CLEAN WATER ACT

SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM

INFORMATION/EDUCATION/TRAINING/DEMONSTRATION PROJECT

FINAL REPORT

"MANAGING THE IMPACTS OF SMALL RESERVOIR FLUSHING"

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PROJECT SUMMARY

PROJECT TITLE: "MANAGING THE IMPACTS OF SMALL RESERVOIR FLUSHING"

PROJECT START DATE: July 1, 2003 PROJECT COMPLETION DATE: June 30, 2009

FUNDING:	TOTAL BUDGET:	$196,610
	TOTAL EPA GRANT:	99,100
	TOTAL EXPENDITURES OF EPA FUNDS:	99,100
	TOTAL SECTION 319 MATCH ACCRUED:	97,510
	BUDGET REVISIONS:	0
	TOTAL EXPENDITURES:	$196,610

SUMMARY ACCOMPLISHMENTS

This study examined the issue of management of small, run-of-river reservoirs from the perspective of minimizing the negative consequences of sediment releases from reservoirs on downstream aquatic resources and water quality. This topic was examined using First Dam on the Logan River, Logan, Utah, as a case study. The principal accomplishments of the study are development of: (1) management, monitoring, and reporting protocols for sediment control at First Dam; (2) a set of general guidelines for construction of sediment management plans and for conducting sediment flushing and sluicing events on small dams in Utah; and (3) a detailed sediment management plan for the operators of First Dam. In total, these accomplishments represent a set of recommendations for best practices with respect to releasing sediment from small run-of-river reservoirs in order to protect valuable downstream aquatic resources.

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EXECUTIVE SUMMARY

This project identified and examined inexpensive techniques for managing sediment releases from small reservoirs so as to reduce the rate at which sediments are deposited into the reservoir and to protect downstream aquatic resources from damage that might be sustained from sediment releases. The project was conducted from July 1, 2003, through June 30, 2009. It was funded by USEPA §319 money ($99,100), and with financial matching funds from the Utah State University Facilities and Planning Department ($10,000), the Utah Division of Wildlife Resources ($20,000), the Utah Water Research Laboratory at Utah State University ($26,060), and the Office of the Vice President for Research at Utah State University ($41,450) for a total match of $97,510.

The goal of the project was to develop and disseminate management guidelines for the flushing/sluicing of sediments from small reservoirs to minimize environmental impacts on water quality and aquatic resources, with emphasis on reservoirs located in regions with arid climates, such as Utah. These guidelines are based on hydrology and geology of the watershed within which the reservoir is located, on the requirements of downstream aquatic species and water users, and on the hydraulic characteristics of the dam, itself. The project used First Dam, a small dam owned by Utah State University on the Logan River at the mouth of Logan Canyon, as a case study. Management guidelines were developed by the project and implemented in the form of a sediment management plan for First Dam. Dissemination of this information has taken the form of presentations at statewide water users conferences, meetings with representatives of numerous state regulatory and planning agencies, and development of electronic distribution facilities.

Significantly, the project identified and documented general procedures for preparing and implementing a sediment management plan for small reservoirs. This includes detailed recommendations for using hydrologic information, for understanding the limitations of dam outlet works and spillways in supporting sediment flushing/sluicing, for determining the water quality constraints that must be met in order to protect downstream species during a sediment release event, for minimal but necessary monitoring of stream flow and water quality, and for documenting the results of sediment management activities. Essentially, this represents a first design of a new best management practice (BMP) to be employed in sediment control for small reservoirs. The project materials and lessons learned will be employed by the state Department of Environmental Quality in coordination with the NPS Task Force Sub-committee in revising and upgrading the state NPS Management Plan for Hydrologic Modification.

INTRODUCTION

The Problem

Sediment eventually fills reservoirs, quickly in some cases, but usually not for many years. In percentage terms, the highest rates for loss of storage are found in the smallest reservoirs, while the lowest rates are in the largest reservoirs. The life span of a reservoir is determined by the rate at which sediments reduce the storage capacity. The rate at which storage is lost for a given reservoir depends upon the sediment yield from the catchment area and the rate at which sediments from the catchment accumulate in the reservoir. The sediment yield is dependent upon the rate of erosion and the transport, by water, of the sediment within the catchments. Generally, coarser materials are deposited at the upstream end of the reservoir, often creating a form that is recognizable as a delta. Finer materials may reach the dam and affect the design and operation of the outlet works.

