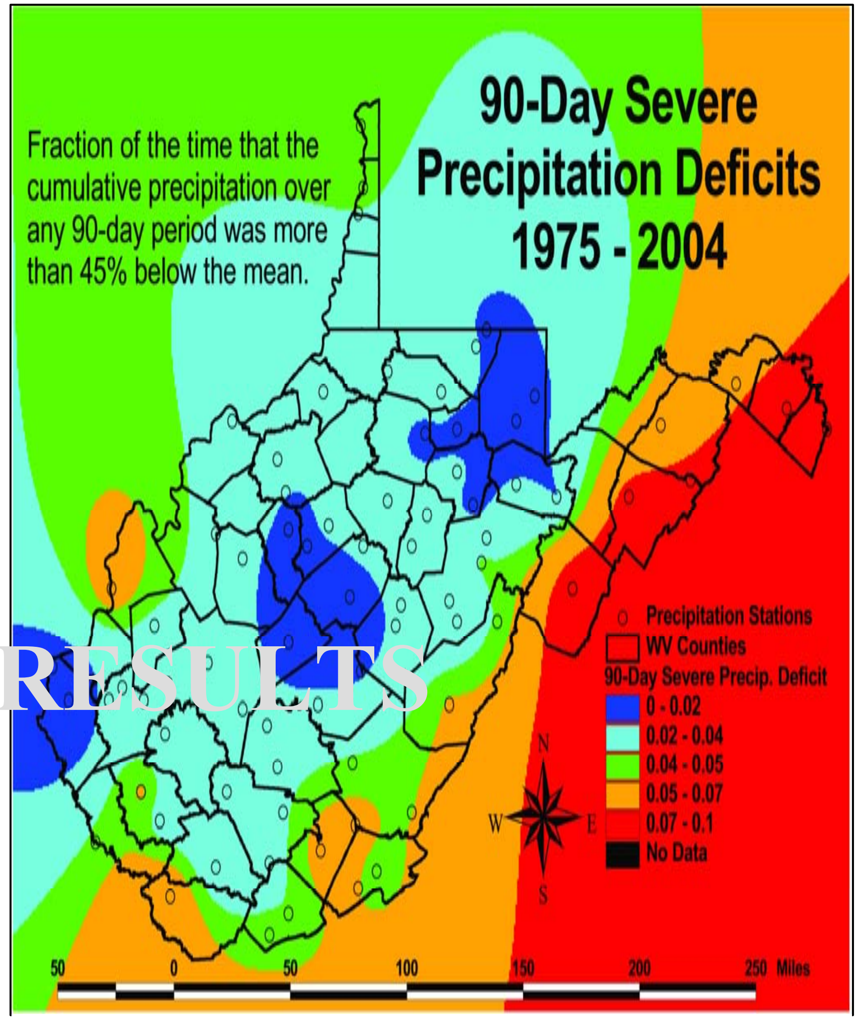


Figure 14 Precipitation Drought Indicator
This indicator is used in the index. The 90-day deficits indicate medium-term precipitation deficits, 30-day (short-term) and 360-day (long-term) deficits are also calculated and included in the index. Precipitation station coverage in the state is adequate.

The combined data for the drought index are spatially based on precipitation gage location. Each precipitation gage is assigned a corresponding PDSI value (climatological region) and a corresponding stream gage based first on shared watershed and then, where there are multiple stream gages in a watershed, by proximity. At each gage site, all three indicators are evaluated separately, on a daily basis over the past 30 years, for drought severity ratings. Precipitation station points are assessed by number of days spent in drought, with each day being weighted by the severity of the drought ranking of each indicator and by the number of the three factors indicating drought (one, two or three indicators in extreme or sever drought on any given day). Cumulative index values for each station are then gridded across the state, and spatially-weighted values assigned to each county and 8-digit watershed.

DROUGHT INDEX VARIABLES

- X Reservoir levels
- X Groundwater
- • Soil moisture (Palmer Drought Severity Index)
- • Precipitation
- • Stream gages

$$D_i = \frac{1}{9}\left[P_i^{30} + P_i^{90} + P_i^{365} + 3S_i + 3I_i\right]$$

D = Drought severity index for a particular precipitation gage.

t = Time index, days.

