Determination of Daily Sediment, Nutrient, and Sediment-Associated Chemical Concentrations and Loads for the Conterminous United States

A Proposal to Establish a Long-Term, Base-Funded, Network-Design National Monitoring Network to Generate Sediment, Nutrient, and Sediment-Associated Chemical Concentrations, Loads, Budgets and Temporal Trends

Piloted in the Mississippi River Basin

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EXECUTIVE SUMMARY

A **National Sediment and Water-Quality Monitoring Network**, composed of some 400 to 450 sites is proposed for implementation at an annual estimated cost of **$75-$90 million**. This level of funding will generate a nationally consistent data set that will help address the environmental, engineering, and socioeconomic impacts associated with sediments, nutrients, and sediment-associated chemical constituents. While the cost of this program is not minor, it can be shown to amount to <1% of the current annual estimated costs for dealing with ongoing sediment and water-quality issues. The proposed monitoring program will not only establish a long-term historic record, but will improve the science surrounding sediment and water-quality monitoring, as well management capabilities for maintaining sustainable national water resources. This monitoring program will build on, fill in the gaps, and provide a nationally consistent framework for existing and future programs, and permit the tracking of sediments, nutrients, sediment-associated chemicals, and water quality from headwater streams [Hydrologic Benchmark Network (HBN)], through medium-sized river basins [National Water Quality Assessment Program (NAWQA), through major river basins [National Stream Quality Accounting Network (NASQAN)], and ultimately to coastal outlets (NASQAN).

This proposal describes the need for a national network, but focuses on the thrusts and requirements for initiation of a **Mississippi River Basin (MRB) Pilot Program**. The MRB Program includes some 68 monitoring sites, at a cost of **$18 million in the first year, and about $14 million per annum in subsequent years** (see Appendix 1: Budget; Appendix 2 Site List); it is proposed until it is subsumed by initiation of the National Network.

MAJOR SEDIMENT-RELATED ISSUES

The environmental, engineering, and socioeconomic effects of changes in the annual fluxes of sediments, nutrients, and sediment-associated chemical constituents are well-established and substantial. For example, Louisiana loses an average of 65-100 km^2 of its coastal wetlands annually. Sediment-bound nutrients contribute to eutrophication in a number of economically significant water bodies, including Chesapeake Bay, the northern Gulf of Mexico, and San Francisco Bay. Much of the soil eroded from croplands is captured by and reduces the capacity of water-supply reservoirs, in some cases at rapid rates. Persistent environmental contaminants, such as sediment-bound PCB's in New York's Hudson River, can bioaccumulate and impair the health of aquatic organisms and higher-level consumers.

In North America alone, the physical, chemical, and biological damage attributable to fluvial sediment and sediment-associated chemical constituents has been estimated to range from **$20-$50 billion** annually. Recent information on sediment-related expenditures include:

- The Agricultural Research Service and USGS estimate that the costs associated with sediment damage and remediation on reservoir-storage facilities totals **$2.5 billion annually**.
- The COE estimates that the costs of created wetlands with dredge spoils ranges from about $120-$170 thousand/hectare; hence, using dredged material to backfill areas equal to the annual loss of Louisiana's coastal wetlands would require about **$0.8-$1.1 billion annually**.
- In support of about 490 million tonnes of commerce on the Mississippi and Ohio Rivers in 2007, the COE and contractors dredged 158 million m^3 of material costing about **$1 billion**.
- Since 2006, the COE's annual expenditures on the Missouri River Recovery Program to partly restore various ecological systems have totaled about **$55 million.**
- Since 1986, the COE's annual expenditures on the Upper Mississippi and Illinois Rivers, under the Environmental Management Program, on average, exceeded **$20 million** annually.

Additionally, proposed projects to address sediment/water quality-related issues include:

- Flow diversions for at least 20 sites along the Mississippi River to build wetlands in Louisiana; if only 3-5 diversions actually are constructed, the cost would be **$1.5-$2.5 billion**.
- Low-water water-supply infrastructure upgrades and Federal levee repairs in the Missouri River, Kansas City, MO, are expected to cost **$625 million**.

The benefits of the proposed long-term monitoring network will be substantial, if only in improving how sediment and water-quality issues are addressed. Lack of an adequate monitoring network now requires the development of many project proposals and dredging works without a clear understanding of sedimentary system dynamics. This can, and has resulted in some projects, such as diversion structures, being mis-located, or has led to unintended and undesirable consequences associated with the structures. With Federal, state, and local resources inadequate to address these issues, expending funds and resources on these projects, without the requisite basic resource and process information on which reliable predictions of benefits are predicated, would be imprudent at best.

PROGRAMMATIC OBJECTIVES

Effective sediment, nutrient, and particulate-chemical management in the U.S. requires a clear understanding of the sources, sinks, pathways, and fluxes of these constituents. This only can be achieved through data collection and analyses that describe the concentrations and loads, in conjunction with an understanding of the fundamental transport processes of these materials and from models that use those data to simulate/predict responses to potential management options.

