StreamStats
Interactive Web Map Application

Submitted to:
Renewable Resource Grant and Loan Program

Submitted by:
DNRC, Water Resources Division
PO Box 201601
Helena, MT 59620-1601
May 15, 2010

Contact:
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Application Summary

1. **Name of Applicant:** Montana DNRC Water Resources Division

2. **Project Title:** StreamStats Interactive Web Map Application

3. **Federal Tax Identification Number:** 81-0302402

4. **Type of Entity:** State Government

5. **Type of Project:** State Water Plan (Water Information Management and Distribution)

6. **Project Location:** Statewide

7. **State Senate District:** N/A **State House District:** N/A

8. **Population Served by Project:** N/A

9. **Households Served by Project:** N/A

10. **Number of Farms or Ranches Served by Project:** N/A

11. **Number of Acres Served by Project:** N/A

12. **County:** N/A

Proposed Funding Sources:

Proposed Project Budget			
Funding Source	**Amount**	**Type**	**Committed/Uncommitted**
RRGL Grant	$100,000	cash	Uncommitted
Legislative Appropriation (State Water Plan) to DNRC	$46,000	cash	Committed
MT Dept of Transportation Research Grant to USGS	$130,000	cash	Uncommitted
MT Dept of Transportation (Engineering)	$5,000	in kind	Uncommitted
MT Dept of Natural Resources (WRD - Floodplains)	$20,000	cash	Uncommitted
MT Dept of Natural Resources (WRD - Floodplains)	$2,500	in kind	Uncommitted
MT Dept of Natural Resources (WRD - Water Management)	$56,500	in kind	Committed
USGS Cooperative Assistance to States Program	$197,333	federal match	Committed
Estimated Total Project Cost	**$557,333**		

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Authorizing Statement:

I hereby declare that the information included in and all attachments to this application are true, complete, and accurate to the best of my knowledge, and that the proposed project complies with all applicable state, local, and federal laws and regulations.

I further declare that, for MT DNRC, Water Resources Division, I am legally authorized to enter into a binding contract with the Department of Natural Resources and Conservation to obtain funding if this application is approved. I understand that all funds must be authorized by the Montana Legislature and that grant funds will become available only as Resource Indemnity Trust Fund interest is earned.

Name: Tom Schultz Date: 5/12/10

Authorized Representative (signature)

Title: Water Resources Division Administrator

2.0 Proposal Abstract

Applicant Name: **DNRC Water Resources Division**

Project Title: **StreamStats Interactive Web Map Application**

Project Description:

StreamStats is an interactive, Web-based map application for providing streamflow statistics, such as the 100-year flood and the 7-day, 10-year low flow. The overall goal of this project is to develop a state-wide hydrological data delivery tool (web-based decision support system) to support water resources planning and management. By developing and disseminating hydrological data via the Internet, StreamStats will facilitate development of projects and programs aimed at the conservation, development, utilization, and sustainability of Montana's water resources at the local, regional and statewide level. Stream flow statistics are needed for water supply planning and management, water rights adjudication, water quality regulation, biological habitat assessment, floodplain delineation, and infrastructure design.

Using StreamStats, stream flow statistics can be obtained at data collection stations (stream gages), and for ungaged sites selected by the user. StreamStats users can point and click on data collection stations in their Web browser to obtain previously determined streamflow statistics and other information for individual stream gages. Users can also point and click on any stream shown on the map to obtain flow statistics for ungaged sites. For ungaged sites, StreamStats determines the watershed boundary above a user-selected point and then measures physical and climatic characteristics of the watershed by use of a Geographic Information System (GIS). StreamStats then inserts the watershed's characteristics into previously determined regression equations to produce stream flow statistics.

3.0 Resource and Citizen Benefits Narrative

Applicant Name: **DNRC Water Resources Division**

Project Title: **StreamStats Interactive Web Map Application**

Montana faces an increasing set of water resource challenges. Aging infrastructure, rapid population growth, depletion of groundwater resources, impaired water quality associated with particular land uses and land covers, water needed for human and environmental uses, and climate variability all play a role in determining the amount of fresh water available at any given place and time. Water shortage and water-use conflicts have become more commonplace in many areas of Montana, even in normal water years. As competition for water grows – for agriculture, growing cities and communities, energy production, and the environment, the need for information and tools to aid water resource decision-making also grows. Water supply limitations and increasing demand are exacerbating the challenges facing traditional water management approaches based on antiquated hydrological predictions and water use estimates.

The project proposed herein – StreamStats - is a central component of DNRC's overall strategy to provide basic water supply and use information under the State Water Plan. Recent amendments made by the 2009 State Legislature to Montana's water planning legislation (MCA 85-1-203) reflect the water resource challenges faced by the state. In general, the legislation directs DNRC to characterize the state's water resources, inventory the myriad demands placed on those resources, and make recommendations regarding the means by which these water resources may be applied for the benefit of the people. DNRC's approach to implementing the state water planning legislation is multi-faceted, and reflects the basic relationship between water supply, water use, and water availability. Having credible estimates of water supply and water use are fundamental to understanding water availability in any given watershed, and DNRC's submittals to the Renewable Resource Grant Program reflect the need for this type of information.

Credible estimates of water availability, particularly in light of variables such as prolonged drought and climate change, are fundamental to understanding the effects of increased demand on existing water supplies and uses. With respect to water supply and climate variability, an important feature of the StreamStats project is incorporation of the last decades' worth of stream gage data into the low flow analyses. From 2000 to 2008, most of Montana's watersheds experienced unprecedented drought. The last USGS flow frequency report for Montana (Parrett and others, 2004) was based on data through water year 1998. The updated flow frequency information generated by the proposed StreamStats project would include 11 additional years of flow records from the approximately 250 stream gages operated in Montana (see Figure 4.1), including 18 relatively new gages that have achieved at least 10 years of record since 1998. By incorporating these newest data, consumers of hydrologic information via the StreamStats interactive web map application will receive hydrologic estimates based the latest data available.

The StreamStats Project will produce an interactive web map application designed to provide quantitative water supply information at a consistent scale (1:100,000) across the entire state of Montana. Together with the existing stream gage network operated by USGS and other state and local partners, it forms the foundation of DNRC's approach to quantifying <u>water supply</u> under the State Water Plan. Combined with the irrigated lands mapping proposal intended to address <u>water use</u> within Montana, StreamStats will support the quantitative assessment of water availability within a given watershed. When combined with data from other sources, such as the DNRC water rights database, it will provide significant insight into the often large disparity between water claimed via the water rights system, and water produced in any given basin.

4.0 Technical Narrative

Applicant Name: **DNRC Water Resources Division**

Project Title: **StreamStats Interactive Web Map Application**

4.1 Project Identification

StreamStats is an interactive, Web-based map application for providing streamflow statistics, such as the 100-year flood and the 7-day, 10-year low flow. Stream flow statistics are needed for water supply planning and management, water rights adjudication, water quality regulation, biological habitat assessment, floodplain delineation, and infrastructure design. Using StreamStats, stream flow statistics can be obtained at data collection stations (stream gages), and for ungaged sites selected by the user. StreamStats users can point and click on data collection stations in their Web browser to obtain previously determined streamflow statistics and other information for individual stream gages. Users can also point and click on any stream shown on the map to obtain flow statistics for ungaged sites. For ungaged sites, StreamStats determines the watershed boundary above a user-selected point and then measures physical and climatic characteristics of the watershed by use of a Geographic Information System (GIS). StreamStats then inserts the watershed's characteristics into previously determined regression equations to produce the stream flow statistics.

4.2 Project History

The development of geographic information systems (GIS) has made possible the compilation and analysis of large amounts of geospatial information on a watershed basis. Recent software developments and increased availability of geospatial datasets (including detailed soils, geology, climate, and land-cover/use data), have further automated the compilation and analysis of topographic and environmental characteristics of watersheds. These advances, coupled with the increased accessibility to information provided by the Internet, offer this opportunity for improved distribution and use of Montana stream flow information via StreamStats.

StreamStats was developed cooperatively by the U.S. Geological Survey (USGS) and the Environmental Systems Research Institute, Inc. (ESRI, http://www.esri.com), and was designed for national implementation in cooperation individual states. USGS initially launched StreamStats in 2000 for the State of Massachusetts (Reis et al. 2000). Since then 20 states have fully implemented StreamStats (including the neighboring state of Idaho), 6 states are undergoing internal testing of StreamStats, and 11 states (including North Dakota and South Dakota) are undergoing implementation for StreamStats (Alan Rea, personal communication 2010). States that have yet to implement StreamStats include Montana and Wyoming (http://water.usgs.gov/osw/streamstats/ssonline.html).

4.3 Project Purpose

The overall goal of this project is to develop a state-wide hydrological data delivery tool (web-based decision support system) to support water resources planning and management. By developing and disseminating these data via the Internet, StreamStats is intended to facilitate development of projects and programs aimed at the conservation, development, utilization, and sustainability of Montana's water resources at the local, regional and statewide level. The proposed StreamStats project has five primary objectives:

1. **Coordinate project activities to ensure successful outcomes**. Development and implementation of StreamStats for Montana is a multi-phased project with several tasks occurring simultaneously over an approximately two-year period. Close coordination between state and federal partners is critical to a successful conclusion and active project management is necessary to engage Montana's professional water resource community and the public. Because of the technical obstacles involved with development of the tool at high resolution (1:24,000), the initial version of the tool proposed under this application will be developed at medium resolution (1:100,000) so as to expedite deployment of StreamStats and quickly build a user base through which future improvements may be scoped (see Section 4.6 – Alternatives).

2. **Develop standard low flow hydrologic statistics for gaged basins within Montana**. Peak-flow statistics (e.g., flood frequencies) are currently being computed for the entire state by the USGS under agreement to Montana Department of Transportation (MDT), so the RRGL project proposed herein would emphasize development of flow statistics not addressed by the MDT project, namely low flows. Low flow statistics are a necessary element for many water resource applications (e.g., water rights administration, wastewater discharge permitting, TMDL development, instream flow agreements, aquatic habitat assessments, etc.)

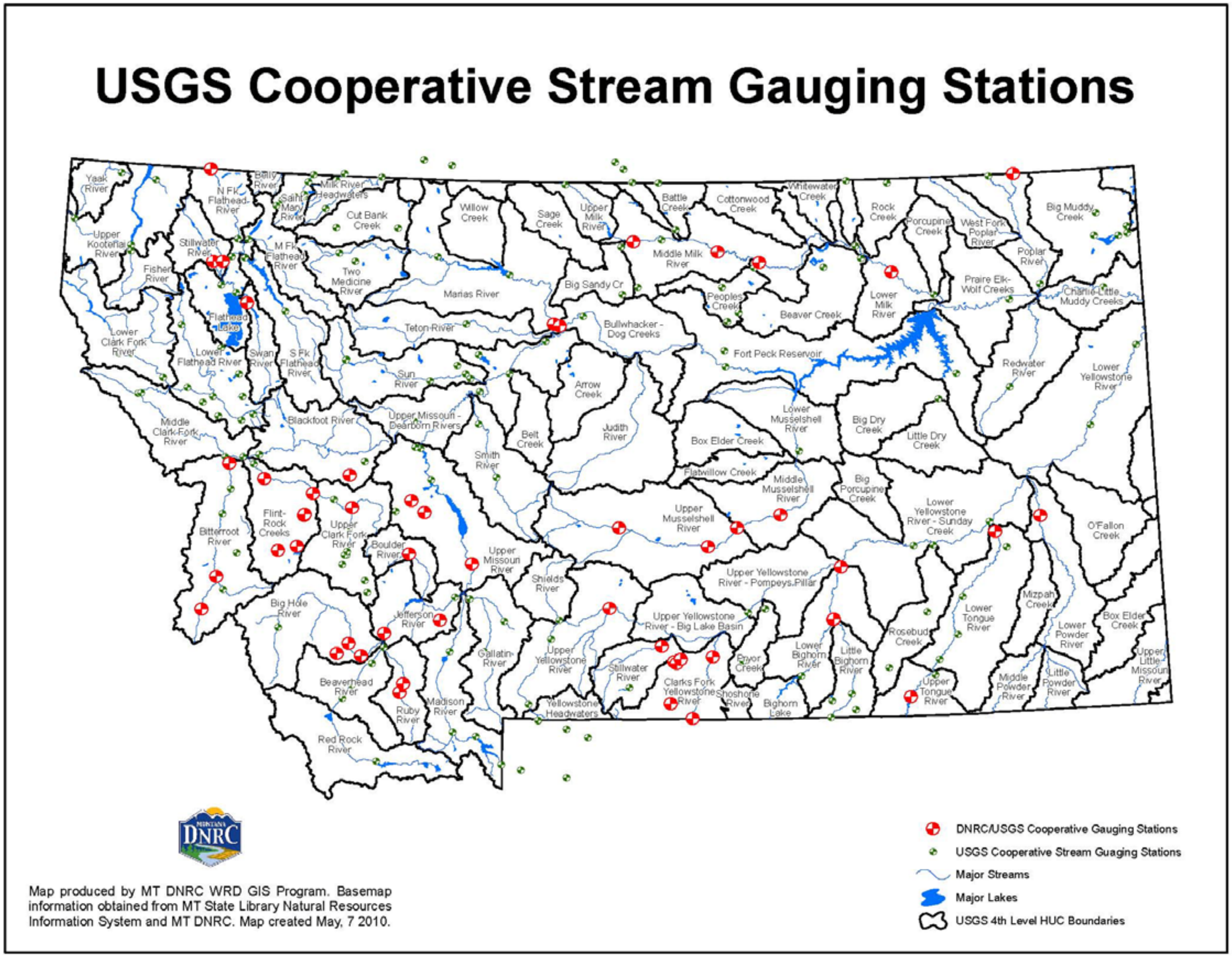
3. **Compute basin characteristics for gaged and ungaged basins in Montana**. This objective would prepare statewide GIS datasets and extend the basin characteristic computations at gauged locations for use at ungaged locations. The USGS is currently engaged in computation of basin characteristics for gaged basins within Montana. NHDplus (National Hydrography Dataset Plus - an application-ready integrated suite of hydrography data) is anticipated in late 2010 and early 2011. NED (National Elevation Dataset) will be used as the basis for determination of basin topographic characteristics. Geospatial datasets for other non-topographic basin characteristics (e.g., precipitation, soils, land-cover, etc.) are also being compiled by USGS.