= Duration of the total precipitation deficit

code; 30, 60, or 365 days.

P_i^t = The *t*-day total precipitation deficit code.

S_i = 30-day mean stream discharge flow rate deficit code.

I_i = Palmer drought index code for precipitation

Figure 15 WV Drought Index Equation

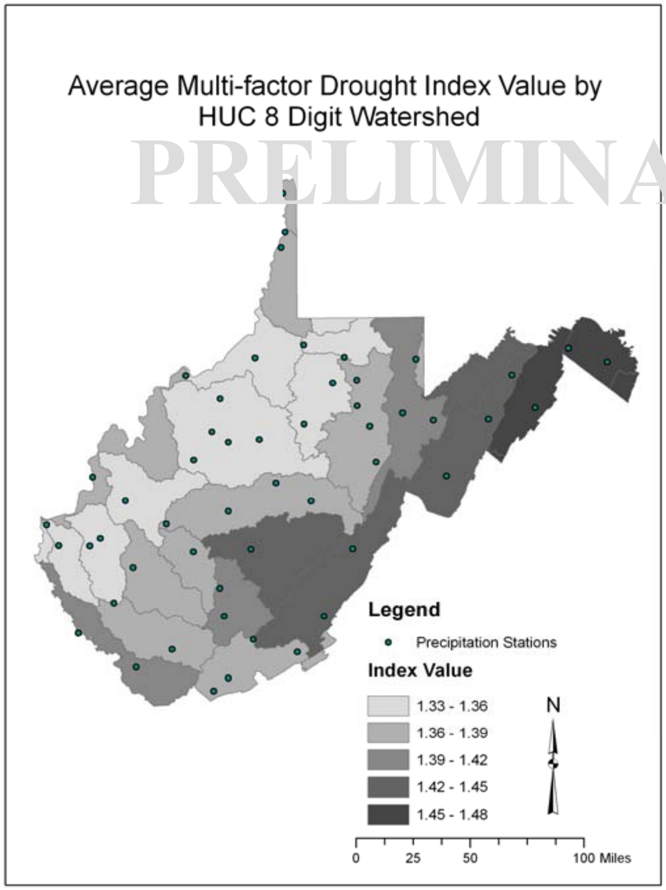


Figure 16 Drought Index by 8-Digit Watershed

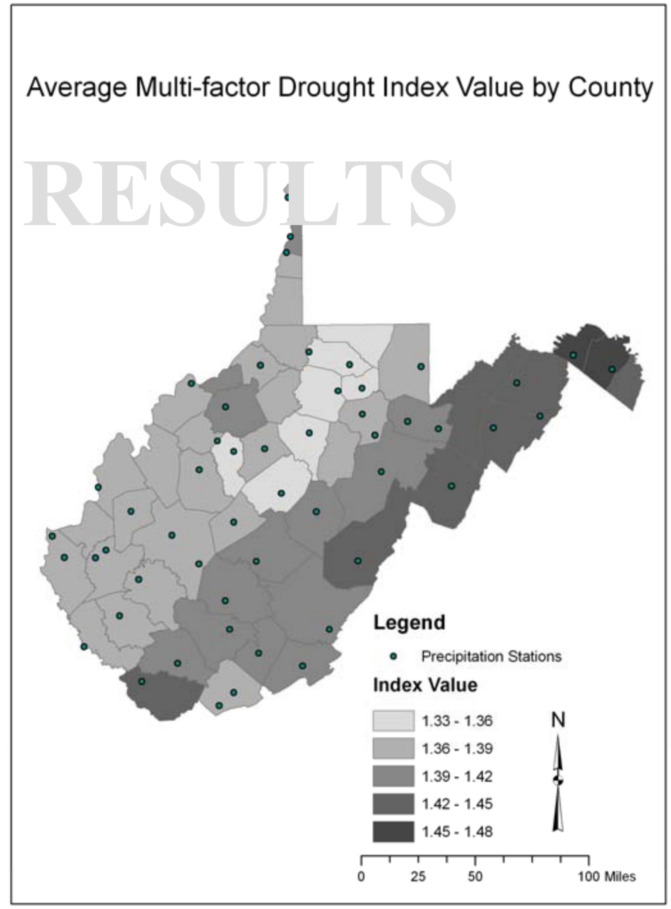


Figure 17 Drought Index Values by County

3.2.3 Impact of drought and low flows on beneficial use (4.1)

Data do not exist for most drought/low flow impacts on beneficial uses at the local or state levels. Furthermore, because drought affects beneficial uses of water resources differently depending on the season, duration, and type of drought as well as region-specific competing demands on water resources, it is difficult to extrapolate generalizations from case-specific data. But below are some important issues that should be considered in the evaluation of state water resources.