Technological advances, coupled with manual measurements and analyses, provide the capacity to continuously monitor the daily transport of sediments, nutrients, and sediment-associated chemical constituents in a reliable and cost-effective manner at hundreds of key sites in the U.S., as part of a comprehensive National Monitoring Network. The implementation of a monitoring program of this magnitude would benefit from an initial piloting exercise to finalize the requisite instrumentation, sampling, processing, and analytical protocols, and data-management tools to be used in a nationally consistent program. Because the MRB represents a microcosm of most of the sediment, nutrient, and sediment-associated chemical issues facing the Nation as a whole, as well as representing a variety of fluvial environments, it is an ideal area for a pilot program prior to full implementation of a National Monitoring Program.

MISSISSIPPI RIVER BASIN (MRB) PILOT PROGRAM

A MRB Pilot Program will address two major objectives:

1. Establish a sediment, nutrient, and sediment-associated chemical monitoring program for the Mississippi, Missouri, and Ohio Rivers, and their major tributaries, that can be used to compute accurate sediment, nutrient, and sediment-associated chemical budgets, at critical spatial and temporal scales, within acceptable and quantifiable error limits, and

2. Using the data collected and budgets computed in Objective 1, along with available historic data, determine the availability of sediment for various uses; trends in suspended-sediment concentrations (SSC), sediment character/grain size, nutrients, sediment-associated chemistry; and the impacts of spatial and temporal trends in these constituents on various economic, ecologic, and restoration activities and characteristics in the MRB.

Detailed goals, the approach, benefits, costs, monitoring locations, constituents to be monitored, and related information are contained in the main proposal and appendices that follow.

INTRODUCTION

Background and Sediment-Related Problems

Over the past 100 years, based on a combination of in-stream measurements as well as modeling results, marked changes have been identified in the annual sediment fluxes of many major river systems (e.g., Meade, et al., 1990; Milliman, et al., 1995; Syvitski, et al., 2005; Syvitski and Kettner, 2008; Walling, 2008) (see Appendix 4 for references). In many cases, these changes have resulted from diverse anthropogenic activities that have directly or indirectly affected the hydrologic cycle (resulting in changes in discharge and/or sediment availability) through one or more of such diverse factors as: (1) urbanization; (2) population growth; (3) deforestation; (4) mineral extraction; (5) water exploitation; (6) changing agricultural practices; and (7) various engineering projects such as dam and reservoir construction and removal (e.g., Syvitski, et al., 2005; Walling, 2006; 2008). Global climate change, whether the result of natural weather cycles, or through emissions of anthropogenically generated greenhouse gases, also can lead to altered patterns of weathering and erosion with concomitant changes in the annual fluxes of sediments, nutrients, and sediment-associated chemical constituents (e.g., Syvitski and Kettner, 2008; Walling, 2008). Altered trends in annual sediment fluxes can generate numerous downstream effects that can engender a variety of hydrologic, ecologic, socioeconomic, and engineering problems.

The scope of fluvial sediment-related problems has expanded dramatically during the last several decades. Historically, fluvial sediment was viewed solely as a physical and/or engineering issue. Within that context, programs and studies focused on problems such as reservoir infilling, channel and harbor silting, and soil erosion and loss. Those historically recognized sediment-related effects are as important today as nearly a century ago when the U. S. Geological Survey (USGS) and other Federal agencies began monitoring fluvial suspended-sediment concentrations (SSCs) and fluxes in the Colorado and Mississippi River Basins. For example, U.S. croplands lose soil from wind and water erosion at an average rate of 17 tonnes ha^{-1} y^{-1} whereas pasture soil losses are almost two-thirds less (USDA, 1989). In 2001, the United States annually lost almost 2 billion tonnes of cropland soil through erosion (Montgomery, 2007). In urban areas, water-related erosion rates can be one to two orders of magnitude higher than in agricultural areas due to the presence of large amounts of impervious surfaces that disrupt the hydrologic cycle (Horowitz, et al., 2008). Substantial quantities of this eroded material eventually finds its way into rivers and streams, and eventually discharges to the coastal zone.

Owing to a variety of physical and chemical factors, in conjunction with aquatic physicochemical conditions, fluvial sediments also can act as both sources and carriers of a wide variety of organic and inorganic chemical constituents (e.g., Förstner and Wittmann, 1981; Luthy, et al., 1997; Warren, et al, 2003; Horowitz, 2008a). Chemical constituents that primarily are sediment-associated include heavy metals/trace elements (e.g., Cu, Zn, Pb, As, Hg), nutrients (e.g., P, N, Si, C), and persistent organic compounds such as polycylic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxin, kepone, and chlorinated pesticides (e.g., Aldrin, Chlordane, Mirex, and DDT and its breakdown products DDD and DDE; U.S. EPA, 1997; Simpson, et al., 2005; Horowitz, 2008a). In 1997, the U.S. EPA evaluated sediment chemical data from over 21,000 locations in the U.S. and found that 26% had ‘a higher probability’ and 49% had an ‘intermediate probability’ of adverse effects on aquatic life and human health. The sediment-associated chemical constituents most often associated with these increased probabilities were PCBs, Hg, DDT, Cu, Ni, and Pb (U.S. EPA, 1997).

