REVIEW OF UTAH'S 319 NONPOINT SOURCE PROGRAM

PART II: ASSESSMENT OF BEST MANAGEMENT PRACTICE IMPLEMENTATION, MAINTENANCE AND EFFECTIVENESS

Prepared for
Utah Division of Water Quality

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1 INTRODUCTION

Nonpoint source (NPS) pollution remains a significant public policy concern in the State of Utah. In contrast to pollution from point-sources (e.g., factories or sewage treatment plants), NPS pollution is diffuse, originating from a wide range of small sources dispersed across the landscape. In Utah, the most common agents of NPS pollution are sediments, nutrients, heavy metals, salts, and pathogens (UDEQ 2010).

The dispersed character of NPS pollution presents challenges for efforts to address pollution problems because large numbers of actors are involved and changes made by each individual may not be significant enough to noticeably improve environmental conditions. A major focus of NPS pollution control is the development of public programs to encourage voluntary changes at the landscape scale in individual behaviors thought to contribute to documented water quality problems.

Utah's efforts to address NPS water pollution problems have been guided by the 1972 federal Clean Water Act and supported with federal funds under Section 319(h) of the CWA program allocated to states by the U.S. Environmental Protection Agency (with an additional 40% nonfederal match for both staffing and program support provided by the state). Since 1990, the state NPS program has expended almost $30 million to address water quality problems (UDEQ 2009). More than half of these funds have gone to watershed projects that typically involve cost-sharing, technical assistance, and educational programs to encourage landowners to implement appropriate best management practices (BMPs) to reduce pollution loadings to impaired waterways.

Evidence suggests that public efforts to reduce NPS water pollution in Utah have been successful. A comprehensive water quality monitoring program tracks current conditions and water quality trends for all 14,250 miles of rivers and streams, and nearly 3,000 lakes and reservoirs in Utah (UDEQ 2009). State agency assessments suggest that 30% of Utah's waters have impairments that prevent them from meeting their expected uses (UDEQ 2006). Nevertheless, a detailed assessment of the impact of public 319-funded projects have had on measured water quality has yet to be conducted in the state.

Our team was contracted by the Utah DEQ in the fall of 2010 to carry out a "critical assessment of Utah's 319 program administration and activities, and assessments of the impact, effectiveness and long-term maintenance of a scientifically valid and representative sample of 319-funded NPS BMPs in Utah."

This effort included three core objectives:

- Objective 1: Evaluate efficiency and effectiveness of Utah's NPS Program.
- Objective 2: Assess the water quality impact and effectiveness of representative 319-funded projects.
- Objective 3: Assess long-term maintenance and impact of representative 319-funded projects.

For the first objective we analyzed program records and interviewed 319 program administrators and staff to assess the overall design and implementation procedures associated with the Utah 319 program. The methods and results of Objective I are included in a companion report (Review of Utah's 319 Nonpoint Source Program. Part I: Program Administration and Operation).

This document focuses on the Objectives II and III. We selected representative watersheds that had received substantial funds from the Utah 319 program over the last 20 years. These watersheds are described in Section 2.

As per our contract agreement, analysis of BMP impacts focused on five types of BMPs:

- Animal waste practices
- Irrigation practices
- Upland grazing practices
- Rural stream projects
- Urban stream projects

The 319 projects in each selected watershed included at least 2 types of BMPs. We randomly selected particular projects in each of these watersheds to study in more detail. In total, this provided a scientifically valid and representative sample of the targeted 319-funded NPS BMPs in Utah.

In Section 3, we describe the fieldwork and modeling activities we used to determine the impact, effectiveness and long-term maintenance of these 319-funded NPS BMPs. We used a combination of methods, including collection of secondary data, interviews with 319 project recipients, field observations of BMPs, and modeling of BMP effects at the watershed scale.

Section 4 provides a discussion of our results. Complete reports can be found in Technical Appendices I-III. Section 5 summarizes our findings, and provides a set of conclusions and recommendations for ways to improve the efficiency and impact of the Utah 319 program.

2 DESCRIPTION OF STUDY WATERSHEDS

2.1 Beaver River

The Beaver River flows through a large, open landscape in southern Utah, running out of the mountains, through the town of Beaver and several other smaller towns, until emptying into the Minersville Reservoir. Many small tributaries contribute to the Beaver before it reaches the reservoir. The watershed includes large areas of irrigated agriculture croplands and pasturelands. . Although dairy farming was of considerable agricultural importance in the past, it has declined in recent years. Beef and hay production are major components of the agricultural sector in the watershed. The Beaver River is a flashy system, with considerable variation in flows after rain storms, and the river and its tributaries are completely dewatered at times as a result of diversions for irrigation usage.

The Beaver River Watershed project first received EPA 319 funding in August 1994, with the last projects completed in September 2009. Most funding was provided and projects implemented in the early 2000s. A total of 32 landowners received 319 funds to implement water quality BMPs.

According to the Beaver Soil Conservation District's final report (BSCD 2009:4), excess sediments, phosphorus and nitrogen came from multiple nonpoint sources, including uplands, eroding stream banks, irrigated land s and animal operations. The report concludes that "The net effect from these pollutants was deterioration in the quality of water in the Beaver River, its tributaries and the Minersville Reservoir." Irrigation, streambank, upland, and animal waste projects were all examined in the Beaver. The projects were dispersed in time and space over a very large area surrounding the river, including on highly erodible land in the nearby hills.

We obtained information about 319-funded projects with the cooperation of staff at the UACD office serving the Beaver area, which is located in Panguitch, out of the watershed, and is not housed with the local NRCS office.

2.2 Chalk Creek

Chalk Creek is located in a relatively narrow mountain valley in northern Utah. Chalk Creek contributes to Echo Reservoir, and ultimately drains to the Weber River. Land uses in the watershed are primarily agricultural, with dispersed homes throughout much of the area as well. The river is used for irrigation withdrawals, but runs year-round. Many producers in Chalk Creek keep livestock in the area during the winter months, utilizing federal grazing allotments or other pastures during much of the rest of the year.

The original 319 project was initiated in 1990 and extended until 2004. The primary focus was reducing sediment and phosphorus inputs into Echo Reservoir. The reservoir functions as a sedimentation basin but when it is drawn down, sediments and associated phosphorus are released into the Weber River downstream (Green 2005:4   Green (2005:4) reported that the Chalk Creek project appeared to have reduced total phosphorus loads in the river, but there was no significant sediment reduction.

According to Green (2005:5) , “the major goals of the project are to improve the overall quality of water within the watershed to meet state standards for the designated water uses by reducing the amount of sediment, animal waste and nutrients that enter Chalk Creek and Echo Reservoir, develop the fishery of both Chalk Creek and the Echo Reservoir to achieve their potential for fish production, reduce the sediment delivery from Chalk Creek to Echo Reservoir by achieving long term stability of stream channels, and stream banks, and provide protective cover to rangeland, and inform and educate the public concerning the causes of water quality problems and the need for everyone's involvement to solve these problems.”

Most of the project work was implemented in the late 1990s and early 2000s, although some projects continue to the present. Efforts have focused on restoration of eroded streambanks and stream channels, improving riparian area conditions, shifting from flood to sprinkler irrigation, and improving rangeland conditions to reduce sediment erosion (Green 2005).

A large coordinated irrigation project implemented in 2003 also involved numerous small farmers along the lower reaches of Chalk Creek. Most projects were conducted on the main stem of Chalk Creek, with some additional work on one major tributary.

Information about projects was obtained initially through the cooperation of staff at the local USDA Service Center in Coalville, where UACD and NRCS employees work closely together on projects.

2.3 Jordan River

The Jordan River flows from Utah Lake northward, through the wide, urbanized Salt Lake Valley, ultimately discharging into the Great Salt Lake. A number of streams originating in the mountains to the east drain to the Jordan River, although many of these streams are channelized or piped as they move through the urban areas. Much of the Jordan River is also channelized, with very little agricultural lands or open space in the immediate vicinity of the river. The hydrograph is highly regulated, and driven by storm events and releases from Utah Lake.

Numerous streambank stabilization projects have been implemented along the river, although project staff indicated that none were directly funded with UDEQ 319 funds. Most of these projects were managed out of the offices of Salt Lake County and other local municipalities. Because we were asked to evaluate urban riparian projects, we deviated from our focus on 319 projects in this one watershed.
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2.4 Middle Bear River in Cache County (mainstem and Cub River)

The Bear River originates in the Uinta Mountains in Utah, flows north into Wyoming and Idaho before returning to Utah, ultimately flowing into the Great Salt Lake. The Middle Bear River watershed includes all lands draining to the river from Alexander Dam in Idaho to Cutler Dam. This study encompassed the Utah portion of the Middle Bear's watershed. This area includes forest service lands to the east, with a mix of agricultural lands and towns in the valleys. Agricultural activities include numerous dairy operations, and dryland and irrigated pasture and croplands.

Two areas in the Middle Bear have received 319 funding to implement agricultural BMPs: the Cub River watershed and drainage near the mainstem Bear River near the towns of Amalga and Benson. Work in both areas began in 2000 and was completed in 2009. The goals for both projects were to reduce high levels of phosphorus and sediment and improve dissolved oxygen concentrations in the Bear River and Cutler Reservoir. Other identified concerns in the Amalga-Benson area include temperature modification and E coli bacteria in the waterways.

Efforts in both these sub-watersheds include reducing nutrient and sediment loads from animal feeding operations, improving pasture and upland management, and stabilizing the river's riparian corridor (Bowcutt 2009:4 and 2010)

The majority of time and 319 funding in both watersheds went toward improved storage and management of animal waste, as well as changes in fencing and watering facilities to allow the removal of livestock from streambanks and riparian areas. Most of these 319 projects, however, were animal waste management projects initiated since approximately 2003.

We obtained information from both the NRCS and UACD staff, who share an office building and work closely on project management, funding, and file management.

2.5 San Pitch

The San Pitch River runs through a wide agricultural valley with numerous small towns scattered throughout it. The river is almost completely de-watered during most of the summer, at times fed only by flows from shallow springs, which appear to be at least partially fed by irrigation return flows. There is very little reservoir storage in the area, so stream flows are heavily dependent on snow pack and rain events.

Issues of concern in this watershed include increased salinity arising from irrigation return flows as well as natural sources, nutrients entering from animal feeding operations and associated with sediments in runoff, and sediments from various sources, ranging from pasture runoff to mass wasting in canyons.

The 319-funded conservation projects were largely implemented between 2003-2010. The majority of the projects focused on streambank and irrigation issues.

Information about 319 projects was obtained with the assistance of staff at the local UACD office, which is housed with the NRCS in the USDA field office in the southern part of the valley.

2.6 Upper Sevier

This project focused on the Upper Sevier watershed, which incorporated lands draining to main stem of the Sevier in the Panguitch area, and lands draining to the East Fork of the Sevier River in the vicinity of the town of Antimony. The Upper Sevier near Panguitch runs through open agricultural land and near the town of Panguitch. The East Fork is confined to the narrow Black and Kingston Canyons. The mainstem river's hydrograph is much more variable than that of the East Fork, which is fed primarily from Otter Creek and Tropic reservoirs.

Identified water quality issues in these reaches include high phosphorus and sediment loads. These stressors have impacted stream habitat and dissolved oxygen concentrations in 3 eutrophic waterbodies: Otter Creek Reservoir, Piute Reservoir and Panguitch Lake as well as Navajo Lake, which is also downstream.

The 319 projects in these areas have focused on improving fish habitat through restoration of stream and riparian areas and reduction of pollutant runoff from livestock and nearby pastures. (Dodds 2011). The Sevier 319 projects were implemented in two phases, 2005-2007, and 2007-2010. These included a number of extensive but patchily dispersed stream projects along both the South and East Forks of the river.

The UACD office serving the Upper Sevier area is located in a building across the street from the USDA Service center, and only minimal coordination has appeared to take place.

3 METHODS

3.1 Selection of Watersheds

Our original proposal (Summer 2009) to the Utah DWQ was based on the assumption that detailed information about all 319-funded best management practices was available and sorted by watershed. We planned to use this information as the basis for selecting watersheds and specific BMP implementations for more intensive study. The tracking data for 319 project contracts and individual landowners was, in reality, inconsistent or incomplete. Also local watershed offices were reluctant to disclose detailed information about individual landowner conservation contracts and activities. We then turned to annual reports from the UDEQ to the USEPA for each of the major watershed projects to determine the types and extent of 319-funded BMP projects across the state. While inconsistent in the level of detail about individual landowner projects, our inventory based on these reports provided sufficient information to select 6 watersheds for more intensive study.

The six watersheds chosen are described in Section 2 (Figure 1). The categories of BMPs that were the focus in each watershed are:

- Beaver (Beaver County): Animal waste, upland grazing, irrigation
- Chalk Creek (Summit County): Rural stream, irrigation, upland grazing
- Jordan (Salt Lake County): Urban stream
- Middle Bear ((Cache County): Animal waste, upland grazing
- San Pitch (Sanpete County): Irrigation, rural stream
- Upper Sevier (Sevier County): Rural stream, irrigation

For the 5 rural or mixed watersheds, we created an integrated spatial database of watershed scale information from secondary sources (such as physical geography, water monitoring sites, land ownership and land use, etc.) and created template maps for each of these watersheds to use in our fieldwork and modeling efforts.

The assessment of urban stream BMPs differed significantly from the other BMPs. While all these urban stream BMPs were located along the Jordan River, they had mainly been implemented by local municipalities, and none were funded by 319 grants. Because private landowners were not involved in most projects, we adopted a unique approach to collecting data in this watershed – with interviews focused on project managers in city and county offices, and field assessments focused on publicly owned land. As a result of these differences, the urban BMPs in the Jordan River watershed are evaluated and discussed separately from the other BMPs in Section 4.1.5.

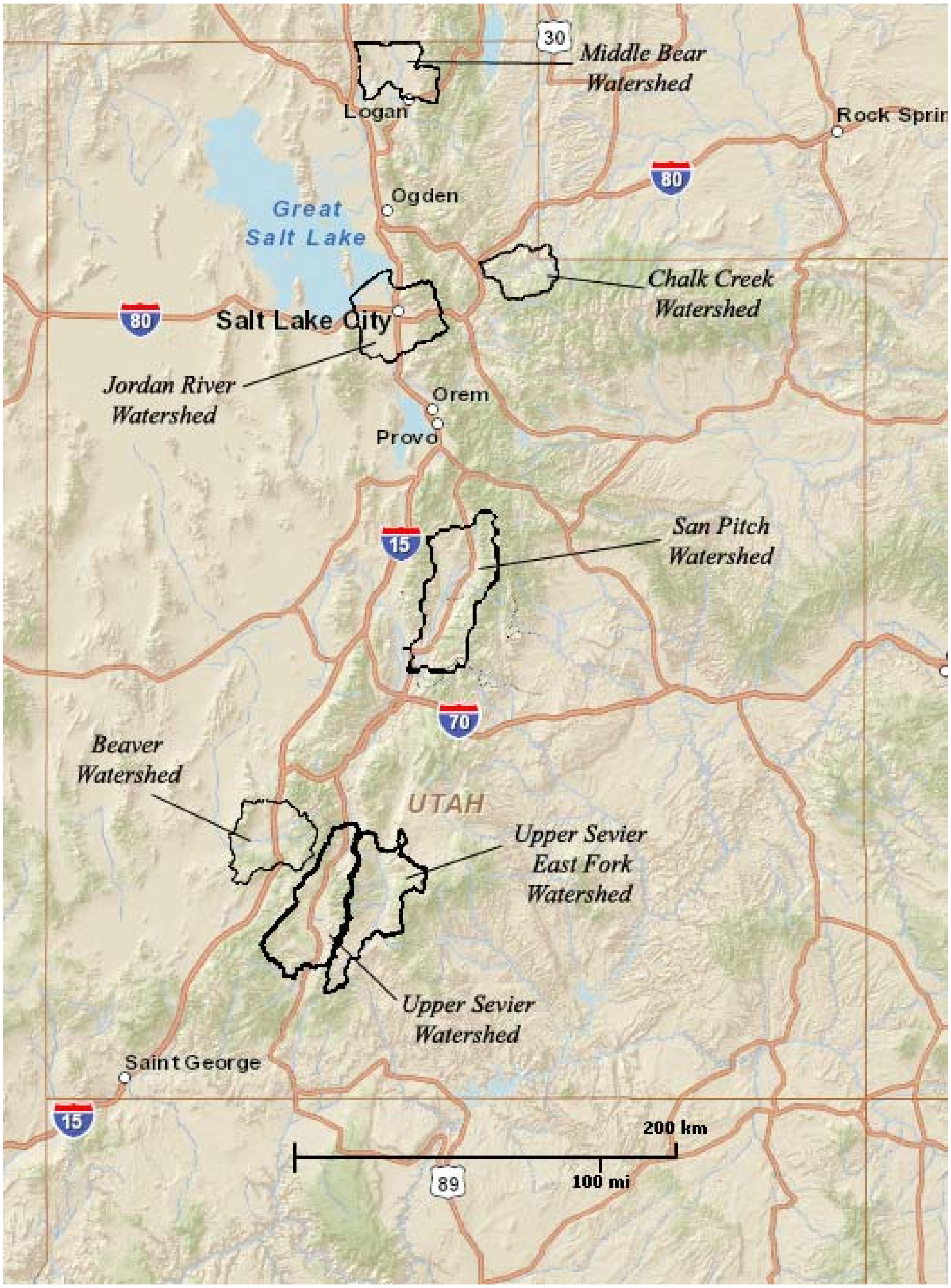

Figure 1: Map of Selected Study Watersheds

3.2 Local Files Review and Selection of Individual BMP Projects

We used local conservation office files and annual reports (from NRCS field offices or local Conservation District offices) to create a detailed database of 319-funded projects. 319-funded BMP project information at the local level is usually found in files that also include information about conservation projects funded by the NRCS. The NRCS is prohibited by law from releasing information about the names, locations, or types of practices to the public. We secured formal agreements with the State Director of the NRCS to allow our project team to review files (with a requirement that we maintain the confidentiality of individual-level information). We received this formal memorandum of understanding from the USDA/NRCS office in October of 2011. It was only at this point that we were legally able to initiate review of conservation program files and initiate contacts with local landowners and project participants for interviews and fieldwork.

Our systematic review of the local conservation office files allowed us to identify the types, locations, and collaborator contact information for the full set of 319-funded conservation projects. This process allowed us to also identify some additional 319-projects that were not discussed in the annual reports, as well as remove from our sampling frame projects that (according to the local file records) were either mischaracterized or did not receive any 319 funds. We selected at least 14 instances of each type of BMP from across the full suite of study watersheds to use as case studies for more intensive study.

Using the complete list of 319-funded project recipients (and BMP types) for each watershed, we conducted a systematic random sample within each BMP type category to identify people to contact for on-farm interviews. The criteria for selecting individual BMPs for intensive study involved (a) whether or not the project received any funding from the 319-program, and (b) whether or not the project was a type of BMP for which the watershed had been selected.

Anticipated numbers of 319-funded BMPs by watershed and our final targeted number of interviews by BMP type, are summarized in Table 1A. Initially, we estimated the numbers of projects in each watershed by BMP type based on tables and information present in annual reports for each project. We adjusted some of these numbers after visiting field offices to verify project details in individual landowner files. We used these adjusted BMP counts to generate a target sample size by watershed and type of BMP (Table 1B).

Table 1: Revised BMP Cooperator Sampling Plan for Interviews, by BMP type and Watershed

1A. Best Estimate of Total 319-funded BMP Projects in Watershed (based on annual reports and file reviews)

	Animal Waste	Irrigation	Rural Stream	Upland grazing	Total
Chalk Creek	-	8	12	11	**31**
Cub & Amalga/Benson	24	1	4	5	**32**
Beaver	4	9	8	11	**32**
San Pitch	1	15	6	11	**33**
Upper Sevier	-	8	16	1	**25**
Total	**27**	**41**	**46**	**39**	**153**

1B.

	SAMPLING TARGET - INTERVIEWS				
	Animal Waste	Irrigation	Rural Stream	Upland grazing	Total
Chalk Creek	-	1	6	1	**8**
Cub & Amalga/Benson	9	-	-	3	**12**
Beaver	4	3	4	3	**14**
San Pitch	-	6	3	4	**13**
Upper Sevier	-	3	4	1	**8**
Total BMP projects	**13**	**13**	**17**	**12**	**55**

	COMPLETED INTERVIEWS				
	Animal Waste	Irrigation	Rural Stream	Upland grazing	Total
Chalk Creek	-	3	7	4	8
Cub & Amalga/Benson	9	-	-	3	12
Beaver	5	4	4	2	10
San Pitch	2	6	4	4	10
Upper Sevier	-	3	5	1	9
Total Interviews*					49
Total BMP projects	**16**	**16**	**20**	**14**	**66**

** = Seventeen interviews were done on farms that had implemented multiple types of BMPs.*

3.3 Summary of Methods

A core part of our approach involved site visits with individual landowners who had participated in 319-funded projects in each of the selected watersheds. We relied on interviews with project participants and a visual assessment during field tours of projects for all five types of BMPs. Additional methods used to assess BMP implementation, maintenance and effectiveness varied by the type of BMP studied (see Table 2). In the case of both rural and urban streams, we utilized historic ground-based photographs to carry out repeat photo comparisons across time. For rural streams, we also explored evidence from historic aerial photographs and evidence of instream changes in fish habitat suitability. For animal waste projects, we also compared field observations with project file information about estimated nutrient load reductions that had been calculated by 319 project staff using the Utah Animal Feedlot Runoff Risk Index (UAFRRI).

Finally, we developed watershed scale hydrologic models to simulate the impacts of all four types of 319 project BMPs on nutrient and sediment loadings in rural watersheds. These models allow us to examine the sensitivity of the watershed to BMP implementation (e.g., the total estimated change in pollutant loadings under best-case implementation scenarios) as well as evidence of whether 319 BMPs were effectively targeted toward the most vulnerable areas in the watershed.

Table 2: BMP Impact Assessment Methods Used in Analysis, by BMP Type

METHOD	Animal Waste	Irrigation	Upland	Rural Stream	Urban Stream
LOCAL FILE REVIEW	●	●	●	●	●
INTERVIEWS	●	●	●	●	●
FIELDWORK					
Field visual assessment	●	●	●	●	●
Repeat photo comparisons				●	●
Proper Functioning Condition (PFC)				●	
Historic aerial photography				●	
Fish habitat suitability analysis				●	
WATERSHED MODELING					
Sensitivity analysis	●	●	●	●	

3.4 Interviews with Recipients of 319-funded Conservation Projects

Interviewers utilized a semi-structured interview approach (Jackson-Smith et al. 2010). Interviews were conducted by at least 2 members of our research team to provide opportunities for efficient note-taking and cross-validation of the information. The interview focused on the landowners' experiences working with the 319 project staff, and elicited detailed information about BMP implementation and maintenance experiences. We also probed during interviews for evidence (from the landowners' perspective) of BMP impacts on targeted water quality objectives. A copy of the interview instrument is located in Appendix 1.

In a few cases, we discovered during the interview that a particular selected project needed to be reclassified into a different BMP category (e.g., a pipeline that was originally considered an irrigation project, but was actually installed to transport spring water through a corral to avoid picking up livestock manure, thus was reclassified as an animal waste project).

The interviews served as a useful basis for direct evaluation of BMP success, but also provided a starting point for more intensive fieldwork to assess BMP condition and impacts (described below). Following each interview, a systematic narrative summary of the answers to our questions were produced by one member of the interview team, and then checked for accuracy and completeness by the second member of the team. Interviews were often integrated with a field reconnaissance to visually assess BMP implementation, maintenance, condition, and impact.

The youngest person we interviewed was in their early 30's, and the oldest were in their 80's. Most names in the project files were male, so we began by contacting this particular individual to set up an interview. We often were directed to another individual to interview (perhaps someone with more current information about the status and performance of BMPs), and frequently interviewed spouses and members of older or younger generations at the same time.

We did not collect systematic or extensive demographic information on the individuals we interviewed. However, we spoke with a wide variety of individuals. Most were full and part time farmers, but we also discovered project cooperators who were homeowners with streamside property but no agricultural activities, and agency employees in charge of projects on public lands. These represent the range of landowners who typically work on watershed conservation projects.

3.5 Field methods

In addition to interviews with landowners or land managers, we also gathered site specific information about the different BMPs to make a visual determination about whether a particular BMP had been effectively implemented, maintained and had resulted in the desired impact on receiving waters. Because of the diversity of BMPs, we utilized a range of methodologies in different combinations at each location. The formal procedures used with each method are described below.

3.5.1 Field Reconnaissance (conducted for all BMPs)

Each interview was typically accompanied a survey of the property with the landowner or operator to review the locations, conditions, and visual evidence of impacts associated with 319-funded BMPs. These walking tours provided important insights and were summarized in written narrative documents following each interview. These narrative documents were then used as raw data to support cross-project synthesis and discovery of generalized patterns.

Animal Waste

We located files for all animal waste management projects, either in the NRCS offices or in the local CD offices. During animal waste project interviews, we identified the different components of the larger project, and their location relative to receiving waters and other important landscape features. We identified project elements that were not documented in the project files. We were not able to visit or identify all sites where manure from the project was spread or stored. Therefore, we only collected brief, key, anecdotal information on field spreading practices, and focused our efforts on understanding direct runoff potential from corrals, milking parlors, and other livestock holding facilities.

The Utah DWQ project reports for each of the watersheds often included calculations of load reduction estimates for many animal waste projects. These models include the Utah Animal Feedlot Runoff Risk Index (UAFRRI), and Utah Manure Application Risk Index (UMARI), and EPA's Spreadsheet Tool for Estimating Pollutant Loads (STEPL). The original input data for these calculations was only available for four of the animal waste projects we evaluated, and only in the Middle Bear watershed. For these four projects, we conducted one extra site visit and attempted to validate the model assumptions and assess the basic validity of the results.

As noted previously, the extensive information required to validate the assumptions of the UMARI (manure field spreading) model was beyond the scope of the in-person site-visit interview format. Therefore, the inputs into the UMARI calculations (such as acreages, distance from water, crop types, etc.), were not attempted to validate the assumptions of that model.

In addition, the data that went into original pre-project UMARI calculations was largely unavailable. STEPL was used in many watersheds to estimate pollutant loads. Most watersheds used this model for non-animal waste projects, but STEPL also contains standardized calculations for animal waste projects. We did not use STEPL information or find examples of STEPL being used to calculate nutrient load changes from animal waste projects.

Irrigation

When speaking to individuals about irrigation projects, we asked them to help us understand the project as a whole, not just their portion. Our assessment of irrigation projects was based primarily on interviews and associated field visits.

When addressing irrigation projects during the interview phase, we sought to confirm or correct the information from the project files, understand the spatial location of the irrigation changes in relation to relevant impaired water bodies in the watershed, and learn from the landowner how they viewed the project. We asked about conditions prior to project implementation and any relevant water quality concerns (such as topsoil loss or tail water from saturated fields) and whether the landowner felt that the project had met its water quality goals. We also probed further to determine whether associated management changes (such as implementation of an irrigation plan) had been followed, and whether that could have influenced the effectiveness of the irrigation projects' water quality goals. In most cases, we were shown the fields that had been converted to a new irrigation type, and were able to visually assess the slope, potential runoff paths, proximity to the river, and other locally relevant factors.

Upland

During upland project interviews, we strove to understand how the projects had contributed to water quality improvements, whether maintenance of behaviors or infrastructure might contribute to the long term effectiveness of the practice, and how the project had been perceived by the landowner or operator – both from a water quality and from a utility point of view. In some cases, we were able to visit the location of the projects and assess the projects first hand. In the majority of cases, however, the general location and current situation was only described, leaving us to interpret the landowner's presentation of the projects without our own independent viewing. This reliance on operator's interpretation created greater uncertainty for upland water-quality-improvement projects than for other types of BMPS.

Rural Stream Projects

During the streambank restoration project interviews, we assessed the extent and effectiveness of the project while ascertaining the benefit to operators. We asked about conditions prior to project implementation and whether the landowner felt that the project had met its water quality goals as well as any perceived benefits to the operator. We also discussed implementation and maintenance challenges, recommendations for future projects, and overall satisfaction of the program. During site visits, we were able to gain an appreciation of the level of success of each project. Through the interview process, we strove to isolate the factors that determined a given project's success or failure.

3.5.2 Repeat Photo Comparisons (utilized for both rural and urban stream BMPs)

Project files for several of the watersheds had extensive archives of photographs documenting field conditions before, during, and after the implementation of riparian / stream (and a few other) BMPs. Whenever possible, we used these historic photos as reference points, and took repeat photos at all possible (or identifiable) stream BMP locations.

The historic photo archives tended to be very uneven in quality, were often not initiated until BMP construction work had already begun, and were not always easy to locate in the field (e.g., GPS location information was often missing and/or not accurate).

Following procedures outlined in the published literature (Carsteson and Hocker 2006, Newman and Swanson 2008, Ripple and Beschta 2004, Webb, Boyer and Turner 2010), the photos were organized into matched sets per photopoint location for analysis. We constructed sets of matched photographs of stream BMPs at 70 distinct photopoint locations across 27 projects. Several projects had more than one photopoint with repeat images. A total of 195 photos were used, with between 2 and 7 photos at each photopoint location.

The sets of matched photos were given to three raters who independently made qualitative observations and for each time period ranked the condition of the riparian zone, the bank structure, and the stream channel. They also ranked the overall impact of the project on combined conditions. Rankings were based on a 1 to 5 scale, where 1 = much worse, 2 = a little worse, 3 = neutral or mixed, 4 = a little better, 5 = much better.

To validate the reliability of the qualitative ratings, we compared the degree of consistency across the three raters. The results demonstrated a high degree of consistency. Among the three raters, their scores for any single set of photo point images varied by an average less than 1 point, and over 85 percent of photopoint locations received ratings that varied by one point or less.

3.5.3 Proper Functioning Condition Scoring (for rural riparian / stream BMPs)

We conducted instream and near-stream assessments of a subset of stream reaches, using the Proper Functioning Condition technique, developed jointly by the USFS, BLM, and NRCS (See BLM Technical Reference 1737-15, 1998). This technique is often conducted with landowners as an educational tool to learn about stream structure and function. It can also be used as an iterative tool, allowing comparisons from one date to another. In this case, we did not have initial (or pre-project) data so were not able to make comparisons. We were, however, able to use these as a subjective measure of the status of each reach, and were able to compare different reaches in a river.[1]

We conducted PFC surveys on 4 projects in Chalk Creek, 3 in the Upper Sevier, and 4 in the San Pitch. We had landowner permission in all cases. This provided us with a sample containing a wide range of project types, ages, and levels of success (as determined from the preliminary interview results).

Interdisciplinary teams, with a minimum of three individuals from different relevant disciplines conducted each reach analysis. One team member was in attendance at every PFC to provide consistency of analysis. The team walked the full reach of the landowner's property along the river, a distance ranging between 0.25 and 2 miles. Although specific project work, such as barbs or plantings, was not necessarily done on the full length, we chose to assess the overall condition of the landowner's stretch of stream, particularly since it was frequently unclear exactly where work had and had not taken place in the past. In all but one instance, the landowners were not present for the PFC, but provided the team with explanations of property boundaries to ensure the accuracy of our location throughout the day. After the team had fully walked the length of

[1] At the same time, we did not have the resources to systematically conduct PFC assessments on untreated or 'control' reaches of river in the areas around stream projects. This limits our ability to make strong claims that PFC results are uniquely attributable to the implementation of stream BMPs.

river, all members convened to review the 17-question analysis sheet (See Table 3) and decide via consensus on each ranking.

Data Collection and Analysis

PFC surveys attempt to assess the condition of a stream with respect to different functional categories (hydrology, vegetation, and erosion/deposition). The ratings are qualitative and made by team consensus. Each reach was also assigned to one of four functional categories: Proper Functioning Condition, Functioning-at-Risk with an upward trend, Functioning-at-risk with a downward trend, or Nonfunctioning. Determinations of the direction of trend were done via visual inspection of risk factors, and assisted by review of pre-and post-project photos which were available as printouts during the PFC assessment walk. In one case, one person owned a particularly long stretch of river which was clearly divided between a project area and an upper section that had not received any work due to very different conditions. We only present the results from the PFC on the lower section relevant to the 319 project work.

No comparable pre-project data was available for the sites where we conducted field analysis.

Table 3: Evaluation criteria used to determine Proper Functioning Condition scores.

HYDROLOGY

1) Floodplain above bankfull is inundated in “relatively frequent” events
2) Where beaver dams are present they are active and stable
3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)
4) Riparian-wetland area is widening or has achieved potential extent
5) Upland watershed is not contributing to riparian-wetland degradation

VEGETATION

6) There is diverse age-class distribution of riparian-wetland vegetation (recruitment for maintenance/recovery)
7) There is diverse composition of riparian-wetland vegetation (for maintenance/recovery)
8) Species present indicate maintenance of riparian-wetland soil moisture characteristics
9) Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high-streamflow events
10) Riparian-wetland plants exhibit high vigor
11) Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows
12) Plant communities are an adequate source of coarse and/or large woody material (for maintenance/recovery)

EROSION/DEPOSITION

13) Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody material) are adequate to dissipate energy
14) Point bars are revegetating with riparian-wetland vegetation
15) Lateral stream movement is associated with natural sinuosity
16) System is vertically stable
17) Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)

3.5.4 Fish Habitat Assessment

Many of the 319-funded BMP projects included goals for riparian and fish habitat improvements in addition to improving water quality. We used several methods to evaluate evidence of rural stream BMP impacts on riparian and fish habitat outcomes, including contemporary field habitat assessments and an analysis of historic biological monitoring data collected by other agencies.

Our ability to evaluate BMP effectiveness was limited by a lack of information about stream ecological condition prior to project implementation. Available data from the project sites were largely qualitative (e.g., photographs and anecdotal accounts). When available, quantitative data were often patchy in time and space. Because current ecological conditions may represent only one stage along a trajectory of recovery or degradation, determining long-term trends (past and future projection) was not possible without multiple data points in time. The spatially patchy data also restricted our ability to determine whether observed conditions are due to local- or watershed-scale influences.

Recognizing these limitations, we assessed current ecological conditions and past trends at four rural stream BMP sites in the Chalk Creek watershed. We utilized all available pre- and post-project data from a variety of sources to assess the physical and biological conditions of the Chalk Creek watershed, with a focus on habitat suitability for the threatened Bonneville cutthroat trout (BCT). Chalk Creek is an extremely important watershed for Bonneville cutthroat trout (BCT) conservation efforts, containing one of the stronger and larger metapopulations within the fish species' historic range. As a tributary to the Weber River, Chalk Creek and its tributaries are designated as 3A: protected for cold water game fish and the aquatic life necessary to support these fish. Our assessment of Chalk Creek also serves as an example of how a field monitoring program can be paired with basin-wide data to aid in evaluating BMP effectiveness in a larger watershed context.

We collected and analyzed historic aquatic and riparian habitat monitoring data from sites on or near the selected BMP project locations. We used frequency distributions of monitoring data from sites throughout the Southern Rocky Mountain region to assess the condition of habitat variables on Chalk Creek with respect to regional norms. We also evaluated fish population status in Chalk Creek using biological monitoring data collected by state and federal wildlife agencies between 1970 and 2002 at several sites throughout the watershed. Past data used in this study were collected using U.S. EPA Environmental Monitoring and Assessment Program Western Streams (EMAP-West) data, and fish population data collected by the Utah Division of Wildlife Resources (UDWR). Both the EMAP monitoring site and one of the UDWR sites (Section 02 Low) were located downstream of the field sites. Remaining UDWR sites (Section 02 High and Section 03 Low, Middle, and High) were located upstream of the field sites.

In November 2011, we also collected primary data during baseflow conditions on several 200 m-long stream reaches at each of four 319-funded stream BMP locations to assess fish habitat conditions. Data were collected at 20 cross-sections per reach and 12 points per cross-section on particle size distributions, streamflow discharge, water quality, benthic macroinvertebrates, and evidence of micro-habitat (substrate, flow depth, flow velocity, overhead cover, and habitat unit type). We used these data to evaluate site-scale habitat quality by comparing measured physical parameters in 2002 and 2011 to criteria defined by the cutthroat trout habitat suitability index (HSI) (Hickman and Raleigh, 1982). More technical details about our methods are available in the full report (Technical Appendix II).

Given the time- and cost-intensive nature of these efforts, we were not able to conduct this type of analysis for all watersheds under study. Rather, these results lend insight into BMP effectiveness in other watersheds with similar physical attributes, ecological characteristics, and project types. In addition, we compare the results of our efforts with those from less rigorous methods at the same sites to evaluate what level of monitoring intensity might be necessary to capture the effects of BMPs on ecological condition.

3.5.5 Historical Aerial Photography

We used landscape scale historic aerial photographs to evaluate temporal trends for three key indicators of stream condition: rates of lateral channel migration, channel width, and riparian area vegetative cover. These indicators were calculated for Chalk Creek, San Pitch and the Upper Sevier, watersheds where stream projects comprised a significant portion of the 319 efforts. We calculated each watershed as a whole (to use as a benchmark), and then separately for sections of the stream that either received or did not receive BMP treatments.

Our goal was to measure stream conditions at roughly 10-year intervals from the mid-20th century through the present. We obtained aerial photographs from several sources, including the U.S. Department of Agriculture Aerial Photography Field Office, the U. S. Geological Survey Earth Resources and Science Center, and the Utah State Geographic Information Database. Arc Info version 10.1 was used to georeference the aerial photographs and create a GIS for analysis of the study areas. See the full technical report (Technical Appendix I) for details on this process.

Analysis of Stream Channel Characteristics

Rectified aerial images were overlain to compute rates of lateral channel migration (LCM), as a proxy for bank erosion rates. Average channel width and the percent of riparian cover at different time steps in the record were also calculated. These are both important indicators of the proximate cause of lateral channel migration, but also were the main focus of many of the stream restoration techniques employed in these watersheds.

Rates of LCM were computed using the following steps. The left and right active channel boundaries were digitized. Using the newly created active channel boundary a centerline was created for the channel using ET Geowizards- an application which works in concert with ArcInfo to create an accurate active channel centerline. The active channel centerlines for each time step were then superimposed to define polygons that represented the area of floodplain that was eroded in each time period. Following the method of Micheli and Kirchner (2002), the average migration rate (m/y) for each eroded-area polygon was computed by dividing the polygon area by one-half its perimeter and then by the number of years elapsed between time steps. Mean annual LCM for the entire reach in each time period was taken as the average migration rate of all polygons in that time period; the number of polygons used in computing this average ranged from 23 to 175. Calculated polygons with annual migration rates smaller than image rectification error was considered undetectable within the range of expected error and were excluded from the calculation of average LCM for a given time period (Constantine et al., 2009). In this way, georectification error was incorporated into the estimates of LCM rates. Mean annual LCM for the entire reach in each time period was taken as the average migration rate of all polygons in that time period.

Active channel width (m) was calculated along the entire study reach at each time step by dividing the area of a polygon between left and right channel banks by one-half the perimeter of the polygon. Computed widths for each polygon were then averaged to determine the mean channel width for the study reach at a given time step.

To calculate the percent of riparian cover, a buffer around the active channel centerline was created. Buffer widths were 10, 20, and 25 m (for the San Pitch, Sevier and Chalk Creek watersheds, respectively). Within the buffer zone all margins of vegetation was digitized into a polygon. Each polygons area was calculated and summed and the ratio of vegetated area to total buffer zone was calculated.

The analysis focused on restoration/mitigation of river reaches along the mainstems and major tributaries of the rivers in each of the three study watersheds. Results of fieldwork conducted for the interviews (described above) were used to identify starting and ending points for river stretches that had received “treatment” using 319 project funds. Areas immediately upstream or downstream with similar geologic features where no known 319-funded work had been done were considered “non-treatment” reaches.

On Chalk Creek, a nearly continuous zone of analysis (including both treatment and non-treatment) areas was used ranging from Coalville, Utah upstream for roughly 14 kilometers. Because of the extensive stream work within the Chalk Creek watershed, the majority of the river sections studied were classified as ‘treatment’ areas. To protect the identity of project participants, the exact location of the analysis areas are not shown here.

On the both the Sevier and San Pitch rivers there were distinct analysis zones that were included in our analysis. For the analysis in the Upper Sevier watersheds, which encompassed a much larger spatial extent, the availability of imagery was not consistent across the study reaches. In the end, completed GIS coverage’s were developed from available aerial photographs taken in 1943, 1953, 1963, 1965, 1970, 1974, 1976, 1984, 1987, 1993, 2006, and 2011. Each focus reach had sub-reaches which were classified as either treatment or non-treatment locations. In the Sevier and San Pitch watersheds the non-treatment reach was equal to or greater spatially than that of the treatment reach.

The analysis focused on restoration/mitigation of river reaches along the San Pitch and Sevier rivers. For the purposes of succinct communication “treatment” reaches either had re-introduction of riparian vegetation or construction of stream bank protection while “non-treatment” reaches had no physical restorative techniques applied. On the both the Sevier and San Pitch rivers there were (5) and (3) **“reaches of focus”** respectively that served as separate zones of analysis. Within each reach of focus there were several sub-reaches had either treatment or non-treatment conditions. In all cases the non-treatment reach was equal to or greater spatially than that of the treatment reach. Furthermore, the non-treatment reaches were analyzed both upstream and downstream of the treatment reaches for better geographic contrast. Each reach of focus within the Sevier River was analyzed as a separate area and has its own set of images and associated dates of image acquisition.

3.6 Water Quality Trends and Watershed Modeling

We utilized information from the entire watershed to model the likely watershed-scale impacts of the full set of 319 funded BMPs on changes in water quality for the targeted pollutants of interest.

3.6.1 Historical Data Acquisition

Historical water quality data were obtained from a number of sources for this study. The primary database used was EPA's STORET database, to which the State of Utah has uploaded its water quality database through 2005. Additional data were obtained directly through the State of Utah Division of Water Quality and from a variety of TMDL reports for the various watersheds included in the study. References for those reports are provided in Table 4. For details, the reader is referred to those reports.

Table 4: TMDL Report References for Project Watersheds

Watershed	Year	Reference
Chalk Creek	1994	USDA. 1994. Chalk Creek Watershed, Coordinated Resource Management Plan. May, 1994.
Middle Bear River	2010	SWCA. 2010. Middle Bear River and Cutler Reservoir, Total Maximum Daily Load (TMDL). UT Div. of Water Quality. Feb. 2010.
Upper Sevier River/Otter Creek	2004, 2006	Harris, J., H. Judd. 2004. Upper Sevier River, Total Maximum Daily Load and Water Quality Management Plan. UT Div. of Water Quality. Aug. 2004. Cirrus Environmental Solutions. 2006. Otter Creek, Total Maximum Daily Load and Water Quality Management Plan. UT Div. of Water Quality, Harris, J., C. Adams. Aug. 2006.
San Pitch River	2003	Millennium Science and Engineering. 2003. San Pitch River Watershed. Total Maximum Daily Load, Water Quality Management Plan. UT Div. of Water Quality, Harris, J., C. Adams. Nov. 2003.
Beaver River	2000	UTDWQ. 2000. Beaver River Watershed. Total Maximum Daily Load, Water Quality Management Plan. UT. Div. of Water Quality. 2000.

3.6.2 Water Quality Data Analysis Summary

The full list of STORET monitoring stations and observation counts for flow rate, dissolved oxygen, total phosphorus, ammonium- and nitrate nitrogen, and total suspended solids are found in Tables 13 to 17 in Appendix III.

