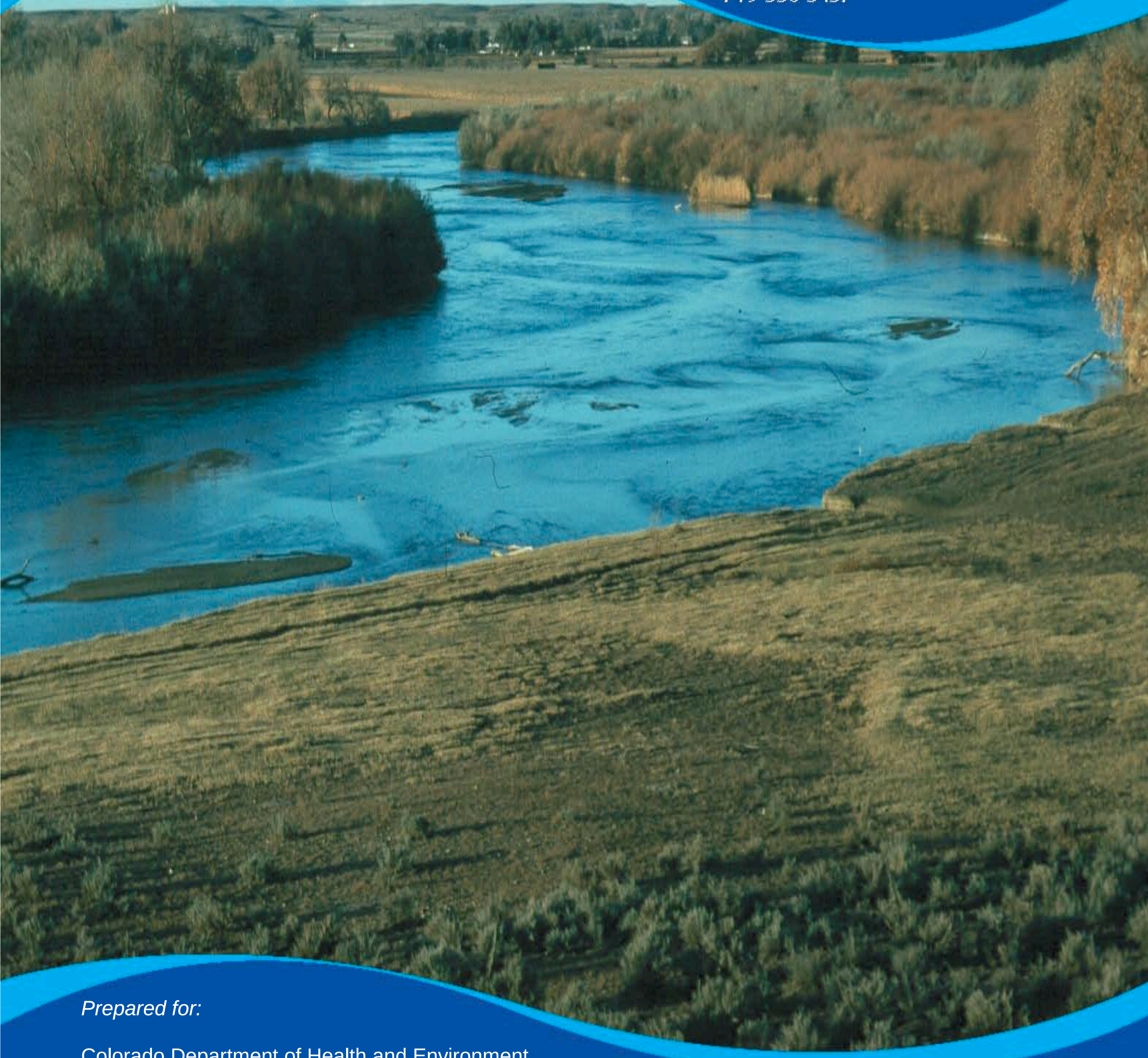
LOWER ARKANSAS WATERSHED PLAN

Prepared by:

Southeast Colorado Resource Conservation & Development
3505 South Main Street
Lamar, Colorado 81052
719-336-3437



Prepared for:

Colorado Department of Health and Environment
Water Quality Control Division
4300 Cherry Creek Drive South
Denver, Colorado 80246-1530
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Prepared by:

The Southeast Colorado RC&D
3505 South Main Street
Lamar, Colorado 81052
719-336-3437

Facilitation & Support Services by:

Tetra Tech
1900 S. Sunset Street, Unit 1-F
Longmont, Colorado 80501
Tetra Tech Job No. 133-5377.001

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Causes and sources that will need to be controlled to achieve load reductions

Previous studies have identified sedimentation, salinity, selenium, uranium and iron as high-priority pollutants that are degrading the surface water quality, its alluvium, and aquatic life habitat within the Arkansas River watershed. The Arkansas River and its tributaries are impaired by non-point source pollution, and many of these tributaries are listed on the 303(d) list for selenium and/or iron (Figure ES-1).

Figure ES-1. Impaired Waterbodies in the Lower Arkansas Watershed

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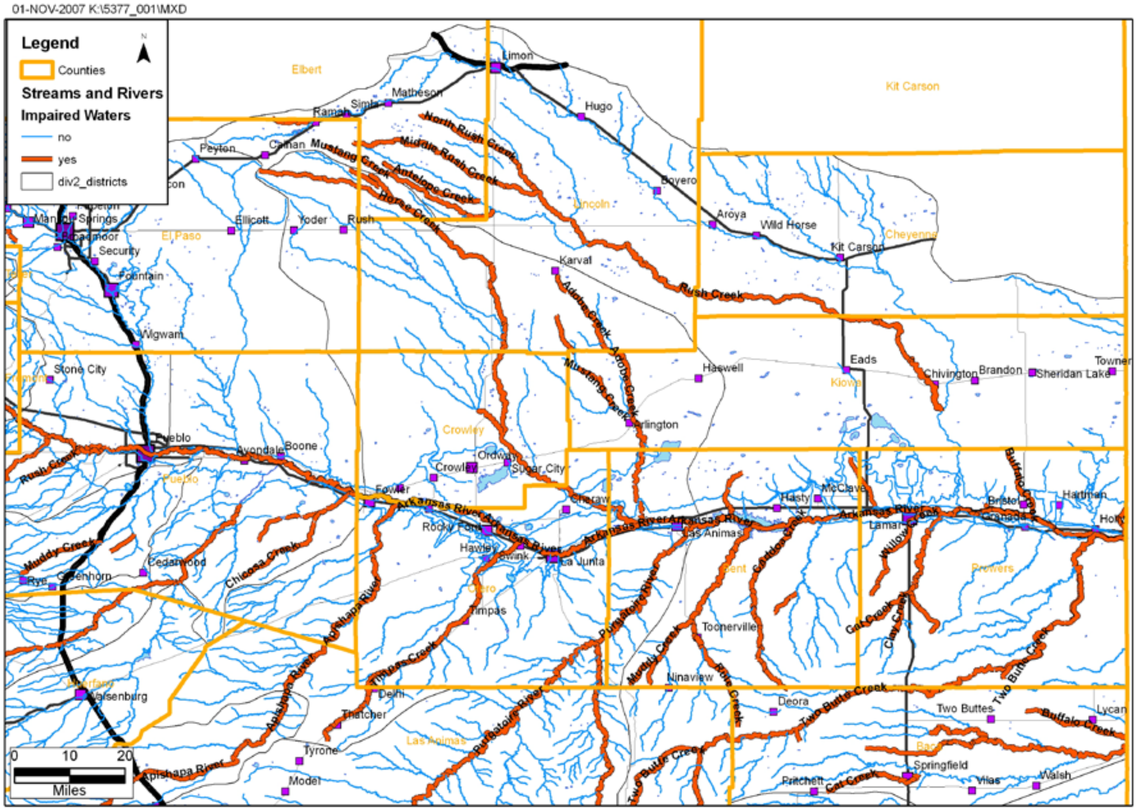

Water resource issues affecting the health of the area's aquatic ecosystems include stream flow regulation through dams and diversions as required by the Colorado and Kansas compact and degradation of riparian areas by the highly invasive plant species, Tamarisk. Moreover, the Lower Arkansas River has been determined to be the most saline stream of its size in the United States, due to excessive irrigation, seepage from earthen canals, inadequate drainage facilities, and a rising ground water table that leaches underlying geologic marine shale formations, including the Pierre Shale. The average salinity levels increase from approximately 300 ppm near Pueblo to over 4000 ppm in Holly. Intensive irrigation of the alluvial soils, and underlying marine shale, accelerates dissolution of inherent salts and metals (e.g. selenium and iron) into the underlying alluvial aquifer that flows to the river. Excessive amounts of selenium can impair aquatic life and bioaccumulation up the food chain can occur and cause toxicity to birds, mammals, and humans. As more agricultural drainage is returned to the rivers, the level of dissolved solids and sediment also cause problems in this watershed.

Other concerns include wind erosion, soil compaction due to tillage practices, increased salinity of cropland due to irrigation water management practices, and overall degradation of soil quality.

Major nonpoint sources have been identified as irrigated and non-irrigated agriculture, animal feeding operations (AFOs), grazing, and water management. Over-irrigation has created shallow water tables not only under irrigated land but also under adjacent fallow land, contributing to substantial salt and metal loading to the river from return flows. Irrigated lands and the location of the marine shale that promotes elevated selenium and iron loads in the watershed are depicted in this Watershed Plan (see Figure 1-13) highlighting potential areas for nonpoint source reductions. Point sources include agriculture-related industry and publicly owned wastewater treatment facilities.

Estimate of load reductions expected for the management measures

At a national, state and local level considerable research and demonstration of selenium, salinity, and sediment reduction control strategies has been conducted. As pilot studies have been completed, pollutant reduction effectiveness has been evaluated. Table ES-1 provides a summary of management strategies and source control measures, along with the pollutant reduction effectiveness, cost, and sources of data and information. Monitoring programs in the Lower Arkansas Watershed will provide data to support pollutant reduction effectiveness of the implemented programs.

Table ES-1. Summary of Management Measures and Pollutant Reduction Effectiveness

Management Measures	Constituent	Pollutant Reduction Effectiveness	Cost	Source of Data and Information
PAM application	Sediment Selenium	Reduces existing loading; effectiveness varies based on sunlight exposure and application techniques Application on furrow irrigation, 65% - 98% reduction of sediment in runoff waters. 39% - 87% reduction in seepage.	$140/lb selenium reduction; requires annual application $4/acre	GRSTF, 2001 Valliant 1998 - 2002 Gates (LAWCD meeting, 2007)
Canal Lining	Selenium Salinity Uranium	Reduces existing selenium and salinity loading; long term improvement. 28% - 50% selenium reduction in the Montrose Arroyo; slightly less effective in salt load reductions	$1,600/lb Selenium removed annually	GRSTF, 2001 Butler, 2001
Lateral Piping	Selenium Salinity	Reduces existing selenium and salinity loading; long term improvement.	$930/lb selenium removed annually	GRSTF, 2001
Drainage Improvements (Tile Drains)	Selenium Salinity Uranium	With an impermeable layer installed tile drain reduce deep percolation from irrigation. Reduces seepage and existing loading. Effectiveness highly variable based on site specific hydrogeologic conditions. California applications provided salt and selenium reductions. GRSTF notes that detailed	Costs vary depending on site characteristics; cost per pound of selenium load reduction not available.	GRSTF, 2001 Pacheco Water District, San Jaoquin Valley Drainage Project, 2000

Management Measures	Constituent	Pollutant Reduction Effectiveness	Cost	Source of Data and Information
		knowledge of depth to selenium rich shale and detailed design for application is required.		
Irrigation improvements (drip irrigation, sprinkler, gated pipe, etc.)	Selenium Uranium	Reduces existing loading	Drip irrigation more costly - $700/pound; protection of water rights would be needed as conserved water may be used by downstream or junior water rights holders; considerations for this use and potential selenium load reductions needed.	GRSTF, 2001
Sewage treatment plants and related facilities (convert homes on septic tanks)	Selenium	Reduces existing loading. Permanent sewage treatment plants can prevent future loadings. Load reduction typically small unless very unique site-specific characteristics exist.	Costs vary. Plants require large capital investment and annual O&M costs.	GRSTF, 2001
Reverse Osmosis	Selenium Salinity Sediment	Demonstrated technology that produces high quality treated water	$185 to $568 per acre-foot of water treated	California Department of Water Resources, 2005
Nanofiltration	Selenium Salinity Sediment	Up to 95% removal of selenium from drainage waters in the San Joaquin Valley	$600 - $1000 per acre-foot of water treated (includes amortized construction and O&M costs)	California Department of Water Resources, 2005
Evaporation Ponds	Selenium Salinity Other Salts	Reduces existing loads.	$630 per acre-foot treated (+2.8M/yr O&M costs at San Joaquin Valley facility)	California Department of Water Resources, 2005
Constructed wetlands	Selenium	Bench scale operations have indicated high selenium removal rates.	$50-$330 per acre-foot treated (straw bale amendment adds $80 per acre-foot)	California Department of Water Resources, 2005
Anaerobic Removal	Selenium	Reduces existing loads.	$200-$500 per acre-foot treated (includes capital and O&M costs)	California Department of Water Resources, 2005
Precipitation by Ferrous Hydroxide	Selenium	Pilot study at Murietta Farms achieved 90% reduction in selenate concentration. Cost effective final polishing step following microbial treatment	$270 per acre-foot	California Department of Water Resources, 2005
Algal Removal	Selenium	Pilot project selenium removal rates have varied from one order of magnitude to 40-80%	$104-$272 per acre-foot treated	California Department of Water Resources, 2005
Agroforestry	Selenium	Need more information of effectiveness for selenium removal	$150 per acre-foot of treated water	California Department of Water Resources, 2005
Monitor soil moisture and applied water	Selenium	Likely reduces existing loading	Costs vary	GRSTF, 2001
Land Preservation	Selenium Sediment	Reduces potential future selenium loading; does not	Costs vary based on location of land.	GRSTF, 2001

Management Measures	Constituent	Pollutant Reduction Effectiveness	Cost	Source of Data and Information
		reduce existing loading.		
Public Outreach	Selenium Salinity Sediment	Unknown selenium, salinity and sediment load reduction, however, programs have resulted in water conservation of 10% to 25%	About $75,000/year for full time position, including administrative support, facilities, and related expenses.	

Nonpoint management measures to achieve load reductions

The following nonpoint source management measures are recommended based on assessment of existing and projected conditions in the Lower Arkansas River watershed to achieve load reductions. The recommended management strategies and programs supported by the watershed stakeholders and their general implementation priority (i.e. short-term and long-term) over an 8-10 year period are provided in Table ES-2. The management strategies described herein are broken down into the following categories to allow for determination of the optimum combination of nonstructural, structural, and regulatory solutions to address nonpoint source reductions. All management strategies require funding.

- Land Management
- Irrigation Management
- Habitat Improvements
- Sustainable Strategies
- Regulatory Management
- Waste Management/Treatment
- Funding
- Public Involvement

Table ES-2. Recommended Management Strategies and Implementation Priority

Land Management	
Promote Land Conservation	Short-term
Develop priorities for land conservation (i.e. Lands which are selenium hot spots, Stream preservation corridors, Floodplains, and River corridor areas to promote river access and trail system)	
Implement Land Conservation Mechanisms	Short- and Long-Term
1. Acquisition of conservations easements through various programs 2. Support local districts and municipalities in efforts to conserve priority areas 3. Develop program for short-term and long-term conservation of lands. Landowners would "bid" their lands into a trust program for short-term or long-term.	
Irrigation Management	
Renovate and Maintain Historic Drainage Systems	Long-term
Early farmers created a vast drainage network which has since become rundown or inoperable due to lack of maintenance. Renovating and	

maintaining the system would encourage drainage, reduce waterlogging, and could improve water quality. There is also potential for creating a market for providing maintenance services. An incentive must be provided for landowners to maintain their drainage ditches.	
PAM Application	Short-term
PAM, a polyacrylamide, has proven to be effective in reducing erosion by preventing sediment transport in irrigation water. PAM is sprayed in solution in a dry canal or added to sediment-loaded flow. It seals and prevents seepage.	
Sprinkler or Drip Irrigation	Short-term
Implement irrigation efficiencies via sprinkler or drip irrigation.	
Earthen Channel Lining/Replacement	Long-term
Replace earthen line channels with PVC pipe or concrete lining to reduce seepage and leaching of selenate shales.	
Active Land Management	Short- and Long-Term
Combination of measures, trials of alternative crop selection and changes in operation to improve water quality; Regular fallowing and crop rotation; manage the water table to increase its contribution to crop transpiration, decrease evaporative losses, and to prevent waterlogging.	
Conduct Special Studies to Optimize Water Quality Benefits	Short-term
Continue strong working relationship with federal agencies and state academia to better define key locations and opportunities to create irrigation efficiencies and water quality enhancement.	
Habitat Improvements	
Tamarisk Eradication	Short-term
Continue and expand tamarisk removal and potentially use tamarisk biomass for energy production.	
Promote Public Access to the River	Long-term
Integrate river corridor, access, hiking and biking trails along the river to promote awareness and recreational opportunities.	
Sustainable Strategies	
Carbon Trading/Biofuel Production	Short-term
Canola is just one crop that provides for high uptake of selenium. In conjunction with this, it serves as an excellent biofuel. Appropriate canola plant varietals for the Lower Arkansas climate are still being considered, however other viable biofuel plant species can create a sustainable program that can be integrated with a carbon trading program in the watershed. Evaluate production of canola, a crop that serves as an excellent biofuel and has a high potential for selenium uptake. Implement Carbon Trading program.	
Solar Energy Production	Long-term
Encourage shift of land use to solar energy production where feasible. Currently, solar is only feasible for those with large tax liability looking for tax breaks. Could work to encourage large-scale installers responding to Xcel RFPs to site locations in the Valley.	
Harvest Energy from AFO Waste	Long-term
AFO operators could harvest energy from animal wastes to produce electricity. Electricity could be used to power their operations or sold to other energy users in the area. Pilot economic feasibility studies have been conducted. Currently, manure is used in the valley for land application; however, it is just a fairly expensive proposition for the feedlot owner and the farmer unless the sites are close to the feedlot.	

Small-Scale Wind Farms	Long-term
Small-scale wind installations are being used to power water pumping stations in Bent County. Implementing wind farms, in areas that are non-irrigable, non-productive (i.e. over-laden by marine shale or highly saline soils), and ideally located on the bluffs, could employ more people and have the opportunity to sell energy at retail rates, while providing water quality improvements. Pilot scale installations will address the obstacle of not having availability to production tax credits given to large-scale wind facilities while quantifying water quality benefit.	
Regulatory Management	
Watershed-based Incentives	Short- and Long-Term
Create trading incentives for public and private entities to implement water quality controls, enhanced BMPs and other water quality incentives geared to reduce key constituents of concern (i.e. selenium, nutrients, sediment, etc.).	
Ordinances	Short- and Long-Term
Create stormwater, land management or water quality policy and criteria that offer greater water quality benefits. Examples of ordinances may include requiring landowners that sell water rights to reseed lands prior to selling water.	
Stormwater Controls	Short-term
Coordinate with upper basin areas that are stormwater permittees to control sediment and nutrient loads on the river.	
Waste Management/Treatment	
Harvest Energy from AFO Waste	Long-term
AFO operators could harvest energy from animal wastes to produce electricity. Electricity could be used to power their operations or sold to other energy users in the area. Pilot economic feasibility studies have been conducted. While manure is used in the valley for land application, it is a fairly expensive proposition for the feedlot owner and the farmer unless the sites are close to the feedlot.	
Hazardous Waste and Materials Pick-Up	Short-term
Provide monthly pick-up of hazardous chemicals, paints, etc.; quarterly schedule for each county in conjunction with other community activities.	
Funding	
Identify Funding Mechanisms	Short- and Long-Term
Identify and develop new funding mechanisms to meet watershed goals. Implement a variety of federal, state, local, and private funding mechanisms to meet funding goals of an additional $2 million dollars annually.	
Develop an overall business program and financing plan.	Short-Term
Grants are not the long-term solutions. Market based solutions offer the most effective long-term financial stability.	
Participate with federally funded programs that support sustainable agricultural and habitat protection and restoration	Long-Term
Consider programs such as Conservation Reserve Program, Environmental Quality Incentives Program (EQIP), Partners for Fish and Wildlife, Wetlands Reserve Program, and Wildlife Habitat Incentives Program (WHIP) are federal programs appropriate to fund efforts in the watershed.	

Collaborate with other private and public interest groups to leverage funding mechanisms to meet watershed goals	Long-Term
Coordinate with other public and interest groups to obtain additional funding, recognizing there may be opportunities to view problems as business opportunities.	
Public Involvement	
Retain a Watershed Coordinator	Short-term
The Lower Arkansas Watershed Coordinator will foster community-based watershed management in the Lower Arkansas basin and be the point of contact to manage and facilitate watershed efforts.	
Develop and Implement a Comprehensive Public Involvement Plan	Short-term
The PIP will provide mechanisms to promote stakeholder involvement, encouraging, federal, state, and local interest. An open line of communication with other RC&Ds will also be promoted.	
Develop a Lower Arkansas River Watershed Website	Short-term
The website will help communicate watershed information to stakeholders and allow for easy distribution of watershed information, project highlights, grant pursuits, and monitoring efforts. Links to the website will be created from other existing websites, including the Arkansas River Tamarisk Coalition website.	

Estimate of technical and financial assistance needed to implement plan

The anticipated financial resources required to address and implement water quality improvements in the Lower Arkansas River watershed exceed the existing budget. Supplemental funding sources, an estimated $1.5 – 2 million annually, must be acquired to effectively implement management strategies in the watershed. In order to implement the recommended management strategies, additional funding and partnerships are imperative. Funding options, will be pursued beginning January, 2008 and continue throughout the watershed process. An implementation sub-committee will be formed and public support secured for each project and management program implemented. As funding is received, projects will be designed, implemented, and monitored.

There are significant opportunities to work collaboratively with the local, state, and federal government to achieve water quality improvements. Continued work with other partners in the watershed will further reveal the potential for leveraging funding opportunities. There are forces presently at work within the Lower Arkansas Watershed, creating potential synergy for decisive and positive action.

Future funding needs within the watershed include dollars for both nonstructural approaches and capital construction dollars (hard costs) and funding for administration and planning (soft costs). Many philosophical discussions arise over who should share in these costs supporting the watershed vision and other actions that must be taken to meet water quality goals.

Several broad categories of technical and financial sources were considered including federal, state, local, and private sources. Potential technical assistance and funding sources to support implementation of watershed management strategies outlined in this plan are summarized in Table ES-3.

Table ES-3. Potential Technical Assistance and Funding Mechanisms

	Agency	Program

	Agency	Program
Federal	EPA/ CDPHE-WQCD	Section 319 Nonpoint Source Grant
	EPA/CDPHE-WQCD	Nonpoint Source Mini-grants
	EPA	Targeted Watersheds Grants
	EPA	Clean Water State Revolving Fund
	EPA/ NFWF, NAC & NOAA	Five-Star Restoration Program
	EPA	Water Quality Cooperative Agreements
	USFWS	Landowner Incentive Program (LIP)
	USDA-NRCS	EQIP
	USDA-NRCS	Wildlife Habitat Incentives Program (WHIP)
	USDA	District Conservation Technician Program
	USDA-FSA	Conservation Reserve Enhancement Program (CREP)
	USDOT	Transportation Equity Act for the 21st Century (TEA-21)
	USFS	Urban and Community Forestry Challenge Cost-Share Awards
	NFWF	Keystone Initiatives
	NFWF	Special Grants
	Grants.gov	Reference to federal list
	All Federal Agencies	Database for Federal Funding Alternatives
State	CDOW-DNR	Wetlands for Wildlife Program Private Land Programs State Trust Lands/ Public Access Program
	CDOW/Colorado Watershed Network	River Watch Program
	Great Outdoors Colorado (GOCO)	State Trails Grant Program/ Wildlife Grants
	State Universities (CSU, CU, Colorado School of Mines)	Research Programs
Local	Municipalities	Stormwater Utility Fees
	Watershed Stakeholders	Watershed-based Trading Program
	Watershed Groups	Fundraising Events
		Endowments
Private	Various (Ford Foundation, Aspen Institute, Lindbergh Foundation, etc.)	Transfer Guidelines Committee Watershed Contribution to support meeting water quality requirement associated with potential water use transfer.
	Municipal Utilities/Water Interests/Tri State	Tamarisk Reclamation Projects

	Agency	Program
	Generation	
	Hunting Clubs	Conservation Easement Acquisition
	Nature Conservancy and Ducks Unlimited	

Implementation Schedule

In order for this Watershed Plan to be an effective planning and educational tool, watershed stakeholders must continue their involvement to foster solutions to watershed issues. Watershed issues will be brought to the public's attention through local outreach activities including notices in newspapers, fundraisers, festivals and community events. Quarterly watershed meetings and a watershed website will support stakeholder outreach efforts. Support from government entities and stakeholders are also required for implementation of immediate and future watershed projects.

As shown on Table ES-4, Implementation Plan Schedule, the watershed plan will be published, distributed, and submitted to the WQCD and USEPA by the end of the fourth quarter of 2007. Other projects, management strategies, and outreach efforts will be implemented, as identified, over a ten-year period.

Table ES-4. Implementation Plan Schedule

Year One	
Category	**Project**
Public Outreach	Develop Watershed Plan
Public Outreach	Hire a Watershed Coordinator
Public Outreach	Develop Watershed Website
Funding	Develop a business and financial plan
Funding	Secure grant funding
Regulatory	Identify water quality mitigation projects for water transfer legislation
Irrigation Management	Implement PAM on canals, active land management and conduct drip irrigation
Habitat Improvements	Tamarisk Reclamation
Sustainable Strategies	Carbon Trading/Biofuel Production
Year Two	
Public Outreach	Develop and implement public improvement plan
Public Outreach	Hazardous Waste Material Pick Up
Land Management	Develop land conservation priorities
Habitat Improvements	Tamarisk Reclamation
Sustainable Strategies	Implement carbon Trading/Biofuel Production projects
Funding	Secure grant funding
Year Three	
Regulatory	Implement water quality projects for IBCC Mitigation Bank
Habitat Improvements	Tamarisk Reclamation
Sustainable Strategies	Implement carbon Trading/Biofuel Production projects
Land Management	Acquire conservation easement and implement land bidding

	program
Funding	Secure grant funding
Year Four	
Habitat Improvements	Watershed Trading/Selenium and Biological Monitoring
Habitat Improvements	Tamarisk Reclamation
Sustainable Strategies	Implement carbon Trading/Biofuel Production projects
Funding	Secure grant funding
Year Five	
Sustainable Strategies	Harvest energy from AFO wastes/
Habitat Improvements	Tamarisk Reclamation
Sustainable Strategies	Implement carbon Trading/Biofuel Production projects
Funding	Secure grant funding
Regulatory	Implement Watershed based Trading project
Year Six	
Irrigation Management	Renovate and Maintain Drain System
Habitat Improvements	Tamarisk Reclamation
Sustainable Strategies	Implement carbon Trading/Biofuel Production projects
Funding	Secure grant funding
Land Management	Acquire conservation easement and implement land bidding program
Regulatory	Implement Watershed based Trading project
Year Seven	
Irrigation Management	Earthen channel lining replacement with PVC,etc.
Irrigation Management	Renovate and Maintain Drain System
Funding	Secure grant funding
Regulatory	Implement Watershed based Trading project
Land Management	Acquire conservation easement and implement land bidding program
Year Eight	
Sustainable strategy	Solar energy/Wind farming on non productive lands
Funding	Secure grant funding
Irrigation Management	Renovate and Maintain Drain System
Land Management	Acquire conservation easement and implement land bidding program
Year Nine	
Funding	Secure grant funding
Irrigation Management	Renovate and Maintain Drain System
Land Management	Acquire conservation easement and implement land bidding program
Habitat Improvements	Tamarisk Reclamation/Public Access
Year Ten	

Funding	Secure grant funding
Irrigation Management	Renovate and Maintain Drain System
Land Management	Acquire conservation easement and implement land bidding program
Habitat Improvements	Tamarisk Reclamation/Public access

Information and education to implement the management program

The Lower Arkansas River Basin is comprised of interested stakeholders, including private, local, state, and federal entities committed to finding ways to reduce pollutants and aid in the implementation of restoration and protection measures in the watershed. The following organizations have taken an active role in the Lower Arkansas River Basin water quality issues and have helped to contributed to planning, research, or shaping water quality management strategies:

- Colorado State University Agricultural Research Center
- Southeast Colorado Water Conservancy District
- Crowley County
- National Park Service
- National Renewable Energy Laboratory
- United States Geological Survey
- Colorado Department of Public Health and Environment
- Colorado Water Conservation Board
- Colorado Division of Wildlife
- Lower Arkansas Water Conservancy District
- United States Department of Agriculture, National Resource Conservation Service

Public involvement is a key component in the watershed planning process. By involving the public, diverse ideas and stewardship practices are broadly discussed and integrated in the plan. The Southeast Colorado RC&D and Crowley County contacted several agencies and individuals to announce watershed activities, including, public watershed meetings. Announcements on the radio and articles in the local papers, public notices, news release, speakers' bureau, and presentations about the watershed plan process informed many stakeholders. The public information, education and outreach goals and objectives of the Lower Arkansas River Watershed Improvement Association are summarized in Table ES-5.