NON-CONSUMPTIVE
Ecological Services
Habitat
Effluent dilution
Temperature/oxygen regulation
Ambient/soil moisture
Input to natural production functions (tree, plant, animal growth)
Recreation/Tourism
Swimming
Fishing
Boating/rafting
Aesthetic/existence values
Direct Market Services
Aquaculture
Public utility supply
Hydro-energy production
Transportation
Barge and boat movement
CONSUMPTIVE USES
Industrial/commercial
Public utility supply
Energy production
Agriculture
Water bottling
Mining/natural resource extraction

Table 3 Beneficial Uses Affected by Low Flow Conditions

The section below identifies main categories of beneficial water use and describes how low flow conditions could impact those uses. Information was requested for drought-impact estimates for at least one case in each category. This is followed by a review of the US Army Corps of Engineers' drought-based integrated water resource management strategy in the Kanawha River Valley, which focuses on balancing the protection of different types of beneficial use during resource scarcity.

Beneficial uses of water can be classified as consumptive or non-consumptive. Non-consumptive uses can be further divided into the following categories: ecological services, recreation and tourism, direct-market services, and transportation. The list in Table 1 is by no means complete. Each region and watershed has a unique docket of water users and resource needs, which are often interrelated and interdependent. Some of these would be addressed by a survey or focus group meetings of water resource management stakeholders. State programs like Pennsylvania's have watershed or regional committees to monitor, manage, and seek public feedback on such region-specific issues continually.

Ecological services of stream flows include natural habitat and effluent dilution, temperature and oxygen regulation, and it functions as an input in the production of natural goods and services. Naturally occurring low flow conditions reflect the expected fluctuations of dynamic ecosystems. These natural events should be understood and anticipated in land and water use planning and development.

An unnatural increase in the frequency or duration of low flow conditions may have a negative impact on the beneficial use of water through the destabilization of natural streambed morphology, degradation and reduction of wildlife habitat and other ecological services such as prevention of eutrophication. Low flows reduce stream velocity and result the reduced capacity for the water to carry out natural stream-cleansing services, leading to embeddedness and loss of aquatic habitat.

Drought conditions can also have costly effects on state forest ecosystems. Drought increases tree susceptibility to disease, and it is identified by the State All Hazards Plan as a factor in the spread of wildfires. Drought-related losses were compounded in 1999 by extensive forest fires understood to have been an effect of the dry weather conditions. Between 1991 and 2000 on average 1,080 wildfires burned 65,435 acres per year in West Virginia costing the state $196,700,200 (almost exclusively in the Southwestern region of the state). Wildfires can reduce post-fire landscapes' ability to retain soil moisture in the short run, exacerbating sedimentation and flash flooding factors.

Water-based recreation and tourism is widely recognized to be an engine of economic growth at local and state levels. Tourism and amusement-related sectors are leading the state in employment generation where other traditional sectors are declining. Fishing and boating are two important water-dependent recreation industries in the state.

Low flows can reduce fishing and rafting opportunities directly through insufficient flow and/or indirectly if reduced water quantities translate into quality problems that produce odor, public health threats, and reduced stream clarity. Whitewater rafting alone has consistently attracted over 200,000 visitors to the state annually for the past decade. As surrounding states invest in the development of competing recreation and tourism industries, protecting water quality and quantity will become increasingly important.