The data were imported into a SQL Server database housed at Utah State University for analysis and summary (waterdata.usu.edu). This section summarizes the historical data germane to this project: flow, dissolved oxygen, phosphorus, nitrogen, and total suspended solids, for purposes of study area assessment and for setting the historical context for the modeling results provided subsequently. The summaries are provided below by watershed. Only those monitoring sites for which significant numbers of observations (≥ 40) are available are included in the summaries.

Summary statistics for the data for each watershed for the monitoring locations with ≥ 40 observations, a list of stations analyzed for the watersheds, a table of number of observations for each parameter, and time series plots and histograms for each of total phosphorus, total suspended solids, ammonium-nitrogen and nitrate-nitrogen are all found in the full report in Technical Appendix III. The list of UDWQ STORET sites and the number of observations present in the database for each parameter (flow, dissolved oxygen, total suspended solids, total phosphorus, ammonia-nitrogen and nitrate-nitrogen) and for each watershed is provided in Technical Appendix 3. All statistical calculations are done using the statistical software R (Ihaka and Gentleman, 1996, R Development Core Team, 2008).

3.6.3 Selection of Modeling Approach

Although a number of models have been developed for assessment of nonpoint source pollution and the impacts of conservation practices (e.g., SWAT, SWMM, UAFRII, RUSLE, and StepL), these models have limitations that may constrain their use in specific instances. The primary concern with most models is that the original scope in their development, and the databases upon which they rely, was for wetter regions of the country with sustained flows and less 'flashy' rainfall-runoff relationships in lower elevation regions. These restrictions have led us in the past to development of a model that has a hydrological component heavily used in Utah-type landscapes (TopNET) linked to moderate scale empirically derived relationships between land use and concentrations of key constituents in runoff via an event mean concentration (Tarboton, 2002). The limitations of other models and the modeling approach used for this project are described in significant detail in Technical Appendix III.

3.6.4 Model Scoping

Sites and Maps

Table 5 summarizes statistics for the project watersheds that were used in the modeling portion of this project. Detailed watershed maps are provided in Technical Appendix III and show the delineated subbasins, 319 and other project locations, flow and water quality monitoring stations, stream courses and reservoirs, and other water-related features.

Table 5: Watershed information summaries for 319 rural watershed project sites

Item	Chalk Creek	Middle Bear River	Upper Sevier River	San Pitch River	Beaver River
Contributing watershed area (mi^2)	268	776	1,300	1686	521
Tributary/river miles (estimated)	100	2,000	300	300	200
Land use/cover					
Agriculture	3%	15%	3%	45%	7%
Upland Grazing	71%	78%	33%	17%	45%
Upland Forest	25%	5%	51%	36%	36%
Other[2]	1%	2%	13%	2%	12%
Elevation range, ft.	5,560 - 10,600	4,500 - 10,000	6,000 - 10,500	4,500-11,000	5,503 - 12,100
319 Projects assessed	26	29	26	27	34
Animal Waste mgmt.	x[3]	X	x	x	X
Irrigation improvement	X	x	X	X	X
Streambank restoration/ protection	X	X	X	X	X
Upland improvement	X	X	x	X	X

3.6.5 Modeling Description

Modeling Approach

The BMP assessment modeling used for this study has three primary elements: 1) system hydrology, 2) watershed land use-dependent response to precipitation events and aquifer conditions, and 3) response of stream/river water quality to loads from the watershed, including effects of local land use on runoff water quality. Each of these elements will be briefly described here; details are provided in the various references and in the Technical Appendix III.

[2] Urban, water, wetland, conservation, desert
[3] X = Major focus, x = minor focus

Components

We utilized **TOPMODEL** (Beven and Kirkby 1979, Beven *et al*. 1995, Bandaragoda *et al*. 2004) as the hydrology model for each of the watersheds. It was developed to address many of the limitations present in other hydrology models for mountainous regions with snowmelt-dominated runoff patterns. It requires that the watershed be delineated into distinct subbasins with known topography, soils, and land use/land cover information. Climatic records are then used to estimate evaporation, runoff, and base flows averaged over each subbasin. The subbasins are then connected to provide estimates of stream flow at key locations along river courses.

The **Watershed Response Model (WRM)** is then used to convert watershed runoff and base flow estimates to pollutant loads into watercourses from each subbasin. The runoff and base flow from each subbasin estimated from TOPMODEL is redistributed uniformly over the subbasin and land use, land cover, and soils information is used to estimate the constituent loads from each land use/land cover/soils combination, information that is either taken from the literature (e.g. Merriman, Gitau, and Chaubey, 2009), or by calibration to in-stream water quality data. These loads are then summed over each of the areas characterized by that combination to provide estimates of the total loads from each subbasin that are delivered to the receiving water.

Lastly, the flows, stream morphometry, upstream conditions, climate data, and subbasin loads are used to predict in-stream water quality conditions using a **River Response Model (RRM)** to estimate conditions from intermediate and downstream locations along the receiving water length. In this study, the Qual2E model (Brown and Barnwell, 1987) is used to predict in-stream conditions. Qual2E accounts for temperature, dissolved oxygen and biochemical oxygen demand (BOD), dissolved solids, the fate of nutrients (nitrogen and phosphorus), chlorophyll a, and bacteria, as well as three additional water quality measures defined by the analyst. To use QUAL2E in this context, the stream network is divided into links that connect junctions where the stream proper intersects a subbasin outlet. Each link, or stream reach between two tributaries, is represented by a QUAL2E input file that describes the physical setting, the hydraulics of flow, the energy balance for temperature calculations, reaction and mass transfer kinetics, point loads, and diversion flows. The link connections ensure the correct sequence of model calculations.

3.6.6 Data Used in Watershed Models

Conservation Practice Information

The purpose of the modeling effort was to estimate the impact of implementing conservation practices (practices) on water quality as a measure of the effectiveness of the 319 program. To do so requires information concerning the degree of effectiveness of particular practices at the farm scale, preferably in environments similar to those being modeled. Unfortunately, such information is lacking at the farm scale because of difficulties in assessing how well a particular practice at a particular farm affects water quality. It is only on an aggregate scale where a number of similar practices are in place that such efficiency estimates are possible.

The Natural Resource Conservation Service (NRCS) has catalogued over 160 agricultural BMPs and their effectiveness (Merriman, Gitau and Chaubey, 2009) taking into account the inevitable time lags involved from when the practice is implemented to when the improvements in water quality are realized. A large amount of variability in effectiveness in the literature makes numerical removed efficiency data difficult to characterize. A small database was constructed with estimates of conservation practice efficiency estimates for use in the model for each practice (summarized in Technical Appendix III). For model simulations, the database is queried for each study site and the pertinent nutrient load is reduced by the percentage from the database. Sensitivity analysis was used to address uncertainty in the BMP effectiveness inputs. For each conservation project in the study, GIS files were created based on information collected in our review of project files and the field interviews. This information was used to create a practice database that identifies the location and descriptive characteristics of each 319-funded practice.

Other Details

The major driver for runoff is precipitation and other climate-related data. Climate data for each of the sites was gathered from the Utah Climate Center at Utah State University (ref) and other sources (refs) for the time period from 1990 to the present for use in the model. Most climate-related data were daily averages, however some observations were on a more frequent basis and were averaged over each day for model use. Land use/land cover and soils data were obtained from the State of Utah statewide land cover dataset (State of Utah 2012). The event mean concentrations (EMC) associated with each land cover/land use were obtained from a database of EMCs built for an earlier project in the Middle Bear River (USU 2009)

3.6.7 Execution

The models were executed over a 15 year time period, using input information from 1990-2005, so that the effects of the conservation practices can be assessed over a variety of climatic and flow conditions. Precipitation and other climate data were used in TOPNET to estimate runoff, base, and river flows, those flows were applied to the land use/cover data on the landscape to determine the non-point loads to the river reaches, and the river response model was executed to the lower boundaries of the project watersheds to assess the impact of the practices on in-stream nutrient levels. Details of the model results are voluminous and are provided in Technical Appendix III.

4 RESULTS

4.1 Impacts of Different Types of BMPs

A major objective of this study was to assess the implementation, maintenance, and impacts of 319-funded BMPs on water quality outcomes. As noted above, we used multiple methods to assess different kinds of BMPs across all of our study watersheds. In this section, we begin by describing evidence for overall BMP implementation, maintenance and effectiveness by BMP type (based on our fieldwork in each watershed). Next, we present evidence of BMP impacts by type of BMP. Within each of those sections, we summarize results based on different methodologies separately. We conclude this section with an integrated summary that compares and merges results from different methods. Where appropriate, we make note of some important differences across watersheds within each BMP type. A separate section (5.2) is devoted to a full discussion of watershed scale modeling results.

4.1.1 Overall Implementation, Maintenance and Perceived Effectiveness

Our interviews suggest that, overall, efforts to implement BMPs across the five rural watersheds went relatively smoothly. Our interviews focused only on 319-program funded watershed BMPs that file records and project staff suggested had been successfully implemented in the field. As a result, we found very few instances where a project cooperator reported that the BMP had never been implemented. The only cases of 'non-implementation' related to management-oriented BMPs (like improved nutrient management, grazing management, or irrigation management) where it was not uncommon for interviewees to report that they had little or no recollection of receiving a plan or changing their management practices subsequent to installation of physical BMPs.

The producers did report a range of experiences relating to BMP implementation (Figure 2). While nearly half of all BMPs were implemented with no complications, a sizeable portion of BMP projects experienced at least minor implementation challenges. Most challenges were instances where design or engineering problems required significant adaptation and adjustment in the field to make certain that the BMP would work effectively. Other implementation problems reflected poor communication between program staff and project cooperators. These complexities are evident in the proportions of BMP projects whose implementations were described in mixed negative/positive terms. We discuss specific examples of implementation challenges in more detailed sections of the report below.

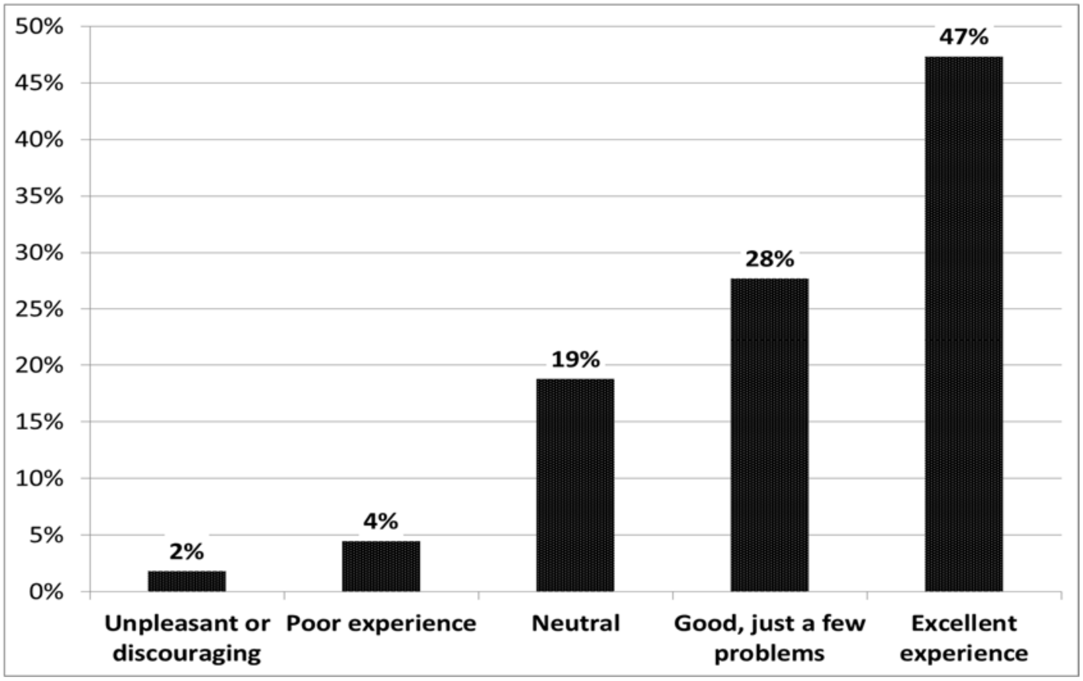

Figure 2: Percent of BMP Implementation Experiences Reported as Positive or Negative

The project cooperators in our interviews were also asked whether each BMP had a positive or negative impact on (a) their farming operations, and (b) water quality in the targeted water body. While we recognize that producers' perceptions are an incomplete source of information about both types of impacts, we did find some interesting patterns. Figure 3 shows the proportion of BMPs that were reported in our interviews as having a positive or negative impact on the farming operation and local water quality. The project cooperators, in total, felt that perceived over half of all BMPs had a clear positive benefit to the producer's farm operation. Another 26 percent of BMPs had slightly positive impacts on the farm. About a quarter of all watershed BMPs were seen having no net impact on the farm. Almost none of the BMPs were reported as having a net negative impact on the operation.

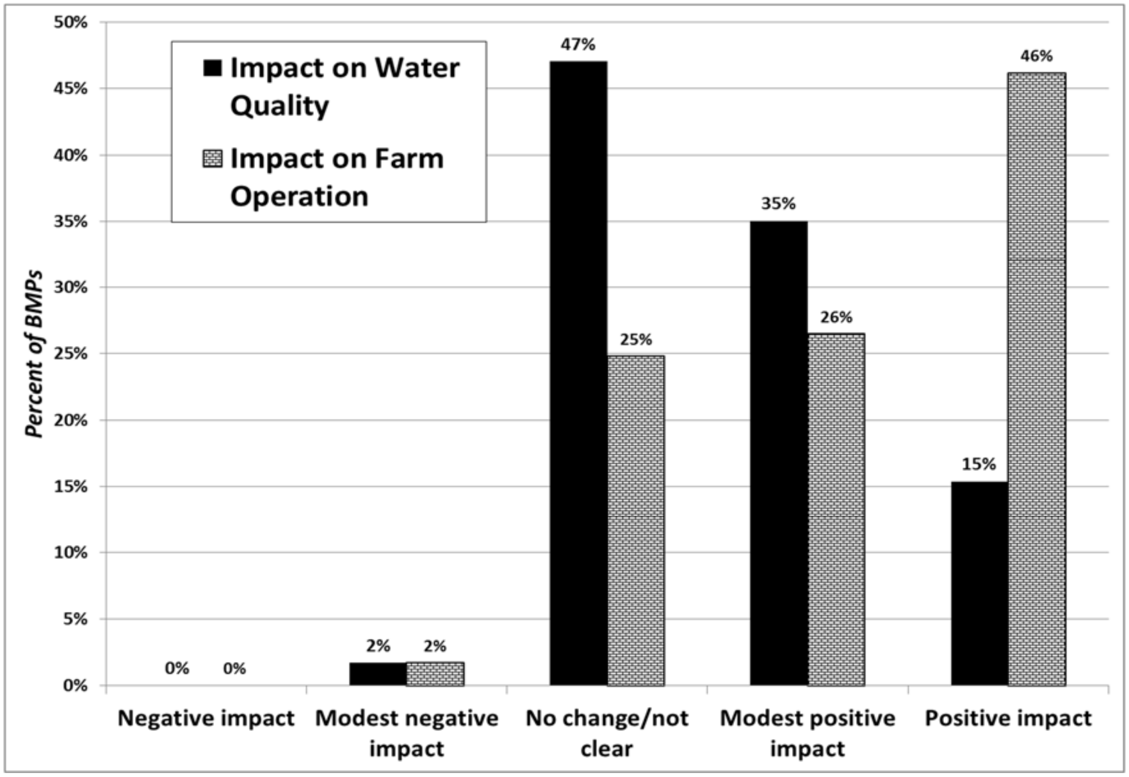

Figure 3: Percent of BMPs Perceived by Producers to have Positive and Negative Impacts on the Farming Operation and Local Water Quality

Project cooperators in our interviews were generally less likely to report a positive impact on water quality than on their operation. Only about one in eight BMPs were perceived by the respondents to have a notable positive impact on water quality conditions in the targeted water body. Another third of BMPs were perceived as likely to have had a modest positive benefit. For almost half of the BMPs, the producers did not see any clear evidence (pro or con) that the BMP had notably affected water quality in their watershed.

The levels of positive implementation experience and impacts on farming operations and water quality differed significantly by BMP type. Figure 4 shows the proportion of BMPs rated as somewhat positive or very positive separately for each of four broad categories of practices. Initially, it appears that irrigation and stream projects experienced the fewest problems with implementation (with 100 and 81 percent having positive experiences). The animal waste projects were the most likely to have implementation problems, with less than half described as being installed without any notable problems. Common animal waste implementation challenges are described in more detail in section 4.1.2 below.

As mentioned above, only about half of all BMPs in our study were viewed by project cooperators as having a noticeable impact on local water quality. Figure 4 disaggregates the producer perceptions of BMP impacts on water quality by different category of BMP. What is apparent is that positive impacts on water quality were most commonly reported for stream and animal waste BMPs, and least likely to be reported by recipients of irrigation and upland/grazing BMPs. In fact, less than half of the instances of the latter two categories of BMPs were seen by project participants as having an impact on the targeted water body.

Meanwhile, the vast majority of BMPs in the study were reported as having positive impacts on farming operations. Irrigation and upland projects were the most beneficial to cooperators, while stream projects were least likely to be associated with a positive impact (though nearly two-thirds of stream BMPs were seen as having a positive benefit to the farm).

The relatively high perceived benefits of 319 BMPs on non-water quality related outcomes is striking, especially when compared to notably lower rates of perceived impacts on water quality. This underscores the fact that producers tend to participate in voluntary watershed conservation programs mainly when the impacts of specific contracted BMPs include operational benefits in addition to environmental benefits (Jackson-Smith et al. 2011).

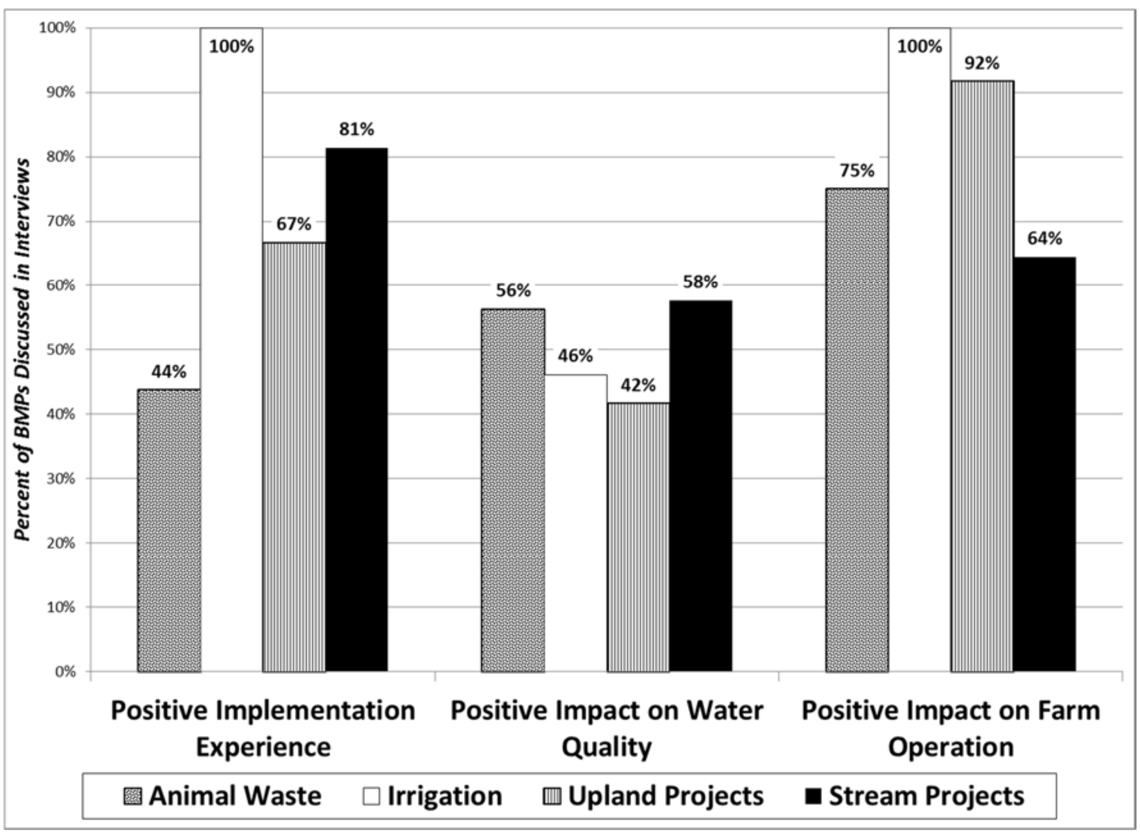

Figure 4: Percent of BMPs Perceived by Producers to have Positive and Negative Implementation Experience and Impacts on the Farming Operation and Local Water Quality, by BMP Type

In addition to producer perceptions of impacts, our field team made a qualitative assessment about the likelihood that water quality benefits resulted from each BMP implementation. The evidence for their assessment included a review of the project file, feedback from the producers during the interview, visual assessment of BMP conditions, and a site visit and walk-around (often supplemented by aerial photographs) to evaluate potential pathways for particulate or soluble pollutant and water movement.

The results of the field assessments are summarized by BMP type and watershed in Figure 5 and in Table 6. The field teams rated over half of all BMPs (51%) included in our study as having had a clear positive benefit to water quality, and another 9% with a likely positive impact. About a quarter of all BMPs in rural watersheds were considered unlikely to have resulted in improved water quality. This determination was usually based on the placement of the BMPs relative to the targeted water body. In other cases, BMPs designed primarily to accommodate other goals (such as irrigation efficiency) did not appear to always have an obvious water quality impact.

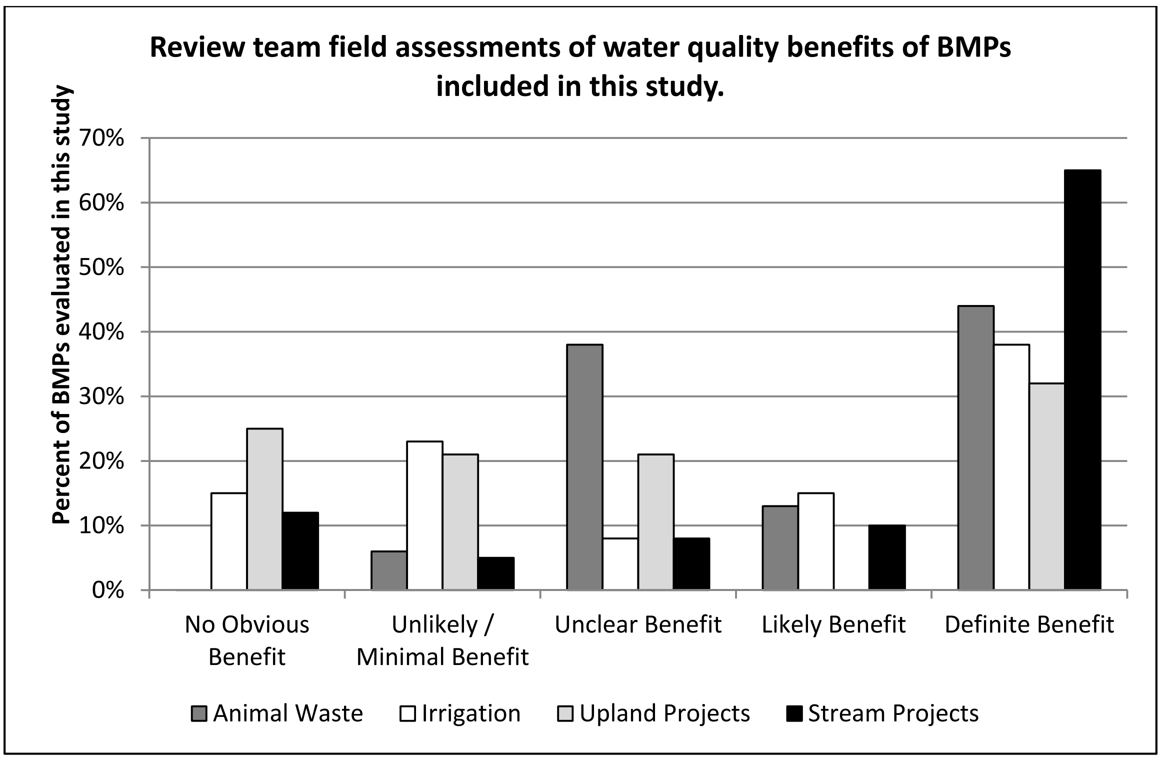

Figure 5: Field Team assessment of likely water quality benefits of BMPS included in this study.

Table 6: Summary Score from Interview Team Regarding Likely Water Quality Benefits of Individual Projects, by BMP Type and Watershed.

		Evidence of Positive Impact on Water Quality in Watershed				
Characteristic	**Projects Studied**	**No Obvious Benefit**	**Unlikely / Minimal Benefit**	**Unclear Benefit**	**Likely Benefit**	**Definite Benefit**
Type of Practice						
Animal Waste	16	0%	6%	38%	13%	44%
Irrigation	13	15%	23%	8%	15%	38%
Upland Projects	28	25%	21%	21%	0%	32%
Stream Projects	60	12%	5%	8%	10%	65%
(Subcategory)						
Plantings	20	15%	5%	15%	10%	55%
Riparian Fencing	16	6%	0%	0%	6%	88%
Rock Work	17	12%	6%	6%	12%	65%
Other	7	14%	14%	14%	14%	43%
Combined	117	14%	11%	15%	9%	51%
Watershed						
Watershed A	17	29%	6%	12%	12%	41%
Watershed B	25	12%	24%	8%	0%	56%
Watershed C	28	12%	8%	20%	24%	36%
Watershed D	25	10%	10%	15%	5%	60%
Watershed E	20	4%	7%	21%	4%	64%

4.1.2 Animal Waste BMPs

Types of Projects Examined

The 16 animal waste projects we visited and assessed all had similar goals of separating clean water runoff from animal waste and eliminating runoff of waste to target waterbodies. However, the projects varied considerably in design, implementation, location on the landscape, and other factors. Most BMPS consisted of improved animal waste management structures associated with active dairies. In several cases, animals were relocated from a riparian area. Three projects consisted of rerouting springs or irrigation ditches that had originally flowed through the feedlot or corral.

Table 7: Number of Animal Waste Project Interviews/Field Visits by Watershed

Watershed	Number of interviews
Chalk Creek	0
Middle Bear	9
Beaver	5
San Pitch	2
Upper Sevier	0

Data Sources

The majority of animal waste management projects appear to have received NRCS technical and engineering assistance. In these cases, project files included more comprehensive documentation of engineering plans and pre-project conditions. When Nutrient Management Plans were present, they were only found in NRCS files. When NRCS and UACD offices were housed within the same building (Chalk Creek, Middle Bear, and San Pitch), this was especially likely to be true. At CD offices located in separate buildings from NRCS field offices (Beaver and Upper Sevier), data on animal waste management projects was less reliable and contained less information.

Interview Goals & Challenges

During animal waste project interviews, we sought to assess the project goals, its relative location on the landscape within the watershed, and the relevance of that location to potential water quality improvement practices. Because each system is unique to the landscape of the local area and the history of a particular operation, getting key information in an efficient way that valued the producer’s time often presented a challenge. Those projects involving improvements to existing infrastructure required explanations from the farmer about how the system worked prior to the 319 project implementation. Gathering sufficient details to fully assess the effectiveness of efforts involving application of animal waste to nearby fields was outside the scope of our time-limited face to face interviews. As a result, we only collected brief, key, anecdotal information on field spreading practices, and focused our efforts on understanding direct runoff potential from corrals, milking parlors, and other livestock holding facilities.

Project Implementation Information

All of the animal waste projects involved structural changes in livestock holding and feeding areas. On most[4] of the projects, prior to BMP implementation livestock waste was not effectively contained on the property. Although vastly different in scope and implementation, these projects typically involved several major components:

- Concrete pads graded to facilitate manure scraping and direct drainage;
- Concrete bunkers & separators;
- Below-grade liquid collection tanks – usually concrete;
- Evaporation ponds; and
- Piping and pumps to move waste to designated areas

In addition, three projects included piping of irrigation water to prevent it from receiving animal wastes.

Operators' implementation experiences varied widely. Some operators took advantage of the 319 funding to expand or modernize their operations, while others viewed the projects primarily as a way to meet anticipated EPA requirements. Generally, the operators who saw a clear benefit both to their operation and to water quality reported the most successful implementation experiences.

The most common concerns the operators had about these projects was related to their engineering and design. Some examples include:

- Evaporation ponds – particularly in drier southern Utah – were much larger than the operators thought necessary. Concrete walls were designed to be 6-8" thick with extensive rebar, when the operator felt that 4" walls would have been sufficient.
- Pumps requiring the addition of 3-phase power were added to the design when the farmer felt that smaller pumps would have been sufficient.
- In some cases, manure storage areas had to be redesigned by the operator so that tractor access for scraping and piling manure was physically possible in the space allowed.
- The apparent NRCS requirement that only new equipment be purchased with cost-share funds was felt to unnecessarily increase costs. In these cases, operators felt that like-new equipment could was available, more appropriate for the project, and would have been less expensive.

The only other significant implementation challenge that arose during the interview process was from a non-dairy operator who was compelled to pipe an open ditch under his feedlot. When digging the trench to sink the pipe, the excavators found solid bedrock less than two feet below grade, requiring extensive blasting to create the channel for the pipe and dramatically escalating the cost of the project.

[4] Uncertainty in the actual numbers of operations is due, to a large extent, by the incomplete nature of many of the files. This varied from watershed to watershed but limited our ability to document prior conditions, particularly in the Upper Sevier watershed.

Otherwise, most operators were pleased with the process of the physical improvements, the reimbursement structure, and were largely able to continue normal operations during project implementation.

Ongoing Management

Manure management plans were included in most of the animal waste management projects, particularly those that presented the opportunity for changes in waste management techniques. Very few operators, however, specifically mentioned the formal plans when asked how the projects had impacted their management of livestock manure. Responses to the question "how has this changed your waste management?" ranged widely. Several dairy operators provided detailed explanations of waste spreading changes – how specific fields far from view but immediately adjacent to a river now received liquid waste unless it was too muddy to access the fields, for example. Others explained that the changes (often, an evaporation pond) had reduced liquid runoff leaving their property, but had changed nothing about how they managed solid wastes. Several dairy farmers noted that their neighbors' fields were less fertilized as a result of the liquids containment, and suggested that the neighbors now had less fertile fields. Several others explained that having to now actively spread liquids on pastures or crop fields rather than let them run off into adjacent water bodies, as had occurred previously, had created extra work for them. In one case, the operator was able to stop spreading liquids entirely, leaving his honey wagon rusting nearby. In short, the management response to installation of new waste management structures was extremely varied, and depended significantly on the individual producers' prior management system, the previous runoff conditions, and acreage and equipment available to the operator.

Assessing Impacts: Value to Producers

Producers had very mixed reviews of the value of animal waste management systems to their operation. Some appreciated reductions in demand on their time and/or long-term cost savings. However, not all projects were beneficial to the farmers' bottom lines; in many cases, the increased labor required to manage the new systems, the cost of the project, or both, created dissatisfaction with portions of the projects. The perceived avoidance of federal regulatory action was cited by many as a motivating factor for doing some projects.

The most common benefits to producers were:

- Decreased labor resulting from improved waste separation (all liquid and all solid waste is easier to handle than a slurry mixture of the two);
- Improved structures for waste pick-up/scraping that decreased labor needs;
- Cleaner corrals and general areas, which provided for general health and image benefits and improved neighbor relations.

Costs to the producers included:

- Increased labor spent pumping liquid waste in cases where liquids were previously allowed to flow off the property unmanaged;
- Increased labor and costs to keep electric pumps functional to move liquid waste ;

- Requirements to cover large upfront cost of the project;
- Time required for the producer to work closely with, and sometimes correct, designers of new structures, to ensure that the structures would be functional for the farmers;
- Separators and evaporation ponds reduced the amount of nitrogen available to operators to spread on their fields ;

In general, water quality improvement for its own sake was not a driving force in producer decisions to implement animal waste management projects. Although many producers appreciate the value of clean water generally, the perceived threat of federal regulation, plus the existence of current funding sources to address the problem proactively, was of primary concern to many of them. It did not appear that many of the projects would have taken place at the farmer's behest without those outside motivations.

Assessing Impacts: Water Quality Improvements

Based on farmer perceptions and our field reconnaissance, the water quality improvements from animal waste management projects appeared to vary widely. Effectiveness of projects at reducing nutrient loads appears to be most affected by the location of the project on the landscape and the quality of the engineering design. That said, management actions taken by the producers have the potential to greatly enhance or completely eliminate the potential water quality improvements from a project.

From a water quality perspective, we categorized animal waste projects into three broad categories.

- Clear (perceived) improvements: waste management system design and associated manure management practices that clearly reduced the flow of waste directly into impaired water bodies.
- Possible improvements: projects with locations and practices that might logically be able to improve water quality, but where additional data would be critical to confirming the outcome.
- Doubtful projects: Projects where water quality improvements are not likely.

Clear Improvements

In several of the situations, the likelihood of dramatic improvement was quite high despite the absence of numerical data to support these conclusions. For example, one 100-cow dairy we visited had originally only captured milk barn liquids. Manure liquids and solids had been simply pushed into an adjacent field. This had resulted in substantial drainage off the property and into a ditch system specifically designed to take local dairy wastes (and storm water) to the adjacent river. The producer used 319 funds to build a large evaporation pond which appeared to completely contain all milk barn and manure liquids. Although the dairy was more than a mile from the receiving water body, the original waste route was clearly identifiable. The producer explained that the volume of waste leaving this property had gone down to almost nothing, even in the very wet spring of 2011.

In a second, even more dramatic example, a dairy located less than 50 feet from a river had been designed with three underground drains that took the milking parlor and manure liquids directly from the corrals into the river. The 319 project adjusted his infrastructure to improve or add more liquids and solids storage areas, and rearrange flow paths on the operation so that the drains only contained fresh water overflow from watering troughs in the corrals.

Possible Improvements

The improvements on a majority of sites we visited were less certain. Although the project designs often appeared likely to reduce the flows of animal wastes to nearby waters, it was often unclear whether the project would have resulted in an actual water quality improvement. Uncertainty arose from two factors: project location and management practices.

For example, we evaluated two projects that were very similar except for their location relative to a receiving water body. One was immediately adjacent to a water body and the other was far enough from receiving waters that it was difficult to envision a pathway that the waste could have taken. It was particularly difficult to assess past flow paths (overland or subsurface) with confidence.

At another site, wastes originally flowed from the corral areas to a low spot in an adjacent field, where the liquids slowly evaporated. After the BMP project, wastes are more effectively separated onsite, and solids are captured and removed for spreading on other crop fields. However, liquid waste still flows to the same low spot in the field, where a natural clay base holds it. Although the pond is within several hundred feet of the river, there is no current overland flow path. In this and several other sites, management practices appeared focused on modifying phosphorus transport across the landscape, with little regard to nitrogen transport, which is typically more mobile in soils and groundwater.

In another category of projects, uncertainty about its impact stemmed from the lack of information available on the history of management practices. In these cases, onsite manure management practices had usually been clearly successful, but associated changes in manure spreading behavior were difficult to evaluate. For example, one medium-sized dairy had made major infrastructure changes that effectively contained almost all waste onsite until it was hauled away to be spread on fields. However, the closest (most convenient) field for spreading was the same field into which the waste ran previous to the project implementation. Finally, some of the operators interviewed indicated that pre-implementation runoff risks may have had a negative water quality impact in a "100 year storm event" where substantial rains or snowmelt would cause flooding that could wash waste to a riparian area. However, none of the operators had personally experienced these conditions. Therefore, improvements to these operations have a clear, but only hypothetical water quality impact.

Doubtful Projects

In we were unable to identify any obvious benefits to water quality from the BMPs. One project modified an existing manure storage system to expand storage capacity and make it easier to use. However, the associated changes in how liquids were managed appeared to simply result in mechanical spreading of liquids over a field which had previously received liquid overflow from stored manure. While the new system facilitates more careful management of manure applications, any net benefit would depend on changes in the rates, timing, and methods of application (which were not very evident on this farm). Moreover, a ditch that accumulated runoff at the low end of the field did not appear to have ever had any direct path to the targeted river. In this case, both the nature of changed management practices and the location on the landscape led us to doubt that the project had much chance to impact water quality in the targeted waterbody.

UAFRRI Model Application

All of the projects we evaluated that reported pollutant reductions based these on the UAFRRI model. The model is quite sensitive to its specific input parameters (e.g. area of operation, number of animals in operation, frequency of scraping, and weather conditions). However, documentation for this model was missing in most cases and the original input data for the model could only be found for 4 projects. Without clear management records, the actual impact of an operation as modeled by UAFRRI is impossible to determine. For example, Figure 6 shows UAFRRI predictions of total phosphorus runoff based on assumptions of scraping frequency. UAFRRI's runoff predictions are extremely sensitive to this frequency, which is a management decision that may vary widely throughout a year or with different operators. In the absence of any monitoring data verifying this assumption, the UAFRRI prediction of total phosphorus runoff should be considered unreliable.

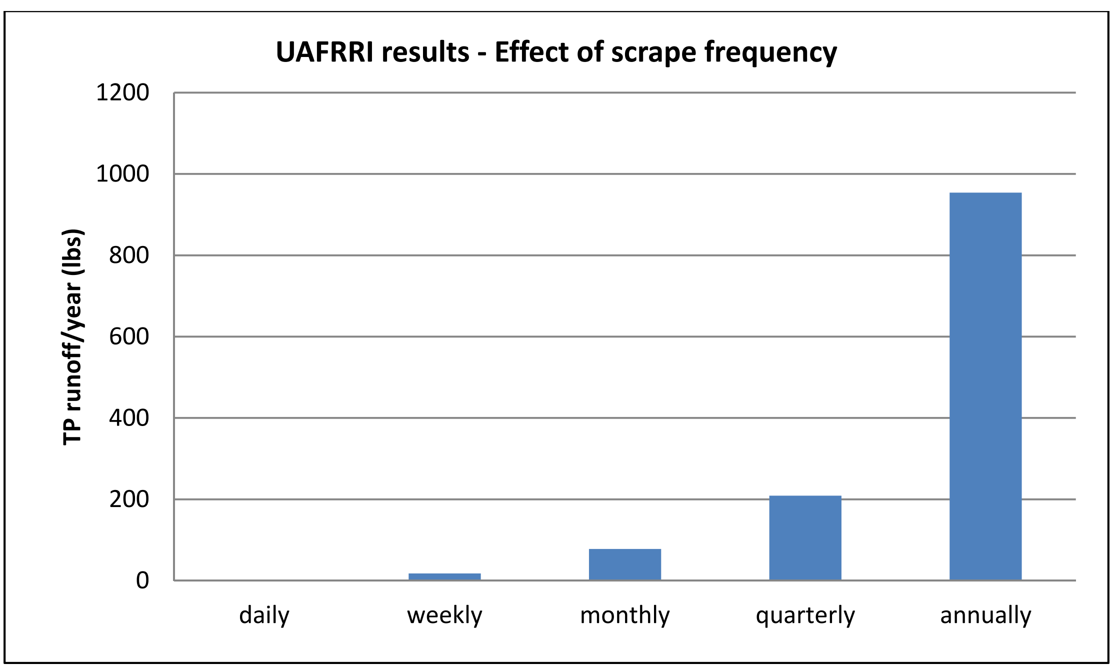

Figure 6: Total Phosphorus in runoff predicted by UAFRRI model. Everything was held constant except the assumed scrape and haul frequencies.

Animal Waste BMP Impact Summary

- All of the projects that were still in place and serving their intended purpose did contain waste. However, the actual water quality benefit of the projects to the watershed was not always clear.
- Operators who worked closely with engineers during the design process tended to have more successful projects both in terms of water quality improvement and ongoing management.
- Rarely was any type of data collected prior to project implementation, making quantitative water quality improvement assessment difficult.
- Documented use of UAFRRI to estimate project impacts was infrequent. Although final reports included UAFRRI calculations for almost every project, the original input data could only be found for 4 projects). When UAFRRI was used, original input data required for the model were not provided, making it difficult to determine reliable estimates of actual quantitative improvements.
- Animal waste projects in general have better documentation than other types of projects. This is likely due to the frequency with which multiple funding sources and NRCS engineers are involved with the projects. In general, more data was available for projects with substantial funding from other (e.g. USDA) sources and supplemental 319 funds.
- At least three dairy farmers were under the impression that the goal of the projects they were asked to do was simply to keep their runoff on-site or comply with EPA regulations. They had no idea that water quality in another water body was the reason for the project funding. Therefore, they accepted designs that achieved runoff containment even when they felt that the requirements were odd or meaningless for their operation.
- Surface movement of nutrient laden water (i.e., P) was the primary focus of the projects. If changes in water flow created increased infiltration (i.e., N), farmers did not appear to be aware or able to articulate this potential problem.

Animal Waste Conclusions/Recommendations

- Engineers should work more closely with reluctant operators to ensure buy-in and understanding of water quality goals, increasing the chances of project success
- In order to accurately assess actual water quality impact, better data needs to be 1) collected and 2) recorded it the producer’s file, prior to project implementation.
- Location on the landscape and actual flow paths need to be part of the calculations and assessments of project need and project impact in a way that does not currently appear to be occurring.
- Landowners need to fully understand water quality reason for implementations
- Assumptions about manure management that are used in nutrient reduction models need to be verified along with other operation and management checks.

4.1.3 Irrigation BMPs

Types of Projects Examined

All the irrigation projects we reviewed involved a conversion from one type of irrigation system to another. These included conversions from flood-to-gated-pipe, flood-to-pivot, flood-to-wheel-line, flood-to-K-line, and wheel-line-to-pivot projects. We examined irrigation projects in four of the five agricultural watersheds sampled (Table 8). Particularly in the southern Utah watersheds, storage ponds and pumps were a frequent component of the projects. Generally, irrigation projects were specific to individual farming operations. However, three of the irrigation projects we evaluated were part of much larger community or multi-family projects.

Table 8: Number of Irrigation Project Interviews/Field Visits by Watershed

Watershed	Number of interviews
Chalk Creek	3
Middle Bear	0
Beaver	4
San Pitch	6
Upper Sevier	3

Data Sources

Very little data about the irrigation BMP projects was available in the project files that we examined. In some cases, the only information were brief project implementation descriptions and receipts indicating lengths of pipe and other equipment purchased. Projects with no NRCS involvement had particularly sparse pre-project information, but even NRCS files had little or no data on pre-project conditions. The primary goal of irrigation projects was to reduce surface runoff from irrigation tailwater. Changes in the volume and quality of water diverted for irrigation use and the mechanism for how it returns to a river is, therefore, of critical importance. These data were not available to our team. Irrigation diversion volumes were usually discussed in the interviews by the operators in very qualitative terms (e.g. one quarter of the ditch every 18 days, regardless of what the flow in the ditch is). While this reflects how irrigation systems are actually managed, it makes it difficult to estimate the volumes of water flows pre- and post-project. Not having this critical baseline data makes assessment of the water quality impact of irrigation projects very difficult to calculate.

Project Implementation Information

With the exception of several major canal company irrigation initiatives that typically involved piping open ditches, most projects were a simple conversion to a more efficient form of irrigation. The vast majority of 319 implementations converted open flood irrigation to some sort of sprinkler system. However, some cases simply converted to gated pipe, resulting in a more controlled form of flooding.

The single-operator irrigation implementations were generally very straightforward. Only minor concerns emerged, such as operators' regrets about not taking more advantage of the 319 funding opportunities to convert additional fields or to upgrade to a pivot instead of a wheel line.