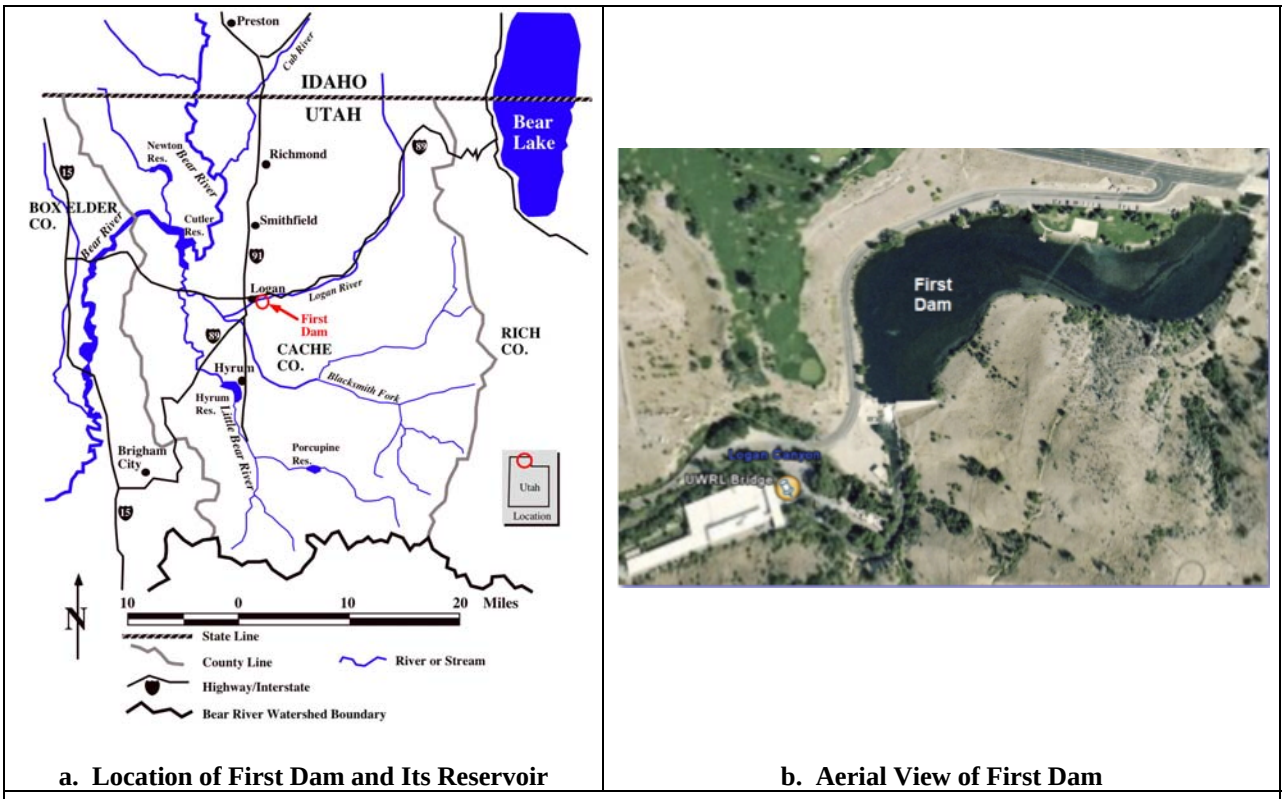
One way to preserve reservoir storage is to flush or sluice sediments through outlet works within the dam. Sediment flushing is a technique in which the flow velocities in a reservoir are increased to such an extent that deposited sediments are remobilized and transported though the available reservoir outlets. Sediment sluicing involves the establishment of temporary changes in the flow patterns through a reservoir, such as by opening an outlet from the reservoir that is normally closed, in order to provide greater capacity for the moving water to pass sediments that are entering the reservoir through (or sometimes around) the system, rather than depositing them in the reservoir.

Research on sediment management methods has focused almost exclusively on maintaining reservoir capacity and extending the economic lifespan of the dam, and little work has been done to understand the consequences that flushing or sluicing might have on downstream biotic resources. The sediment releases that result from these sediment management activities can produce a significant impact on downstream water quality and deleteriously affect the fish and invertebrate populations in the tailraces, often for many miles in the stream channel downstream of the dams.

The purpose of this study is to develop and present a set of guidelines intended to help in the generation of sediment management plans for small run-of-river reservoirs in Utah. The objective of such plans is to minimize the negative consequences of sediment flushing or sluicing on downstream aquatic resources and water quality. Recommendations are also made for monitoring the effectiveness of sediment management activities and for reporting sediment management results. The work reported here is based on research done at First Dam on the Logan River in Logan, Utah, and draws heavily upon the results and experience of sediment management over the course of the project to provide examples of the various components of a sediment management plan.

Logan River Case Study Area and History

First Dam is located on the Logan River at the mouth of Logan Canyon (see Figure 1). The impoundment behind the dam is a popular recreational place, and the river downstream of the dam provides habitat for various cold-water fish and is a very popular trout stream. First Dam is a small diversion facility with very little storage (approximately 60 acft). In addition to recreational opportunities, First Dam is used to generate power and to supply water to the hydraulics research facilities at the Utah Water Research Laboratory at Utah State University. It was constructed in 1911, and in many ways it is similar to hundreds of small dams in Utah. Over its life, the reservoir has accumulated sediment at an average rate of about 0.5 acft per year.



a. Location of First Dam and Its Reservoir **b. Aerial View of First Dam**

Figure 1: Location Map and Aerial View of First Dam on the Logan River

First Dam has had a history of creating downstream fish-kills as the result of infrequent maintenance actions that have been required on the dam from time to time. In 2000, a new set of repairs was scheduled to address upstream and downstream structural damage to the dam from waves, concrete spalling, etc. In addition, the mass of the dam had to be increased in order to address seismic issues. In October of 2001, the reservoir pool elevation was drawn down so this rehabilitation work could be conducted. This resulted in a flushing event that killed an estimated 2,000 catchable size game fish for a two-mile reach of the river downstream of First Dam (see Figure 2). The flushing of sediment and the prolonged drawdown of the reservoir deposited sediments in the downstream channel of the Logan River (Figure 3), which affected fish spawning beds and invertebrate populations. Some of the sediment that was released from the

reservoir was deposited in downstream irrigation canals, which generated substantial clean-up costs for the affected irrigation systems.

Figure 2: Fish Killed by the October 2001 Flushing of First Dam

Prior to the event, the owners of the dam had worked with the design engineer, the contractor, and various representatives from the Utah Department of Natural Resources and the Department of Environmental Quality to acquire the necessary stream alteration permit, to schedule and plan for the lowering of the reservoir pool elevation, to conduct the required construction activities, and to re-commission the dam. The plan called for a very slow and gradual lowering of the pool so that minimal mobilization of sediments would result. However, subsequent enquiries into the event revealed that those responsible for planning the reservoir pool drawdown and rehabilitation activities were poorly informed about several factors, including:

- the real risk of flushing sediment and the potential for causing downstream damage,
- legal water quality requirements, and
- the rights of other water users on the Logan River.