4. **Compute regression equations for hydrological statistics and gaged basin characteristics.** Using the results obtained from previous investigations, the hydrologic statistics (Objective 2) and the basin characteristics (Objective 3), will be used to develop regression equations for the gauged basins. The regression equations developed for gauged basins will enable the calculation of hydrologic statistics in ungauged basins.

5. **Implement a Web-based interactive tool (StreamStats) to automate calculation and delivery of stream flow statistics**. Objective 5 is the culminating phase of the project. The StreamStats tool will utilize basin characteristics developed under Objective 3 and regression equations developed under Objective 4 to compute stream flow statistics at ungaged locations on demand, and serve the results via the Internet. StreamStats is easy to use, requiring only that the user click on a map to identify the stream location of interest. If the location is at or near a stream flow gaging station (see Figure 4.1), the web tool will calculate stream flow statistics based on available stream flow records. If the location is ungaged, the web tool will delineate the basin boundary, determine basin characteristics, and calculate all stream flow statistics that can be estimated using regression equations (Objective 4). The user can then download a map of the basin and a stream flow statistics summary that includes confidence intervals and an explanation of the results.

Completion of Objectives 2 (low flow statistics at gaged locations) and 3 (basin characteristics) would be prerequisite to Objectives 4 (regression equations) and 5 (StreamStats interactive map application).

Figure 4.1 – USGS Stream Gage Locations in Montana



4.4 Existing Conditions

The USGS Montana Water Science Center has developed a range of hydrologic statistics to describe stream flow measured using the USGS gauging network. These statistics are frequently used by the water resource community in Montana and are an accepted way to represent stream flow conditions (Parrett and others, 2004). Advances in statistical software packages have integrated these statistics into routines to efficiently calculate statistics for large numbers of gage records (McCarthy, 2005).

While these existing information sources are useful to many water resource applications, the hydrologic statistics described are not comprehensive and in some cases additional statistics are needed to adequately characterize a given river or stream. The most recently published statistical information (Parrett and other, 2004) utilizes gage records through 1998. Since then, 10+ years of additional data have been collected, including some of the driest years on record. Some gages have been shut down; others have been added to the monitoring network. This information needs to be updated and distributed using present day analytical and information management techniques.

Much of the work towards development of StreamStats is currently underway. The statewide GIS datasets mentioned in 4.3.3 are under development by the USGS at the national level, and DNRC WRD/NRIS at the state level. In addition, the USGS, under agreement with MDT, is currently updating and will be publishing flow statistics for high flows at gaged locations (see 4.4.1). These are important contributions because flow statistics and GIS datasets are foundational elements of StreamStats. The fact that USGS is already under agreement with MDT to produce updated flood frequencies means that other resources can be made available for development of low flow statistics which are critical to water planning and development of the State Water Plan (§85-1-203).

4.5 Outcomes

The health and economic welfare of Montana's population is dependent on a continuing supply of fresh water. Outcomes from this project include more informed decisions regarding the state's water resources. StreamStats would provide a consistent level of standardized quantitative information regarding Montana's surface water supply. Water supply information, when combined with other elements of the State Water Plan – namely water use, will allow estimation of water availability in a given watershed. And water availability is central to a wide range of water resource decisions and development considerations. StreamStats will provide basic water supply information suitable for reconnaissance-level inquiries within individual watersheds. It is not, however, a substitute for watershed-specific hydrologic investigations. It is intended to provide consistent water resource information state-wide, and as such, must be used accordingly.

4.6 Alternatives

StreamStats will use existing proven methods that hydrologists and other water resource professionals employ to estimate stream flow at any given ungaged location. Through GIS and database technology, StreamStats determines watershed boundaries and measures physical and climatic characteristics of watersheds for ungaged sites by use of a GIS, and then inserts the characteristics into previously determined regression equations to return stream flow statistics. Once operational, StreamStats will provide a basic reference for any assessment, protection, or restoration activity involving surface water resources.

Alternatives include "no action" or "business as usual" for water resource professionals working on projects that require stream flow information. Calculation of stream flow statistics would still be necessary, and hydrologists or other qualified personnel would still apply a variety of standard techniques to the calculation of streamflow statistics. Depending on the application or need for accuracy, these techniques could range from detailed hydrological analyses (expensive) to a "back of the envelope" (inexpensive) type calculations.

Estimation of long-term stream flow statistics can be slow and personnel intensive, might be performed using different methods with varying documentation and scientific validity, and often are not feasible for the public and non-hydrologists because they require training, multiple data sources, and expensive computer software and resources. A web-based interactive tool (StreamStats) developed by the U.S. Geological Survey (USGS) provides a convenient, standardized, state-of-the-art tool for determining stream flow statistics at any stream location within Montana.

The project proposed herein would develop StreamStats at a medium resolution scale (1:100,000). This is in contrast to development at a high resolution scale (1:24,000). This means that some of the foundational GIS datasets, in particular the NHD, WBD and the DEMs, will be at a lower resolution than what could ultimately be achieved. The reason for targeting a medium resolution version of StreamStats as the deliverable for this project is time and money. Some of these high resolution datasets, such as the NHD, are still under development and it will be several years before they are of sufficient quality for use in StreamStats.

In contrast, a medium resolution version of the NHD is complete, and delivery of an updated version that includes value-added features (NHDPlus) is anticipated in late 2010 and early 2011. In order to deliver StreamStats in a 3-year timeframe (see Section 4.9 – Project Schedule), it is necessary to pursue a medium resolution version as an initial end product. Having a functional tool sooner, rather than later, will help build support to produce future versions at a higher resolution.

4.7 Cost Benefit Analysis (Alternatives)

Development of StreamStats is an investment in the future of water resource management for Montana. Deployment of the StreamStats utility will standardize water quantity information to a level suitable for many routine water-related administrative applications (e.g., water rights applications, habitat assessments, 310 and 404 permits, infrastructure design, etc.). Estimation of long-term stream flow statistics can be slow and personnel intensive, and often are not feasible for the public and non-hydrologists because they require training, multiple data sources, and expensive computer software and resources. Compared to manual methods, StreamStats reduces the average time needed to estimate streamflow statistics for ungaged sites from several hours to several minutes. In addition, usage of StreamStats does not require specialized training in hydrology or engineering. Considering the broad applicability of StreamStats to a wide variety of projects, this represents a significant reduction in the cost of providing the information necessary for a multitude of water-related decisions. Amortized over the relatively foreseeable future (25 years), the upfront costs to develop StreamStats will be more than offset by the savings realized by individual programs and users.

4.8 Implementation Plan

4.8.1 Project Approach

The overall approach is to capitalize on USGS's institutional experience implementing StreamStats in other states (e.g., Idaho) while tailoring results and functionality to Montana's hydrology and program needs. The foundational elements of the project – flow statistics, basin characteristics, regression equations, and the GIS on which StreamStats is based, would be developed by the USGS - Montana

Water Science Center with assistance from the National Office of Surface Water. Final databases and GIS layers necessary for operation of the StreamStats Interactive Web Map Application would be housed on servers located at the USGS's Regional Office in Denver. As shown in Table 4.1 – Project Schedule, work on the foundational elements would proceed concurrently over an approximately three-year time frame, and conclude by the end of federal fiscal year 2012.

4.8.2 Project Tasks (steps to meet Project Goal and Objectives)

1. **Coordinate Project Activities** – Coordination and project management are necessary to ensure a successful outcome. They are described below by six tasks:

    a. Project Scoping and Design – The needed functionality and statistical results will be determined through a front-end scoping and design process to ensure that science, policy, management, and regulatory needs are met. DNRC WRD personnel will coordinate amongst state and local agencies, and USGS will coordinate amongst federal agencies. Both agencies, USGS and DNRC, will jointly prepare a scoping report that documents the front-end scoping and design process and assembles a list of beneficial hydrologic statistics for calculation.

    b. Contract Management – Work under the Renewable Resource Grant will be conducted under a Joint Funding Agreement (JFA) between DNRC Water Resource Division and USGS. Through the USGS Cooperative Program, local partners are eligible for 60% local /40% federal cost-share. Day to day contract management would be provided by DNRC WRD planning personnel with oversight from the WMB Chief and DNRC WRD Administrative Officer.

    c. User Group Education/Public Involvement – Once internal testing is complete and the project is ready for public consumption, a series of educational meetings will be held as necessary for project cooperators and other interested parties for purposes of demonstrating StreamStats and answering questions related to its use. These meetings will be conducted jointly by USGS and DNRC personnel during the "roll-out" phase of the project.

    d. Product Review/Quality Control – Necessary for all technical elements of the project: hydrological statistics, basin characteristics, regression equations, and the interactive map application (StreamStats). USGS would be responsible for technical work product review and quality control. Beta testing of StreamStats would be conducted through a selected set of external users.

    e. Prepare and Publish StreamStats Fact Sheet that describes the StreamStats interactive web map application. This is standard USGS procedure for publicizing StreamStats. USGS would be responsible for authorship, layout, and design.

    f. Prepare RRGL Grant Reports as per program requirements.

2. **Develop Flow Statistics** – As a start, analysis methods described in McCarthy (2005), Henriksen and others (2006), Pyrce (2004), Risley and others (2008), and Sando and others (2009) will be used to compute both high-flow and low-flow hydrological statistics. Additional methods may be necessary to compute all of the statistics identified as beneficial by other agencies. The

desired statistics will be computed using statistical software so that a systematic approach will be used for all gages with suitable stream flow records. Several tasks are necessary to accomplish this objective:

a. Identify suitable gages with sufficient duration and quality of records within Montana and near the Montana border in adjacent states. Typically 10 years of record is sufficient. (USGS)

b. Compile hydrological statistics that are of value to cooperators (USGS). These include peak flow, flood frequency, and low-flow statistics, as well as other parameters necessary to fully characterize stream for planning, regulatory and administrative purposes.

c. Prepare Draft Report that documents methods and results of statistical low flow analysis (USGS).

d. Review Draft Report both internally within USGS and externally by DNRC and other qualified agency cooperators (USGS).

e. Prepare and Publish Final Report in the form of a USGS Scientific Investigation Report. In addition, the stream flow statistics will be available on the Internet via StreamStats (once implementation is complete) (USGS).

3. **Compute Basin Characteristics** - Basin characteristics will be computed using GIS techniques (as well as those that in the past were computed using manual techniques) for about 286 gaging stations in Montana. Several tasks are necessary to accomplish this objective:

   a. Delineate Basin Boundaries and Compute Topographic Characteristics using GIS analysis of land surface elevation, hydrography, and watershed boundary geospatial datasets (NED, NHD and WBD) (USGS).

   b. Compute Non-Topographic Basin Characteristics using GIS analysis of land cover, soils, geology, and climatic data (NLCD, STATSGO, PRISM, etc.) (USGS).

   c. Compare Manually-Derived and GIS-Derived Basin Characteristics to verify that GIS-computed characteristics are accurate and to understand effects of differing computational methods on existing regression equations. For all gaging stations, manually- and GIS-computed basin characteristics will be compiled and differences between the methods will be statistically summarized (USGS).

   d. Evaluate Effects of Manually-Derived vs. GIS-Derived Basin Characteristics on regression equation results for purposes of assessing the suitability of using GIS-computed basin characteristics in existing regression equations. Existing regression equations will be run using both manually- and GIS-computed basin characteristics for several ungaged stream sites in each region. The results will be compared and statistically summarized. Final product will be a Microsoft Access database containing GIS-computed basin characteristics for selected gaging stations in Montana. (USGS)

4. Compute Regression Equations - Analyses will be restricted to selected N-day, T-year low-flows (e.g., 1Q10, 7Q2, 7Q10, 7Q20, 30Q5, and 30Q10) that are most commonly used in dealing with low-flow issues (Pyrce, 2004). The N-day, T-year low flow represents the minimum average discharge for "N" consecutive days that has an average recurrence interval of once every "T" years. For example, the 7-day, 10-year low flow (7Q10) represents the minimum average discharge for 7 consecutive days, which has an average recurrence interval of once every 10 years. Low-flow data from 286 gaging stations in Montana (McCarthy, 2005) will be used in analyses. Several steps are necessary to accomplish this objective:

a. Define Appropriate Regression Regions that are (USGS) :
    - Generally hydrologically homogeneous,
    - Include gaging stations that have similar basin characteristics, and
    - Have enough hydrologic variability to define the hydrologic variability associated with basin characteristic variability.

b. Develop Regional Regression Equations through use of logistic regression to estimate the probability that a given N-day low flow statistic will be zero within a given region. Logistic regression provides a means of incorporating zero-flow information into regional low-flow analyses (Tasker, 1989; Ludwig and Tasker, 1993; Hosmer and Lemeshow, 2000). Logistic regression analyses will be performed using the S-plus software package (MathSoft, 1999). Equations that relate the probability of a given N-day low flow equaling zero to basin characteristics will be developed for each identified region. Final regression equations will be developed using generalized-least-squares regression. (USGS)

c. Prepare Draft Report that documents methods and results of regression analysis. (USGS)

d. Review Draft Report both internally within USGS and externally by DNRC and other qualified agency cooperators. (USGS)

e. Prepare and Publish Final Report as a USGS Scientific Investigations Report. (USGS)

5. **Develop Interactive Web Map Application** (StreamStats User Interface) – When a user clicks at a gaged or ungaged stream flow location, basin characteristics needed as regression parameters are first calculated for that location using GIS datasets, and then the regression equations are run to provide estimates of stream flow statistics for the ungaged site. Although these datasets will have previously been used for computing basin characteristics at existing stream gaging stations, additional preprocessing and cataloging will be required for incorporation into StreamStats. Work under this objective can be grouped into five tasks:

a. Populate Stream Flow Statistics Database using MS Access and a data entry tool called StreamStatsDB. This database will include stream flow statistics for active and discontinued Montana stream gages, descriptive information, and basin and climate information. Primary sources for stream flow statistics include McCarthy (2005), and Parrett and Johnson (2004). (USGS)

b. Develop GIS and Web Site Map Base Layers needed for:

    - *Web site map display* - Digital Raster Graphic (DRG) maps will be used at large scales, while color-shaded relief maps with streams, roads, and towns will be used at smaller scales.