We also interviewed individuals involved in three expansive canal company projects. These projects involved thousands of feet of conversion from open ditch to pressurized pipe and, in one case, installation of a large supply pond. In one of the projects, a lack of buy-in among a small minority of the company shareholders affected the design and extent (thus, the potential water quality benefit) of the project. Ultimately, those shareholders who did not participate in the project cost share did not receive pressurized water from the project. Despite political and financing challenges all of these projects were considered successful by those interviewed. In one of these large projects, one of the operators involved felt that his portion of the project had been over-engineered and that smaller pumps and lines would have been more reasonable.

Irrigation Plans and Ongoing Management

In addition to the new infrastructure, irrigation management plans may also have been provided to the irrigators, but these were never found in the project files. Presumably, these would have included specific instructions on volumes, timing and distribution of irrigation water, as well as maintenance and other long-term management details. Regardless, in our interviews there was a notable absence of any mention of irrigation plans as an important element of irrigation management practices. Several irrigators recalled a discussion about irrigation practices during installation of the new systems, but none could recall having been provided with a specific irrigation plan. This could be because the plans were never provided. Alternatively, plans could have been provided but forgotten, either because the plan was never implemented or because the plan elements had been so fully integrated into system operations that the original document was forgotten. Because the project files did not include any management recommendations, we were not able to determine if original technical recommendations were being followed as intended. Only one producer made any mention of having been provided with any plan relating to his irrigation system. He explained that he had agreed to use the equipment on the ranch, and not sell it, but did not recall any instruction on irrigation rates or other water management.

Assessing Impacts: Value to Producers

Producers were almost uniformly enthusiastic about the benefits of their irrigation projects. The most common benefits producers mentioned were:

- Improved coverage of water across fields, which producers suggested allowed them to use less water
- Improved production in fields (both crops and pasture)
- Decreased labor requirements (in most cases)
- Increased control over timing and volume of irrigation water application

Other benefits, noted by a smaller portion of the interviewees, included:

- Improved water storage options, allowing irrigators more flexibility than infrequently timed water share allocations provided
- The potential to irrigate new areas, if this is allowed by their existing water rights.
- Less seepage loss from unlined canals (in those cases where open ditches were piped)
- One irrigation project reduced loading of water into a municipal water treatment plant that was previously exceeding the system's treatment capacity

In general, producer decisions to implement irrigation improvement projects did not appear to be driven by water quality improvement considerations. However, one producer did explain that the opportunity to improve irrigation was instrumental to his willingness to participate in other cost-share programs that improved his animal waste management. In several conversations, producers had difficulty recalling whether (or were surprised to learn that) a water quality program was the funding source for their irrigation improvements. One man changed his mind multiple times throughout the conversation as he tried to recall which of his pivots had been installed with 319 funding. After much consideration of years, costs, and who had been providing technical assistance, he finally settled on an accounting of the events that, in the end, did not reconcile with acreage totals from the files. Clearly, water quality improvement goals were not a significant enough component of project planning for the landowner to associate them with the project several years later.

One issue raised by several producers related to the choice between diesel and electric motors during the design process. Some operators reported not using their sprinklers when diesel fuel prices are very high, lessening some of the potential water quality benefits.

Assessing Impacts: Water Quality Improvements

The range of potential water quality improvements from irrigation work varied widely from project to project. We based our field assessment primarily on the probability that return flows had entered receiving waters before project implementation, compared to current conditions.

Using this approach, the projects we reviewed fell into several categories:

- Clear (perceived) improvements: irrigation design and practice that clearly reduced return flows directly into impaired water bodies;
- Possible improvements: projects with locations and practices that might logically be able to impact water quality in the impaired water body, but where additional data would be critical to determine the magnitude of change;
- Doubtful projects: Projects whose locations or design suggest that water quality improvements were unlikely to have resulted from project implementation. It is also unlikely that water quality improvement was a meaningful part of the project design.

Clear Improvements

The interviews and field observations on several projects provided sufficient understanding of the project to point to clear water quality benefits, though direct measurements of impacts were not possible. In one case, project funds were used for a large, community-wide conversion from flood to sprinkler irrigation which dramatically reduced stormwater overflows from the local water treatment plant. In another case with a single irrigator, the project installed a collection pond, which allowed the producer to retain his allotted share of water without being forced to apply it all during the actual diversion time. In this case, historical aerial images confirm the dramatic change in crop production and water efficiency in both of the farmer's fields. This project also clearly resulted in less sediment-laden tail water entering the river.

Although the evidence is strong that these projects reduced pollutant inputs into receiving waters, data were not available to actually compute the load reductions.

Possible Improvements

In most of the irrigation projects, the concept behind project designs usually appeared sound, but it was difficult to fully understand the degree of improvement based only on the interview information, file data, and site visit. In most cases, we did not have sufficient information to make a clear determination of water quality benefits. Factors which influenced our ability to assess the potential water quality benefits of these projects included:

- Whether or not the irrigation system was running at the time (which allows a visual inspection of its performance);
- Presence of physical evidence of pre-project irrigation ditches or flow paths
- Evidence that recent heavy rainfall events had either created direct flow paths to water bodies or were contained by the new system;
- The ability of the person interviewed to recall where tail water/return flows had occurred;
- The ability or willingness of the interviewee to provide specific information on the volume and timing of their water turns (this is a sensitive subject for many irrigators);
- Our ability to place information about the volume or timing of irrigation water applications in a broader biophysical context (soil characteristics, slope, etc.) in a way that would allow us to understand whether runoff would or would not be a concern.

A case in a southern Utah watershed illustrates many of these uncertainties. A pivot had been installed, replacing several wheel lines, on a sloped field uphill from a dry wash. Whether the original wheel lines had allowed tail water to leave the field would depend on application rates that were unknown even to the farmer, and soil characteristics impossible to determine during the interview process and not available in the project files. Moreover, site conditions made it impossible to determine the likelihood that any tail water leaving the field would actually reach the dry wash or the targeted river.

In another central-Utah location, a steeply sloped field was converted from flood to sprinkler irrigation. A large irrigation canal down gradient of this field intercepts any surface runoff. The sprinkler irrigation has clearly reduced surface runoff from these fields, but because the canal water is still used on other fields before it reaches a river, the impact on the targeted waterbody cannot be easily determined.

Doubtful Projects

A small percentage of the projects appeared to have had very little potential for improving water quality. In the most notable example, while clearly of tremendous value to the families involved, our field assessment suggests that it was highly unlikely to have impacted water quality in the targeted water body. The location of the project was in dry uplands more than a mile uphill and across a highway from the targeted river. The project converted a large, multi-pasture flood-irrigated system into a multi-pivot, much more efficient and functional system. Prior to installation of the new pipes, seepage losses from the system was estimated by one of the project participants to be over half the water diverted into the fields. The positive impact of the project on the productivity of the farm fields was very clear. However, our informants' historical knowledge of the local water systems suggested that the previous irrigation system inefficiencies were not negatively impacting the river. In their assessment, neither the previous nor the current systems have any visual overland flows, and the river is over a mile away.

We want to be clear that by almost any other standard, this project was highly successful. The family made significant investments to buy into the project, and realized clear results in increased crop production. The project appears to have been thoughtfully implemented and well coordinated with neighbors. The irrigation efficiency of the area clearly improved dramatically, reducing loss to areas that were otherwise rocky, difficult to use pastures.

Other Observations

It should be noted that an important factor in relying on interviews with producers to assess benefits from irrigation projects relates to how the producers think about water flows. From a water quality assessment point of view, information about tail water flows is critical, but these are of much less importance to producers than the size of diversions and water inputs onto their property. As a result, producers usually had little information about even the presence/absence of tail water, let alone observations about possible erosion and sediment transport impacts.

Irrigation Summary

- Operators were overwhelmingly satisfied with the operational benefit of the irrigation projects, citing reduced labor and increased forage or crop production.
- Operators were often unaware that the funding for the irrigation projects was specifically intended to improve water quality.
- Projects that exhibited a clear impact on water quality were in close proximity to receiving waters.
- Some irrigation projects appear to have been funded without regard for the ability of the irrigation changes to impact the affected water body. (At a minimum, any pre-project conditions that might have impacted targeted water bodies were not sufficiently documented.)
- As pre- and post-project photographs are infrequently taken on irrigation projects, it was difficult to assess pre-conditions. The most useful data on previous tail water flows came from a combination of Google Earth aerial imagery (which depended on data unrelated to the time scale of the projects) and farmer interview data.
- The quality of information obtained from irrigation project cooperators in the interviews varied considerably based on how well the landowner understood the water quality problem associated with his pre-project irrigation system. Landowners who did not think they had a water quality problem, or who did not recall that their project funding was intended to address water quality in the first place, were often unable to confidently describe tail water or runoff preconditions.
- Very little pre-project quantitative data (e.g. tail water flow volumes, application rates, etc.) was available, preventing quantitative assessments of potential impact.
- Producers reported several instances where design specifications for their irrigation systems were not appropriate for their local conditions. For example, in their judgment pumps were included when gravity would have been sufficient.

Irrigation Conclusions/Recommendations

- Seek out ways to quantify benefits (better time management, better crop coverage, etc.) associated with improved irrigation.
- To accurately assess water quality improvement potential, better pre-implementation data should be collected and/or modeled, including measured or well-estimated tailwater flows and water quality, evidence of subsurface recharge and verification of any modeling inputs.
- Pre and post project photographs of field and river conditions (beyond pictures of physical irrigation infrastructure) should be taken to help document the original impact to receiving waters and the improvements derived from changes in irrigation systems. Photographs should include discharge from fields to ditches.
- Maps should be created to document original pathways from irrigated fields to receiving waters and changes resulting from irrigation changes.
- Greater scrutiny should be used in approving projects based on proximity to receiving waters and/or potential to improve water quality in receiving waters.
- Document any risks to groundwater from flood irrigation and presumed benefits from altered irrigation.

4.1.4 Upland Grazing BMPs

Types of Projects Examined

The upland projects funded by 319 varied considerably in scope and purpose, including projects for range vegetation improvement (reseeding, brush removal, etc.), fences, water developments (catchment ponds or spring developments), or combinations of many of these elements. “Prescribed grazing” appeared as a practice in several cases but was always linked to the implementation of another practice, such as seeding or fencing.

Data Sources

The main sources of data on upland projects were the interviews and associated field visits. No pre- project data of any nature was available. In only two projects, project photos were available, but were of construction activity (e.g. of water development projects) and were not helpful or illustrative of pre-project conditions.

Many of the files for this type of project also lacked adequate geographical references to determine potential water quality impact of the practices. Frequently, the maps and geological data did not provide data sufficient to locate pastures or structures and Public Lands Survey System (PLSS) references were not provided in many files.

Table 9: Number of Upland Grazing Project Interviews/Field Visits by Watershed

Watershed	Number of interviews
Chalk Creek	4
Middle Bear	3
Beaver	2
San Pitch	4
Upper Sevier	1

Project Implementation Information

Overall, operators were very pleased with the implementation experience of the upland and grazing projects. In the Beaver watershed, operators were particularly pleased with assistance in the choice of seed mixes for the seeding projects.

We only heard minor frustrations with upland project implementations. Among these were difficulties with seed establishment, at times requiring reseeding. In one case, fencing was installed that lacked gates wide enough for a specifically required drill seeder to go through, requiring removal and reworking of brand new gates and fencing to allow completion of subsequent project phases.

In one case, a project was implemented on public lands with private grazing rights. The operator was interested in expanding the project to include several catchment ponds, but felt that the obstacles and impact study requirements were too great on federal land.

Ongoing Management

Although many of the upland fencing and seeding projects included a "prescribed grazing" component, it was very difficult to assess the efficacy or continued use of this practice through file review or interviews. The files did not contain detail on exact management practices (for example, which fields were to be rested or recommended rotations), and operators' recollections of the management requirements were often lacking in detail. For example, some ranchers explained that they had to rest newly seeded pastures for two years, but did not recall specific suggestions for stock rotation or utilization rates that might have been part of a prescribed grazing plan. No written grazing plans were included in files we examined and only two producers mentioned grazing plans at all. One producer told us that he had been given a detailed, Animal-Unit-Month-based plan to follow. The only other producer who mentioned a grazing plan explained that there had been a grazing plan when his fences went in, but he had "kind of forgot about it" in the intervening years. Even in these cases, however, it was not possible to determine whether current grazing management follows the original plans.

Pasture seedings funded by 319 projects were implemented with the intention of improving water quality, but were most appealing to livestock operators because of the potential to increase plant cover and improve forage conditions. As a result, the responses of cooperators to our interview questions clearly indicate that they manage these fields now based on livestock production goals, not water quality considerations.

Assessing Impacts: Value to Producers

Every producer we spoke with was pleased with their upland projects. Projects included vegetation treatments (sagebrush spraying or disking), subsequent drill seeding, fencing to improve animal grazing rotation options, and water developments (troughs and ponds). As noted above, for the producers the primary benefits were improvements to their livestock operations. In all cases, the suites of upland BMPs allowed producers to improve their grazing management options and pasture/rangeland conditions. Several individuals appreciated the fact that 319-funded livestock water system components allowed them to keep their animals on upland pastures for longer periods, therefore alleviating pressure on other pastures, particularly those in riparian areas. Similarly, combinations of brush treatment, reseeding, and fencing projects were seen as increasing the available forage in upland areas.

Assessing Impacts: Water Quality Improvements

Most interviewees who installed upland grazing BMPs were either unaware or had forgotten that these aspects of their projects were intended to improve water quality. As a result, they were not usually able to provide much information about impacts on water quality on their operations. Our own ability to document impacts was hindered by the fact that none of the upland project files included sufficient pre-project information to assess the degree of water quality impairment (or, in some cases, even the nature of the problem) which the project was designed to address. While official files generally contained information about project details, such as acreage treated or length of fence, descriptions of upland preconditions were rarely present in the files. As a result, we relied upon the producers we interviewed to describe pre-project conditions.

Combining information from the project files, the producer interviews, and a field reconnaissance visit, we identified three distinct categories of upland projects that were likely to demonstrate some positive water quality benefits:

1. Changes to range management where seeding or increased grazing rest times (from the use of cross fencing) could potentially reduce rates of soil erosion and surface runoff.

   The goal of many of the upland BMPs was clearly to increase vegetative cover and stabilize soils to prevent erosion and overland runoff of sediment. However, producers did not often report significant visual changes in runoff conditions. For example, one producer used 319 program funding to reseed approximately 10 acres of unirrigated upland pasture to improve grazing conditions. When asked to describe the pre-project conditions, he explained that it had been “unsuitable for grazing.” When pressed further to see if he remembered particular runoff problems or soil loss from the area, he explained that not much had changed. However, within just a few feet of where the conversation took place, extensive evidence of active gully erosion was visible. Without a clear understanding of the change in percent vegetated cover in that field, it was difficult to determine whether the project had had any impact.

2. Installation of sediment capture ponds to slow water movement and reduce overland transport of soil and nutrients.

   These included installation of structures to create ponds that would slow overland flows and retain sediments. Here again, the lack of pre-project data on erosion or sedimentation rates makes it difficult to document water quality impacts. However, visual evidence suggests that sediments were being captured in these structures on collaborating farms. For example, we visited one grazed area on BLM land in southern Utah where several catchment ponds had been installed to provide a dual sediment capture and livestock water benefit. The ponds had clearly captured both water and sediment, which would otherwise have ended up in an irrigation ditch. The producer explained that several ponds would need to be cleaned soon to maintain their function—so they were clearly serving the intended function.

3. Improving grazing opportunities in upland pastures to allow for rotation of livestock away from riparian areas.

   The water quality impact of many upland BMPs is also derived from the use of upland pastures or rangelands to reduce grazing pressure in more sensitive riparian landscapes. This ‘indirect’ benefit is distinct from the direct reductions in erosion mentioned in the two previous examples. One farmer in southern Utah explained how a series of 319-funded upland brush treatment, seeding, fencing, and water trough projects had allowed him to dramatically reduce the grazing pressure on a completely separate riparian area. The upland

> improvements provided him with several months of winter grazing opportunity, which allowed him to rest several flood-irrigated lowland pastures during times when they would have otherwise been grazed. As a result, he feels that the projects have greatly improved both upland vegetation cover (thereby reducing runoff) and also dramatically improved the conditions in the lowland pastures near the river (by reducing grazing pressure).

In addition to cases where water quality impacts were positive (though difficult to quantify), we noted two ways in which the BMPs resulted in diminished water quality benefits.

First, there were several upland projects whose effects might reduce localized sediment transport, but where their position on the landscape seemed unlikely to contribute to water quality conditions in the targeted water body. For example, a spring development done in northern Utah changed the cattle watering situation from a muddy, trampled natural spring to a concrete trough surrounded by gravel. The situation for the animals and for the vegetation down slope of the spring was undoubtedly improved by the project. However, both the water from the original spring and the overflow from the current trough return to the ground within 50 feet of the trough, and have no overland connection to the targeted river (which is located several miles from the project site). The lack of overland flow suggests that the project would have had little impact on water quality for the watershed as a whole.

Second, once increased vegetation has been established, producers commonly reported increasing livestock stocking rates, as these improved fields are seen as valuable new grazing resources - particularly in dry years such as 2012. For example, a reseeded pasture that effectively increased vegetative soil cover may, as intended, provided increased soil stability. However, the increased forage availability may mean that the pasture will be grazed more frequently, or for longer, than it was before the seeding. To understand the net impact of the project on water quality, both changes would need to be included in the calculation: the increase in cover from the seeding, as well as the decrease in cover from increased grazing pressure. We did not carry out any direct measurements of pasture conditions, but the interviews and field visits suggested that expanded grazing rates or extended grazing seasons may counteract some of the potential water quality benefits of the projects.

In sum, a detailed quantitative assessment of changes was not possible based on information in the project files or our site visits. However, our qualitative assessment suggests that some types of projects, when appropriately located, have real potential to address water quality concerns locally and possibly in the watershed as a whole. As noted below, more detailed data on pre-project conditions is critical to measuring change (and is usually lacking in project files), and modeling efforts to simulate benefits must account for changes in producer behaviors to improved range conditions.

Upland/Grazing Summary

- Upland BMP projects varied widely in type and extent. These seemed to have the least documentation of water quality problems, and were the most difficult to assess both during field visits and in interviews.
- Implementations of these types of projects were relatively straightforward and did not entail major engineering or bureaucratic challenges
- Generally, operators reported clear benefits to their livestock management and production from these projects
- This type of project may have positive water quality impacts if the following are accomplished:
    - Seeding improves vegetation cover and reduces overland soil erosion processes;
    - Sediment capture ponds slow water movement and sediment transport;
    - Creating new grazing opportunities in upland areas relieve grazing pressure in more sensitive areas (particularly near the targeted rivers).
- Rarely was any type of data collected prior to project implementation.
- Although range reseeding projects might have the potential to reduce runoff, the grazing management choices of individual landowners have the potential to undo or minimize the effects, and the specifics of those changes since the project was implemented are generally not available in either the files or during the interview with the producers.
- The practice of 'prescribed grazing' (which was included in a few contracts) was not adequately delineated in the files and not recognized by producers as a significant change in traditional management practices to allow us to confidently equate the inclusion of this practice in project plans with actual improved water quality outcomes.

Upland/Grazing Conclusions/Recommendations

- In order to accurately assess actual water quality impact, better data needs to be collected prior to project implementation. Examples include better maps, georeferenced locations of visibly eroding areas, pre-project measurements or photos of bare ground and vegetation cover, and documentation of flow paths from project areas to receiving waters.
- As upland/grazing projects vary widely in scope, post-project monitoring and assessment would benefit from a description of the specific water quality problem a project was meant to address.
- Specific and standardized geographic data (including maps of fields) should be added to files to guide long-term monitoring and assessment of project benefits.
- Any prescribed management practices should be specifically delineated.
- Training should be provided when management practices are included with structural implementation.

4.1.5 Rural Stream BMPs

Beyond field interviews, the majority of our field assessment efforts focused on rural stream projects. Stream-oriented BMPs were quite diverse. Projects commonly supported installation of instream structures (barbs, v-notches, etc.), streambank reconstruction and reinforcement, bank and riparian zone plantings, and fencing to protect riparian areas from livestock grazing. In response, our team deployed a wide range of methodologies to assess the impacts of these diverse stream BMPs on stream channels, streambanks, riparian zones, and (ultimately) water quality and instream fish habitat.

We recognize that upland projects (animal waste, grazing and irrigation) all had potential impacts on instream conditions as well, but budgetary constraints precluded using all techniques in all cases. We felt that the most detailed and diverse assessment approach was justified for rural stream projects because these comprised the majority of 319 funded projects in these watersheds. However, a better understanding of the relative effectiveness of these different approaches in detecting large scale changes in receiving waters will be useful in developing future monitoring and assessment approaches for any of the diverse BMPs included in this report.

In the sections below, we summarize separately the results from the following methodological approaches:

- Interviews and Field Reconnaissance
- Repeat Photograph Comparisons
- Proper Functioning Condition Analyses
- Fish Habitat Suitability Analyses, and
- Historic Aerial Photography Analyses

We conclude this section with a comparison of the results from different evaluation methods, and comments about what this suggests for a more strategic and efficient approach to monitoring impacts of rural stream BMPs in the future.

4.1.5.1 Results of Interviews and Field Reconnaissance Work

Interviews with collaborators who implemented rural stream BMPs and field reconnaissance efforts were conducted in four of our rural study watersheds (

Table 10)[5]. Rather than detail the different results for each watershed, we focus here on the integrated findings from our 20 combined interviews.

[5] In addition, we evaluated urban stream BMP projects in the Jordan River watershed, but believe that the results of these urban projects are not directly comparable to efforts to improve streams in rural and agricultural areas. As a result, they are summarized in a different section of this report.

Table 10: Number of Rural Stream BMP Project Interviews/Field Visits by Watershed

Watershed	Number of interviews
Chalk Creek	7
Middle Bear	0
Beaver	4
San Pitch	4
Upper Sevier	5

Although the general intent and nature of the projects was similar, many different techniques, strategies, goals, and implementations were found from project to project, even within the same watershed. Typically (particularly on private land), streambank erosion prevention was identified in project documents as the primary goal. In a few cases, however, instream fish habitat improvement was the primary project focus.

All of the projects involved at least one of the following work elements:
- Debris removal, ranging from old cars to broken concrete slabs;
- Earth work, usually bank sloping but occasionally creation of new channels;
- Engineered bank stabilization in the form of revetments or rip-rap most often consisting of timber or boulders;
- Rock or log structures constructed in the stream bank and channel to influence flow patterns, including barbs, vanes, j-hooks, and drop structures;
- Riparian fencing, sometimes including livestock crossing and/or water access structures, with the goal of removing animals from riparian areas.

Water quality impacts likely ranged from reduced sediment loads, reduced inputs of nutrients, metals, bacteria or organic materials associated with sediments, and improved temperature and dissolved oxygen associated from changes in stream form and increased shade.

Data Sources

Stream restoration project file documentation was inconsistent. Some files noted only basic goals and listed materials used on reimbursements and receipts, whereas other files included maps, schematic designs, locations of barbs, species of vegetation planted, and other valuable details. Despite the documentation challenges, most stream projects were easily located on base maps by watershed coordinators or other CD staff.

In addition to the file data, other existing data sources included before-and-after photos from many of the projects, fish habitat and population data in some river reaches, and aerial photography at a river-reach scale. Although we were told that stream channel morphology and water quality monitoring data were collected at several locations, we were not able to obtain the actual data to perform pre-and post-project comparisons.

Implementation challenges:

Specific implementation challenges related to permitting, engineering, funding, and planting activities.

- *Permitting Challenges*

For projects involving structural changes to streambanks and stream channels, it was necessary to get permits before commencing work. In those situations without a watershed coordinator, producers were frustrated and unclear on who to contact and how to actual acquire these permits. Depending on the year a project was implemented, these types of stream projects were either covered under a broad permit encompassing multiple stream improvement projects on a given stretch, or might have required multiple individual permits from a variety of agencies. In most cases, the watershed coordinator facilitated permitting and many operators did not even mention that a permit had been needed. Permitting frustrations, however, were mentioned by several landowners. These individuals saw permitting as a waste of time for landowners who were not familiar with the process or had not been given adequate information to facilitate the process of obtaining the necessary permits. In one case a private landowner started work before obtaining the proper permits and legal actions were initiated. In this case, however, a watershed coordinator intervened, obtained the proper permits and helped the operator obtain 319 funding to complete the project under permitted guidelines.

- *Engineering Challenges*

In some of the earliest stream projects, NRCS engineers assisted with specific implementation plans. During the implementation period that we evaluated, it became less common for NRCS to provide design support, and 319-funded watershed projects relied more on less qualified individuals (watershed coordinators, heavy equipment operators, etc.) to design stream projects. When engineering assistance was available (i.e. for the older projects), projects appeared to be more successful. UACD has now hired an engineer specifically for this purpose, so this concern has been addressed in more recent projects

Landowners had mixed reactions to the design recommendations and specifications for their projects. On several projects, landowners considered the designs excessively complex and expensive relative to the perceived operational benefit. In other cases, however, specific engineering plans clearly facilitated implementation and successful outcomes. The differences between these two groups appeared to be attributable to the level of involvement and qualifications of the respective watershed coordinator.

In most cases, rockwork and other stabilization structures were installed when flow was at a minimum during the late summer and fall months. The more effectively engineered designs specifically incorporated stream flows and flood frequencies into the plan. However, projects that lacked proper engineering assistance appeared to employ a lot of guesswork. One contractor who did much of the backhoe work for one watershed said this work "is as much of an art as a science." Even in cases with proper engineering, however, high runoff years contributed to notable setbacks in stream conditions.

- *Financial challenges*

Certain interviewees expressed frustration regarding the financial aspects of the project funding. In one watershed, a contractor responsible for several projects was under the impression that he could not receive reimbursement until the project received a final sign-off. In one case, he had tens of thousands of dollars in materials and labor extended while waiting for the landowner to complete a fence. In another situation, the operator mentioned the personal challenges he had encountered with tax liability for cost-share payments he had received. He noted that vague concerns about how this can impact a farm's finances make it harder to enlist new landowners, even when project results are visible and of interest to other landowners.

- *Timing challenges*

Coordinating the various phases of stream projects also posed a challenge. For example, projects involving streambank stabilization often included vegetative plantings with protective fences as part of the contract. Seasonal weather conditions and operators' financial resources sometimes caused a time lapse between planting and fencing phases. When the fences were not erected immediately following plantings, cattle or other livestock may have grazed and trampled the new plants, reducing the likelihood of establishment success.

- *Challenges with Establishing Vegetation*

Almost all streambank restoration projects included vegetation plantings. Usually these involved willows, sometimes accompanied by additional grass/forbs, or by a more diverse combination of riparian trees and shrubs. Although most sites had at least some visible willow plantings that survived, several operators noted that whether willows were able to become established depended on their ability to have consistent access to water. Use of a high-powered planting tool (a "stinger") facilitated deeper planting, but other approaches were also successful when careful attention was paid to the depth and location of the plants.

In at least two of the watersheds, willows were planted by volunteers. In general, experience using volunteers was positive, and landowners accepted the possibly lower establishment rates than might have been achieved with a paid contractor.

Different techniques: a trained team from another agency

Two projects among those we evaluated were not implemented by private landowners, but rather by the Utah Division of Wildlife Resources (DWR). Both the goals and implementation techniques on these sites differed somewhat from projects on private agricultural lands. The primary goal of the DWR implementations is to enhance fish habitat and provide angler opportunities. As a result, more river movement was allowed for in the project design. In addition, more substantial earth moving – for example, digging completely new channels – was done than in private projects. Implementations in several reaches spanned multiple years and sometimes involved the creation of new channels where existing streambeds were too incised and too close to roadways to reshape using standard methods. Implementation was done by a dedicated team of DWR employees with a focus on instream habitat restoration. Implementation challenges for these projects were primarily technical, and included the difficulty of getting the entire flow to transfer into the newly built channels. The need to immediately place rocks in the new channel to install barbs, vanes, etc. put pressure on project staff to work quickly and innovatively. One respondent noted that making the new stream channel with as many turns and meanders as they did added unnecessary complexity and difficulty to the project, and if they were to redo it, fewer, larger turns would have been easier to implement.

Ongoing Management of Stream BMPs

The most relevant ongoing "management" needs for stream projects include fence maintenance and associated livestock management. Most fences we observed were still in place, and were being used as intended to restrict livestock access to the riparian area. In only a few cases, the riparian area was used as an alternate pasture. However, we did not see any instances where livestock access had notably degraded riparian areas, mainly because the vegetation had clearly been given ample time to regrow before animals were allowed back into the area.

The primary maintenance issue associated with riparian fences was that lateral channel migration often threatened the structural integrity of the fence itself, washing out posts and wire or even entire hog panels. In some cases, the fence may simply have been placed too close to the river to survive normal stream channel migration. However, we saw several instances where the combination of stream stabilization work in one area combined with fencing along entire stretches downstream may have put fences in non-stabilized areas at greater risk of falling into the river. Operators seemed somewhat at a loss as to how to handle this situation and were discouraged by the prospect of fixing a fence that might soon fall in again. In the two least successful stream projects (both in the Upper Sevier), fencing installed as part of the project was beginning to fall into the river and the operator had not (yet, at least) made attempts to relocate the fence.

Other than standard riparian fence maintenance and livestock management, we saw very little ongoing management related to instream and streambank projects. In general very little management is needed once riparian area vegetation has become established. Even in the mostly successful projects, however, washouts do occur during extreme storms or spring runoff events, leaving exposed banks susceptible to continued erosion. These projects would benefit from revisiting the compromised reaches and adding more material or replanting vegetation that has been washed out. According to the interviews, the vast majority of the washouts occurred in the subsequent first or second spring runoff seasons following the implementations before the vegetation could become established. Unsurprisingly, projects implemented in years immediately prior to heavy spring runoff seem to have suffered the most vegetation loss. There was little evidence that project staff had devoted time and resources to monitoring the condition of stream projects on an ongoing basis.

Assessing Impacts: Value to Producers

Three types of individuals participated in stream restoration projects: agricultural producers, non-agricultural homeowners, and the Division of Wildlife Resources (DWR).

In the case of the agricultural producers, the primary benefit of stream projects was prevention of the loss of valuable farmland. In some cases, erosion had previously cut up to 40' feet into the operators' fields. This reduced the availability and productivity of crop fields and pastures.

Many farmers and ranchers also expressed satisfaction from the perceived ecological benefits associated with improved streambank conditions. These individuals enjoyed the more natural riparian environment and some were pleased by increased numbers of wildlife such as deer attracted to their property.

The non-agricultural landowners expressed an interest primarily in erosion control protecting their structures, and also highlighted the value of improved riparian condition (for its own sake, as well as potentially water quality/sediment reduction improvements). Although several of the non-agricultural landowners did own small numbers of chickens, horses, or cattle, it was clear that they were not primarily agricultural operators. The restoration of the river to a more natural state was usually one of the top objectives among these non-agricultural landowners.

The specific goal of the DWR projects, from the agency's standpoint, was to improve fish habitat and provide additional opportunities for anglers. The interviewees for these projects were very satisfied that the stream work performed met this objective. They were also pleased by the improvements in riparian vegetation condition and diversity, overall system resiliency in recent flood years, reduced erosion, and the rising water table.

Assessing Impacts: Water Quality Improvements

Based on the perceptions and experiences of our interviewees, and visual evidence collected during our field visits, nearly all the stream BMP projects seem highly likely to have improved water quality, particularly with regard to reduced sediment loads from bank erosion. During site visits, it was often clear which reaches of the river had been improved because the unimproved adjacent reaches were markedly more eroded. Most operators expressed the belief that the project had a positive impact on water quality based on their observation that "I did the project, my banks are now more stable and eroding less; therefore the water quality must be better." For those who had allowed fish monitoring and angler access on their property as part of the project, improvements in fish numbers, angler success, and apparent fish habitat quality was commonly noted.

Unfortunately, not all of the stream projects were completely successful. In some cases, project work was only done on the most vulnerable reaches of a stream. The reaches that were improved were markedly better. However, reaches that were not stabilized did not fare as well, potentially because of subsequent flow changes created by the improvements in other areas.

The impact of a stream BMP project on water quality also was mediated by the severity of spring runoff levels in the first few years. High runoff can be devastating to a project: much of the newly planted vegetation can be washed away and high waters can completely change the course of the stream rendering flow control structures (barbs, vanes, etc.) completely ineffective or even counterproductive given the new stream channel. In the same watershed with the same contractors, projects completed in 2006 and 2007 fared much better than the projects completed in 2008 because of the heavy runoff and flooding in the spring of 2009.

Several projects were deemed less successful because vegetative plantings did not have a chance to become established enough to stabilize banks. This was due to three primary reasons:

- The planting took place in a very dry year and, without supplemental irrigation, the young vegetation simply did not proliferate.
- We heard of instances where the willows were not planted deeply enough for them to stay wet and establish root systems. According to interviews, in later projects, the incorporation of specialized equipment called stingers were said to have produced better results.
- According to one interview, in projects that involved riparian fencing, the fence was not completed until well after the plantings went in. Failure to keep livestock off of the new plantings substantially reduced their effectiveness. Producers who installed their own fences as part of the cost share were not always forthcoming about this issue.

Two projects specifically were currently at a point where their stability appears to be decreasing, and are likely to create continued problems both for the landowners, their neighbors, and water quality. The poor project performance on these two sites appears related to poor engineering or project design, and should receive attention from the local watershed coordinator.

Rural Stream BMP Interviews Summary

In summary, it appears that the majority of stream projects were moderately to highly successful, and are quite likely to have had a positive impact on water quality.

- Successful streambank improvement projects were universally considered to have a positive water quality impact from both the perspective of the operators and through qualitative field assessment.
- Streambank projects appear to provide little direct operational benefit to agricultural producers other than potential prevention of land loss caused by erosion.
- Different project objectives incorporate different restoration techniques and produce somewhat different results. In the DWR projects that valued increasing fish habitat, more river migration was considered acceptable than in the private projects.
- Less successful streambank projects were compromised by the following factors:

    - Lack of engineering expertise by the implementer or contractor;
    - Severity of the following spring runoffs;
    - Issues with vegetation plantings.
- Because riparian restoration falls outside of the skill set of most agricultural producers, the level of involvement and expertise of the watershed coordinator (or other specialists) is more critical to the success of these types of projects than in other BMP's.
- Very little pre or post-implementation monitoring and follow-up has been done, although this varied between watersheds. One operator told us that our site visit was the first contact regarding the project since its implementation in 2008.

Streambank Restoration Interviews Conclusions & Recommendations

- To ensure a greater chance of implementation success, specialized engineering and river restoration design expertise should be committed to streambank restoration projects.
- To encourage the establishment of vegetation, ideally riparian fencing should be included in all implementations where livestock has access to the stream. Focus should be placed on keeping animals away from the plantings during the establishment period by stressing that fencing is implemented concurrently or before plantings or with livestock rotation programs.
- Consider establishing a reserve fund or escrow to provide for repairs and maintenance subsequent to the following spring runoffs. Minor repairs or tweaks immediately following high water periods may be a cost effective way of achieving greater success.
- The projects that were included in these interviews generally focused on "structural" solutions to address channel migration and instability. In recent years, restoration efforts that include resting a riparian area or introducer beavers have become more common. These did not come up in the interviews but we feel should be part of the recommendations when considering new approaches to projects this type.

4.1.5.2 Results of Photo Comparisons

Paired photographs taken over time provided another window into the long-term impact of stream BMPs in our study watersheds. As noted above, our ability to use photo comparisons to evaluate BMPs was limited by the availability and quality of photographs in each of the watershed project offices. Three rural watersheds, Chalk Creek, San Pitch, and Sevier River, had matched sets of photographs appropriate for comparing the effectiveness of riparian BMPs.

Our three raters used evidence from the matched photographs to compare riparian zone condition, streambank structural conditions, stream channel conditions, and an overall condition. For each of these categories the raters score each photo point site on a 5 pt. scale ranging from improving (5), unchanged (3), to deteriorating (1).

Table 11 summarizes the comparisons. We eliminated any photopoints where the raters' scores deviated by more than 3. We then averaged the remaining scores.

Table 11: Summarized photo-comparison results for three rural watersheds. *"Max difference" indicates the range of raters' scores. Paired photos were not included in this summary when the raters' scores varied by more than 3.*

			Riparian Zone Condition		**Bank Structural Condition**		**Stream Channel Condition**		**OVERALL PROJECT IMPACTS**	
Site	*Number of Photo Pairs*	*Number of Raters*	*Average Rating*	*Max Differ-ence*	*Average Rating*	*Max Differ-ence*	*Average Rating*	*Max Differ-ence*	*Average Rating*	*Max Differ-ence*
CHALK CREEK										
B	3	3	4.3	1	4.4	2	4.3	2	4.4	2
C	3	3	4.7	2	4.6	2	4.7	3	4.7	2
E	3	3	4.6	1	4.3	2	4.1	2	4.4	2
F	1	3	5.0	0	5.0	0	4.7	0	5.0	0
G	1	3	4.7	0	4.7	0	4.7	0	5.0	0
SAN PITCH										
J	2	3	4.3	1	4.5	1	4.2	1	4.3	1
K	2	2	4.3	2	4.5	1	3.8	2	4.5	1
L	3	3	4.3	1	4.2	2	3.5	3	4.2	2
M	2	3	4.5	0	2.5	2	4.0	1	4.3	1
SEVIER										
N	4	2	2.8	3	2.9	3	3.1	3	2.5	1
P	1	2	4.5	1	5.0	0	4.5	1	4.5	1
Q	1	2	4.5	1	4.5	1	4.0	2	4.5	1

Chalk Creek

We were able to obtain matched photographs for 16 distinct photo points in the Chalk Creek watershed. Because we often had multiple points for a single landowner's stream projects, these represented 5 total stream BMP project sites. Chalk Creek implementations were among the earliest that we evaluated. As a result, many of these riparian projects had been in place for at least a decade.

Every site within the Chalk Creek watershed had average scores over 3 (indicating consistent improvement), 90% had scores over 4 (indicating strong improvement suggesting strong improvement). Nearly 40 percent of photo point ratings had a 5.0 score – representing unanimous agreement among the raters that there was strong evidence of improvement from BMP installation. The average of all photo point scores in Chalk Creek was 4.6 on a 5 point scale.

The strongest improvements at Chalk Creek photo points reflected changes in riparian zone conditions (usually associated with installation of a fence to separate grazing livestock from the stream) and bank structural conditions (increased stability, decreased slope and/or sloughing). Evidence of sustained improvements in stream channel conditions was less clear from the photographs, although in at least one set of photos, the raters noted that the channel had clearly narrowed with obvious pool formation.

The paired photos also provided evidence of project limitations. At one site, the raters all noted that revegetation had occurred in what appeared to be "bedrock material" in the banks, rather than in mature soils.

San Pitch

We were able to obtain matched photographs for 18 distinct photo points in the San Pitch watershed, which represented 5 total stream BMP project sites. Like Chalk Creek, every site within the San Pitch watershed had average scores over 3 (suggesting consistent improvement), but a slightly lower percentage (70%) had scores over 4 (suggesting strong improvement). About 20 percent of photo point ratings had a 5.0 score – representing unanimous agreement among the raters that there was strong evidence of improvement from BMP installation. The average of all photo point scores in San Pitch was 4.3 on a 5 point scale.

The strongest evidence of improvement at San Pitch photo points reflected changes in riparian zone conditions. Evidence of sustained improvements in streambank conditions was less clear from the photographs, and there were more sites where photos provided inconclusive evidence of improvement.

Taken as a whole, the matched photos in the San Pitch watershed were less helpful than they were for the other watersheds. While the overall project goals in this watershed were to improve the stability of the stream channels and enhance the riparian corridor to reduce sediment, TDS, and phosphorus loading, the goals at each individual site were less clearly apparent, though most projects mainly focused on improving riparian vegetation. Fewer of the available historic photos had dates and photos were often taken at different angles, times of day, etc.). In some cases, "before" photos didn't exist and the photo series began at construction. Because the San Pitch projects were more recent, the vegetation associated with these projects was not as mature, making comparisons somewhat more difficult.

Sevier River

We were able to obtain matched photographs for 9 distinct photo points in the Sevier River watershed, which represented 3 total stream BMP project sites. All but one available photo point site in the Sevier watershed demonstrated evidence of improvement. One photo point location demonstrated significant deterioration in conditions on all four measures. Overall, 90% had average scores over 3 (suggesting consistent improvement), and about 70% of sites had scores over 4 (suggesting strong improvement). About 25 percent of photo point ratings had a 5.0 score – representing unanimous agreement among the raters that there was strong evidence of improvement from BMP installation. The average of all photo point scores in the Sevier River watershed was 4.2 on a 5 point scale.

In contrast to the previous two watersheds, the strongest evidence of improvement at Sevier River photo points reflected changes in streambank and stream channel conditions. There was less improvement in riparian zone conditions here compared to the other watersheds.

Overall

At locations where well-matched photos were available, we saw consistent evidence of improvements in riparian zone, stream bank, and stream channel conditions in each of the three watersheds. In a few locations, visual evidence of positive impacts was hard to discern. In only one site did we see clear evidence of deteriorating conditions in the post-BMP period.

The use of repeat photography to track the implementation, maintenance and effectiveness of stream BMPs seems to hold great promise. Where well-matched photos were available across a long-enough time period, these photos provided good evidence of response. The use of multiple raters showed that photo comparison ratings were consistent and reliable. The inclusion of narrative comments from the photo raters also provided depth and detail for our analysis.

Nevertheless, in many locations the availability of historic photographs to use as pre-project benchmarks was very limited, and the quality of the post-project photographic record varied widely. "pre" photos rarely seemed to be taken during the project planning stage, but rather as an afterthought when construction was about to begin. In some cases, it was evident that construction had already begun. A more systematic attempt to gather regular photographic evidence (from the same vantage points, times of day, and seasons) would provide a more robust and accurate source of information about BMP effectiveness.

4.1.5.3 Results of Proper Functioning Condition Analyses

On eleven of the rural stream BMP project interviews, our field team carried out systematic assessments of stream and streambank conditions using the Proper Functioning Condition (PFC) assessment protocol (described in the methods section). Results from these assessments are summarized in Table 12. Eleven reaches in 3 watersheds were assessed. Seven of these reaches were found to be in proper functioning condition, while 3 reaches were identified as 'Functional at Risk' (one in each watershed). One segment in the Sevier River watershed was determined to be nonfunctional at the time of our fieldwork.

Table 12: Results of Proper Functioning Condition Scoring

		Number of "Yes" Responses			
Site	**Watershed**	**HYDROLOGY SECTION** *(out of 5 possible)**	**VEGETATION SECTION** *(out of 7 possible)*	**EROSION / DEPOSITION SECTION** *(out of 5 possible)*	**Overall Proper Functioning Condition Rating**
B	Chalk Creek	**3**	**7**	**1**	Functional - At Risk (direction uncertain)
C	Chalk Creek	**3**	**7**	**4**	PFC
E	Chalk Creek	**4**	**7**	**5**	PFC
G	Chalk Creek	**4**	**7**	**4**	PFC
J	San Pitch	**2**	**3**	**3**	Functional - At Risk (improving)
K	San Pitch	**4**	**6**	**5**	PFC
L	San Pitch	**3**	**6**	**2**	PFC
M	San Pitch	**4**	**6**	**4**	PFC
N	Upper Sevier	**3**	**3**	**1**	Functional - At Risk (worsening)
O	Upper Sevier	**5**	**7**	**5**	PFC
P	Upper Sevier	**1**	**5**	**0**	Non-Functional

*Note: * = On the hydrology section, all but one project had N/A on the beaver dam question.*

The PFC assessment includes ‘yes’ or ‘no’ ratings on 17 criteria organized into three major structural and functional categories: hydrology, vegetation and erosion/deposition. None of the reaches was rated “yes” in all of the possible metrics used in the PFC analysis.
Table 11 shows the number of responses in each category for each site assessed.