Table ES-5. Public Information, Education and Outreach Goals and Objectives

Goals	Promote public awareness and involvement in watershed management.
	Work cooperatively with other related stakeholder groups and federal, state, and local agencies to promote holistic watershed health.
	Promote good stewardship of water resources through leadership, cooperation, financial support, and incentives.
	Retain a Watershed Coordinator
	Develop a Lower Arkansas River Watershed Website
	Develop and Implement a Comprehensive Public Involvement Plan
	Identify an agency to manage and serve as a repository for watershed

Objectives	geographic information system tools, resources information and maps.
	Implement a Hazardous Waste pick up service in conjunction with community events, fairs, and Earth Day events.
	Through cooperative efforts with other watershed groups and agencies, identify and develop new funding mechanisms to meet watershed goals.
	Enhance the Lower Arkansas River and its tributaries through volunteer efforts.
Objectives continued	Publicize upcoming meetings via website, public notices, news releases, speaker's bureau, and presentation.
	Promote and highly publicize projects that are implemented to improve the watershed and reduce pollutant loads.
	Encourage regional development of pollutant reduction projects through cooperative arrangements.
	Highlight protected riparian areas, preserved buffer zones, conservation easements, and public access areas through educational outreach mechanisms such as signage and kiosks located in the watershed.
	Educate and empower local land use agencies and elected officials on watershed improvement goals, priority projects, and measurable improvements.

Description of interim measurable milestones for determining whether the management controls are being implemented

Adaptive management incorporates the use of adaptive, or flexible, management, which is imperative due to the inherent uncertainties in understanding natural systems and processes at work within the watershed. Adaptive management is the appropriate management approach for the Lower Arkansas River Watershed as it supports pre-TMDL efforts and encourages processes by which new information about the health of the watershed is incorporated into the watershed management plan, blending research, monitoring, and practical management and observation. These approaches, including a phased TMDL strategy, will allow the Lower Arkansas Watershed Improvement Association better estimate load reductions and what management strategies work.

The implementation schedule, provided in Table ES-4 above, will provide one important mechanism for determining whether milestones and control measures are being implemented. Another interim measurable milestone is monitoring data that will be collected from management strategies that are implemented as a result of this watershed plan. Pollutant load reductions resulting from management strategies will be monitored by establishing a baseline condition and conducting groundwater and/or surface water monitoring to quantify pollutant reductions.

Criteria to determine whether loading reductions are being achieved

Consistent with adaptive management approaches, a phased TMDL strategy is recommended. This phased approach recognizes that the TMDL has elements of uncertainty which need further monitoring, evaluation, and implementation of controls and management strategies designed to improve the water quality. (see EPA, *Guidance for Water Quality Based Decisions*, 1991). Implementation of a phased approach to TMDL development will allow controls on nonpoint sources to be implemented to meet watershed goals and continued water quality monitoring, specific modeling and special investigative studies be conducted. As the future water quality activities are implemented, as funding allows, the TMDL will be re-visited over an 8-10 year period.

The watershed stakeholders and project leads will be responsible for tracking progress and measuring, documenting, and communicating benefits of various management strategies to the Lower Arkansas Watershed Association. Measurable improvements may address quantity, quality, ecology, habitat, or user related improvement. Criteria to determine whether loading reductions are being achieved may include reduction in selenium or salinity load, habitat improvement through eradication of tamarisk or creation of habitat, increase in abundance and diversity of certain aquatic species, greater recreational opportunities, and/or increased property values. Ambient conditions, beneficial use assessments, and environmental indicators may also be used to assess progress, with all assumptions, predictions, and trends being validated to the most practicable extent. The measures of progress and success will be evaluated against the management plan to ensure proper completion of tasks, management efforts, and implementation.

Monitoring to evaluate the effectiveness of implementation

The USGS has established a strategic monitoring program and QA/QC protocol for baseline indicator constituents collected by their agency. However, based on watershed issues and concerns, other watershed partners will continue to collect water quality data and information to more accurately characterize water quality, calculate pollutant loading, and changes affected by implementation of BMPs and other watershed efforts targeted to improve water quality and watershed health.

The monitoring program proposed by the Lower Arkansas Watershed Improvement Association suggests a core set of baseline indicators, plus supplemental indicators selected according to site-specific or project-specific decision criteria. As funding allows, the core indicators will be monitored routinely to assess attainment of water quality standards and designated uses. Core indicators in the Lower Arkansas Valley may include salinity, specific conductance, sulfates, pH and temperature. Supplemental indicators will be monitored to understand load reductions associated with implementation of management strategies, pilot projects, and case studies. Supplemental indicators in the Lower Arkansas Valley may include nutrients, uranium, selenium, crop tolerance, and fisheries productivity. All monitoring program efforts will be supplemented with a sample analysis plan (SAP) and quality assurance project plan (QAPP).

Stakeholders have suggested coordinated water quality monitoring in the Lower Arkansas River – a plan where each entity required sampling flows and quality, would conduct their sampling on the same date in a coordinated fashion. This would provide “snapshots” of river health and clues regarding the relationships between upstream practices and water quality, and downstream water quality.

Pollutant load reductions resulting from management strategies and implementation projects will be monitored by establishing a baseline condition and conducting groundwater and/or surface water monitoring to quantify pollutant reductions. If a baseline condition cannot be established using existing data, new data should be collected prior to implementation in order to quantify reductions and effectiveness. The scale of the monitoring program should be consistent with the scale of particular BMPs. If a BMP is a field-scale measure, monitoring should be conducted on the field-scale.

To supplement field- or sub-basin scale monitoring, monitoring stations should be located at regular intervals, bracketing known or suspected sources along the length of the Lower Arkansas River. These stations should be sampled on a regular basis for selenium, salinity, iron, uranium, E. coli and other potential parameters of concern. Such a uniform monitoring plan will establish baseline conditions in the river and allow quantification of changes effected by implementation of management strategies.

As data sets are analyzed and pollutant loads and reductions are quantified, the ultimate targets will be determined. Generally speaking, watershed targets may include reduction of selenium, salinity, sediment and iron loads to support beneficial uses and the watershed vision. However, targets may also include non-traditional approaches, such as, habitat improvement, creation of habitat, increase in abundance and diversity of certain aquatic species, greater recreational opportunities, and/or increased property values.

The organization of this Watershed Plan follows the nine elements of the watershed planning approach as recognized by the Colorado Department of Public Health and Environment. A complete description of the nine elements can be found in Colorado's Watershed Cookbook: Recipe for a Watershed Plan developed by the Colorado Department of Public Health and Environment. A summary of the nine elements can be found as follows:

EPA WATERSHED-BASED PLAN CHECKLIST

		PAGE
☒	1. An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in your watershed-based plan.	1-14 thru 1-17
☒	2. An estimate of the load reductions expected for the management measures described in Part 6 (Watershed Management Action Strategy, Policies and Program) of your watershed plan.	6-8 thru 6-11
☒	3. A description of the nonpoint management measures that will need to be implemented to achieve the identified load reductions.	7-1 thru 7-3
☒	4. An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement your watershed plan.	7-3 thru 7-6
☒	5. A schedule for implementation of the management program that is reasonably expeditious.	Table 6-1 (pages 6-6 thru 6-8) 7-1 thru 7-3
☒	6. An information and education component that will be used to enhance public understanding of the program and encourage their early and continued participation in selecting, designing, and implementing the management program.	Section 2
☒	7. A description of interim measurable milestones for determining whether the management program or measures or other control actions are being implemented.	3-1 thru 3-3 7-7 8-1
☒	8. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards, beneficial uses or other appropriate end targets.	4-6, 8-1
☒	9. A monitoring component to evaluate the effectiveness of the implementation efforts over time and measured against the criteria established to document load reductions.	4-6

LOWER ARKANSAS WATERSHED PLAN

Photo for Cover and Title Page by Mary M. Miller, USDA-NRCS

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1.0 Watershed Characterization and Regulatory Framework

Watershed protection can be defined in many ways. Across Colorado, many unique approaches have improved water quality through enabling measures that reduce stormwater runoff and erosion of soil that could cause sediment, agricultural products, livestock waste, and other pollutants to enter streams, rivers, and other water bodies, which in turn can impact its beneficial uses.

A number of watershed pollutants affect the quality of the Lower Arkansas watershed, such as sediment, nutrients, metals, and salinity. In June 2007, the Colorado Water Quality Control Commission (WQCC) adopted water quality standards and use classifications for the Arkansas River (Regulation 32). Discussions during the 2007 hearing emphasized nonpoint source pollution controls for surface water and ground water as a priority, including the naturally occurring geological sources of salts, selenium, and iron. Recognizing the rich agricultural and recreational history of the Lower Arkansas River Watershed, and the vast canal systems that have diverted and distributed water of the Arkansas River to fields in the seven county region over a hundred years ago, the Lower Arkansas Watershed Plan focus is on identification of water quality issues and reducing pollutants through identification and *implementation* of management strategies and solutions.

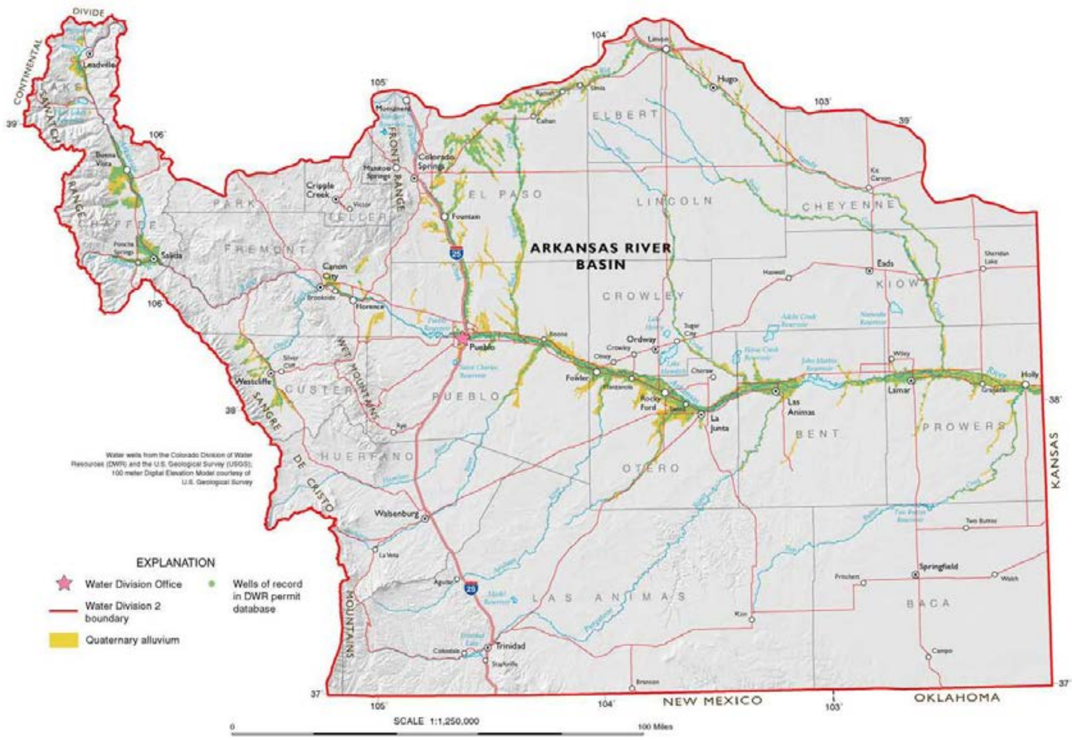
> *The Lower Arkansas Watershed Plan offers a vision of improving water quality by integrating watershed goals for sustainable community and agricultural development, water supply, fisheries, habitat preservation, flood control, and recreation.*

This section describes existing conditions, characterizing the Lower Arkansas watershed features, its regulatory issues and processes.

1.1 Watershed Description & Features

The Arkansas River Basin, at 28,286 square miles (more than 18 million acres), is the largest basin in Colorado. The headwaters originate near Leadville, flowing from northwest to southeast across agricultural land into the urbanized areas of Pueblo, Rocky Ford, La Junta, Las Animas, Lamar, and Holly before leaving the state at the Kansas border (Figure 1-1).

Figure 1-1. Arkansas River Basin in Colorado



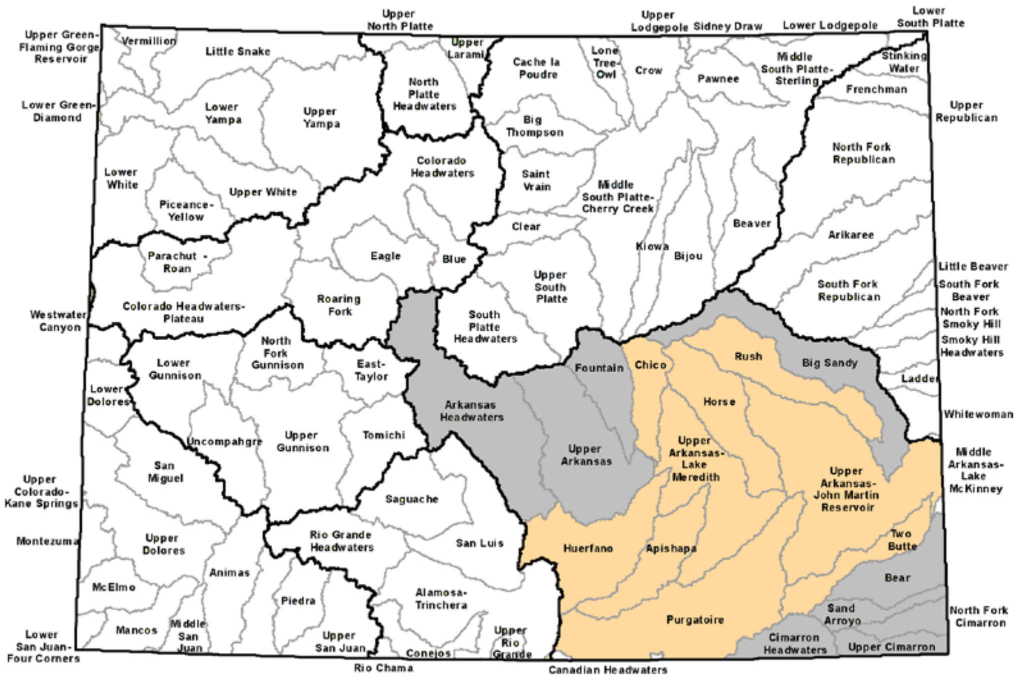
The Arkansas River sub-basins include the Upper Arkansas River, Middle Arkansas River, Fountain Creek, Lower Arkansas River and the Cimarron River. The Lower Arkansas Valley watershed covers a smaller portion of the entire Arkansas River Basin, and consists of an interlocking web of varied land uses, irrigation-stream aquifer interactions, water rights and compact issues. Irrigation and rich farmland in this region has resulted in productive agricultural economies and scenic rural landscapes. The Lower Arkansas Valley is a major agricultural area featuring some of the most productive lands in Colorado for growing onions, cantaloupe, watermelons, peppers, tomatoes, cucumbers, alfalfa, corn and wheat. Beyond the valley floor, the watershed turns to short grass prairie with the major form of land management being livestock production.

The focus of this watershed plan, the Lower Arkansas River Watershed (Figure 1-2) encompasses a seven-county region (Huerfano, Las Animas, Bent, Prowers, Crowley, Kiowa, and Otero) and is comprised of ten sub-watersheds with their corresponding 8-digit hydrologic unit code (HUC) identifier:

- Horse Creek (HUC11020008)
- John Martin Reservoir (HUC11020009)
- Two Buttes Creek (HUC11020013)
- Rush (HUC11020012)
- Purgatoire River (HUC11020010)
- Lake Meredith (HUC11020005)
- Huerfano River (HUC11020006)
- Chico Creek (HUC11020004)

- Apishapa River (HUC11020007)
- Ordway (HUC11020005)

Figure 1-2. Lower Arkansas Watershed & Sub-watersheds
Sub-watersheds (shaded in brown)



1.2 Watershed Hydrology

Physiographic Features: The Arkansas Valley originates upstream from Leadville, Colorado, at an elevation of more than 14,000 feet. A notable feature of the Arkansas River Drainage Basin, which encompasses about 26,150 square miles excluding the Cimarron River watershed, is that its headwaters are at the highest point (14,433 ft above mean sea level) in Colorado. The river leaves the state downstream at the lowest point in Colorado of less than 3,400 feet elevation. Between these two points the river flows about 360 miles through Colorado. The river's transition from the mountains to the plains is near Canon City, 36 miles west of Pueblo. West of this transition the river gradient averages about 40 feet per mile; east of this point the river gradient is reduced to a little less than nine feet per mile.

The Sawatch Mountain Range separates the basin from the Colorado River Drainage Basin on the northwest. The Sangre de Cristo and Culebra Ranges to the southwest separate the basin from the Rio Grande Drainage Basin.. There are 23 peaks in these three mountain ranges that have elevations greater than 14,000 feet above sea level. On the north, the Mosquito Mountain Range and Monument Divide also referred to as the Palmer Lake Divide or Palmer ridge separates the northern boundary from the South Platte River Drainage Basin.

The basin is typically divided into two physiographic provinces; to the west is the Southern Rocky Mountain Province while to the east is the Great Plains Province. The division between the two provinces is approximately at the 105-degree parallel (longitude). The Southern Rocky Mountain Province consists primarily of the mountain area underlain by Precambrian igneous and metamorphic rock formations. Late Cretaceous marine shales and limestones underlie the Great Plains Province. The Great Plains Province can be further divided into the "Colorado Piedmont" and the "Raton Section." A parallel line divides them approximately 25 miles south of the Arkansas River representing the elevated plain north of the line and the trenched peneplain south of the line. The Lower Arkansas Watershed lies in both the Colorado Piedmont and the Raton Sections.

Surface and groundwater are the primary water sources. Surface water supplies consist of both direct-diverted, native waters and transmountain-diverted water imported in to the Arkansas River Basin. Since 1996 all diversions of tributary groundwater (wells) for irrigation including those within the proposed project area are subject to specific augmentation requirements. Based on whether the groundwater source is used as supplemental or sole source water supply for irrigation purposes, a percentage of the total water pumped is to be replaced to the Arkansas River. This replacement of these so-called presumptive stream depletions are placed to prevent material injury to senior surface water rights and depletions to the Colorado-Kansas stateline flows under the Colorado-Kansas Compact.

Drought is common within this watershed. Hot, dry summers contribute to dry soils and potential for soil erosion. Rainfall occurs as frontal storms in the spring and early summer and high intensity, convective thunderstorms occur in late summer; such rainfall is frequently limited to a small geographic area of the watershed. However, much of the area is more directly dependent on snowfall and mountain storage than in rainfall. Precipitation ranges of 11.5" to 14" annually.

Major surface water streams in the Lower Arkansas watershed include the Purgatoire River, Huerfano River, Chicosa Creek, Timpas Creek, Two Butte Creek, Apishipa River, Rush Creek and Adobe Creek, and Horse Creek. Peak streamflows are typically observed during snowmelt runoff periods, March through May (Figure 1-3). Snowmelt runoff peaks have exceeded 2000 cubic feet per second (cfs) near La Junta and average approximately 200 cfs. Downstream flows near Lamar average 75 cfs. Water diverted from the Western Slope combined with water from the Arkansas River Basin, provides an average annual water supply of 80,400 acre-feet for municipal, irrigation, and domestic uses.

The emphasis of this watershed plan is the nine sub-watersheds as shown in figure 1.2. The total area within these nine sub-watersheds is approximately 16,904 sq. miles, representing about 65% of the total Arkansas Basin. Each of these sub-watersheds is discussed in detail in section 1.4.

1.3 Contemporary Irrigation

Historically, the area of land irrigated in the Arkansas Valley has remained relatively stable. In 1969 the U.S. Bureau of Reclamation (1969) estimated the land-irrigated equal to about 415,000 acres. In the mid 1980's the estimated number of irrigated acres was cited to be about 411,000 acres, of which 56,000 acres are located in the upper portions of the basin (Dash and Ortiz, 1996, Litke and Appel, 1986). The seasonal water supply in the basin is subject to considerable fluctuation. Waters native to the Arkansas River, its tributaries, and water imported into the basin via the Frying Pan Arkansas Project, are used and reused. The basin also includes a number of storage reservoirs. Institutionally Arkansas River Drainage Basin (Water Division II) is divided into 13 Water Districts. For a complete description of the operations of the various water systems, the reader is referred to Abbott (1985).

Arkansas River Mainstem. In the upper reach of the Arkansas River above Pueblo Reservoir (Districts 11, 12) water is diverted to irrigate alfalfa, hay, or irrigated pasture, and serves small orchards. Major conveyance systems include the South Canon Ditch, Pump Ditch and the Crooked Ditch, Canon City Hydraulic Ditch, Fruitland Ditch, Grandview Ditch, Canon City and Oil Creek (Mill) Ditch, Fremont County Ditch, Union, Hannenkratt ditch, and the Lester and Atteberry ditch.

Below Pueblo Reservoir Major irrigation conveyances diverting from the main stem of the Arkansas River in Water District 14 are the Bessemer Ditch, Colorado Canal, Rocky Ford Highline Canal, and Oxford Farmers Ditch. There are also several small irrigation ditches including the Hamp-Bell, West Pueblo, Riverside Dairy, Excelsior, and Collier.

Above John Martin Reservoir the Otero, Catlin, Holbrook, Fort Lyon Storage, Rocky Ford, Fort Lyon, and Las Animas Consolidated Canals headgates are all in Water District 17. The canal and ditch systems on the mainstem below John Martin Reservoir are in Water District 67; these include the Fort Bent Canal, Keesee, Amity Canal, Lamar Canal, Hyde, Manvel, X-Y Canal and Graham Ditch, Buffalo Canal and Sisson Ditch. Although the diversion of the Frontier Ditch is physically located in Colorado just west of the state line it irrigates cropland in Kansas and therefore considered a Kansas ditch.

Arkansas River Tributaries. There are a number of significant water conveyance systems that divert water from Arkansas River tributaries. Included in the Wet Mountain Valley, located in Custer and Fremont County is the DeWeese-Dye ditch; located on Fourmile, Hardscrabble, and Beaver Creeks are Park Center, Hardscrabble ditch, and Brush Hollow Supply Ditch.

Other tributaries with minor diversions include Fountain Creek and the Apishapa River. Serving the terrace lands on Fountain Creek between Colorado Springs and Pueblo are the Fountain Mutual ditch and the Chilicott Canal. Limited water is diverted for irrigation In the upper reach of the Apishapa River from the Escondito, Salisbury and Widderfield ditches

The main tributary of the St. Charles River, is Greenhorn Creek the location of the earliest priority in the Arkansas River basin: the Hicklin ditch, with a water right from spring 1859. Smaller ditches include St. Charles Flood, Tucker, Fairhurst,, McDowell, Chase, Wagner, Eagle, Fisher,Bryson, and Anderson.

Diversions on the upper Huerfano River include the Medano Ditch and small direct diversions on Pass, Williams, and Turkey Creeks convey water to a number of ranches near Red Wing, Colorado. Other diversions include the Orlando Ditch, Huerfano Valley, Farmers Nepesta, and Welton Ditch. Also there are waters used for irrigation supply from the Cucharas River, tributary to the Huerfano River. These are Middle Creek, Wahatoya Creek, Abeyta Creek, Bear Creek, and Santa Clara Creek, and the Gomez Ditch.

The other tributary supplying significant water for irrigation is the Purgatoire River. Diverted through eight structures on the Purgatoire River's, water is delivered to 11 ditch companies and entities from the Bureau of Reclamation's "Trinidad project." Diverting water from the north side of the river include the Salas, Burns and Duncan, Hoehne, Model Inlet/Johns Flood, El Moro, and Picketwire. The Lewelling-McCormick, South Side, Victor Florez, and Chilili Ditches divert water from the south side of the Purgatoire River. Downstream from the Purgatoire Canyon and above the confluence with the Arkansas River are the headgates of the Ninemile and the Highland Canals.

Drainage Districts. Within the Arkansas River Drainage Basin there were 31 separate drainage districts, many of which are now inactive, which were established under statute during the early twentieth century. These included the May Valley, Wiley of Big Bend, Pleasant Valley, Vista del Rio, East May Valley, McClave, Deadman, Lubers, Kornman, Riverview, Granada, Holly, Hasty, Arbor, Prowers, A.B.S. Company East Farm, Las Animas Consolidated, Consolidated Extension, A.B.S. Company No.1, A.B.S. Company No. 2, Olney Springs, King Center, Ordway No.1, Valley View, Crowley, Numa, Grand View, Patterson Hollow, Holbrook and Fairmont.

Authorized under the 1911 and 1919 Colorado *Drainage District Acts*, the organization of these districts in Water Districts 17 and 67 led to the construction of an extensive drainage infrastructure consisting of about 107 miles of open drains and about 84 miles of subsurface tile drains[1]. This network that served nearly 100,000 acres was constructed for the purpose of maintaining productivity while providing return flows, is now in varied state of disrepair, deterioration, and dysfunction. Much of the original underground infrastructure, which was completed by 1925, can no longer be located.