The U.S. faces substantial management problems associated with erosion, and with altered transport and deposition rates of fluvial sediment, nutrients, and sediment-associated chemical constituents – problems that only can be addressed with adequate, reliable and consistent data and assessments to describe these processes. These problems include, but are not limited to eutrophication in large water bodies such as the Chesapeake and San Francisco Bays, expansion of the hypoxic zone in the northern Gulf of Mexico, and loss of Gulf coast wetlands due to erosion and subsidence, but also include water-quality and geomorphological problems on inland waterways like the Missouri, Mississippi and Ohio Rivers, reservoir systems, and problems in smaller watersheds such as those on various State 303D lists. Although these problems are well described, the magnitude and the sediment-related processes that led to these conditions are inadequately quantified nor completely understood. Until sufficient data are available on the causative processes and sediment sources that produce these problems, responsible management options tend to be limited.

National Sediment and Particulate Chemistry Monitoring Program

Capability and Need

This increased understanding of the nature and scope of sediment-related issues has occurred in conjunction with substantive improvements in monitoring equipment and methods that can produce continuous or near-continuous and quantifiably accurate physical and chemical measurements of sediment, nutrients, and sediment-associated chemical concentrations (Horowitz, 2008b; Gray and Gartner, 2009; Gray and Gartner, 2010a, 2010b). Advances in *in situ* instrumentation, analytical capabilities, and database management make these objectives more tractable and achievable, in a more accurate and cost-effective manner, than would have been possible even a decade ago (Gray and Gartner, 2009; Rasmussen et al., 2009). These advances are further supported by improved sediment, nutrient, and sediment-associated constituent modeling capabilities (Schwarz, 2009). However, maximum benefit from these models requires accurate current data as well as consistent updating, to reflect changes due to climate variations, engineering structures, and the implementation of various management options.

The Nation would benefit substantially from the acquisition of continuous, accurate, and consistent fluvial sediment, nutrient, and sediment-associated chemical data as part of a National Monitoring Network. Effective sediment monitoring necessarily includes work to determine sediment sources, grain-size characterization, means of entrainment and transport, method and location of deposition, as well as evaluations of the effectiveness of management actions. A well-supported network of monitoring sites, located from headwater streams to ocean outlets, is a fundamental requirement to meet this objective. Data and interpretations from this network also would be applicable to the goals of several other existing Federal programs including the National Water Census, the National Climate Change Monitoring Network, and the Regional Sediment Management Program. The proposed monitoring program also would provide connecting links between a number of other existing programs because it would permit sediment, nutrients, sediment-associated chemical, and water quality tracking from headwater streams [Hydrologic Benchmark Network (HBN)], through medium-sized river basins [National Water Quality Assessment Program (NAWQA)], through major river basins [National Stream Quality Accounting Network (NASQAN)], and ultimately to coastal outlets (NASQAN). Lastly, the proposed nationally consistent sediment and water quality-monitoring program would serve as a 'backbone', as well as a 'living laboratory' for evaluating new techniques and protocols, as well as providing a data and interpretive framework for addressing more regional and local issues. Because sediment, unlike water, tends to move from source to ultimate sink (e.g., coastal discharge) at a relatively slow pace (e.g., Horowitz, et al., 2001; Meade and Moody, 2010), management actions or other changes affecting sediment supply and transport (e.g., erosion, engineering structures) in the upper part of a basin may take decades to manifest themselves in the most downstream parts of the same system; hence, the monitoring commitment must be lengthy – at least decadal – to detect statistically significant changes.

Changing patterns of annual sediment loadings, sediment grain-size, nutrient, and sediment-associated chemical fluxes in the Mississippi River Basin (MRB; Fig. 1) undoubtedly encompass the majority of the problems/effects cited above (e.g., Meade, 1995; Mossa, 1996; Stone et al., 1997; van Heerden and DeRouen, Jr., 1997; Thorne, et al., 2008; Horowitz, 2010; Meade and Moody, 2010). Erosion along the Louisiana coast has been and continues to be extensive; since the 1950s, wetland losses have been estimated to average as much as 100 km^2 y^{-1}, and landward erosion rates of as much as 20 m y^{-1} have been noted (e.g., van Heerden and DeRouen, Jr., 1997). The land loss impacts of the storm/tidal surges associated with the relatively recent landfalls (August-September, 2005) of Hurricanes Katrina and Rita, and the subsequent flooding of New Orleans have largely been ascribed to land subsidence, in conjunction with the major loss of coastal wetlands and barrier islands which help reduce storm surges (e.g., Waltham 2005). Further, a number of Louisiana coastal and wetland restoration plans/projects are predicated on the assumption that the Mississippi River can be 'mined' for material for that purpose (Davis, Jr., 1997; Thorne, et al., 2008). However, recent studies indicate that sediment loads in the MRB have steadily declined over recent decades (e.g., Thorne, et al., 2008; Horowitz, 2010; Meade and Moody, 2010). Lastly, the growing spatial and temporal extent of the Gulf of Mexico hypoxic zone has been ascribed, at least in part, to nutrient enrichment from U.S. Midwestern agricultural sources (e.g., Walker and Srinivasan, 1995; Goolsby et al., 1999; Turner et al., 2007). As it has been estimated that MRB sediments deliver about 85%, 30%, and 50%, respectively, of the annual fluxes of P, N, and organic carbon to the northern Gulf of Mexico, changing sediment fluxes also may affect the spatial and/or temporal extent of the hypoxic zone (e.g., Walker and Srinivasan, 1995; Horowitz et al., 2001; USGS, 2004; Turner et al., 2007). The potential conflict between the need for additional sediment to help restore and maintain wetlands and barrier islands, juxtaposed against the increased nutrient and chemical loadings associated with increased sediment fluxes, represents an environmental conundrum that requires accurate data to reach a resolution. Because the MRB represents a microcosm of most of the sediment, nutrient, and sediment-associated chemical issues facing the Nation as a whole, as well as representing a variety of fluvial environments and sediment characteristics, it is an ideal area in which to pilot all the instrumentation, sampling and analytical protocols, and data management tools that would be used in a nationally consistent program.