Two of our study reaches were determined to have very little natural lateral movement, due to the use of stream channel stabilization work at potentially erodible curves. This underscores a potential problem with stabilization as a strategy to restore proper functioning condition. However, on almost every other factor, these stretches appeared healthy and functional.

Both the ‘non-functional’ and ‘functional-at-risk downward trend’ (FAR/DT) reaches in the Sevier River exhibited functionality concerns in all three categories. Both cases exhibited little functionality with respect to erosion and deposition processes. . The non-functional reach exhibited substantial concerns about hydrologic processes while vegetation limitations were identified as a problem in the FAR/DT reach.

Taken as a whole, our field assessments for functional condition of streamwork project areas suggest several conclusions:

- The majority of project areas are properly functioning or trending upward, a strong endorsement that the projects have been highly successful overall at improving stream stability and functional condition.
- As would be expected if projects are well designed and maintained, the older and more established projects were in better condition than those projects where vegetation has not had as much time to establish
- Projects in watersheds with a greater apparent fluctuation in flows in response to storm events seemed more likely to be categorized as “At Risk.”
- The distribution of at-risk projects across all three watersheds may relate to specific problems in the design or implementation of those projects, rather than watershed wide concerns.

One of the greatest strengths of the PFC process is as an educational tool for local landowners. It can also be used to suggest ways to address ongoing challenges and identify potential new project needs. Many of the landowners we spoke with were interested in the results of our work, and requested detailed information from their own properties once our analysis was complete. Those details were provided to the landowners but are not presented in this report, both due to the site-specific nature and the lack of ability to generalize between sites at that level of detail.

4.1.5.4 Results of Fish Habitat Suitability Analysis

Chalk Creek: Habitat suitability assessment in 2011

Four Chalk Creek stream BMP sites were monitored in November 2011 using a composite habitat suitability index for cutthroat trout based on depth, velocity, substrate, and cover. Table 13 provides the ranges for each measurement included in the Habitat Suitability Index.

Table 13: Habitat suitability values of flow depth, flow velocity, percent of overhead cover, substrate type, percent streambed fine sediment, percent pools, percent streambank vegetation, and percent stable streambank for adult BCT (determined from the habitat suitability index for cutthroat trout, Hickman and Raleigh 1982).

Physical variable	Poor	Average	Good
Point-scale metrics			
Depth (cm)			
≤5m width channel	< 13	13 – 30	> 30
>5m width channel	< 23	23 – 45	> 45
Velocity (cm/s)	< 10; > 22	14 – 22	10 – 14
Cover (%)	< 14	14 – 25	> 25
Dominant substrate	Fines, bedrock, small gravel, or large boulders are dominant; rubble and small boulders are insignificant	Rubble, gravel, boulders, and fines occur in approximately equal amounts or rubble-large gravel mixtures are dominant; aquatic vegetation may or may not be present	Rubble or small boulders; aquatic vegetation in spring areas; limited amounts of gravel, large boulders, or bedrock
Reach-scale metrics			
Fine sediment (%)			
Spawning	> 20	10 – 20	< 10
Riffle-run	> 40	15 – 40	< 15
Percent pools (%)	< 5	5 – 40; >70	40 – 70
Percent vegetation (%)	< 60	60 – 150	> 150
Percent stable bank (%)	< 30	30 – 80	> 80

We rated the habitat of the four reaches as mostly "poor", with no "good" habitat and very little "average" habitat. We determined, however, that depth and substrate conditions were generally suitable for trout and the poor ranking was mostly due to poorly rated flow velocities (i.e., too high or too low) and limited overhead cover. Macroinvertebrate metrics indicate that water quality and fine sediment pollution are not affecting the quality of habitat for trout (discussed below), but that some food resources may be limited due to low diversity at all sites.

In total we collected velocities at 20 cross sections per stream reach, at 12 points per cross section. Our results show a relatively wide range of velocities at each site (
Table **14**).

Table 14: Reach-averaged channel morphology metrics and streamflow discharge of four reaches located within BMP project sites in the Chalk Creek watershed, November 2011.

	C	B	G	F
Width (m)	8.95 (0.23)	8.87 (0.46)	7.96 (0.29)	7.49 (0.37)
Average depth (m)	0.32 (0.01)	0.32 (0.02)	0.22 (0.01)	0.20 (0.01)
Near-bed velocity (m/s)	0.11 (0.01)	0.03 (0.01)	-0.01 (0.02)	0.05 (0.01)
Average velocity (m/s)	0.33 (0.02)	0.20 (0.02)	0.19 (0.02)	0.19 (0.01)
Discharge (m^3/s)	1.39	1.44	0.57	0.36

Notes: Sites ordered from downstream to upstream (C, B, G, and F). Values are means (SE). All measurements were taken during baseflow conditions.

All had relatively high coefficients of variation (standard deviation/mean) in average velocity (1.03 – 1.77), with the most downstream site having the lowest variance and the second-most upstream site having the highest. All except the most downstream site had reach-averaged velocities ~0.20 m/s (0.7 ft/s), which is within the suitable range shown in
Table 14. Thus the high proportion of poorly rated velocities at these three sites may be overrepresented and not biologically meaningful for adult trout, since trout may be able to avoid unsuitable velocities by moving to other areas of the channel. High average velocities and lower variance at the most downstream site are probably due to a higher discharge, fewer riffles and pools, and a high proportion of fast-moving flatwater runs (indicating less hydraulic and physical complexity) at this site, characteristics which may be less suitable for BCT.

Velocity requirements vary seasonally and among BCT life stages due to differences in life history traits and body sizes. Fry typically utilize shallow (<50 cm) water along stream edges where velocities are low (< 25 cm/s). Larger juveniles and adults will use deeper and faster water, usually among rocks and other forms of cover. Adult trout increase foraging efficiency by moving into high-velocity water only to feed and then returning to low-velocity areas for resting and holding. Thus optimal habitat contains a range of velocity conditions. For this reason, it is important to recognize that physical habitat diversity is crucial to providing suitable habitat for the range of life stages and behaviors necessary for survival of the species, a factor not necessarily reflected in the HSI ratings.

Our results suggest that a lack of cover may be limiting the quality of trout habitat at all sites, particularly the most downstream site. More than 75% of all four sites were without cover, indicating that reach-wide cover is suboptimal for trout. Our habitat suitability ranking was based on the percent cover at each measurement point, not just presence/absence, resulting in even lower habitat suitability ratings (i.e., mostly "poor" conditions < 14%). Large woody debris and overhead cover were notably lacking at all except the most upstream site.

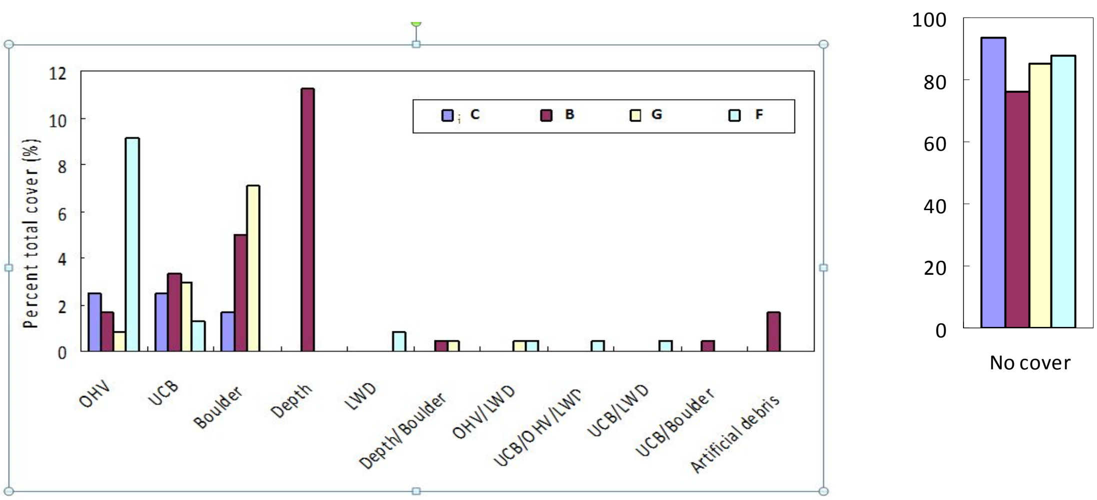

Figure 7: Frequency of different cover types based on 240 point measurements (12 points on 20 cross-sections) at each of four reaches located within BMP project sites in the Chalk Creek watershed, November 2011.

Notes: OHV = overhanging vegetation, UCB = undercut bank; LWD = large woody debris. In some cases, more than one cover type was present, thus these are quantified as separate categories (e.g., UCB/OHV/LWD) and not included in the individual categories with only one cover type. Note the different scale for the "No cover" category. See text for a complete explanation of cover types.

Overhead cover is a critical component of trout habitat quality, providing refugia from predators, high temperatures, and high-velocity water. Overhanging riparian vegetation provides allocthonous organic matter, large woody debris, and shade to help control water temperatures. Vegetation also helps stabilize banks, maintaining undercut sections and reducing inputs from both bank and hillslope erosion.

The limited riparian growth along these reaches is reflected in relatively low numbers of shredder macroinvertebrates at all sites (compared to other functional feeding groups), which feed on allochthonous debris (e.g., leaves) that fall into the stream from streamside vegetation. However, riparian vegetation at all sites was dominated by willow, which is not expected to contribute large logs or branches to the stream, thus a limited amount of large woody debris may be natural for this system.

Bank stabilization measures may have unintended negative effects on instream habitat cover and complexity by reducing large woody debris inputs and paradoxically constraining the growth of riparian vegetation. In a meandering river, cut bank erosion during high flow events leads to the deposition of point bars, which provides sediment suitable for the establishment of pioneer plant species such as willow and cottonwood (Read 1958, Everitt 1968, Wilson 1970, Johnson et al. 1976, Noble 1979). Point bar deposition and bank erosion also leads to channel migration and eventual meander cutoffs, which provide valuable off-channel spawning and winter rearing habitat for salmonids, including overflow channels, sloughs, and wetlands (Beechie et al. 1994). Immobile or permanent structures placed within the banks (e.g., rock barbs) can present problems for normally dynamic systems by limiting the growth of vegetation and reducing small-scale channel adjustments (Thompson 2002). Thus although the stream bank stabilization measures on Chalk Creek were intended to limit local bank erosion and enhance vegetative growth, it is important to note that constraining lateral channel migration and overbank flooding may have unintended consequences for LWD input, plant establishment, and in turn, overhead cover for fish.

We also found that the percentage of pools was low (absent or suboptimal) at three of the four sites, mainly due to a large proportion of fast-water runs and riffles. Pool-riffle ratio is an indicator of habitat diversity. Most previous studies have suggested that high quality habitat contains a relatively even ratio (i.e., 1:1) of these pools to riffles (Platts et al. 1983, Nickelson et al. 1992), whereas others have found that a ratio of 0.4:1 can support a high biomass of salmonids and areas with high pool-riffle ratios can also maintain a high salmonid biomass (Platts et al. 1983). Only the second-most downstream site B had a ratio close to the optimal 1:1; all other sites had lower pool-riffle ratios.

All sites had a relatively low percentage of fine sediment (< 10%), thus excess fine sediment does not appear to be limiting habitat quality at these sites. Without more detailed and continuous measures of turbidity and nutrient levels, we are unable to assess whether other aspects of water quality may have detrimental impacts on BCT in this system. However, given the low levels of streambed fines and other positive biological indicators, it appears that water quality issues associated with fine sediment (e.g., turbidity, phosphorous) are likely not a problem in this system.

Chalk Creek: Comparison of 2002 and 2011 habitat conditions

Data from the EMAP-West monitoring site (downstream of the BMP field sites) collected in 2002 provide a comparison with the field sites we visited in 2011. In 2002, the EMAP-West site had an average quality rating for percent pools (29%), higher than we found at any of the field sites in 2011.

Table 15: Habitat suitability ratings for four reach-averaged metrics, two streambank metrics, and a composite index based on depth, particle size, and cover on the Chalk Creek EMAP-West monitoring site, September 2002. This site is downstream of all 4 of the BMP project reaches.

Metric	Value	Rating
Mean particle size (mm)	32.6	Average
Mean thalweg depth (m)	0.38	Average
Percent all cover types (%)	42.3	Good
Composite rating	--	Average
Percent pools (%)	29.2	Average
Percent streambank vegetation (%)	237.9	Good
Percent stable streambank (%)	60.3	Average

In this system, a lower percentage of pools reflects a higher proportion of fastwater areas such as runs, rather than a reduction in flow depth (mean depth was ~0.35 m in both years). Runs and pools are both relatively deep and smooth-surfaced, thus some difference may be attributed to methodological bias in the identification of habitat type. Alternatively, faster flows in 2011 may have been due to a higher flow discharge on the sampling date; the hydrologic record from the Chalk Creek gage reported a discharge of 0.26 m^3/s on September 14, 2002, and 1.16 m^3/s on November 11, 2011. A hydraulic geometry relation for mean velocity developed from channel measurements at the gaging station shows that an increase in discharge of this magnitude would more than double the mean velocity from 0.15 to 0.37 m/s (Figure 8). Although channel morphology likely differs at the study site, we expect the effects of higher discharge on velocity to be similar.

Data from the 2002 EMAP-West survey indicate that habitat quality in 2002 was relatively high (See Technical Appendix II), at least during the growing season, but our 2011 field surveys show that overhead cover was limiting at these sites in the fall of 2011. We would expect bank stabilization and riparian improvement efforts to result in a gradual increase in vegetative cover over time, but we cannot say with certainty whether this has occurred.

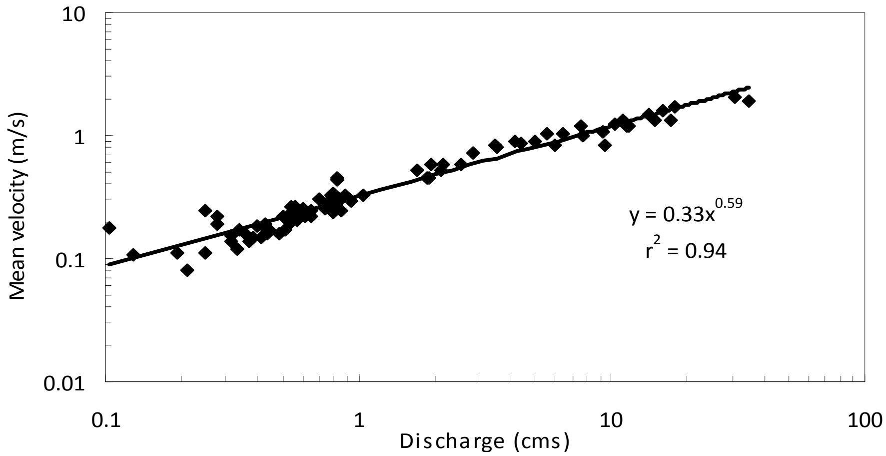

Figure 8: Hydraulic geometry relation between mean flow velocity and discharge at the USGS gaging station Chalk Creek at Coalville (10131000) from 2002-2011.

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Chalk Creek: Fish Population Status

Accounting for these differences in sampling methodology, we estimated population densities for all fish species and species richness for all sites and dates (Figure 9. We combined biological data from the EMAP-West site with those from the UDWR survey sites to assess spatial and temporal trends in fish populations of Chalk Creek. Our temporal analysis is limited, however, to only four years of data that is both non-sequential and of varying quality. UDWR's site Section 2-Low is located very close to the EMAP-West site, downstream of project site C (<0.5 km). Therefore, for the purposes of this study, we have combined these data in order to establish population estimates over time.

Fish population surveys were conducted at this site in 1970, 1991, 1997, and 1999. Fish populations were estimated from a one-pass electrofishing survey in 1970 and two-pass electrofishing surveys in all other years. UDWR also conducted surveys at five other sites upstream: Section 2-High (sampled in 1968, 1992, and 1999) and Section 3-Low, -Medium, and -High (all sampled in 1999). Section 2-High is located ~ 4 km downstream of project site F, whereas all Section 3 sites are located much farther upstream near the town of Pineview. Two-pass electrofishing surveys were conducted in 1992 and 1999 (all sites), whereas a one-pass survey was conducted in 1968. Population estimates were made using a modified Zippin multiple pass depletion formula. However, for some species in certain years, population estimates were not available because more fish were caught on the second pass. Furthermore, in some years the reports include combined counts for related species (e.g., Utah and mountain suckers; longnose and speckled dace).

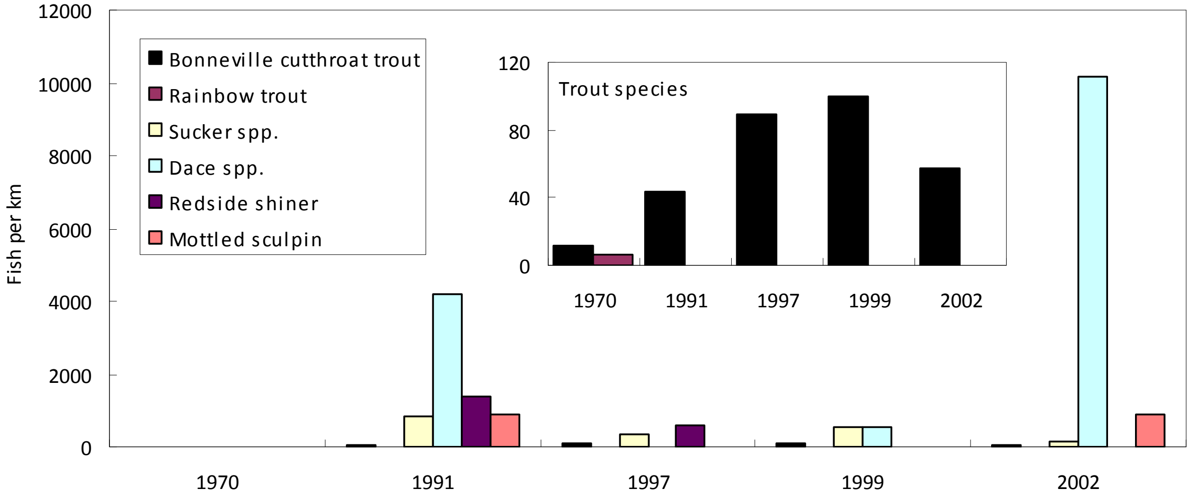


Figure 9: Population density estimates (see note below Table 9) for all fish species sampled at the UDWR site Section 2-Low (1970-1999) and the EMAP-West monitoring site (2002) on Chalk Creek.

Although differences in sampling methodology among years limit our ability to assess fish population trends on Chalk Creek, we can make some general conclusions from the available data. At the most downstream UDWR site (Section 2-Low), there was a general increase in BCT abundance from 1970-1999, but a corresponding decrease in populations of sucker species, dace species, redside shiners, and mottled sculpin (Table 16).

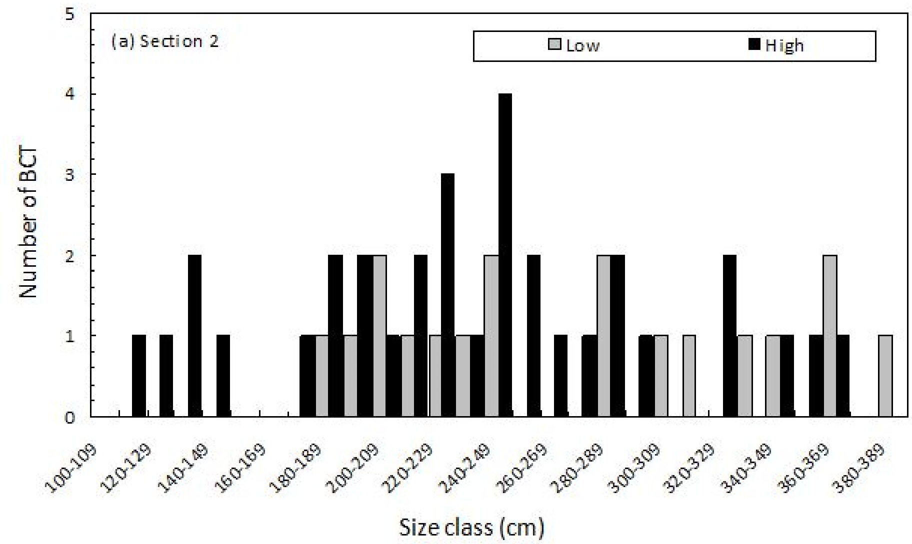
Table 16: Abundance, population density, and species richness estimates (see note) for all fish species sampled at the UDWR site Section 2-Low (1970-1999) and the EMAP-West monitoring site (2002) on Chalk Creek.

Year	Bonneville cutthroat trout	Rainbow trout	Sucker spp.	Dace spp.	Redside shiner	Mottled sculpin	All species
Number fish caught							
1970	2	1	---	0	0	---	3
1991	7	0	98	355	76	86	622
1997	17	0	91	48	29	34	219
1999	19	0	36	21	0	0	76
2002	4	0	10	713	0	63	790
Number fish per km (see note)							
1970*	12	6	---	---	---	---	18
1991†	44	0	820	4216	1370	873	7323
1997§	89	0	362	---	605	---	1056
1999§	100	0	553	537	0	0	1190
2002**	57	0	143	10186	0	900	11286
Species richness (see note)							
	All	Natives	Non-natives				
1970	4	3	1				
1991	5	5	0				
1997	5	5	0				
1999	3	3	0				
2002	4	4	0				

Interestingly, when a nearby site was sampled by EMAP-West in 2002, BCT populations were markedly reduced from 1999 levels, sucker species continued their decline, and redside shiners remained absent, but speckled dace were present in very large numbers and mottled sculpin were moderately abundant. A size frequency distribution for BCT at the UDWR site Section 2-Low in 1999 shows an absence of smaller age classes (Figure 10) that persists in the 2002 EMAP-West survey (Table 16) suggesting that this site is not an important spawning or rearing location for BCT in Chalk Creek; spawning likely occurs in the South Fork of Chalk Creek and its tributaries (Thompson 2000). A habitat quality assessment conducted by UDWR in 1999 identified cover and macroinvertebrate density as limiting factors, but the site appeared to be maintaining a moderate adult population higher than was predicted for the existing habitat (Thompson 2000). UDWR speculated that the one non-native salmonid (rainbow trout) caught in 1970 was probably planted.

Comparing fish population metrics of the 2002 EMAP-West site on Chalk Creek with sites throughout the region, we rated the Chalk Creek site better than "degraded" but still far below what would be considered "undisturbed" conditions. Nevertheless, the presence of BCT in the basin and the lack of non-native species are encouraging. During 1998-1999 surveys of Chalk Creek and its tributaries, UDWR found BCT present on 167 stream kilometers in the drainage. Although non-native brown and rainbow trout were present in lower reaches of Chalk Creek, the diversion barrier 4 km upstream of Coalville effectively prevented the upstream migration of non-native fish from lower reaches and Echo Reservoir – no rainbow or brown were found upstream of the barrier during the 1998-1999 surveys. However, it is important to also recognize that this barrier prevents the migration of BCT, with unknown effects on the health and viability of the native population. In 1999, only two non-native brook trout were found in the drainage, likely due to escapement from private ponds and privately owned sections of streams that have been stocked by landowners throughout the drainage for the past 50-100 years.

Despite a history of rainbow trout stocking in Chalk Creek (500-1000 stocked annually at bridge crossings until 1998), all trout caught in 1997 and 1999 phenotypically looked like Bonneville cutthroat trout (Thompson 2000). UDWR suspected that following the cessation of stocking in 1998, the low number of non-native trout that were present would have soon left the system and were prevented from upstream migration by the diversion barrier. Like lower sites, an upstream UDWR monitoring site also appeared to be maintaining a moderate adult population of BCT in 1999, although the population declined from 1968-1999. Smaller age classes present at this upstream site were attributed to spawning in the East Fork of Chalk Creek, the confluence being just upstream from the site (Thompson 2000).



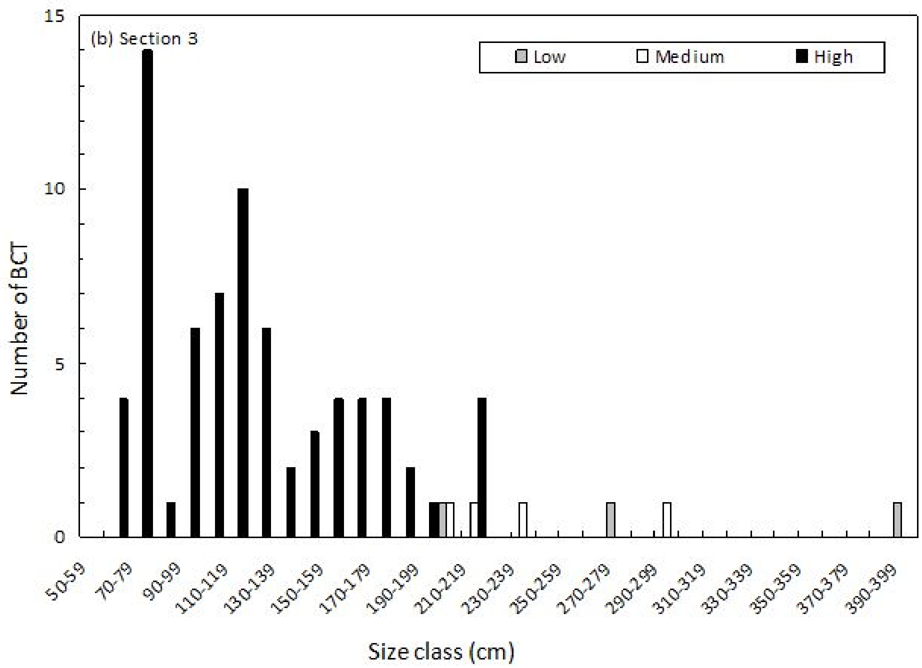


Figure 10: Size distribution of Bonneville cutthroat trout sampled by UDWR in 1999 on two sections of Chalk Creek: (a) Section 2 sites Low and High, located between the diversion barrier 4 km upstream from Coalville upstream to the East Fork of Chalk Creek; and (b) Section 3 sites Low, Medium, and High, located between the East Fork of Chalk Creek confluence upstream to the headwaters.

Given the low numbers of non-native trout, the long history of pond stocking, and little evidence for past hybridization (all cutthroat trout phenotypically resembled BCT), the threat of non-native trout establishing in the Chalk Creek drainage appears to be negligible. If a goal of BMP implementation is to maintain a healthy and viable population of BCT in the basin, attention should be focused on improving and maintaining the quality of instream habitat, particularly in headwater reaches and tributaries (e.g., East Fork) that are utilized for spawning and rearing by BCT. Overall, the absence of non-native fish species in this system is heartening, given the profound impact that introduced species can have on native fish populations in the western U.S. via predation, competition, introgressive hybridization, disease transmission, and other pathways (Dunham et al. 2002, Weigel et al. 2003, Koel et al. 2005). If improvements to the biological fish community are desired, rehabilitation efforts should aim to increase the abundance and age structure of cutthroat trout and/or the number of coldwater native species (e.g., minnows).

Chalk Creek: Summary and Conclusions

Despite the spatial and temporal patchiness of the available data and differences in methodology among data sources, our analysis generated a few key findings.

- Overall, habitat quality of the study sites was moderate relative to suitability criteria and other sites in the region, but improvements to habitat could still be made. Flow velocity, overhead cover, and the percentage of pools were the least suitable habitat variables at most sites. Higher rated variables included metrics of streambed fine sediment, habitat complexity, substrate size, and flow depth.
- Fish population data from 1970 to 2002 indicate a negligible impact of non-native species on the BCT metapopulation in the Chalk Creek drainage. A diversion barrier 4 km upstream from Coalville (downstream from study sites) effectively prevents upstream migration of non-native trout from Echo Reservoir and downstream reaches. However, this barrier also prevents the upstream migration of BCT, with unknown effects on the native population in the watershed. BCT size distributions show that headwater reaches and upstream tributaries serve as important spawning and rearing habitat for BCT, thus it seems critical that connectivity with upstream reaches be maintained if maintaining a healthy population of BCT in the watershed is desired.
- Without knowledge of other limiting factors not assessed in this study (e.g., disease, food availability), our results suggest habitat quality could be improved in some reaches by increasing overhead cover, which may increase BCT density, distribution, and size structure in the watershed.

Sevier & San Pitch Rivers: Assessment of UDWR Monitoring Data

Although we did not collect primary data in watersheds other than Chalk Creek, we did locate existing monitoring data from state wildlife agencies that allowed us to examine evidence for impacts of BMP projects on ecological conditions and fish populations in the Sevier and San Pitch watershed study areas.

In 2004, the UDWR's Southern Regional Office conducted several restoration projects on the East Fork of the Sevier River aimed at improving habitat for both native and sport fishes (native cutthroat and non-native brown and rainbow trout). From 2004 to 2009, UDWR sampled fish populations (two- or three-pass electrofishing surveys) at four sites on the East Fork and around Black Canyon Wildlife Management Area (WMA) to evaluate fish community response to restoration; sampling was not conducted prior to project implementation or in 2005-2006 due to high flows (Bennion and Cox, 2009). Quantitative habitat characteristics (e.g., substrate, percent available habitat) and fish densities were also sampled in a more comprehensive manner at eight stations on the East Fork in August 2010 (Bennion, 2010).

Of the four stations sampled from 2004-2009, two (Stations 2 and 3) were within restored sections of river and two were unrestored reference sites upstream (Station 4) and downstream (Station 1) of the restored area. Despite large floods in the winter of 2004 and spring of 2005 that damaged some restoration features (e.g., rock barbs, root wads), both Stations 2 and 3 retained several artificial structures such as rock vanes and large boulders that created large slackwater areas and deep pools (Bennion and Cox, 2009). Similar structures were found in unrestored stations, including root wads, pools, overhanging vegetation, undercut banks, and slackwaters.

In 2009, native fish densities were highest at the most downstream reference station and lowest at the two restored sites (Figure 11). In contrast, trout densities in 2009 increased in an upstream direction, independent of restoration status (Figure 12), although downstream stations 1 and 2 had the highest trout species diversity. From 2004-2009, overall native fish densities declined in the restored stations, but increased or remained static in the reference stations. Densities of southern leatherside, a native species of concern in Utah, declined from 2004-2009 at all stations except reference Station 1, with dramatic reductions from 2008 to 2009 (e.g., >60% decline) that were not seen in sampling years 2004 and 2007. 2009 trout densities were much higher than in the previous three years of sampling (Figure 10), but this increase may be due to the annual stocking of cutthroat that has occurred since before the study began (S. G. Beckstrom, personal communication). Without information about stocking densities, composition, or location, we cannot evaluate whether stocking or other factors have resulted in the increase in trout densities at these sites.

In all sampling years, the unrestored reference Station 1 had the highest native fish densities. Whereas Station 1 and Station 3 showed evidence of native fish reproduction and recruitment, low numbers of young native fish at two stations (2 and 4) indicated limited recruitment. Given the availability of beneficial habitat features (e.g., undercut banks, overhanging vegetation, and a large slackwater) at these sites and the direct relationship between increased trout densities and leatherside declines across all stations (e.g., Station 1 had the highest number of natives and lowest number of trout), it is possible that the recruitment success of young native fish was limited by trout presence (e.g., through depredation). However, the primary mechanism explaining native fish declines and limited recruitment remains unclear. At restored stations 2 and 3, the initial increase of native fish and leatherside between 2004 and 2007 inferred a positive response to restoration activities, but dramatic declines in both leatherside and native fish numbers in 2009 indicate that fish abundance and distribution may be influenced by other factors than restoration activity.

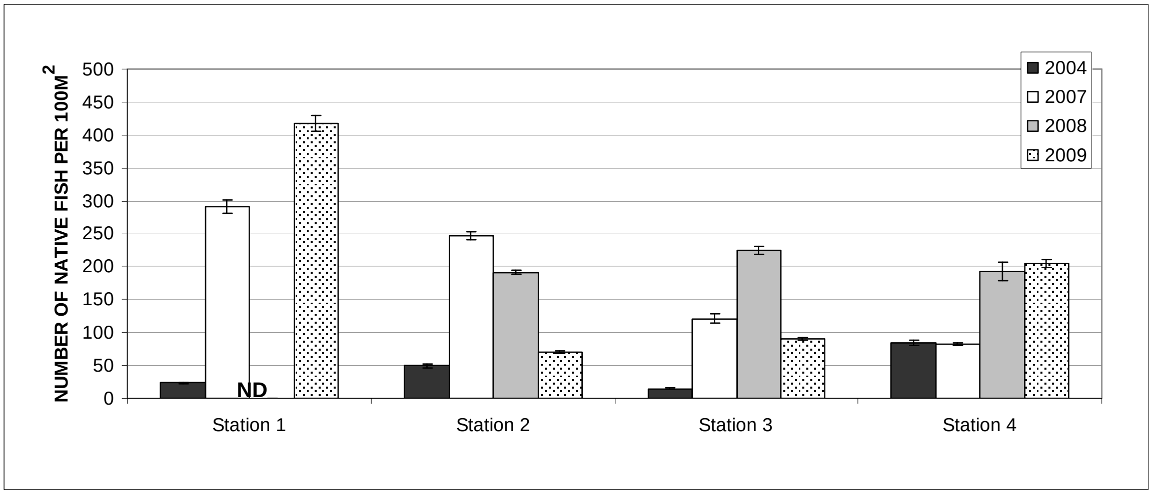


Figure 11: Number of native fish collected by station per 100 m^2 of stream in the East Fork of the Sevier River near Black Canyon WMA during quantitative electro-shocking efforts in 2004, 2007, 2008, and 2009. Error bars = +/- 95% confidence interval.

In Figures 11 and 12, Stations 2 and 3 were within restored sections of river. Stations 1 and 4 were unrestored reference sites. Station 1 was upstream, and Station 4 was downstream. Image source: Bennion and Cox, 2009.

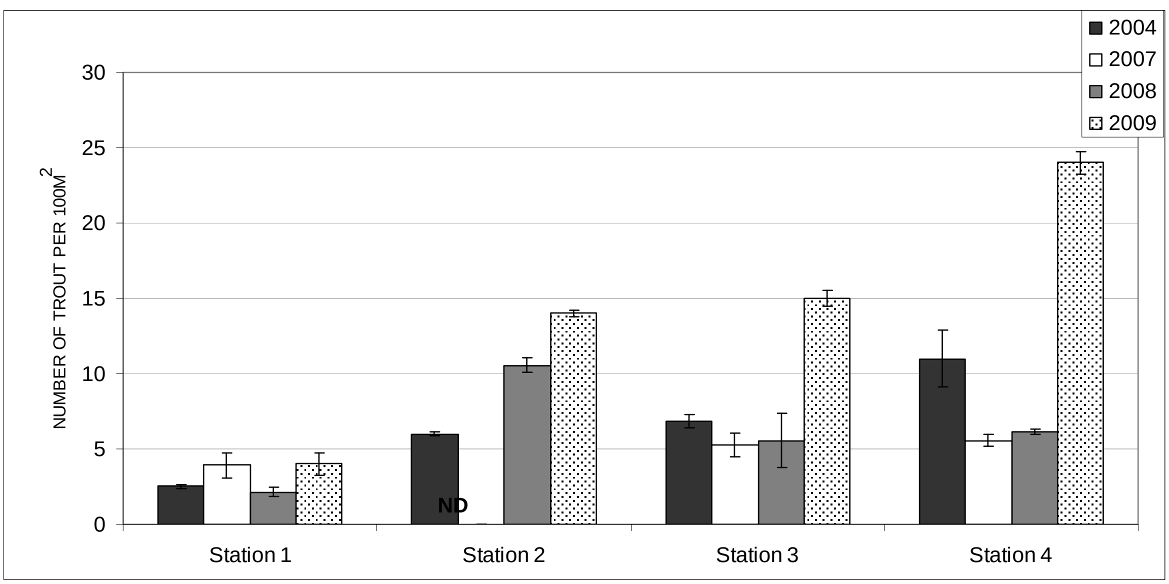


Figure 12: Number of trout (brown, rainbow, and cutthroat) collected by station per 100 m^2 of stream in the East Fork of the Sevier River near Black Canyon WMA during quantitative electro-shocking efforts in 2004, 2007, 2008, and 2009. Error bars = +/- 95% confidence interval.

Although fish communities were sampled again in 2010, differences in sampling methodology and study locations make comparisons with earlier data difficult (the 2010 surveys were intended to provide baseline data for a long-term southern leatherside monitoring program). However, the 2010 sampling efforts do provide a more comprehensive survey of fish densities and habitat characteristics at eight sites along the East Fork (Bennion, 2010). Given that only one of these sites was located within the treatment area (S. G. Beckstrom, personal communication), we used the 2010 data to characterize general conditions within the watershed rather than assess restoration effects. Specifically, we used two habitat metrics (i.e., percent pools and percent fine sediment (sand and silt) to rate habitat quality at each station using a basic trout habitat suitability index (Hickman and Raleigh, 1982), acknowledging that many other physical factors influence habitat quality. Based only on the percentage of pools, we rated habitat quality at the eight stations as average or good (>5% of reach in pools); however, based on the percentage of fines, habitat quality all stations except two would be considered poor (>20% fine sediment; silt-dominant) (Figure 13). Interestingly, the 2010 surveys found little correlation between habitat or substrate type and southern leatherside densities at these sites, but overall low trout densities might be explained by the abundance of fine sediment in this system. A more thorough evaluation of habitat conditions is needed to elucidate the relationship between habitat quality and fish densities in this system.

NOTE: More detailed information on the 2004-2010 sampling efforts and notes and data from qualitative population surveys conducted prior to restoration (1995, 1997, 2002, 2003, and 2004) can be accessed from UDWR personnel of the Southern Regional Office (S.G. Beckstrom, UDWR, personal communication)

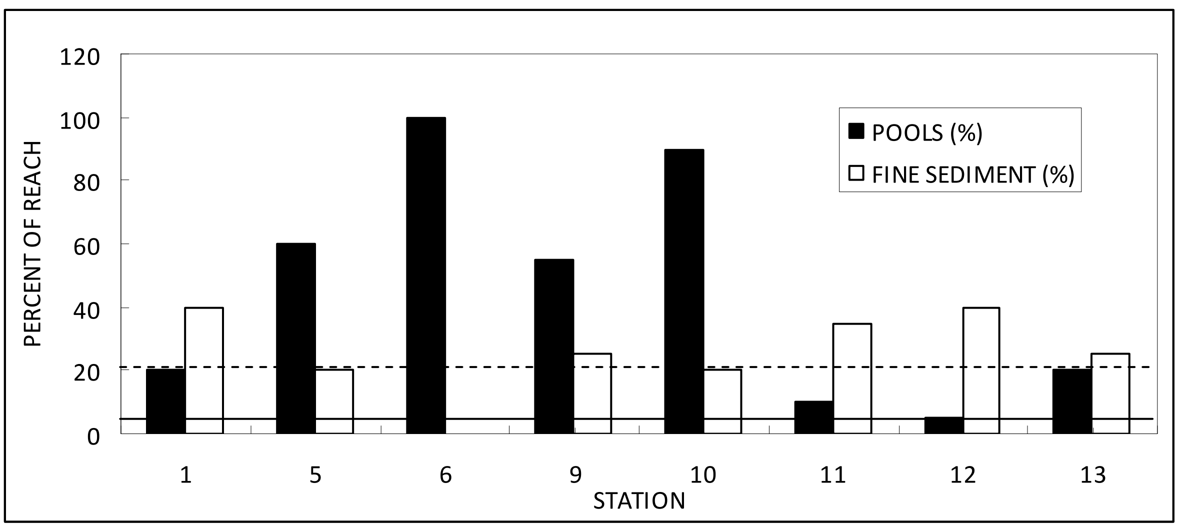


Figure 13: Percentage of pools and fine sediment (silt and sand) at eight monitoring stations of the East Fork of the Sevier River in August, 2010.

Solid line indicates the percentage of pools *below* which habitat quality would be considered "poor" based on a trout habitat suitability index; dashed line indicates the percentage of fine sediment *above* which habitat quality would be considered "poor." Data source: Bennion, 2010.

San Pitch River

A monitoring program conducted by the UDWR assessed the effects of physical restoration on fish populations and habitat quality at two sites on the San Pitch River, Utah (Slater and Wiley, 2006). Restoration on the San Pitch in 2003 and 2004 included the placement of structures (e.g., root wads, log vanes, grade control) to stabilize banks and provide fish habitat, as well as fencing to exclude livestock and allow vegetation reestablishment along ~3,000-4,000 linear feet of stream. In addition, willows and grasses were planted, as one of the main goals behind both structure placement and livestock exclusion was to allow the vegetation to be re-established and hold the banks and create additional cover. Prior to and annually for 2-3 years after restoration, UDWR conducted fish surveys and measured habitat conditions at the two sites, data which were then used to estimate exotic brown trout populations and predict trout biomass from a habitat quality index.

Trout numbers and biomass increased annually at both sites (Figure 14) reaching significantly higher levels relative to pre-restoration conditions (a 46-356% increase for trout >150 mm). In addition, the native leatherside chub was sampled in restored areas for the first time in 2006. Habitat quality measurements also predicted large increases in trout biomass relative to control conditions, which showed no change or a decrease in predicted trout biomass. Among habitat conditions, the area of overhead cover (all forms) exhibited the most marked improvement, increasing annually at both sites (reaching >1,000-2,000% of pre-construction levels by 2006).

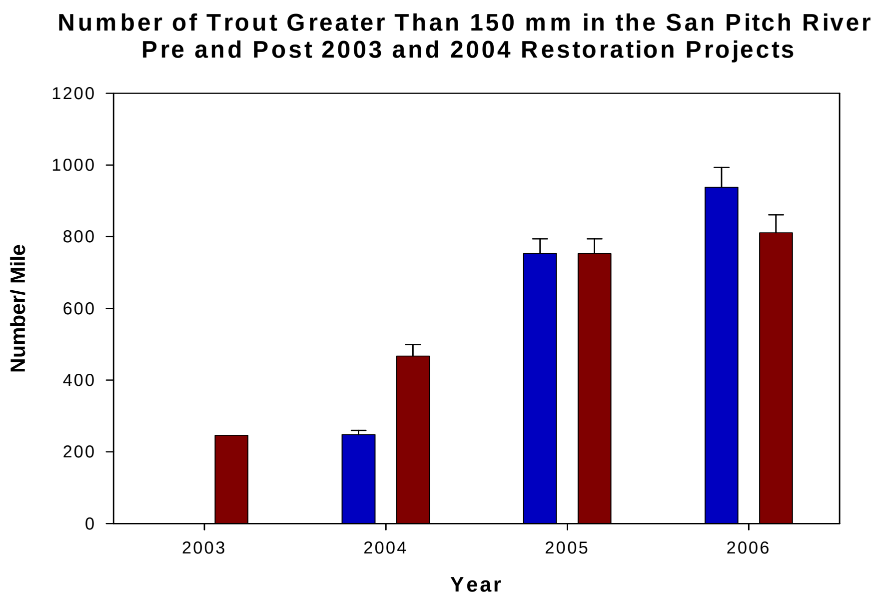


Figure 14: Trout numbers in the San Pitch River before and after restoration projects were completed in 2003and 2004.