WV Department of Agriculture figures indicate that WV aquaculture (primarily for trout stocking) is a $2 million-a-year subsector activity that generates an additional $1 million in related income and taxes. Anglers' visits alone generate $2.5 million per 20,000 fishing trips. According to the DNR, trout stocked in 1999 were significantly smaller than previous years due to drought conditions that started in the summer of 1998 (1.9 trout per pound down from the average 1.5 – more than a 20% production loss). Groundwater sources for commercial fishery production and adequate stream flows to attract anglers and protect fish habitat are important economic resources that are sensitive to natural flows.

Direct market services include aquaculture, public water utilities, and hydro-energy production. Drought threatens these uses when there is insufficient water to continue operations at full capacity. Reduced capacity for these users relates directly to reduced production and/or increased costs of production – resulting in lost revenue accordingly. In the cases of public utilities and hydro-energy production, drought-related production reductions often occur at the same time demand increases (watering lawns, swimming pools, running air conditioning etc.). Potential losses in each care are site and drought specific.

In Berkeley County in 2002, drought caused a 25% reduction in water supply as a result of a 50% reduction in the flow rate of two major springs. While the county is attempting to prepare for the next drought, population growth will inevitably result in future socio-economic droughts. Maryland granted temporary permission to increase daily maximum withdrawals from the Potomac River by over 30% (2.67 to 3.864 MGD) and emergency withdrawals of 5.52 MGD.

County officials are concerned about growing groundwater scarcity due to the increased percent coverage of impervious surfaces in the county (limiting aquifer recharge) and degraded groundwater quality (reducing the quantity of useable water supply/increasing treatment costs). Costly temporary building and development halts have already been implemented in the Eastern Panhandle and parts of Maryland due to water scarcity.

Consumptive uses of water include industrial manufacturing, public utilities with trans-basin service districts; energy production that requires water for cooling towers, agriculture that exports production, water bottling facilities, and mining/natural resource extraction operations that result in bulk transfers of groundwater to surface water.

Drought and low flow conditions threaten energy production when discharge stream temperatures or flows limit facilities' discharge water or when intake water temperatures or flows reduce cooling capacity of the plant. Power companies do not keep records of drought-related production losses and estimates of such losses would have to be made on a facility-by-facility basis. Power generation is affected by drought because temperature and flow of cooling water supply are determinants of the plant production capacity. The impact on each plant is unique and event-specific.

Agriculture production is threatened by drought when goods are smaller in size, misshapen, or diseased due to drought stress. The Department of Agriculture compiled historical data on financial compensation for drought-related agriculture losses but the data was not continuous enough to generate a meaningful report. Though during the 1999 drought alone, USDA reported the $200 million in agriculture-related drought losses.

There are 155 DHHR-licensed water-bottling facilities in the state (11 are WV-owned). Water bottling facilities are not required to report the quantity of water they extract to any state agency (with the exception of the current DEP survey). There are no regulations that require facilities to measure the effects of pumping on neighboring wells or to determine baseline supplies/flows. Facilities are only regulated by DHHR for water quality and facility sanitation regulations. Low flows can threaten water-bottling facilities if other users who rely on surface water are forced to switch to groundwater sources, becoming competing users. As well, excessive surface water consumption can reduce groundwater recharge rates in some cases depending on the region's geology, hydrology and economic activities.

Monroe County, home to a number of spring water bottlers and a growing population, is currently working to prevent conflict over surface and groundwater supplies through countywide planning. Jefferson County's efforts to plan for future water supplies were limited to public utility planning. The county's Source Water Assessment and Protection Program (SWAP) specifically notes that a new water-intensive manufacturing facility or water-bottling facility in the area would result in severe water scarcity for the public water utility.

3.2.4 Evaluate current or potential in- or off-stream practices that may exacerbate low flow conditions (Element 5)

As stated above, distinguishing natural from anthropogenic causes of water scarcity can be difficult to impossible. Understanding the relationship between surface and groundwater movement, particularly in karst areas, can make it nearly impossible to predict where and to what degree one user's withdrawal or diversions may impact another's supply. This complication is compounded by the fact that there is little to no data on withdrawal quantities – making it impossible to understand how those withdrawals impact the hydrology around them.