    - *Drainage basin boundary delineation and computation of topographic characteristics* (e.g., basin area, basin slope, mean basin elevation, etc.). NHDPlus

(Horizon Systems Corporation, 2006) with 30-meter Digital Elevation Models (DEMs), 1:100,000 scale hydrographic data (medium resolution NHD), and 1:24,000 scale Watershed Boundary Data (WBD) will be used.

- *Computation of non-topographic basin characteristics* (e.g., land cover, soils, geology, precipitation, etc.).

c. Develop Regression Equation Database that enables estimation of stream flow statistics at ungaged sites. This database will contain all data needed for applying existing stream flow statistics regression equations that are suitable for inclusion in StreamStats, including explanatory variable coefficients, regional boundaries for which the equations apply, valid ranges for explanatory variables, and routines for determining confidence intervals about the estimates (USGS).

d. Web Site Review and Testing GIS-determined basin characteristics using StreamStats will be compared with external GIS calculations for a subset of existing gaging stations. The StreamStats ungaged site process will be run on a representative sample of the stream flow gaging stations previously used in regression analyses. The estimated stream flow statistics and basin characteristics from StreamStats will be compared with reported predictions and basin characteristics to detect for the presence of bias or differences in the precision of the estimates. If bias is found, then adjustments to the StreamStats measurement methods will be attempted to eliminate the bias. If differences in precision are found, then those differences will be made known to StreamStats users (USGS).

e. Web Site Implementation (Public Roll-Out) StreamStats will be an extension of the nationally-developed StreamStats application developed specifically for Montana; a USGS Fact Sheet will be prepared that discusses use of the Montana StreamStats web site and issues related to transition from use of manually-computed to GIS-computed basin characteristics in the application of stream flow-statistics regression equations (USGS).

4.9 Project Schedule

Table 4.1 contains the project schedule. The overall project timeline is approximately 3 ½ years. Scoping will commence in the latter half of calendar year 2010 with project management and coordination activities occurring through-out the life of the project. Work under Objective 2 (Development of Flow Statistics) will begin in the fall of 2010 and continue for approximately 2 years. Basin Characteristics (Objective 3) and computation of regression equations (Objective 4) occur starting in 2011 and continue through 2012. Similarly, development of the StreamStats web map application will start midway in 2012 and continue through federal fiscal year 2013. Final report on flow statistics (Objective 2) is due at the end of federal fiscal year 2012. The regression equation report (Objective 4) is due midway through federal fiscal year 2013, and the public roll-out of the StreamStats web map application is due the end of federal fiscal year 2013. Renewable Resource Grant reports are due quarterly with the final grant report due the end of calendar year 2013 (midway through state fiscal year 2014).

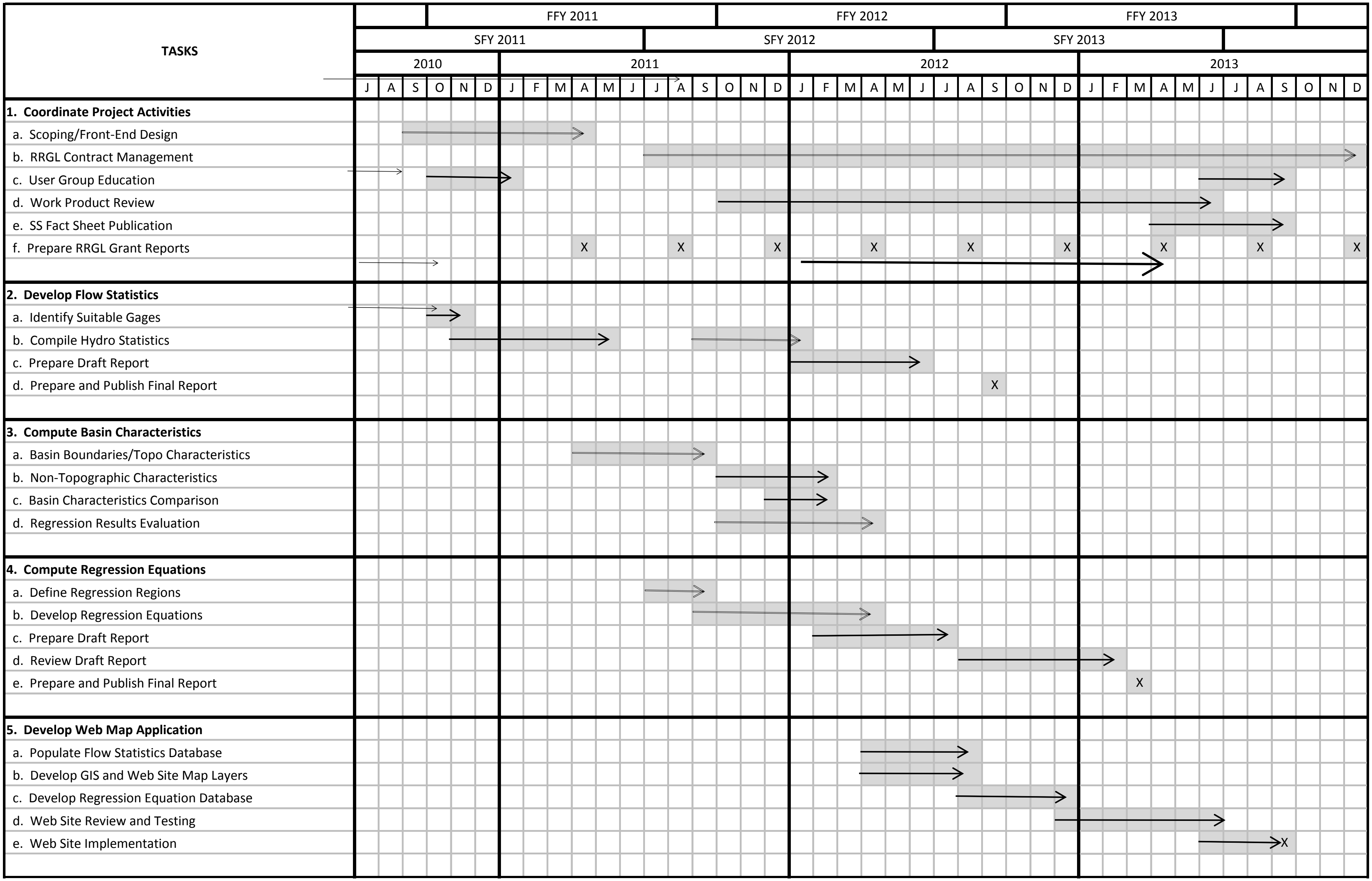


Table 4.1 – Project Schedule

4.10 Technical Documentation (References)

Berkas, W.R., and others, published annually, Water Resources Data, Montana, U.S. Geological Survey Water-Data Reports, variously paged.

Daly, C., Gibson, W.P., Doggett, M., Smith, J., and Taylor, G., 2004, Up-to-date monthly climate maps for the conterminous United States. Proc., 14th AMS Conf. on Applied Climatology, 84th AMS Annual Meeting Combined Preprints, Amer. Meteorological Soc., Seattle, WA, January 13-16, 2004, Paper P5.1, CD-ROM.

Henriksen, J. A., Heasley, J., Kennen, J.G., and Niewsand, S. 2006, Users' manual for the hydroecological integrity assessment process software (including the New Jersey Assessment Tools): U.S. Geological Survey, Biological Resources Discipline, Open File Report 2006-1093, 71 p.

Hosmer, D.W., and Lemeshow, S., 2000, Applied logistic regression: New York, John Wiley & Sons, Inc., 373 p.

Lawlor, S.M., 2004, Determination of channel-morphology characteristics, bankfull discharge, and various design-peak discharges in western Montana: U.S. Geological Survey Scientific Investigations Report 2004-5263, 26 p.

Ludwig, A.H., and Tasker, G.D., 1993, Regionalization of low-flow characteristics of Arkansas streams: U.S. Geological Survey Water-Resources Investigations Report 93-4013, 19 p.

Maidment, David, ed., 2002, Arc Hydro: GIS for Water Resources: ESRI Press, Redlands, California.

MathSoft, 1999, S-PLUS 2000 guide to statistics: Seattle, Washington, volumes I, II, and III, various pagination.

McCarthy, P.M., 2005, Statistical summaries of stream flow in Montana and adjacent areas, water years 1900 through 2002: U.S. Geological Survey Scientific-Investigations Report 2004-5266, 317 p.

Parrett, Charles, and Cartier, K.D., 1990, Methods for estimating monthly stream flow characteristics at ungaged sites in western Montana: U.S. Geological Survey Water-Supply Paper 2365, 30 p.

Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p.

Parrett, Charles, Johnson, D.R., and Hull, J.A., 1989, Estimates of monthly stream flow characteristics at selected sites in the upper Missouri River basin, Montana, base period water years 1937-86: U.S. Geological Survey Water-Resources Investigations Report 89-4082.

Pyrce, Rich, 2004, Hydrological low flow indices and their uses: Trent University Watershed Science Centre Report 04-2004, 33p.

Raines, G.L., and Johnson, B.R., 1996, Digital representation of the Montana state geologic map -- a contribution to the Interior Columbia River Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-691, 19 p.

Rea, Al, 2010, personal communication, April 22, 2010, at 2010 Intermountain GIS User Conference, presentation on USGS StreamStats Program, Bozeman, Montana.

Risley, John, Stonewall, Adam, and Haluska, Tana, 2008, Estimating flow-duration and low-flow frequency statistics for unregulated streams in Oregon: U.S. Geological Survey Scientific Investigations Report 2008-5126, 22 p.

Ross, C. P., Andres, D. A., and Witkind, I. J., 1955, Geologic map of Montana: U.S. Geological Survey, plate 2, Scale 1:500,000.

Sando, S.K., Morgan, T.J., Dutton, D.M., and McCarthy, P.M., 2009, Estimation of stream flow characteristics for Charles M. Russell National Wildlife Refuge, northeastern Montana: U.S. Geological Survey Scientific Investigations Report 2009–5009, 60 p.

Tasker, G.D., 1989, Regionalization of low flow characteristics using logistic and GLS regression, in Kavvas, M.L., ed., New directions for surface water modeling: IAHS Publication No. 181, p. 323-331.

U.S. Department of Agriculture, 1994, State soil geographic (STATSGO) database data use information: U.S. Department of Agriculture-Natural Resources Conservation Service Miscellaneous Publication 1492, 113 p.

U.S. Geological Survey, 2004, StreamStats -- A U.S. Geological Survey Web Application for Stream Information: U.S. Geological Survey Fact Sheet 2004-3115, accessed on the internet on July 26, 2006 at http://md.water.usgs.gov/publications/fs-2004-3115/.

Vogelmann, J.E., Sohl, T.L., Campbell, P.V., and Shaw, D.M., 1998, Regional land-cover characterization using Landsat Thematic Mapper data and ancillary data sources: Environmental Monitoring and Assessment v. 51, p. 415-428 (URL: http://landcover.usgs.gov/natllandcover.asp).

5.0 Project Management Plan

Applicant Name: **DNRC Water Resources Division**

Project Title: **StreamStats Interactive Web Map Application**

Completion of the technical tasks leading to the ultimate project deliverable, i.e. the StreamStats Interactive Web Map Application, is the responsibility of the US Geological Survey - Montana Water Science Center (USGS MTWSC), under the direction of the Studies Section Chief. Product quality assurance will be performed internally according to standard USGS review protocols by qualified personnel external to the Montana Water Science Center, and other state and federal agency personnel with vested interests in the StreamStats tool. Key personnel include hydrologists and GIS specialists located at the USGS MTWSC located in Helena, and similar specialists and planning staff located at the DNRC Water Resources Division Headquarters in Helena.

DNRC - WRD would provide project management services and oversight on behalf of the State of Montana, and would be responsible for preparation of grant reports and other tasks associated with RRGL grant administration. Planning staff from the Water Management Bureau would interact regularly with agency personnel and members of the water resource consulting community, as well as watershed groups and conservation districts to receive scoping input and communicate project progress.

The lead cooperators on the project would be USGS and DNRC; roles and responsibilities for the project will be set forth in a cooperative agreement document. Primary state – federal collaboration and communication on the project will be between DNRC and USGS. Internal communication on the project will be achieved via phone calls, email, and written memoranda. When necessary, regular meetings amongst specialists involved in the project will be convened to resolve issues and report progress. Management issues will be resolved via the USGS Montana Water Science Center Director and the DNRC Water Resources Division Administrator. Routine communications on the project will occur between DNRC Water Management Bureau planning personnel and the USGS MTWSC Studies Section Chief.

While StreamStats is a technical tool intended to serve the needs of water resource professionals, it is important to communicate its utility to the broad spectrum of water users and other members of the public concerned with water supply. StreamStats is a central element of the water supply component of the State Water Plan. Public involvement will be conducted under the auspices of the State Water Plan via oral briefing to the three main basin water user councils: Yellowstone, Missouri and Clark Fork (§85-1-203(4)(a)). Briefings and instruction on use of StreamStats will be provided as requested by watershed groups, conservation districts, local government, legislative committees, trade organizations, and other interested parties.