Mean water depth and macroinvertebrate density also increased annually, suggesting improved habitat complexity and food resources. Temperatures remained within a range considered suitable for trout (2-22 degrees C). Meanwhile, the length of eroded bank (linear feet) declined in each year, despite extremely high 2005 spring flows and damage to some banks and habitat structures. Pre- and post-restoration photographs showed the grading of banks and vegetation regrowth at both sites in the year after construction. Together, these results suggest that relatively small-scale physical restoration projects – including livestock exclusion, bank stabilization, and instream structures – have had positive effects on habitat quality and trout populations on the San Pitch River in the three years immediately following construction. Determining which actions have been the most effective (e.g., fencing versus structure placement), whether these positive responses will persist over time, and if these local projects will have larger, population-scale impacts requires ongoing monitoring at these and other sites throughout the basin. Furthermore, by integrating these results with those from other Utah watersheds, there is potential to evaluate whether local-scale physical stream restoration can have sustainable and widespread impacts on aquatic systems and fish populations throughout the state.

Table 17 summarizes evidence of potential impacts of BMP implementations in Chalk Creek, Sevier and San Pitch watersheds on fisheries metrics.

Table 17: Summary of Evidence of BMP Impacts on Aquatic Ecology by Watershed Location, Metric, and Data Source. Details of responses included in text.

			Effect of BMP Implementations			
Site	**Metric**	**Method**	**Clear Positive Response**	**Likely Positive Response**	**No Change**	**Clear Negative Response**
Chalk Creek	Fish Habitat	Online database and field assessment			X	X
	Native Fish	Online database and literature review		X		X
	Exotic Fish	Online database and literature review			X	
Upper Sevier	Fish Habitat	Literature review		X		
	Native Fish	Literature review				X
	Exotic Fish	Literature review		X		
San Pitch	Fish Habitat	Literature review	X			
	Native Fish	Literature review		X		
	Exotic Fish	Literature review	X			

4.1.5.5 Results of Historic Aerial Photography Analysis

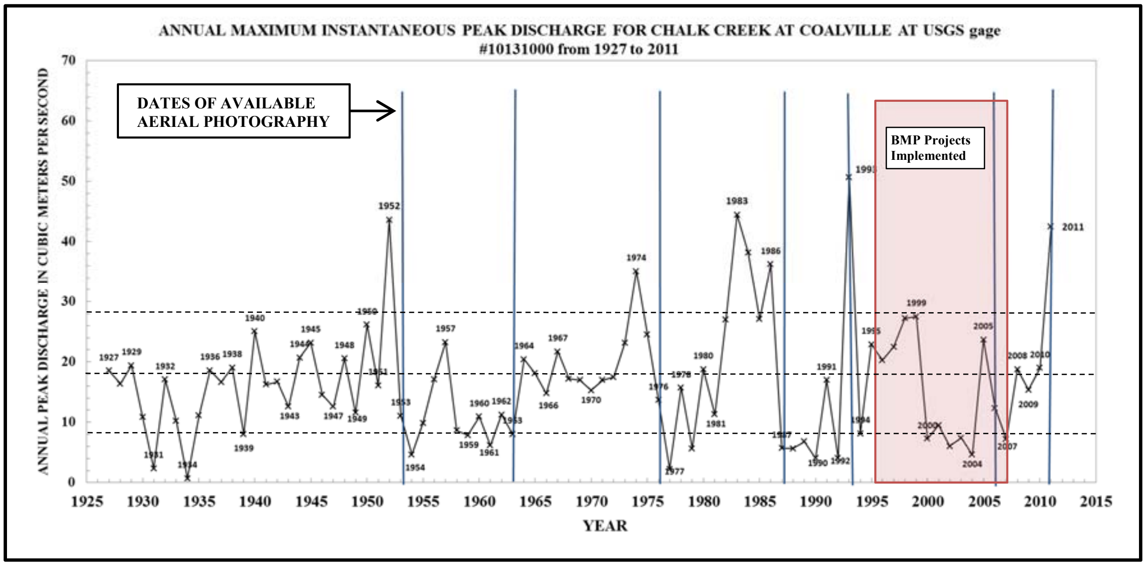
Modern Changes vs. Historic Rates of Change

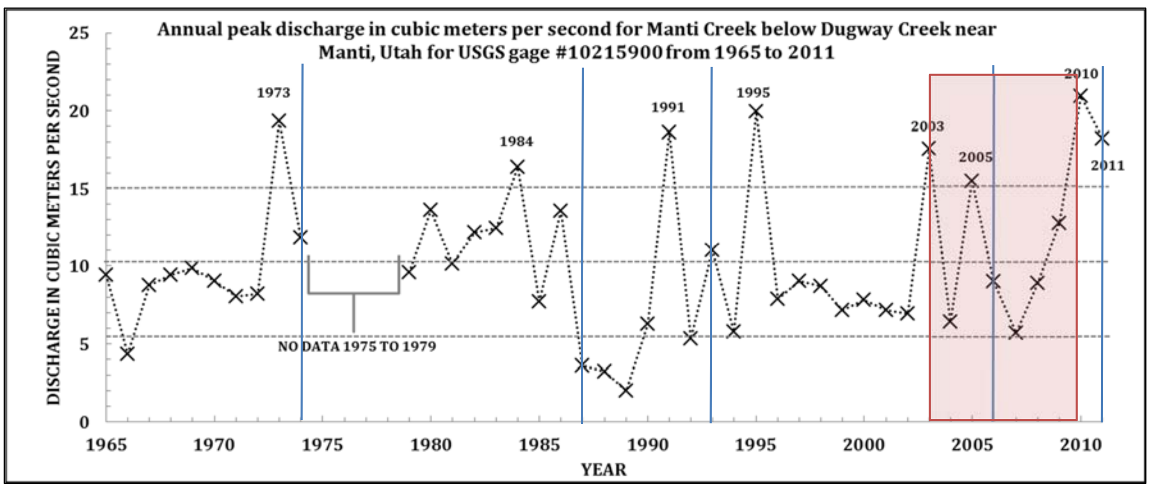
As described in the Methods section, we utilized historic aerial photographs to identify trends in stream channel and streambank conditions in a long-term context, and to highlight potential differences between treatment and control sections of targeted rivers in three study watersheds. We analyzed each watershed as a whole (to use as a benchmark), and then separately for sections of the stream that either received or did not receive BMP treatments

As background, it is important to appreciate that rivers are dynamic physical structures on the landscape, and the impacts of human interventions (like the use of protective BMPs) are often difficult to tease out against the backdrop of 'normal' patterns of change. In the semi-arid Intermountain West, it is also common for snowmelt-driven rivers to exhibit a 'flashy' character where unusually high flows can occur during spring runoff. The erosive force of these relatively short-term events result in lateral movement of channels, changes in channel widths, and the width and density of riparian zones. Different types of human activities (like impoundments, irrigation diversions, changes in land use, vegetation changes, etc.) can both moderate or increase these natural processes.

Figure 15 shows the historic 'hydrograph' for three of our study watersheds (Chalk Creek, San Pitch, and Upper Sevier). Each graph covers the years for which USGS data are available (which varies by watershed). The solid lines on the Chalk Creek graph and the 'Xs' on the Manti Creek and Sevier River graphs represent annual peak flows (or 'maximum peak discharge') at one representative US Geological Survey monitoring site in each watershed. The middle horizontal dotted line on each graph represents the average peak flows for the entire period of record, while the top and bottom dotted lines represent one standard deviation above and below the mean.

The graphs illustrate how unusually high peak flows – those more than one standard deviation above the historic average – occur with some regularity in each watershed (though the exact years of unusually high flows vary somewhat from place to place). We generally would expect higher rates of lateral channel migration (LCM) and widening channel widths in the aftermath of these unusually high peak flow events. Riparian vegetation loss is usually a result of anthropogenic forces and not high flow events but the loss of riparian vegetation can contribute to higher rates of LCM and larger channel widths.





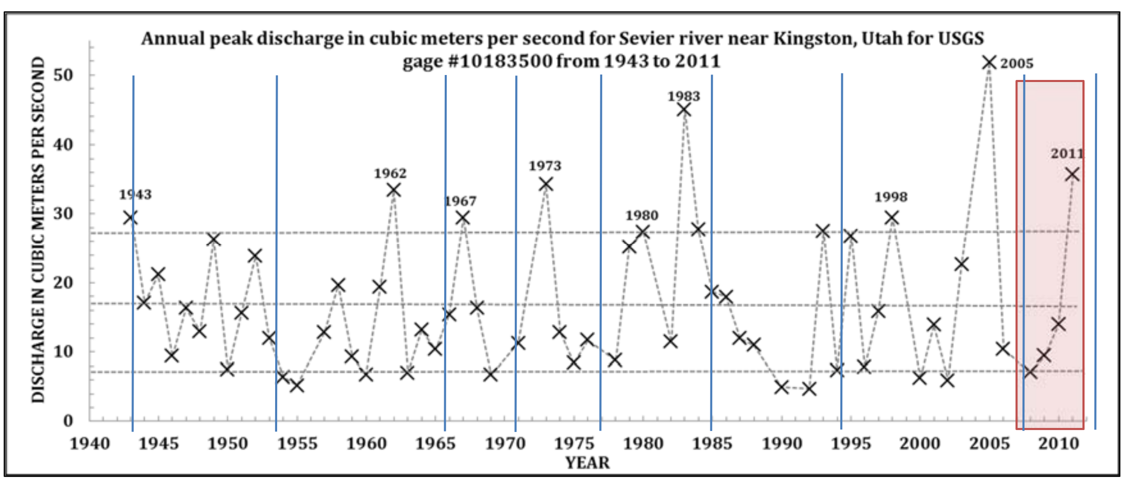


Figure 15: Peak Discharge Hydrographs, Timing of Aerial Photographs, and Project Implementation for Chalk Creek, San Pitch and Sevier River Watersheds.

The graph for Chalk Creek shows that the main period of BMP implementation (mid-1990s through mid-2000s) was bracketed by two years of unusually high flows (1993 and 2011), but there were no peak flows that exceeded 1 standard deviation from average during the time most 319-project BMPs were implemented.

By contrast, while the graphs for the San Pitch and Upper Sevier Watersheds also show high flows from the early 90s and in recent years, they also show one or more unusually high peak flow years in the mid-2000s that coincided more within their periods of BMP implementation.

Historic Patterns of Changes in River Conditions in Study Watersheds

Through systematic comparison of historic photographs across time, we were able to estimate three key indicators of changes in river conditions across time: lateral channel migration (LCM), active channel width and percent vegetation.

Chalk Creek

The results of Chalk Creek are summarized in Figure 16 (A-C). The years during which 319-funded stream BMPs were implemented in Chalk Creek are highlighted in the pink box.

Lateral channel migration (LCM) averaged roughly 1 meter per year from the early 1950s through the mid-1970s (Figure 16A). This jumped up to over 1.4 meters per year between 1976-1987 (likely related to high flows in 1983 and 1986), and 1.8 meters per year between 1987-1993 (most likely a reflection of historically high flows in 1993). These rates dropped to less than 0.74 meters per year during the 1993-2006 period (a time when most BMPs were adopted), and rose only to 0.6 meters per year in the short post-BMP period.

The decline in mean LCM rates during the most recent two periods provide some indirect evidence that stream BMPs are potentially stabilizing the movement of Chalk Creek. However, the fact that there were no years with peak flows above 1 standard deviation from normal since the early 1990s (until 2011) may also account for some of the observed reduction in mean channel migration rates. That said, the analysis for the most recent period (2006-2011) which includes observations about channel characteristics measured after the historically high flows in the spring/early summer of 2011, also suggests a more stable or resilient stream system.

Figure 16B shows Chalk Creek's average active channel width over the full length of Chalk Creek at seven points in time since the early 1950s. In general, healthy mountain stream systems have a deeper and narrower channel, and a widening of the channel is seen as evidence of disturbance in the natural stream system. Results suggest that the mean stream channel width dropped in the 1950s, then increased steadily through the early 1990s (the point in time when the 319 BMP projects were initiated). Mean channel widths measured in the post-BMP implementation periods suggest a much narrower channel – consistent with the notion that BMPs are improving the performance of Chalk Creek.

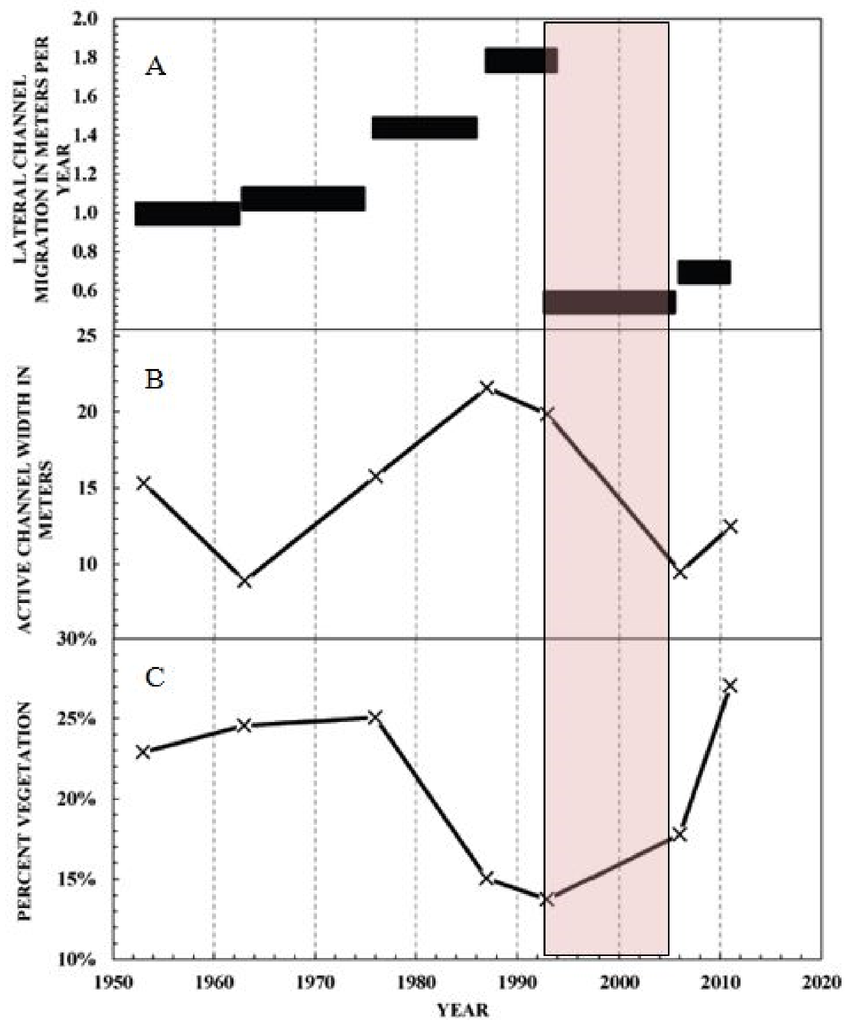


Figure 16: Measurements of Change in River Morphology in Chalk Creek, 1953-2011

Figure 16C shows the percent of the immediate riparian zone along Chalk Creek which is covered with vegetation. Here we see evidence for a significant decline in riparian vegetation cover along Chalk Creek between the late 1970s and the early 1990s. Many of the 319 BMPs in Chalk Creek sought to reestablish riparian vegetation. Results of this analysis suggest that the average vegetative cover throughout the Chalk Creek system increased between the pre- and post-BMP periods, with the highest historic measured levels of vegetation occurring in the most recent (2011) observation period.

Taken as a whole, these results suggest that the implementation of stream-oriented BMP projects in Chalk Creek are associated with improvements in overall stream system conditions. Lateral channel migration rates remain at historically low levels, active channel widths have declined, and riparian vegetation has increased substantially.

San Pitch River

Results for a similar analysis of historic trends in the San Pitch River watershed are presented in Figure 17 below. In this case, we focus on five years of observation between 1963 and 2011 (the times when comparable aerial imagery was available). Compared to results from Chalk Creek, over the same time period the San Pitch watershed has experienced more modest changes in two of the three indicators of stream condition. The mean rate of lateral channel migration rose slightly late 1970s and 1980s (Figure 17A), and appears to have declined both before and after the implementation of stream BMPs. Meanwhile, the average width of the active channel rose from 1963 to 1993, but has remained almost constant in the watershed since that time (Figure 17B). The most striking historic changes in the San Pitch watershed are a rapid decline in riparian vegetative cover between 1973 and 1993, followed by a slow but steady increase between 1993 and 2011 (Figure 17C).

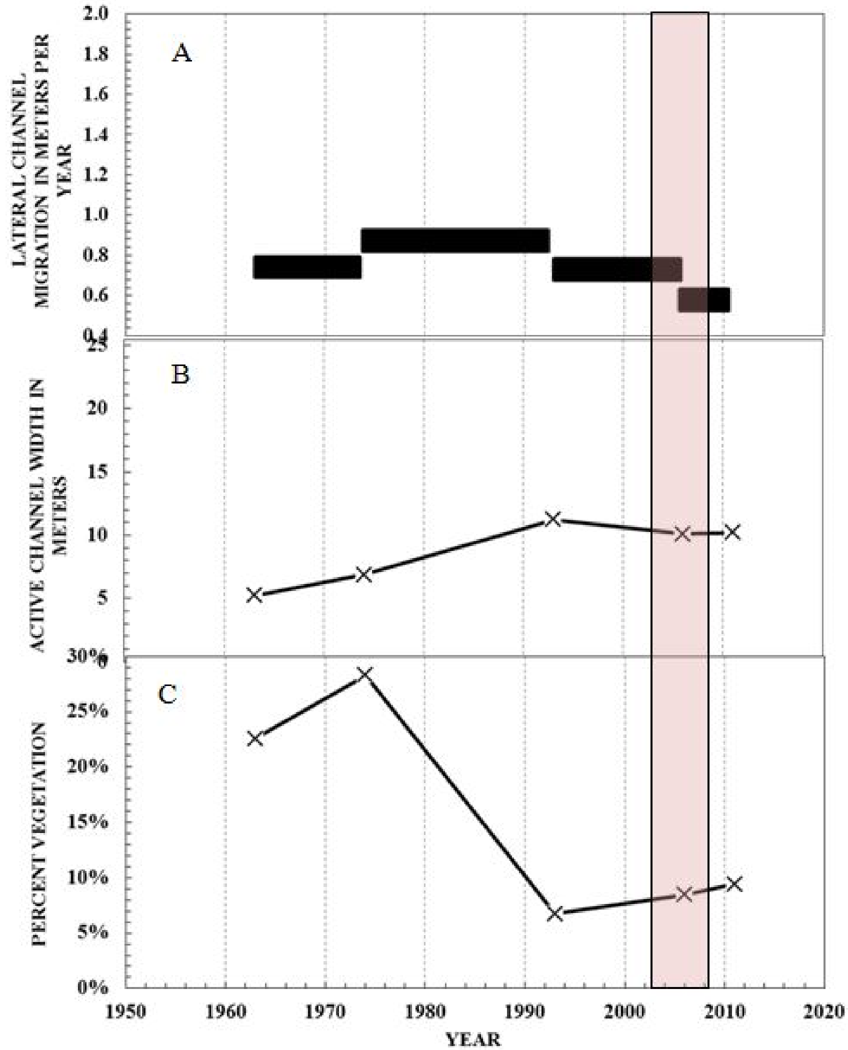


Figure 17: Measurements of Change in River Morphology in the San Pitch River, 1963-2011

Sevier River Watershed

Because of the much larger size of the Sevier River 319 project watershed (which included stretches within both the main and east forks of the river), we did not have the resources to conduct an analysis along large enough segments of the study areas to reliably estimate similar watershed-scale trends across time. We did gather information about five distinct river reaches within the Sevier River system that are used in the analyses presented below.

Comparing trends in BMP vs. Non-BMP reaches

While historic shifts in watershed-wide trends are an important way to benchmark current overall stream conditions, we used our site visits and project files to identify stream reaches that received 319-funded stream BMPs, and also stretches of river where we are believe did not receive any 319 funded BMP implementation. We used this information to compare river conditions and trends for BMP and non-BMP reaches within all three study watersheds.

Chalk Creek

Figure 18 presents historic mean rates of lateral channel migration (LCM) separately for reaches of Chalk Creek that did (and did not) receive 319-funded BMPs. Remembering that the BMPs were not implemented until the 1990s and early 2000s, it is apparent that the BMP reaches in Chalk Creek had notably higher rates of LCM than untreated zones in the 1980s, but lower rates of LCM in the early 1990s (just prior to project implementation). In the period after 319 projects were installed, the rate of LCM dropped in both BMP and non-BMP areas.

Meanwhile, BMP zones appear to have slightly higher average rates of LCM than areas that did not receive BMPs. From these results, it is difficult to know whether the higher rates of LCM in the post-BMP period reflect greater vulnerabilities to LCM in areas treated with BMPs (which would appear to be true in the 1980s, but not in the years just prior to 319 project work), or whether BMP implementation actually raised LCM rates above background levels.

Figure 19 shows similar comparisons for the average active channel width in BMP and non-BMP reaches of Chalk Creek. Results suggest that BMP implementation areas had slightly narrower channels in the 50s and 60s, but wider active channel s in the two decades preceding 319 project implementation. After project implementations, the average channel widths in BMP and non-BMP reaches were nearly identical. Meanwhile, historic trends in active channel width tend to track in similar directions for both BMP and non-BMP zones. For example, in the period following BMP implementation, channel widths narrowed significantly in both BMP and non-BMP areas, suggesting that BMP installation is unlikely the only explanation for the observed change.

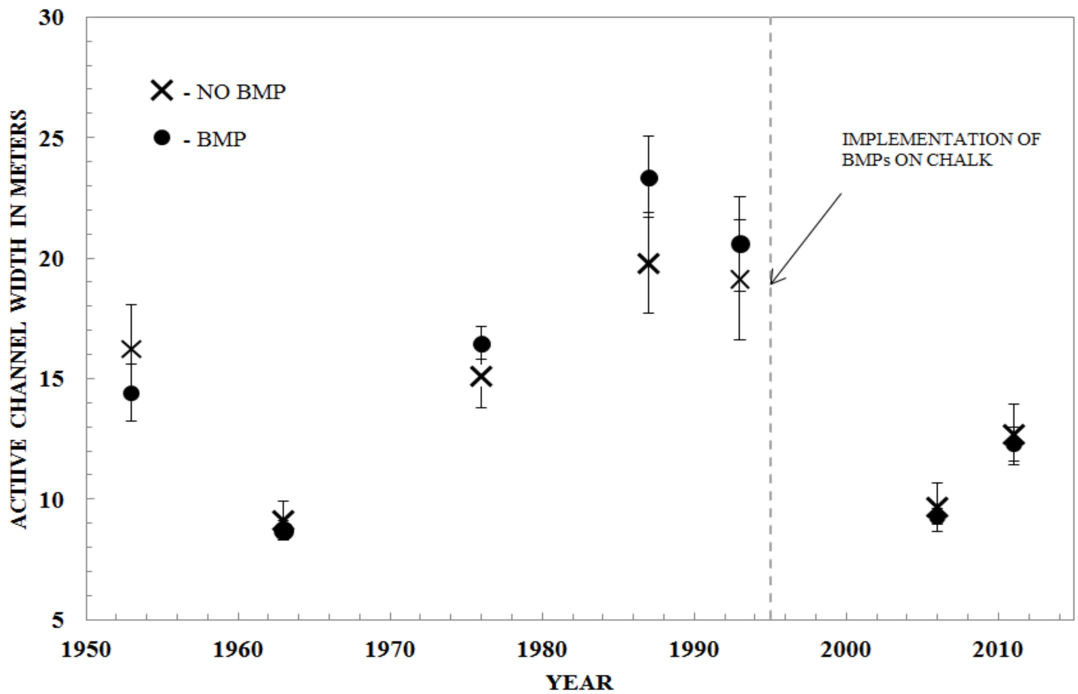


Figure 18: Comparison of Mean Active Channel Width, BMP and Non-BMP stretches of Chalk Creek, 1953-2011.

The third indicator of stream conditions is the percent of riparian area that is covered with vegetation in the aerial photographs. Results in Figure 20 suggest that during the 25 years prior to the 319-project, BMP reaches in Chalk Creek had more vegetation in their riparian zones (on average) than stretches of river which did not receive BMP projects. After project implementation, BMP and non-BMP zones appear to have nearly identical rates of riparian vegetative cover. Again, historic trends in riparian cover in the watershed track in similar directions within both BMP and non-BMP reaches, with significant gains in riparian vegetation both inside and outside BMP areas over the last 20 years.

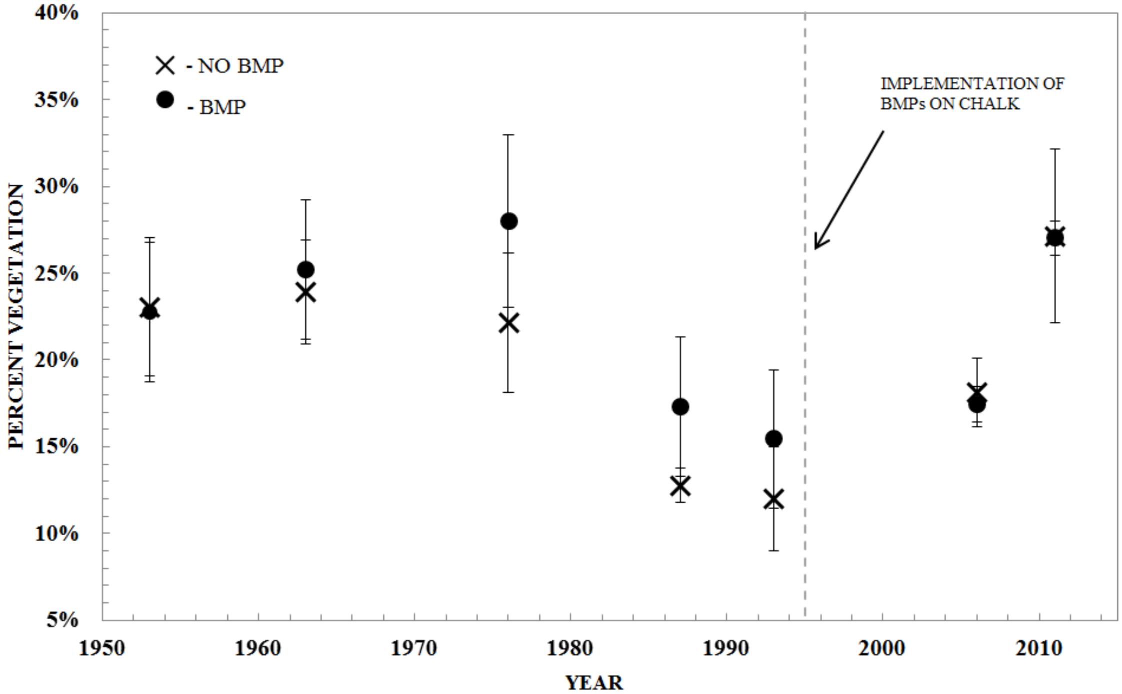


Figure 19: Comparison of Percent Vegetation in Riparian Zones, BMP and Non-BMP stretches of the Chalk Creek, 1953-2011.

San Pitch

Results for similar analyses of BMP and non-BMP reaches in the upper San Pitch river system are presented in Figure 21 (A-C). The results here suggest that BMP and non-BMP sites are quite similar across most measurement periods. There is a slightly higher rate of lateral channel migration and active stream channels are somewhat wider in non-BMP regions, though these differences predate implementation of 319 stream projects in the early 2000s. Riparian vegetation is slightly higher in BMP reaches in the 60s and 70s, but these differences disappear by the 1990s and appear to be slightly lower in BMP areas in the most recent measurement period (2011). Overall, these results suggest little systematic impact of BMP implementation on broader patterns of stream morphology in the upper San Pitch River.

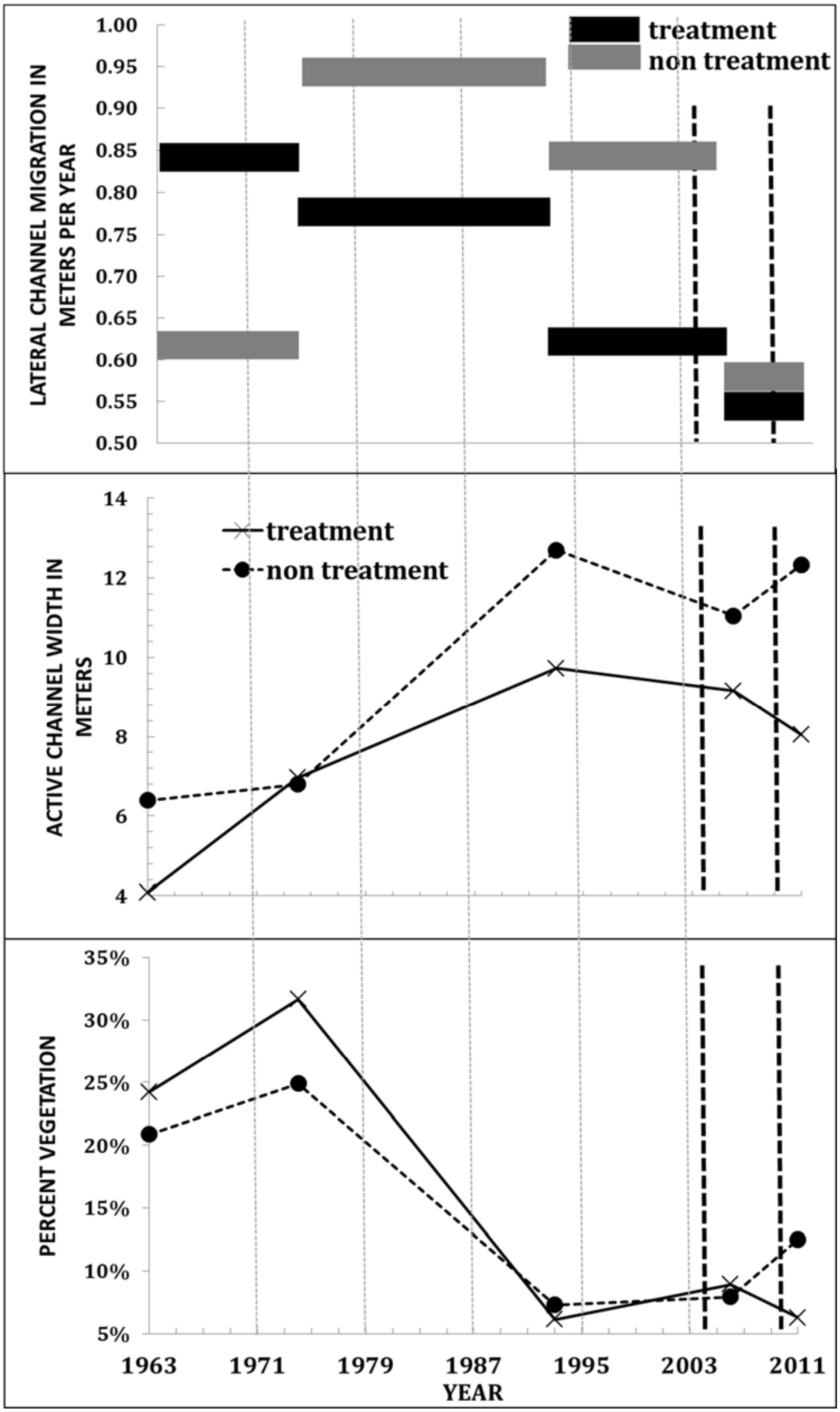


Figure 20: Comparison of River Morphology, BMP and Non-BMP stretches of the Upper San Pitch River, 1963-2011.

Sevier River

Because of the sheer size of the Sevier River basin, we picked five distinct river reaches for analysis that each included stretches in which 319 BMPs were known to have been implemented (treatment areas) and similar stretches nearby without known 319 BMPs (non-treatment areas). In addition, unlike the Chalk Creek and San Pitch study areas, we decided not to aggregate results of the various analysis reaches. This is because some of the reaches included relatively narrow runs of river inside mountain canyons (with steeper gradients and more confining geographic conditions), and other areas that were in open settled valleys.

Within each of the five study reaches, we estimated historic rates of lateral channel migration, the widths of the active river channel, and percentage of bordering riparian zones that were covered with vegetation. In addition, because aerial photography was not available in each reach for the same years, our analysis covers different periods of time for each reach. Because of concerns about the reliability of the results (due to sparse data), we do not present results here for reach 5. However, separate results for each of the other four reaches are presented in Figure 22.

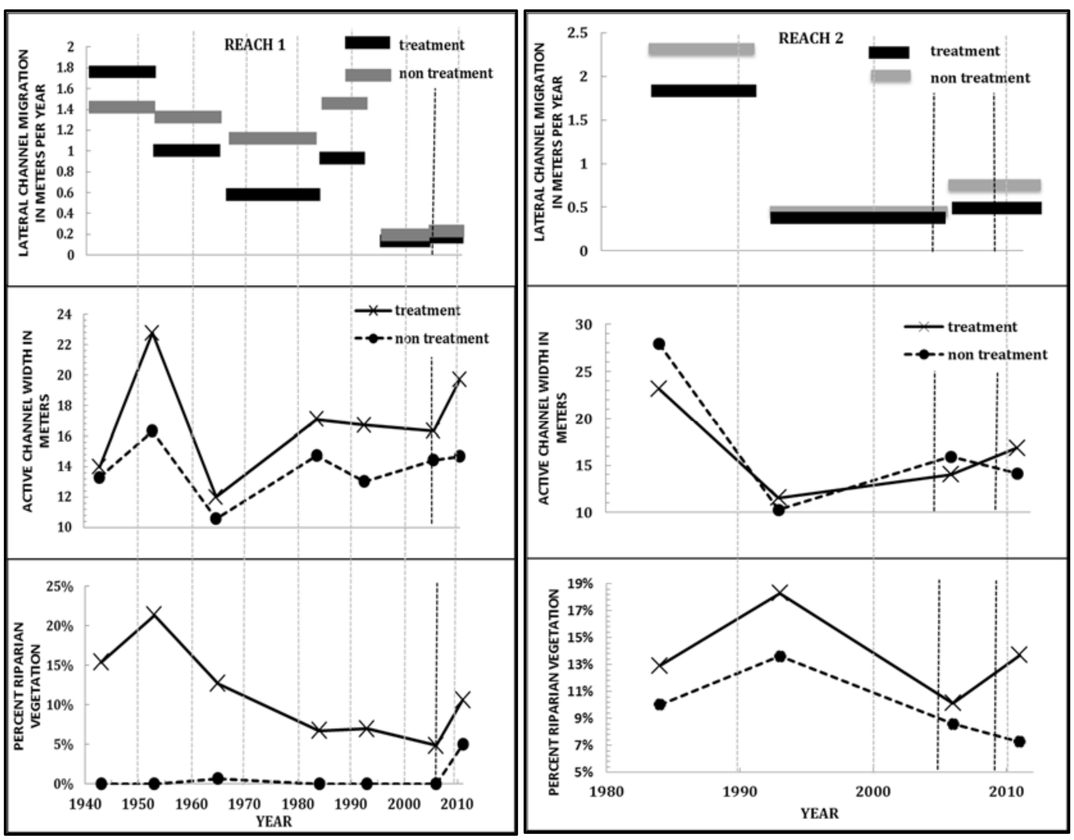


Figure 21: Historic Changes in Stream Morphology Indicators, East Fork of Sevier River, 1940-2011.

The analyses of two reaches on the East Fork of the Sevier River (Figure 22 - #1 and #2) present similar stories (though for a longer time period in reach #1 than in reach #2). Generally speaking lateral channel migration rates were higher in non-BMP stretches of river both before and after the 319 BMP projects were implemented. In the most recent period (2006-2011), rates of LCM are only slightly higher in untreated areas.

Average channel widths are higher in BMP treated reaches during each measurement period for reach 1, but show little systematic difference in reach #2. In both reaches, there is a spike in average active channel width between 2006-2011 in the BMP treated river segments, but not in the untreated areas.

Finally, there is consistently more riparian vegetation at each measurement period along the stretches of river that received 319 BMPs, and a notable jump in riparian vegetation in BMP zones after projects were implemented.

The results for reaches #3 and #4 (Figure 23) reflect watershed conditions over time in the South (or Main) fork of the Sevier River. Here, the story in reach 3 (which reflects the open valley around Panguitch, Utah) suggest steady declines in lateral channel migration rates since the 1960s, with BMP implementation areas showing slightly higher LCM rates prior to the 319 project, and lower rates after the project. Conversely, in reach 4 (which reflects conditions in the narrower canyon valleys upstream), we see increases in LCM through the early 1990s, then a significant drop during the 10-15 years immediately preceding implementation of 319 BMP projects. While BMPs were implemented in river stretches that had higher recent rates of LCM, the difference between treated and untreated sections of river are not very striking.

In terms of changes in active channel width, BMP treated areas within both reach 3 and 4 appear to have had wider channels prior to project implementation, with some evidence that BMPs produced reduced channel widths compared to untreated areas (particularly in reach 4).

Finally, as in the other watersheds, there is a general long-term trend toward reduced vegetative cover in riparian areas in reach 3 (though this is only true since the mid-1980s in reach 4). BMP areas had slightly less riparian vegetation on average immediately prior to the 319 projects, but only showed a trend of increasing vegetation in one of the reaches (reach 3).

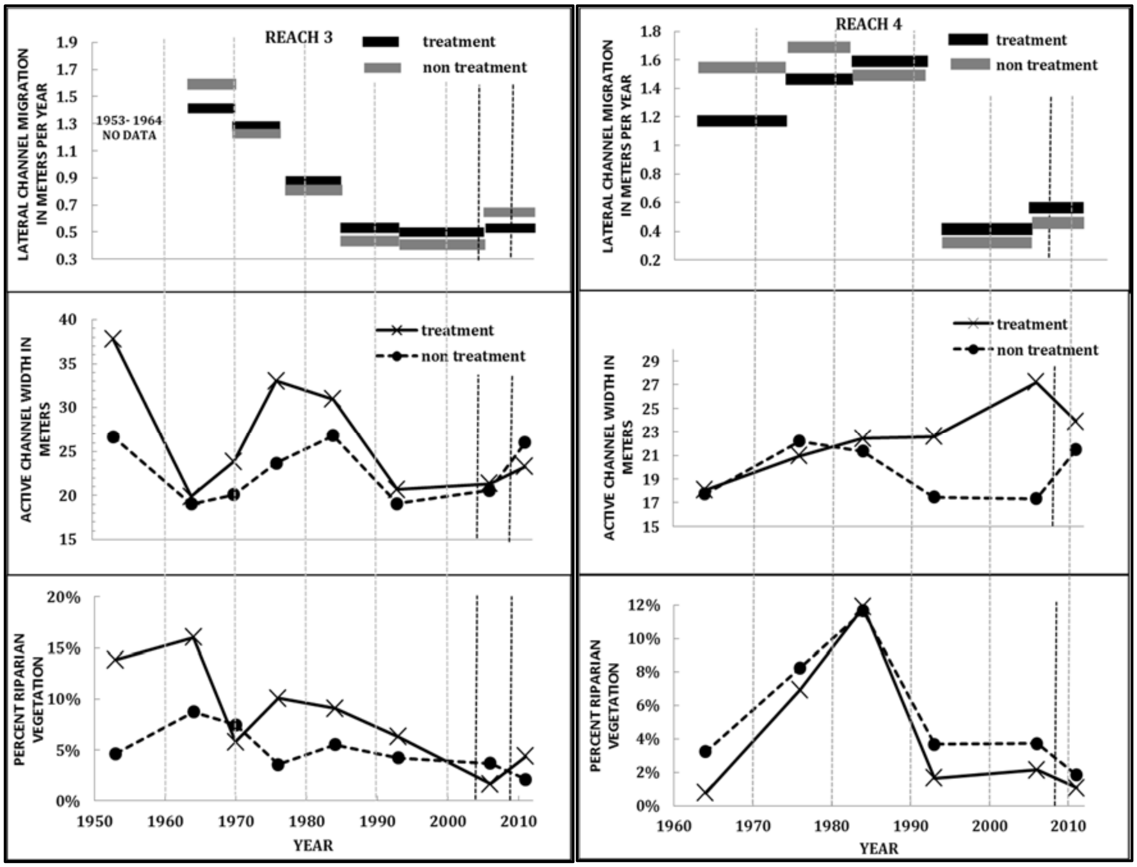


Figure 22: Historic Changes in Stream Morphology Indicators, South Fork of Sevier River, 1940-2011.

Summary of Historic Aerial Photographic Analysis Results

In all three watersheds, the analysis of historical aerial photographs underscores the dynamic character of stream channel morphology in Utah. In every case, the rates of lateral channel migration, mean active channel widths, and percent vegetation in riparian areas have fluctuated widely over the last 60 years. This long-run pattern of variation is linked to climatic events, land use changes, and factors other than BMP use or non-use. It also underscores how difficult it is to attribute any recent changes in stream characteristics solely to the presence or absence of BMPs. Also, definitive results (positive or negative) associated with any stream restoration or mitigation project can take many years to become evident. As such, on-going monitoring is required to develop the strongest and most reliable assessments of long-term stream health and stability.

That noted, when we compare BMP treated reaches with nearby non-BMP treated reaches over the same time periods, we have some tentative evidence about whether BMP implementation is likely to have deflected long-run trends in stream channel dynamics. In this sense, the results of our analysis are mixed.

First, the strongest evidence of positive impacts of stream BMPs was found in the Chalk Creek watershed. Overall, compared to historic trends, the post-319 project implementation periods experienced lower rates of lateral channel migration, narrowing of active channel widths, and increases in riparian vegetation (all of which are the desired outcomes associated with use of stream BMPs). However, when BMP and non-BMP stretches are compared, it is not clear that BMPs are responsible for most of the decline in LCM in the watershed (since declines were more dramatic within non-treated reaches), nor are BMP treated areas experiencing faster gains in riparian vegetation. The strongest evidence of positive project impacts is that BMP use seems to have accelerated the narrowing of channel widths.

In the San Pitch watershed, we see overall long term reductions in LCM, but a gradual widening of channels and decline of riparian vegetation throughout the reaches included in the analysis. Places where BMPs were installed did not have dramatically different river conditions than places that did receive BMPs. Finally, the use of BMPs is not clearly associated with pronounced changes in LCM or riparian vegetation trends, though there is some evidence that BMP areas had narrower active channels.

Patterns of change in the Sevier River watershed are much more volatile – both across time periods, and across different reaches of the river. While overall rates of channel migration are notably lower over time in each study segment, most reaches have relatively wide channel widths and relatively low rates of riparian vegetation. There is some evidence that BMP use has increased riparian vegetation cover (since 2006 in the East Fork compared to non-treated areas), but similar gains were not seen in project areas in the South Fork of the river.

Taken as a whole, it is clear that larger forces of change (such as high spring runoff flows and flooding events) are likely more important drivers of stream morphology than the use of 319-funded BMPs. While there is some evidence of localized positive BMP impacts, when placed in a historic context (and when compared to non-treated areas), the evidence of BMP effectiveness is relatively weak. This is where a system-wide or watershed implementation would prove more effective. There appeared to be instances where BMPs were implemented in a reach but could have been degraded by a lack of BMP implementation upstream from the project. In Chalk Creek, stream BMP implementation appeared to affect the majority of the study region (with associated positive outcomes), compared to the Sevier which reflected the implementation of stream BMPs on relatively isolated reaches with long stretches of untreated stream interspersed with project sites.

4.1.5.6 Comparison of Evidence of Rural Stream BMP Impacts from Different Methods

Because we utilized a wide range of methodologies to assess the benefits of stream-oriented BMPs in three watersheds, we are able to compare the conclusions derived from the use of different methods. In Table 18, we summarize the findings for each specific project site included in our study where we had evidence of impacts from a range of assessment methodologies. To allow comparisons across the different methodologies, we devised a simple 3-level scoring system:

+ Clear evidence of positive BMP impacts or improving trends,

+/- Mixed evidence: some positive impacts, but negative conditions persist, and

\- Either lack of evidence of improved conditions or a suggestion that conditions had deteriorated since BMP implementation.