In addition, prior to the 2001 event, sediment management had never been a focus in the operation of First Dam. Since loss of storage volume does not affect the uses of the dam, and since there had never been a sediment management plan put into place, sediments have simply been allowed to accumulate in the reservoir until maintenance activities required that the pool elevation be drawn down. Such activities have always resulted in the generation of downstream environmental problems. In this regard, First Dam is representative of many small dams in Utah, with respect to both the sediment problem and the need to provide basic sediment management guidelines and tools for the owners and operators of small dams.

Following the 2001 event, research was conducted to develop a sediment management plan for First Dam. The intent of this research was two-fold: (1) prepare a sediment management plan for First Dam that would minimize the potential for downstream damage that might result from future maintenance work on the dam, and (2) use the experience gained in these activities to prepare a set of suggested general guidelines that could be used by the owners and operators of small dams in Utah to develop their own sediment management plans and, if followed, to conduct sediment flushing/sluicing activities.

In the research conducted to understand and plan for sediment management at First Dam, it became clear that several factors should be addressed in the design of a sediment management plan for small reservoirs and in conducting flushing or sluicing events. These include:

- characterization of the sediment management problem
- sediment management plan formulation
- monitoring guidelines and recommendations
- recommendations for reporting

These issues have been specifically documented in the sediment management plan prepared for the owners and operators of First Dam, and have been outlined in the proposed general guidelines, submitted to the Utah Department of Environmental Quality under separate cover. A copy of the recommended guidelines and a copy of the sediment management plan for First Dam can be obtained at: http://uwrl.usu.edu/documents/firstDam/sediment.html.

Figure 3: Sediment Deposition Downstream of First Dam after the October 2001 Flushing Event

Consistency with State NPS Management Program

The project supports the information and education (I&E) needs of Utah as identified in the State's NPS management Plan (Utah Department of Environmental Quality, 2000). This plan calls for continued support of I&E projects by §319 funds, especially those that have potential statewide impact. By developing and disseminating a set of guidelines for management of sediment in small reservoirs, the project will have such a significant impact.

The problem is not an isolated one. Utah alone has hundreds of low-head power dams and irrigation storage and diversion dams, as do each of the Mountain West states. All of these require periodic dam maintenance, which includes flushing and/or sluicing. These dams are also on streams that are cold-water habitat for trout and the basis for economically important recreation fisheries, as well as a source of water for agriculture and domestic uses.

PROJECT GOALS, OBJECTIVES, AND ACTIVITIES

The goal of this project is to develop and disseminate management guidelines for the flushing and sluicing of sediments from small reservoirs to minimize environmental impacts on downstream water quality and aquatic resources, with emphasis on reservoirs located in regions with arid climates, such as Utah. These guidelines are based on hydrology and geology of the watershed within which the reservoir is located, on the hydraulic characteristics of the reservoir itself, on the requirements of other water users and of downstream fisheries and aquatic resources.

The objectives and tasks of the project were:

Objective 1: "Develop and document a detailed conceptual approach to sediment flushing for small reservoirs." To achieve this objective, two tasks were accomplished. The first was a thorough literature review to touch on the physical and chemical aspects of sediment flushing. Using this as a basis, the second task was to develop a detailed conceptual approach for flushing sediments, using First Dam as an illustrative example.

Objective 2: "Evaluate the extent and toxic potential of anoxic bottom sediments that might be rapidly released at the initiation of reservoir flushing/sluicing." This first required sampling and testing of reservoir sediments and river water quality. A second task to accomplish this objective was to design, implement, and monitor sediment mobilization procedures for the case study reservoir, First Dam.

Objective 3: "Design, test, evaluate, and help implement a recommended plan for managing the sediment budget of the case study reservoir and the toxicity of its anoxic bottom sediments, with the goal of minimizing the negative downstream impacts of flushing/sluicing procedures." To achieve this objective, information generated from previous tasks was used to design, implement, and monitor sediment mobilization procedures for First Dam. These procedures were tested over a series of years during high runoff periods in the spring.

Objective 4:"Utilize the information collected on the case study reservoir to develop management guidelines for implementing these procedures on other small reservoirs, and disseminate these guidelines to operators of small reservoirs in Utah." Drawing from the multi-year experience of sediment flushing/sluicing at First Dam, the project developed a general set of recommendations for management of sediments in small reservoirs. Further, a sediment management plan was prepared for the operation of First Dam, and project personnel have worked with the operators of First Dam to implement the plan. Information has also been disseminated to interested parties through two presentations at the annual Utah Water Users Conference, presentations before numerous state water management agencies, and through the preparation for electronic distribution of sediment management guidelines and other materials prepared by the project.

Planned and Actual Products and Completion Dates

Activity on the planned and actual project products is summarized in Table 1. All but one of the project products were successfully developed over the course of the project. However, Product 9 relates to activities required by the Utah Department of Environmental Quality that must be performed after completion of this project.

Table 1: Summary of Project Products

Product	Description	Date Met
1	A report detailing the conceptual approach for reservoir flushing/sluicing, including a summary of the literature.	January, 2005
2	Data on sediment and water quality samples.	continuous
3	A report on recommendations for managing sediment toxicity during flushing/sluicing operations.	April, 2006
4	A report identifying and evaluating the hydraulic constraints on managing flushing flows through First Dam and the hydrologic conditions appropriate for flushing/sluicing sediments from the bottom of the reservoir.	April, 2006
5	A report recommending general procedures for evaluating the watershed hydrology in conjunction with the hydraulic operational characteristics of a small dam for purposes of conducting sediment flushing/sluicing.	April, 2006
6	A report documenting recommendations for sediment management for First Dam.	May, 2007
7	A report summarizing recommended guidelines for sediment management in small reservoirs.	May, 2009
8	Dissemination in electronic and hard copy form of the general guidelines to Utah water resources agencies, river commissioners, water conservation districts and dam owners and operators.	on-going
9	Preparation of a portion of the revised State NPS Hydromod Plan related to management and operation of reservoirs related to flushing of sediment storage.	N/A
10	Preparation and submittal of required project reports.	various