Proposal Scope

This proposal, and the National Monitoring Network that it seeks to develop may be viewed as:

1) A stand-alone pilot program, beginning as soon as practicable and as funding levels permit, that will establish a uniform, basinwide, sediment, nutrient, and sediment-associated chemical monitoring program incorporating 68 sites based on specific data objectives and network design that employs consistent sample collection, sample processing, and analytical protocols at appropriate spatial and temporal scales to address the major issues in the MRB and permit sound management decisions; and as

2) A pilot for a nationally consistent and comprehensive HUC6-based sediment, sediment characterization, nutrient, and sediment-associated chemical, and water quality-monitoring program, based on National Monitoring Network (NMN) criteria, incorporating some 400 to 450 sites that will require a 2012 budget initiative to implement. This monitoring program would permit sediment budget, sediment character, sediment-associated chemical, and water quality tracking from headwater streams to coastal outlets.

Objectives

The proposed MRB pilot program is intended to form a long-term framework for all sediment- and water quality-monitoring efforts in the basin. It is not intended to replace or address various local and/or subbasin issues that may require intensive (spatial or temporal) shorter-term studies. There are two major basinwide objectives associated with this proposal:

1. Establish a sediment, nutrient, and sediment-associated chemical monitoring program for the MRB that can be used to compute accurate sediment, nutrient, and sediment-associated chemical budgets, at critical spatial and temporal scales within acceptable and quantifiable error limits, and

2. Using the data collected and budgets computed in Objective 1, along with available historic data, determine the availability of sediment for various uses; trends in SSCs, sediment character/grain size, nutrients, sediment-associated chemistry; and the impacts of spatial and temporal trends for these parameters on various economic, ecologic, and restoration activities and characteristics in the MRB.

Regardless of the variety of approaches/methods/techniques/instrumentation that may be applied to meet these objectives, the underlying requirements basically remain unchanged:

- Establish a monitoring network that will serve as a long-term, consistent, and coherent framework for all monitoring efforts in the MRB and which will permit, at a minimum, the determination of site-specific mean daily discharges, as well as sediment, grain size, nutrient, and sediment-associated chemical concentrations for load determination at various levels of spatial and temporal resolution,

- Process historic data for trend determinations, within known error limits, and to establish baseline (at least relative to 1950s levels) conditions, and

- Ensure that the time-series and related data are publically available for use in synthesizing cause-and-effect relations that, in turn, can be used to model alternative management scenarios. Plans are to store the sample and continuous sensor data in USGS NWIS. These data are accessed and displayed through NWISweb (http://waterdata.usgs.gov/nwis/qw/), Water Quality Watch (http://waterwatch.usgs.gov/wqwatch/), and National Real-time Water Quality (http://nrtwq.usgs.gov). Additionally, historic data of demonstrably adequate reliability that is found as part of this program but do not reside in NWIS will be added and used as part of trend analyses.

The major objectives for the proposed monitoring program are dependent upon and/or encompass a variety of short- (1-3 years), medium- (3-10 years), and long-term (>10 years) goals and deliverables, as well as a limited number of projects intended to evaluate various tools/approaches that hopefully will enhance and/or expand monitoring capabilities within the MRB, but which also could be applied nationally, and to complete a retrospective analysis of recoverable historic data to develop baselines and evaluate long-term trends in sediment, nutrients, and sediment-associated chemical concentrations and fluxes.

Summary of Goals and Deliverables by Time Category

Short-Term Goals/Deliverables (1-3 years)

1) Final site selection.
2) Site instrumentation (e.g., discharge, turbidity, U.V. nitrate sensors, dcp).
3) Manual sampling and physical and chemical analyses (12 to 20/year) using traditional techniques to develop sediment, grain-size, and chemical constituent concentrations and loads/fluxes, to calibrate various surrogate measurements/instrumentation, and to provide error estimates.
4) Development of a WWW-accessible portal to a database for current and historic MRB data.
5) Development of a real-time MRB WWW-accessible web page.
6) Retrospective analysis of historic data.
7) Fact-sheet on the MRB monitoring program.

Medium-Term Goals/Deliverables (3-10 years)

1) Continued manual sampling to verify the estimates from various surrogate measurements/instrumentation, and to provide error estimates (12/year).
2) Complete evaluation of alternative surrogates (e.g., hydroacoustics for SSC/grain size; bed-sited sonar for bedload).
3) Initial sediment budgets for major subbasins, tributaries, and mainstem MRB sites.
4) First evaluation of decadal trends in SSC, nutrients, sediment-associated constituents, and water quality.