It is not completely understood what inspired such a large drainage district movement in the Lower Arkansas Valley, relative to other areas of the state that generally did not experience such a movement. In later years, drainage problems of a more or less serious nature were well documented for various points throughout the lower valley. Subdrainage problems were particularly notable in the area east of Las Animas, Colorado. In 1942, backwater and silting up of the Arkansas River was noted by the Federal Land Bank as causing problems with some of the drainage systems. This is also the case today. Elsewhere, some of the tile drains were observed to have settled over the years, generally leading to their removal rather than being rehabilitated. Both backwater and silting up of the Lower Arkansas River, settled drains, and dilapidated observation manholes continue to be at the core of drainage problems in the lower valley.

It is known that many of the drainage districts had problems meeting annual assessments during the Depression. This resulted in considerable deferred maintenance on the drainage systems. The Reconstruction Finance Corporation under the Roosevelt Administration provided funds to refinance many of the indebted district serial bonds. However, this refinancing was followed by

[1] Personal communication, 2004, J. Welkins-Wells, Department of Sociology, Colorado State University, Fort Collins, Colorado.

another reduction in average annual farm income due to the termination of sugar production in the 1970s. This economic slump led to further deferred maintenance of the drainage systems.

In subsequent years, farm income declined further, leading to reluctance on the part of growers to raise drainage district assessments to meet an emerging problem for crop production in the lower valley. Meanwhile, those growers who were familiar with the whereabouts of tile drain systems were beginning to pass on. Today, there is a core of older growers whose knowledge will be vital to any proposed rehabilitation of the lower valley's drainage systems. Action must be taken immediately to safeguard this important information. Their knowledge will be essential to the proposed study's success.

It is known that many of the subsurface drains continue to carry substantial water. This is observable at identifiable outlets along wasteways, and by observing flows through very dilapidated wooden manholes throughout the lower valley. Some engineering designs of the drainage systems are available in the archives of local county assessor's offices. However, they are incomplete and often do not represent the final installation locations, particularly of the tile drain systems. Only the location of principal open collector drains is clearly observable.

Over the years, and often due to the transfer of ownership of land, there has been a loss of knowledge of the whereabouts of the tile drains under farm ground leading to these open surface collectors. This has often led to the tile drains being damaged during land preparation or during the installation of natural gas and other utility pipelines in the valley.

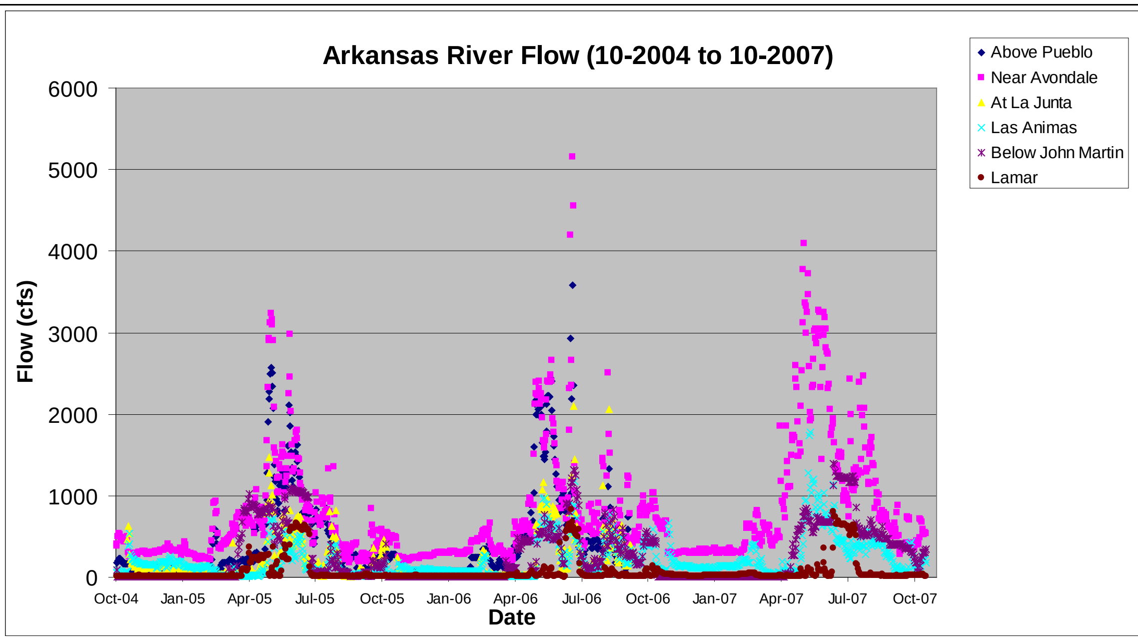


Figure 1-3. Recent Lower Arkansas River Hydrology

John Martin Reservoir, the largest reservoir in the watershed, holds 228,828 acre-feet of water for municipal, irrigation and recreational uses. Water held in John Martin Reservoir helps Colorado meet its Arkansas River Compact requirements. Other plains reservoirs are used primarily for irrigation purposes and include Lake Meredith and Horse Creek Reservoir.

1.4 Geology, Geography, and Soils

The Lower Arkansas Watershed largely falls within the Southwestern Tablelands ecoregion, a large area of irregular and dissected plains underlain by marine shale and sandstone. In the Lower Arkansas watershed, varying climatic conditions, erodible alkaline soils and Pierre Shale geologic formations can naturally affect the quality of water under human-created circumstances, including elevated selenium, iron, and salinity concentrations. The general area is characterized by Front Range Fans, Piedmont Plains and Tablelands, Mesa de Maya/Black Mesa, Purgatoire Hills and Canyons, Piñon -Juniper Woodlands and Savannas, Pine-Oak Woodlands, Foothill Grasslands, Sand Sheets, Rolling Sand Plains, Moderate Relief Plains, and Flat to Rolling Plains.

The Natural Resources Conservation Service (NRCS) has developed Water Resources Assessments, including geographical information system (GIS) mapping and ecoregion descriptions for many of the sub-watersheds in the Lower Arkansas River Watershed. A more detailed description of these sub-watershed features is provided herein.

Horse Creek Sub-watershed. The Horse Creek Sub-watershed (Figure 1-4) is a highly rural watershed that covers approximately 910,973 acres within the Lower Arkansas River Basin. This area is characterized by broad plains areas broken up by streams and rivers. The highest elevations are on the northwestern side of the watershed and the land slopes down to the lowest elevations in the southeast. The majority of the Horse Watershed consists of rangeland. Cropland is almost evenly divided between irrigated along the floodplains and dryland crops on the upland. Within the Horse Watershed there are approximately 688,565 acres of land utilized for farms and ranches.

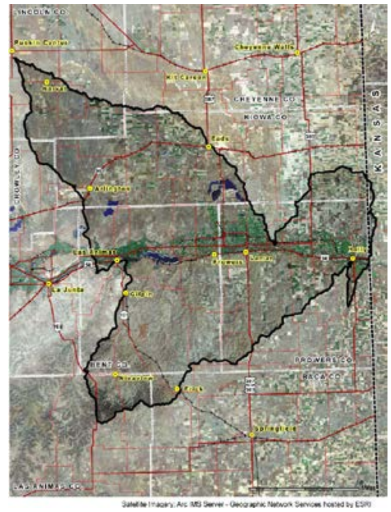
Figure 1-4 Horse Creek Sub-watershed

Satellite Imagery: Arc IMS Server - Geographic Network Services hosted by ESRI

John Martin Reservoir Sub-watershed.

The Upper Arkansas—John Martin Reservoir Sub-watershed encompasses approximately 2,466,682 acres across 8 counties (Figure 1-5). The area is characterized by three distinctive ecoregions—Central High Plains, Upper Arkansas Valley Rolling Plains, and Central High Tableland. The Central High Plains have broad plains divided by streams and rivers. Soils are deep and formed in aeolian and alluvial materials. Native vegetation was once short grass prairie, but now most areas consist of fallow cropland rotations or rangeland. Some cropland areas are irrigated, and irrigation runoff is a potential pollutant for local water-bodies.

Figure 1-5 John Martin Reservoir



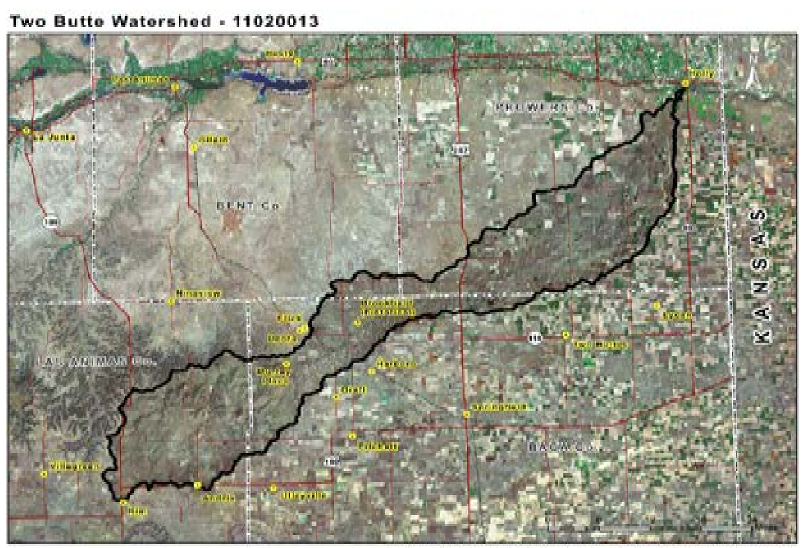
The Upper Arkansas Valley Rolling Plains ecoregion area has broad, rippled shale plains occurring along the upper tributaries of the Arkansas River. Soils tend to be shallow to deep and were formed in loess, aeolian, alluvial, and outwash materials. Native vegetation was once short grass prairie, and piñon and juniper stands, however, nearly all of this area is now range-land. Small areas of irrigated cropland occur along the floodplains and terraces.

The Central High Tableland ecoregion area features level to gently rolling loess-mantled tableland. Major river valleys are bordered by steep slopes. Soils are deep. Native vegetation was once short grass prairie, but nearly all of this area is now cropland—both dry land small grain crops, as well as irrigated corn and grain sorghum. Within the Upper Arkansas-John Martin Reservoir Watershed there are approximately 1,524,190 acres of land being utilized for farming or ranching.

Two Buttes Creek Sub-watershed.

The Two Buttes Sub-watershed is a rural watershed that covers approximately 516,035 acres across 4 counties and is located in the southern plains of Colorado (Figure 1-6). The vast majority of the land is used for rangeland with some dryland crops.

Figure 1-6 Two Buttes Creek Sub-watershed



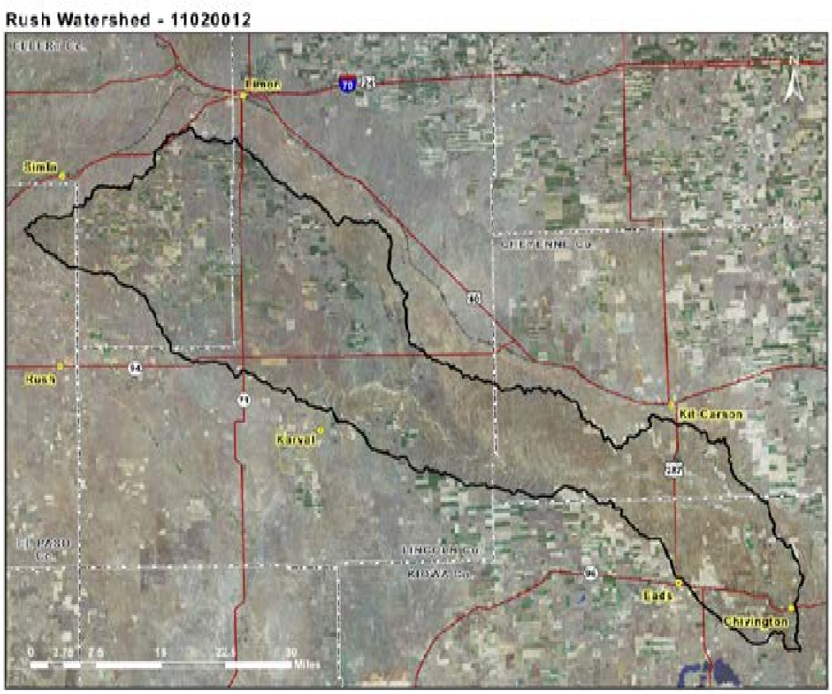
The Central High Plains ecoregion is represented in this watershed, and features broad, rippling to rolling plains dissected by streams and rivers. Soils tend to be deep and were formed in eolian and alluvial materials. Pre-settlement vegetation was once short grass prairie, but nearly all of this area consists now of fallow cropland rotations or rangeland. Some cropland areas are irrigated.

The Upper Arkansas Valley Rolling Plains ecoregion is represented within this watershed, and features broad, rolling shale plains that occur along the upper tributaries of the Arkansas River. Soils tend to be shallow to deep and were formed in loess, eolian, alluvial, and outwash materials. Pre-settlement vegetation was once short grass prairie and piñon and juniper stands on the stony and rocky soils, but nearly all of this area is now rangeland. Small areas of irrigated cropland occur along the floodplains and terraces.

The Central High Tableland ecroregion is also represented, and consists of broad, level to rolling, loess-mantled tableland. Soils tend to be deep. Native vegetation was once short grass prairie, but now nearly all of this area is cropland, both dryland small grain crops and irrigated corn and grain sorghum. Within the Two Butte Watershed there are approximately 478,230 acres of land utilized for farming or ranching.

Rush Sub-watershed. The Rush Watershed is located in the Lower Arkansas River Basin on the eastern plains of Colorado (Figure 1-7). Within the Rush Watershed there are approximately 1,136,462 acres of land across 5 counties being used for farming or ranching. Approximately 807,113 acres in the Rush Watershed are privately owned. There are 54,059 acres of state controlled land and no federally controlled lands. As of April 2005 there are 64,329 acres of land in the Conservation Reserve Program.

Figure 1-7 Rush Sub-watershed



Southern Rocky Mountain Foothills ecoregion is represented in this watershed, and this area is generally a transition between the Great Plains and the Southern Rocky Mountains. Native vegetation ranges from grasslands and shrubs to ponderosa pine and Rocky Mountain Douglas fir forest.

The Central High Plains, Southern Part eco-region is represented as well, and features broad, rippling to rolling plains dissected by streams and rivers. Soils tend to be deep and were formed in aeolian and alluvial materials. Native vegetation was once short grass prairie, but nearly all of this area consists now of fallow cropland rotations or rangeland. Some cropland areas are irrigated.

Additionally, the Upper Arkansas Valley Rolling Plains ecoregion is present in the watershed, and features rippling to rolling shale plains occurring along the upper tributaries of the Arkansas River. Soils tend to be shallow to deep and were formed in loess, aeolian, alluvial, and outwash materials. Because the soils are rocky, native vegetation was once short grass prairie, as well as pinion and juniper stands. Nearly all of this area is now rangeland. Small areas of irrigated cropland occur along the floodplains and terraces.

Purgatoire River Sub-watershed. The Purgatoire River sub-watershed encompasses 2,122,320 acres and extends across four counties (Figure 1-8). This is the largest sub-watershed in the basin. This region is best characterized by steep, high mountain ranges and mountain valleys. Vegetation typically consists of sagebrush grass at low elevations, and coniferous forest to alpine tundra as elevation increases.

The Southern Rocky Mountain Foothills ecoregion portion of this watershed is generally a transitional area between the Great Plains and the Southern Rocky Mountains. Native vegetation typically consists of grasslands and shrubs, ponderosa pine, or Rocky Mountain Douglas fir forest.

Within the Central Great Plains, Southern Part ecoregion portion of this watershed, the geography tends toward broad, rippling to rolling plains dissected by streams and rivers. Soils tend to be deep and were formed in eolian and alluvial materials. Native vegetation originally consisted of short grass prairie, however, now nearly all of this area in fallow cropland rotations or range-land. Some cropland areas are irrigated.

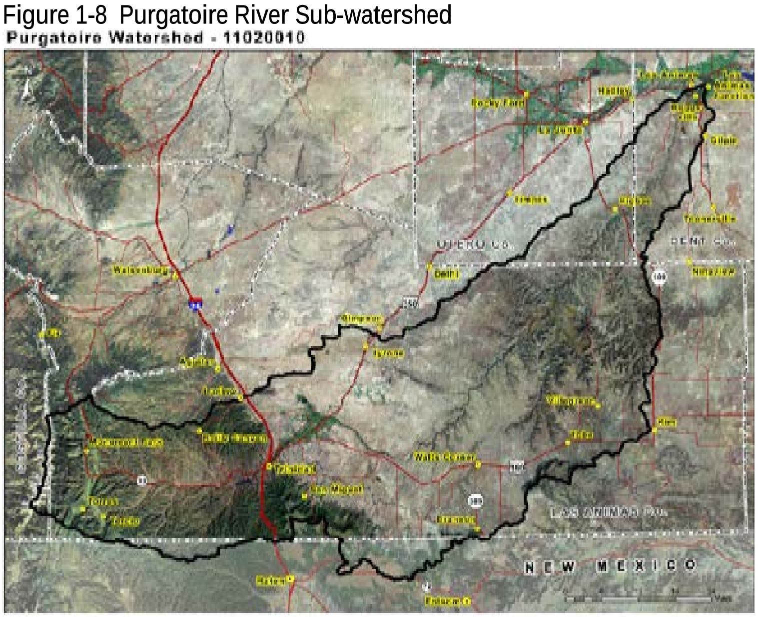


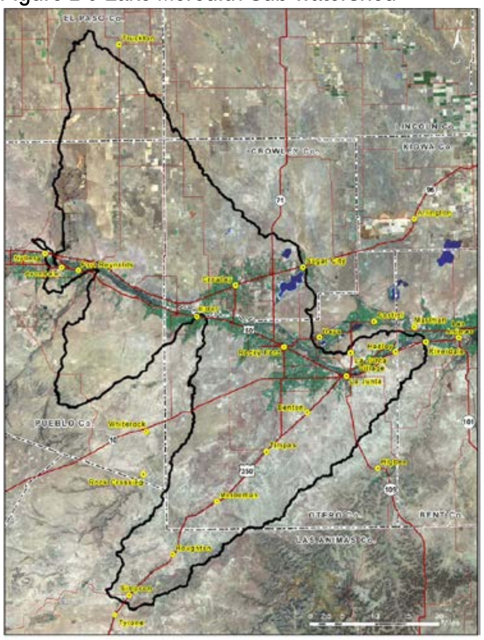
Figure 1-8 Purgatoire River Sub-watershed

The Upper Arkansas Valley Rolling Plains portion of this watershed consists of rippling to rolling shale plains occurring along the upper tributaries of the Arkansas River. Local relief can reach up to 200 feet. Soils tend to be shallow to deep and were formed in loess, eolian, alluvial, and outwash materials. Due to the stony or rocky nature of the soils, native vegetation was once short grass prairie, pinion and juniper stands, but today nearly all of this area is in rangeland. Small areas of irrigated cropland occur along the floodplains and terraces.

The Purgatoire watershed also has the Northern New Mexico Highlands ecoregion, which can be characterized as broad, rippling plains broken by closed basins and drainageways that have smooth-shaped valley floors. Native vegetation typically consists of mid-grass or short-grass prairie in the lowland areas, as well as pinion and juniper stands in the higher elevations and on the breaks. The soils are formed in weathered sedimentary rocks of Cretaceous age and igneous rocks of Tertiary and Quaternary age. Within the Purgatoire Watershed there are approximately 1,581,906 acres of land across four counties being utilized for farming or ranching.

__Lake Meredith Sub-watershed.__ This region is generally a transition area between the Great Plains and the Southern Rocky Mountains (Figure 1-9). Characteristic native vegetation ranges from grasslands and shrubs to ponderosa pine and Rocky Mountain Douglas fir forest.

Figure 1-9 Lake Meredith Sub-watershed

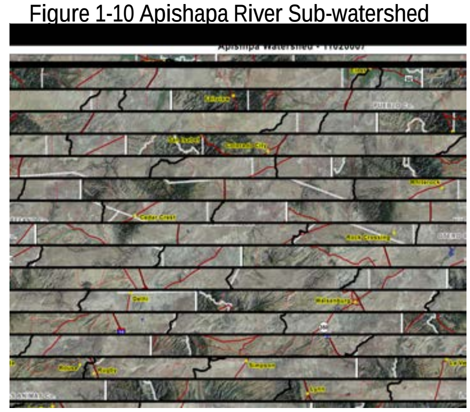


The Upper Arkansas Valley Rolling Plains CRA is broad, undulating to rolling shale plains occurring along the upper tributaries of the Arkansas River. Soils tend to be shallow to deep and were formed in loess, aeolian, alluvial, and outwash materials. Native vegetation was once short-grass prairie, and pinion and juniper stands on the rocky soils, although nearly all of this area is now rangeland. Small areas of irrigated cropland occur along the floodplains and terraces. The Arkansas River and associated riparian areas of Lake Meredith provides permanent aquatic habitat. Stock ponds, tributaries to the Arkansas River, and a few playas in the northern part of the watershed provide seasonal to intermittent aquatic habitats. Economically important wildlife species that occur in the watershed include black bullhead, catfish, sunfish, crappie, yellow perch, bluegill, largemouth bass, snow geese, pronghorn (antelope), mule and white-tailed deer, mourning dove, and scaled quail. Wild turkey, pheasant, and bobwhite quail can be found along the Arkansas River corridor and some of the major tributaries. Within the Lake Meredith Watershed there are approximately 1,413,670 acres of land.

__Apishapa River Sub-watershed__ This area is generally a transition area between the Great Plains and the Southern Rocky Mountains (Figure 1-10). Characteristic native vegetation ranges from grasslands and shrubs to ponderosa pine and Rocky Mountain Douglas fir forest.

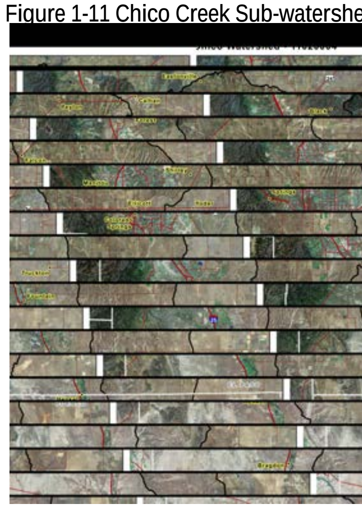
Nearly all of this land is rangeland. Small areas of irrigated cropland occur along the floodplains and terraces. Vegetation is sagebrush-grass to ponderosa pine and Rocky Mountain Douglas fir forest. Within the watershed area are 610,875 acres utilized for farms and ranches while the total watershed area encompasses 690,077 acres.

Figure 1-10 Apishapa River Sub-watershed



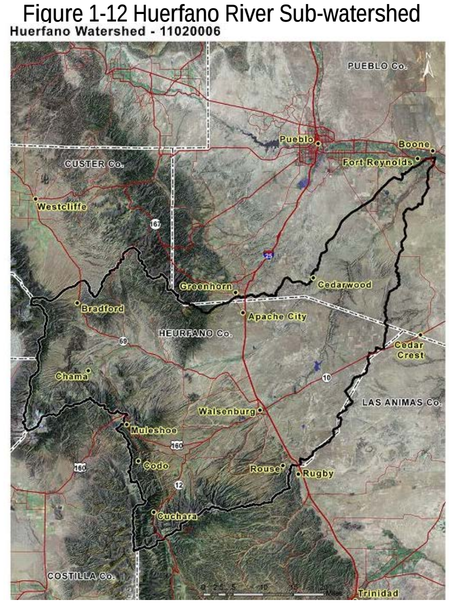
__Chico Creek Sub-watershed.__ This area is generally a transition area between the Great Plains and the Southern Rocky Mountains (Figure 1-11). The total number of acres in the sub-watershed is equal to 463,984 acres. Characteristic native vegetation ranges from grasslands and shrubs to ponderosa pine and Rocky Mountain Douglas fir forest. Within the Chico Creek Watershed there are approximately 453,449 acres utilized for farming and ranching. Nearly all of this area is in rangeland, but small areas of irrigated cropland occur along the floodplains and terraces. Soils tend to be shallow to deep and formed in loess, Aeolian, alluvial and outwash materials. Economically important wildlife species include black bullhead, green sunfish, pronghorn antelope, mule and white-tailed deer, mourning dove, and scaled quail.

Figure 1-11 Chico Creek Sub-watershed



__Huerfano River Sub-watershed:__ This area is generally a transition area between the Great Plains and the Southern Rocky Mountains (Figure 1-12). Characteristic native vegetation ranges from shortgrass prairie to foothills shrublands to coniferous forest. Soils are shallow to deep and formed in loess, Aeolian, alluvial and outwash materials. Vegetation The area is predominantly rangeland, and approximately 958,521 acres are utilized for farms and ranches. The total acreage within the watershed is 1,187,993. The elevations range from 6,500 to 14,400 feet. Economically important wildlife include black bullhead, green sunfish, trout, antelope, mule and white-tailed deer, elk, wild turkey, and scaled quail. Pheasant and bobwhite quail are also found near the mouth of the watershed.

Figure 1-12 Huerfano River Sub-watershed



1.5 Wildlife Species

There are diverse terrestrial and riparian habitat types within the planning area. Terrestrial habitat types in this watershed range greatly from short-grass prairie, to foothills, shrublands, and even coniferous forest. Wildlife species found in this watershed are equally diverse. A number of economically important wildlife species occur in the watershed and include black bullhead, sunfish, pronghorn (antelope), mule and white-tailed deer, elk, wild turkey, pheasant (limited area), mourning dove, and scaled quail. Rare, threatened, or endangered species for the Lower Arkansas River Watershed include the following species summarized in Table 1-1.