Results are presented for each of three watersheds in which we had multiple measures of outcomes at individual BMP implementation sites (the Chalk Creek, San Pitch, and Sevier Rivers). The underlying evidence for scoring each site into one of these categories is included in the sections above (or in the more detailed technical reports appended to this report). In all three watersheds, we

- Conducted field visits/interviews with project cooperators,
- Made a formal assessment of "Proper Functioning Condition" in selected reaches,
- Compared before and after photographs of stream BMP locations where available, and
- Used historic aerial imagery to evaluate trends in stream channel morphology and riparian vegetation in BMP locations (and comparison control sites).

In addition, for the Chalk Creek watershed we also conducted intensive field measurements to estimate a Habitat Suitability Index for targeted fish species at four BMP project locations.

Each row in Table 18 represents a single stream reach or landowner property where a suite of stream-oriented BMPs were implemented. Initially, it is clear that within a single stream reach (or project site), a single methodology often produced evidence of both positive and negative impacts from BMP implementation. For example, evidence from our interviews with landowners suggest that a difficult BMP implementation experience was associated with poor maintenance and low perceived water quality outcomes in one location (Site A), but good maintenance and improved water quality in another (Site E). Similarly, evidence from historical aerial photographic records suggest that stream BMP efforts at Site A were associated with documented improvements in lateral stream channel migration rates, no significant change in channel width, and lower than average rates of improvement in riparian vegetation.

Table 18: Evidence of Stream BMP Impacts at Individual Project Sites from Multiple Measures, Chalk Creek Watershed.

Site	Watershed	Fieldwork Assessment			Perceived Producer Benefits		PFC	Site Photo Comp	Historical Aerial Photos			Habitat Suitability Index (HSI) Analysis			
		I	M	WQ	WQ	Op	Score	Trend	LCM	CW	Veg	C / V	D	S	P
A	CC	+/-	+/-	-	+/-	+/-	nd	nd	+	+/-	-	nd	nd	nd	nd
B	CC	+	+	+	+	+	+/-	+	+	+	+	-	-	+/-	+/-
C	CC	+	+	+	+	+	+	+	+	+	+	-	-	+/-	+
D	CC	-	-	-	-	-	nd	nd	nd	nd	nd	nd	nd	nd	nd
E	CC	+/-	+	+	+/-	+/-	+	+/-	+	+	+	nd	nd	nd	nd
F	CC	+	+	+	+	+/-	nd	+	-	+/-	-	-	-	+	-
G	CC	+	+	+	+	+	+	+	+/-	+	+	-	-	+	-
H	CC	+	+	+	+	+	nd	nd	+/-	+	+	nd	nd	nd	nd
I	SP	nd	nd	nd	nd	nd	nd	+	+	+	+	nd	nd	nd	nd
J	SP	+/-	+	+	+/-	+/-	+/-	+	+	+	-	nd	nd	nd	nd
K	SP	+	+	+	+/-	+	+	+	-	+/-	-	nd	nd	nd	nd
L	SP	+/-	+	+/-	+	+	+	+	-	+/-	-	nd	nd	nd	nd
M	SP	+/-	+	+	+	+/-	+	+/-	+	+	-	nd	nd	nd	nd
N	US	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+	+	+	nd	nd	nd	nd
O	US	+	+	+	+	+	+	nd	+	-	-	nd	nd	nd	nd
P	US	+/-	+	+/-	+/-	+/-	-	+	+	+	+	nd	nd	nd	nd
Q	US	+	+	+	+	+	nd	+	-	+	+/-	nd	nd	nd	nd

NOTES: I = Positive Implementation experience; M = Successful Maintenance of BMP; WQ = Estimated BMP impact on local water quality
Perceived Benefits: WQ = Perceived water quality benefit; Op = Perceived benefit to operation
Aerial Photos: LCM = Lateral Channel Migration; CW = Channel Width; Veg = Riparian Vegetation Cover
HIS Index: C/V = Cover/Velocity; D = Depth; S = Substrate; P = % Pools
+ = positive experience or outcome; +/- = mixed experience or outcome; - = poor experience or outcome
nd = no data collected on this indicator
CC = Chalk Creek; SP = San Pitch; US = Upper Sevier

Table 18 shows the degree to which different methods produced similar (or contrasting) evidence of positive BMP impacts. Evidence from interviews of poor BMP maintenance and perceived water quality impacts were supported by the mixed record of benefits as measured by the aerial photographs (Site A) or photo comparisons (Site E).

Generally speaking, landowner perceptions of BMP impacts were consistent with the results of PFC field assessments. The Sevier River sites with the most pessimistic interview results were also the places where an evaluation of proper functioning condition (PFC) obtained from systematic observation of the same stream reach produced evidence of persistent problems.

However, sites where interviewees reported generally positive experience with BMP implementation, maintenance and effectiveness (Sites B, C, F, G, and H) these assessments are not consistently supported by results of PFC, aerial photograph trends, and on-site habitat suitability analysis. On Site B, positive interview results were found even when the PFC analysis suggested 'at risk' conditions and where habitat suitability for targeted fish species remained in poor condition.

This suggests that landowners are not always in a position to 'see' how the outcomes at their own property compare with long-term trends in stream conditions throughout the watershed and/or changes in less visible instream fish habitat conditions.

Interestingly, direct measures of changes in stream geomorphological conditions from the air (historical aerial photograph analysis) did not consistently predict results of more fine-grained assessment of instream fish habitat conditions. This might be because reducing rates of lateral channel migration, narrowing channel widths, and increasing riparian vegetation cover are insufficient to address the all the instream conditions or factors which limit re-establishment of targeted fish species.

It appears that using interviews alone as the basis for measuring BMP impacts and effectiveness can also miss important variation in outcomes that were evident from using other methodologies. More importantly, there was little systematic relationship between landowner self-reports of successful BMP implementation, maintenance, and water quality outcomes and results of historic aerial photographic analysis. This supports the conclusion that individual landowners and project participants may not have the temporal or spatial perspective to really know if their BMPs are producing changes in stream conditions that are better or worse than would otherwise have occurred.

Overall

The comparison of different evaluation methods suggests that documenting BMP impacts at a single site will be more accurate and robust if multiple methods are used. Each method appears to provide a separate (if overlapping) window into the various kinds of impacts on water quality outcomes.

Interviews provide rich information about the technical and managerial obstacles encountered when implementing and maintaining BMPs as part of watershed projects. However, individual landowners are often not in the best position to see the full impacts of their BMPs on water quality outcomes – both on their farm, and in the larger watershed context. To document those impacts, relatively simple approaches (like systematic and periodic PFC assessments and/or well-designed longitudinal matched photographic records) can provide important evidence of stream BMP effectiveness.

The use of more expensive and labor intensive methods of assessment (like analysis of historic aerial photographic records at the reach or watershed scale, or intensive habitat suitability measurements at the site or project scale) clearly provides additional and more authoritative evidence of impacts that does not always confirm the results of the cheaper and simpler approaches. It would seem worthwhile to use these on a less frequent (but systematic) basis to ground truth BMP impact results derived from less costly and complicated methods.

4.1.6 Urban Stream BMPs

Jordan River BMP Assessment Overview

Of the watersheds in our study, only the Jordan River had a sufficient number of urban stream corridor BMPS for evaluation. However, we learned, following consultation with local watershed coordinators and city and county staff, that the BMPs located along the Jordan River corridor did not involve319 funds. With the approval of UDWQ, we evaluated the effectiveness of these urban BMPs none-the-less, as these provided our best chance to learn from typical implementations of urban river restoration BMPs.

We identified a suite of urban river BMP projects based on conversations with local government staff, and from a review of public websites hosted by both Salt Lake City (http://www.slcgov.com/node/627) and Salt Lake County (http://www.watershed.slco.org/html/projects.html). This resulted in a master list of 15 projects. All urban stream projects included in our analysis were implemented on public (county of municipal) lands by the relevant governing authority. These projects were all located along the ongoing Jordan River Parkway Trail project, often in small parks. Any streambank restoration projects conducted in the area by non-governmental organizations (NGOs) or private landowners were not evaluated.

Information and resources used in this analysis included a review of the physical files for the individual projects, in addition to interviews with the Salt Lake County Flood Control Supervisor and the Salt Lake County Watershed Engineer. No other interviews were conducted, primarily because people involved during the time of implementation of the respective projects are no longer holding those positions. We also collected examples of pre- and post-project photographs from local government office files. Finally, a visual field inspection and effort to retake updated photographs for all the projects were completed where access permitted (27 photo locations across 13 project sites).

Generally, the urban stream projects involved revetments and riprap with willow, cottonwood and other vegetative plantings. The two primary focuses of the implementations were erosion prevention and restoration and protection of the banks for recreational use. Prior to the implementations, the streambanks had little vegetation and were suffering from substantial erosion. This river migration and land loss posed problems to the urban environment on several fronts: (1) existing structures and land uses were threatened; (2) unstable river channels were not able to accommodate storm water management and flood control; and (3) a stable stream is required to accommodate bridges and fencing associated with the Jordan River Parkway Trail and other similar recreational uses.

Many of the photographs taken prior to project implementation were actually taken during the early stages of construction and did not effectively demonstrate the extent of the erosion. Those photographs taken before BMPs were installed often depicted substantial erosion or, in the specific areas like the Walden Park project, showed revetment boulders protecting erosion but little or no vegetation on stream banks.

Two of the projects included in this analysis were completed within the context of an EPA Superfund cleanup (Midvale Slag and Sharon Steel). The conditions of these sites were more severely degraded than straightforward erosion and vegetation problems. These projects involved removing toxic tailings from metal manufacturing. As part of these projects, wetland ponds were constructed and the streambanks were recontoured and stabilized.

Two of the projects incorporated coir fabric (a bio-degradable textile of coconut shell fibers) terraces before backfilling and planting. These projects were implemented on relatively straight reaches of the river that also, because of adequate distance from structures, did not require intensive boulder stabilization techniques. The advantage of the coir method is that it stabilizes the river for several years so the natural vegetation can become established, then bio-degrades, leaving a completely natural stabilization system in place long term.

A practice common to many of the implementations was to install an irrigation system to aid vegetative growth in the riparian zone. The more recent 2010-11 projects both included irrigation systems that are still in place. The irrigation systems on two of the older projects were failing and vegetation conditions were noticeably poorer in quality than areas where the irrigation systems were functioning properly. Irrigation is also important to establishing more diverse and moisture sensitive types of vegetation required to create a more complex plant community than simply willows and grasses.

Overall, the urban stream projects we studied in the Jordan River watershed were all still in place and, particularly with the older and more established projects, showed marked improvements over pre-project conditions. Even the Walden Park project, which was only completed in 2008, had 20’ high trees and lush grasses and other flora along the banks. The projects completed in the late 1990’s had even more mature vegetation and stabilized banks.

Implementation & Maintenance Challenges

Urban stream work in the Jordan River poses unique implementation challenges. These include urban stormwater flows, more complex landownership patterns, complexities associated with accommodating other land uses and the intense human management of the river system.

Storm water in an urban environment presents a complex set of challenges beyond high flows from snowmelt. The loss of pervious surfaces with urbanization result in rapidly fluctuating river flows during storm or snowmelt events. In fact, the Salt Lake County watershed coordination team operates within the County’s flood control division.

Land ownership in an urban environment also poses challenges to improvement projects from both an engineering and maintenance standpoint. Land ownership along the river corridor is varied and patchy. The lack of continuity of ownership creates additional issues in project design because of lack of control of upstream practices. Moreover, projects often have to be divided into shorter stretches where access and ownership allows. It is the policy of Salt Lake County not to work on private land whenever possible because of liability and maintenance issues. In the rare case when performing work on private land, Salt Lake County requires maintenance and access easements from the private landowners. This requirement can create resistance and bureaucratic obstacles.

Another important difference between urban and rural implementations is the human factor. According to the interviews, unlike livestock, people resent being fenced off from parkland or wild areas, even for a short period of time. When fencing is absolutely required, such as through the Utah Transit Authority high-speed rail yard, it must be robust enough to prevent humans from crossing it. However, extensive signage and light fencing around new plantings are more typical in the implementations. According to the interviewees, vandalism is not frequent, but people ignoring signs and trampling sensitive areas are a constant problem.

One of the challenges unique to the Jordan River was the presence of beavers that were destroying the newly planted cottonwoods along the riverbank. This required individual protective wrapping of all the saplings. In some cases, new trees had to be planted. The interviewees indicated that this was more than a mere inconvenience because they were required to reallocate resources back to a project that had been completed to prevent further loss and ensure success of the project.

Another issue that particularly impacts storm water management but also affects scheduling of the various improvement projects is the somewhat inconsistent dam release of Utah Lake. According to the interviewees, Utah Lake is managed to maintain a fairly narrow range of lake level. Any time lake level rises above a designated level, water is released into the Jordan River. River levels can rise over 3' during these releases. Although some notice is given, this has apparently caused problems with project implementations as well as storm water planning.

According to our informants, Jordan River projects required a great deal of material and creative approaches because river movement and land loss are not acceptable in an urban environment. Temporary construction of access roads to the sites, complex engineering challenges posed by existing structures, and municipal level permitting and compliance standards for construction, urban projects can add significant expense.

Administrative Challenges

For the most part, Salt Lake County obtains funding for streambank restoration and improvement projects independently of the municipal and county budgets. The maintenance budgets of the municipal parks departments and the county flood control division were not sufficient for major river projects, which typically required outside funding. Among the funding sources for the projects reviewed for this report were the *American Recovery and Reinvestment Act* (ARRA), the EPA Superfund, and the Jordan River Parkway Trail funding package. Some of the projects were supplemented by private contributions. Finding funding for these projects has been an ongoing challenge. The ARRA monies are largely depleted so continued work on the Jordan River will require further funding. It was not clear from our interviews whether 319 grants have been available for these projects in the past.

Ongoing maintenance, however, poses fewer problems. Unlike most rural municipalities, both the county and local cities have dedicated budgetary resources for flood control and parks budgets, and trained crews which monitor and repair damages to city or county property on a regular basis. These existing human and logistical resources are sometimes used to sustain long-term maintenance and monitoring of water quality projects.

There is currently no mechanism in place to encourage private landowners to implement streambank and water quality improvements. Although the county and municipalities control large amounts of land along the Jordan River, they are interspersed with many privately owned reaches. Moreover, many of the tributary streams that feed the Jordan (not examined in this study) run through private lands. Salt Lake County has largely avoided joint public/private projects because of administrative and bureaucratic challenges.

Evidence of Water Quality Impact

Both of the individuals interviewed felt that the urban stream BMP projects were likely to have substantially improved water quality in the Jordan River. A physical inspection of the sites (and comparison with historic photos and other information in the project files) suggested that erosion had been substantially reduced in all sites through a combination of recontouring, revetments, and vegetative plantings. Furthermore, the two sites that were part of the EPA Superfund project likely further improved water quality by containing and removing toxins that may have been leaching into the stream.

These projects also achieved the secondary goal of restoring the river banks to more natural conditions, creating a pleasant streamside environment for recreational use.

Summary of findings

- Project implementations along the Jordan River appear to have been largely successful in improving streambank stabilization and natural habitat.
- For a variety of reasons, streambank improvement projects in urban environments appear to be significantly more complex and expensive per mile than their rural counterparts.
- The primary goals of streambank improvement projects, from the point of view of those implemented, are for flood control and recreational enjoyment, not water quality improvement.
- Substantial improvement projects in the Jordan River are funded almost exclusively outside of municipal and county budgets.
- Few, if any, significant improvement projects have been implemented on private lands in the Jordan River watershed.
- Both the county and individual municipalities have budgets for ongoing maintenance, including regular monitoring.

Conclusion

Overall, urban stream BMP projects in our study were successfully implemented and maintained, and are likely to have improved water quality. Urban stream BMP projects face unique challenges associated with urban stormwater runoff, land ownership, a more rigid built environment, recreational uses of stream areas, and complexities created by human-managed hydrologic flows.

While the budget for water quality projects typically relies on external grant funds, urban cities and counties do have existing staff and equipment that can be utilized to help construct, maintain, and monitor the condition of stream BMPs over time. Project staff showed expertise and competence in streambank improvement while operating within a well-structured organization for effective implementation, maintenance, and monitoring of the projects.

None of the Jordan River watershed projects received 319 funding. However, with other funding sources (such as ARRA) drying up, our informants felt they could benefit from future 319 funding. They felt that their experience with previous projects, existing human and infrastructure resources used for related purposes, and a capacity to manage large project budgets position them for high impact projects under the 319 program.

On the urban public lands, continued streambank improvement will happen as part of larger public space land use initiatives and storm water and flood control programs. However, the speed at which they are completed is almost entirely dependent on availability of external funding sources.

4.2 Water Quality Summaries

4.2.1 Middle Bear River Watershed

The water quality along the Bear River mainstem above the confluence with Cutler Reservoir (Station 4903260) is generally consistent with rivers draining an agricultural watersheds. Total phosphorus ranges from 0.015 mg/L – 0.46 mg/L, with more than 75% of observed concentrations above the State of Utah's indicator value of 0.05 mg/L. Similarly, ammonium-nitrogen ranges from 0.02 to 1.05 mg/L, with 75% of observations above 0.06 mg/L-N, however these levels are below the water quality guidelines of 1-3 mg/L NH_4-N at typical high pH and temperature values of 8 and 20 degrees centigrade). Total suspended solids range from 4 to > 500 mg/L with 75% of observations exceeding 20 mg/L. All dissolved oxygen observations exceeded 5 mg/L.

In the tributaries, conditions are highly variable. Newton Creek (4903100) is similar to the Bear River mainstem while High Creek (4904300) has much lower nutrients and suspended solids. The Cub River (4904250) and Spring Creek (4904310) have elevated nutrients (total P 0.005 – 5.04 mg/L, NH_4-N + NO_3-N 0.05 – 1.1 mg/L) and suspended solids (1 – 675 mg/L). Clay Slough (4904720), a drain into Cutler Reservoir, has total phosphorus levels up to 6 mg/L, total nitrogen exceeding 10 mg/L-N, and suspended solids from 5 to 322 mg/L.

4.2.2 Chalk Creek

The water quality in Chalk Creek reflects its source in phosphorus rich geological formations in that the total phosphorus levels at the UT/WY border range from 0.046 – 0.36 mg/L and exceed state guidelines in more than 70% of the observations. Ammonia-nitrogen levels are relatively low, while suspended solids concentrations are moderate (3 to 310 mg/L but 75% are < 80 mg/L). In Chalk Creek above the South Fork Confluence (4926290) water quality is little changed. The water quality in the South Fork (4926360) and East Fork (4926370) is similar to Chalk Creek above this confluence. Near the confluence with the Weber (4926530) the total phosphorus ranges from 0.05 to 1.2 mg/L (median = 0.1 mg/L) and generally exceed state guidelines. Total nitrogen levels range from 0.03 mg/L-N to 3.6 mg/L-N, and reflect inputs from the watershed. Dissolved oxygen exceeds 6 mg/L in all but one sample, above the Pine Cliff Campground culvert (4926380), where dissolved oxygen was 5.81 mg/L.

4.2.3 Upper Sevier River

The upper end of the Sevier River near Hatch (4949650) has total phosphorus concentrations exceeding state indicator values, ranging from 0.05 to 0.2 mg/L, in all observations in the database. Downstream, near Circleville (4949450), little change in either total phosphorus or total nitrogen has occurred. However, increases are seen in total suspended solids over this approximately 40-mile stretch of river. Dissolved oxygen remains above 5.5 mg/L in all observations.

As with the Middle Bear, the Upper Sevier tributaries are generally consistent, with total phosphorus concentration ranges of 0.05 – 0.1 and total nitrogen ranging from 0.01 to 3 mg/L in most tributaries. Panguitch Lake nutrient levels are high (up to 2.8 mg/L total P and 8.5 mg/L total N) and it's dissolved oxygen has been observed to drop to near zero and range as high as 16 mg/L, reflecting excessive algae growth supersaturating the water during the day.

4.2.4 San Pitch River

In the San Pitch River watershed, total phosphorus generally ranges from 0.05 mg/L to 0.5 mg/L in the river mainstem with occasional extreme values near Chester (4946650), with total nitrogen ranging from 0.05 to over 8 mg/L-N. Suspended solids vary from 2 to 1500 mg/L in the mainstem and as high as 12,200 mg/L in Six Mile Creek near Sterling, UT (4946360). Nutrient and suspended solids levels are low in Manti Creek at the Forest Service boundary (4946370). Dissolved oxygen concentrations are depressed at three locations on the San Pitch mainstem: near Manti (4946450), W. of Chester (4946650), and above the Moroni WWTP (4946960), where the DO drops below 5 mg/L frequently.

4.2.5 Beaver River

Total nutrient concentrations in the Beaver River mainstem are generally moderate, ranging from < 0.05 to 0.18 mg/L, somewhat above state guidelines of 0.05 mg/L. Total nitrogen ranges from 0.05 to 0.5 mg/L with one exception at near the USGS gage (5940440) at which the maximum total N exceeded 2 mg/L on one occasion. These nitrogen concentrations are among the lower of the project watersheds.

4.3 Watershed Scale Modeling

Details of the model results are extensive and are provided in the Technical Appendix III in the form of time series and frequency plots of concentrations and loads, and summary tables for each of the watersheds and key subbasins within each of the watersheds. To illustrate the approach, detailed description of the model analysis is provided below for the Middle Bear River watershed. Summaries of results for all watersheds are then reported in Table 19.

4.3.1 Middle Bear River Watershed

The model results for the effects of conservation practices on loads and in-stream concentrations are described here in the form of time series plots for loads from key drainages in the watershed and the impact of those loads on downstream concentrations of nutrients, and dissolved oxygen. The base case is taken from the modeling results with no conservation practices.

Figure 23 shows the watershed delineation for the Middle Bear. In all 11 subbasins were identified during delineation, three of which provide the most direct influence on the Bear River mainstem: 1) Subbasin 7 through which the Bear River flows in from Idaho, 2) Subbasin 3 that includes the Cub River and Richmond, and 3) Subbasin 50 that includes the Bear River above Benson and the Smithfield urban and agricultural areas. These drainages will be the focus of the loads due to their size, contributions to the overall load, and the fact that they contain a large number of the conservation projects studied here.

Table 19 and

Table 20

Table 20 show the modeled nutrient loads and concentrations within various subwatersheds under both 'no 319 project status quo' and 'conservation practice' scenarios. Both tables illustrate that daily loads are highly variable across space and reflect the influence of seasonal fluctuations characteristic of snowmelt-driven hydrologic systems. A close examination of the results suggests that the relative change in loadings (under BMP vs. no-BMP conditions) is significantly greater during higher runoff time periods (generally winter and spring months). The effectiveness of the conservation practices also depend on the conditions they're designed to mitigate. Those practices designed to mitigate storm runoff, e.g. animal feeding operation flow diversion, are more likely to be effective during storms. Those designed for longer term system improvement, such as riparian fencing or irrigation improvement will be effective over a longer term. These effects are apparent in the modeling results where the improvements associated with the longer-term practices are sustained over the time, while those designed for storm water management are effective primarily during runoff periods.

A comparison across the two tables (and the graphics in Figure 24 - Figure 27) documents the significant spatial variability across the subbasins in the watershed. A few subbasins account for the bulk of the estimated nutrient loadings in the area (the top 5 subbasins contributed 55% and 78% of the total of P and N, respectively). Similarly, because not all subbasins are equal contributors of nutrient loads – and because BMP implementations were concentrated in a few subbasins – the estimated benefits of BMP implementation are attributable to just one subbasin. Subbasin 7 contributed nearly all of the improvement from the status quo to the conservation practice scenario (roughly 22% decline at the subbasin scale). Changes were also noted in Subbasins 27 and 49, though the model's predicted net impacts of BMPs there served to increase predicted nutrient loads.

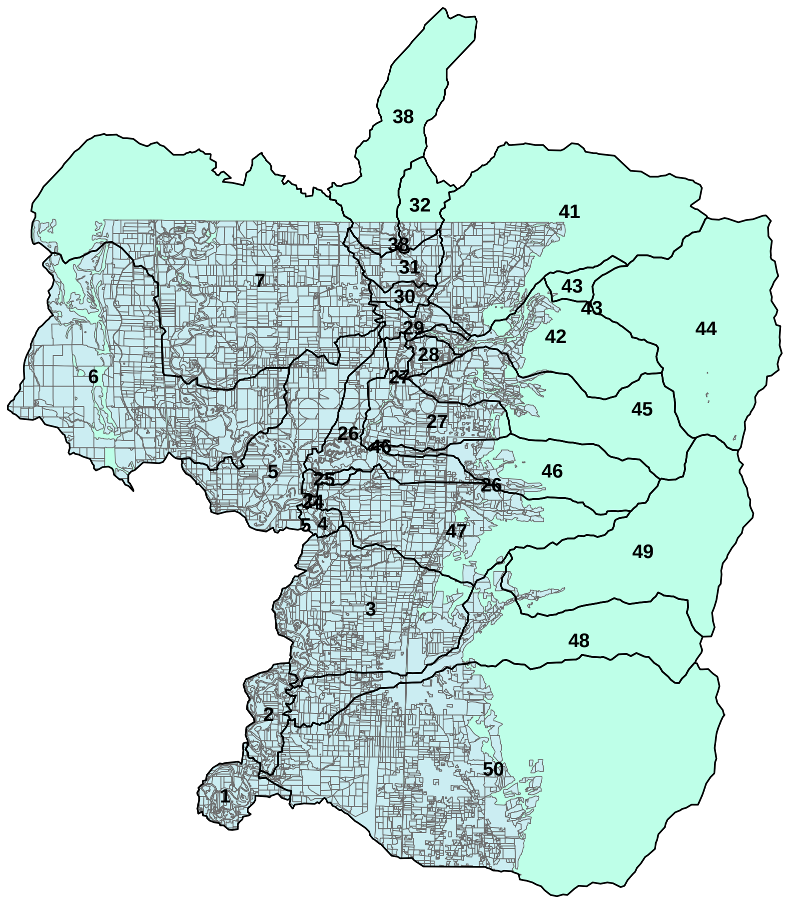


Figure 23: Middle Bear River Subbasin Delineation and Water-Related Land Use

While significant changes were visible at the subbasin scale, the modeled impacts of the full suite of 319 BMPs on overall nutrient loadings at the terminal outlet of the Middle Bear watershed were small. This reflects the fact that no changes were seen in most subbasins and a relatively small fraction of the land area was impacted by the 319 projects. Figure 27 compares the predicted nutrient daily loadings for the no-BMP and 319-BMP scenarios over the 15 year simulation period.

Load

Figure 29 and Figure 30 (subset of 12 subbasins), and Tables 16 and 17 show the predicted phosphorus and nitrogen loads in the subbasins identified for the Middle Bear River Watershed due to the conservation practices in the Utah 319 program. As shown in the tables, subbasins vary widely in their total loads with and without conservation, due to their variation in size, the portion of the subbasin devoted to agriculture, and the proximity of the producers and conservation practices to receiving waters. Only a small fraction of producers in the Middle Bear River Watershed are involved with 319 projects, primarily animal waste management projects for which the BMP effectiveness is in the 20% range for both total phosphorus and total nitrogen. The land affected by the projects covered < 1 % of the total land area. These results show that, although the load reductions afforded by the 319 projects are real, particularly on a subbasin basis, a significantly larger proportion of the loads need to be targeted to significantly impact downstream water quality. The average total phosphorus load to the Bear River for the status quo scenario was 30.8 kg/d compared to the conservation practices scenario load of 29.4 kg/d. For total nitrogen the reduction in average daily load was from 152 to 136 kg/d. On an annual basis this translates to a reduction in total phosphorus of 512 kg/yr and 5,938 kg/yr for total nitrogen.

Table 19: Total Phosphorus and Nitrogen Loads by Subbasin and Season for Middle Bear River Watershed, averaged over 15 year simulation period (kg/d) – Status Quo

Subbasin	Total Phosphorus Loads (kg/d), aggregated over season				Total Nitrogen Loads (kg/d), aggregated over season			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
1	0.099	0.0497	0.0155	0.0569	0.055	0.0275	0.0086	0.0315
2	0.101	0.0413	0.0116	0.0554	0.056	0.0230	0.0065	0.0308
3	0.943	0.3684	0.0979	0.4836	0.510	0.1999	0.0536	0.2621
4	0.044	0.0172	0.0046	0.0228	0.022	0.0088	0.0024	0.0116
5	0.655	0.3153	0.0634	0.3246	0.361	0.1736	0.0349	0.1784
6	1.550	0.7474	0.1498	0.7692	0.892	0.4272	0.0834	0.4327
7	3.323	1.2898	0.2509	1.6088	1.821	0.7081	0.1390	0.8804
24	0.011	0.0019	0.0002	0.0013	0.042	0.0058	0.0001	0.0025
25	0.031	0.0135	0.0032	0.0147	0.016	0.0071	0.0017	0.0077
26	0.321	0.1425	0.0366	0.1621	0.170	0.0755	0.0194	0.0858
27	0.440	0.1871	0.0448	0.2108	0.241	0.1045	0.0304	0.1311
28	0.110	0.0473	0.0134	0.0582	0.060	0.0258	0.0074	0.0318
29	0.108	0.0445	0.0128	0.0573	0.058	0.0239	0.0068	0.0307
30	0.063	0.0246	0.0070	0.0327	0.034	0.0133	0.0038	0.0178
31	0.157	0.0615	0.0173	0.0811	0.086	0.0339	0.0096	0.0448
38	0.803	0.4246	0.0751	0.3857	0.428	0.2278	0.0415	0.2090
41	1.165	0.6541	0.1504	0.7509	0.629	0.3545	0.0826	0.4054
42	0.760	1.8846	0.1624	0.3308	1.333	4.8948	0.7334	0.3842
43	0.252	0.2428	0.0043	0.0246	0.936	1.0339	0.0238	0.0626
44	1.749	7.0937	0.0901	0.5339	4.976	22.2405	0.3821	1.0361
45	1.280	2.4123	0.2859	0.7497	1.518	3.4648	0.7704	0.5589
46	0.508	0.8879	0.1529	0.4220	0.539	1.3570	0.3948	0.3160
47	0.779	0.4481	0.1013	0.4706	0.426	0.2454	0.0562	0.2591
48	1.046	1.4601	0.2284	0.6720	0.695	1.3526	0.3653	0.4361
49	0.777	3.1485	0.2266	0.2109	3.674	15.8338	1.7879	0.6783
50	2.021	1.7759	0.2498	1.0955	1.163	1.0850	0.2939	1.0225
All Basins	19.1	23.8	2.46	9.59	20.741	53.9479	5.3392	7.5478

Table 20: Total Phosphorus and Nitrogen Loads by Subbasin and Season for Middle Bear River Watershed, averaged over 15 year simulation period (kg/d) – Conservation Practices

Subbasin	Total Phosphorus Loads (kg/d), aggregated over season				Total Nitrogen Loads (kg/d), aggregated over season			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
1	0.099	0.0497	0.0155	0.0569	0.055	0.0275	0.0086	0.0315
2	0.101	0.0413	0.0116	0.0554	0.056	0.0230	0.0065	0.0308
3	0.943	0.3684	0.0979	0.4836	0.510	0.1999	0.0536	0.2621
4	0.044	0.0172	0.0046	0.0228	0.022	0.0088	0.0024	0.0116
5	0.655	0.3153	0.0634	0.3246	0.361	0.1736	0.0349	0.1784
6	1.550	0.7474	0.1498	0.7692	0.892	0.4272	0.0834	0.4327
7	2.604	1.0108	0.1967	1.2607	1.415	0.5506	0.1084	0.6844
24	0.011	0.0019	0.0002	0.0013	0.042	0.0058	0.0001	0.0025
25	0.031	0.0135	0.0032	0.0147	0.016	0.0071	0.0017	0.0077
26	0.321	0.1425	0.0366	0.1621	0.170	0.0755	0.0194	0.0858
27	0.441	0.1878	0.0455	0.2128	0.241	0.1045	0.0304	0.1311
28	0.110	0.0473	0.0134	0.0582	0.060	0.0258	0.0074	0.0318
29	0.108	0.0445	0.0128	0.0573	0.058	0.0239	0.0068	0.0307
30	0.063	0.0246	0.0070	0.0327	0.034	0.0133	0.0038	0.0178
31	0.157	0.0615	0.0173	0.0811	0.086	0.0339	0.0096	0.0448
38	0.803	0.4246	0.0751	0.3857	0.428	0.2278	0.0415	0.2090
41	1.165	0.6541	0.1504	0.7509	0.629	0.3545	0.0826	0.4054
42	0.760	1.8846	0.1624	0.3308	1.333	4.8948	0.7334	0.3842
43	0.252	0.2428	0.0043	0.0246	0.936	1.0339	0.0238	0.0626
44	1.749	7.0937	0.0901	0.5339	4.976	22.2405	0.3821	1.0361
45	1.280	2.4123	0.2859	0.7497	1.518	3.4648	0.7704	0.5589
46	0.508	0.8879	0.1529	0.4220	0.539	1.3570	0.3948	0.3160
47	0.779	0.4481	0.1013	0.4706	0.426	0.2454	0.0562	0.2591
48	1.046	1.4601	0.2284	0.6720	0.695	1.3526	0.3653	0.4361
49	0.777	3.1485	0.2266	0.2109	3.674	15.8338	1.7879	0.6783
50	2.021	1.7759	0.2498	1.0955	1.163	1.0850	0.2939	1.0225
All Basins	18.4	23.5	2.41	9.24	20.335	53.7904	5.3087	7.3518

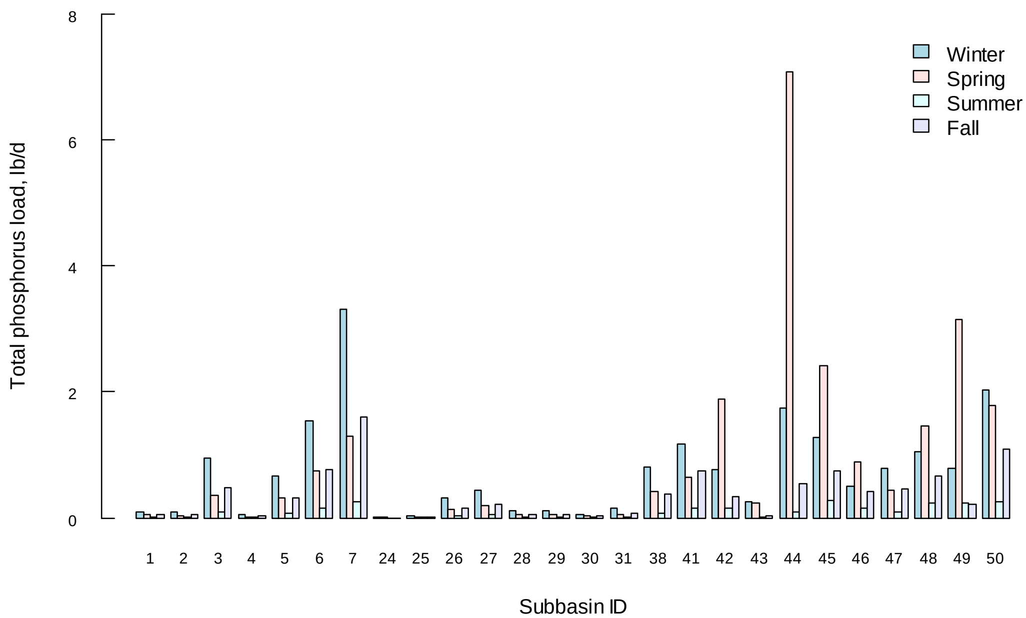


Figure 24: Seasonal Total Phosphorus Load (kg/d) Summary by Catchment for Middle Bear River Status Quo Simulation

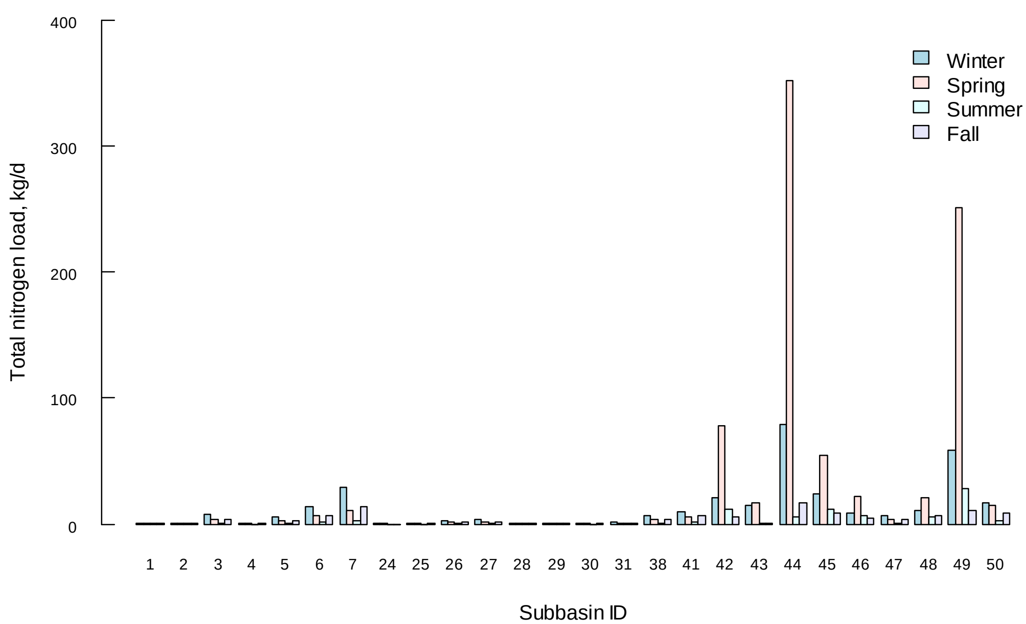


Figure 25: Seasonal Total Nitrogen Load (kg/d) Summary by Catchment for Middle Bear River Status Quo Simulation

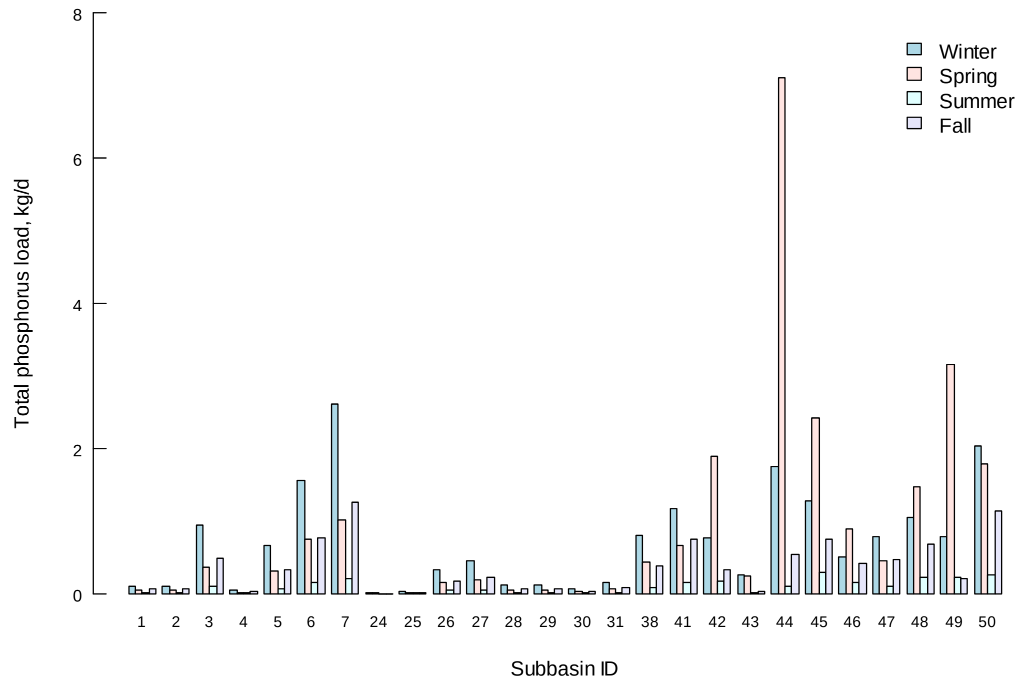


Figure 26: Seasonal Total Phosphorus Load (kg/d) Summary by Catchment for Middle Bear River Conservation Practices Simulation

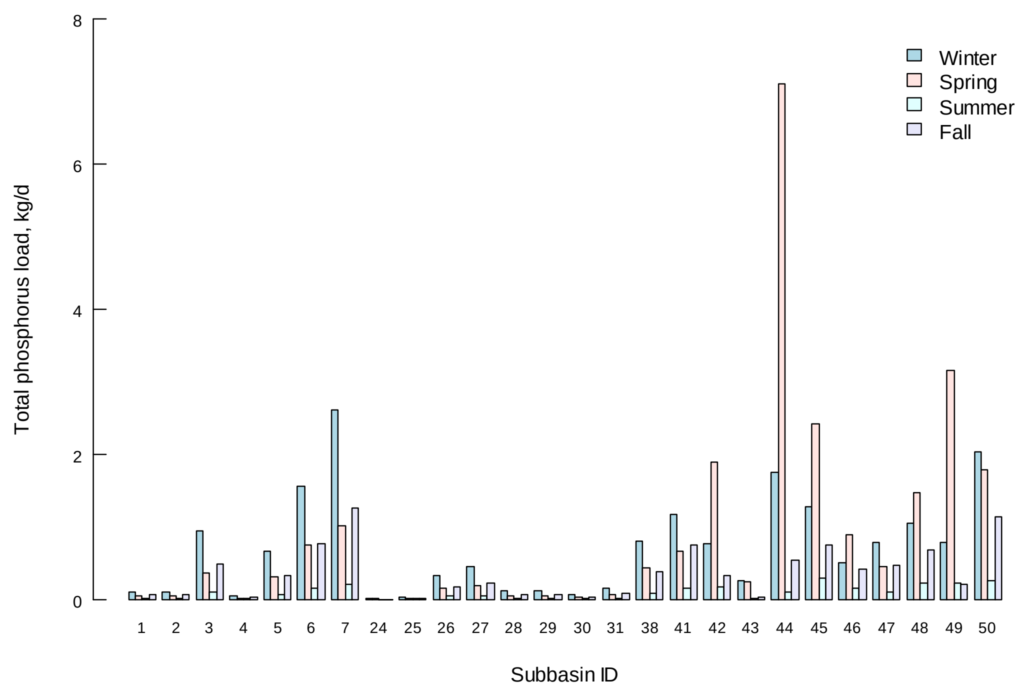


Figure 27: Seasonal Total Nitrogen Load (kg/d) Summary by Catchment for Middle Bear River Conservation Practices Simulation