Long-Term Goals/Deliverables (>10 years)

1) Continued manual sampling to verify the various surrogate measurements/instrumentation and to provide error estimates (12/year).
2) Detailed sediment budgets identifying major sources, sinks, and pathways.
3) Finalize decadal trends in sediment fluxes, sediment grain-size, nutrients, sediment chemistry, and water quality.

Program Management

The MRB pilot program will require a full-time program manager (PM). The PM will be responsible for issuing annual instructions for all site/sampling/analytical operations and procedures, ensuring programmatic consistency through training and on-site reviews, preparation of an appropriate programmatic fact-sheet, preparation of annual budgets, and annual funding disbursements. The PM will oversee the data management portion of the program, and the data portal for the MRB Pilot Program World Wide Website. The PM will be responsible for the publication of periodic electronic data reports, serve as the clearinghouse for all publications resulting from the MRB pilot program, issue press releases as appropriate, and provide responses to both internal and external information requests. Lastly, the PM will be responsible for maintaining contact with other organizations, committees, groups, etc. (e.g., the Gulf Hypoxia Task Force) working in the MRB. The PM will require two full-time assistants, one to provide technical/scientific support, and the other to provide administrative/financial/accounting support and to oversee disbursements. The PM also will require at least part-time GIS support to provide maps/figures as required, and to supply information on drainage area, climate, land-use distributions, geology, etc. for addition to the site descriptions available through the program website and to aid in data interpretations.

As soon as practicable, the PM will formulate and convene an MRB Monitoring Program Technical Advisory Committee consisting of no more than 10 members. This group will consist of three USGS and three COE members, and if possible, at least 1 member from the U.S. EPA, NOAA, and the NRCS. Initially, this group should meet at least semi-annually, and subsequently as necessary, but at least once a year to provide technical support to the PM, as well as review the progress of the program, help set priorities for future work, adjust the direction of the program as necessary, and bring in other agencies and groups as needed to make this as National a program as possible.

Data Management

As close to the inception of the proposed monitoring effort as possible, a searchable and interactive database will be developed, and subsequently maintained using NWISWeb and other previously described on-line tools to display real-time data, to store all the data generated by the new monitoring program, and to store as much historic data on sediment, nutrients, sediment-associated chemistry, sediment grain-size distributions, and water quality that can be recovered from current electronic (e.g., NWIS) as well as hard-copy sources (e.g., annual WSC data reports). Initial evaluations indicate that there is a substantial amount of recoverable data (electronic and in paper form); however, there also appears to be a substantial amount of ‘missing/lost’ data. Every effort will be made to recover as much historic data as possible, as these provide a basis for comparisons with recent data. At a minimum, the historical database should extend backwards to the timeframe when current depth-and-width-integrated isokinetic sampling equipment and protocols became the norm for collecting sediment samples and data (~the early 1950s). A retrospective analysis of historic data, establishing historic baselines, should be completed within the first three years of the program. The proposed database will be publically available through the World Wide Web using standard browser software and should permit both data mining and data downloading. A full-time database manager and at least a part-time webmaster will be required to manage and maintain the database and website.

Geographic Scope

A substantial number of sites in the MRB have, at one time or another, been monitored for discharge as well as various constituents. The list – available on request – was culled to address the spatial and sediment budget requirements of the monitoring program. Proposed monitoring sites include all the upstream locations of major dams in the Missouri River as well as all major tributary inputs. A similar approach was used in the Ohio River system. Sufficient sites in the upper, middle, and lower Mississippi River mainstem were selected to characterize the sediment, nutrient, and sediment-associated chemical contributions in each section, and to permit characterization of the changes in these parameters as sediment moves through the system as far downstream as the upstream end of the ‘Bird’s Foot Delta’ at/or near Venice, LA. The Atchafalaya River sites extend from the Old River Control Structure through to the two distributary outlets at Wax Lake and Morgan City, LA. Additional sites located on the Arkansas and Yazoo Rivers are included. Special emphasis was placed on including those sites where historic data are available to help establish baselines and long-term trends.

Monitoring Site Instrumentation and Manual Data and Sample Collection

The selected sites (Appendix 2) are divided into two groups: Priority 1 and Priority 2. Priority 1 sites, about a third of the total, are considered fundamental to understanding the movement and storage of sediment and constituents leading to the Mississippi River mouth. They consist of