6.0 Financial Plan

Applicant Name: **DNRC Water Resources Division**

Project Title: **StreamStats Interactive Web Map Application**

6.1 Financial Narrative

The bulk of requested grant funds ($99,000) will be used for technical services associated with USGS development and deployment of the StreamStats Web Map Application for Montana. Under the USGS Cooperative Water Program (Co-Op Program), costs associated with the project would be split under a 60% state – 40% federal cost-share agreement. The USGS Co-Op program is an ongoing partnership between the USGS and non-Federal agencies. Agencies, or "Cooperators," that participate in the Cooperative Water Program are primarily State, Tribal, county, and municipal agencies with water resources management and policy responsibilities. In Montana, many of the 250 stream gages in the state are operated under a Cooperative Agreement between MT DNRC and the USGS (See Figure 4.1). For the proposed RRGL StreamStats project, the “Cooperator” will be the MT DNRC, Water Resources Division.

Sections 6.1, 6.2, and 6.3 show RRG costs associated with Contract Administration, Technical Services, and Total Costs, respectively. Appendix “A” shows StreamStats project costs by task (see Section 4.8.2 – Project Tasks). The total project budget is $557,333. Cash contributions from state agencies totaling $296,000 (including $100,000 from the RRGL Program), plus the USGS Co-Op program match of $197,333 would be used over an approximately 3-year timeframe to supply the technical services necessary to deploy a medium resolution version of StreamStats covering the entire State of Montana.

The bulk of the RRG professional and technical costs (Section 6.3) would be used for development of the foundational elements of StreamStats: flow statistics (Section 4.3.2), basin characteristics (Section 4.3.3), regression equations (Section 4.3.4), and the actual StreamStats interactive web map application. The project sponsor, DNRC - Water Management Bureau, would contribute a total of $102,500 through a combination of direct funding ($46,000) to the USGS, and provision of in-kind services ($56,500). The $46,000 is a one-time allocation by the 2009 State Legislature for the State Water Plan. The $56,500 in-kind service contribution would be in the form of planning services for project coordination and management, and technical services in the form of GIS services and hydrologist time for work product review. All contract administration, including management of the Cooperative Agreement, record-keeping, invoice approval, and preparation of quarterly and final RRG reports would be handled DNRC, Water Management Bureau and is included in the Professional and Technical Services (see Section 6.3 below).

Partner contributions include $130,000 in cash from MT Department of Transportation (MDT) in the form of a research grant to USGS (see Appendix “C”), and $20,000 in cash from DNRC, Water Operations Bureau (Floodplains). Both of these direct funding contributions are for production of flow statistics (see Section 4.3.2), a foundational element of StreamStats. It is estimated that these agencies will contribute approximately $5,000 and $2,500, respectively, through provision of quality control and technical work product review services.

6.2 Contract Administration

Category	DNRC Grant (RRG)	Project Sponsor (DNRC WMB)	DNRC Water Operations	MDT	USGS	Total
Administration						
Subtotal						
Communications						$0
Supplies	$1,000				$667	$1,667
Travel						$0
Rental						$0
Subtotal	$1,000				$667	$1,667
Total Administration	$1,000				$667	$1,667

6.3 Professional and Technical Costs

Category	DNRC Grant (RRG)	Project Sponsor (DNRC WMB)	DNRC Water Operations	MDT	USGS	Total
Professional/tech*						
Planners		$33,000				$33,000
Hydrologists	$30,000	$41,250	$16,875	$101,250	$117,500	$306,875
GIS Specialists	$44,250	$2,875	$0	$0	$30,166	$77,291
Subtotal	$74,250	$77,125	$16,875	$101,250	$147,666	$417,166
Indirect Costs (25%)						
(benefits, overhead, travel, etc)	$24,750	$25,375	$5,625	$33,750	$49,000	$138,500
Subtotal	$24,750	$25,375	$5,625	$33,750	$49,000	$138,500
Total Professional	$99,000	$102,500	$22,500	$135,000	$196,666	$555,666

*professional hourly rate = $85 per hour
Indirect costs calculated at 25% of fully loaded billing rate

6.4 Total Costs

Category	DNRC Grant (RRG)	Project Sponsor (DNRC WMB)	DNRC Water Operations	MDT	USGS	Total
Total Admin	$1,000	$0	$0	$0	$667	$1,667
Total Prof/Technical	$99,000	$102,500	$22,500	$135,000	$196,666	$555,666
Total Construction	n/a	n/a	n/a	n/a	n/a	n/a
Total Project Cost	$100,000	$102,500	$22,500	$135,000	$197,333	$557,333

7.0 Environmental Evaluation

Applicant Name: **DNRC Water Resources Division**

Project Title: **StreamStats Interactive Web Map Application**

Montana faces an increasing set of water resource challenges. Aging infrastructure, rapid population growth, depletion of groundwater resources, impaired water quality associated with particular land uses and land covers, water needed for human and environmental uses, and climate variability all play a role in determining the amount of fresh water available at any given place and time. Water shortage and water-use conflicts have become more commonplace in many areas of Montana, even in normal water years. As competition for water grows – for agriculture, growing cities and communities, energy production, and the environment, the need for information and tools to aid water resource decision-making also grows. Water supply limitations and increasing demand are exacerbating the challenges facing traditional water management approaches based on antiquated hydrological predictions and water use estimates.

StreamStats is an interactive, Web-based map application for providing stream flow statistics, such as the 100-year flood and the 7-day, 10-year low flow. It is a central element of the water supply component of the State Water Plan. The overall goal of the StreamStats project is to provide a state-wide hydrological data delivery tool (web-based decision support system) to support water resources planning and management. As such it will support evaluation of potential environmental impacts associated with water resource development proposals. The StreamStats Project will produce an interactive web map application designed to provide quantitative water supply information at a consistent scale (1:100,000) across the entire state of Montana. Together with the existing stream gage network operated by USGS and other state and local partners, it forms the foundation of DNRC's approach to quantifying water supply under the State Water Plan. Combined with the irrigated lands mapping proposal intended to address water use within Montana, StreamStats will support the quantitative assessment of water availability within a given watershed. When combined with data from other sources, such as the DNRC water rights database, it will provide significant insight into the often large disparity between water claimed via the water rights system, and water produced in any given basin.

7.0 Environmental Checklist

Impact Type : N – No impact/not applicable **B –** Potentially beneficial **A –** Potentially adverse **P –** Agency approval/permits required **M –** Mitigation required

PHYSICAL ENVIRONMENT	
Impact Type	**Resource and Description of Potential Impact to the Resource**
N	**1. Soil suitability, topographic and/or geologic constraints (e.g., soil lump, steep slopes, subsidence, seismic activity)** *Comments and source of information*:
N	**2. Hazardous facilities (e.g., power lines, hazardous waste sites, acceptable distance from explosive and flammable hazards including chemical/petrochemical storage tanks, underground fuel storage tanks, and related facilities such as natural gas storage facilities and propane storage tanks)** *Comments and source of information*:
N	**3. Surrounding air quality (e.g., dust, odors, emissions)** *Comments and source of information*:
N	**4. Groundwater resources and aquifers (e.g., quantity, quality, distribution, depth to groundwater, sole source aquifers)** *Comments and source of information*:
B	**5. Surface water/water quality, quantity, and distribution (e.g., streams, lakes, storm runoff, irrigation systems, canals)** *Comments and source of information*: StreamStats will facilitate the distribution of hydrological information on which to base surface water management decisions
B	**6. Floodplains and floodplain management (Identify any floodplains within one mile of**

		the boundary of the project.) *Comments and source of information*: StreamStats will provide flow frequency and flow duration information that will facilitate floodplain management and infrastructure design.
B	**7.**	**Wetlands (Identify any wetlands within one mile of the boundary of the project and state potential impacts.)** *Comments and source of information*: The basin delineation feature of StreamStats will facilitate the identification of wetlands potentially impacted by development proposals.
N	**8.**	**Agricultural lands, production, and farmland protection (e.g., grazing, forestry, cropland, prime or unique agricultural lands) Identify any prime or important farm ground or forest lands within one mile of the boundary of the project.** *Comments and source of information*:
N	**9.**	**Vegetation and wildlife species and habitats, including fish (e.g., terrestrial, avian, and aquatic life and habitats)** *Comments and source of information*:
N	**10.**	**Unique, endangered, fragile, or limited environmental resources, including endangered species (e.g., plants, fish, or wildlife)** *Comments and source of information*:
N	**11.**	**Unique natural features (e.g., geologic features)** *Comments and source of information*:
N	**12.**	**Access to, and quality of, recreational and wilderness activities, public lands and waterways, and public open space** *Comments and source of information*:

HUMAN POPULATION	
N	**1. Visual quality – coherence, diversity, compatibility of use and scale, aesthetics** *Comments and source of information*:
N	**2. Nuisances (e.g., glare, fumes)** *Comments and source of information*:
N	**3. Noise – suitable separation between housing and other noise-sensitive activities and major noise sources (aircraft, highways, and railroads)** *Comments and source of information*:
N	**4. Historic properties, cultural, and archaeological resources** *Comments and source of information*:
N	**5. Changes in demographic (population) characteristics (e.g., quantity, distribution, density)** *Comments and source of information*:
N	**6. General housing conditions – quality, quantity, affordability** *Comments and source of information*:
N	**7. Businesses or residents (for example, loss of, displacement, or relocation)** *Comments and source of information*:

N	**8. Public health and safety** *Comments and source of information*:
N	**9. Local employment – quantity or distribution of employment, economic impact** *Comments and source of information*:
N	**10. Income patterns – economic impact** *Comments and source of information*:
N	**11. Local and state tax base and revenues** *Comments and source of information*:
N	**12. Educational facilities – schools, colleges, universities** *Comments and source of information*:
N	**13. Commercial and industrial facilities – production and activity, growth or decline** *Comments and source of information*:
N	**14. Health care – medical services** *Comments and source of information*:
N	**15. Social services – governmental services (e.g., demand on)** *Comments and source of information*:

N	**16. Social structures and mores (standards of social conduct/social conventions)** *Comments and source of information*:
N	**17. Land use compatibility (e.g., growth, land use change, development activity, adjacent land uses, and potential conflicts)** *Comments and source of information*:
N	**18. Energy resources – consumption and conservation** *Comments and source of information*:
N	**19. Solid waste management** *Comments and source of information*:
N	**20. Wastewater treatment – sewage system** *Comments and source of information*:
B	**21. Storm water – surface drainage** *Comments and source of information*: StreamStats will facilitate the analysis of surface water drainage impacts.
B	**22. Community water supply** *Comments and source of information*: StreamStats will facilitate the analysis of community water supplies.
N	**23. Public safety – police**

	Comments and source of information:
N	**24. Fire protection – hazards** *Comments and source of information*:
N	**25. Emergency medical services** *Comments and source of information*:
N	**26. Parks, playgrounds, and open space** *Comments and source of information*:
N	**27. Cultural facilities, cultural uniqueness, and diversity** *Comments and source of information*:
N	**28. Transportation networks and traffic flow conflicts (e.g., rail; auto, including local traffic; airport runway clear zones – avoidance of incompatible land use in airport runway clear zones)** *Comments and source of information*:
N	**29. Consistency with local ordinances, resolutions, or plans (e.g., conformance with local comprehensive plans, zoning, or capital improvement plans)** *Comments and source of information*:
N	**30. Private property rights – Is there a regulatory action or project activity that reduces, minimizes, or eliminates the use of private property?** *Comments and source of information*:

Appendix "A"

Stream Stats Project Budget by Task

TASKS	DNRC RRG	DNRC WMB		DNRC WOB		MDT		TOTAL State/Local		USGS Coop Match	TOTAL COST
	Cash	Cash	In-kind	Cash	In-kind	Cash	In-kind	Cash	In-kind		
1. Coordinate Project Activities											
a. Scoping/Front-End Design	$0	$0	$10,000	$0	$0	$0	$0	$0	$10,000	$0	$10,000
b. RRGL Contract Management	$0	$0	$10,000	$0	$0	$0	$0	$0	$10,000	$0	$10,000
c. User Group Education	$0	$0	$10,000	$0	$0	$0	$0	$0	$10,000	$0	$10,000
d. Work Product Review	$0	$0	$10,000	$0	$0	$0	$0	$0	$10,000	$0	$10,000
e. SS Fact Sheet Publication	$1,000	$0	$1,000	$0	$0	$0	$0	$1,000	$1,000	$667	$2,667
f. Prepare RRGL Grant Reports	$0	$0	$3,000	$0	$0	$0	$0	$0	$3,000	$0	$3,000
subtotal	**$1,000**	**$0**	**$44,000**	**$0**	**$0**	**$0**	**$0**	**$1,000**	**$44,000**	**$667**	**$45,667**
2. Develop Flow Statistics											
a. Identify Suitable Gages	$0	$6,000	$0	$0	$0	$32,500	$0	$38,500	$0	$25,667	$64,167
b. Compile Hydro Statistics	$5,000	$40,000	$0	$0	$0	$32,500	$0	$77,500	$0	$51,667	$129,167
c. Prepare Draft Report	$5,000	$0	$5,000	$10,000	$2,500	$32,500	$2,500	$47,500	$10,000	$31,667	$89,167
d. Prepare and Publish Final Report	$5,000	$0	$0	$10,000	$0	$32,500	$2,500	$47,500	$2,500	$31,667	$81,667
subtotal	**$15,000**	**$46,000**	**$5,000**	**$20,000**	**$2,500**	**$130,000**	**$5,000**	**$211,000**	**$12,500**	**$140,667**	**$364,167**
3. Compute Basin Characteristics											
a. Basin Boundaries/Topo Characteristics	$5,000	$0	$0	$0	$0	$0	$0	$5,000	$0	$3,333	$8,333
b. Non-Topographic Characteristics	$5,000	$0	$0	$0	$0	$0	$0	$5,000	$0	$3,333	$8,333
c. Basin Characteristics Comparison	$5,000	$0	$0	$0	$0	$0	$0	$5,000	$0	$3,333	$8,333
d. Regression Results Evaluation	$5,000	$0	$0	$0	$0	$0	$0	$5,000	$0	$3,333	$8,333
subtotal	**$20,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$20,000**	**$0**	**$13,333**	**$33,333**
4. Compute Regression Equations											
a. Define Regression Regions	$5,000	$0	$0	$0	$0	$0	$0	$5,000	$0	$3,333	$8,333
b. Develop Regression Equations	$5,000	$0	$0	$0	$0	$0	$0	$5,000	$0	$3,333	$8,333
c. Prepare Draft Report	$5,000	$0	$0	$0	$0	$0	$0	$5,000	$0	$3,333	$8,333
d. Review Draft Report	$5,000	$0	$5,000	$0	$0	$0	$0	$5,000	$5,000	$3,333	$13,333
e. Prepare and Publish Final Report	$5,000	$0	$0	$0	$0	$0	$0	$5,000	$0	$3,333	$8,333
subtotal	**$25,000**	**$0**	**$5,000**	**$0**	**$0**	**$0**	**$0**	**$25,000**	**$5,000**	**$16,667**	**$46,667**
5. Develop Web Map Application											
a. Populate Flow Statistics Database	$5,000	$0	$0	$0	$0	$0	$0	$5,000	$0	$3,333	$8,333
b. Develop GIS and Web Site Map Layers	$10,000	$0	$0	$0	$0	$0	$0	$10,000	$0	$6,667	$16,667
c. Develop Regression Equation Database	$10,000	$0	$0	$0	$0	$0	$0	$10,000	$0	$6,667	$16,667
d. Web Site Review and Testing	$4,000	$0	$2,500	$0	$0	$0	$0	$4,000	$2,500	$2,667	$9,167
e. Web Site Implementation	$10,000	$0	$0	$0	$0	$0	$0	$10,000	$0	$6,667	$16,667
subtotal	**$39,000**	**$0**	**$2,500**	**$0**	**$0**	**$0**	**$0**	**$39,000**	**$2,500**	**$26,000**	**$67,500**
TOTAL	**$100,000**	**$46,000**	**$56,500**	**$20,000**	**$2,500**	**$130,000**	**$5,000**	**$296,000**	**$64,000**	**$197,333**	**$557,333**