Table 1-1. Summary of Threatened or Endangered Species in the Lower Arkansas Watershed

State & Federal, Threatened, Endangered, or Candidate Species, and Species of Special Concern in the Lower Arkansas Watershed Planning Area			
Common Name	Scientific Name	Status	Comments
American Peregrine Falcon	Falco peregrinus anatum	State Concern	Occurs in the watershed
Arkansas Darter	Etheostoma cragini	Candidate	Occurs in the watershed
Bald Eagle	*Haliaeetus leucocephalus*	Threatened	May migrate through watershed
Black-footed Ferret	*Mustela nigripes*	Endangered	No current records of occurrence in this watershed
Black-tailed Prairie Dog	Cynomys ludovicianus	State Concern	Occurs in the watershed
Burrowing Owl	Athene cunicularia	Threatened	Occurs in the watershed
Canada Lynx	Lynx canadensis	Threatened	Occurs in the watershed
Common Kingsnake	Lampropeltis getula	State Concern	May occur in the watershed
Couch's Spadefoot Toad	Scaphiopus couchii	State Concern	Occurs in the watershed
Ferruginous Hawk	Buteo regalis	State Concern	Occurs in the watershed
Flathead Chub	Platygobio gracilus	State Concern	Occurs in the watershed
Great Plains Narrowmouth Toad	Gastrophryne olivacea	State Concern	Occurs in the watershed
Greater Sandhill Crane	Grus canadensis tabida	Special Concern	Occurs in the watershed
Greenback Cutthroat Trout	Oncorhynchus clarki stomias	Threatened	Occurs in the watershed
Least Tern (interior)	Sterna antillarum athalassos	Endangered	Occurs in the watershed
Lesser Prairie Chicken	Tympanuchus pallidicinctus	Candidate	Occurs in the watershed
Long-billed Curlew	Numenius americanus	State Concern	Occurs in the watershed
Massasauga	Sistrurus catenatus	State Concern	Occurs in the watershed
Mexican Spotted Owl	Strix occidentalis lucida	Threatened	Occurs in the watershed
Mountain Plover	Charadrius montanus	State Concern	Occurs in the watershed
Northern Leopard Frog	Rana pipiens	State Concern	Occurs in the watershed
Piping Plover	Charadrius melodus	Threatened	Occurs in the watershed
Plains Leopard Frog	Rana blairi	State Concern	Occurs in the watershed
Plains Minnow	Hybognathus placitus	Endangered	Occurs in the watershed
Preble's Meadow Jumping Mouse	Zapus hudsonius preblei	Threatened	Occurs in the watershed

State & Federal, Threatened, Endangered, or Candidate Species, and Species of Special Concern in the Lower Arkansas Watershed Planning Area			
Common Name	Scientific Name	Status	Comments
Suckermouth Minnow	Phenacobius mirabilis	State Endangered	Occurs in the watershed
Swift Fox	Vulpes velox	State Concern	Occurs in the watershed
Texas Blind Snake	Leptotyphlops dulcis	State Concern	May Occur in the watershed
Texas Horned Lizard	Phrynosoma cornutum	State Concern	Occurs in the watershed
Townsend's Big-eared bat	Corynorhinus townsendii pallescens	State Concern	May Occur in the watershed
Triploid Checkered Whiptail	Cnemidophorus neotesselatus	State Concern	Occurs in the watershed
Yellow Mud Turtle	Kinosternon flavescens	State Concern	Occurs in the watershed
Suckermouth Minnow	Phenacobius mirabilis	Endangered	Occurs in the watershed
Western Snowy Plover	Charadrius alexandrinus	State Concern	May Occur in the watershed
Yellow-Billed Cuckoo	Coccyzus americanus	Candidate	Occurs in the watershed

1.6 Demographics & Land Use

1.6.1 Population

Of the nine total river basins in Colorado, the largest is the Arkansas. Demographically the Arkansas composes 20% of the state's population. Table 1-2 approximates population by sub-watersheds in the Lower Arkansas. The total population within the Lower Arkansas Watershed represents approximately 10.5% of the state population or about half of the population of the entire Arkansas basin.

Table 1-2. Population by Sub-Watershed

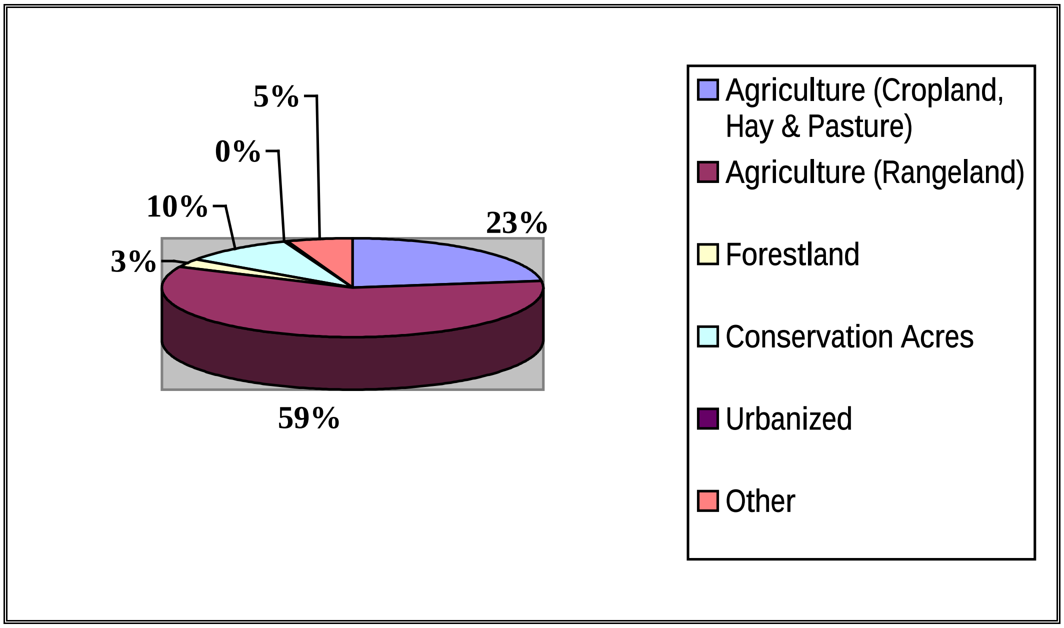
Sub-Watershed	Population
Horse Creek	82,173
John Martin	14,116
Two Buttes Creek	4,277
Rush	118,303
Purgatoire River	13,211
Lake Meredith	100,823
Huerfano River	7,562
Chico Creek	152,912
Apishapa River	5,401

Source: RWA Social Data Pages excerpted from U.S. Census Data

1.6.2 Land Use/Land Cover

The primary land use within the watershed is rangeland. Irrigated agriculture occurs along the Arkansas River, and dryland farming is found primarily in the north half of the region (Figure 1-13). Sub-watershed acreages used for farming and ranching are depicted in Figure 1-14.

Figure 1-13. Lower Arkansas Watershed Planning Area—Land Use
Note: Does not include Huerfano or Chico Sub-watershed



Source: NRCS, Watershed Profile: 2005 Farm Bill Programs Activity in the Lower Arkansas Watershed

Figure 1-14. Farming/Ranching in the Lower Arkansas Watershed

Photo by Mary M. Miller, USDA-NRCS.

1.7 Municipal Water Sources

Water quality is an issue for most water providers as various contaminants are near or exceed maximum allowable drinking water limits for constituents such as uranium, gross alpha, selenium, radon and sulfate. It is not uncommon for sources of water to be blended to meet drinking water standards for selenium and other contaminants. Most communities in the Lower Arkansas River rely upon groundwater as their source for drinking water supplies. Some communities also use springs or surface water. Many public water suppliers have augmentation plans which restrict their ability to select other water supplies because of legal implications and costs.

Appendix A lists the community water systems in the watershed. Because the source water quality in the Lower Arkansas River watershed may be impacted by the leaching of pollutants into the groundwater, more detailed source water protection planning is important. Source water plans identify areas for additional controls or pollution prevention measures.

At the present time there are two municipal reverse osmosis (RO) treatment systems in the basin. Of these the Las Animas RO water treatment system is the oldest, while the La Junta RO treatment system was completed in 2006. While the concentrate ("brine") disposal can be a concern, the La Junta facility mixes the concentrate with the influent of the wastewater treatment system before discharge of the effluent back to the Arkansas River. The majority of the customers have abandoned the use of water softeners, which in theory the pollutant load of the discharge back to the River is near the same as the pollutant load of the water supply itself. The City of La Junta implemented this RO water treatment system to specifically address significant water quality impacts of the source water.

1.8 Wastewater Treatment Facilities

There are approximately 25 wastewater treatment facilities (WWTFs) in the Lower Arkansas River Watershed (Table 1-3). The treatment process utilized by most of the smaller communities is aerated lagoon systems. Aerated wastewater lagoon systems are effective at reducing Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS) with minimal operator involvement, but are not designed to consistently treat or reduce metal or ammonia concentrations. The City of La Junta is the primary municipality utilizing mechanical treatment processes.

Table 1-3. Summary of Wastewater Treatment Facilities in the Lower Arkansas Basin

Facility	Treatment Process	Hydraulic Capacity MGD	Disposal Method
Crowley Correctional Facility	Aerated Lagoon	0.32	Direct Discharge
Rocky Ford Sewage Lagoons (NE)	Aerated Lagoon	1.2	Direct Discharge
La Junta, City of (COG650060)	Mechanical	1.3	Direct Discharge
La Junta, City of (CO0021261)	Mechanical	2.5	Direct Discharge
Manzanola WWTP (COG589012)	Aerated Lagoon	0.125	Direct Discharge
Las Animas, Muni P&L (0801100005)	Aerated Lagoon	---	Direct Discharge

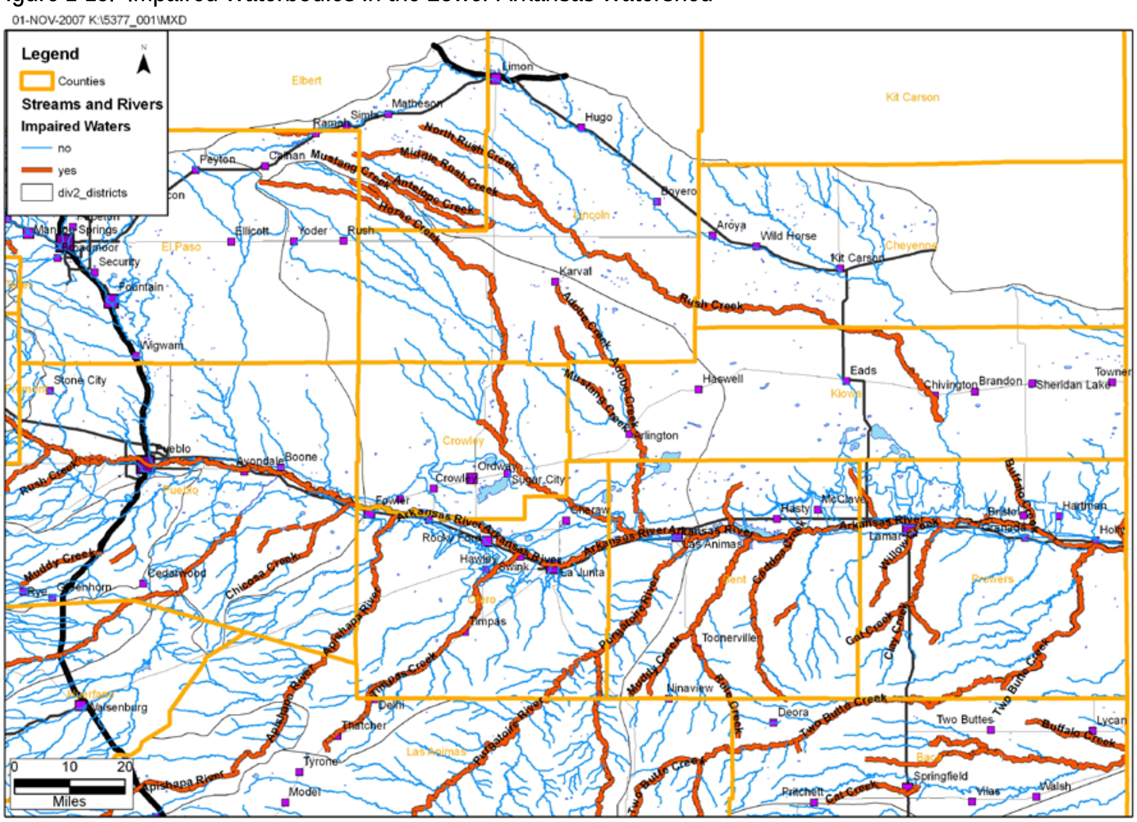
Facility	Treatment Process	Hydraulic Capacity	Disposal Method
		MGD	
Las Animas, City of (CO0040690)	Aerated Lagoon	0.5	Direct Discharge
Walsenburg WWTP (Martin Lake; 0641099)	Aerated Lagoon	Avg. = 0.089 MGD Max. = 0.214 MGD	Direct Discharge
Trinidad WWTP (0641018)	Mechanical	0.24	Direct Discharge
Monument Lake Water Treatment Facility (0640035/0641035)	Aerated Lagoon	0.006 MGD	---
Walsenburg (0640099)	---	---	---
Trinidad Water Treatment Facility (0641018)	---	---	---

- - - Information not available

1.9 Water Quality

Previous studies have identified sedimentation, salinity, selenium, uranium and iron as high-priority pollutants that are degrading the surface water quality, its alluvium, and aquatic life habitat within the watershed. The Arkansas River and its tributaries are impaired by non-point source pollution, and many of these tributaries are listed on the 303(d) list for selenium and/or iron (Figure 1-15).

Figure 1-15. Impaired Waterbodies in the Lower Arkansas Watershed



Water resource issues affecting the health of the area's aquatic ecosystems include stream flow regulation through dams and diversions as required by the Colorado and Kansas compact and degradation of riparian areas by the highly invasive plant species, Tamarisk. Moreover, the Lower Arkansas River has been determined to be the most saline stream of its size in the United States, due to excessive irrigation, seepage from earthen canals, inadequate drainage facilities, and a rising ground water table that leaches underlying geologic marine shale formations, including the Pierre Shale. The average salinity levels increase from approximately 300 ppm near Pueblo to over 4000 ppm in Holly. Intensive irrigation of the alluvial soils, and underlying marine shale, accelerates dissolution of inherent salts and metals (e.g. selenium and iron) into the underlying alluvial aquifer that flows to the river. Excessive amounts of selenium can impair aquatic life and bioaccumulation up the food chain can occur and cause toxicity to birds, mammals, and humans. As more agricultural drainage is returned to the rivers, the level of dissolved solids and sediment also cause problems in this watershed. Other concerns include wind erosion, soil compaction due to tillage practices, increased salinity of cropland due to irrigation water management practices, and overall degradation of soil quality.

1.9.1 Sources of Pollutant Loads

Major nonpoint sources have been identified as irrigated and non-irrigated agriculture, animal feeding operations (AFOs), grazing, and water management. Over-irrigation has created shallow water tables not only under irrigated land but also under adjacent fallow land, contributing to substantial salt and metal loading to the river from return flows. As previously discussed the basin is divided into the two physiographic provinces. The province referred to as the Great Plains Province is divided into the Colorado Piedmont and the Raton Section. Geologically this Great Plains Province is underlain by Late Cretaceous marine shales and limestones. These geologic formations include Pierre Shale, the Sharon Springs Niobrara Shale and Limestone, Carlile/Graneros Shale, and Greenhorn Limestone, which contain significant amounts of easily weathered selenium, uranium, iron, and soluble salts. The weathering process in combination with high water tables produces significant pollutant loads.

Figure 1-16 depicts irrigated lands and the location of the marine shale that promotes elevated selenium and iron loads in the watershed. Point sources include agriculture-related industry and publicly owned wastewater treatment facilities. The reader is referred to Table 1-3 that provides a summary of the publicly owned wastewater treatment facilities in the Lower Arkansas Basin.

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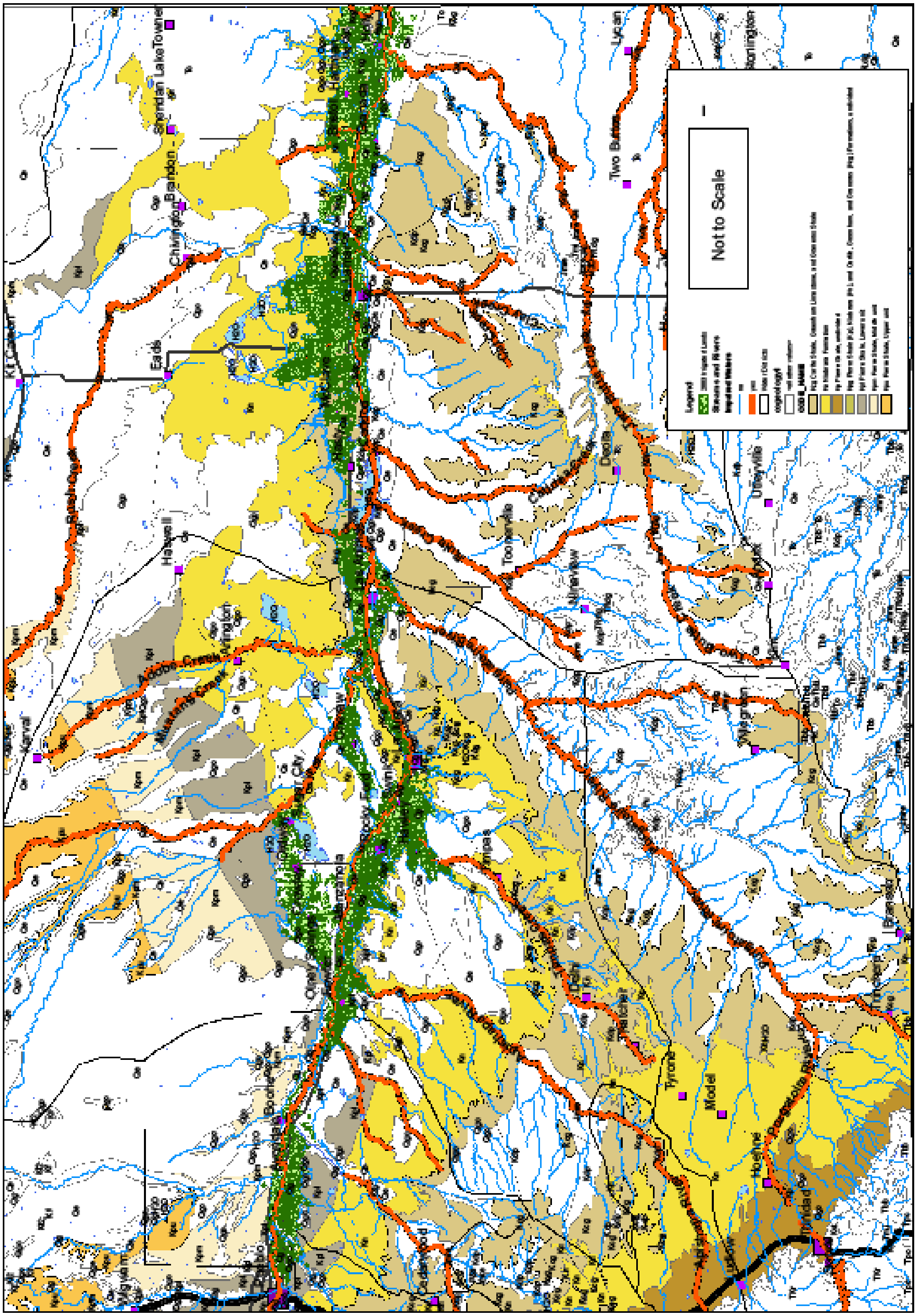


FIGURE 1-16 IRRIGATED LANDS & MARINE SHALE IN THE LOWER ARKANSAS WATERSHED

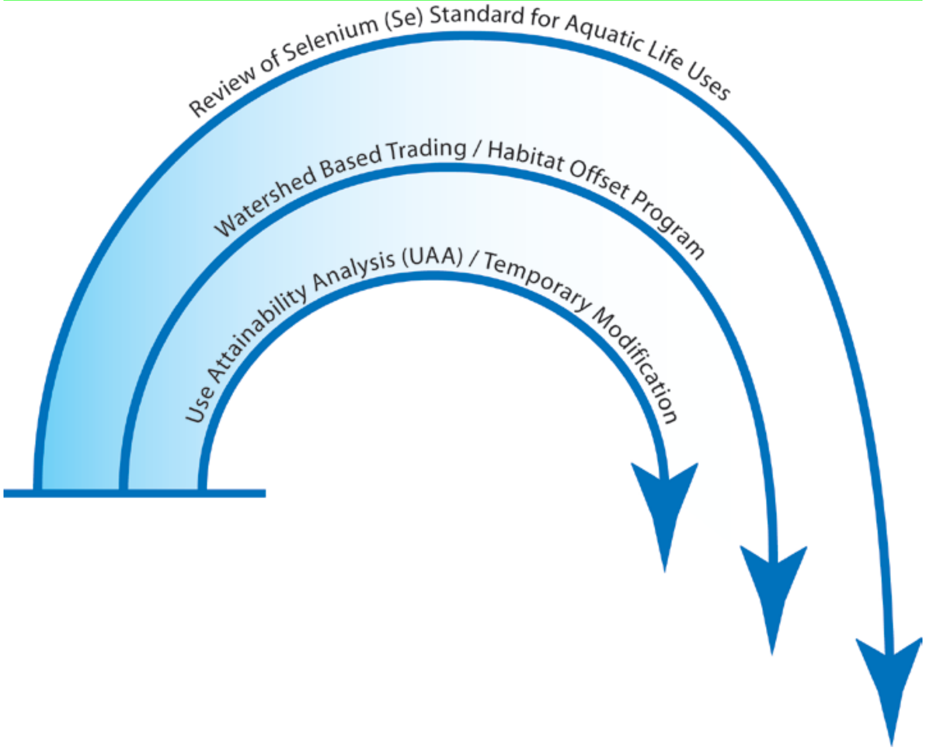
1.10 Regulatory Issues and Processes

The Arkansas River and its tributaries have many uses: agricultural, water supply, industrial, recreational, and flood control. In 2006, the WQCC placed 26 segments of the Arkansas River and selected tributaries on the 303(d) list of impaired streams for iron and selenium.

The state has adopted a water quality standard for selenium of 4.6 ug/L to protect aquatic life. At the June 2007 WQCC rulemaking hearing regarding triennial review of standards and classifications for the Arkansas River Basin (Regulation 32), the WQCD and parties to the hearing described the uncertainties of the selenium sources and the standard itself. While the sources of selenium are uncertain, it is known that selenium is found in many marine shale geologic formations. As an example the Pierre Shale formation is one of these formations which, as previously discussed, underlay's the Lower Arkansas River watershed. Selenium concentrations in some of the tributaries to the river have exceeded 100 ug/L due to the proximity of water resources to the seliniferous marine shale. Also ambient conditions at many locations in the watershed exceed the acute standard of 18.4 ug/L. Selenium from the shale leaches into the surface and groundwater system due to natural processes, such as, snowmelt, rainfall, and stormwater runoff and human induced processes such as irrigation return flows and groundwater infiltration. It is still uncertain how much of the existing water quality is caused by natural sources versus human activities. There is also significant uncertainty regarding the long-term appropriateness of the underlying selenium standard. At this hearing, the WQCC adopted temporary modifications for many river segments, recognizing current conditions while providing an opportunity to resolve the uncertainty. It is unreasonable to have a standard that is less than the background level of the water source.

The Lower Arkansas Watershed Improvement Association has taken a three tier approach to managing regulatory issues, recognizing short, intermediate, and long term regulatory management efforts (Figure 1-17) in a complementary fashion. The longer term approach, reevaluating the aquatic life classification system for aquatic life uses, requires extensive monitoring, data collection and study. In conjunction with other Arkansas River stakeholder groups and agencies, the Lower Arkansas is collecting data to support this effort. While these studies proceed, a variety of water quality management strategies will be implemented, as described in detail in Section 6, including more immediate controls that should improve water quality and make measurable improvements towards achieving compliance with the Clean Water Act. Intermediate range strategies that allow flexibility in the methods to achieve compliance with water quality standards and use classifications are Watershed-based Trading and Offset Programs. These intermediate strategies have a goal of attaining water quality standards designed to be protective of aquatic life use and also serve as an implementation tool to meet potential future Total Maximum Daily Load (TMDL) requirements. The watershed-based trading and offset programs do not question the underlying standards but recognize that if the selenium standards are changed, the utility and need for this program may vary. Temporary modifications represent a short-term framework for obtaining temporary relief from water quality standards. This short term approach provides information and basic premise for conducting a use attainability analysis, which can determine the feasibility for site specific standards.

Figure 1-17 Regulatory Management Framework



2.0 Watershed Partnerships

This plan was initiated by the Southeast Resource Conservation & Development (RC&D), Lower Arkansas Watershed Improvement Association, and developed as a cooperative effort. A broad range of participants have been encouraged to be involved with establishment of the watershed plan, identifying sources of pollutants in the watershed, as well as reduction goals for point sources and non-point sources of selenium, nutrients, and other pollutants flowing into the Arkansas River.

As a community-based project, landowners, industry, government, community organizations and citizens from all facets of community life have participated in the strategy development of the watershed management plan and the associated implementation strategies. The result of the outreach efforts and cooperative think-tank has been the development of strategies to reduce pollutants from a variety of sources. Documented in detail later in this plan, these sources include:

- Point Source Dischargers
- Non-point Sources
- Industrial Storm Water
- Agricultural Activities
- Construction Activities
- Transportation Activities
- On-site Sewage Disposal Systems
- In-stream Processes
- Sub-basin Watershed Management Efforts

Oversight for plan development was provided by the Southeast Colorado RC&D. The efforts were communicated and discussed with public participants via direct mailings, electronic communication, stakeholder meetings, watershed conferences, and river tours.

2.1 Watershed Partners

The Lower Arkansas River Basin is comprised of interested stakeholders, including private, local, state, and federal entities committed to finding ways to reduce pollutants and aid in the implementation of restoration and protection measures in the watershed. The following organizations have taken an active role in the Lower Arkansas River Basin water quality issues and have helped to contributed to planning, research, or shaping water quality management strategies:

Colorado Department of Public Health and Environment
Southeast Colorado Resource Conservation & Development
Colorado Division of Wildlife
Colorado State University College of Agricultural Sciences
Colorado State University Department of Civil and Environmental Engineering
Colorado State University Extension
Colorado State University Water Resources Research Institute
Colorado Water Conservation Board
Conservation Districts
Lower Arkansas Water Conservancy District

Lower Arkansas Watershed Work Group
National Park Service
Southeast Colorado Water Conservancy District
United States Department of Agriculture, National Resource Conservation Service
United States Geological Survey

2.2 Categories of Stakeholders

Stakeholders include conservancy groups, water specialists, scientists, elected officials, the environmental community, federal and state agencies, municipalities, water and wastewater providers, academics, recreation users, agricultural users, private landowners, and members of the public. A list of stakeholder groups and contacts active in the Lower Arkansas Watershed Improvement Association are provided in Appendix B.

2.3 Public Information, Education and Outreach Activities

Public involvement is a key component in the watershed planning process. By involving the public, diverse ideas and stewardship practices are broadly discussed and integrated in the plan. The Southeast Colorado RC&D and Crowley County contacted several agencies and individuals to announce watershed activities, including, public watershed meetings. Announcements on the radio and articles in the local papers, public notices, news release, speakers' bureau, and presentations about the watershed plan process informed many stakeholders.

The public information, education and outreach goals and objectives of the Lower Arkansas River Watershed Improvement Association are summarized in Table 2-1.

Table 2-1. Public Information, Education and Outreach Goals and Objectives

Goals	Promote public awareness and involvement in watershed management.
	Work cooperatively with other related stakeholder groups and federal, state, and local agencies to promote holistic watershed health.
	Promote good stewardship of water resources through leadership, cooperation, financial support, and incentives.
Objectives	Retain a Watershed Coordinator
	Develop a Lower Arkansas River Watershed Website
	Develop and Implement a Comprehensive Public Involvement Plan
	Identify an agency to manage and serve as a repository for watershed geographic information system tools, resources information and maps.
	Implement a Hazardous Waste pick up service in conjunction with community events, fairs, and Earth Day events.
	Through cooperative efforts with other watershed groups and agencies, identify and develop new funding mechanisms to meet watershed goals.
	Enhance the Lower Arkansas River and its tributaries through volunteer efforts.
	Train volunteers for water quality monitoring and utilize when possible.
	Publicize upcoming meetings via website, public notices, news releases, speaker's bureau, and presentation.
	Promote and highly publicize projects that are implemented to improve the watershed and reduce pollutant loads.
	Encourage regional development of pollutant reduction projects through cooperative arrangements.
	Highlight protected riparian areas, preserved buffer zones, conservation easements, and public access areas through educational outreach mechanisms such as signage and kiosks located in the watershed.
	Inform and empower local land use agencies and elected officials on watershed improvement goals, priority projects, and measurable improvements.

Watershed meetings have occurred to support watershed management activities, regulatory processes, and outreach. Many of the meetings support a host of watershed efforts led by key collaborating agencies, including the NRCS, and the Southeast Water Conservancy District (SECWCD), etc.