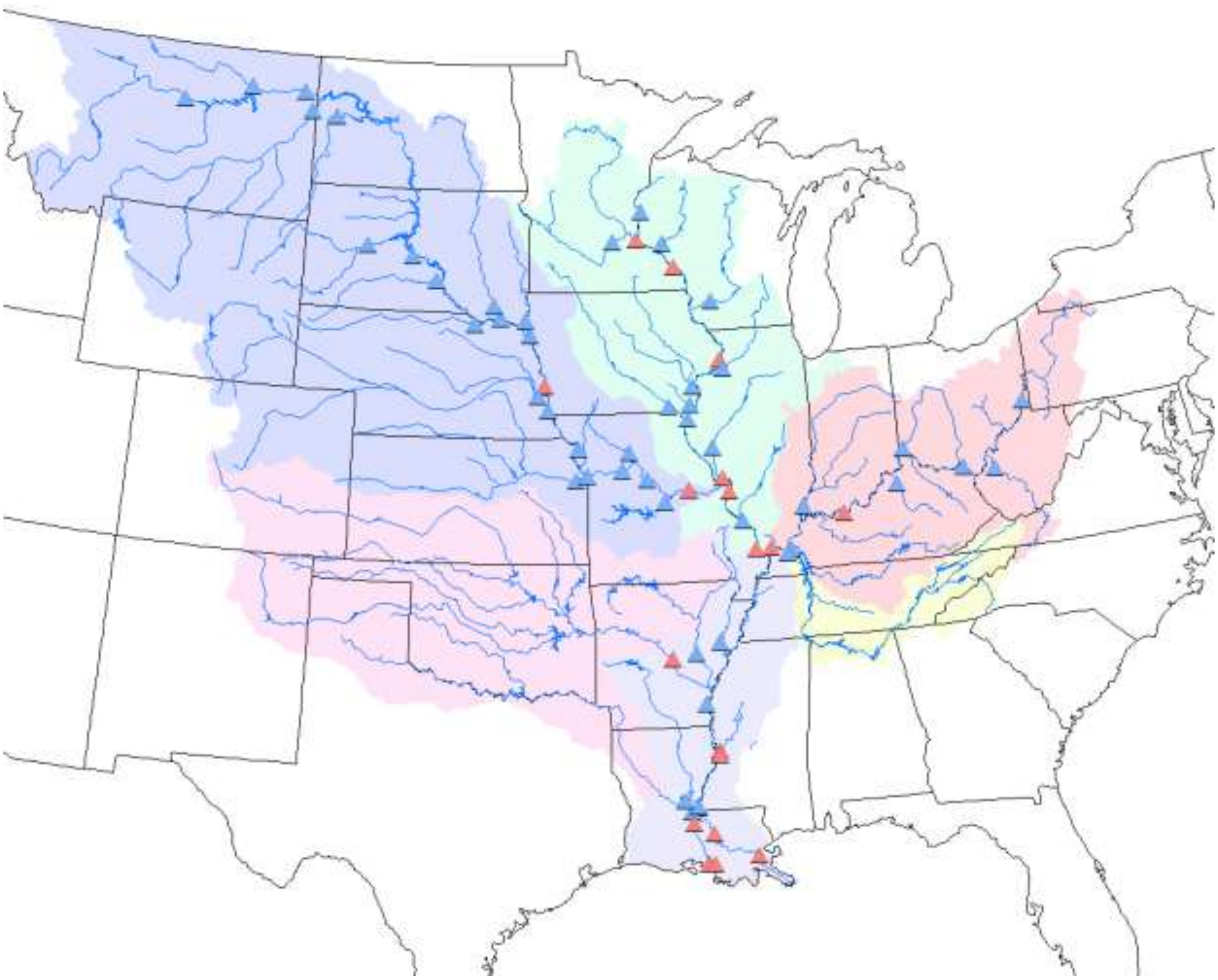
Mississippi and Atchafalaya mainstem, and Missouri, Ohio, Arkansas, and Yazoo River locations at or near where they enter the mainstem. Priority 2 sites address transport issues in smaller but important basins, and provide specific information on such issues as the effects of the Missouri River dams and large-scale/ubiquitous river training features.

All sites will be equipped for real-time data transmission so that data/measurements will be World Wide Web-accessible within hours of generation. All the sites will be instrumented with turbidimeters and acoustic backscatter meters (surrogates for SSC and some sediment-associated chemical constituents) as well as ultraviolet dissolved-nitrate sensors. In addition, the Priority 1 sites will be used to evaluate the utility of additional instrumentation as well as protocols for their use throughout the monitoring network (e.g., hydroacoustics for SSC and grain-size categories; laser instruments for grain-size classes and SSC; and hydroacoustics for bedload monitoring).

Manual sampling (with both traditional and selected surrogate instruments) at all sites will be hydrologically rather than calendar-based, with the intent of covering at least 80 to 85% of the annual ranges of discharge. Special emphasis will be placed on collecting samples during high-flow periods when SSCs and fluxes are at a maximum to adequately calibrate the surrogate sensors near the tops of their respective measurement ranges. The Priority 1 sites, at least during the first three years of the program, will be sampled at a greater frequency (20/year) than the Priority 2 sites (12/year) to speed the surrogate calibration process and to establish broadscale concentration and flux patterns in the MRB. However, all manual samples will be analyzed for the same list of constituents (Appendix 3). The yardstick for selection of appropriate surrogate measurements will be predicated on comparisons with laboratory-derived concentrations/calculated values from manual calibration samples. Although surrogate consistency throughout the network would be the preferred result, improved accuracy may require site-specific selections.

Because the fluvial system under consideration is highly dynamic and because the MRB is undergoing active management and engineered adjustments (e.g., dredging, diversion construction, introduction of land-based BMPs to reduce erosion), a minimum level of manual sampling will continue throughout the life of the program to ensure that instrument and model calibrations can be adjusted if necessary so that they remain as accurate as possible. In addition, measurements, analytical data, and calculated values derived from the manual samples will be used in establishing estimation errors for surrogate-derived data. Finally, as the MRB network is intended as a long-term program, it is likely that new monitoring technologies/capabilities will be developed during the course of its lifetime. Manual samples as well as standard measurements and analytical procedures always will be the yardstick to determine if new instrumentation should either replace or enhance then current surrogate measurements and/or equipment.