StStreamStats Project Budget by Task

Appendix “B”

Letters of Support

(Hard copies to follow via U.S. Postal Service)

Appendix “C”

USGS Flood Frequency Proposal to MDT

Flood-Frequency Analyses for U.S. Geological Survey Gaging Stations Based on Data through Water Year 2009

By

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U.S. Department of the Interior
U.S. Geological Survey

A proposal prepared for the Montana Department of Transportation

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November 18, 2009

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Problem statement

The U.S. Geological Survey (USGS) publishes flood-frequency estimates that are used for the economical design of water conveyance and storage structures such as culverts, bridges, storm sewers, dams, and levees. Reliable flood-frequency information also is crucial for effective planning and management of water resources and floodplains, to protect lives and property in flood-prone areas, and for the determination of actuarial flood-insurance rates. For several applications, including Federal Emergency Management Agency (FEMA) 100-year floodplain delineation and U.S. Department of Transportation Federal Highway Administration bridge and culvert design, USGS flood-frequency estimates generally are required.

Since the mid-1980's large parts of Montana have experienced two severe droughts. Occurrence of these droughts during a relatively short time frame has the potential to substantially affect flood-frequency estimates for short-term gaging stations. Further, recent climatic patterns, and uncertainties concerning the roles of natural versus anthropogenic factors as driving forces, have led some researchers to question some of the basic premises of typical flood-frequency methods. There is a substantial need to evaluate the effects of differences in data-collection periods and variability in climatic conditions on our understanding of flood hydrology in Montana.

Flood-frequency estimation for northwestern Montana is complicated by infrequent unusually large floods. Typical flood-frequency methods generally do not provide accurate flood-frequency estimates for this situation. Previous flood-frequency analyses for northwestern Montana accounted for this issue by using an approach that was performed on a station-by-station basis. There are two primary concerns relating to a station-by-station approach: 1) the ability to attain consistency in flood-frequency estimates for basins with similar climatic and hydrogeologic characteristics, but differing by whether or not the data-collection periods include any unusually large floods; and 2) the ability to accurately estimate the true frequency of occurrence of unusually large floods based primarily on the limited data available for a single gaging station. There is a need to investigate the use of a regional approach to improve flood-frequency estimates for northwestern Montana.

Up-to-date USGS flood-frequency estimates are of particular value to the Montana Department of Transportation (MDT) because they serve as the basis of hydrologic analyses for road structures with design criteria dependent on flood characteristics. The last USGS flood-frequency report for Montana was based on data through water year 1998. Updated flood-frequency information would include 11 additional years of peak-flow records and 18 new stations that have achieved at least 10 years of record since 1998. Although a substantial part of the proposed project involves a routine update of important hydrologic information, there are specific vital research activities that are proposed to improve flood-frequency estimates and investigate effects of recent climatic patterns on flood frequency estimates.

Background summary

The purpose of this research is to determine flood-frequency estimates for USGS gaging stations in Montana. Flood-frequency estimates are determined by fitting a log-Pearson Type III probability distribution to the recorded annual peak flows using methods described in Bulletin 17B of the U.S. Interagency Advisory Committee on Water Data (1982). However, Bulletin 17B analyses using default procedures do not always provide the most accurate flood-frequency estimates for gaging stations with complicating factors. Research activities in the proposed project will focus on improving flood-frequency estimates for gaging stations and publishing the flood-frequency estimates along with detailed documentation of the specific methods used to develop the frequency estimates.

Objectives

The primary objectives of the proposed project include:

1) Determine flood-frequency estimates (recurrence intervals of 1.5, 2, 2.33, 5, 10, 25, 50, 100, 200, and 500 years) for more than 660 USGS gaging stations in Montana based on data through water year 2009. These flood-frequency estimates are routinely used by MDT for design purposes.
2) Investigate methods of adjusting flood-frequency estimates for short-term gaging stations with data restricted to either unusually wet or dry periods (including 1985-present).
3) Investigate the effects of climatic variability on our understanding of flood hydrology in Montana and potential emerging methods for determining more accurate flood-frequency estimates.
4) Investigate the use of a regional approach for flood-frequency analysis in northwestern Montana, where unusually large (but infrequent) floods complicate flood-frequency estimates.

Benefits

Up-to-date flood-frequency estimates will meet critical needs for numerous structure-design and floodplain-management issues in Montana, especially for MDT. Further, the proposed research will provide valuable information for evaluating the effects of climatic patterns on flood-frequency estimates and investigating emerging flood-frequency methods that address climatic uncertainty. The final report from this study will be patterned after a report from a similar study in South Dakota (*http://pubs.er.usgs.gov/usgspubs/sir/sir20085104*) and readily available in hard-copy and on-line. The report will provide detailed documentation of methods, which will be of substantial value to MDT and other users in defending design flows and performing auxiliary analyses. This work also will substantially streamline the process of updating flood-frequency estimates and lower the cost of future updates.

Specific benefits to MDT and the taxpayer include:

- Economical hydraulic design. Updating and publishing flood-frequency estimates will allow MDT to use the most current hydrologic data available and will:
  - Assist designers in accurately selecting proper culvert sizes and bridge openings, and reduce the risk of over- or under-sizing.
  - Reduce construction costs that result from oversized culverts and bridge openings based on outdated hydrologic data.
  - Save a significant amount of preliminary-engineering time by being able to use published information when designing hydraulic features, assisting with MDT maintenance activities, and responding to damage claims.
- Establishment of road grades and low beam elevations. Setting road grades is predicated upon establishment of accurate flood elevation data. Updated flood-frequency estimates will allow MDT staff to more confidently provide the appropriate level of service to the road user, and evaluate risks to the road facility and upstream properties during flood events.
- Defending against lawsuits. It is important to be able to technically justify the specific flood-frequency estimates used in various design applications. Design flows should be based on the most up-to-date data and methods available. Design flows that are not accurately determined are subject to question by other engineers and might result in costly litigation.
- Securing floodplain permits. Permitting MDT facilities in floodplains is becoming increasingly common. The authorization of construction in floodplains is scrutinized by local floodplain authorities, FEMA and DNRC engineers. The most recent flood-frequency data is required for the permitting process.
- Stream restoration and fish passage. MDT projects sometimes require stream relocation and/or mitigation to reduce environmental impacts and allow fish passage. The design and implementation of mitigation activities requires up-to-date hydrologic data and is subject to review by other agencies.
- Preliminary-engineering and planning process. Up-to-date flood-frequency estimates will allow MDT to make good planning level decisions and preliminary engineering cost estimates for system facility upgrades or reconstruction efforts.

Potential consequences of not updating flood-frequency estimates include:

- **Under-design**, resulting in either flood or road damage, or **over-design**, resulting in unnecessary capital expenditures based on outdated analysis.
- Inability to defend against damage claims and lawsuits resulting from flood damage with potential substantial cost of fixing an existing problem or paying damage claims.
- Falling further behind in analyzing hydrologic data that is being collected annually by USGS in cooperation with MDT.
- Failing to remain current with emerging methods of flood-frequency analysis.

Research Plan

The research plan for the proposed project includes the following major tasks:

Task 1: Conduct and document Standard Log-Pearson III flood-flood frequency analyses for U.S. Geological Survey continuous and crest-stage gaging stations

Task 2: Investigate application of record-extension methods for improving flood-frequency estimates for short-term gaging stations with data restricted to either unusually dry or wet periods

Task 3: Investigate effects of climatic variability on Montana flood hydrology and initiate systematic tracking of stationarity (that is, does what happened in the past accurately reflect what will happen in the future) of flood-frequency data for Montana

Task 4: Investigate application of regional mixed-population analysis for northwestern Montana

Detailed discussion of the tasks is presented below and in the attached appendices.

Flood-frequency estimates for USGS gaging stations generally will be updated using standard procedures presented in Bulletin 17B. However, if default Bulletin 17B methods are applied to gaging stations with short or unusually wet or dry data-collection periods (including the period 1985-2008 in some areas) there is potential for introducing substantial inconsistency between gaging stations. Specific methods that will be investigated for adjusting flood-frequency estimates to compensate for period-of-record effects are presented in more detail in Appendix A.

Recent climatic patterns, and uncertainties concerning the relative contributions of natural and anthropogenic factors as driving forces, have led some researchers to question some of the basic premises of typical flood-frequency methods, including stationarity of peak-flow records. There is a substantial need to begin systematic tracking of stationarity of peak-flow records in Montana. Specific methods that will be investigated to remain current with emerging climatic and hydrologic research, and initiate systematic tracking of stationarity of peak-flow records for Montana are presented in more detail in Appendix A.

Flood-frequency estimation for some gaging stations in northwestern Montana is complicated by the presence of a small number of unusually large floods during the period of record. In previous USGS flood-frequency reports, a mixed-population flood-frequency analysis was performed on a station-by-station basis to improve flood-frequency estimates for these gaging stations. However, a regional mixed-population analysis might provide further improvement to flood-frequency estimates in northwestern Montana, and also potentially have application to other parts of Montana. Specific methods concerning application of the regional mixed-population analysis are presented in more detail in Appendix B.

Products

The following products will be produced as a result of the proposed project:

- Quarterly progress reports
- Draft report for review prior to publication
- Final report
- Various conference presentations and final presentation to MDT

As work progresses on the proposed study, preliminary results will be made available to MDT for review on a provisional basis to allow timely application of study results.

The final report will be a USGS Scientific Investigations Report similar to Sando and others (2008; *http://pubs.er.usgs.gov/usgspubs/sir/sir20085104*). This report will be available in hard copy and also on-line. Data presented will include default Bulletin 17b frequency estimates and also recommended frequency estimates when default Bulletin 17b methods do not provide accurate results. Detailed information on the specific parameters used to develop the frequency estimates will be presented to allow users to defend design flows and facilitate conducting auxiliary analyses. Frequency curves and annual peak-flow data will be presented in figures to show how well the frequency estimates represent the recorded data and also to show long-term patterns in annual peak flows for individual gaging stations. Further, some of the information produced from the proposed study will be made available on-line by link from the USGS Montana Water Science Center web site (for example, see: *http://mt.water.usgs.gov/freq?page_type=table*).

Implementation

The results of the proposed project will be available to MDT and other users to aid in determining flood characteristics critical to structure design. Updating the flood-frequency estimates for the USGS gaging station network will ensure that flood-frequency information is current and based on up-to-date methods.

Project Schedule

Table 1. Project schedule

Work tasks	Milestone dates	FY 2010			FY 2011												FY 2012											
		J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
Project commencement	07/15/10	X																										
1. Conduct and document standard log-Pearson III flood frequency analyses for about 650 USGS gaging stations		X	X	X	X	X	X	X	X	X																		
1a. Document regulatory structures that influence peak flows at gaging stations		X	X	X																								
1b. Construct table of regulating structures and stations influenced		X	X	X																								
1c. Retrieve and format peak-flow data		X	X																									
1d. Perform flood-frequency analyses			X	X	X	X	X	X	X																			
1e. Construct figures and tables of frequency results and accompanying documentation							X	X	X	X																		
2. Investigate application of record-extension methods for improving flood-frequency estimates for short-term gaging stations						X	X	X	X	X	X	X	X	X	X													
2a. Identify gaging stations with less than 15 years of record or with longer periods of record but substantially influence by unusual climatic conditions						X	X	X																				
2b. Conduct correlation analyses to determine appropriate index stations						X	X	X																				
2c. Conduct Bulletin 17b 2-station analyses and MOVE.1 analyses for record extension							X	X	X	X	X	X																
2d. Examine record-extension results for reasonableness of fit											X	X																
2e. Table record-extension results and accompanying documentation												X	X	X	X													
3. Initiate systematic tracking of stationarity of flood-frequency data for Montana										X	X	X	X	X	X	X	X	X	X									
3a. Identify long-term unregulated stations to serve as regional index stations										X	X																	
3b. Conduct statistical analyses of temporal variability in peak flows for regional index stations											X	X	X	X	X	X												
3c. Investigate emerging methods for addressing temporal variability in peak-flow analyses or nonstationary peak-flow records																X	X											
3d. Construct figures and tables presenting results																	X	X	X									
4. Investigate application of regional mixed-populations analyses for Montana					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X							
4a. Investigate occurrence of high-outlier peak flows in northwestern Montana and define mixed-population region					X	X	X	X																				
4b. Investigate relative probability of occurrence of independent ordinary peak flows and high-outlier peak flows								X	X	X	X	X	X	X	X													
4c. Construct normalized high-outlier peak-flow probability distribution													X	X	X	X	X	X										
4d. Conduct regional mixed-population frequency analyses for northwestern Montana gaging stations																	X	X	X	X								
4e. Construct figures and tables presenting results																			X	X	X							
5. Quarterly progress reports					X			X			X			X			X			X			X			X		
6. Report preparation																	X	X	X	X	X	X	X	X	X	X	X	X
6a. Prepare draft tables and figures																	X	X	X									
6b. Prepare draft text and submit draft report	03/31/12																		X	X	X	X						
6c. Review and address comments; prepare for publication																							X	X	X	X	X	X
6d. Submit final report	09/30/12																											X

Staffing

Pete McCarthy will serve as the project chief and co-principal investigator. Pete has been a hydrologist with USGS for 8 years, and has worked on various hydraulic and hydrologic studies, including managing the data-collection activities of the crest-stage gaging station network, and conducting time-of-travel and geomorphologic studies. Pete will conduct most of the analyses for the proposed project and will serve as the primary point of contact with MDT.