Evaluation of Goal Achievement

The issue of unwanted sediment release from First Dam as the result of infrequent maintenance requirements has created problems for downstream water users and threatened valuable downstream aquatic resources on numerous occasions over the nearly 100-year live of the facility. The sediment management plan developed and implemented for First Dam will serve to (1) reduce the rate at which sediments accumulate in the reservoir, thus extending the value of the resource for recreational and other uses, and (2) reduce the amount of sediment that will be discharged from the reservoir in future maintenance activities. Further, the activities conducted over the duration of the project to prepare for and conduct sediment flushing/sluicing events have revealed specific issues that must be addressed anytime that an operational or maintenance action at First Dam will produce the possibility of sediment releases. Key among these issues are: (1) implementation of monitoring protocols that can be used to manage flushing/sluicing and maintain downstream conditions within boundaries that protect valuable aquatic resources; (2) development of a better understanding of how the dam owner can interface with local water users and the several state agencies that might be involved with management of aquatic resources and enforcement of state water quality regulations; (3) identification of the limits of sediment management actions that are feasible for First Dam, and design of emergency procedures that can be followed in order to protect the most valuable downstream aquatic species if future maintenance activities will produce sediment releases that cannot be suitablycontrolled; and (4) identification of limitations in Utah water quality regulations that present constraints on the effective management of sediment releases from small reservoirs.

LONG-TERM RESULTS IN TERMS OF BEHAVIOR MODIFICATION AND STREAM QUALITY

Over time, sediment accumulates in the reservoir behind First Dam in the absence of regular management activities to control this phenomenon. When infrequent maintenance activities on the dam require a lowering of the reservoir pool elevation, these accumulated sediments can be rapidly released, causing serious damage to downstream water users and fisheries. This project has designed and implemented sediment management protocols that minimize the rate of sediment accumulation and reduce the amount of sediment that will be released during infrequent maintenance activities. Essentially, the sediment management protocols that have been developed for First Dam pass more of the spring runoff sediments through the facility than would be the case in the absence of their implementation. This is done during a time of the year when sediment concentrations are already at their natural high levels, so downstream aquatic resources are not harmed. Great care must be taken to effect flushing/sluicing at times when river flows and natural background sediment concentrations are sufficiently high in order to take maximum advantage of the limited hydraulic capacity of the reservoir release structures and to protect downstream aquatic resources and water users. The owner and operator of First Dam are committed to following the protocols that have been designed. In the long term, this commitment will result in fewer and less serious downstream sediment problems on the Logan River.

BEST MANAGEMENT PRACTICES (BMPs) DEVELOPED

The BMP developed and implemented in this project is directed at managing sediments in small run-of-river reservoirs. The guidelines for designing and implementing a sediment management plan for a small, low-head dam incorporate information about watershed hydrology and geology, dam hydraulics, downstream fisheries and aquatic habitat requirements, coordination with local water users and state water management agencies, and legal requirements such as water rights and water quality regulations. Results of flushing/sluicing events conducted on First Dam on the Logan River indicate that, given the hydraulic limitations of the structure of the dam itself, it is possible to route much of the spring runoff sediment through the reservoir instead of allowing it to accumulate in the reservoir. This is illustrated in Figure 4, which shows river turbidity at identical real-time gauges located immediately upstream and downstream (labeled, respectively, "USGS Turbidity" and "UWRL Turbidity") during a flushing/sluicing event that was conducted in the spring of 2007. This illustrates that the sediment released when the low-level outlet valves were opened produced an initial spike that was much lower than earlier spring time turbidity levels in the river (which reached maximum levels of nearly 160 NTU; see Figure 5), and, as a result, insufficient to cause downstream damage. However, total sediment releases from the reservoir during this period slightly exceeded total sediment inflows, indicating that little net sediment accumulation occurred during this portion of the runoff period.