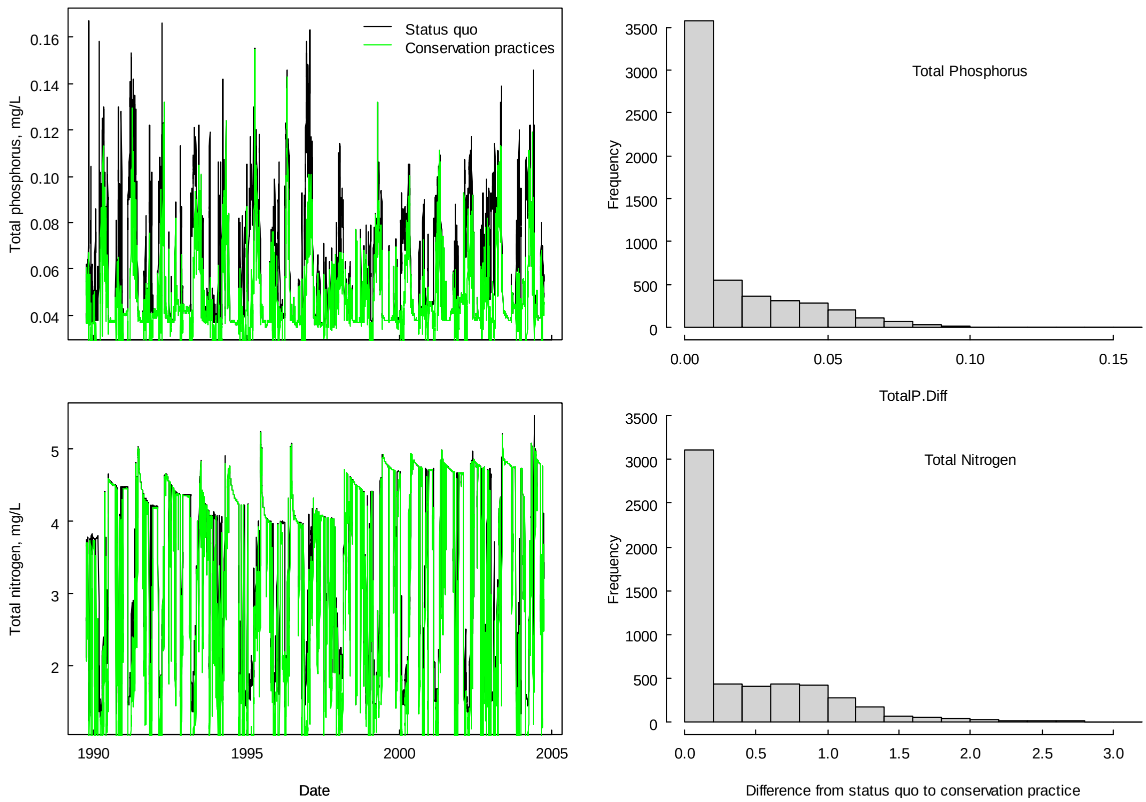


Figure 28: Modeled Total Phosphorus and Nitrogen Concentrations at receptor, Middle Bear River, Comparing Status Quo with Conservation practices

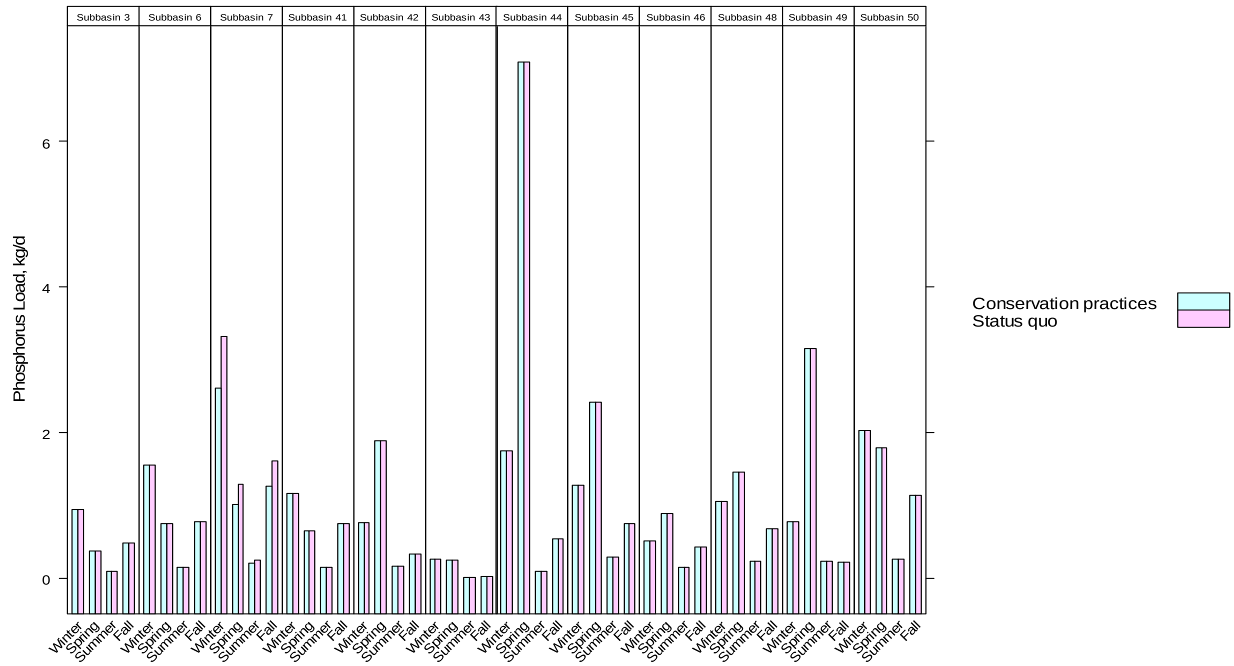


Figure 29: Seasonal Total Phosphorus Load (kg/d) Comparison by Catchment for the Middle Bear River Status Quo and Conservation Practice Simulation

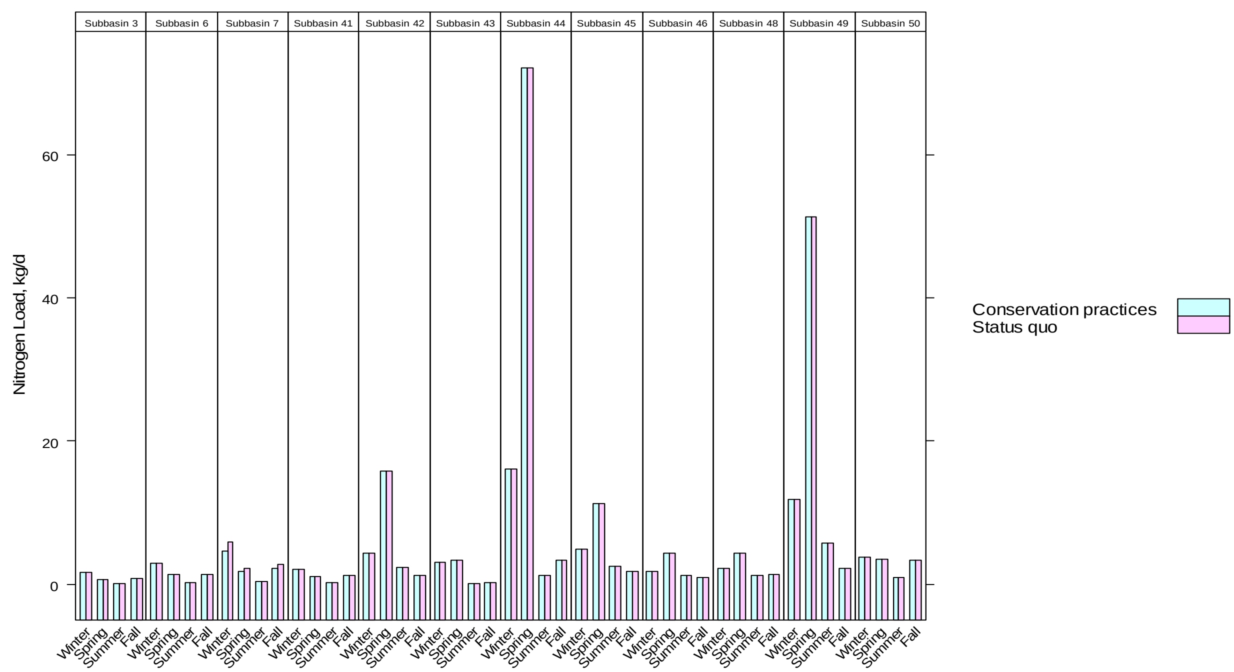


Figure 30: Seasonal Total Nitrogen Load (kg/d) Comparison by Catchment for the Middle Bear River Status Quo and Conservation Practice Simulation

4.3.2 Chalk Creek Watershed

Similar results are shown for the Chalk Creek watershed. Figure 31 shows the watershed delineation for the Chalk Creek drainage. In all 3 subbasins were identified during delineation, each of which provide direct influence on Chalk Creek. Figure 32 and Figure 33 and Table 21 and Table 22 show the estimate changes in nutrient loads at the downstream receptor due to the conservation efforts evaluated in this project. For Chalk Creek all of the projects were location in Subbasin 1 and so the only changes in load are seen there. The changes are modest but are time dependent with larger differences seen in winter and spring than in summer or fall. Larger differences are found for phosphorus than for nitrogen. This is expected since the projects were directed primarily at phosphorus mitigation. As shown in Table 29, total estimated annual reductions resulting from the 319 projects are approximately 921 kg/yr and 370 kg/yr for total phosphorus and nitrogen, or 2.6% and 0.23% respectively.

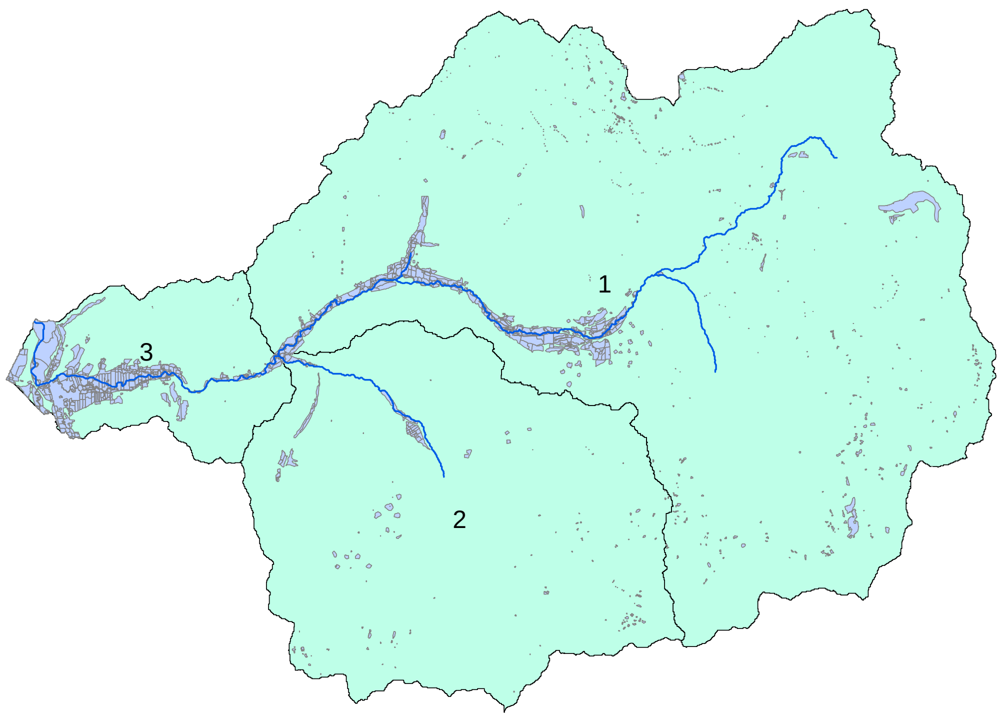


Figure 31: Chalk Creek Subbasin Delineation with Water-related Land Use

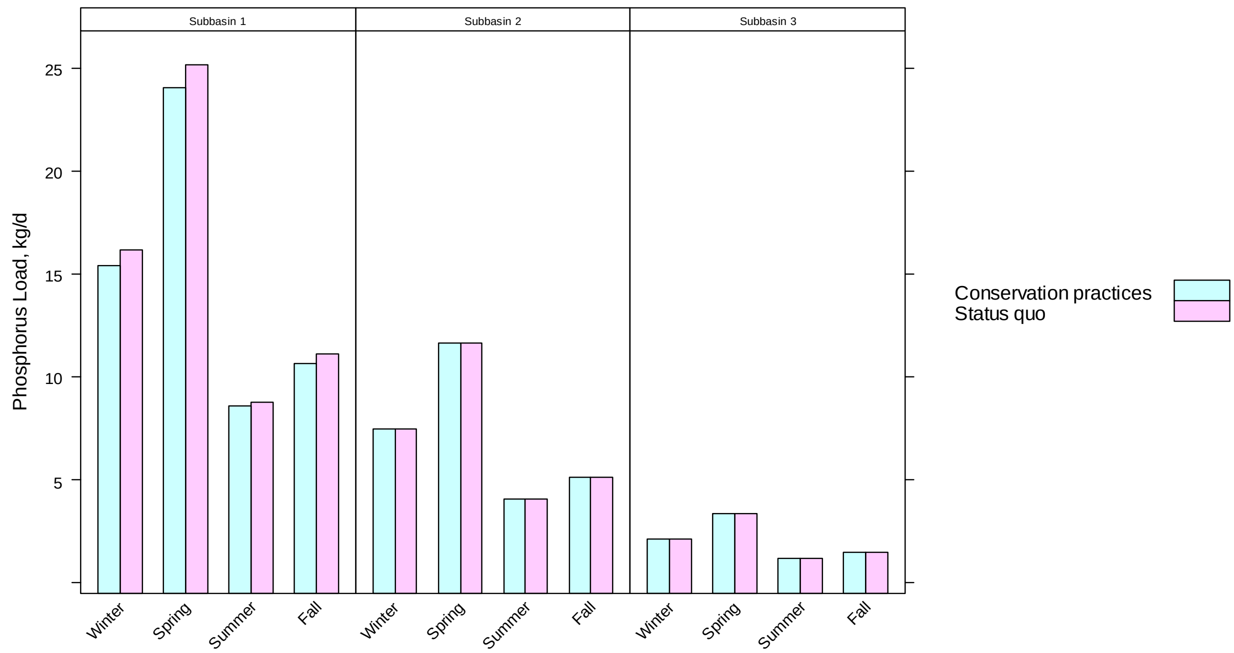


Figure 32: Seasonal Total Phosphorus Load (kg/d) Comparison by Catchment for Chalk Creek Status Quo and Conservation Practice Simulation

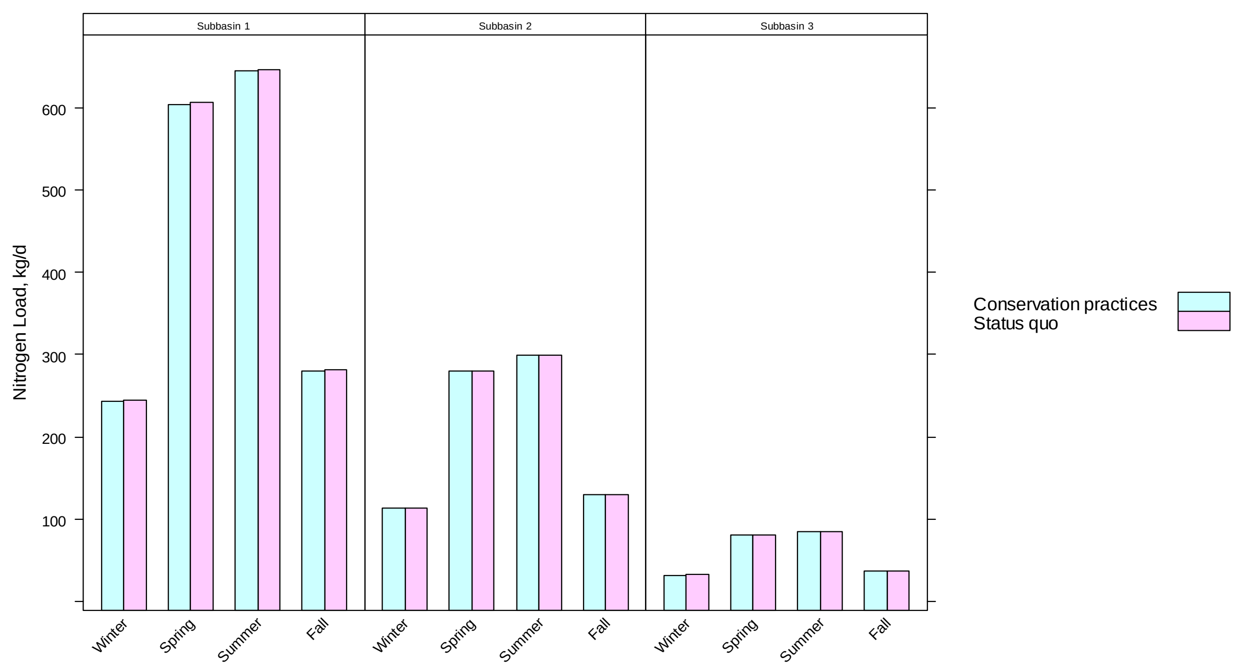


Figure 33: Seasonal Total Nitrogen Load (kg/d) Comparison by Catchment for Chalk Creek Status Quo and Conservation Practice Simulation

Table 21: Total Phosphorus and Nitrogen Loads by Subbasin and Season for Chalk Creek Watershed, averaged over 15 year simulation period (kg/d) – Status Quo

Subbasin	Total Phosphorus Loads (kg/d), aggregated over season				Total Nitrogen Loads (kg/d), aggregated over season			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
1	16.2	25.1	8.8	11.1	245	606	645	281
2	7.5	11.6	4.1	5.1	113	280	299	130
3	2.1	3.3	1.2	1.5	32	80	86	37
All Basins	25.8	40.0	14.1	17.6	390	966	1030	448

Table 22: Total Phosphorus and Nitrogen Loads by Subbasin and Season for Chalk Creek Watershed, averaged over 15 year simulation period (kg/d) – Conservation Practices

Subbasin	Total Phosphorus Loads (kg/d), aggregated over season				Total Nitrogen Loads (kg/d), aggregated over season			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
1	15.4	24.0	8.6	10.6	243	603	644	280
2	7.5	11.6	4.1	5.1	113	280	299	130
3	2.1	3.3	1.2	1.5	32	80	86	37
All Basins	25.0	38.9	13.9	17.2	388	964	1029	447

4.3.3 Upper Sevier River Watershed

Figure 34 shows the watershed delineation for the Sevier River drainage. Ten subbasins were identified during delineation, each of which provides direct influence on the Sevier River, and the 319 projects are concentration in subbasins 1, 3, and 5, which are also the sources of most of the phosphorus and nitrogen loads. During higher runoff periods (generally winter and spring months), the relative change in load is significantly greater than during other times, although all of the changes are small due to the small fraction of the land area effected by conservation projects. Figure 35 and Figure 36, and Table 23 and Table 24 summarize those loads for each subbasin/season pair. From Table 29, total estimated annual reductions resulting from the 319 projects are approximately 190 kg/yr and 137 kg/yr for total phosphorus and nitrogen, or 0.28% and 0.08% respectively.

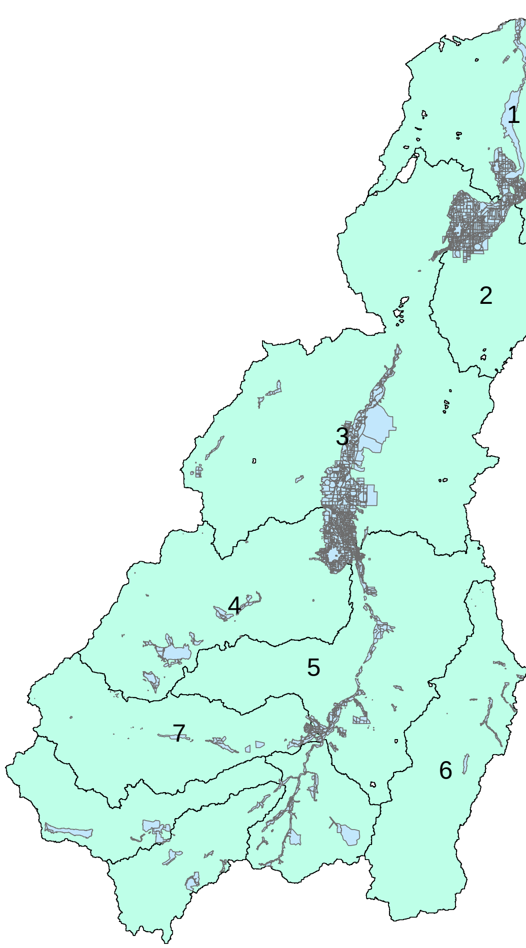


Figure 34: Upper Sevier River Subbasin Delineation with Water-related land use

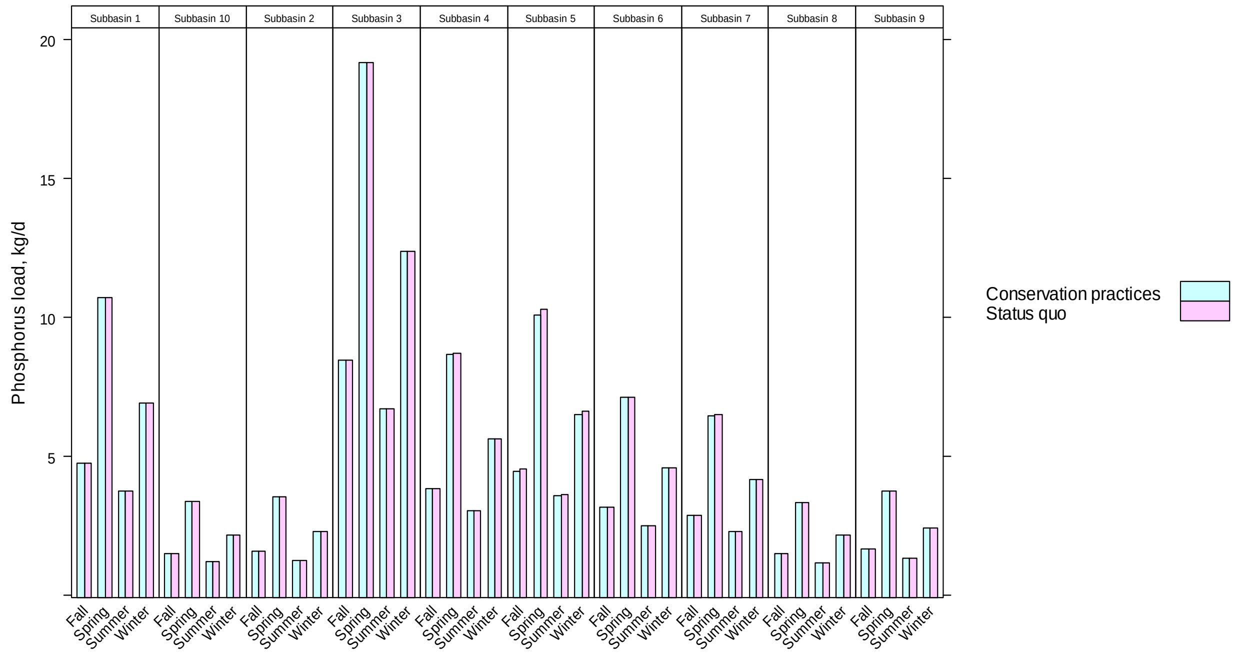


Figure 35: Seasonal Total Phosphorus Load (kg/d) Comparison by Catchment for the Upper Sevier River Status Quo and Conservation Practice Simulation

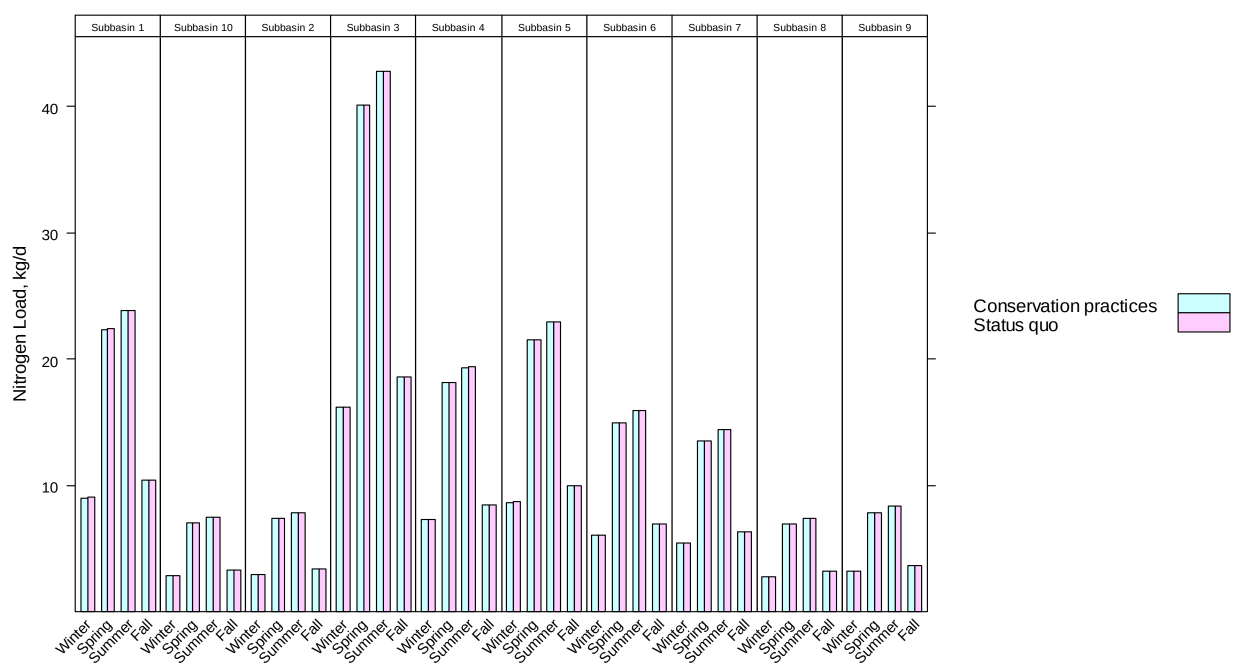


Figure 36: Seasonal Total Nitrogen Load (kg/d) Comparison by Catchment for the Upper Sevier River Status Quo and Conservation Practice Simulation

Table 23: Total Phosphorus and Nitrogen Loads by Subbasin and Season for the Upper Sevier River Watershed, averaged over 15 year simulation period (kg/d) – Status Quo

Subbasin	Total Phosphorus Loads (kg/d), aggregated over season				Total Nitrogen Loads (kg/d), aggregated over season			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
1	6.893	10.6979	3.7354	4.7218	9.04	22.41	23.87	10.39
2	2.2637	3.5133	1.2267	1.5507	2.97	7.36	7.84	3.41
3	12.3426	19.1559	6.6887	8.4549	16.20	40.12	42.74	18.61
4	5.5896	8.6752	3.0291	3.829	7.33	18.17	19.36	8.43
5	6.6209	10.2757	3.588	4.5354	8.69	21.52	22.93	9.98
6	4.5873	7.1195	2.4859	3.1424	6.02	14.91	15.89	6.92
7	4.1652	6.4644	2.2572	2.8532	5.47	13.54	14.42	6.28
8	2.1397	3.3209	1.1595	1.4657	2.81	6.96	7.41	3.23
9	2.4174	3.7519	1.3101	1.656	3.17	7.86	8.37	3.65
10	2.1585	3.3501	1.1698	1.4786	2.83	7.02	7.47	3.25
Total	49.178	76.3247	26.6503	33.6878	64.53	159.86	170.30	74.16

Table 24: Total Phosphorus and Nitrogen Loads by Subbasin and Season for the Upper Sevier River Watershed, averaged over 15 year simulation period (kg/d) – Conservation Practices

Subbasin	Total Phosphorus Loads (kg/d), aggregated over season				Total Nitrogen Loads (kg/d), aggregated over season			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
1	6.8906	10.6918	3.7285	4.719	9.02	22.34	23.80	10.36
2	2.2637	3.5133	1.2267	1.5507	2.97	7.36	7.84	3.41
3	12.3422	19.1549	6.6875	8.4545	16.19	40.11	42.73	18.61
4	5.5886	8.6727	3.0267	3.8279	7.33	18.15	19.33	8.42
5	6.4706	10.0619	3.5505	4.4422	8.66	21.49	22.92	9.97
6	4.5873	7.1195	2.4859	3.1424	6.02	14.91	15.89	6.92
7	4.1646	6.4636	2.257	2.8529	5.47	13.54	14.42	6.28
8	2.1397	3.3209	1.1595	1.4657	2.81	6.96	7.41	3.23
9	2.4174	3.7519	1.3101	1.656	3.17	7.86	8.37	3.65
10	2.1585	3.3501	1.1698	1.4786	2.83	7.02	7.47	3.25
Total	49.0234	76.1005	26.6023	33.5899	64.47	159.73	170.19	74.10

4.3.4 San Pitch River Watershed

Figure 37 shows the watershed delineation for the San Pitch River drainage. In all 10 subbasins were identified during delineation, all of which provide direct influence on the San Pitch River with 319 projects limited to small parcels in subbasins 1-4, while the highest loads are from subbasins 1, 8, 2, 10, and 5 for both phosphorus and nitrogen. Although the relative change in load is significantly greater during winter and spring than during other times, the overall project impact is estimated to be small. Figure 38 and Figure 39, and Table 26 and Table 25 summarize those loads for each subbasin/season pair. From Table 29, total estimated annual reductions resulting from the 319 projects are approximately 6 kg/yr and 18 kg/yr for total phosphorus and nitrogen, or 0.04% and 0.02% respectively. These changes are modest, reflecting the small fraction of the phosphorus-generating land area affect by conservation projects in the San Pitch watershed.

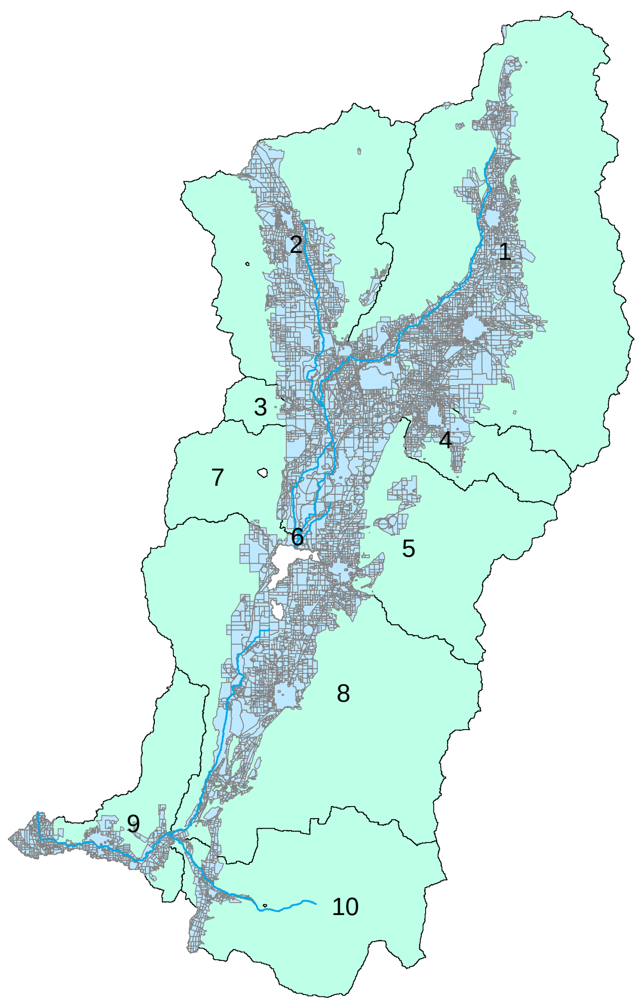


Figure 37: San Pitch River Subbasin Delineation with Water-related land use

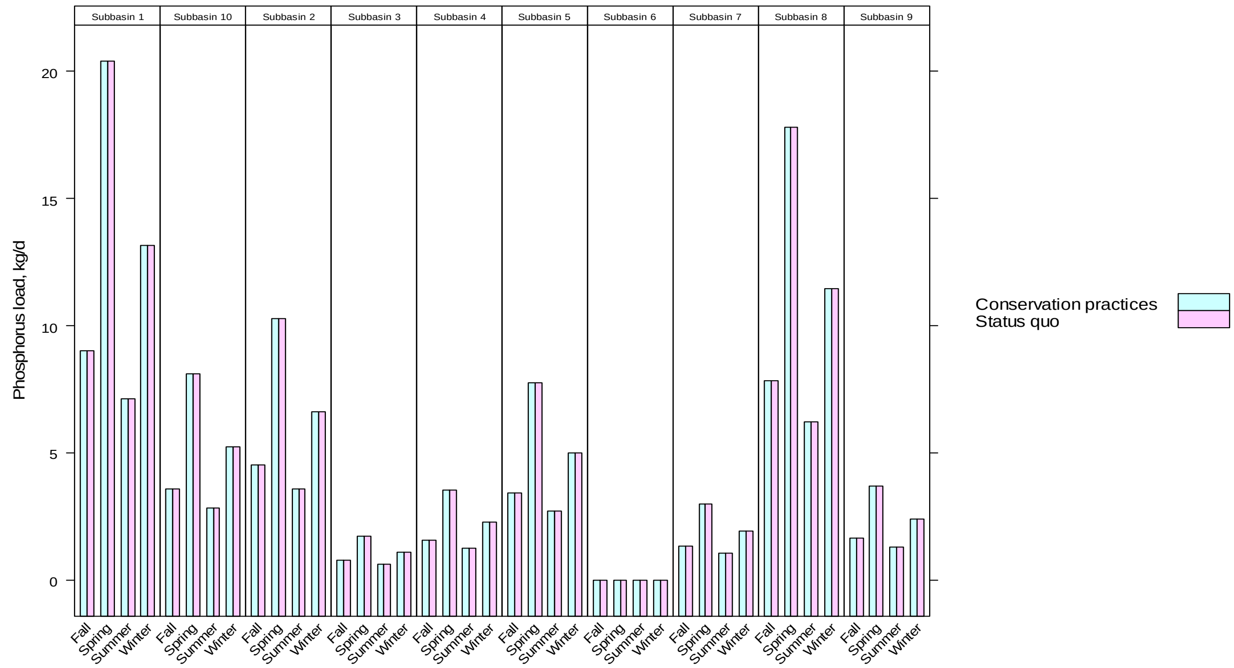


Figure 38: Seasonal Total Phosphorus Load (kg/d) Comparison by Catchment for the San Pitch River Status Quo and Conservation Practice Simulation

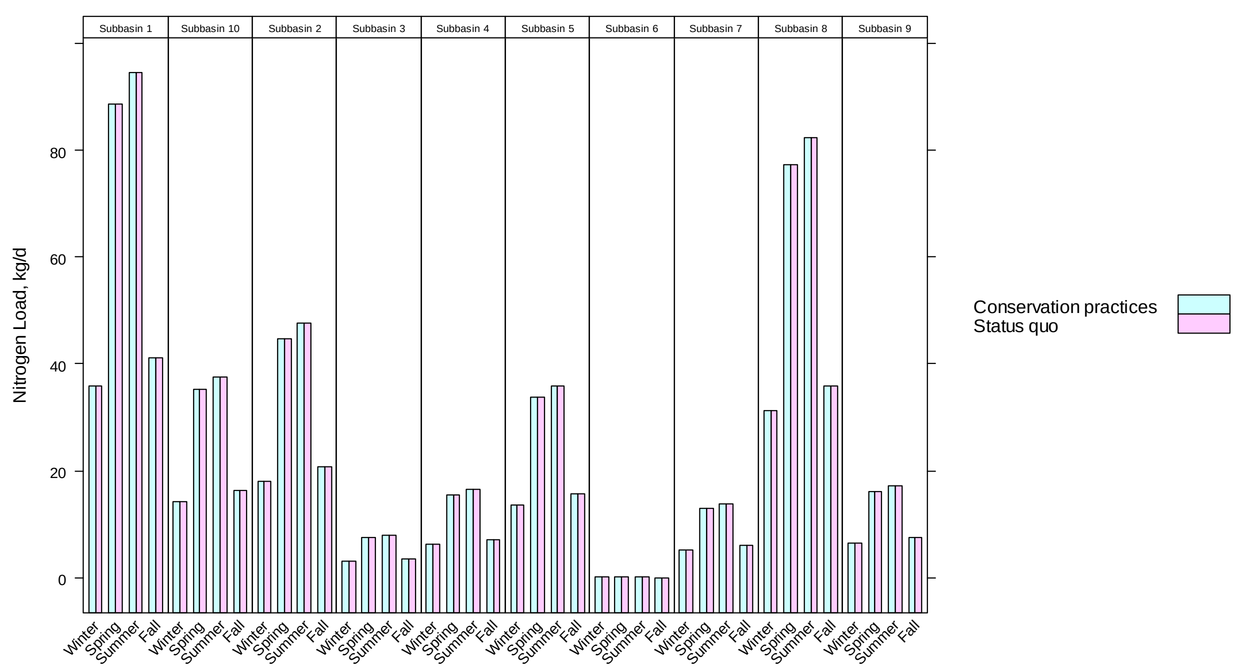


Figure 39: Seasonal Total Nitrogen Load (kg/d) Comparison by Catchment for the San Pitch River Status Quo and Conservation Practice Simulation

Table 25: Total Phosphorus and Nitrogen Loads by Subbasin and Season for the San Pitch River Watershed, averaged over 15 year simulation period (kg/d) – Status Quo

Subbasin	Total Phosphorus Loads (kg/d), aggregated over season				Total Nitrogen Loads (kg/d), aggregated over season			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
1	13.14904	20.40744	7.1257	9.00735	35.808	88.71	94.504	41.151
2	6.62485	10.28183	3.5901	4.53815	18.041	44.70	47.614	20.733
3	1.11004	1.7228	0.6016	0.7604	3.023	7.49	7.978	3.474
4	2.28815	3.55124	1.24	1.56743	6.231	15.44	16.445	7.161
5	4.99806	7.75704	2.7085	3.42377	13.611	33.72	35.922	15.642
6	0.00116	0.00227	0.0017	0.00103	0.026	0.05	0.038	0.023
7	1.92045	2.98056	1.0407	1.31555	5.230	12.96	13.803	6.010
8	11.46263	17.79012	6.2118	7.85212	31.216	77.34	82.384	35.873
9	2.3889	3.7076	1.2946	1.63644	6.506	16.12	17.169	7.476
10	5.23099	8.11855	2.8348	3.58333	14.245	35.29	37.596	16.371
Total	49.17428	76.31944	26.6494	33.68557	133.938	331.81	353.453	153.915

Table 26: Total Phosphorus and Nitrogen Loads by Subbasin and Season for the San Pitch River Watershed, averaged over 15 year simulation period (kg/d) – Conservation Practices

Subbasin	Total Phosphorus Loads (kg/d), aggregated over season				Total Nitrogen Loads (kg/d), aggregated over season			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
1	13.14126	20.39547	7.1217	9.00207	35.790	88.67	94.456	41.130
2	6.61641	10.26919	3.5866	4.5326	18.027	44.66	47.580	20.718
3	1.11004	1.7228	0.6016	0.7604	3.023	7.49	7.978	3.474
4	2.28607	3.54827	1.2395	1.56614	6.231	15.44	16.445	7.161
5	4.99806	7.75704	2.7085	3.42377	13.611	33.72	35.922	15.642
6	0.00116	0.00227	0.0017	0.00103	0.026	0.05	0.038	0.023
7	1.92045	2.98056	1.0407	1.31555	5.230	12.96	13.803	6.010
8	11.46263	17.79012	6.2118	7.85212	31.216	77.34	82.384	35.873
9	2.3889	3.7076	1.2946	1.63644	6.506	16.12	17.169	7.476
10	5.23099	8.11855	2.8348	3.58333	14.245	35.29	37.596	16.371
Total	49.15598	76.29187	26.6414	33.67345	133.904	331.73	353.371	153.878

4.3.5 Beaver River Watershed

Figure 40 shows the watershed delineation for the Beaver River drainage. In all 10 subbasins were identified during delineation, all of which provide direct influence on the Beaver River. The bulk of the loads come from subbasins 10, 2, 4, 9, and 7, with the bulk of the projects location in subbasins 7, 9, and 10. During higher runoff time periods (generally winter and spring months), the relative change in load is significantly greater than during other times in subbasin 9, where the largest impacts are seen. The degree of effectiveness appears to depend on hydrologic conditions in the watershed. Table 27 and Table 28 summarize those loads for each subbasin/season pair. From Table 29, total estimated annual reductions resulting from the 319 projects are approximately 31 kg/yr and 8 kg/yr for total phosphorus and nitrogen, or 0.19% and 0.02% respectively. Similar to the San Pitch watershed, the effects of conservation practices in the Beaver watershed are small due to the small affected area compared to the overall watershed size.