Steve Sando will serve as co-principal investigator. Steve has been a hydrologist with USGS for over 20 years and has worked on various hydrologic studies, including several flood-frequency and streamflow characteristics studies in both Montana and South Dakota. Steve will serve primarily in an oversight role, providing guidance for the proposed project, which is very similar to a project that was completed in South Dakota (Sando and others, 2008; *http://pubs.er.usgs.gov/usgspubs/sir/sir20085104*).

Table 2. Summary of hours

Name or title	Role in study	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6
Peter McCarthy	Co-principal investigator	430	330	330	530	100	480
Steve Sando	Co-principal investigator	60	80	80	125	0	80
Support staff	Report editing	0	0	0	0	0	100
	Total	490	410	410	655	100	660

Facilities

All facilities, equipment, and workspace necessary for completing the project tasks will be provided by the USGS.

MDT Involvement

All of the proposed work will be conducted by USGS. MDT involvement primarily will include review of the draft report for technical content. Periodic consultation with MDT will be conducted

Budget

This project is being supported by funding from the USGS Cooperative Water Program ($100,000) (*http://water.usgs.gov/coop/*) and the Montana Department of Natural Resources and Conservation ($20,000) (MDNRC), matched by $130,000 in MDT funding (table 3). The budget summary with breakdown by major cost category is shown in table 4. ***It should be noted that the $100,000 funding by USGS represents the maximum funding currently available.***

Table 3. Budget summary by State and Federal fiscal year.

State fiscal year	USGS	MDT	MDNRC	TOTAL
2011	$48,750	$56,875	$16,250	$121,875
2012	$39,800	$55,950	$3,750	$99,500
2013	$11,450	$17,175	$0	$28,625
TOTAL	$100,000	$130,000	$20,000	$250,000
Federal fiscal year	USGS	MDT	MDNRC	TOTAL
2010	$18,000	$22,000	$5,000	$45,000
2011	$41,000	$46,500	$15,000	$102,500
2012	$41,000	$61,500	$0	$102,500
TOTAL	$100,000	$130,000	$20,000	$250,000

Table 4. Budget summary by major cost category by State and Federal fiscal year.

State fiscal year	Salaries	Benefits and overhead	Printing	TOTAL
2011	$74,345	$47,530	$0	$121,875
2012	$60,695	$38,805	$0	$99,500
2013	$15,020	$9,605	$4,000	$28,625
TOTAL	$150,060	$95,940	$4,000	$250,000
Federal fiscal year	Salaries	Benefits and overhead	Printing	TOTAL
2010	$27,450	$17,550	$0	$45,000
2011	$62,525	$39,975	$0	$102,500
2012	$60,085	$38,415	$4,000	$102,500
TOTAL	$150,060	$95,940	$4,000	$250,000

References Cited

Alley, W.M., and Burns, A.W., 1983, Mixed station extension of monthly streamflow records: Journal of Hydraulic Engineering, American Society of Civil Engineers, v. 109, no. 10, p. 1272-1284.

Matalas, N.C., and Jacobs, Barbara, 1964, A correlation procedure for augmenting hydrologic data: U.S. Geological Survey Professional Paper 434-E, 7 p.

Milly, P.C.D., Betancourt, Julio, Falkenmark, Malin, Hirsch, R.M., Kundzewicz, Z.W., Lettenmaier, D.P., and Stouffer, R.J., 2008, Stationarity is dead – whither water management?: Science, v. 319, p. 573-574.

U.S. Interagency Advisory Council on Water Data, 1982, Guidelines for determining flood flow frequency: Hydrology Subcommittee, Bulletin 17B, appendices 1-14, 28 p.

Omang, R.J., 1992, Analysis of the magnitude and frequency of floods and the peak-flow gaging network in Montana: U.S. Geological Survey Water-Resources Investigations Report 92-4048, 70 p.

Omang, R.J., Parrett, Charles, and Hull, 1986, Methods for estimating magnitude and frequency of floods in Montana based on data through 1983: U.S. Geological Survey Water-Resources Investigations Report 86-4027, 85 p.

Parrett, Charles, and Johnson, 2003, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, appendix, 48 p.

Parrett, Charles, and Omang, R.J., 1981, Revised techniques for estimating magnitude and frequency of floods in Montana: U.S. Geological Survey Open-File Report 81-917, 66 p.

Sando, S.K., Driscoll, D.G., and Parrett, Charles, 2008, Peak-flow frequency estimates based on data through water year 2001 for selected streamflow-gaging stations in South Dakota: U.S. Scientific Investigations Report 2008-5104, appendices 1-2, 42 p.

APPENDIX A: INFORMATION SUPPORTING THE NEED FOR RESEARCH ON PERIOD-OF-RECORD AND STATIONARITY ISSUES

Problem

Since the early to mid-1980's large parts of Montana have experienced two severe droughts. Occurrence of these dry periods during a relatively short time frame has the potential to substantially affect flood-frequency estimates for gaging stations with relatively short periods of record. Further, recent climatic patterns, and uncertainties concerning the relative contributions of natural and anthropogenic factors as driving forces, have led some researchers to question some of the basic premises of flood-frequency methods typically used for structure design (Milly and others, 2008). There is a substantial need to evaluate the effects of differences in period-of-record on our understanding of flood hydrology in Montana, and also to begin systematic tracking of stationarity of peak-flow records in Montana.

Percent differences in peak-flow characteristics for the period 1985-2008 relative to long-term periods-of-record (table 5, fig. 1) indicate substantial deviation from normal for a large area of Montana. This is especially true for gaging stations on or near the Rocky Mountain Front, and the eastern plains. Figure 2 presents locations of peak-flow gaging stations in Montana; about 50 stations with peak-flow records restricted to post-1985 are specifically identified. Areas with high densities of stations with peak-flow records restricted to post 1985 (indicated on fig. 2) have potential for producing flood-frequency estimates with substantial inconsistencies between stations.

Comparison between flood-frequency curves based on 1985-2008 data and flood-frequency curves based on long-term period-of-record data (figs. 3 and 4) shows effects of recent climatic patterns on flood-frequency estimates. In areas where streamflow conditions during 1985-2008 were substantially lower than long-term streamflow conditions (represented by gaging station 06062500 – Ten Mile Creek near Rimini, Mont.; map number 3, fig. 1; fig. 3), flood-frequency estimates for gaging stations with recent short-term records, might be expected to be relatively lower than nearby gaging stations with longer-term records. In areas where streamflow conditions during 1985-2008 were moderately lower than long-term (represented by gaging station 12354500 – Clark Fork at St. Regis, Mont.; map number 11, fig. 1; fig. 4), flood-frequency estimates for gaging stations with recent short-term records, might be expected to be moderately lower than longer-term stations.

The proposed study will investigate methods of adjusting flood-frequency estimates for gaging stations with anomalous periods of record. Further, temporal patterns in peak-flow records of long-term gaging stations will be investigated to begin systematic tracking of stationarity of peak-flow records in Montana.

Methods

Fitting the LPIII distribution to systematic records of annual peak flows is the currently accepted methodology for estimating flood frequency for design purposes. However, if default Bulletin 17b methods are applied to gaging stations with anomalous periods-of-record (including the period 1985-2008 in some areas) there is potential for introducing substantial inconsistency between gaging stations.

Record extension methods, including the Bulletin 17b 2-station analysis (Matalas and Jacobs, 1964) and the Maintenance of Variance type I analysis (MOVE.1; Alley and Burns, 1983) provide methods for adjusting flood-frequency estimates to compensate for period-of-record effects. Figures 5 and 6 show application of the Bulletin 17b 2-station and MOVE.1 analyses to two gaging stations with peak-flow records restricted to post-1985. Adjustments to the flood-frequency estimates for these gaging stations range from very large (fig. 5) to moderate (fig. 6).

Where applicable, record-extension methods will provide improved flood-frequency estimates for some short-term gaging stations. Further, consistency in flood-frequency estimates between closely-located gaging stations with different periods of record will be improved. Thus, application of currently accepted flood-frequency methods will be improved. However, uncertainties in the driving forces of recent climatic patterns and whether the recent patterns will actually prevail on a long-term basis might have substantial effects on what are considered appropriate flood-frequency methods in the future.

To remain current with emerging climatic and hydrologic research, initiation of systematic tracking of stationarity in peak-flow records for Montana is proposed. Temporal patterns in statistics of peak-flow records (that is, the mean, standard deviation, and skew) will be investigated for long-term stations. Spatial variability in any apparent temporal trends also will be investigated. Further, a literature review and consultation with USGS researchers will be conducted on nonstationary probabilistic models and the potential for application to flood-frequency analyses in Montana.

Table 5. (Appendix A) Selected long-term gaging stations with 72 or more years of systematic peak-flow records.

Map number (figure 1)	Station identification	Station Name	Drainage area (mi^2)
1	06025500	Big Hole River near Melrose	2,476
2	06052500	Gallatin River at Logan	1,795
3	06062500	Tenmile Creek near Rimini	31
4	06089000	Sun River near Vaughn	1,849
5	06099500	Marias River near Shelby	3,242
6	06120500	Musselshell River at Harlowton	1,125
7	06177500	Redwater River at Circle	547
8	06178000	Poplar River at international boundary	358
9	06192500	Yellowstone River near Livingston	3,551
10	06326500	Powder River near Locate	13,068
11	12354500	Clark Fork at St. Regis	10,709
12	12372000	Flathead River near Polson	7,096

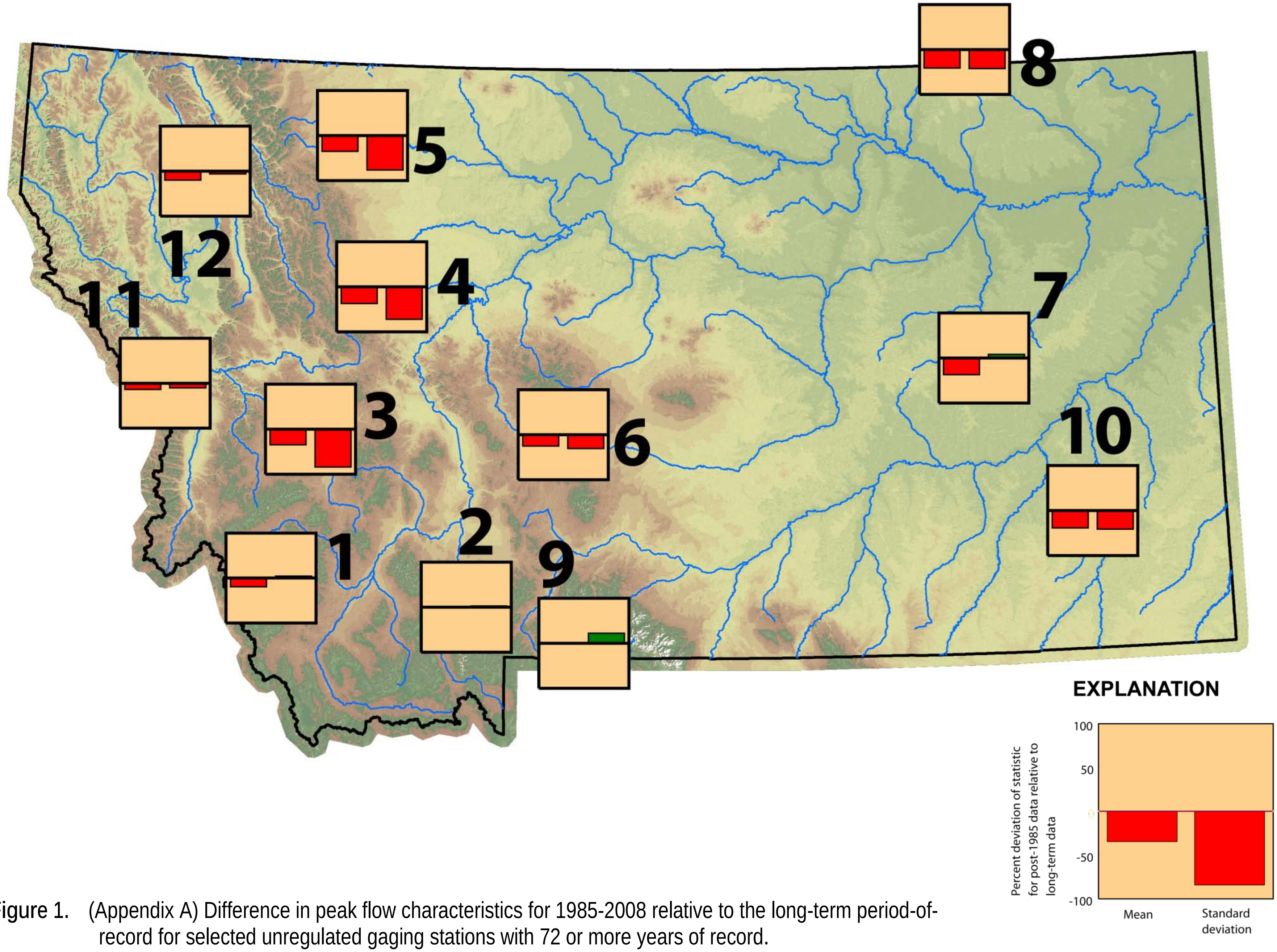


Figure 1. (Appendix A) Difference in peak flow characteristics for 1985-2008 relative to the long-term period-of-record for selected unregulated gaging stations with 72 or more years of record.