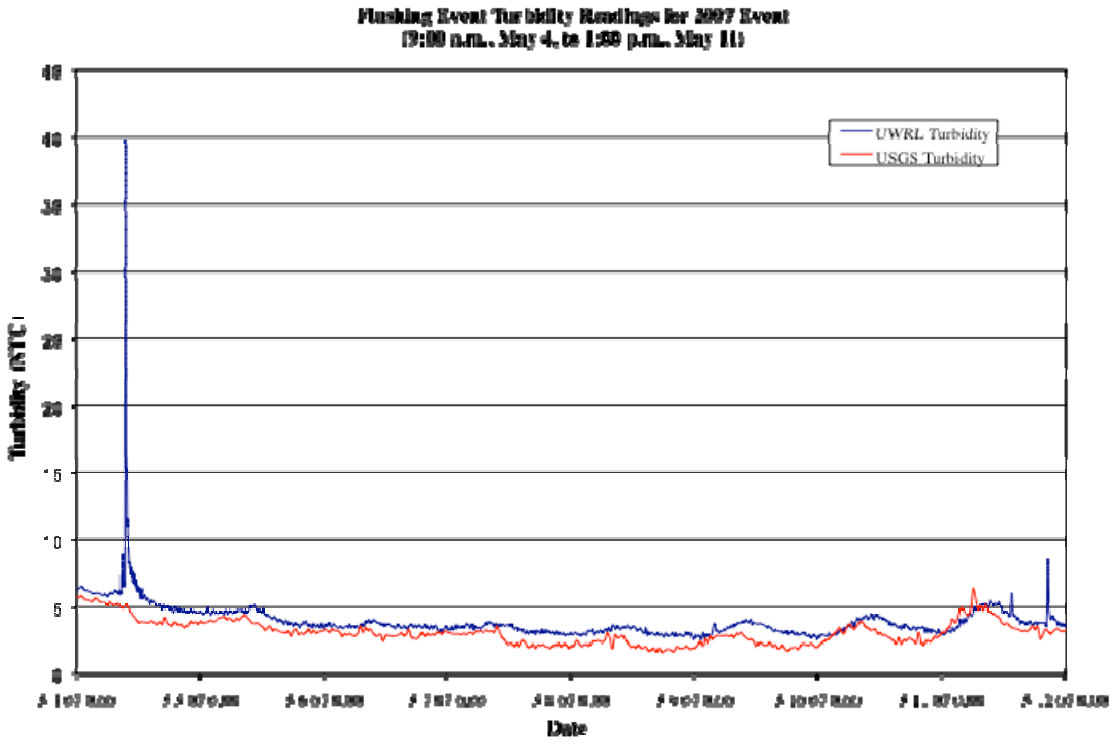


Figure 4: Turbidity Time Series Data from the 2007 Flushing/Sluicing Event at First Dam

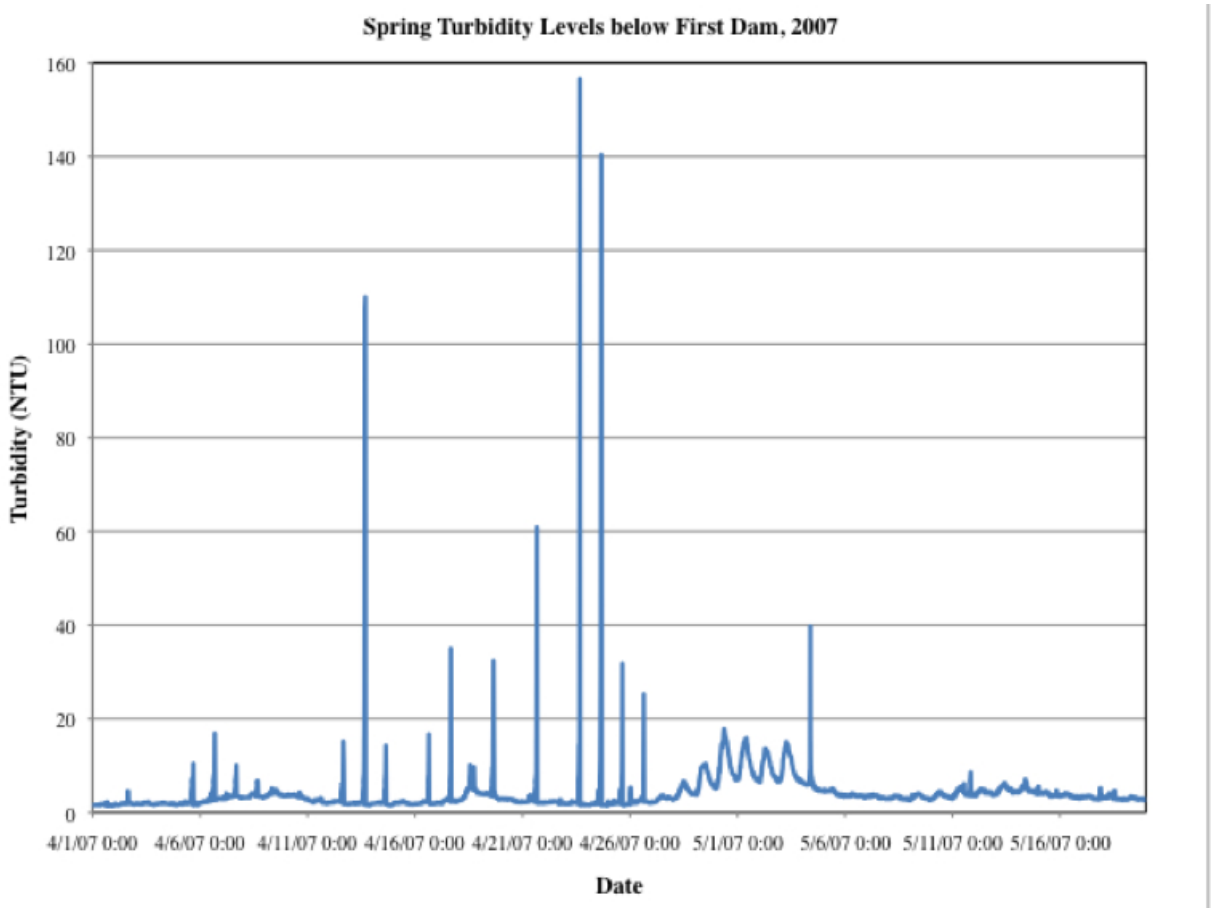


Figure 5: Spring Turbidity Levels below First Dam in 2007

MONITORING RESULTS FOR DEMONSTRATION PROJECTS

This project is actually a combination of I&E and BMP development and demonstration. The principal product for the I&E portion of the project consists of the set of general recommendations for the design and implementation of a sediment management plan for small reservoirs. To that end, a document detailing the general guidelines, including monitoring and reporting recommendations, has been submitted to the Utah Department of Environmental Quality. Further, presentations have been made before water users groups and a at variety of meetings with representatives of various state agencies including the Utah Division of Water Resources and the Utah Division of Water Rights. I&E activities will continue after the project in the form of electronic distribution of the project materials and data, and in the form of participation by faculty at the Utah Water Research Laboratory in the NPS Task Force.

Given the almost total lack of research on reservoir sediment management measures to protect downstream aquatic resources, this project also by necessity had to take on a BMP development and demonstration aspect. The nature of the procedures developed during the project and the

effectiveness of the BMP design, insofar as this can be estimated, are briefly discussed in the following section.