Figure 1: Map showing locations of 68 proposed monitoring sites for the MRB Pilot Program designated as Priority 1 (red) and Priority 2 gage locations.



APPENDIX 1

BUDGET, MISSISSIPPI RIVER BASIN PILOT PROGRAM

This 11-category, 2-page budget is based on operating 68 continuous-monitoring sites for measuring suspended-sediment, nutrient, and particulate-chemical concentrations and fluxes, and for monitoring bedload at 6 of them. Costs for continuous streamflow at each site are borne by the USGS and are not included. The costs presuppose that all sites are monitored throughout each year.

Tasks/Numbers/Cost (inc. 3% inflation factor)	# of Sites	# of Samples per Site	Cost per sample X $1,000	2012 X $1,000	2013 X $1,000	2014 X $1,000	2015 X $1,000	2016 X $1,000
1a. Collection of sediment and water quality samples at each site; drop to 12 samples/year after 3rd year.	20	20	$4.50	$1,800	$1,854	$1,910	$1,210	$1,246
1b. Collection of sediment and water quality samples at each site.	48	12	$4.50	$2,592	$2,670	$2,750	$2,832	$2,917
2a. Routine analysis for constituents in appendix 3 -Priority 1 Sites; drop to 12 samples/year after 3rd year.	20	20	$2.50	$1,000	$1,030	$1,061	$672	$692
2b. Routine full grain-size analysis for Priority 1 Sites.	20	20	$0.15	$60	$62	$64	$40	$41
2c. Routine analysis for constituents in appendix 3 -Priority 2 Sites.	48	12	$2.50	$1,440	$1,483	$1,528	$1,574	$1,621
2d. Routine full grain-size analysis for Priority 2 Sites.	48	12	$0.15	$86	$89	$92	$95	$98
3. Non routine analysis for constituents in appendix 3--sampled annually.	68	2	$4.00	$544	$560	$577	$594	$612
4. Installation and purchase of water-quality monitors equipped with temperature, specific conductance, turbidity, and dissolved oxygen, and dual-frequency side-looking acoustic backscatter meters (all equipment purchased).	68	1	$40	$2,720	$0	$0	$0	$0
5. Operation and maintenance and real-time record working finalized every 3 months for temperature, specific conductance, turbidity, dissolved oxygen, and ABS sediment.	68	1	$56	$3,808	$3,922	$4,040	$4,161	$4,286
6. Installation and purchase of UV nitrate sensor	68	1	$20	$1,360	$0	$0	$0	$0
7. Additional cost for operation and maintenance of UV nitrate sensor.	68	1	$12	$816	$840	$866	$892	$918
8. Network management and quality assurance, fact sheet publication, and additional publications (e.g., concentration and load computation, SSC and nutrient model development).				$500	$750	$773	$796	$820

9. Enhancement of existing NRTWQ web page to display all continuous and discrete sample data as an interface to NWIS for all newly collected data for all Mississippi River Basin sites.				**$100**	**$100**	**$0**	**$0**	**$0**
10. Assembly of historic data from Corps and USGS, entry into NWIS, and Retrospective analysis resulting in publication of reports.				**$300**	**$500**	**$250**	**$0**	**$0**
11. Installation, operation, maintenance, and development of methods to measure the phase distribution of sediment transport using enhanced optic, acoustic and laser technology at 6 sites. Sites will include 3 Mississippi River and 3 tributaries (2 in the Missouri River). Operation starts in 2012. Evaluation will be completed and published in 2014.	**6**	**6**	**$13.50**	**$486**	**$501**	**$0**	**$0**	**$0**
Totals ($thousands)				**$17,612**	**$14,362**	**$13,909**	**$12,865**	**$13,251**
Annual cost per site for 68 sites ($thousands)	**68**			**$259**	**$211**	**$205**	**$189**	**$195**

APPENDIX 2

PROPOSED MONITORING SITES, MISSISSIPPI RIVER BASIN PILOT PROGRAM*

Basin	Priority	Site Number	Site Location
MO MAIN	2	6115200	Landusky, MT
MO MAIN	2	6185500	Culbertson, MT
MO MAIN	2	6467500	Yankton, SD
MO MAIN	2	6486000	Sioux City, IA
MO MAIN	2	6807000	Nebraska City, NE
MO MAIN	1	6610000	Omaha, NE
MO MAIN	2	6818000	St. Joseph, MO
MO MAIN	2	6893000	Kansas City, MO
MO MAIN	2	6895500	Waverly, MO
MO MAIN	2	6909000	Boonville, MO
MO MAIN	1	6934500	Hermann, MO
MO TRIB	2	6174500	Milk River at Nashua, MT
MO TRIB	2	6329500	Yellowstone River at Sydney, MT
MO TRIB	2	6337000	Little Missouri River at Watford City, ND
MO TRIB	2	6438500	Cheyenne River near Plainview, SD
MO TRIB	2	6441500	Bad River near Ft. Pierre, SD
MO TRIB	2	6452000	White River near Oacoma, SD
MO TRIB	2	6465500	Niobrara River near Verdel, NE
MO TRIB	2	6478500	James R. at Scotland, SD
MO TRIB	2	6805500	Platte R. at Louisville, NE
MO TRIB	2	6485500	Big Sioux at Akron, IA
MO TRIB	2	6926510	Osage R. at St. Thomas, MO
MO TRIB	2	6902000	Grand R. at Sumner, MO
MO TRIB	2	6892350	Kansas R. at DeSoto, KS
MS MAIN	1	5331580	Hastings, MN
MS MAIN	1	5378500	Winona, MN
MS MAIN	1	5420500	Clinton, IA
MS MAIN	2	5474500	Keokuk, IA
MS MAIN	1	7010000	St. Louis, MO
MS MAIN	2	7020500	Chester, IL
MS MAIN	1	7022000	Thebes, IL
MS MAIN	1	5587455	Grafton, IL
MS MAIN	1		Hickman, KY or Memphis, TN
MS MAIN	2	7265450	Arkansas City, AR
MS MAIN	1	7289000	Vicksburg, MS
MS MAIN	1	7374000	Baton Rouge, LA
MS MAIN	1	7374525	Belle Chasse, LA
MS MAIN	2	310552091361200	Coochie, LA
MS MAIN	1	7374000	Venice, LA
(cont)	(cont)	(cont)	(cont)