A snapshot of recent outreach activities is summarized below.

- August, 2005: Arkansas River Watershed Meeting, Input and management strategies, Trinidad, Colorado.
- January, 2006: Input for Triennial review, Arkansas River Rulemaking Hearing.
- July, 2006. Discussion on selenium uptake, Guest Speaker: Dr. Gary Banuelos, SECWCD.
- February, 2007. Discussion on salinity and selenium; Coordination on Arkansas River Rulemaking Hearing.
- June, 2007: Water Quality Control Commission Hearing on Classifications, Standards, and Temporary Modifications for the Lower Arkansas River.

- July/September 2007: Arkansas River Watershed Invasive Plants Plan (ARKWIPP), SECWCD.
- August, 2007: Lower Arkansas Watershed Meeting, Local NRCS offices.
- September 18, 2007: Stakeholders meeting in Bent Fort, CO regarding watershed planning issues and water quality goals.
- October 29, 2007: Stakeholders meeting on watershed plan, strategies and priorities.

2.4 Watershed Organization Structure

The Southeast Colorado RC&D was one of the original partners in establishing a forum to discuss basin-wide water quality issues associated with the Arkansas River Basin in Colorado. As an apolitical body with local representation and 501(c) (3) designation, it is well suited to lead the Lower Arkansas Watershed Improvement Association efforts. The Southeast Colorado RC&D acts as the umbrella under which coordinating agencies of all types operate to promote and implement watershed improvements (Figure 2-1). Together, the Southeast Colorado RC&D and its coordinating agencies form the framework for a collaborative effort toward improvement and protection of water quality, aquatic life habitat, and recreational opportunities, while promoting compatible land use practices.

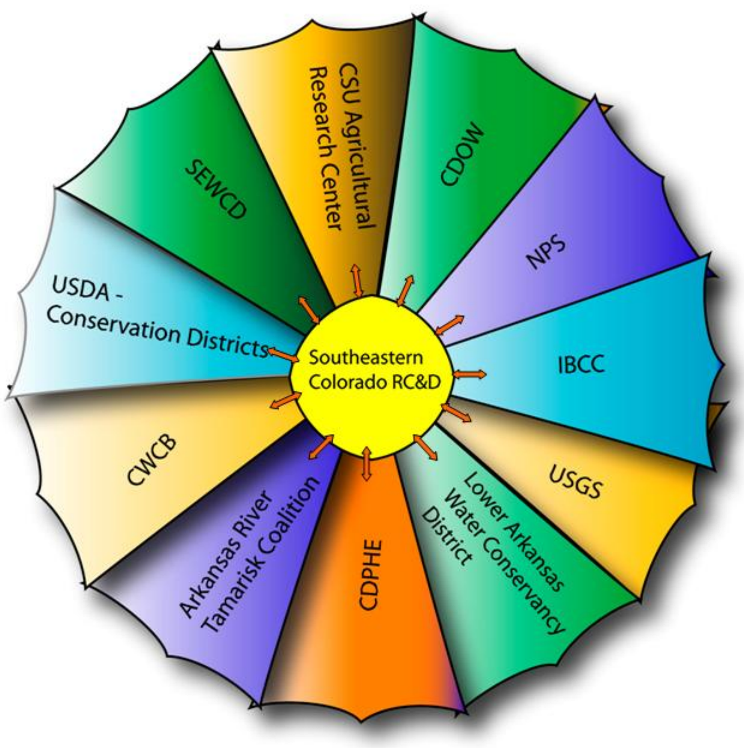
There are many organizations involved with planning processes and studies relevant to the Upper Arkansas Watershed. Each may conduct independent studies, or cooperative studies. The lead agency is not static, but varies dependent upon the research or activity being conducted. However, there is a compelling need to coordinate the activities and assure widespread dissemination of the research findings. All agencies would coordinate with the Southeast Colorado RC&D on water aspects of research and projects.

The Clean Water Act identifies certain roles for watershed planning, management and operation. The Southeast Colorado RC&D would serve as the 208 Planning Agency, which EPA identifies as an entity with the capability and responsibility for developing and implementing watershed management plans for the Lower Arkansas River basin. As the planning agency, Southeast Colorado RC&D would collaborate with many other entities undertaking activities related to water quality improvements such as the Tamanisk Coalition, NRCS and CSU – Extension Program.

Local governments have an important role as the 208 management agencies – those entities with the land use jurisdictions and authority to implement various controls on point source and nonpoint sources. The 208 Management Agencies for the lower Arkansas River are all incorporated municipalities and counties within the watershed.

The Clean Water Act also recognizes the operating agencies – those entities which own and operate wastewater treatment facilities. Every entity operating a wastewater treatment facility (greater than 2000 gallons per day) is designated as an operating agency for point sources. The 208 operating agencies are listed in Appendix D

Figure 2-3. Lower Arkansas Watershed Improvement Association



2.5 Integration with Other Planning Efforts and Watershed Programs

The Lower Arkansas Watershed Plan has been developed in coordination with multiple federal, state, and local agencies. The plan complements a host of other planning efforts, including the agricultural engineering, extension projects, and academic researched performed by Colorado State University, the continued outreach and extension work provided by the NRCS's local conservancy districts, the 208 Water Quality Management Agencies, and the monitoring and research conducted by the USGS.

3.0 Watershed Vision

The Watershed Vision provides the foundation for the Lower Arkansas Watershed Plan.

The Vision of the Lower Arkansas River Watershed Plan

...develop the blueprint that will integrate watershed goals for sustainable community and agricultural development, water supply, fisheries, habitat preservation, flood control and recreation, and wildlife habitat, to support water quality improvement in the Lower Arkansas River basin.

3.1 Watershed Goals & Objectives

Specific goals and objectives have been defined that support the Vision of the Lower Arkansas Watershed Plan. The goals are what the stakeholders and other cooperating agencies desire to achieve in a number of areas, and the objectives are measurable ways to achieve the goals (Figure 3-1).

The goals are specific, quantifiable, consistent with stakeholder input, and regulatory requirements. The objectives for the Lower Arkansas watershed and sub-watersheds provide the actions necessary to meet the goals (Table 3-1).

Table 3-1. Watershed Management Goals and Objectives	
Goals	Maintain and enhance beneficial uses of the watershed.
	Reduce selenium, salinity, and sediment loads in the watershed.
	Maintain and enhance overall diversity of habitat in the watershed.
	Promote good stewardship of water resources through incentives to public and private interests.
Objectives	
	Restore, reclaim, and enhance the Arkansas River and its tributaries.
	Promote land conservation related to water quality.
	Renovate and maintain historic drainage systems to encourage drainage, reduce water logging, and improve water quality.
	Reuse applied irrigation water on-site.
	Replace earthen channels with canal lining options such as PAM, concrete lining, or PVC pipe to reduce seepage and leaching of selenate shale.
	Promote irrigation efficiencies with moisture sensors, drip irrigation, etc.
	Implement habitat offsets programs.
	Long-term management of Tamarisk to improve water quality and quantity, habitat, promote public access to the river, and reduce the risk of flooding and fire.
	Investigate economic and water quality benefits associated with implementation of wind farming or solar energy generation on non-productive lands.
	Harvest energy from animal wastes to produce electricity allowing a power offset for their operations or sold to other energy users in the area.
	Create stormwater, land management or water quality policy and criteria that offer greater water quality benefits. Examples of ordinances may include requiring landowners that sell water rights to reseed lands prior to selling water.
	Promote watershed-based trading incentives for public and private entities to implement water quality controls, enhanced BMPs and other water quality incentives geared to reduce key constituents of concern (i.e. selenium, nutrients, sediment, etc.).
	Construct wetlands to provide a mechanical and biochemical filter capable of removing contaminants from water.
	Pilot test implementation of selenium reducing management strategies like phyto-remediation and including disposal methodologies. Use Indian mustard, canola, tall fescue, kenaf or birdsfoot trefoil to accumulate or volatize selenium and render it unavailable to fish and wildlife.
	Canola is just one crop that provides for high uptake of selenium. In conjunction with this, it serves as an excellent biofuel. Appropriate canola plant varietals for the Lower Arkansas climate are still being considered, however other viable biofuel plant species can create a sustainable program that can be integrated with a carbon trading program in the watershed. Evaluate production of canola, a crop that serves as an excellent biofuel and has a high potential for selenium uptake. Implement Carbon Trading program.
	Implement bioremediation techniques that use algae or bacteria to uptake or reduce selenium to the elemental (less toxic) form
	Identify and promote the preservation of buffer zones for water quality.
	Optimize water quality improvement and watershed health by implementing BMPs that focus on source areas.

Table 3-1. Watershed Management Goals and Objectives	
	Protect sensitive areas and vulnerable resources.
	Promote weed control efforts & implement weed control education.

Section 8 details the water quality management strategies that support the goals for the watershed, recognizing a broad brush approach is not appropriate for the variable sub-watersheds and land uses in the lower Arkansas River watershed.

4.0 Watershed Information Sources, Monitoring Plan, and Data Inventories

Many federal, state, and local entities collect data and information in the Arkansas River basin. Data collection, while driven by regulatory processes, continues by various stakeholders. This section describes the information sources, data inventory status, database issues, and the monitoring plan for the Lower Arkansas Watershed.

4.1 Information Sources

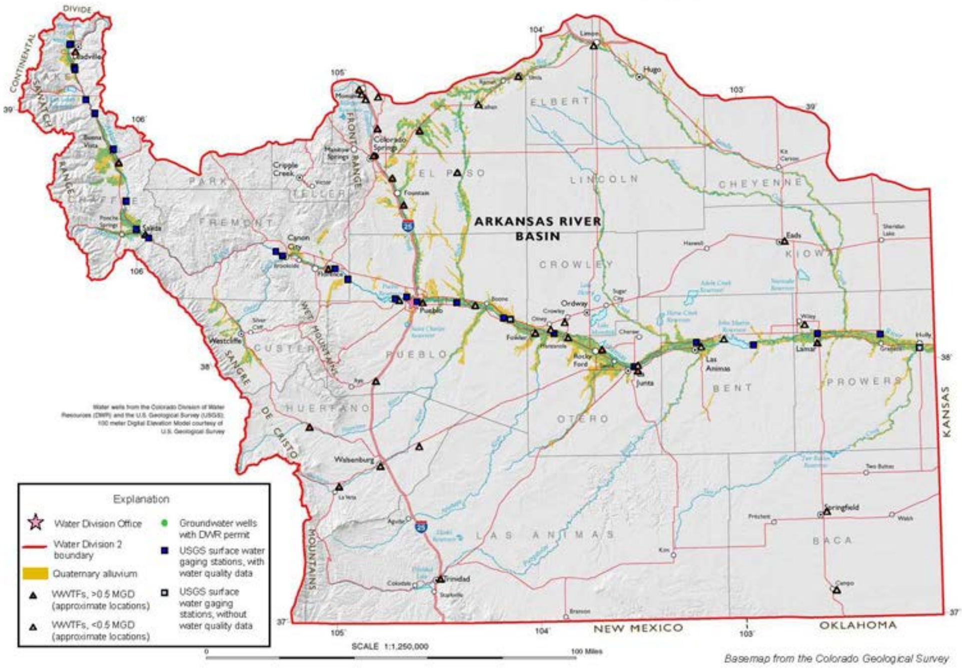
Water quality data and information has been collected primarily by the US Geological Survey (USGS), Colorado Division of Water Resources (CDWR), Colorado State University (CSU), and the Colorado Department of Public Health and Environment, Water Quality Control Division (WQCD), wastewater treatment facilities, and the Colorado Division of Wildlife. Although these agencies conduct water quality monitoring, no complete data base with all information has been compiled.

A complete data base would enhance decision-making, allow stakeholders to identify water quality monitoring gaps, and improve future research and implementation efforts. In recent years, there have been several efforts to implement a common water quality data base. In 2002 the USGS developed the framework and populated the data base with all known water quality data sets that could be electronically obtained. Currently, a newly established project sponsored by the USGS is compiling addition water quality data to be placed in this common data base.

4.1.1 U.S. Geological Survey

The USGS has collected surface water and ground water data and information in the Arkansas River basin. The USGS and the CDWR maintain several gauging stations along the Lower

Figure 4-1 Map of the Arkansas River Basin with the approximate locations of USGS gaging stations, DWR permitted groundwater wells and WWTFs



Arkansas River and its major tributaries (Figure 4-1). Many USGS gauging stations continuously measure flow, temperature, and specific conductance with the period of record dating as far back as 95 years at some locations. The CDWR stations continuously measure flow only. The USGS has measured other water quality parameters (ammonia, nitrates, selenium, sulfate, etc.) at irregular intervals at some stations.

4.1.2 Colorado State University

Since 1999, CSU has gathered data in an upstream region of the Lower Arkansas Valley. This region was selected to be representative of hydro-geologic and agronomic conditions upstream of John Martin Reservoir. Within the study region, there are major irrigation canals, many smaller irrigation and drainage ditches, eight tributaries, three main reservoirs, and over 280 active pumping wells. Investigations in the study region include groundwater monitoring, well installation and observation, surface water salinity measurements, intensive soil salinity monitoring, topographic and hydrographic surveying using differential global positioning systems (GPS), measurement of soil and aquifer properties, measurement of seepage from irrigation canals, measurement of irrigation applications and runoff, measurement of crop yield, and other related activities. A downstream study region was defined in 2002 and data have been gathered from 118 monitoring wells and several surface water monitoring sites. Hydraulic conductivity, TDS, flow, selenium, and other parameters have been measured (CSU 2006).

The most comprehensive report by CSU to date regarding these intensive monitoring and data gathering effort is *Toward Optimal Water Management in Colorado's Lower Arkansas River Valley: Monitoring and Modeling to Enhance Agriculture and Environment (CSU, 2006)t.* The report describes the extensive field data and modeling tools being developed and incorporated into a decision-making framework that focuses on meeting the following goals:

1. Maximizing the net economic benefits to agricultural production from reduction in salinity and waterlogging;
2. Minimizing salinity and selenium concentrations at key river locations, including the Colorado-Kansas state line; and
3. Maximizing "liberated" water from reduction in nonbeneficial consumptive use due to high water tables under fallow alluvial land and from invasive phreatophyte vegetation (Tamarisk) along the river corridor.

One strategy considered for water quality improvement is to cease irrigated agriculture on those areas which have high selenium-laden soils. Moreover, as Lower Arkansas River water supplies are sold for municipal and industrial uses outside the watershed, all types of irrigated lands cease production. CSU has also published reports on the economic impact of reduced irrigated acreage in the Arkansas River Valley. This analysis is included in *"Economic Impact Analysis of Reduced Irrigated Acreage in Four River Basins in Colorado"* (CSU, 2007). The study seeks to correlate increasing water demand from the municipal and industrial sector with reduced irrigated acres.

4.1.3 Colorado Department of Public Health and Environment, Water Quality Control Division

The WQCD (Colorado Department of Public Health and Environment) has conducted water quality monitoring, data collection and data analysis in the Arkansas River basin to support the triennial review hearing in the Arkansas River basin. The WQCD has prepared a data base used for the 2007 Arkansas hearings and their water quality information. The water quality in the Arkansas River Basin was comprehensively assessed by the WQCD in 2001- 2002, with results indicating that more than 2,000 river miles and more than 150 lake acres are impaired. A comprehensive alluvial aquifer monitoring program was recently established, including drilling a total of 20 monitoring wells in the watershed, to understand the inter-relationship between the river, its alluvium, and agricultural practices on irrigable and non-irrigable lands. Data is stored in the EPA's Storage and Retrieval (STORET) system, providing a repository of water quality information and monitoring results.

4.1.4 US Department of Agriculture, National Resource Conservation Service

The USDA-NRCS has conducted studies, collected soils information, and provided outreach to water users in the Lower Arkansas River watershed. These efforts can be categorized into three general activities: 1) general watershed studies, 2) watershed NEPA environmental assessments, and 3) rapid watershed assessments.

Two general watershed studies were conducted in 1981 and 1992. The objective of these studies was to identify potential water quality project areas that could be implemented to produce a positive effect on salinity levels in the Arkansas River. As a part of the 1992 study, a canal system model and a river model were developed for purposes of making water quality evaluations on the 16 canal systems east of Pueblo.

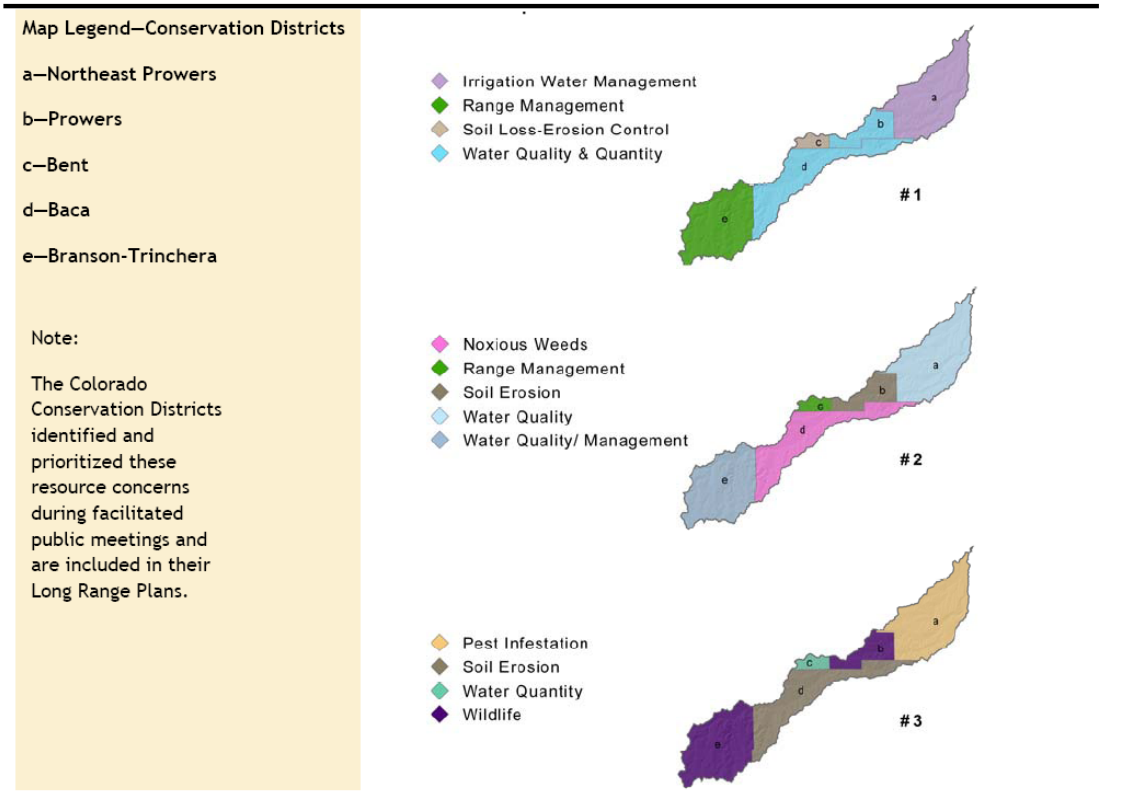
The second major activity by the USDA-NRCS has been the development of small watershed plans under the PL-566 Small Watershed Program. These studies consisted of environmental assessments of proposed actions and effects within selected watershed areas. To date there are four completed watershed plans. These are listed as follows:

- Six Mile – St. Charles
- Highline Breaks
- Limestone-Graveyard
- Holbrook

In all cases, the goals of these watershed projects include the improvement of surface and groundwater quality by reducing the non-point agricultural contribution of both heavy and trace metals, salts, sediment, and nutrients.

More recently, the NRCS completed a series of Rapid Watershed Assessments (RWAs) in the Lower Arkansas Basin (USDA-NRCS, 2007). The RWA's address single hydrologic units, providing a watershed overview, common resource areas, data on land ownership, vegetation, precipitation, social makeup, land capability, natural resource concerns, conservation systems and threatened and endangered species. Examples of information provided in the RWA's are shown in Figure 4-2 (natural resource concerns).
USDA Rapid Watershed Assessment
http://www.co.nrcs.usda.gov/technical/Water Res/WaterResources.html.

Figure 4-2 Two Butte Watershed Natural Resource Concerns: Conservation District's (CD) Ranking of Natural Resource Concerns



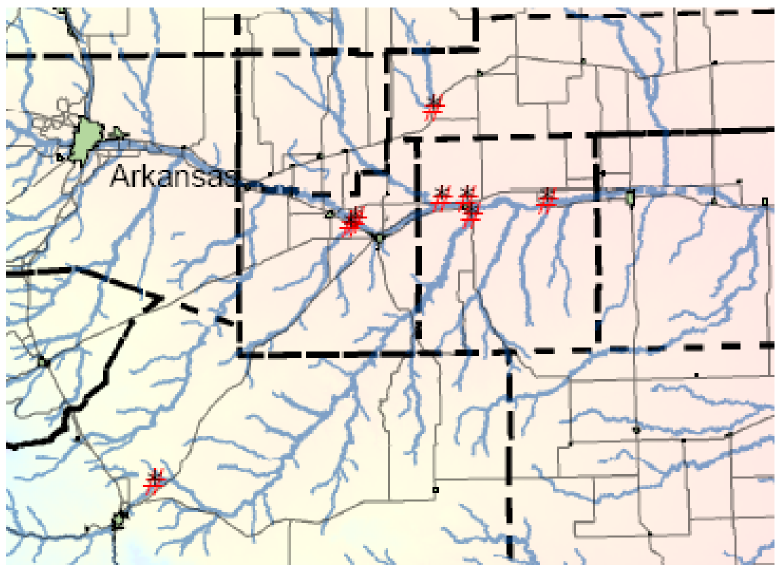
4.1.5 Municipal and Privately Owned Wastewater Treatment Facilities (WWTFs)

There are approximately 39 WWTFs in the watershed. Table 1-3 summarizes the wastewater service providers in the Lower Arkansas Watershed. Wastewater treatment providers collect water quality data and information as required in their permits. Dischargers in the Lower Arkansas River basin are motivated to improve water quality and have made substantial efforts to collect data and conduct studies to determine the sources and solutions to the selenium levels. As described in Section 2, each of these entities would be a 208 Operating Agency.

4.1.6 Colorado River Watch

Colorado River Watch is a cooperative effort between the Colorado Watershed Network and CDOW. The philosophy behind River Watch is to train private and public school teachers and students to collect and analyze samples. The goals of the program are to provide hands-on experience for individuals to understand the value and function of the river ecosystem and to collect quality water and aquatic ecosystem data over space and time to be used for the CWA and other water quality decision-making processes. Figure 4-3 shows the River Watch stations in the Lower Arkansas Watershed. Data is easily accessible from their website at http://www.wildlife.state.co.us/riverwatch/default.aspx.

Figure 4-3 River Watch Monitoring Stations Located in the Lower Arkansas Watershed



4.2 Data Inventories

More recently, the USGS has been tasked to inventory and compile a Microsoft Access database that includes ground water and surface water quality data in the watershed; however as this project has not received Phase II funding, a report was never published, nor is the database easily accessible for public or stakeholder use.

When funded in its entirety, the finished work products and database will facilitate assessment of factors that have affected historic and current water quality in the Lower Arkansas.

Targeted constituents that will be included in the database are:

- total dissolved solids,
- specific conductance,

- salinity,
- pH,
- water temperature,
- dissolved oxygen,
- sulfate,
- other major ions, uranium, selenium, and nutrients.

Ancillary data sets, such as streamflow information and ground-water levels, and selected GIS (Geographic Information System) digital data sets will also be compiled and included in the data base for later phases (USGS, 2002).

4.3 Data Gaps

Most of the detailed monitoring in the watershed has been a result of USGS monitoring programs and CSU research and studies. USGS monitoring stations are located along the mainstem bracketing known and/or suspected sources along the length of the Lower Arkansas River, monitoring baseline indicators such as specific conductivity, pH, sulfates, and temperature. However, data gaps exist for various supplemental indicators, particularly metals (selenium, uranium and iron) and nutrients. Spatial data gaps also occur outside of the more heavily studied areas. As soil characteristics vary widely on a small scale and may cause small scale variability in water quality, more site specific monitoring may be required.

4.4 Monitoring Program

The USGS has established a strategic monitoring program and QA/QC protocol for baseline indicator constituents collected by their agency. However, based on watershed issues and concerns, other watershed partners will continue to collect water quality data and information to more accurately characterize water quality, calculate pollutant loading, and changes affected by implementation of BMPs and other watershed efforts targeted to improve water quality and watershed health.

Monitoring efforts have been extended recently to include the Cucharas River. The purpose of this on-going monitoring project is to collect water quality data and information related to the discharge of Coal Bed Methane (CBM) waters to the Cucharas River. In 2006 a reconnaissance survey was conducted. Based on this initial study a complete monitoring program was established in 2007 consisting of 17 monitoring sites from near La Veta to east of Walsenburg.

The monitoring program proposed by the Lower Arkansas Watershed Improvement Association suggests a core set of baseline indicators, plus supplemental indicators selected according to site-specific or project-specific decision criteria. As funding allows, the core indicators will be monitored routinely to assess attainment of water quality standards and designated uses. Core indicators in the Lower Arkansas Valley may include salinity, specific conductance, sulfates, pH and temperature. Supplemental indicators will be monitored to understand load reductions associated with implementation of management strategies, pilot projects, and case studies (EPA, 2000). Supplemental indicators in the Lower Arkansas Valley may include nutrients, uranium, selenium, crop tolerance, and fisheries productivity. All monitoring program efforts will be supplemented with a sample analysis plan (SAP) and quality assurance project plan (QAPP).

Stakeholders have suggested coordinated water quality monitoring in the Lower Arkansas River – a plan where each entity required to sample flows and quality, would conduct their sampling on the same date in a coordinated fashion. This would provide "snapshots" of river health and clues regarding the relationships between upstream practices and water quality, and downstream water quality.

4.4.1 Quantifying Measures of Success

Pollutant load reductions resulting from management strategies and implementation projects will be monitored by establishing a baseline condition and conducting groundwater and/or surface water monitoring to quantify pollutant reductions. If a baseline condition cannot be established using existing data, new data should be collected prior to implementation in order to quantify reductions and effectiveness. The scale of the monitoring program should be consistent with the scale of particular BMPs. If a BMP is a field-scale measure, monitoring should be conducted on the field-scale.

To supplement field- or sub-basin scale monitoring, monitoring stations should be located at regular intervals, bracketing known or suspected sources along the length of the Lower Arkansas River. These stations should be sampled on a regular basis for selenium, salinity, sediment, iron, uranium, E. coli and other potential parameters of concern. Such a uniform monitoring plan will establish baseline conditions in the river and allow quantification of changes effected by implementation of management strategies (EPA, 2000; USGS, 2004).

As data sets are analyzed and pollutant loads and reductions are quantified, the ultimate targets will be determined. Generally speaking, watershed targets may include reduction of selenium, salinity, sediment and iron loads to support beneficial uses and the watershed vision. However, targets may also include non-traditional approaches, such as, habitat improvement, creation of habitat, increase in abundance and diversity of certain aquatic species, greater recreational opportunities, and/or increased property values.

5.0 Data Analyses and Characterizations

This section summarizes data analyses and identifies water quality relationships and potential trends based on the data available. These data analyses can be used to prioritize and support planning goals and objectives that will influence the watershed management process.