Five general category practices have been identified to date as exacerbating low flow conditions. These problems are interrelated in many ways, as is illustrated in the discussion below. But general categories include the following:

- Over-extraction (DNR v Tingler, 2005)
- Rapid growth/contamination (Eastern Panhandle)
- Competing uses (USACE Shared Vision balance of energy, boating, and ecology interests in Gauley basin during drought)
- Resource extraction (mining/quarries; Pennsylvania Act 54)
- Sedimentation (Hurricane, WV)

The WVU Hydrogeology Research Center attempted to identify natural and water resource extraction-based impacts on water levels in aquifers of the Eastern Panhandle, but has largely found the indicators to be confounding, even with significant project-based measurement and monitoring expenditure. DEP efforts to allocate liabilities in stream and well dewatering cases surrounding sub-surface mining operations are also hindered by problems distinguishing between natural and anthropogenic flow factors. Lack of flow and groundwater monitoring data further limits our ability to provide a comprehensive analysis of this already complicated question.

Among the most important practices that exacerbate natural low flow conditions are over-extraction of water for consumptive uses and bulk water transfers (most often related to natural resource extraction). Countless anecdotes circulate of well owners who lose their water supply due to new water extraction practices on a neighboring parcel or due to underground mining activity. In these cases, lack of data and information about groundwater extraction, supply, and underground water flows becomes a serious problem.

In WV, stream and well dewatering problems that stem from nearby mining activity cannot be tracked or monitored without extensive manual research. Pennsylvania mandates regular collection and reporting of mine-related dewatering data (Act 54). WVDEP could use the PA program as a guide for collecting similar pertinent information in order to better monitor this problem.

The WVDNR faced water scarcity problems in Randolph County (WVDNR vs Tingler) when a neighbor began pumping groundwater next to a DNR fish hatchery. The resulting reduced spring flows on DNR property caused the hatchery to close (the case was recently ruled in favor of DNR).

Interestingly, many anthropogenic factors that cause and/or exacerbate low flow conditions can also exacerbate flood conditions. Increased coverage of impervious surfaces and increased erosion are two such factors in West Virginia. Increased sedimentation (the state's leading water quality impairment) from landuse practices that lead to erosion causes sediment to accumulate in streambeds (aggradation). Raised streambeds exacerbate flooding and erosion problems, but result in streams that are increasingly shallow, wider, and warmer, losing more water to evaporation and having lower dissolved oxygen levels than they would in their natural condition.

In Figure 18, the Hurricane Public Water Supply Reservoir illustrates how land use, flooding, and low flows or water scarcity are related issues. Inappropriate land use practices at construction sites (sub-photo) upstream from the reservoir caused almost \$.5 million in damages to this reservoir. Dredging was necessary to increase the water supply. Reduced water storage capacity also brought the floor of the reservoir dangerously close to developed structures and roads. And finally, sediment transport brings with it the transport of pathogens that can contaminate streams and reservoirs. A special enforcement sweep upstream and throughout Putnam County resulted in 119 Notices of Violation at 33 of the 41 inspected sites.

Figure 18 Sedimentation of the Hurricane Reservoir exacerbates low flow conditions and rapid flooding

Landuse changes that significantly increase the degree of imperviousness in a watershed is another contributor to both drought and flood events – this includes mine land reclamation practices as well as urbanization practices. Water that would otherwise percolate into soil and underground aquifer systems instead flows directly into surface water streams, often transporting contaminants such as pesticides, oils, sediments, and other watershed-specific contaminants – a problem particularly in sensitive karst area. Increased surface flow volume and velocity can exacerbate flooding in the short run and destabilize streambeds in the long run.

Canaan Valley Institute was working to develop geospatial models of sediment-based relationships between landuse and changing stream morphology in a sub-watershed of the Little Kanawha as part of its work to update FEMA maps in the watershed. This project is temporarily on hold, but such information would provide important lessons for other areas of the state. Landuse-based reduced flows cannot be summarized quantitatively for the state with existing data. Landuse-related factors are also absent in USGS low-flow modeling efforts.

Drought management Drought's impact on various beneficial uses can also vary depending on how the drought is managed by local and state official and by each water user. A drought warning and response system can help users plan for water scarcity by employing water conservation measures at early onset, by understanding their own use in the context of other users and the watershed system, and by preparing users to contribute to watershed or county-based contingency plans that have been worked out to be acceptable to stakeholders prior to an emergency. The case below illustrates how integrated water resource management reduced and distributed the impact of drought on beneficial uses in a way that was politically accepted due to stakeholder participation in the planning process. It further illustrates how flows can be managed, at least on some streams, by planning for natural low flow conditions.