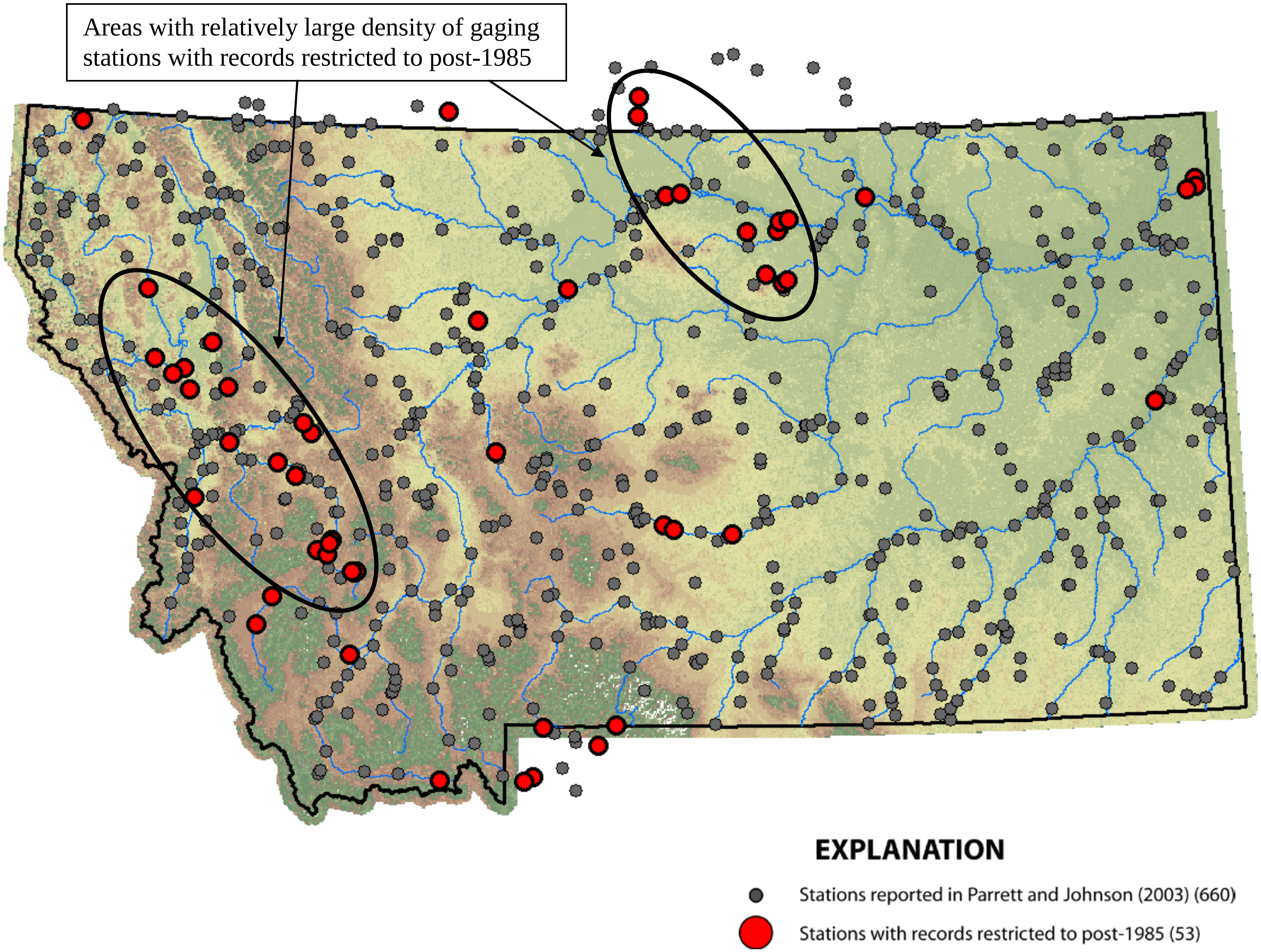


Figure 2. (Appendix A) Locations of selected peak-flow gaging stations.

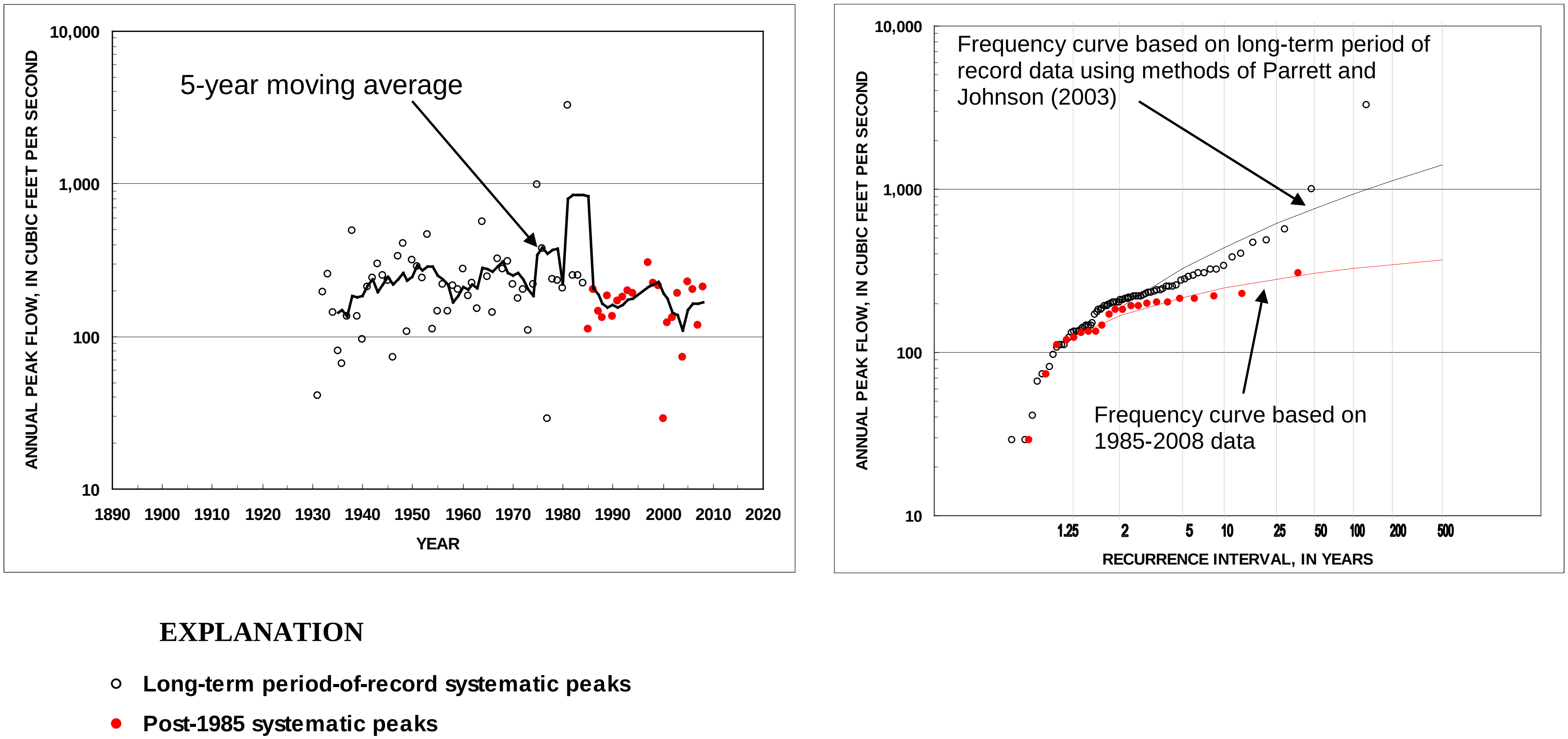
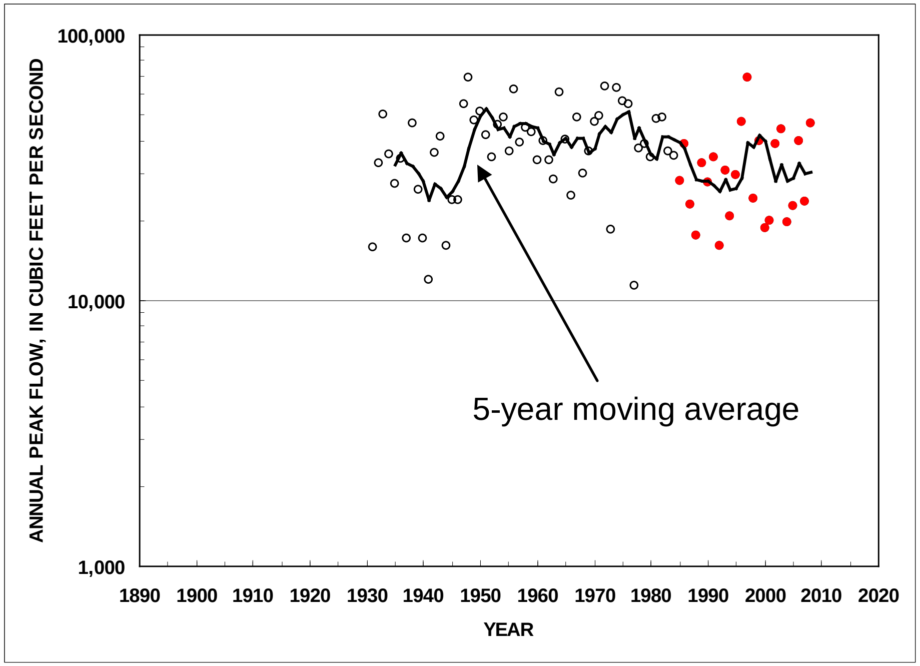
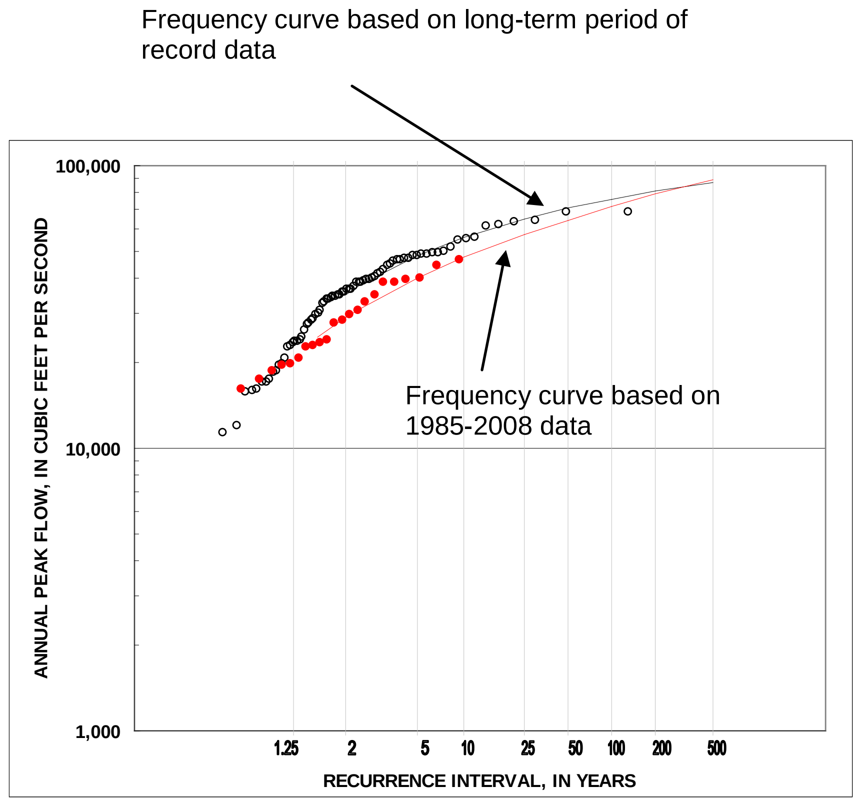


Figure 3. (Appendix A) Comparison of systematic peak-flows and flood-frequency curves between the periods 1985-2008 and the long-term period of record for gaging station 06062500 – Ten Mile Creek near Rimini, Mont. (map number 3, figure 1; table 5).