5.1 Applied Data Sets and Data Management

The USGS has monitored water quantity and quality parameters at several Arkansas mainstem and tributary locations. Data collection began as early as 1945 (for flow records) and continues today. Historic selenium concentrations from upstream to downstream are shown in Figure 5-1. Mainstem locations are shown in blue and tributaries are shown in yellow.

Selenium concentrations exceed the chronic table value standard (TVS) of 4.6 µg/L promulgated in CDPHE-WQCC Regulation No. 31 from near Pueblo to below John Martin Reservoir. Inflow from all major tributaries except the Purgatoire River has historically exceeded the chronic standard. Below John Martin Reservoir, the USGS has monitored flow but not selenium or other water quality parameters.

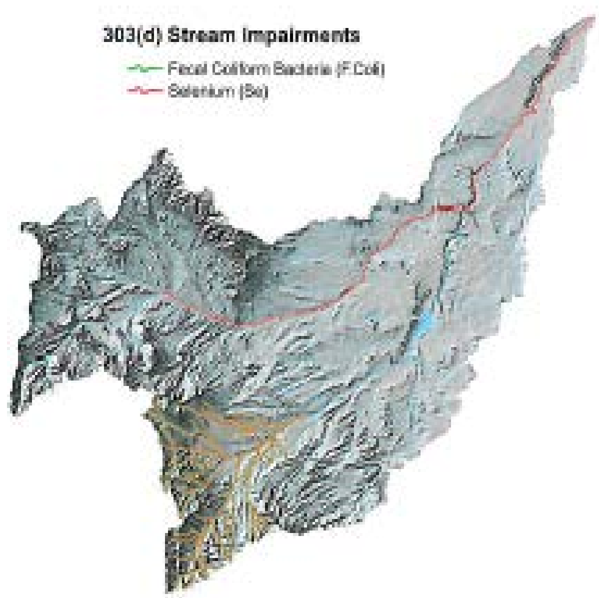
Data from the WQCD has shown that the ambiant selenium concentration in Arkansas River Segment 1b is 15.66 µg/L, based on 90 samples (City of La Junta, 2007). More recent data has shown that the ambient selenium concentration in Segment 1b is 16.6 µg/L based upon 149 samples.

Figure 5-1 Selenium concentration in the Lower Arkansas River and major tributaries.

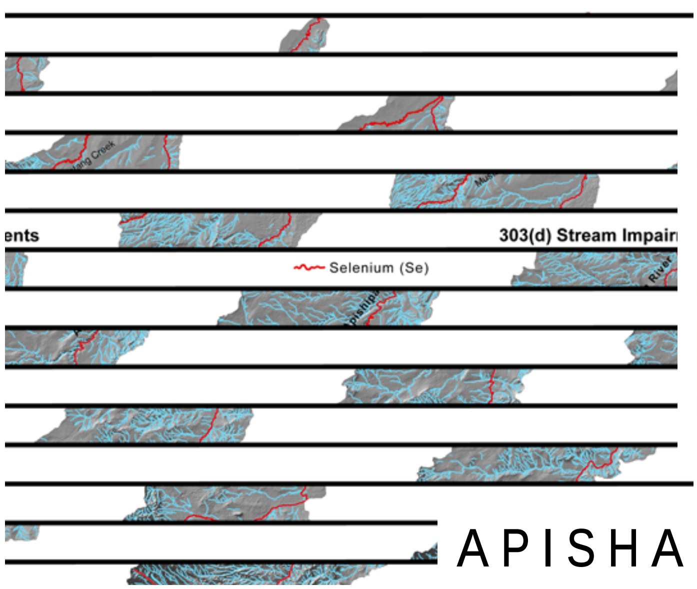
Stream Impairments
Section 303(d) of the Clean Water Act Requires slides to identify and list all water bodies where state water quality standards are not being met.
Thereafter, TMDLs compromising quantitative objectives and strategies have been or will be developed for these impaired waters within the watershed in order to achieve their water quality standards.

Impairment Definitions
Selenium: A naturally occurring metal in marine shale that serves as a micro-nutrient. Excessive amounts impair aquatic life, and bioaccumulation up the food chain occurs causing toxicity to birds, mammals, and humans.

Fecal Coliform Bacteria: bacteria that are associated with human or animal wastes. They usually live in human or animal intestinal tracts, and their presence in drinking water is a strong indication of recent sewage or animal waste contamination.

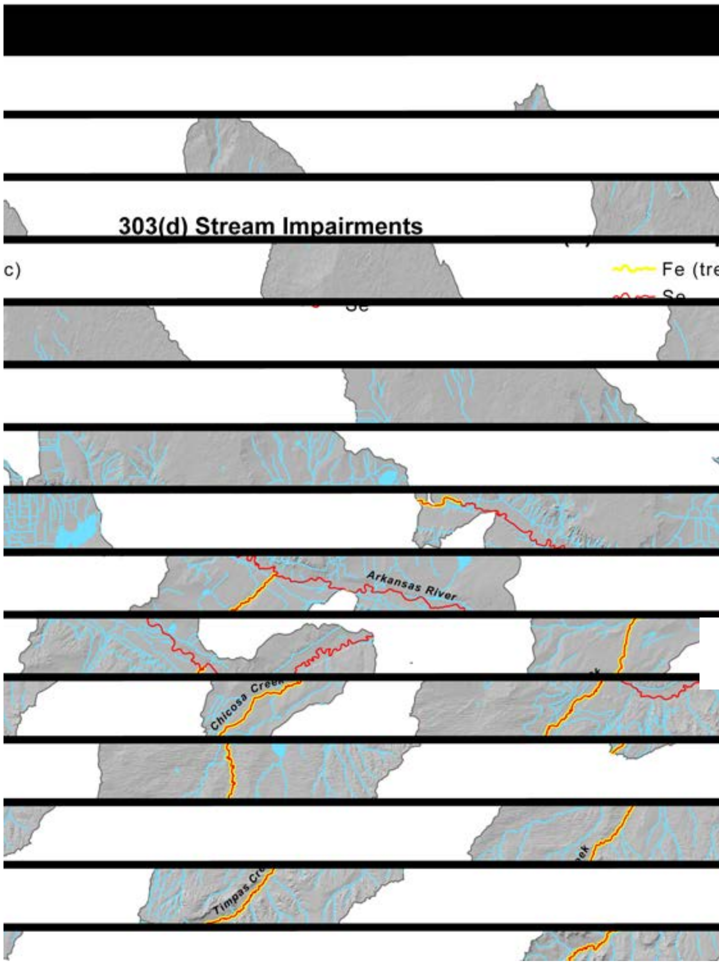


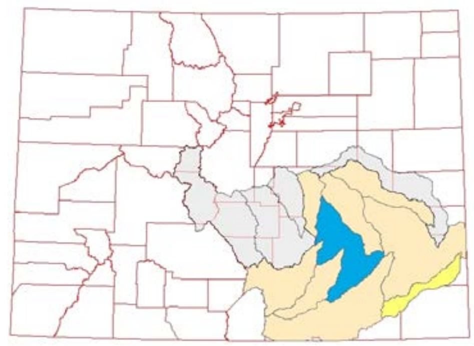
HUERFANO



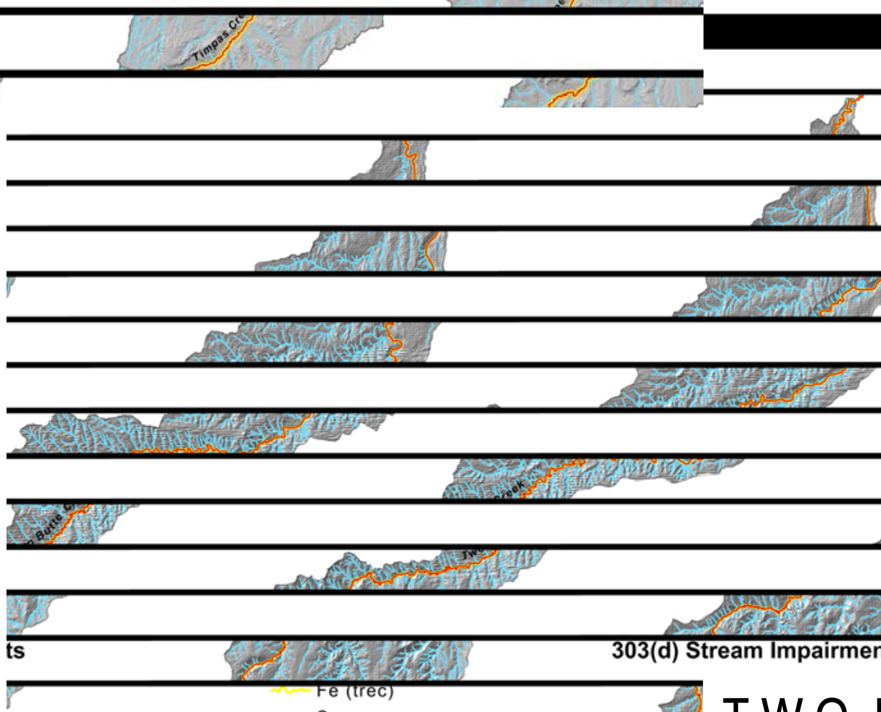
APISHAPA

Figure 5-1 Selenium concentration in the Lower Arkansas River and major tributaries.





LAKE MEREDITH



TWO BUTTES

Figure 5-1 Selenium concentration in the Lower Arkansas River and major tributaries.

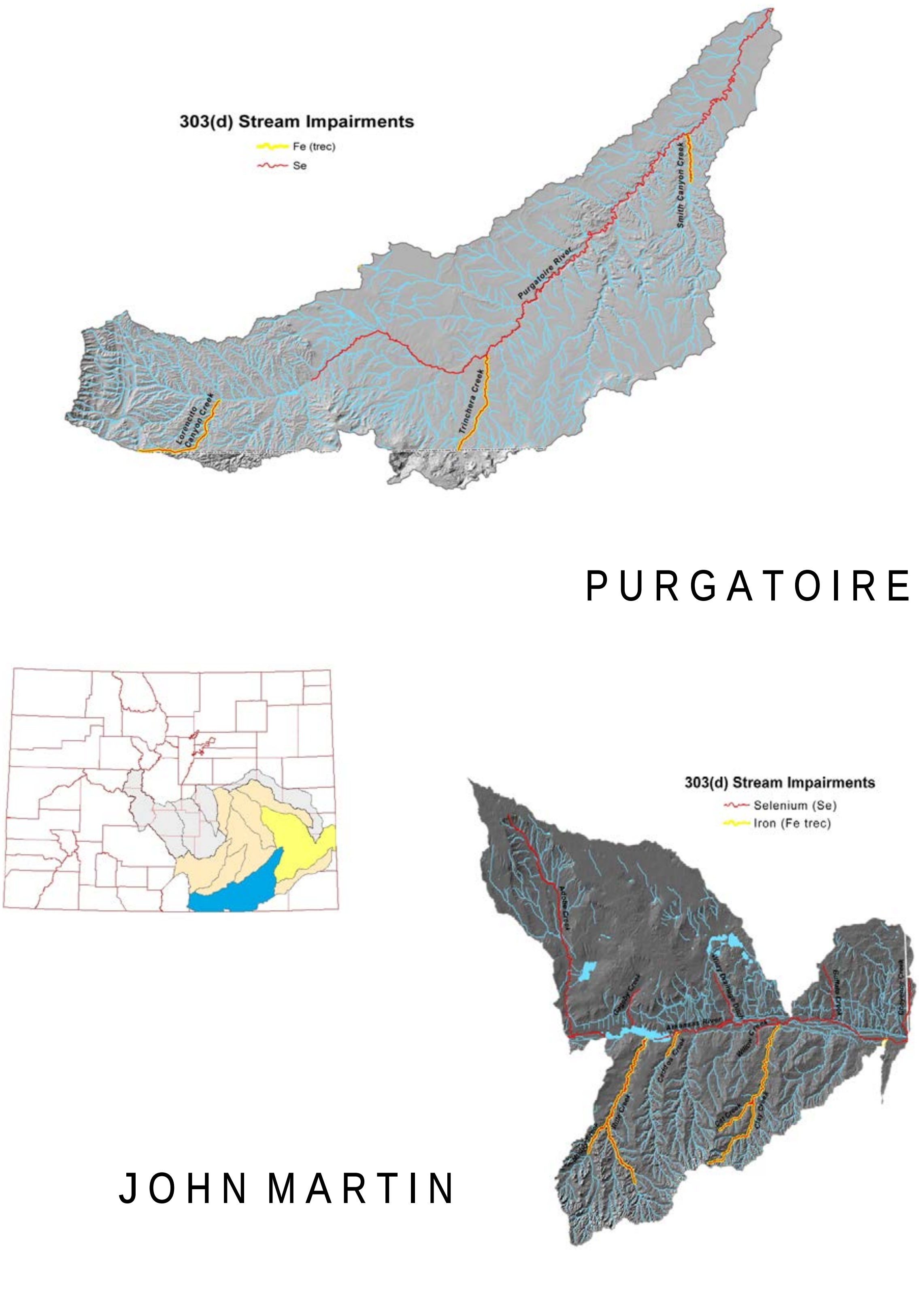
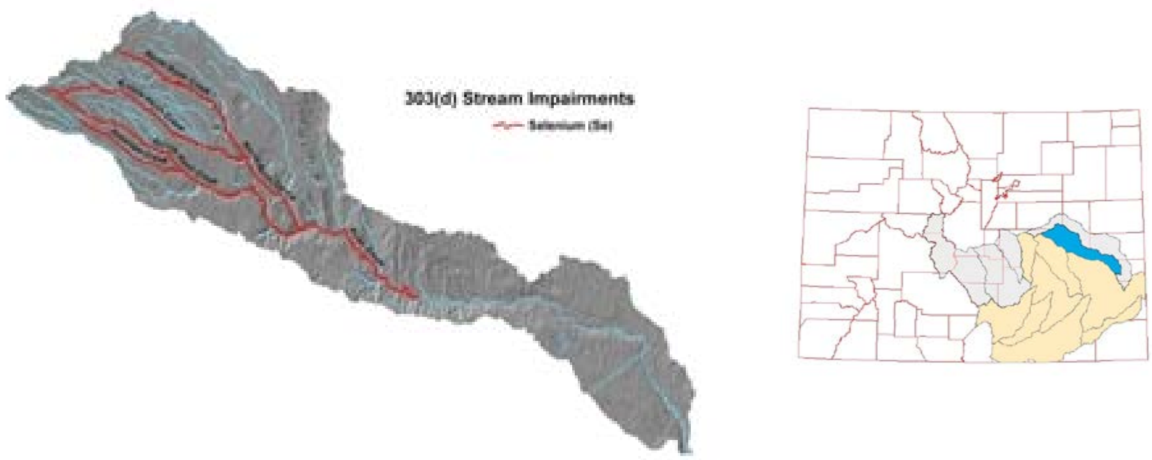


Figure 5-1 Selenium concentration in the Lower Arkansas River and major tributaries



RUSH CREEK

Historic specific conductance in the Lower Arkansas River and major tributaries is shown in Figure 5-2. The median electrical conductivity (EC) of the Arkansas River increases with increasing distance downstream (Figure 1). The lowest values occur in the upper reach. Small increases occur above Canon City. At Canon City the median EC is 0.3 dS/m or about 240 ppm. Between Canon City and Pueblo the salinity nearly doubles. The largest increases occur between La Junta and Las Animas. From the headwaters of the river to the Colorado-Kansas State line the salinity increases nearly 30 fold. The median salinity at the stateline is about 4.1 dS/m. The maximum salinity is about 6.5 dS/m. The total electrolyte concentration within the basin (Figure 2) ranges from about 0.97 meq/l ($m$mol$_c$/l) to 61 meq/l ($m$mol$_c$/l). In terms of the TDS the gravimetric salt content ranges between 76 mg/l to 4058 mg/l

The distribution of the dissolved chemical constituents and relationships of EC to dissolved solids are also very important particularly in evaluating waters suitability and calculating mass balances. The waters of the Arkansas River are primarily gypsiferous (calcium sulfate). The sulfate concentration ranges from about 40 percent (0.71 meq/l) of the total anions (1.78 meq/l) in the headwaters to 85 percent (47.8 meq/l) at the stateline.

In terms of cations, there occurs almost 6 times as much dissolved calcium (0.9 meq/l) as sodium (0.15 meq/l) in the upper reaches. The ratio of calcium to sodium decreases with increasing distance downstream. The concentrations become almost equal below John Martin Reservoir.

Specific conductance is an indicator of dissolved-solids (salinity) concentration. High dissolved solids concentrations are detrimental to the suitability of water for domestic, industrial, and agricultural uses.

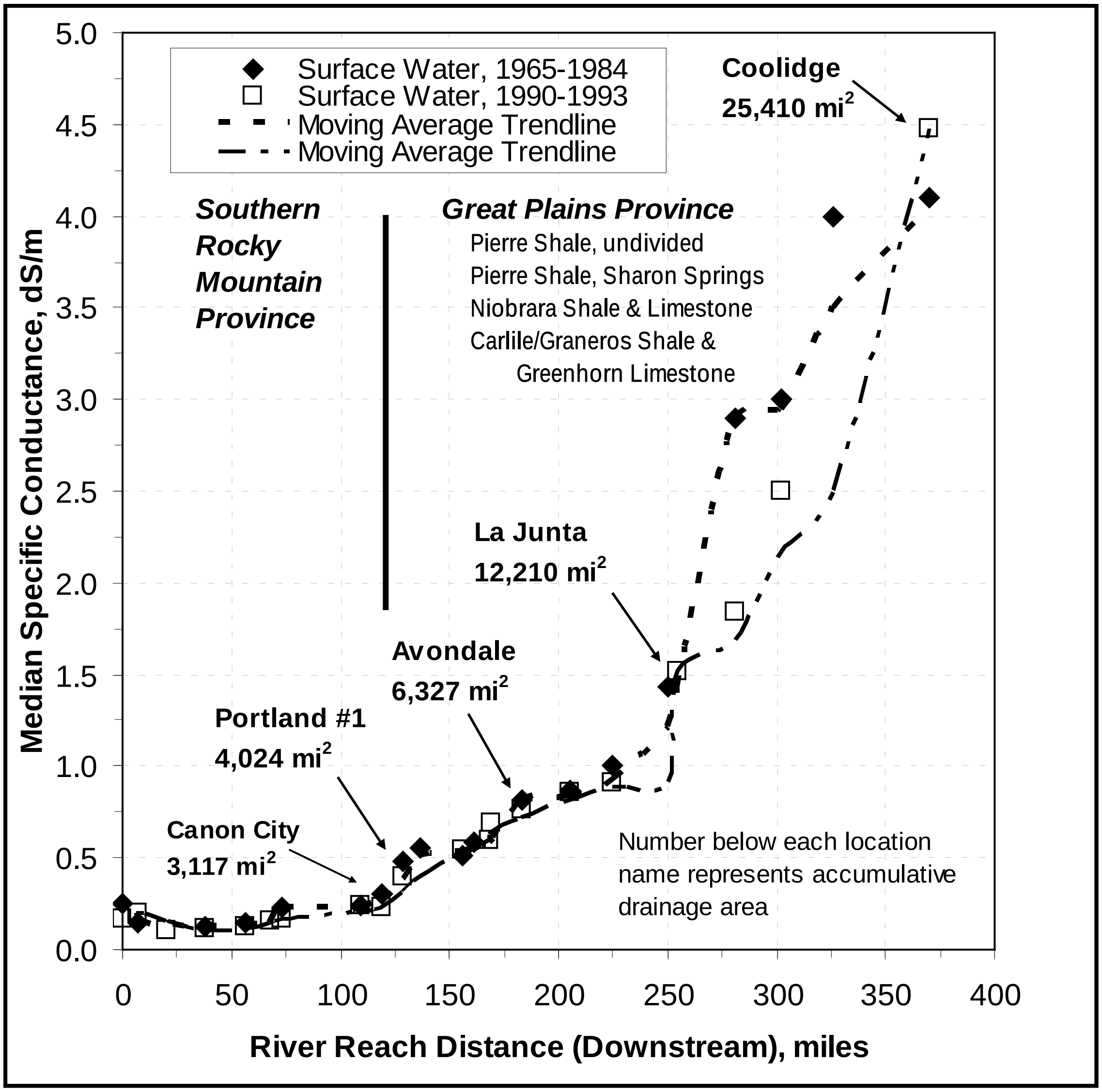


Figure 5-2. Median Specific Conductance in the Lower Arkansas River and major tributaries.
Notes:
1. Data taken from USGS Database, Period of Record 9/19/73 – 5/31/07

Agricultural losses also occur with elevated specific conductance. Tolerance varies by crop type, but losses might occur when salinity reaches 700-850 mg/L. This concentration is equivalent to a specific conductance of 950-1200 uS/cm in the Arkansas River (USGS, 1987).

Specific conductance varies throughout the year due to flow variability. Generally, specific conductance is lowest from May-August due to low specific conductance snowmelt runoff (generally less than 200 uS/cm; USGS, 1998). Specific conductance increases during the fall, winter, and spring when a larger percentage of water is composed of irrigation return flow and municipal discharge. Figure 5-3 shows this relationship.

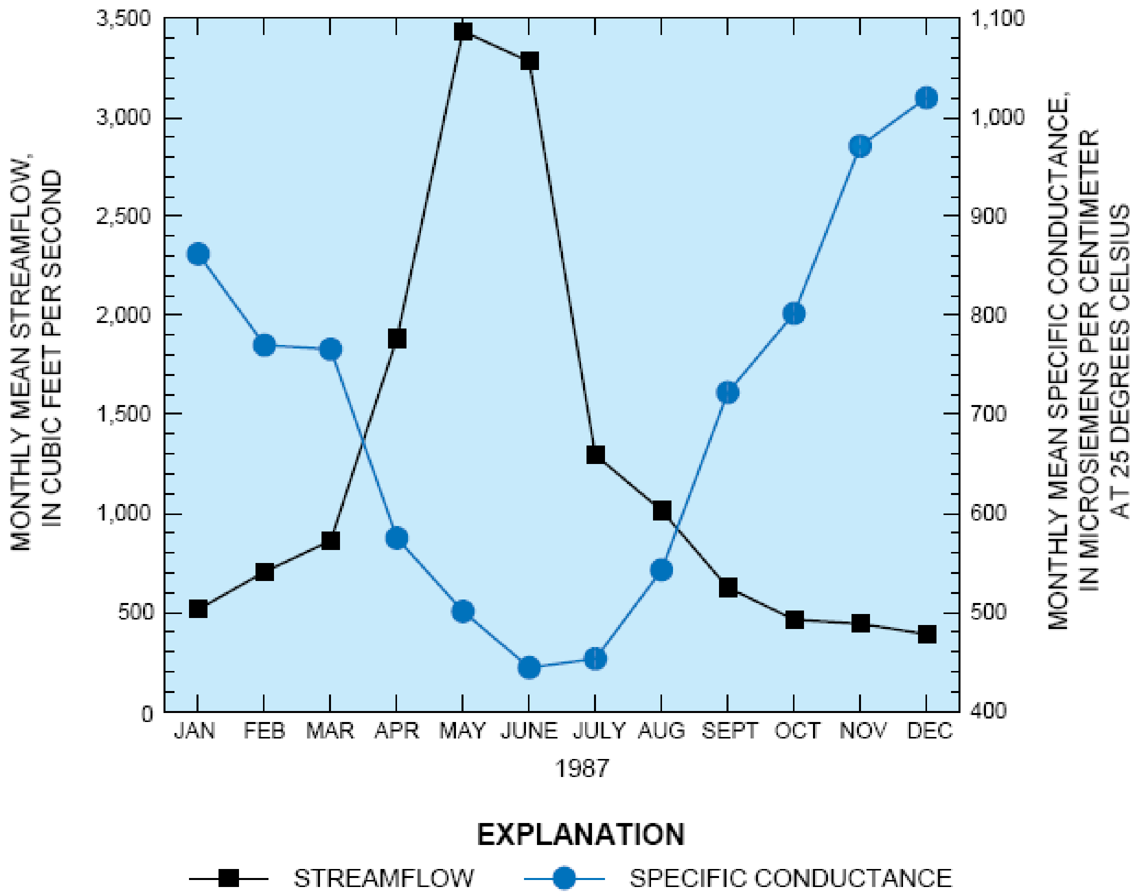


Figure 5-3. Relation of Streamflow to Specific Conductance for the Arkansas River near Avondale, 1987 (USGS, 1998)

Selenium concentration has also been observed to decrease as stream flow increases. Selenium concentrations in John Martin have been fairly constant over time despite a decrease in available water in recent years. Selenium concentration downstream of the reservoir is lower when a higher proportion of the flows are releases from John Martin. Once release curtails, groundwater return flow from irrigated lands comprises the majority of water at the Stateline (State of Kansas, 2007). Return flows have been in direct contact with saline soils and geology of valley lands.

CSU began an extensive data gathering effort in 1998 in order to build data-founded models to assist in moving towards long-term solutions to irrigation-induced water quality and water logging problems in the Arkansas Valley. Two study regions were identified, one upstream of John Martin Reservoir covering approximate 125,000 acres (65,300 irrigated acres) and the second downstream of John Martin Reservoir from Lamar to the Colorado-Kansas state line covering 136,300 acres (81,600 irrigated acres; CSU, 2006). These study areas are shown in Figure 5-4.

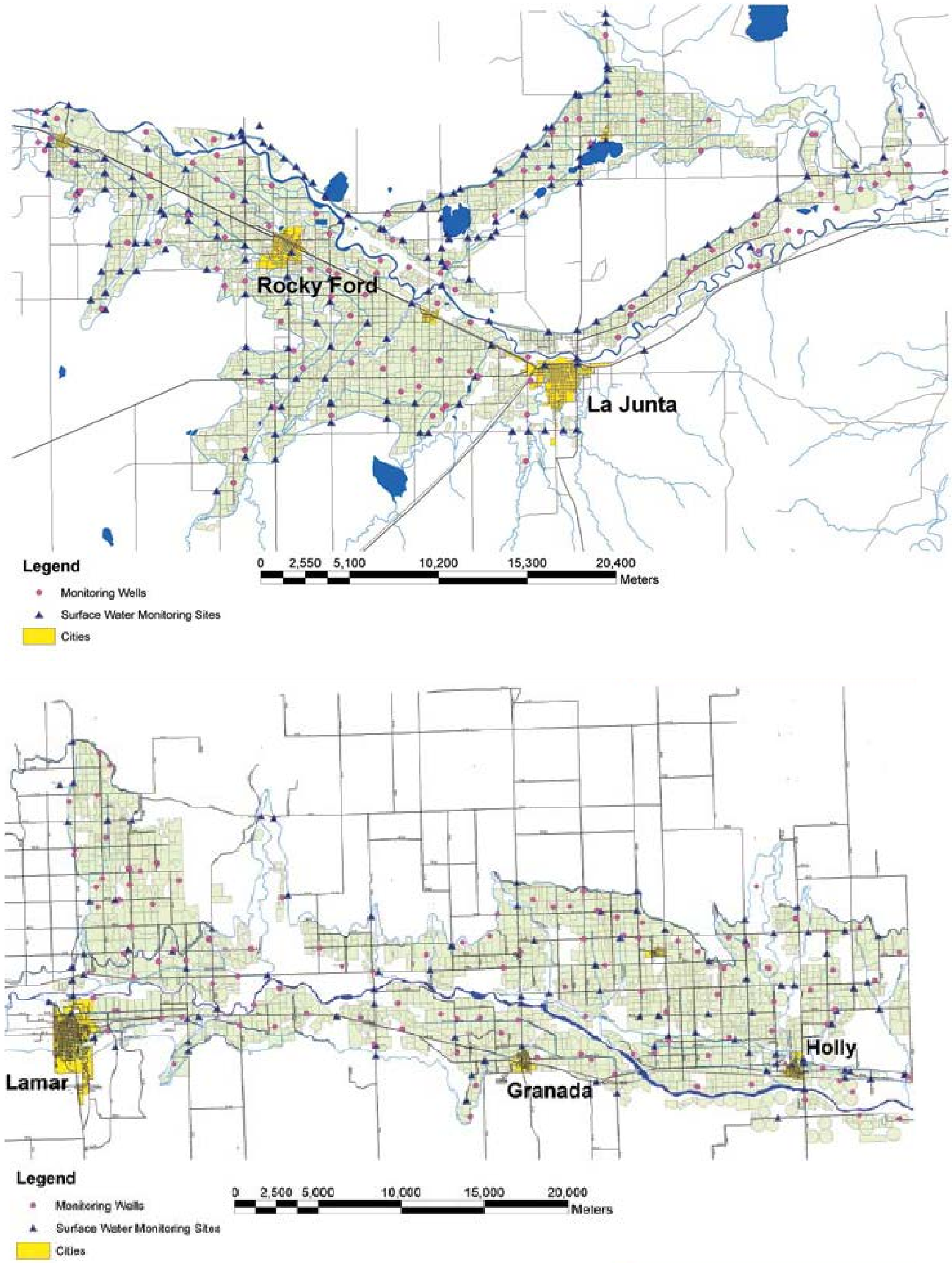


Figure 5-4. CSU Upstream (top) and Downstream (bottom) Study Areas with Monitoring Well and Surface Water Monitoring Sites (CSU, 2006).