MS TRIB	**2**	**5330000**	**Minnesota R. near Jordan, MN**
MS TRIB	**2**	**5369500**	**Chippewa R. at Durand, WI**
MS TRIB	**2**	**5407000**	**Wisconsin R. at Muscoda, WI**
MS TRIB	**2**	**5340500**	**St. Croix R. at St. Croix Falls, WI**
MS TRIB	**2**	**5465500**	**Iowa R. at Wapello, IA**
MS TRIB	**2**	**5490500**	**Des Moines R. at Keosauqua, IA**
MS TRIB	**2**	**5474000**	**Skunk R. at Augusta**
MS TRIB	**2**	**5446500**	**Rock R. near Joslin, IL**
MS TRIB	**2**	**5586100**	**Illinois R. at Valley City, IL**
MS TRIB	**2**	**7047907**	**St. Francis R. at Madison, AR**
MS TRIB	**2**	**7077000**	**White R. at De Valls Bluff, AR**
MS TRIB	**1**	**7263620**	**Arkansas R. bl Little Rock, AR**
MS TRIB	**1**	**7288955**	**Yazoo R. near Long Lake, MS**
LWR MS	**2**		**Red R. below Lock & Dam 1, LA**
LWR MS	**2**	7294800	**Old R.Outfall nr Knox Landing, LA**
LWR MS	**2**	**7381490**	**Atchafalaya R. at Simmesport, LA**
LWR MS	**1**	**7381495**	**Atchafalaya at Melville**
LWR MS	**1**	**7381590**	**Wax Lake at Calumet, LA**
LWR MS	**1**	**7381600**	**Atchafalaya R. at Morgan City, LA**
OH MAIN	**2**	**3112510**	**Ohio R. nr Wheeling, WV**
OH MAIN	**2**	**3216600**	**Ohio R. at Greenup, KY**
OH MAIN	**1**	**3303280**	**Ohio R. at Cannelton Dam, Cannelton, IN**
OH MAIN	**1**	**3612500**	**Ohio R. near Grand Chain, IL**
OH TRIB	**2**	**3201300**	**Kanawaha R at Winfield, WV**
OH TRIB	**2**	**3274600**	**Great Miami R at New Baltimore, OH**
OH TRIB	**2**	**3290500**	**Kentucky River at Lockport, KY**
OH TRIB	**2**	**3378500**	**Wabash R. at New Harmony, IN**
OH TRIB	**2**	**3438500**	**Cumberland R at Smithland, KY**
OH TRIB	**2**	**3609750**	**Tennessee R. at Paducah, KY**

- **Designated as Top Priority (1) and Secondary Priority (2)**

APPENDIX 3

CONSTITUENT LIST, MISSISSIPPI RIVER BASIN PILOT PROGRAM

Filtered Water (Routine)

1) Sulfate
2) Chloride
3) Ammonia
4) Nitrate plus Nitrite
5) Nitrite
6) Total Nitrogen
7) Orthophosphate
8) Total Phosphorus
9) Silica
10) Major ions (Na, K, Ca, Mg)
11) Alkalinity
12) Trace Elements
13) Pesticides
14) Dissolved Organic Carbon
15) pH
16) Conductance
17) Turbidity

Suspended Sediment (Routine)

1) Concentration
2) Full grain-size analyses
3) Surface Area
4) Nutrients (N, P, C)
5) Trace Elements
6) Transport Rates by size class

Suspended Sediments (Non-Routine, Twice/Year)

1) Point Concentration vs Continuous Concentration
2) Full Grain-Size Analysis
3) PAHs
4) PCBs
5) Persistent Organic Pollutants [e.g., pesticides (DDT, DDE, DDD)]

Bed Sediments (Non-Routine. Twice/Year)

1) Full Grain-Size Analysis
2) Surface Area
3) Nutrients (N, P, C)
4) Trace Elements
5) PAHs
6) PCBs
7) Persistent Organic Pollutants [e.g., pesticides (DDT, DDE, DDD)]

Bedload (Non-Routine)

1) Full Grain-Size Analysis
2) Transport rates
3) Percentage of total sediment transport

APPENDIX 4

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