BMP Design Procedures and Effectiveness

There is no manual of Best Management Practices for releasing sediment from small reservoirs while ensuring the health and safety of downstream aquatic resources. The work conducted in this project represents an exploration of what might be possible to accomplish those mutually inconsistent goals (i.e., release of sediment from reservoirs while protecting downstream resources from sediment damage) at one case study dam on the Logan River. The lessons learned by this work and the resulting set of general guidelines for design of a flushing/sluicing plan for small dams represent, essentially, the first attempt at a design of a new BMP.

The general guidelines for design of a flushing/sluicing plan include components for long-term and real-time monitoring, and address issues of long-term sediment budget estimation, real-time control of sediment flushing/sluicing events, and documentation of the consequences of sediment management actions. Careful attention is given to the design of specific protocols for mobilization of reservoir sediments through water releases that take into consideration the hydraulic capacity of the dam to pass flows, versus the natural hydrology of the river. The general guidelines also address details of monitoring design that are needed to provide both real-time assessment of sediment loading during flushing/sluicing events and long-term sediment budget calculations. This is illustrated, for example, by the need to develop real-time monitoring capability for measuring turbidity in order to acquire a relationship between turbidity and total suspended sediment load (as illustrated in Figure 6). Such relationships will have to be generated uniquely at each reservoir site and will require simple, but significant water quality sampling and laboratory analysis to provide mechanisms to translate real-time field data into estimates of total suspended sediments. For example, the TSS-turbidity relationships shown in Figure 5 were developed from a series of grab samples that were processed in the laboratory and that related field measurements of turbidity (obtained with real-time sampling equipment installed by the project) to TSS concentrations as measured in the laboratory. Once this relationship is quantified, it is used to convert real-time turbidity measurements into real-time estimates of TSS concentration. This, in turn, is multiplied by flow rate, measured in real time at the same site, to get sediment loading rates. All of this is used to monitor the sediment budget for the reservoir, both over the period of a flushing/sluicing event and over the entire year. Similar rating curves had to be developed at the real-time monitoring site above First Dam, and for monitoring of stream flow below the dam.

It might be possible to collect sediment concentration and turbidity data from a large number of sites and begin to build a generic relationship that could be tied to certain reservoirs and thereby reduce the amount of data collected at each specific location. This is a potential topic for future research.

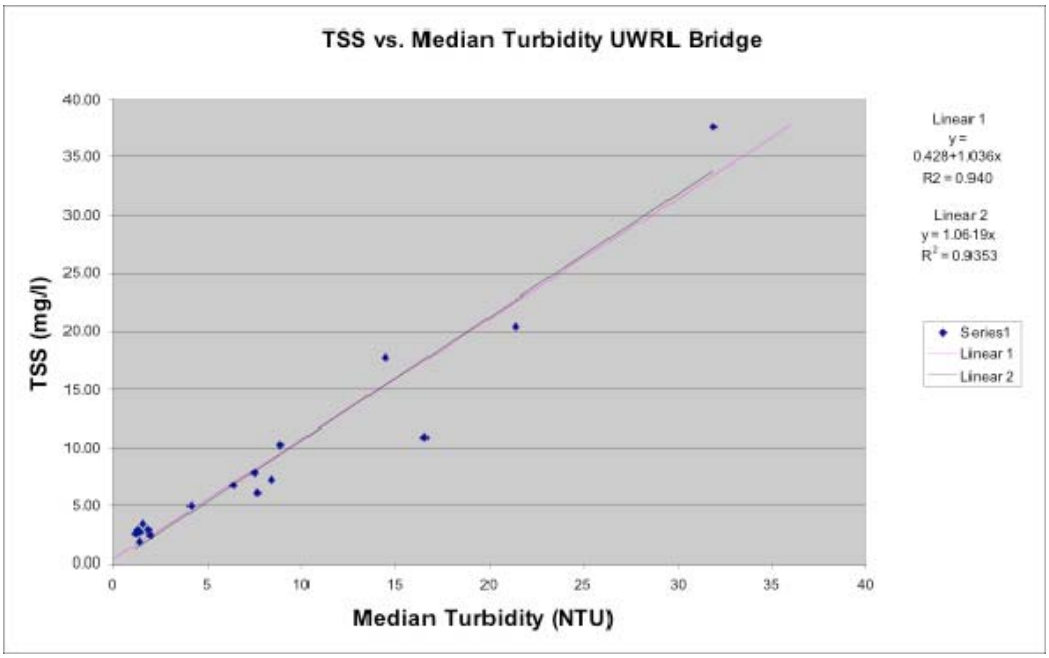


Figure 6: TSS Versus Turbidity Relationship for Conditions at the UWRL Bridge

Most owners of small dams in Utah will not have large amounts of money that they can spend on additional requirements for reservoir operations. In terms of BMP effectiveness, the project was designed to identify those sediment management options that could be feasible at First Dam without incurring huge additional expense in reservoir operations. The philosophy in this approach is that owners and operators of these small facilities in the state will not embrace sediment management protocols if they cannot afford them. With this in mind, the project has identified monitoring and laboratory analyses that are minimal in extent and cost, that could be initially implemented with help that is readily available from private local consultants, and that, with minimal training, could be maintained by the dam operator.(In the case of the real-time monitoring program for First Dam and the associated field data collection and laboratory analyses that were needed to generate the suspended sediment-turbidity curves illustrated in Figure 6 and the other rating curved, e.g., stage versus flow rate, the total equipment and laboratory costs were approximately $15,000. With better knowledge of what is actually needed and with the falling cost of monitoring equipment, these costs could likely be somewhat reduced in applications at other reservoirs.) This is proving to be effective in the case of First Dam, wherein the owner/operator has taken ownership of the sediment management system and now works annually to implement effective sediment flushing/sluicing activities. In this regard, the BMP as applied at First Dam appears to be effective. This will only be fully testable at some future time when serious maintenance requirements will once again require that the reservoir at the dam be de-watered, however.