Data collection has included groundwater monitoring, well installation and observation, analysis or river and tributary flows, analysis of flows diverted to irrigation canals, salinity measurements, soil salinity measurements, topographic and hydrographic surveying using GPS, boreholes to investigate lithology and bedrock, measurement of soil and aquifer properties, irrigation canal seepage measurements, measurement of irrigation and runoff, crop yield measurements, and other related activities. Water quality data for groundwater and surface water including dissolved selenium and iron concentration, total recoverable iron concentration, pH, temperature, dissolved oxygen, oxidation-reduction potential, and concentrations of major ions has been collected sixteen times from April 2003 through July 2005 in the Downstream Study Region. A temporal and spatial data set of this size is one of the largest ever collected in an irrigated alluvial valley (CSU, 2006).

One important aspect of the CSU investigation is the establishment of a clear relationship between soil water salinity (EC_e) and decreased depth to the saline water table. Figure 5-5 shows that soil water salinity, EC_e, increases where the groundwater table is closer to the ground surface. The Downstream Study Region was also found to have EC_e values about 2 dS/m higher than those in the Upstream Study Region (CSU, 2006).

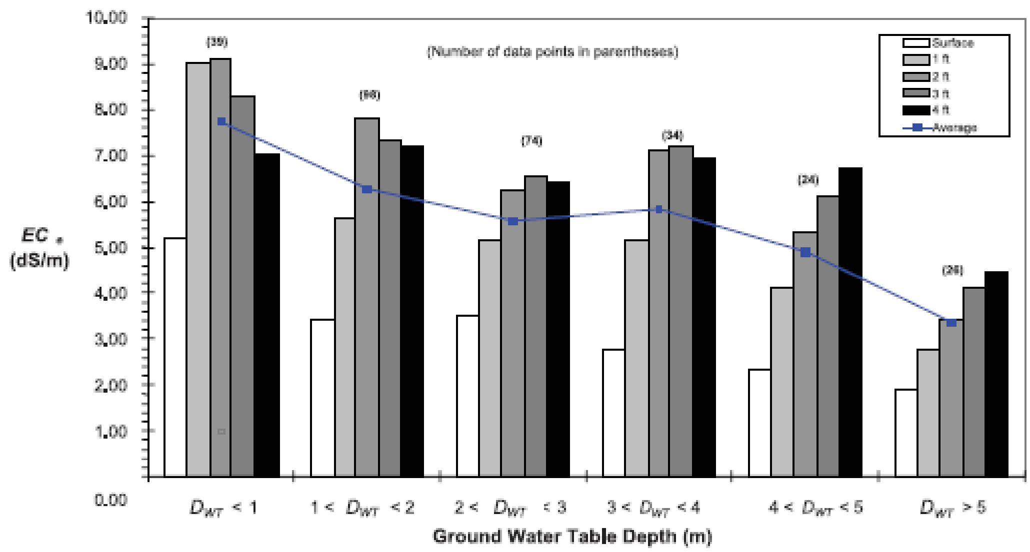


Figure 5-5. Soil Water Salinity Trends in Samples Taken AT Different Depths from EM-38 Calibration Sites in the Downstream Study Region (CSU, 2006)

Dissolved selenium samples taken by CSU from the Arkansas River ranged from 4.2 to 23 µg/L with a median concentration of about 9.4 µg/L (CSU, 2006). Selenium concentrations measured in groundwater wells in the Downstream Study Region are shown in Figure 5-6.

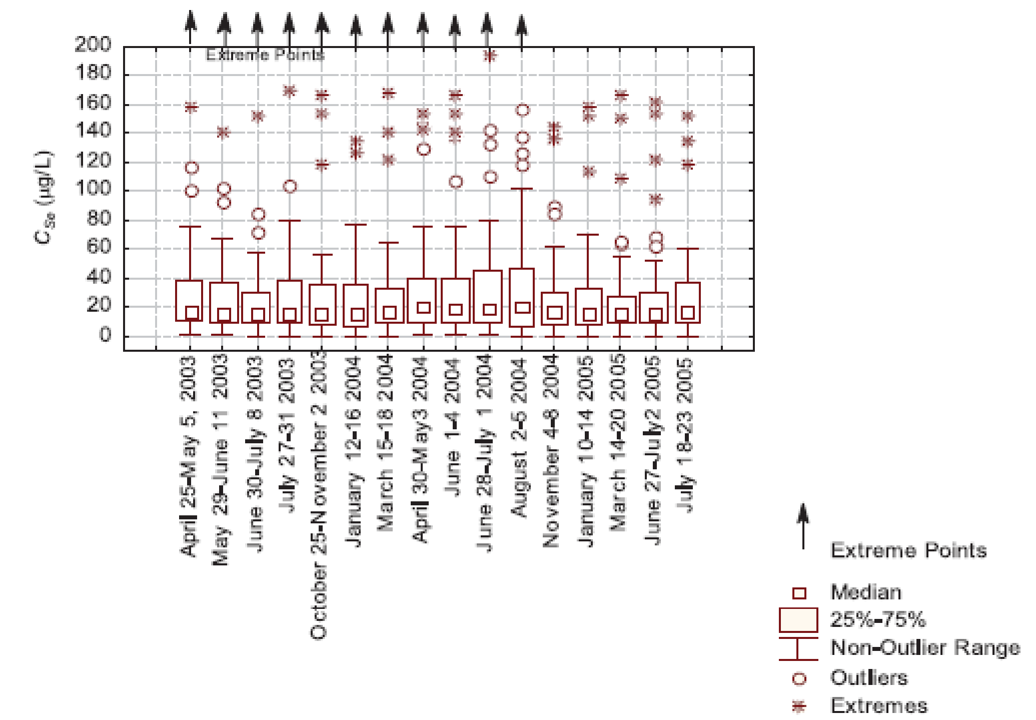


Figure 5-6. Plot of groundwater selenium concentration in monitoring wells within the Downstream Study Region (CSU, 2006)

GIS was used to characterize the spatial and temporal occurrence and severity of dissolved selenium concentrations in the Downstream Study Region. The results showed that selenium concentrations in groundwater ranged from less than 0.4 µg/L to 3,760 µg/L. The median concentration was about 16 µg/L. Groundwater selenium concentrations were found to correspond well with geological formations in the region. Samples taken from shale-derived and slopewash material had a median concentration of 30.8 µg/L while samples taken from alluvial material had a median concentration of 12.2 µg/L. The average selenium loading rate from groundwater, tributaries, and surface runoff and agriculture returns was estimated at about 54.2 lb/mile in 2003-2004 and 74.7 lb/mile in 2004-2005 (CSU, 2006).

5.2 Water Quality and Environmental Models and Modeling

The USGS and CSU have invested in the development of water quality and environmental models developed to support the Lower Arkansas Watershed planning effort.

5.2.1 USGS, Selenium Modeling Tools

Funded by the NIWQP, USGS has been developing decision support tools and selenium loading models specifically for the Uncompahgre Basin. Salinity and selenium water-quality issues in the upper Colorado River Basin of western Colorado have been the focus of remediation efforts for many years. In response to the Salinity Control Act of 1974, the Bureau of Reclamation (BOR) and the Natural Resources Conservation Service (NRCS) have focused on salinity control since 1979 through the Colorado River Basin Salinity Control Program. The primary methods of salinity reduction are the lining of irrigation canals and laterals and assisting farmers to establish more efficient irrigation practices (USGS, 2001). Starting in 1988, the National Irrigation Water Quality Program (NIWQP), a Federal-agency board, began investigations to determine other possible adverse effects irrigation drainage was having on water quality in the western United States. The NIWQP investigations lead to the discovery that irrigation drainage contributes a significant portion of the salinity load of the upper Colorado River Basin and the discovery of high concentrations of selenium in water, biota, and sediment samples. Previous investigations determined a relation exists between subbasin characteristics (Mancos Shale outcrops, agricultural practices, and irrigation water-delivery system design) and salt and selenium loads at the mouths of certain subbasins.

These tools model salt and selenium loading using quantified GIS information and regression analysis to simulate, track, and manage water quality in regions of the upper Colorado River and its tributaries. They also identify locations and quantify areas where salt and selenium load reductions may be feasible and estimate loading scenarios in regions of proposed development or transitional land use. Load reductions for salt and selenium are modeled using remediation scenarios such as polyacrylamide applications in irrigation-delivery systems or improving septic-system placement and construction (US EPA and City of Grand Junction, 2004).

5.2.2 US EPA, Region 8, Salinity Modeling Tools

US EPA, Region 8, has developed salinity modeling tools to better understand the potential impacts of land uses on salt loads and evaluation of best management practices to reduce salinity loading. More recently these models were utilized in Wyoming to evaluate potential salinity impacts from water produced from coal-bed methane application and management approaches to reduce salt loading. These same modeling tools, when integrated with Lower Arkansas River watershed data and information, could be utilized to further understand and evaluate opportunities for salinity load reduction.

5.2.3 CSU, Groundwater and Economic Modeling Tools

CSU researchers have developed and calibrated Groundwater Modeling System (GMS) models to verify the GMS numerical models used for the shallow groundwater flow and salt transport model at the sub-regional scale. The GMS describes the nature and extent of salinity-related problems. The model has been modified to assess impacts of various strategies for improving water and salinity management along the Lower Arkansas River Valley. The GMS is being used to predict water table depth and salinity, soil water salinity, crop yield, rate and concentration of groundwater return flows to the river, and non-beneficial consumptive use under fallow land in response to a suite of discrete improvement alternatives that could be implemented in the watershed. (CSU, 2006).

CSU has also developed a preliminary economic analysis to estimate impacts of various management strategies on costs and returns at the field, regional, and basin scales. Economic data used for this model includes crop prices, quantity and prices of farm inputs used, and costs of on-farm adjustments associated with the different improvement policies being evaluated. Crop enterprise budgets were used as the foundation for this information. Preliminary results indicate that remedial strategies have promising potential to boost net economic benefits from crop production in the Valley when agro-economic benefits are considered (CSU, 2006).

6.0 Watershed Management Action Strategy, Policies, and Programs

6.1 Existing Policies and Programs

Existing policy and programs are based on current federal and state regulatory programs affecting activities within the watershed, namely:

- Water quality;
- Source water protection,
- Stormwater and urban runoff;
- Water resource development;
- Endangered species, wildlife, and riparian habitat;
- Floodplain

6.1.1 Water Quality

The following water quality programs provide a framework for water quality management in the Lower Arkansas Watershed:

- Section 303(d) of the Clean Water Act requires states to identify waters not expected to meet the national goal of being "fishable and swimmable" and to develop Total Maximum Daily Loads (TMDLs) for those waters. The 303(d) list identifies priority waters in the Lower Arkansas watershed requiring a TMDL process.

- The Safe Drinking Water Act delegated to states the source water assessment program, and Colorado has such responsibilities. Colorado's Source Water Assessment and Protection (SWAP) program is implemented by the Colorado Department of Public Health and Environment (CDPHE). To comply with the federal requirements, CDPHE has completed source water assessments for all public drinking water supplies. CDPHE has completed SWAP reports for all communities within the watershed and some plans have been recently updated. The CDPHE strongly encourages stakeholders to participate in the protection phase of the program although participation is voluntary.

- National Pollutant Discharge Elimination System (NPDES) permits issued by the CDPHE to control point source pollutant concentrations. The NPDES program operates with the mission to ensure that all wastewater treatment facilities treat wastewater in compliance with permit limits. NPDES establishes permit limits and specific monitoring and reporting requirements. EPA has set a watershed strategy for NPDES that meshes with its overall watershed approach to address the following focus areas:

    - Statewide coordination
    - Streamlining of permitting process
    - Monitoring and assessment
    - Programmatic measures and environmental indicators

- Public participation
- Enforcement

- Regulation 32, adopted by the WQCC, establishes classifications and numeric standards for the Arkansas River, its tributaries, and standing bodies of water. Classifications identify the actual beneficial uses and numeric standards assign allowable concentrations of various parameters (CDPHE, 2007).

- Temporary Modifications adopted by the WQCC, establish an interim higher selenium standard which reflects recent ambient water quality concentrations of selenium.

- The Colorado Nonpoint Source Management Program, identifying the Lower Arkansas Watershed as in need of a watershed plan in the 2006 Nonpoint Source Program Annual Report.

6.1.2 Stormwater and Urban Runoff

The stormwater permitting program, provided for in the CWA is administered by the State of Colorado, CDPHE, and regulates stormwater runoff to reduce pollutant loads entering streams, lakes, and rivers resulting from urban, agricultural, and industrial runoff. Cities or counties with a population between 10,000 and 100,000 are required by Phase II Stormwater regulations to implement six minimum measures:

- Public education/outreach
- Public involvement
- Illicit discharge detection and elimination
- Construction site runoff control
- Post-construction BMPs
- Pollution prevention/good housekeeping for municipal operations

However, because the population densities in the cities and urbanized areas of the counties in the Lower Arkansas do not meet the 10,000 person threshold for municipal stormwater permits, the program is not implemented in the watershed. Program elements outlined in the Phase II Stormwater program may be suitable, on a site-specific basis for some areas and sources in the watershed. It is worth mentioning that where stormwater does not require a permit, it is considered a nonpoint source of pollution and can be addressed under that program as appropriate.

Notwithstanding the foregoing, industrial uses and animal feeding operations must obtain and comply with stormwater permit requirements through the watershed. For example, Phase II regulations require a construction discharge permit for all construction activities with an area of disturbance greater than 1 acre where runoff enters the waters of the U.S. or a municipal storm sewer.

6.1.3 Water Resources Development

Water use in the Lower Arkansas is governed in two ways:

Colorado water rights administration is governed by the Colorado Constitution, which is implemented by the Office of the State Engineer, Division of Water Resources and ultimately through the rulings and adjudications of Colorado Water courts. The right to appropriate the unappropriated water of the state "shall never be denied" as stated in the Colorado Constitution. The doctrine of prior appropriation governs water rights in Colorado and embodies the fact that while no person can own water in a stream, all people, municipalities, and corporations have the right to use water for beneficial purposes. A recent amendment to the Colorado Water law requires the water courts to consider water quality impacts if more than 900 acre feet of water are transferred for uses outside the watershed.

The Arkansas River Compact, signed in 1948, and recently litigated between Colorado and Kansas on its interpretation, establishes an apportionment of the waters of the Arkansas River between the states of Colorado and Kansas. It states that the usable quantity and availability of waters for use of the water users of Colorado Water District 67 and the State of Kansas shall not be materially depleted or adversely affected.

In 2005, the Colorado Legislature passed House Bill 1177 that created water roundtables for each Colorado watershed to address and consider water needs, water shortages and possible water supply opportunities.

6.1.4 Endangered Species, Wildlife, and Riparian Habitat

- The Endangered Species Act (ESA) aims to conserve and recover species in danger of extinction, and to preserve the habitats and ecosystems these species require. The ESA protects species listed as "endangered" (in danger of becoming extinct) or "threatened" (at risk of becoming an endangered species). Federal threatened and endangered species possibly residing in the Lower Arkansas Watershed include the Arkansas Darter, Interior Least Tern (endangered), Lesser Prairie Chicken, Bald Eagle, and Piping Plover (endangered).

- The U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service have adopted a policy to address species listed or proposed to be on the ESA while protecting and enhancing recreational fisheries. This policy ensures cooperation and coordination between the two administering agencies and promotes collaboration with other federal, state, and tribal fisheries managers.

- Jurisdictional wetlands which are directly connected to navigable water may be protected by the Clean Water Act, Section 404, which regulates the discharge or placement of dredged or fill material into waters and wetlands of the US unless permitted. This 404 permit requirement applies to infrastructure development, channel and waterway modification, maintenance, and/or repairs, and construction of dams or levees. The U.S. Army Corps of Engineers (ACOE) administers the regulatory program with oversight from other federal agencies.

- The Colorado Division of Wildlife (CDOW) manages the Natural Diversity Information Source (NDIS). NDIS provides data and analysis required for decisions on land use affecting animals, plants, and natural communities of the state. NDIS draws upon a variety of sources including CDOW, CNHP, CSU, local governments and other conservation partners.

6.1.5 Floodplain

- The Federal Emergency Management Agency (FEMA) identifies and maps flood hazard areas and procedures for flood map correction and changes pursuant to Title 44 CFR Parts 65, 70, and 72.

- The Colorado Water Conservation Board (CWCB) administers Colorado's Flood Protection Program which is directed in Section 37-60-106(1) C.R.S. (1990) to review and approve floodplain designations prior to adoption by local government entities, prevent flood damages, and provide local entities with technical guidance.

6.2 Proposed Management Strategies, Policies, and Programs

The watershed management approach embraced by the Lower Arkansas River Watershed stakeholders supports the aforementioned existing policies and programs and the watershed goals and objectives established by the stakeholders. This approach increases the number of potential solutions to the problem and provides a flexible framework for considering and integrating all pertinent factors and resources into analysis and solution development. Moreover, if a regulatory strategy is the most effective solution, this holistic approach also offers a comprehensive and effective means by which regulatory solutions can be identified, developed, and implemented.

An array of management and implementation measures were discussed and reviewed for achieving the watershed vision, goals and objectives identified by stakeholders (Appendix E). Successful water quality control programs typically consist of a variety of control measures that are implemented throughout the watershed. Potentially viable management strategies reviewed by stakeholders are depicted on Figure 3-1.

6.3 Recommended Management Strategies

The following actions are recommended based on assessment of existing and projected conditions in the Lower Arkansas River watershed. The recommended management strategies and programs supported by the watershed stakeholders and their general implementation priority over an 8-10 year period are provided in Table 6-1. The management strategies are broken down into the following categories to allow for determination of the optimum combination of nonstructural, structural, and regulatory solutions to include in the implementation plan. All management strategies require funding.

- Land Management
- Irrigation Management
- Habitat Improvements
- Sustainable Strategies
- Regulatory Management
- Waste Management/Treatment
- Funding
- Public Involvement

Table 6-1. Recommended Management Strategies and Implementation Priorities

Land Management	
Promote Land Management	Short-term
Develop priority areas for land use management/conservation (i.e. selenium hot spots, stream preservation corridors, floodplains, and river corridor areas to promote river access and a trail system) Develop framework for a land trust system (components may be modeled after the successful Cacapon and Lost Rivers Land Trust)	
Implement Land Management Mechanisms	Short- and Long-Term
4. Identify a financing strategy for land protection. 5. Develop program for short-term and long-term conservation of lands. Landowners would "bid" their lands into a trust program for short-term or long-term. 6. Acquire conservation easements or land retirement commitments through a land trust or similar program. 7. Support local districts and municipalities in efforts to conserve priority areas.	
Irrigation Management	
Renovate and Maintain Historic Drainage Systems	Long-term
Early farmers created a vast drainage network which has since become rundown or inoperable due to lack of maintenance. Renovating and maintaining the system would encourage drainage, reduce water logging, and could improve water quality. There is also potential for creating a market for providing maintenance services. An incentive must be provided for landowners to maintain their drainage ditches.	
PAM Application	Short-term
PAM, a polyacrylamide, has proven to be effective in reducing erosion by preventing sediment transport in irrigation water. PAM is sprayed in solution in a dry canal or added to sediment-loaded flow. It seals and prevents seepage.	
Sprinkler or Drip Irrigation	Short-term
Implement irrigation efficiencies via sprinkler or drip irrigation.	
Earthen Channel Lining/Replacement	Long-term
Replace earthen line channels with PVC pipe or concrete lining to reduce seepage and leaching of selenate shales.	
Active Land Management	Short- and Long-Term
Combination of measures, trials of alternative crop selection and changes in operation to improve water quality; Regular fallowing and crop rotation; manage the water table to increase its contribution to crop transpiration, decrease evaporative losses, and to prevent water logging.	
Conduct Special Studies to Optimize Water Quality Benefits	Short-term
Continue strong working relationship with federal agencies and state academia to better define key locations and opportunities to create irrigation efficiencies and water quality enhancement.	
Habitat Improvements	
Tamarisk Eradication	Short- and Long-term
Continue and expand tamarisk removal and potentially use tamarisk biomass for energy	

production.	
Promote Public Access to the River	Long-term
Integrate river corridor, access, hiking and biking trails along the river to promote awareness and recreational opportunities.	
Sustainable Strategies	
Carbon Trading/Biofuel Production	Short-term
Canola is just one crop that provides for high uptake of selenium. In conjunction with this, it serves as an excellent biofuel. Appropriate canola plant varietals for the Lower Arkansas climate are still being considered, however other viable biofuel plant species can create a sustainable program that can be integrated with a carbon trading program in the watershed.	
Solar Energy Production	Long-term
Encourage shift of land use to solar energy production where feasible. Currently, solar is only feasible for those with large tax liability looking for tax breaks. Could work to encourage large-scale installers responding to Xcel RFPs to site locations in the Valley.	
Harvest Energy from AFO Waste	Long-term
AFO operators could harvest energy from animal wastes to produce electricity. Electricity could be used to power their operations or sold to other energy users in the area. Pilot economic feasibility studies have been conducted. Currently, manure is used in the valley for land application, however it is just a fairly expensive proposition for the feedlot owner and the farmer unless the sites are close to the feedlot.	
Small-Scale Wind Farms	Long-term
Small-scale wind installations are being used to power water pumping stations in Bent County. Implementing wind farms, in areas that are non-irrigable, non-productive (i.e. over laden by marine shale or highly saline soils), and ideally located on the bluffs, could employ more people and have the opportunity to sell energy at retail rates, while providing water quality improvements. Pilot scale installations will address the obstacle of not having availability to production tax credits given to large-scale wind facilities while quantifying water quality benefit.	
Regulatory Management	
Watershed-based Incentives	Short- and Long-Term
Create trading incentives for public and private entities to implement water quality controls, enhanced BMPs and other water quality incentives geared to reduce key constituents of concern (i.e. selenium, nutrients, sediment, etc.).	
Ordinances	Short- and Long-Term
Create stormwater, land management or water quality policy and criteria that offer greater water quality benefits. Examples of ordinances may include requiring landowners that sell water rights to reseed lands prior to selling water.	
Stormwater Controls (NALMS, 2007)	Short-term
Coordinate with upper basin areas that are stormwater permitees to control sediment and nutrient loads on the river.	
Waste Management/Treatment	
Harvest Energy from AFO Waste	Long-term
AFO operators could harvest energy from animal wastes to produce electricity. Electricity could be used to power their operations or sold to other energy users in the area. Pilot economic feasibility studies have been conducted. While manure is used in the valley for land application, it is a fairly	

expensive proposition for the feedlot owner and the farmer unless the sites are close to the feedlot.	
Hazardous Waste and Materials Pick-Up	Short-term
Provide monthly pick-up of hazardous chemicals, paints, etc.; quarterly schedule for each county in conjunction with other community activities.	
Funding	
Identify Funding Mechanisms	Short- and Long-Term
Identify and develop new funding mechanisms to meet watershed goals. Implement a variety of federal, state, local, and private funding mechanisms to meet funding goals of an additional $2 million dollars annually.	
Develop an overall business program and financing plan.	Short-Term
Grants are not the long term solutions. Market based solutions offer the most effective long term financial stability.	
Participate with federally funded programs that support sustainable agricultural and habitat protection and restoration	Long-Term
Consider programs such as Conservation Reserve Program, Environmental Quality Incentives Program (EQIP), Partners for Fish and Wildlife, Wetlands Reserve Program, and Wildlife Habitat Incentives Program (WHIP) are federal programs appropriate to fund efforts in the watershed.	
Collaborate with other private and public interest groups to leverage funding mechanisms to meet watershed goals	Long-Term
Coordinate with other public and interest groups to obtain additional funding, recognizing there may be opportunities to view problems as business opportunities.	
Public Involvement	
Retain a Watershed Coordinator	Short-term
The Lower Arkansas Watershed Coordinator will foster community-based watershed management in the Lower Arkansas basin and be the point of contact to manage and facilitate watershed efforts.	
Develop and Implement a Comprehensive Public Involvement Plan	Short-term
The PIP will provide mechanisms to promote stakeholder involvement, encouraging, federal, state, and local interest. An open line of communication with other RC&D's will also be promoted.	
Develop a Lower Arkansas River Watershed Website	Short-term
The website will help communicate watershed information to stakeholders and allow for easy distribution of watershed information, project highlights, grant pursuits, and monitoring efforts. Links to the website will be created from other existing websites, including the Arkansas River SECWCD website.	
Educate the Public and Landowners on Economic and Environmental Costs and Benefits	
Present individual landowners and operators with the potential costs, benefits, risks, and profits associated with adoption or rejection of each management strategy. Publicize and educate landowners on long and short term economic incentives for specific management strategies.	

6.3.1 Estimated Pollutant Reduction Effectiveness of Selected Management Measures

At a national, state and local level considerable research and demonstration of selenium, salinity, and sediment reduction control strategies has been conducted. As pilot studies have been completed, pollutant reduction effectiveness has been evaluated. Table 6-2 provides a summary of management measures and source control measures, along with the pollutant reduction effectiveness, cost, and sources of data and information. Monitoring programs in the Lower Arkansas Watershed will provide data to support pollutant reduction effectiveness of the implemented programs.