The Kanawha River The Kanawha River and its tributaries drain 12,300 square miles of land starting in North Carolina and crossing into Virginia and West Virginia before joining the Ohio River. Major tributaries in the state include the Gauley, the New, the Elk and the Greenbrier. Minimum in-stream requirements maintain fish and wildlife habitat, transportation, and ecological services (primarily dilution of downstream effluent discharges) but rely on reservoir releases from Summersville and Sutton dams. The whitewater industry provides the region with millions of dollars in revenue every summer and Appalachian Power Company has hydropower plants on three corps multipurpose reservoirs and owns a fourth reservoir at Claytor Lake.

A drought that began with low rainfall in 1987 and continued through the fall of 1988 restricted important whitewater releases during weekdays, costing millions of dollars in lost local revenues. US Army Corps reservoir releases eventually fell below what was necessary to maintain minimum in-stream flow requirements (for ecological services, wildlife, and transport) at a perceptible cost to water quality and habitat.

USACE convened a study team of experts to evaluate the situation and develop a series of policy alternatives to the status quo management plan. For each alternative, impacts on lake recreation, water quality, rafting, navigation, and hydropower were evaluated. A group of stakeholders was convened to debate the various management scenarios and the corresponding implications. Debate and discussion eventually lead to the endorsement and implementation of situation-tailored plan to manage water resources that both protected the ecological and economic services of the watershed resources.

In 1993, when drought again required exceptional water resource allocation decisions be made, informed and experienced stakeholders reconvened with the Corps using the "Shared Vision" model and decided on a new strategy given the specific drought conditions they faced.

The regional drought watch was lifted after heavy rains eliminated the resource scarcity problem, however, the Kanawha case study illustrates the usefulness of and need for regional drought readiness and management planning. Each drought event poses different types of scarcity depending on when it occurs, duration and other events going on at the time. Each region faces different water resource demands and may prioritize needs for each drought event differently given the temporally and regionally unique context. This is particularly useful when water resource uses can be coordinated to facilitate multiple-use management of scarce resources. Combining the participatory and information-driven approaches of the Shared Vision model helped to develop a team of local experts interested in and capable of finding the best management solution for the region. Such participation is likely to provide additional benefits of stakeholder cooperation during the implementation phase of any drought mitigation plan.

4 Conservation Practices

Identify practices to reduce water withdrawals (Element 9)

Given the state's abundance of water resources, water conservation has not been priority for many lawmakers or regulatory officials. Water conservation practices, in water rich regions, reduce costs associated with water diversion, filtering, transportation, and wastewater treatment.

4.1 WVDEP Survey Results

In preliminary results from the WVDEP Water Users Survey, 76 of 383 respondents claimed to practice some type of water conservation practices. These respondents fell within at least 23 different SIC sectors. Of those 76 respondents, some of the water conservation practices listed were not voluntary or were implemented for objectives that were unrelated to conservation strategies but resulted reduced water use. Practices fell into three Conservation Categories of 1) on-site water reuse or recycling; 2) leak or excess water use detection systems; and 3) eliminating or reducing water use need by employing alternative methods to achieve the same goals.

Washington Works (plastics), in Wood County, stands out among the respondents as having implemented one of the biggest water-saving systems in terms of gallons of water conserved. The plant's survey indicates only, "*Site procedures are in place that include the review of projects impacting water consumption. This review includes consideration of water conservation in the approval process*." The estimated water savings at the plant, which uses ground and surface water for "*Cooling Water, Chemical Reactions, & Steam generation*", is 50,000,000 gallons per month. The facility has capacity to withdraw 3,260,400,000 gallons per month.

The facility is considering plans for "*a project involving the recovery and recycling of steam condensate used in steam production at the site is under consideration. This project would conserve the use of ground water.*" Washington Works' planned projects in Wood County would save 13,000,000 gallons per month at an estimated cost of $2,000,000.