Surface Water Improvements

It should be understood that, on average, the sediment management practices employed at First Dam will not produce better water quality. In fact, during brief periods of sediment flushing, water quality will be slightly worse downstream of the dam. However, when conducted following the rules of monitoring and management that are set out in the First Dam sediment management plan, these sediment releases will not cause harm to downstream fisheries or water users. Further, by reducing the rate at which sediment accumulates in the reservoir, less sediment will be released when serious maintenance efforts are required on the dam, thus resulting in less concern for the potential damage to downstream resources.

Quality Assurance Reporting

Both a Quality Assurance Project Plan (QAPP) and a Sampling and Analysis Plan (SAP) were prepared and implemented for this project. Procedures detailed in the QAPP for assuring the basic components of accuracy, precision, completeness, representativeness, and comparability were closely followed. This included:

- Detailed rules for sample handling and custody;
- QA/QC procedures, including identification of outlier data, implementation of corrective actions, repetition of the analytical batch, calibration controls, and so forth;
- Use of appropriate analytical methods, instrument calibration frequency, and so forth; and
- Data reduction and reporting requirements, both in written and electronic form.

Procedures described in the SAP were also closely followed. These focused on river quality sampling, and on monitoring sediment mobilization during flushing/sluicing events. The sampling process design addressed stream flow monitoring through the use of USGS gauge facilities above First Dam and the installation and maintenance of a real-time gauge at the Utah Water Research Laboratory below the dam; river quality sampling, including issues of location, number, and frequency of samples for temperature, pH, DO, turbidity, and laboratory determination of total suspended sediments, both throughout the year on a periodic schedule to assess ambient river conditions, and, more intensively, during flushing/sluicing events. Sampling methods requirements, as specified in USEPA (1986) and APHA (1988), were followed. All water quality parameters, with the exception of TSS, were measured in-situ. Sample handling and custody requirements, both for the field and in the laboratory, were addressed through the use of field logs, field tracking reports, and laboratory notebooks. Analytical methods requirements were met following USEPA (1986) and/or APHA (1998). Quality control measures implemented for both field and laboratory activities included:

- matrix spike duplicates and matrix spikes,
- blanks,
- laboratory check samples,

- instrument set-up procedures, and
- calibration requirements and procedures.

Instrument calibrations and frequency followed standard operating procedures, including the use of calibration logs.

PUBLIC INVOLVEMENT AND COORDINATION

State Agencies

Over the course of the project, state agency involvement was sought and received from the Utah Department of Environmental Quality, and, in the Department of Natural Resources, the Utah Division of Water Rights, the Utah Division of Water Resources, and the Utah Division of Wildlife Resources. Representatives of these agencies facilitated outreach opportunities, provided valuable information on important aquatic species in the Logan River, and gave frequent and thoughtful recommendations on how to conduct and monitor flushing/sluicing activities at First Dam.

Local Governments and Other Groups

Local groups involved in the project included irrigators and related water users groups, such as the operators of local canal companies and the Logan River Commissioner. These people provided input regarding timing of flushing/sluicing events and agreed to targets that limited turbidity levels that could be allowed during such events. The operators of First Dam were heavily engaged in the project, especially during flushing/sluicing events when they had to manage the hydraulic structures on First Dam in order to address sediment release targets. Numerous faculty at the Utah Water Research Laboratory also participated in the project to provide guidance in sampling protocols and conduct laboratory analyses consistent with the project QAPP and SAP, to measure reservoir bottom sediment distributions, and to assist in understanding the hydraulic limitations of First Dam. Representatives of the local chapter of Trout Unlimited helped in designing the monitoring program for sediment flushing/sluicing events and in understanding the major fish species that were the principal targets of protection during these events.

Other Sources of Funds

Matching funds were provided by the Division of Wildlife Resources in the Utah Department of Natural Resources, the Facilities and Planning Unit of Utah State University, and the Utah Water Research Laboratory and the Vice President for Research at USU. Total matching funds, not counting in-kind match from Trout Unlimited and faculty at the Utah Water Research Laboratory, was $97,510. In addition, the Utah Water Research Laboratory will continue to support monitoring costs for flushing/sluicing events at First Dam on an on-going basis.

ASPECTS OF THE PROJECT THAT DID NOT WORK WELL

A key component of the project that slowed the work in the initial few years was the requirement to negotiate the schedule for sediment flushing/sluicing activities with local water users. The owner of First Dam has a junior, non-consumptive water right on the Logan River. Releases from First Dam must be scheduled so as not to interfere with the more senior water rights held by downstream irrigators. In combination with these legal water rights restrictions, further constraints on when sediment flushing/sluicing can be done are imposed by the biotic requirements of downstream fish species. For example, downstream irrigators would not be opposed to sediment flushing/sluicing during non-irrigation periods, such as in November when flows in the river are low and when flushing would be more hydraulically efficient. However, during these periods various fish species are spawning, and would be negatively affected if increased sediment concentrations were to be placed into the river by reservoir flushing activities. As a result, the period during the year when flushing/sluicing could be allowed was restricted to a very short time during high spring runoff conditions. Even during this period, flushing/sluicing was seriously constrained by water quality conditions imposed by downstream irrigators before they would agree to flushing/sluicing activities at First Dam. Superimposed on these organizational issues were a series of low-flow drought years that generated unusual flow conditions on the Logan River and limited the extent to which flushing/sluicing experimentation could be done. These difficulties were eventually overcome, in part by extending the period of the project contract to allow for more opportunity to work with local water users and to capture a better sampling of annual flow conditions on the river. However, these sorts of issues will no doubt arise in other locations in the state when reservoir operators attempt to conduct controlled flushing/sluicing activities.