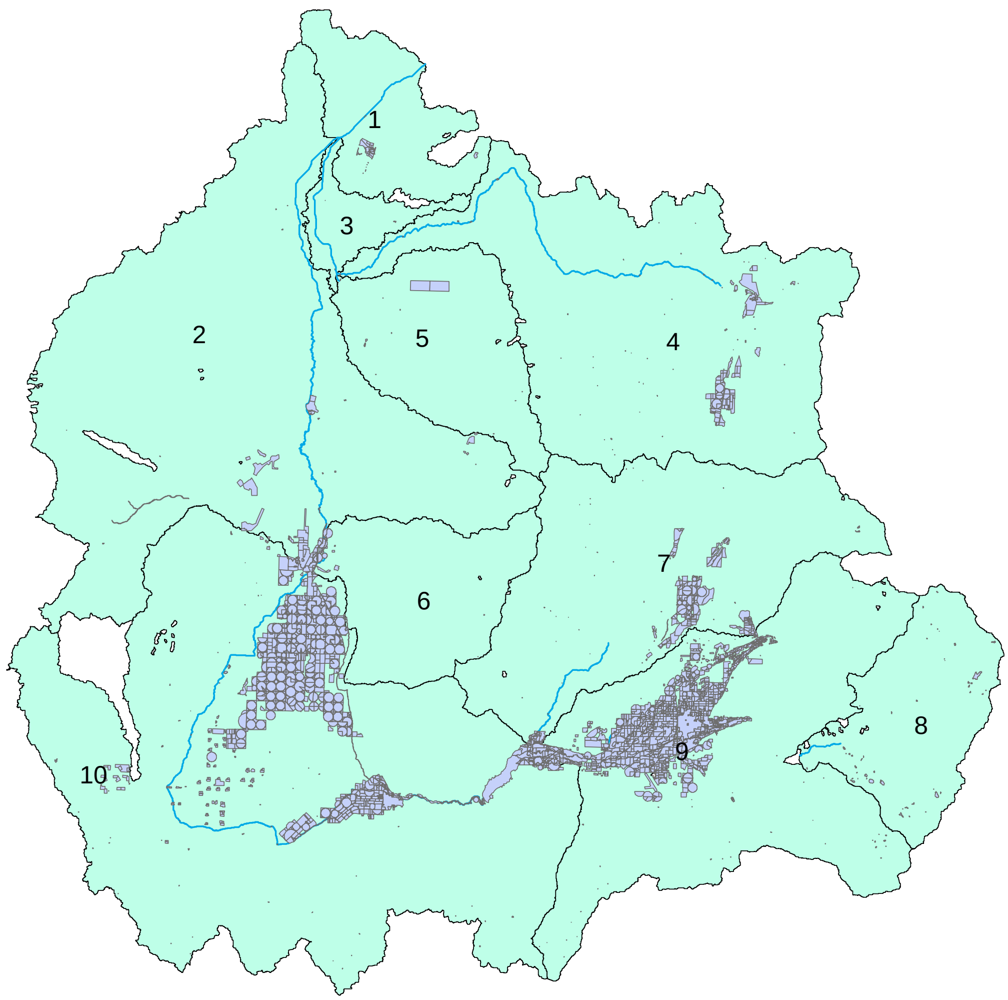


Figure 40: Beaver River Subbasin Delineation with Water-related land use

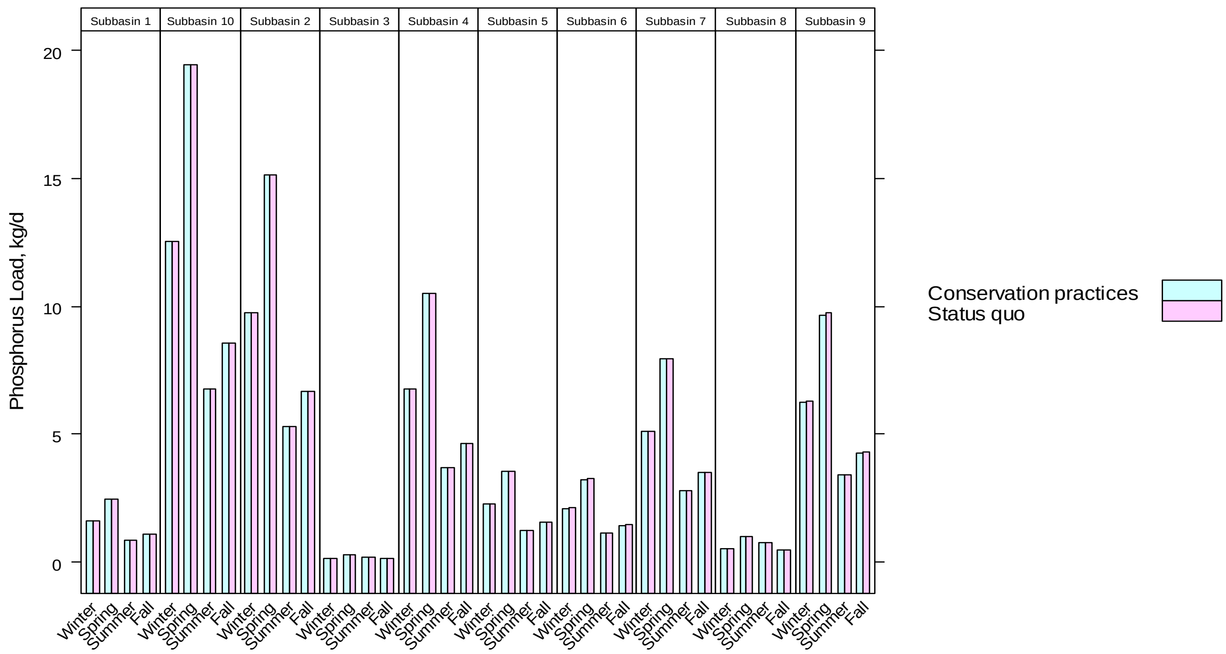


Figure 41: Seasonal Total Phosphorus Load (kg/d) Comparison by Catchment for the Beaver River Status Quo and Conservation Practice Simulation

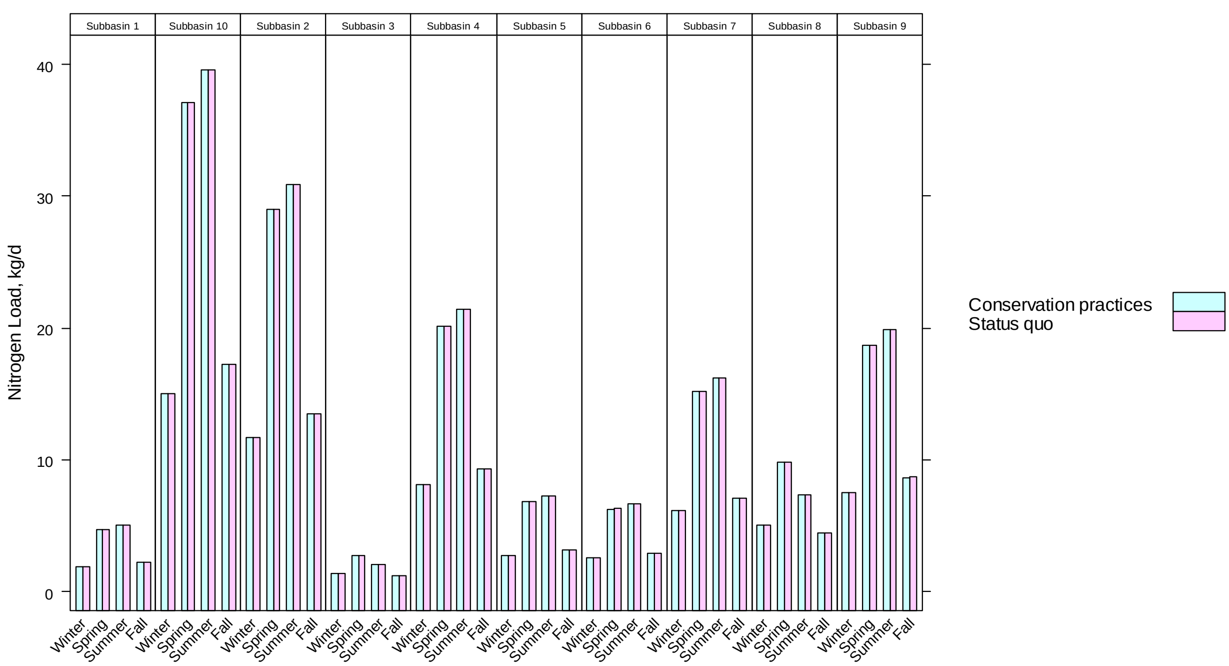


Figure 42: Seasonal Total Nitrogen Load (kg/d) Comparison by Catchment for the Beaver River Status Quo and Conservation Practice Simulation

Table 27: Total Phosphorus and Nitrogen Loads by Subbasin and Season for the Beaver River Watershed, averaged over 15 year simulation period (kg/d) – Status Quo

Subbasin	Total Phosphorus Loads (kg/d), aggregated over season				Total Nitrogen Loads (kg/d), aggregated over season			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
1	1.59347	2.47308	0.86353	1.09156	1.91	4.73	5.04	2.19
2	9.75802	15.14454	5.28802	6.68443	11.69	28.96	30.85	13.43
3	0.14187	0.27828	0.20855	0.12632	1.39	2.72	2.04	1.24
4	6.77343	10.51243	3.67063	4.63993	8.11	20.10	21.42	9.33
5	2.28601	3.54791	1.23883	1.56596	2.74	6.79	7.23	3.15
6	2.11295	3.27932	1.14504	1.44741	2.53	6.27	6.68	2.91
7	5.12788	7.95853	2.77888	3.5127	6.14	15.22	16.21	7.06
8	0.51142	1.00317	0.75181	0.45539	5.01	9.82	7.36	4.46
9	6.28971	9.76169	3.40849	4.30857	7.54	18.67	19.89	8.66
10	12.50994	19.41555	6.77933	8.56955	14.99	37.13	39.55	17.22
Total	47.1047	73.3745	26.13311	32.40183	62.05	150.42	156.27	69.65

Table 28: Total Phosphorus and Nitrogen Loads by Subbasin and Season for the Beaver River Watershed, averaged over 15 year simulation period (kg/d) – Conservation Practices

Subbasin	Total Phosphorus Loads (kg/d), aggregated over season				Total Nitrogen Loads (kg/d), aggregated over season			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
1	1.59347	2.47308	0.86353	1.09156	1.91	4.73	5.04	2.19
2	9.75802	15.14454	5.28802	6.68443	11.69	28.96	30.85	13.43
3	0.14187	0.27828	0.20855	0.12632	1.39	2.72	2.04	1.24
4	6.77343	10.51243	3.67063	4.63993	8.11	20.10	21.42	9.33
5	2.28601	3.54791	1.23883	1.56596	2.74	6.79	7.23	3.15
6	2.07746	3.2281	1.13456	1.42504	2.52	6.25	6.66	2.90
7	5.12788	7.95853	2.77888	3.5127	6.14	15.22	16.21	7.06
8	0.51142	1.00317	0.75181	0.45539	5.01	9.82	7.36	4.46
9	6.22038	9.66297	3.39105	4.26553	7.52	18.65	19.88	8.65
10	12.50994	19.41555	6.77933	8.56955	14.99	37.13	39.55	17.22
Total	46.99988	73.22457	26.10518	32.33642	62.02	150.38	156.25	69.63

4.3.6 Results Review

4.3.6.1 Overall Loading

The subbasin-specific and overall loadings for total phosphorus and total nitrogen are provided in Tables 19 through 28 for the status quo and conservation practice scenarios for each of the modeled project watersheds. The differences in the loadings were substantial among the subbasins. This is expected because of the varying size and land use/land cover for each drainage. The last rows of the tables show the total daily loads averaged over the 15 year scenario period for total phosphorus and nitrogen for the subwatersheds included in the analysis for each watershed.

4.3.6.2 Seasonal Variation

Considerable seasonal variations are seen as well with loadings in the spring up to 5-6 times larger than in the summer. Loadings in winter are sometimes less than in spring and sometimes greater. This would depend on the fraction of the flow that is base flow vs. surface runoff and the land use in the drainage. Loadings in the fall follow similar patterns.

4.3.6.3 Effect of Conservation Practices

Table 29 shows that the overall impact of the conservation practices on the estimated total loads averaged over the 15 year scenario is modest, ranging from 0.04 to 2.59% for total phosphorus and 0.02-0.23% for total nitrogen. The water quality improvements related to individual conservation practices have been found in this modeling work to be incremental. Therefore, the aggregate improvements related to ongoing and future implementation of targeted conservation efforts are predicted to be significant and will provide real impacts on nutrient loads and downstream receptor impacts.

Table 29: Summary of Watershed Water Quality Modeling Results - Utah DEQ 319 Assessment Project – by Watershed – 1990-2004

Result	BMP	Middle Bear River[6]	Chalk Creek	Sevier River	San Pitch River	Beaver River
Total Phosphorus Load (kg/yr)	No	11,245	35,611	67,878	16,931	16,310
	Yes	10,733	34,690	67,688	16,925	16,279
	% Change	4.55	2.59	0.28	0.04	0.19
	Min[7]	10,733	34,690	67,688	16,925	16,277
	Max	10,734	34,690	67,688	16,925	16,279
Total Phosphorus Concentration at WS boundary (mg/L)	No	0.0873	0.148	0.1479	0.1479	0.1424
	Yes	0.0863	0.144	0.1474	0.1478	0.1421
	% Change	1.14	2.59	0.28	0.04	0.19
	Min	0.0861	0.144	0.1475	0.1478	0.1422
	Max	0.0864	0.146	0.1473	0.1478	0.1421
Total Nitrogen Load (kg/yr)	No	55,567	160,543	171,683	88,837	40,185
	Yes	49,629	160,173	171,546	88,819	40,177
	% Change	1.85	0.23	0.08	0.02	0.02
	Min	49,629	160,173	171,546	88,891	40,176
	Max	49,630	160,173	171,546	88,819	40,177
Total Nitrogen Concentration at WS boundary (mg/L)	No	1.72	0.667	0.374	0.777	0.35
	Yes	1.71	0.665	0.373	0.776	0.34
	% Change	0.01	0.23	0.08	0.02	0.02
	Min	1.71	0.665	0.373	0.775	0.34
	Max	1.71	0.664	0.373	0.776	0.34

[6] Middle Bear River loads do not include those from the upstream portion of the Bear River at the release of Oneida Reservoir in Franklin, County, ID ($44.0x10^3$ kg P/yr, $1.67x10^6$ kg N/yr). The concentrations do include the upstream load to demonstrate the overall impact. The % decrease in the total phosphorus and nitrogen in the Middle Bear subbasins alone would decrease by the same fraction as the load.

[7] Min/Max show results for the upper and lower bounds of the range of BMP efficiencies for each of the 319 Projects in a watershed.

4.3.6.4 Downstream Response

The changes in the predicted responses due to the conservation practices in the Middle Bear Watershed in the receiving water (Bear River at Cutler Reservoir) are also small but significant. One reason that the impacts are small is that the total of the phosphorus and nitrogen loads from the Middle Bear Watershed are estimated to be about 26% of the loads from the greater Bear River Watershed in Utah, Wyoming, and Idaho that cross into Utah, and the portion of the subbasins involved in this study cover < 1% of the land area. The total phosphorus concentration in the Bear River as it crosses from southeastern Idaho into Utah at times exceeds the State of Utah guidelines for protection of reservoirs suggesting that balanced conservation efforts are required in the greater Bear River watershed in Utah, Idaho, and Wyoming to come into alignment with those guidelines. Similar to phosphorus, total nitrogen concentrations were predicted to decrease by a small but significant percentage over the 15 year simulation period, for similar reasons.

Predictions for the other four watersheds studied here showed similarly small improvements in the downstream water quality conditions for both total phosphorus and nitrogen, for reasons similar to those for the Middle Bear River. The improvements in total phosphorus are largest in the Middle Bear and Chalk Creek watersheds, with estimated 4.55 and 2.6% decreases respectively, while the largest impact on total nitrogen is in Chalk Creek with a 0.23% decrease. The changes in the remaining watersheds are < 0.25%. In all cases, the affected land areas subject to conservation projects are small fractions of the total watershed area, and also small fractions of the areas with land use that might benefit from those projects.

4.3.6.5 Comparison of watersheds

The watersheds examined in this study varied greatly in size (268 mi^2 to nearly 1,700 mi^2) and land use (3% agriculture to 45% agriculture). Similar numbers of projects were studied (from 26-34). All watersheds had a major focus on streambank-related projects, four had a focus on upland improvement projects and irrigation improvement projects, and three watersheds focused on animal waste management. Appendix III shows the ranges of effectiveness of the various project types as published by the U.S. EPA that was used to assess the impact of these projects on nutrient loads. We emphasize that the 319 projects assessed here do not represent all conservation projects in these watersheds and the small reductions in nutrient loads seen in Table 29 represent a lower bound on the effects of conservation practices watershed-wide.

Load reductions for each watershed are summarized in Figure 44. On a percentage basis, the largest reduction in total phosphorus loads is 4.55% in the Middle Bear River, followed by the Chalk Creek (2.6%), the Sevier River (0.28%), Beaver River (0.19%), and San Pitch (0.04%) watersheds. For nitrogen the ranking is similar, with the Middle Bear River watershed showing the largest reduction (1.85%), followed by the Chalk Creek (0.23%), the Sevier River (0.08%), and the San Pitch and Beaver watersheds (0.02%). The effectiveness of the projects for each watershed follow similar patterns for both nitrogen and phosphorus.

To a certain extent the percentage load reduction for each nutrient followed the fraction of the watershed area affected by the conservation projects, though more so for phosphorus than nitrogen (Figure 45). The relationships are influenced by much more than fraction of area affected, including the influences of project type, condition and pre-project effectiveness, orographic effects on rainfall distribution, presence of groundwater influences on watercourses, fraction of load from agriculture, etc., most of which is beyond the scope of this project.

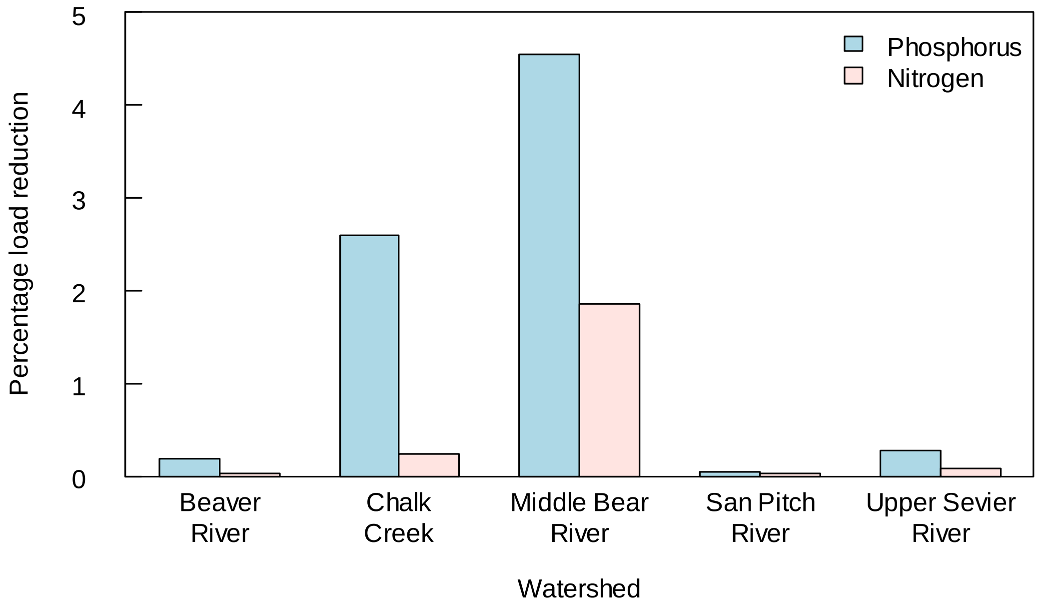


Figure 43: Load reduction for phosphorus and nitrogen for each 319 project watershed.

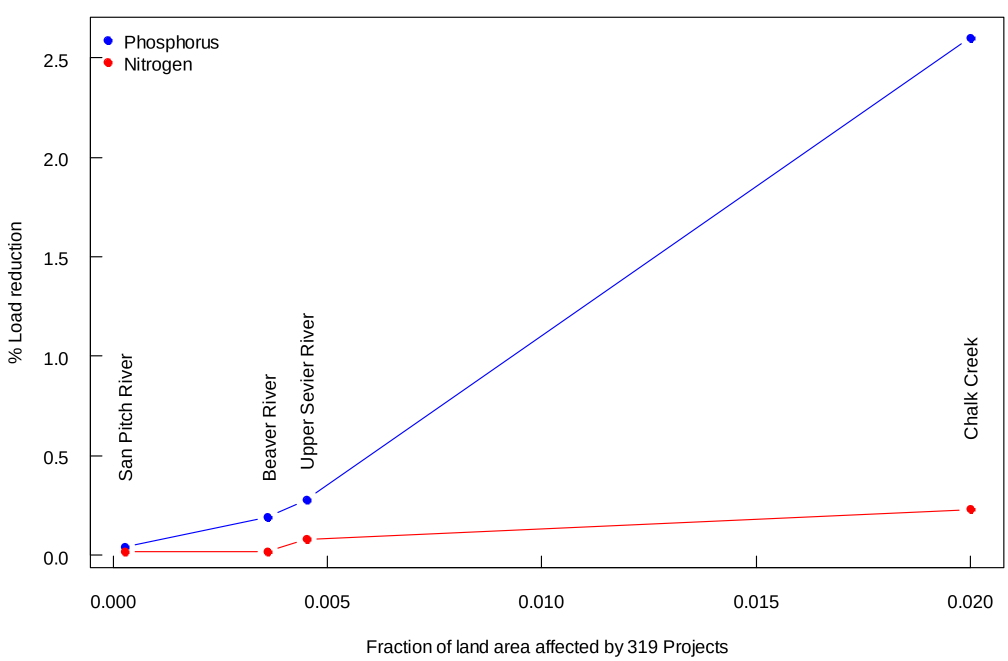


Figure 44: Relation between nutrient removal and fraction of watershed affected by 319 projects.

5 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Assessment of BMP Implementation, Maintenance and Effectiveness

5.1.1 By BMP type

- **Animal waste projects** (16 projects in 4 watersheds)
    - In most cases, projects were designed primarily to reduce phosphorus loading. All of the projects had been implemented and were still in place and generally serving their intended purpose (improved storage & management of animal waste). It is clear that animal waste projects provide consistent improvements in the containment of manure.
    - A number of farmers reported problems in the engineering of BMPs that either over- or under-built the size and durability of animal waste projects. Farmers who had opportunities to work with engineers to adapt designs to their local situation felt that the projects were more effective and efficient.
    - In several cases, the benefits of improved manure containment provide an obvious reduction in phosphorus loading to the targeted water bodies because there had been a direct conduit which has now been eliminated.
    - However, in other cases, the actual water quality benefit of the projects to the watershed was less certain. In these cases, clear flow paths of animal wastes to targeted waterbodies were not apparent either before or after the project was implemented.
    - While containment of manure was improved on all the farms we visited (often quite dramatically), many farmers did not report significant changes in the ways they made decisions about how much and where to spread manure on their fields. There was little evidence that a nutrient management plan or soil phosphorus test results guided their manure spreading decisions.
    - Some dairy farmers were under the impression that the goal of the projects they were asked to do was simply to keep their runoff on-site or comply with EPA regulations. Several did not know that water quality in nearby water bodies was the reason for the project funding. Therefore, they accepted designs that achieved runoff containment even when they felt that the requirements were odd or meaningless for their operation.
    - We found sporadic reporting of UAFRRI model results. Visits to those sites with UAFRRI calculations, found that some of the assumptions behind the model estimates did not reflect actual variability in the operating practices on participating farms (e.g., changes across time in number and types of animals on the farm, variability in scraping frequency, etc.). We believe that the UAFRRI model is a good tool for predicting potential success, but does not reflect the variability found in real world operations. This uncertainty should be explicitly acknowledged when reporting nutrient loading reductions using UAFRRI.
    - Those projects that reported UAFRRI results also reported changes in nitrogen loadings. Our fieldwork suggested that these projects were not designed to eliminate nitrogen transport. As a result, we do not believe that the UAFRRI

estimates are realistic characterizations of nitrogen loads, particularly to groundwater.

- **Irrigation projects** (16 projects in 4 watersheds)

    - The range of estimated water quality improvements from irrigation work varied widely from project to project.
    - Operators were overwhelmingly satisfied with the operational benefits of the irrigation projects, citing reduced labor and increased forage or crop production.
    - Operators were often unaware that the funding for the irrigation projects was specifically intended to improve water quality.
    - Of the irrigation projects, 11 people mentioned that it helped their operations. Of those, half thought it probably improved water quality, while the other half felt it had not likely had any impact.
    - Most of these projects entailed changing from flood to sprinkler or piped irrigation systems. We received contradictory answers during many irrigation-related interviews about whether significant erosion or tail water runoff had been present pre-project. It was clear that most irrigators we spoke with had not been specifically aware enough to recall details of the tail water situation.
    - Very little pre-project quantitative data (e.g. tail water flow volumes, application rates, etc.) was available, preventing quantitative assessments of potential impact.
    - Projects that exhibited the most likely positive impact on water quality were in close proximity to receiving water bodies.

- **Upland grazing** (14 interviews in 5 watersheds)

    - Upland projects varied widely in type and extent. They included changes in range management (seeding, brush control and fencing), sediment capture ponds, and water developments that allowed animals to be removed from riparian areas.
    - Implementations of these types of projects were relatively straightforward and did not entail major engineering or bureaucratic challenges.
    - Generally, operators reported that these projects clearly improved their ability to manage their grazing operations.
    - These projects seemed to have the least documentation of water quality problems in the files, and water quality benefits were the most difficult to assess both during field visits and in interviews. The water quality benefits were almost never explicitly identified (either in files, or by the producers).
    - All producers interviewed felt their operation had benefited from improved forage quality or availability. Roughly a third believed that water quality had been improved, a third felt that it had not had any obvious impact, and a third suggested that any water quality impacts had been limited to their property and had not likely impacted the targeted water body.

- Projects that appeared to have greatest benefits included:
    - Using improved grazing areas to relieve stress on other more sensitive areas near riparian zones.
    - Sediment capture ponds that slow landscape-scale erosion.
    - Seeding and improved management of grazing land that creates net increases in vegetation that may prevent direct soil erosion. (However, in some cases increased grazing pressure as a result of these treatments may have mitigated benefits of improved plant cover.)
- Prescribed grazing, as part of the contract, was not adequately delineated in the files to allow for any kind of impact assessment from these practices. Few producers reported significant changes in grazing management designed to meet water quality goals.
- Conventional indicators of range quality (e.g. stubble height) are not sufficient to estimate net water quality benefits.
- Rarely was any type of data collected prior to project implementation making quantitative assessment of water quality improvements nearly impossible.

- **Rural stream projects** (20 interviews in 4 watersheds, proper functioning condition, paired photo comparisons, fish suitability analysis and aerial photo analysis in 3 watersheds.)

    - When they were successfully implemented, streambank improvement projects were universally considered to have a positive water quality impact from both the perspective of the operators and through qualitative field assessment techniques (interviews, proper functioning condition [PFC] methods, and comparisons of paired photographs across time). Evidence from more quantitative methods (fish habitat suitability analyses and aerial photo analyses) was more ambiguous, and not always consistent with the results of qualitative approaches at both the project and watershed scale.
    -
    - Interviews provided important insights into how stream BMPs were experienced by landowners
        - Most operators were content with how well their stream projects turned out. Several were surprised by the positive results, and four indicated that if they were to do it again, they would have done work on a more extensive scale.
        - Streambank projects appear to provide little direct operational benefit to agricultural producers other than potential prevention of land loss caused by erosion.
        - About half noted that overall water quality in their stream reach was influenced by much more than their BMP project, including upstream land use decisions by others, recent fire activity resulting in erosion, erodability of natural landscapes upstream, variation in irrigation withdrawals, changes from sheep (who don’t wallow in water) to cattle (who do), and the impacts of beavers.

    - Several interviewees specifically noted that the fencing portion had been much more critical to allowing their streambanks to recover than the rockwork or plantings; protecting the stream from livestock so vegetation could reestablish was seen by these individuals as more important than planting any particular types of plants. One operator indicated that stream restoration projects in grazed areas could not succeed without fencing.
    - Less successful streambank projects were compromised by the following factors:
        - Lack of engineering expertise by the implementer or contractor
        - Severity of the following spring runoffs
        - Issues with failed vegetation plantings (related to poor planting practices, lack of protective fencing, bad timing – relative to flooding events, etc.)
    - Different project objectives incorporate different restoration techniques and produce somewhat different results. In the DWR projects on public lands that valued increasing fish habitat, continued active river migration was considered more acceptable than in the private landowner projects that focused more on stabilizing banks to reduce sediment loads and to protect fields from encroachment by the river.
    - Because riparian restoration falls outside of the skill set of most agricultural producers, the level of involvement and expertise of the watershed coordinator (or other specialists) is more critical to the success of these types of projects than in other BMP's.
    - Very little pre or post-implementation monitoring and follow-up has been done on stream projects in these watersheds.
- PFC assessments were conducted in 3 rural watersheds. Results suggested that:
    - The majority of project areas are properly functioning or trending upward, a strong endorsement that the projects have been highly successful overall at improving stream stability and functional condition. Of the 11 sites we analyzed, 7 were in proper functioning condition, 3 were functioning at risk (one trending up), and 1 site was in nonfunctional condition.
    - As would be expected, older projects are in better condition than those projects where vegetation has not had as much time to establish.
    - More recent projects in systems with a greater fluctuation in flows (i.e. flashier systems) are more likely to be categorized as "At Risk."
    - Many of the landowners we spoke with were interested in the results of our work, and requested detailed information from their own properties once our analysis was complete. This confirms the value of the PFC process as an educational tool.
- Comparisons of paired photographs were conducted in 3 rural watersheds.
    - The most obvious improvements in photo comparisons related to growth in riparian area vegetation.
    - In some cases, we could see improvements in the slope and condition of streambanks. This partly relates to the orientation of many photos in several watersheds that made it difficult to track this characteristic across time.

        - Evidence of stream channel improvements was the most difficult to determine based only on photo comparisons.
        - In many cases, "initial" photos were taken after project implementation had begun, making comparisons difficult.
    - Fish habitat suitability analyses (field studies in Chalk Creek and analysis of existing data in 3 watersheds.)
        - In Chalk Creek, the fish habitat suitability study included several criteria. Depth and substrate conditions were generally found to be suitable for trout. Macroinvertebrate metrics indicate no water quality or fine sediment impacts. Poor combined ratings in some cases were due to non-optimal flow velocities (too high or too low) and limited overhead cover.
        - Bank stabilization measures that place immobile or permanent structures within the banks (eg. rock barbs) may have unintended negative impacts on fish habitat. Restricted point bar deposition and bank erosion can reduce valuable off-channel spawning and winter rearing habitat for trout. This, in turn, may reduce growth of riparian vegetation.
        - In the three years following implementation in the San Pitch watershed, analysis of existing data suggests that relatively small-scale restoration projects (e.g. livestock exclusion, bank stabilization and instream structures) have had positive effects on habitat quality and trout populations. Ongoing monitoring is needed to determine which specific BMPs are most effective and whether this response will be retained over time.
        - Native fish numbers in several restored sites in the Sevier watershed showed short term increases, but numbers declined in subsequent years. Factors such as predation by trout may be responsible.
    - Aerial photo analysis (3 rural watersheds)
        - Not all stream project reaches demonstrated net improvements compared to untreated areas of the watershed.
        - The scale of changes associated with individual projects are often overwhelmed by larger watershed processes (e.g., major flood events).

- **Urban stream projects** (1 watershed)
    - The urban stream projects in our study were successfully implemented and maintained, and are likely to have improved water quality.
    - Urban stream BMP projects face unique challenges associated with urban stormwater runoff, land ownership, a more rigid built environment, recreational uses of stream areas, and complexities created by human-managed hydrologic flows.
    - While the budget for water quality projects typically relies on external grant funds, urban cities and counties do have existing staff and equipment that can be utilized to help construct, maintain, and monitor the condition of stream BMPs over time.

5.1.2 Watershed modeling

- Predictions for the watershed models showed similarly small improvements in the downstream water quality conditions for both total phosphorus and nitrogen.
- The effectiveness of the projects for each watershed follow similar patterns for both nitrogen and phosphorus.
- In all cases, the affected land areas subject to conservation projects are small fractions of the total watershed area, and also small fractions of the areas with land use that might benefit from those projects.
- Predicted improvements related to individual conservation practices have been found in this modeling work to be incremental. Therefore, the aggregate improvements related to ongoing and future implementation of targeted conservation efforts are predicted to be significant and will provide real impacts on nutrient loads and downstream receptor impacts.
- We emphasize that the 319 projects assessed here do not represent all conservation projects in these watersheds and the small reductions in nutrient loads seen in our modeling represent a lower bound on the effects of conservation practices watershed-wide.

5.1.3 Overall Implementation and Impacts

- Most 319-funded BMP projects are still in place, still functional, and are appreciated by the landowner.
- From the landowners point of view, the water quality impacts from BMP use are less evident (and important) than the beneficial impacts on labor, productivity, or recreation from the projects.
- Poor engineering design was a major reason for difficulties in implementing animal waste BMPs, and helped explain the least successful rural stream BMP projects.
- Overall, our field assessment concluded that roughly 60 percent of BMPs likely or definitely produced positive impacts on water quality. Another 15 percent were in situations where it was difficult to clearly evaluate the net water quality impacts.
- About a quarter of all BMPs in rural watersheds were considered unlikely to have improved water quality. The lack of impact usually related to the placement of the BMPs in areas which were far from the targeted water body and/or designed mostly to accommodate other goals (like improving irrigation efficiency).

5.2 Overall lessons on implementation & monitoring of conservation projects

- Establishing baselines, clear objectives
  - Rarely was any type of data collected prior to project implementation, making quantitative water quality improvement assessment near impossible.
  - Qualification for receipt of 319 funds was not always based on clear and well documented information about the local water quality problem.
  - In a subset of projects where the water quality benefit was questionable, some still had significant value to the land operator (for example, with irrigation projects), whereas others (for example, an animal waste project in the Middle Bear) had several expensive components which the operator did not see much value in.

- Effective engineering & technical assistance
  - Many interviewees specifically mentioned that NRCS requirements were too specific, unnecessarily costly, and not the most logical way to achieve a successful project. Examples include over-engineered irrigation pumping systems, requirements that new equipment be purchased when used equipment was less expensive and equally effective, and concrete walls with too much expensive reinforcement required.
  - The lack of availability of technical engineering expertise was a substantial concern for the success of several projects. Roughly a third of interviewees had specific complaints about engineering work done by NRCS or UACD staff.
  - Operators who worked closely with engineers during the design process to adapt the plans tended to have more successful projects both in terms of water quality improvement and ongoing management.
  - Engineers should work more closely with reluctant operators to ensure buy-in and improved understanding of water quality goals, increasing the chances of project success

- Project administration
  - Employee turnover in the NRCS and UACD offices puts a burden on landowners, as they re-explain and in some cases re-justify projects that were already moving forward with a previous employee.
  - Individuals in every watershed made recommendations for changes in funding structure and clarity that would help make projects more sustainable and manageable. These included:
    - Creating an errors and omissions fund to cover cost overruns associated with unforeseen engineering changes or errors.
    - Need money to come back the next year and make little tweaks that would help make the project more sustainable long-term, like repositioning rocks, replanting willows in areas where they washed out, etc.
    - Providing sufficient money (or utilizing a more targeted planning process) so that projects could be implemented along enough stretches of the river to really make a difference at the watershed scale.
    - Avoid the boom & bust cycle associated with watershed project funding. It is hard when resources dry up before watershed work is done. Newly won-

over landowners (when a first project works out well) may be discouraged if the funding has completely moved on from their area. Missing out on follow-up opportunities.

- Multiple operators, particularly in smaller communities, mentioned how valuable the project money was to the local economy: both purchases and labor were important and valued contributions, and there is continued strong support for additional funding coming to these watersheds.

- Implementing appropriate monitoring & follow-up over time
  - Project evaluation at the local level (which feeds into the final reports) seems to be based primarily on anecdotal evidence and model projections, not onsite monitoring. In at least one situation, we were informed that we were the first people to visit the location to determine how the project had worked out
  - Pre project data was sparse, in most cases non-existent, and when it did exist, often was not associated with the project files. We often had to inconvenience people in other agencies or rely on sparse information in written reports to determine what monitoring or impact data existed on some projects.
  - Primary data collection and fieldwork provides critical validation of information in project files. Although we were able to access file data on all 319 projects in each watershed, what we learned in the interviews provided important additional information that changed our understanding of what was done and how each practice performed. Using only file data to analyze projects would provide an inaccurate assessment, with potential errors that could not be predicted.
    - Photo point comparisons, despite being the most ubiquitous type of pre-data taken on stream projects, were not consistently taken, labeled, or organized. Almost all photo points lacked GPS coordinates or any description of where they were taken. In some cases, which project they were associated with was also not labeled. It is also not clear how representative the locations of photopoint sites are for a given reach; efforts to randomize locations might help improve the validity of this method for assessing BMP impacts.
    - Many of the "before" photos are actually "in progress" photos. Although they are useful from an implementation standpoint, they do not provide critical information about pre-project conditions.
    - Fish and fish habitat data were not available in the files for the projects, and had to be obtained from third-parties that were not prepared to provide it in a timely or organized manner. These data rarely paired up with the BMP implementation site in either space or time.
  - Landowners often don’t recall which sources funded which projects (multiple pivots paid by different programs, for example), which makes it difficult for them to differentiate 319 funding from other similar conservation projects.

5.3 Conclusions & Recommendations

Conclusion #1: Post-implementation, qualitative reconstruction of pre-project data is fundamentally not an effective method of assessing water quality improvement from projects. Without adequate pre-project data, it is extremely difficult to make direct measurements that assess whether the implemented BMPs led to their intended improvements in water quality conditions.

Recommendation #1: Pre-project condition assessment, even if data is limited, will be critical to any future project assessments. Minimal data to gather in the future could include:

- Labeled photo points, including date, GPS coordinates, and time of day taken
- Short written descriptions of conditions leading to water quality impairment, and the intended process via which the project would be expected to improve conditions.
- If model results are used in final reports, inputs should be available in producer's files for verification and replication

Conclusion #2: Lack of information on – or access to – previous monitoring efforts severely restricted our ability to replicate any data gathering post-project.

Recommendation #2: If technical data is gathered, records must be kept in the relevant project files. A separate section in both NRCS and UACD files dedicated to monitoring information would make post-project monitoring much more straightforward. These data could include:

- Whether pictures were taken, where they are stored, and if they are digital or not
- If pre-project data (water quality, fish data, streambank angle, vegetation composition, Proper Functioning Condition assessments, etc.) were gathered, where to find the data (if appropriate) or meta information on researchers to contact, titles of research reports, descriptions of methodologies, etc. must be kept.

Conclusion #3: Most 319 project implementations appear likely to have positively impacted some aspects of water quality in the targeted water bodies. However, <u>projects which had the greatest potential benefits were those that were thoughtfully designed to improve water quality</u>, by teams of project managers and landowners who understood the problem and worked jointly to solve it.

Recommendation #3: Encourage watershed coordinators to engage landowners more proactively in project planning, not only to ensure benefit to the landowner or operation, but also to ensure they understand and contribute to solving the water quality goals. Landowners have unique understanding of their landscape that can help projects improve the design of BMPs to maximize both operational benefits and water quality outcomes. Communicate clearly with landowners to make sure that their water quality and other goals align with the project design. More successful projects can come from fully informed discussions where everyone's goals are clearly articulated.

Conclusion #4: All types of projects we examined (upland, irrigation, animal waste, and streambank stabilization) had examples of both high-value and low/no-value projects. BMPs that had little impact reflected poor implementation decisions (e.g. which projects to fund, where, and how they were designed) more than inherent problems with the practice type itself.

Recommendation #4: Require more detailed justification of how a specific BMP project will address a known water quality problem. Avoid funding BMPs just because they fit a certain category of approved practice, rather than having clear water quality improvement potential. Require specific statements about intended benefits to water quality, not just generalized statements about practices.

Conclusion #5: Post-project follow-up visits can provide important benefits to watershed conservation efforts. First, there are many instances when small additional investments could be made to correct for design flaws or mitigate impacts of extreme events. Second, field visit provide insights into the strengths and weaknesses of different BMPs that can allow staff to adjust future funding to improve water quality benefits.

Recommendation #5: Do not rely on the landowner to report problems or situations where project components need follow-up. Watershed coordinators or others should follow-up to see if BMPs are still functioning as designed. Projects should allocate some resources to an 'errors and omissions' fund to allow for post-project corrections.

Conclusion #6: It is not clear that project staff always had a robust understanding of the assumptions and limitations of impact assessment models (such as UAFRRI or STEP-L) used in project reports

Recommendation #6: Ensure that watershed coordinators are trained to understand, assess and question, not simply input data to, models used for reporting results. To allow assessment of model estimates in the future, model input data should be included in producer files, along with details about the ways input data were gathered. Auto-updating date fields in the UAFRRI model should be removed from the document to reduce confusion.

Conclusion #7: File information quality varied widely across conservation district offices. Although funding information files were more carefully standardized, details beyond cost and specific practices funded were sometimes completely unavailable. The EPA Grants Reporting and Tracking System (GRTS) has not been used to its full potential to provide detailed and useful tracking of project implementation and outcomes.

Recommendation #7: The state should identify clear protocols for maintaining and storing information about individual BMP projects. The GRTS system should be used as a foundation for future tracking of individual projects and project outcomes. This should include

- Description of project locations, including maps with accurate georeference information,
- Description of both original BMP design and actual project details as implemented,
- Description of water quality concerns and understanding of how proposed BMPs would address these concerns,
- Pre-project water quality monitoring data,
- Data from ongoing monitoring activities,
- Pollutant-load-model input assumptions, and
- Copies of final project assessments (e.g. paragraphs from final reports).

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7 APPENDIX: Copy of Semi-Structured Field Interview Instrument

IMPROVING AG-NPS PROGRAMS IN UTAH
Assessing the Impacts of EPA-319 Funded
Best Management Practices

Utah State University
2012
Landowner / Cooperator Questions

PARTICIPATION IN THE STUDY IS VOLUNTARY.

ALL ANSWERS TO QUESTIONS IN THIS INTERVIEW WILL BE KEPT STRICTLY CONFIDENTIAL,

THE RESULTS WILL ONLY BE USED IN STATISTICAL SUMMARIES. INDIVIDUAL FARM INFORMATION WILL NOT BE IDENTIFIED IN ANY PUBLICATION.

Utah State University

Farm ID number: ______________ **Time: started:** _______

Date of interview: _____________ **Time finished:** ______

Lead interviewer: ______________ **Second interviewer:** ____________

Background data:

- Role of primary person who was interviewed (primary farm operator, etc.)
- Were any other decision makers present?
- Basic information on operation (land usage, type of livestock):

Part A: INFORMATION ABOUT YOUR PROJECTS

- *[Review the list of 319-funded projects with the respondent to confirm the accuracy of the project file information.]*
- Can you think of any additions or deletions from this list?
- Are you still operating the lands covered by these original contracts?
  - Explain what happened:
  - Who operates that land now?
- Any major changes in the operation since these practices went in?

Animal Waste Projects

- What changes were made to your animal waste management systems and structures?
- What were those changes designed to do?
  - New WASTE STORAGE STRUCTURES?
  - Other new infrastructure: CORRALS, PIPING, CEMENT PADS, etc.?
  - Any WASTE MANAGEMENT PLANS?
- 319 funding works to improve water quality. What were the conditions before this project was implemented, and how might they have had an impact on water quality?
- Did everything work like you expected? (Any difficulties encountered?)
- Do you still use the structure and manure management system as planned?
- How did having the new structures affect the way you manage animal wastes?
- Did having storage or structures affect other aspects of your farm or ranch?
- Has maintenance changed since you installed the structure?
- What impacts did your animal waste management projects have on water quality in the ____ River (from what you could see)?
- Were there any other costs or benefits you saw from this project?
  - Operation's economic performance?
  - Quality of life or labor needs?

Upland Projects

- What exactly was done, and why?
  - New FENCING?
  - New WATER DEVELOPMENTS?
  - Any MANAGEMENT PLANS associated with these changes?
  - Any BRUSH MANAGEMENT, pasture SEEDING, etc.?
- 319 funding works to improve water quality. What were the conditions before this project was implemented, and how might they have had an impact on water quality?
- Did everything work like you expected? (Any difficulties encountered?)
- Do you still use the pastures in the same way?
- Do you still use the management plan?
- How did these practices affect how you manage grazing?
  - Stocking rates?
  - Frequency or duration of grazing?
  - Livestock access to rivers or streams?
- How did the changes affect your range conditions?
  - Ground cover/stand establishment?
  - Forage quality?
- What impacts did your grazing and range projects have on water quality in the ___________ River (from what you could see)?
- Were there any other costs or benefits you saw from this project?
  - Operation's economic performance?
  - Quality of life or labor needs?

Irrigation Projects

- What exactly was done, and why?
  - New EQUIPMENT?
  - Any MANAGEMENT PLANS associated with the equipment?
- 319 funding works to improve water quality. What were the conditions before this project was implemented, and how might they have had an impact on water quality?
- Did everything work like you expected? (Any difficulties encountered?)
- Do you still use the equipment?
- Do you still use the management plan?
- How did these practices affect how you manage irrigation?
- How did the practices affect your operation?
- What impacts did your irrigation projects have on water quality in the ___________ River (from what you could see)?
- Were there any other costs or benefits you saw from this project?
  - Operation's economic performance?
  - Quality of life or labor needs?

Stream Restoration Projects

- What exactly was done, and why?
  - o Riparian FENCING?
  - o Any streambank stabilization like BARBS or RIPRAP?
  - o Any PLANTINGS? (what plants?)
- 319 funding works to improve water quality. What were the conditions before this project was implemented, and how might they have had an impact on water quality?
- Did everything work like you expected? (Any difficulties encountered?)
- Do you still use the fences?
- Did the streambank work survive any recent high flows?
- Are the plantings still in place?
- How did having riparian fences affect the way you manage livestock?
- Do livestock currently have access to riparian areas?
- Did you have to make alternative livestock watering arrangements?
- Overall, how did these riparian practices affect how you manage the stream on your property?
- How did this project affect the condition of
  - o The streambanks?
  - o Fish habitat?
- What impacts did your project have on water quality in the ___________ River (from what you could see)?
- Were there any other costs or benefits you saw from this project?
  - o Operation's economic performance?
  - o Quality of life or labor needs?

General Questions

- If you were to do it over, is there anything you would have done differently?
- Do you think that the water quality in the __ River now is any better or worse than it was when the project started?
  - What evidence have you seen?
- What do you think are the best indicators of WQ in the _________ River?