Likewise the Follansbee Coke Plant (129,600,000 gallon monthly withdraw permit) in Brooke County is saving 31,248,000 gallons per month by using cooling water that was previously discharged as boiler feed water.

Both the Follansbee and Washington Works plants fall into Conservation Category 1, intra-system water reuse. In Conservation Category 2, leak or excess water use detection, Huntington Alloys Corporation (28,000,000 gallon monthly withdraw permit) installed leak detection system that reportedly saves the facility 10,000,000 gallons monthly.

A number of coal processing plants cited efforts to reduce water use by recirculating water from sediment ponds back through the facility (Conservation Category 1) and by paving or otherwise treating dusty roads to reduce the use of water in dust-suppression activities (Conservation Category 3).

4.2 Case: Toyota

While not the largest water user in the area, the new Toyota Plant in Buffalo, WV is certainly one of the more innovative and progressive facilities in the state in terms of implementing voluntary conservation standards. The plant is implementing conservation plans that will save them millions of gallons of water per year. While there is no water shortage in the Buffalo area, Toyota understands that capturing, filtering, transporting water, and treating excess wastewater are all costly activities. Reducing use, therefore, reduces operating costs. Toyota's goal is to match the plant's own zero solid waste discharge standard in the area of water resources.

According to Toyota's environmental specialist, Sean McCarthy, stormwater from about 100 acres of impervious surface (building and parking lot) is already captured and used for landscape irrigation (20-25 acres), saving the plant .5 million gallons/year.

Currently, the plant is losing 14 million gallons/year to evaporation while operating its cooling compressors and tower. In an effort to reduce this loss, the plant is in the final research and development stages of an on-site water treatment facility that will help save 10-11 million evaporated gallons/yr. This move will also reduce the plant's demand on the local public water utility to three million gal/yr. Just 20 miles outside of Charleston, this demand reduction will provide the city of Buffalo with important opportunities to extend public service to growing residential and commercial demand without incurring additional capital costs for water system expansions.

5 Conclusions

The West Virginia Legislature, through the Water Resource Protection Act, has recognized that water is a tremendous economic asset in West Virginia and should be managed with the same attention and respect as is given to other capital assets managed by the state. WRI has made significant advances in our efforts to respond to the WRPA research tasks in support of and in collaboration with WVDEP.

Evaluation of the state's water resources is a necessary precursor to developing a water resource plan or associated water resource management strategy. Learning now that there are data and information gaps, understanding why different types of information are important, and learning about water resource data and evaluation practices in other states in the region are critical activities.

Our objective is to provide a final report to the WVDEP containing a comprehensive evaluation of the state water quantity issues defined in SB 163 to the extent possible with existing data. Complementary qualitative data should be collected from local stakeholders (government, private, and organizational) who work on a daily basis with water resources but was not an activity that we could undertake with existing resources. With additional funds sought in 2005, we are working to develop an interagency report gages and wells in the state that will identify gaps and prioritize needed new investments. This will compliment a WRI memorandum to WVDEP which served as comparative summary of water quantity management plans and water quantity monitoring resources in surrounding states. Collectively, this information should provide a solid policy guide with which our state's decision makers can make an active and informed decision about whether and how to continue state efforts to assess and manage our water resources.

6 Publications and Reports

Four quarterly reports were submitted to the WV DEP working group on the WV Water Resources Protection Act throughout the 2005 calendar year.

Herd, R.S. and A.M. Schrecongost, Water as a Commodity: Managing WV Water Resources for Economic Development. Presentation to WV Manufacturers, Annual Meeting, June 7, 2005, Morgantown, WV.

Schrecongost, A.M., WV Water Resource Protection Act, Program Assessment and Management. Presentation to Jackson Kelly Water Resource Seminar, September 7, 2005, Charleston, WV.

Herd, R.S. WV Senate Bill 163, WV Water Resources Inventory and Assessment. Presentation to WV Water Research Institute Advisory Committee annual meeting, October 25, 2005, Morgantown, WV.

Schrecongost, A.M., WV Water Resource Protection Act, Program Assessment and Management Status Report. Presentation to Water Resources Committee of the WV State Legislature, December 2005, Charleston, WV.