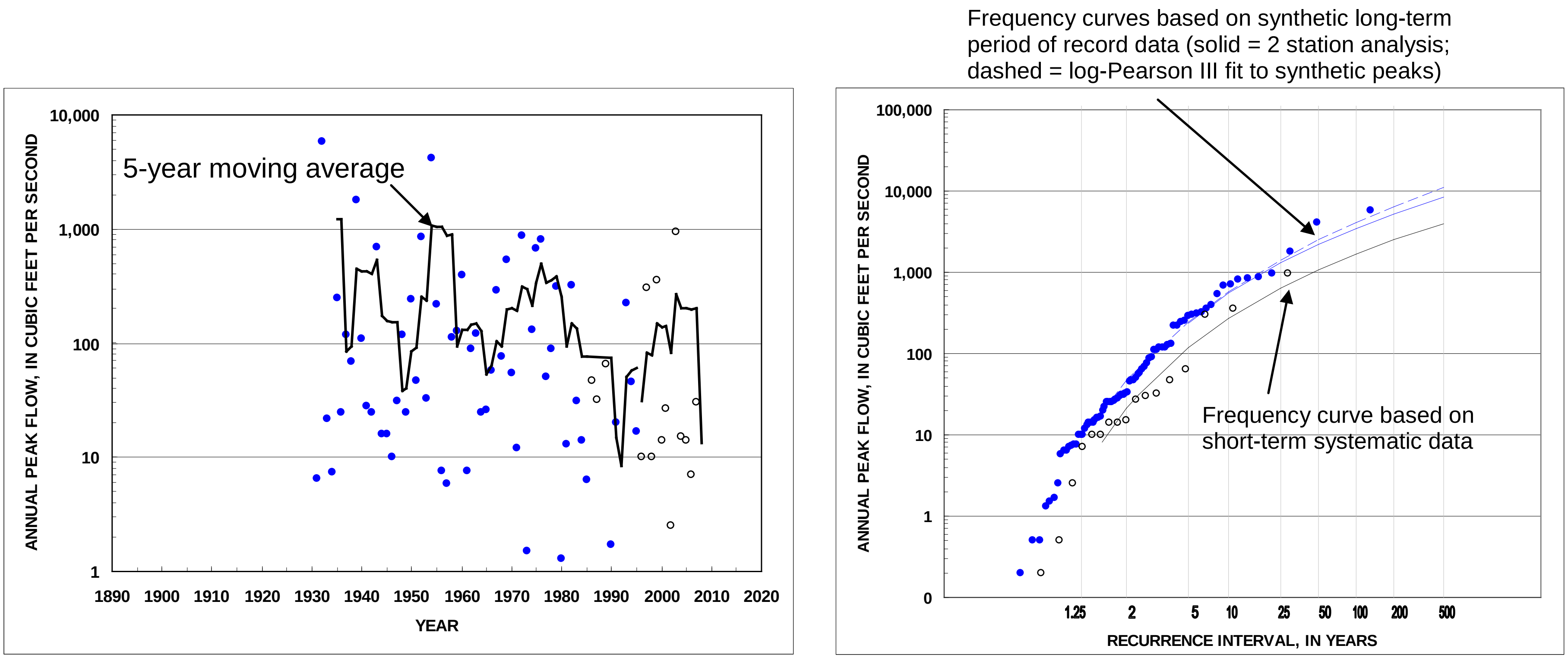


EXPLANATION

○ **Long-term period-of-record systematic peaks**

● **Post-1985 systematic peaks**

Figure 4. (Appendix A) Comparison of systematic peak-flows and flood-frequency curves between the periods 1985-2008 and the long-term period of record for gaging station 12354500 – Clark Fork at St. Regis, Mont. (map number 4, figure 1; table 5).

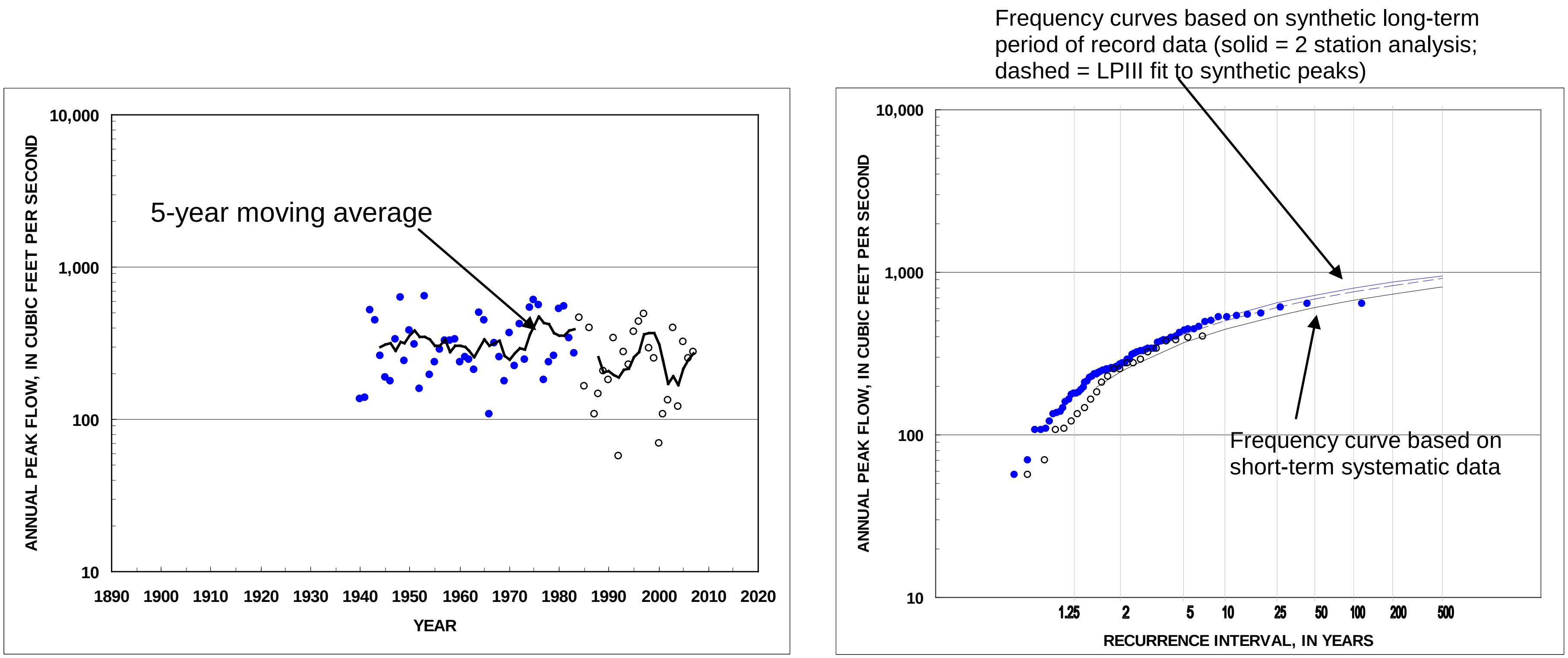


EXPLANATION

○ **Short-term period-of-record systematic peaks**

● **Synthetic (MOVE.1) long-term peak flows**

Figure 5. (Appendix A) Comparison of peak-flows and flood-frequency curves between the short-term systematic record and synthesized long-term record for gaging station 06183750 – Lake Creek near Dagmar, Mont.



EXPLANATION

○ **Short-term period-of-record systematic peaks**

● **Synthetic (MOVE.1) long-term peak flows**

Figure 6. (Appendix A) Comparison of peak-flows and flood-frequency curves between the short-term systematic record and synthesized long-term record for gaging station 12323770 – Warm Springs Creek at Warm Springs, Mont.

APPENDIX B: INFORMATION SUPPORTING THE NEED FOR RESEARCH ON MIXED-POPULATION FLOOD-FREQUENCY ANALYSES FOR NORTHWESTERN MONTANA

Problem

Flood-frequency estimation for some gaging stations in northwestern Montana is complicated by the presence of a small number of unusually large floods during the period of record. For these gaging stations, the log-Pearson Type III probability distribution does not provide a good fit to annual peak flows when all data are combined. Thus, in previous USGS flood-frequency reports, a mixed-population flood-frequency analysis was performed (Parrett and Omang, 1981; Omang and others, 1986; Omang, 1992; Parrett and Johnson, 2003). For individual gaging stations, this involved: 1) investigating the peak-flow records and assigning two or more peak flows as being large rainfall-only peak flows; 2) determining separate probability distributions for the large rainfall-only peak flows and for the ordinary snowmelt/snowmelt-plus-rainfall peak flows; and 3) merging the two probability distributions using joint-probability theory.

There are two primary concerns relating to application of the mixed-population analysis on a station-by-station basis: 1) the ability to attain consistency in flood-frequency estimates for basins with similar climatic and hydrogeologic characteristics, but differing by whether or not systematic records include an unusually large peak flow; and 2) the ability to accurately estimate the true frequency of occurrence of unusually large peak flows based primarily on the limited systematic record available for a single gaging station.

Figure 7 shows gaging stations in the regions of Parrett and Johnson (2003) where mixed-population analyses were applied (the West, Northwest, and Northwest Foothills Regions). In Figure 7, gaging stations where mixed-population analysis was applied are indicated, and also gaging stations that were not operated in 1964 are indicated. The unusually large flood of 1964 serves as a definitive event in performing the mixed-population analysis for many gaging stations in northwestern Montana. Patterns that are apparent in Figure 7 include: 1) some gaging stations that were reported in Parrett and Johnson (2003) that did not include the mixed-population analysis are located in close proximity to gaging stations that did include the mixed-population analysis; 2) several gaging stations reported in Parrett and Johnson (2003) that did not include the mixed-population analysis were not operated during 1964; and 3) several gaging stations that were not reported in Parrett and Johnson (2003) were not operated during 1964. Detailed investigation of factors contributing to these patterns is beyond the scope of this proposal. However, it seems apparent that flood-frequency estimates for gaging stations in northwestern Montana might be improved by using a regionally based approach to mixed-population analysis.

Methods

Sando and others (2008) applied a regional mixed-population analysis to the Black Hills area of South Dakota, where infrequent unusually large flood events complicate flood-frequency estimates. Investigating the application of that method to northwestern Montana is proposed.

Application of the method involves the following primary steps:

1) define the region where the mixed-population analysis applies;
2) determine the relative frequency of independent ordinary peak flows and independent unusually large rainfall-only peak flows in the regional systematic record;
3) normalize the independent unusually large peak flows based on drainage area and fitting a probability distribution to the normalized large peak flows;
4) for each gaging station, determine the probability distribution of ordinary peak flows;
5) for each gaging station, define the site-specific probability distribution of large rainfall-only peak flows by rescaling the normalized large-flow probability distribution on the basis of drainage area; and
6) for each gaging station, merge the ordinary peak-flow distribution and the site-specific large rainfall-only peak flow distribution using joint probability theory.

Application of the regional mixed-population analysis in northwestern Montana should improve the accuracy and consistency of flood-frequency estimates. Also, this method will simplify periodic updates of flood-frequency estimates as additional data collected during periods of varying climatic conditions are incorporated.

The regional mixed-population analysis might also have application in other parts of Montana, including the eastern plains, where infrequent unusually large flood events complicate flood-frequency estimates. Application of the mixed-population analysis to other parts of Montana will be investigated in the proposed study.

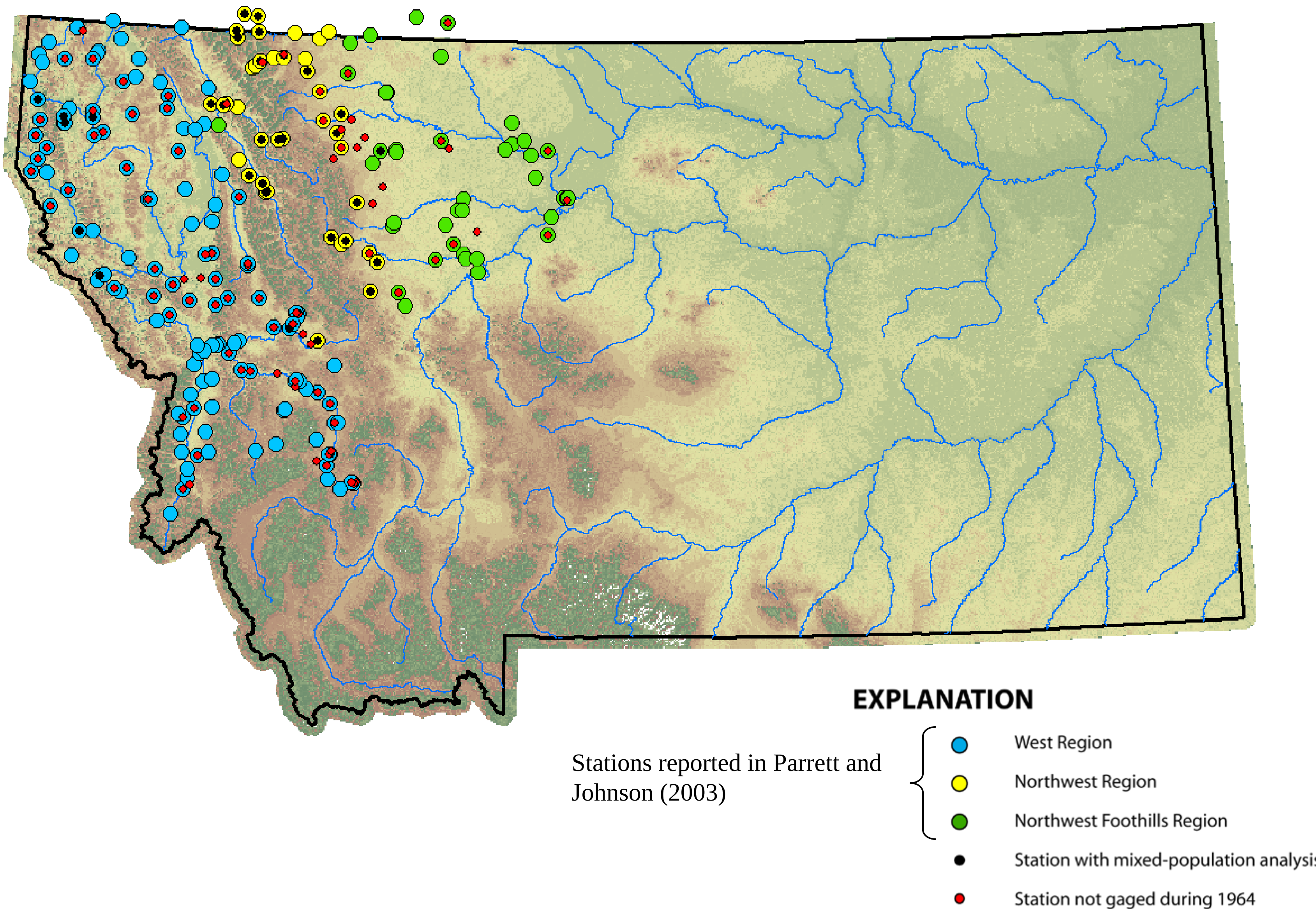


Figure 7. (Appendix B) Selected gaging stations in northwestern Montana.