A less serious problem encountered during the project was with regard to the intent to evaluate sediment toxicity and, more importantly, the value of this information in managing sediment flushing/sluicing activities in real-time. Initially, it was thought that better data on the constituents of sediments deposited in the reservoir at First Dam could yield valuable information on the potential toxicity to fish should those sediments be released. This information, in turn, might be useful in designing sediment flushing activities. This proved to not be the case because of the limited control over releases that is possible with the outlet works that are part of First Dam. As a result, the weight of sampling and monitoring activities was shifted entirely away from reservoir sediments in favor of greater attention on real-time monitoring of in-stream water quality conditions during flushing/sluicing events. Further, maximum aeration was achieved when flows in the Logan River were high enough by simultaneously releasing water and sediments through low-level outlets and passing water over the spillways on the dam. This generated significant turbulence and aeration of anoxic sediments (see Figure 7), thereby increasing dissolved oxygen concentrations and minimizing the deleterious effects of sediment on downstream fish populations.

FUTURE ACTIVITY RECOMMENDATIONS

Lessons learned during the course of this project will be of potential value to owners and operators of small reservoirs and who must contend with the issue of deleterious impacts on downstream resources of sediment releases, and future work should be aimed at information and outreach needs in this area. In addition to this, however, the experience gained during the research for this project has identified possible areas in state water quality policy and standards that should be reconsidered in the light of their implications toward sediment management. Finally, there are additional experiments that could be conducted at First Dam that could generate valuable information about sediment management options if local water users could be persuaded to allow them to be conducted. Recommendations for possible future activity also focus on these issues.

Figure 6: Use of Spillway Releases to Aerate Discharge from the Low-Level Outlets on First Dam (shown on the spillway on the left)

Information and Education Outputs

The guidelines for sediment management in small reservoirs that have been prepared by this project will be posted on a web site managed by the Utah Water Research Laboratory, along with the sediment management plan that has been prepared and implemented for First Dam. These materials, along with other supporting information and data that continue to be used on a real-time basis to improve the management of First Dam, should serve as useful educational devices for managers of small run-of-river facilities in Utah.

Importantly, personnel who have served on the project will continue to work with the Utah Department of Environmental Quality to assist the future NPS Task Force Hydromod Sub-committee in revising and upgrading the state NPS Management Plan for Hydrologic Modification. Lessons learned over the course of the project with respect to the technical procedures for flushing/sluicing sediment, for monitoring and managing sediment release activities, and for maintaining a sediment balance for the reservoir will be of potential value in this regard. So, too, will be the lessons learned with respect to the necessary interfaces between dam operators, other water users, and state regulatory agencies. Of particular value, perhaps, will be the experience gained during the project with the very real physical results of sediment flushing/sluicing activities and the water quality regulations in Utah that, if rigidly enforced, present serious limitations to what might actually be possible in managing sediments in small reservoirs. The following section briefly addresses this issue.

Evaluation of Water Quality Laws Hindering Sediment Management

Utah water quality regulations place strict limits on the amount by which turbidity can be allowed to increase in the stream. Utah limits the allowable increase in turbidity to no more than 10 NTU above background levels. Further, total suspended solids may not exceed 90 mg/l (Utah Administrative Code, R317-5-14). In consideration of the biotic requirements of downstream aquatic life, these standards are far too strict when applied to sediment flushing/sluicing activities. By these standards, a flushing/sluicing event anywhere in the state will be in violation of state law because the turbidity will almost certainly rise above the 10 NTU incremental limit. This is an issue that should be addressed by water quality enforcement agencies if sediment flushing/sluicing is to be allowed as a tool for managing reservoir sediments in protection of downstream fisheries. Currently, the state doses not require a permit for flushing events. However, terms and conditions could potentially be included in the body of stream alteration permits and/or sediment management plans to address these concerns. It should be noted that the 10 NTU incremental limit is extremely prohibitive to flushing/sluicing plans, especially when such events can be conducted with confidence that they will not produce serious consequences for downstream users or fish populations. Researchers at the Utah Water Research Laboratory will be available to participate in future discussions of these issues.

Future Experiments

Continuous stream flow and turbidity data collected both above and below First Dam during the course of the project indicate that significant spikes of sediment are sent down the Logan River as the result of storm events. This is the cause of most of the “spikey” behavior illustrated for the month of April in Figure 5, for example. These spikes create very much the same sort of turbidity/TSS behavior shown by the flushing/sluicing event illustrated in Figure 4, and can happen during various periods of the year during which fish are spawning and farmers are irrigating. However, these natural sediment spikes cause no significant adverse damage to downstream aquatic resources or irrigators. It should be possible to conduct more frequent but small sediment flushing events at First Dam during these periods that would mimic the sediment spikes that are normally seen as the result of natural storm conditions, and to do so without endangering downstream aquatic communities or causing harm to irrigation facilities. Further,

should it be possible to conduct flushing events that mimic natural storm conditions, it might be possible to both sluice sediments during spring and summer storms, as well as mobilize additional bottom sediments during clear-sky conditions. It is recommended that the feasibility of these experiments be explored with local water users.

APPENDIX

1. "Guidelines for Sediment Flushing and Slucing of Small Run-of-River Dams in Utah"by Mac McKee, Director and Lizzette Oman, Research Engineer, Utah Water Research Laboratory, Utah State University, Logan, Utah. June 2010.

2. "A Proposed Sediment Management Plan for First Dam on the Logan River near Logan, Utah" by Lizzette Oman and Mac McKee, Utah Water Research Laboratory, Utah State University, Logan, Utah. June 2020.