Table 6-2. Summary of Pollutant Reduction Effectiveness and Cost of Selected Management Measures

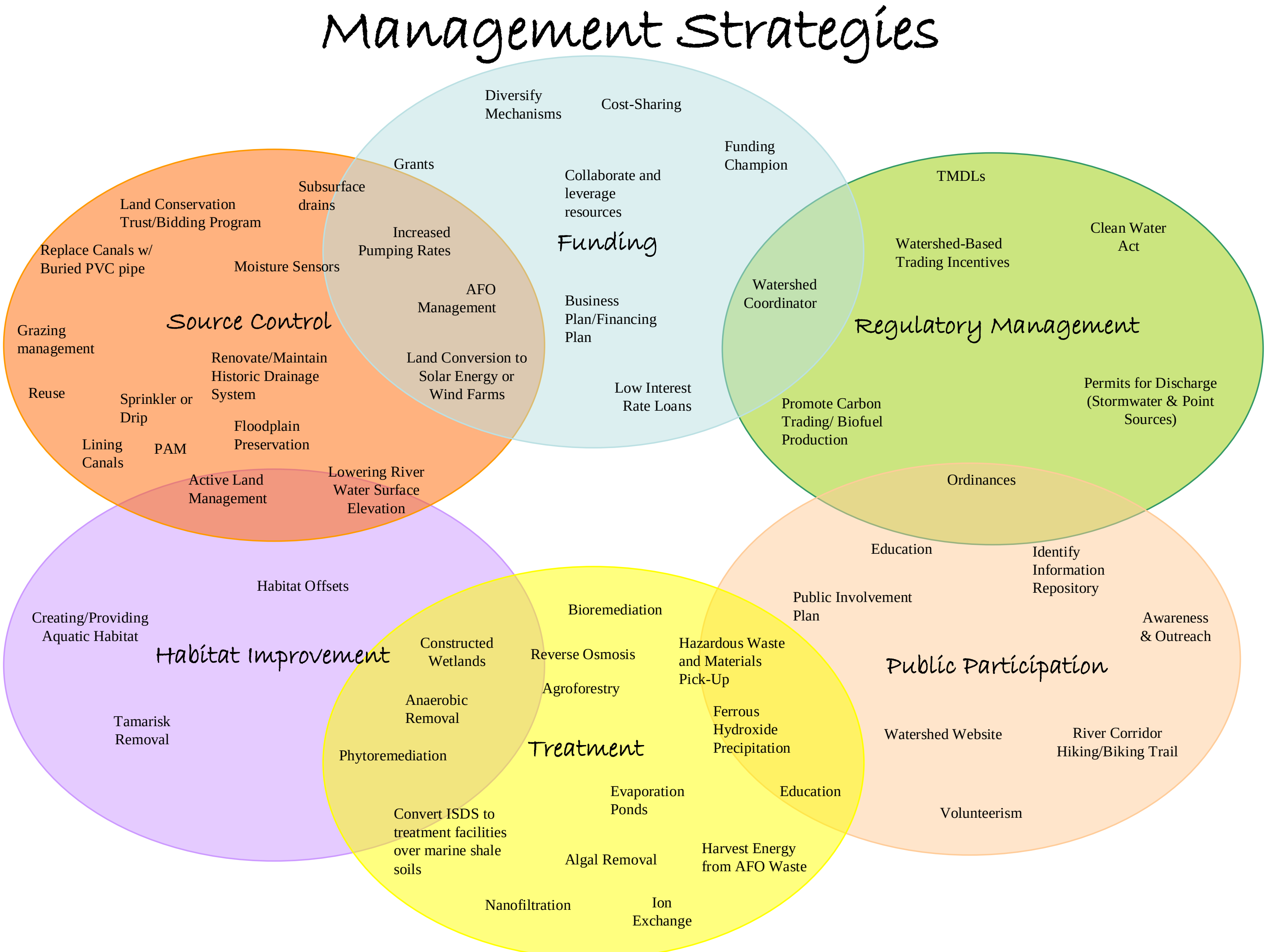
Management Measures	Constituent	Pollutant Reduction Effectiveness	Cost	Source of Data and Information
PAM application	Sediment Selenium	Reduces existing loading; effectiveness varies based on sunlight exposure and application techniques Application on furrow irrigation, 65% - 98% reduction of sediment in runoff waters. 39% - 87% reduction in seepage.	$140/lb selenium reduction; requires annual application $4/acre	GRSTF, 2001 Valliant 1998 - 2002 Gates (LAWCD meeting, 2007)
Canal Lining	Selenium Salinity Uranium	Reduces existing selenium and salinity loading; long term improvement. 28% - 50% selenium reduction in the Montrose Arroyo; slightly less effective in salt load reductions	$1,600/lb Selenium removed annually	GRSTF, 2001 Butler, 2001
Lateral Piping	Selenium Salinity	Reduces existing selenium and salinity loading; long term improvement.	$930/lb selenium removed annually	GRSTF, 2001
Drainage Improvements (Tile Drains)	Selenium Salinity Uranium	With an impermeable layer installed tile drain reduce deep percolation from irrigation. Reduces seepage and existing loading. Effectiveness highly variable based on site specific hydrogeologic conditions. California applications provided salt and selenium reductions. GRSTF notes that detailed knowledge of depth to selenium rich shale and detailed design for application is required.	Costs vary depending on site characteristics; cost per pound of selenium load reduction not available.	GRSTF, 2001 Pacheco Water District, San Jaoquin Valley Drainage Project, 2000
Irrigation improvements (drip irrigation, sprinkler, gated pipe, etc.)	Selenium Uranium	Reduces existing loading	Drip irrigation more costly - $700/pound; protection of water rights would be needed as conserved water may be used by downstream or junior water rights holders; considerations for this use and potential selenium load reductions needed.	GRSTF, 2001
Sewage treatment plants and related facilities (convert homes on septic tanks)	Selenium	Reduces existing loading. Permanent sewage treatment plants can prevent future loadings. Load reduction typically small unless very unique site-specific characteristics exist.	Costs vary. Plants require large capital investment and annual O&M costs.	GRSTF, 2001
Reverse Osmosis	Selenium Salinity	Demonstrated technology that produces high quality treated	$185 to $568 per acre-foot of water treated	California Department of Water Resources,

Management Measures	Constituent	Pollutant Reduction Effectiveness	Cost	Source of Data and Information
	Sediment	water		2005
Nanofiltration	Selenium Salinity Sediment	Up to 95% removal of selenium from drainage waters in the San Joaquin Valley	$600 - $1000 per acre-foot of water treated (includes amortized construction and O&M costs)	California Department of Water Resources, 2005
Evaporation Ponds	Selenium Salinity Other Salts	Reduces existing loads.	$630 per acre-foot treated (+2.8M/yr O&M costs at San Joaquin Valley facility)	California Department of Water Resources, 2005
Constructed wetlands	Selenium	Bench scale operations have indicated high selenium removal rates.	$50-$330 per acre-foot treated (straw bale amendment adds $80 per acre-foot)	California Department of Water Resources, 2005
Anaerobic Removal	Selenium	Reduces existing loads.	$200-$500 per acre-foot treated (includes capital and O&M costs)	California Department of Water Resources, 2005
Precipitation by Ferrous Hydroxide	Selenium	Pilot study at Murietta Farms achieved 90% reduction in selenate concentration. Cost effective final polishing step following microbial treatment	$270 per acre-foot	California Department of Water Resources, 2005
Algal Removal	Selenium	Pilot project selenium removal rates have varied from one order of magnitude to 40-80%	$104-$272 per acre-foot treated	California Department of Water Resources, 2005
Agroforestry	Selenium	Need more information of effectiveness for selenium removal	$150 per acre-foot of treated water	California Department of Water Resources, 2005
Monitor soil moisture and applied water	Selenium	Likely reduces existing loading	Costs vary	GRSTF, 2001
Land Preservation	Selenium Sediment	Reduces potential future selenium loading; does not reduce existing loading.	Costs vary based on location of land.	GRSTF, 2001
Public Outreach	Selenium Salinity Sediment	Unknown selenium, salinity and sediment load reduction, however, programs have resulted in water conservation of 10% to 25%	About $75,000/year for full time position, including administrative support, facilities, and related expenses.	

Sources: Gunnison River Selenium Task Force, 2001.
Gates, 2007.
USGS, Butler, 2001.
California Department of Water Resources, 2005.
Note: These costs are for illustrative purposes and are not intended to be used to consider the feasibility of selenium source control efforts in the Upper Basin as compared to selenium reduction in the Lower Arkansas Watershed.
* Costs based on a variety of assumptions specific to the Uncompahgre Valley as described in the *Evaluation and Screening of Suggested Remediation Measures Lower Gunnison River Basin / Uncompahgre River Area* (Gunnison River Selenium Task Force, 2001). Costs should be viewed as rough estimates and are for comparison purposes only. All costs from GRSTF based on January 2000 price level. Costs do not include potential Natural Resources Conservation Service Environmental Quality Improvement Program or Colorado River Salinity Control Forum cost-sharing. The following general costing and effectiveness assumptions were made (Gunnison River Selenium Task Force, 2001):
a. The average annual selenium loads for some of the key drainage areas are as follows: Loutzenhizer Arroyo basin, 4,900 pounds/year; Gunnison River at Whitewater, 20,800 pounds/year; and, Uncompahgre River at Delta, 7,700 pounds/year.
b. Deep percolation volume of 1 to 1.5 acre-feet per acre was assumed for flood-irrigated land.
c. Deep percolation volume from rural-residential units was assumed to be 0.5 acre-feet/acre (0.2 acre-feet per leach filed and average size lawn contribution of 0.3 acre-feet per acre).
d. Water saved by implementation of a measure was assumed to either remain in the stream or be used in some other manner that did not mobilize additional selenium.

e. Measures potentially involving federal funding or permitting by federal agencies were assumed to require mitigation for losses to wetland and wildlife habitat.
f. For structural measures, cost estimates generally include 20 percent contingencies and 22 percent for engineering, design, contract administration, and overhead costs.
g. Cost per pound of selenium load reduction was computed by dividing the Total Annual Cost by the estimated reduction in selenium load in pounds per year. Total Annual Cost was determined to be the sum of the following: 50-year period annualized implementation cost (using the Fiscal Year 1999 federal planning interest rate of 6.875 percent and a capital recovery factor of 0.0713168); and, annual expenditures for facility operation, maintenance, and administration costs.

Figure 6-1 – Potential Management Strategies to Implement in the Lower Arkansas Watershed



7.0 Implementation Plan Elements

The Lower Arkansas Watershed Plan is the initial step towards developing a documented, comprehensive understanding of the Lower Arkansas Watershed by providing a data inventory and assessment of pertinent problems and pollutants and potential solution strategies. The Plan is a coordinated effort towards developing solutions to improve water quality. As recommended management strategies are implemented, watershed goals will be achieved. This section describes the implementation plan and funding needs to achieve success.

7.1 Implementation Plan

In order for this Watershed Plan to be an effective planning and educational tool, watershed stakeholders must continue their involvement to foster solutions to watershed issues. Watershed issues will be brought to the public's attention through local outreach activities including notices in newspapers, fundraisers, festivals and community events. Quarterly watershed meetings and a watershed website will support stakeholder outreach efforts. Support from government entities and stakeholders are also required for implementation of immediate and future watershed projects.

As shown on Table 7-1, Implementation Plan Schedule, the watershed plan will be published, distributed, and submitted to the WQCD and USEPA by the end of the fourth quarter of 2007. Other projects, management strategies, and outreach efforts will be implemented, as identified, over a ten-year period.

Table 7-1. Implementation Plan, Future Activities in the Lower Arkansas River Watershed

Year One	
Category	Project
Public Outreach	Develop Watershed Plan
Public Information/Education	Hire a Watershed Coordinator
Public Information/Education	Develop Watershed Website
Funding	Develop a Business and Financial Plan
Funding	Secure grant funding
Regulatory	Identify water quality mitigation projects for water transfer legislation/water quality trading and offsets
Irrigation Management	Implement PAM on canals, active land management and conduct drip irrigation
Habitat Improvements	Tamarisk Reclamation
Sustainable Strategies	Identify Market for Carbon Trading/Biofuel Production
Year Two	
Public Outreach	Develop and implement public improvement plan
Public Outreach	Implement Hazardous Waste Material Pick Up Program
Land Management	Develop Land Use Management Priorities
Public Information/Education	Present landowners and operators with costs and benefits of adoption of management strategies
Habitat Improvements	Tamarisk Reclamation

Sustainable Strategies	Implement Carbon Trading/Biofuel Production Projects
Funding	Watershed Coordinator will Secure Grants and Additional Funding
Year Three	
Regulatory	Implement water quality projects for IBCC Mitigation Bank
Habitat Improvements	Tamarisk Reclamation
Sustainable Strategies	Implement carbon Trading/Biofuel Production projects
Public Information/Education	Work with landowners and present incentives for participation in land trust and other management priorities.
Land Management	Acquire conservation easement and implement land trust/bidding program
Funding	Secure grant funding
Year Four	
Habitat Improvements	Watershed Trading/Selenium and Biological Monitoring
Habitat Improvements	Tamarisk Reclamation
Public Information/Education	Educate public on potential benefits of participating in carbon trading program
Sustainable Strategies	Implement carbon Trading/Biofuel Production projects
Funding	Secure grant funding
Year Five	
Sustainable Strategies	Harvest energy from AFO wastes/
Habitat Improvements	Tamarisk Reclamation
Public Information/Education	Educate public on potential benefits of participating in AFO energy harvesting carbon trading program
Sustainable Strategies	Implement carbon Trading/Biofuel Production projects
Funding	Secure grant funding
Regulatory	Implement Watershed based Trading project
Year Six	
Irrigation Management	Renovate and Maintain Drain System
Habitat Improvements	Tamarisk Reclamation
Sustainable Strategies	Implement carbon Trading/Biofuel Production projects
Funding	Secure grant funding
Public Information/Education	Educate public on potential benefits of participating in carbon trading program; encourage agricultural users to obtain funding for irrigation management through programs such as EQIP
Land Management	Acquire conservation easement and implement land bidding program
Regulatory	Implement Watershed based Trading project
Year Seven	
Irrigation Management	Earthen channel lining replacement with PVC,etc.
Irrigation Management	Renovate and Maintain Drain System
Funding	Secure grant funding
Regulatory	Implement Watershed based Trading project
Public Information/Education	Educate public on potential benefits of participating in carbon trading program; encourage agricultural users to obtain funding for irrigation management through programs such as EQIP

Land Management	Acquire conservation easement and implement land bidding program
Year Eight	
Sustainable strategy	Solar energy/Wind farming on non productive lands
Funding	Secure grant funding
Irrigation Management	Renovate and Maintain Drain System
Public Information/Education	Educate public on potential benefits of participating in carbon trading program; encourage agricultural users to obtain funding for irrigation management through programs such as EQIP
Land Management	Acquire conservation easement and implement land bidding program
Year Nine	
Funding	Secure grant funding
Irrigation Management	Renovate and Maintain Drain System
Public Information/Education	Educate public on potential benefits of participating in carbon trading program; encourage agricultural users to obtain funding for irrigation management through programs such as EQIP
Land Management	Acquire conservation easement and implement land bidding program
Habitat Improvements	Tamarisk Reclamation/Public Access
Year Ten	
Funding	Secure grant funding
Irrigation Management	Renovate and Maintain Drain System
Public Information/Education	Educate public on potential benefits of participating in carbon trading program; encourage agricultural users to obtain funding for irrigation management through programs such as EQIP
Land Management	Acquire conservation easement and implement land bidding program
Habitat Improvements	Tamarisk Reclamation/Public access

7.2 Funding Requirements

The anticipated financial resources required to address and implement water quality improvements in the Lower Arkansas River watershed exceed the existing budget. Supplemental funding sources, an estimated $1.5 – 2 million annually, must be acquired to effectively implement management strategies in the watershed. This section discusses potential funding sources to finance the management strategies identified.

In order to implement the recommended management strategies, additional funding and partnerships are imperative. Funding options, described below, will be implemented beginning January, 2008 and continue throughout the watershed process. An implementation sub-committee will be formed and public support secured for each project and management program implemented. As funding is received, projects will be designed, implemented, and monitored.

There are significant opportunities to work collaboratively with the local, state, and federal government to achieve water quality improvements. Continued work with other partners in the watershed will further reveal the potential for leveraging funding opportunities. There are forces presently at work within the Lower Arkansas Watershed, creating potential synergy for decisive and positive action.

7.2.1 Funding Options

Future funding needs within the watershed include dollars for both nonstructural approaches and capital construction dollars (hard costs) and funding for administration and planning (soft costs). Many philosophical discussions arise over who should share in these costs supporting the watershed vision and other actions that must be taken to meet water quality goals.

Several broad categories of fund sources were considered including federal, state, local, and private sources. These funding options are summarized in Table 7-2.

Table 7-2. Potential Funding Mechanisms

	Agency	Program	Details and Applications
Federal	EPA/ CDPHE-WQCD	Section 319 Nonpoint Source Grant	http:www.npscolorado.com/319guide.html Fiscal year 2008 proposals due January 11, 2008.
	EPA	Targeted Watersheds Grants	Competitive grant program that provides funding to community-driven, environmental results oriented watershed projects.
	EPA	Clean Water State Revolving Fund	Provides no interest and low interest loads to communities, citizens groups, businesses, farmers, homeowners, watershed groups, and nonprofits to address polluted runoff. Agriculture, AFO, and stormwater runoff may qualify for funding in the Lower Arkansas Valley. Point and nonpoint source projects may qualify.
	EPA/ NFWF, NAC & NOAA	Five-Star Restoration Program	Supports community-based wetlands and riparian restoration projects. Encourages habitat restoration that provides long-term ecological, educational, and/or socioeconomic benefits.
	EPA	Water Quality Cooperative Agreements	Help states, tribes, interstate agencies, and other public or nonprofit organization develop, implement, and demonstrate innovative approaches relating to causes, effects, extent, prevention, reduction, and elimination of water pollution.
	USFWS	Landowner Incentive Program (LIP)	Provides matching grants to provide technical and financial assistance to private landowners for projects to protect and restore habitats of listed or at-risk species. Example projects include removal of invasive species, modification of grazing practices and fencing to enhance riparian habitat and instream structural improvements.
	USDA-NRCS	EQIP	Provides technical, financial, and educational assistance to farmers and ranchers to address natural resource conservation. Example projects include lining irrigation ditches or installation or more efficient irrigation systems.
	USDA-NRCS	Wildlife Habitat Incentives Program (WHIP)	Voluntary program for people who want to improve wildlife habitat primarily on private lands. The primary target is to improve fish and wildlife habitat.
	USDA	District Conservation Technician Program	Cost-share program to employ staff to implement conservation planning and practices on private lands.
	USDA-FSA	Conservation Reserve Enhancement Program (CREP)	Voluntary land retirement program that helps agricultural producers protect environmentally sensitive land, decrease erosion, restore wildlife habitat, and safeguard ground and surface water.
	USDOT	Transportation Equity Act	http://www.fhwa.dot.gov/tea21/

	Agency	Program	Details and Applications
		for the 21st Century (TEA-21)	
	USFS	Urban and Community Forestry Challenge Cost-Share Awards	http://www.treelink.org/nucfac/ Cost-shares are awarded to achieve support an ecosystem approach to managing urban forests for their benefit to air quality, stormwater runoff, wildlife and fish habitat, and other related ecosystem concerns.
	NFWF	Keystone Initiatives	Provides grants to evaluate best practices and innovative solutions. Initiatives may include invasive species, wildlife and agriculture, and sustainable energy development.
	NFWF	Special Grants	http://www.nfwf.org/AM/Template.cfm?Section=Browse_All_Programs
	All Federal Agencies	Database for Federal Funding Alternatives	http://cfpub.epa.gov/fedfund/. Searchable database of financial assistance sources to fund watershed protection projects.
State	CDOW-DNR	Wetlands for Wildlife Program Private Land Programs State Trust Lands/ Public Access Program	http://wildlife.state.co.us/LandWater/WetlandsProgram/ProjectFunding/ Applications due December 15, 2007. http://wildlife.state.co.us/LandWater/PrivateLandProgram/ http://wildlife.state.co.us/LandWater/StateTrustLands/
	CDPHE – Clean Water Act – 319 NPS	Nonpoint Source Minigrants	Awarded from 319 or State funds to implement nonpoint source pollution reduction projects and to protect or restore watersheds.
	CDOW/Colorado Watershed Network	River Watch Program	Volunteer to monitor water quality and other indicators of watershed health and utilize this data to educate and inform citizens and decision makers.
	Great Outdoors Colorado (GOCO)	State Trails Grant Program/ Wildlife Grants	http://www.goco.org/
	State Universities (CSU, CU, Colorado School of Mines)	Research Programs	Leveraging research to support watershed improvements.
	CSU Extension	Extension Resources	http://www.ext.colostate.edu/menuag.html Resources include crop variety performance testing, limited irrigation management guidance, and water quality programs.
Local	Municipalities	Stormwater Utility Fees	Watershed-specific surcharge to handle the cost of extra services and needs of the watershed.

	Agency	Program	Details and Applications
	Watershed Stakeholders	Watershed-based Trading Program	Provides net financial benefit to participants and can also generate revenue.
	Watershed Groups	Fundraising Events	Examples include auctions, benefits, concerts, festivals, guided tours, or races.
Private	Various (Ford Foundation, Aspen Institute, Lindbergh Foundation, etc.)	Endowments	Can support a variety of watershed enhancement projects.
	Municipal Utilities/Water Interests/Tri State Generation	Transfer Guidelines Committee Watershed Contribution to support meeting water quality requirement associated with potential water use transfer.	Selected Lower Arkansas Watershed projects that require funding can serve as Mitigation projects that water users can financially support to mitigate water quality impacts in the basin.
	Hunting Clubs	Tamarisk Reclamation Projects	Private hunting clubs may financially support tamarisk removal as it supports reclaiming those areas with other appropriate vegetation suitable for waterfowl roosting.
	Nature Conservancy and Ducks Unlimited	Conservation Easement Acquisition	Along stream preservation, riverfront, and wildlife habitat areas

7.3 Measures of Progress and Success

The watershed stakeholders and project leads will be responsible for tracking progress and measuring, documenting, and communicating benefits of various management strategies to the Lower Arkansas Watershed Association. Measurable improvements may address quantity, quality, ecology, habitat, or user related improvement. The criteria that will be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards obtaining water quality standards will be:

- Improvements as reduction in selenium or salinity load
- Habitat improvement through eradication of invasive species with the improvement of the associated wildlife habitat
- Increase in abundance and diversity of certain aquatic species
- Greater recreational opportunities
- Increased property values

Ambient conditions, beneficial use assessments, and environmental indicators may also be used to assess progress, with all assumptions, predictions, and trends being validated to the most practicable extent. The measures of progress and success will be evaluated against the management plan to ensure proper completion of tasks, management efforts, and implementation.

In a five year period it is expected that the implementation efforts will achieve "short-term" management strategies (See Table 6-1). In an eight to ten-year period it is expected that the implementation efforts will have achieved "long-term" management strategies. An annual report will be completed by Southeast Colorado RC&D, Lower Arkansas Watershed Improvement Association, summarizing progress and success stories, pollutant load reductions, funding needs, and support requirements for nonpoint source and other funding programs.

7.4 Addressing the Future (New Concerns & Issues)

Reevaluation of the management plan will occur at 2-year intervals to allow for management strategy updates and implementation and monitoring of projects and programs. Quarterly watershed meetings will garner continued support of watershed implementation and reinforce the Watershed Vision of the Lower Arkansas Watershed Improvement Association.

8.0 TMDL Strategy and Adaptive Watershed Management

Adaptive management incorporates the use of adaptive, or flexible, management, which is imperative due to the inherent uncertainties in understanding natural systems and processes at work within the watershed. Adaptive management is the appropriate management approach for the Lower Arkansas River Watershed as it supports pre-TMDL efforts and encourages processes by which new information about the health of the watershed is incorporated into the watershed management plan, blending research, monitoring, and practical management and observation. These approaches, including a phased TMDL strategy, will allow the Lower Arkansas Watershed Improvement Association to better estimate load reductions and what management strategies work.

The objectives of "adaptive management" include, but are not limited to:

- Create a system to monitor changes in the watershed;
- Evaluate trends using monitoring data;
- Establish priorities for conservation through the development of land-use diversity and management strategies;
- Identify critical threats, such as surface and groundwater pollution, to the watershed or sub-watersheds in order to protect resources and inherent value to society;
- Make watershed management recommendations to ensure sustainable, clean water flow and the maintenance of productive aquatic resources;
- Recommend land-use impact mitigation, habitat restoration programs, and other remediation techniques in watershed disputes;
- Analyze the socio-economic value of the watershed for policy development and management planning;
- Modify the watershed management plan as necessary.

8.1 Recommended TMDL Strategy

Consistent with adaptive management approaches, a phased TMDL strategy is recommended. This phased approach recognizes that the TMDL has elements of uncertainty which need further monitoring, evaluation, and implementation of controls and management strategies designed to improve the water quality. (see EPA, *Guidance for Water Quality Based Decisions*, 1991). The EPA characterizes a phased TMDL as an appropriate mechanism for water quality control. Implementation of a phased approach to TMDL development will allow controls on nonpoint sources to be implemented to meet watershed goals and continued water quality monitoring, specific modeling and special investigative studies be conducted. As the future water quality activities are implemented, as funding allows, the TMDL will be developed and re-visited over an 8-10 year period.

9.0 Literature References

Primary Annotated References:

U.S., 1956. Definite Plan Report of the Frying Pan-Arkansas Project Colorado. Department of Interior.

Abstract:

As one of the earliest documents describing the proposed Frying pan project, the report chronicles the general topographic document of the irrigable lands in the lower Arkansas basin consisting of 242,317 acres of irrigated lands. The report concluded that 91,912 acres of irrigated land had drainage limitations.
In addition, the location and distribution of the 31 drainage districts organized under the 1911 and 1917 drainage statutes is described. These drainage districts with artificial drainage systems both surface and subsurface were constructed coincident with the development of irrigation with the purpose of mitigating high water tables, seepage and salinity problems resulting form irrigation.

Abbott, P.O., 1985. *Description of Water-Systems Operations in the Arkansas River Basin, Colorado.* U.S. Geological Survey Water-Resources Investigation Report 85-4092.

Abstract:

To facilitate a current (1985) project modeling the hydrology of the Arkansas Fiver basin in Colorado, a description of the regulation of water in the basin is necessary. The geographic and climatic setting of the Arkansas River as in that necessitates the use, reuse, importation, and storage of water are discussed. The history of water-resource development in the basin, pal, irrigation, industrial, and multipurpose water systems are described. System descriptions are illustrated with schematic line drawings, and supplemented with physical data tables for the lakes, tunnels, conduits, and canals comprising the various systems. Copies of criteria, under which certain of the water system operate, are included.

Gates, T.K., Garcia, L.A., and Labadie, J.W., 2006. *Toward Optimal Water Management in Colorado's Lower Arkansas River Valley: Monitoring and Modeling to Enhance Agriculture and Environment.* Colorado Water Resources Research Institute Completion Report No. 205.

Abstract:

For several years, Colorado State University has been documenting flow and water quality conditions in Colorado's Lower Arkansas River Valley with the goal of providing data and models that water users and managers can use to enhance both agriculture and the environment in the Valley. Extensive measurements are being made in the field, and some previously gathered data are still undergoing analysis. Models of the irrigated stream-aquifer system are under development, calibration, and refinement. Potential strategies for improving conditions in the river valley are being formulated and investigated. Small-scale pilot testing of solutions are scheduled to begin during the summer of 2006.

The results presented in this technical report are published as a benchmark to document completion of the first phase of this work. They also provide broad information in support of current decision making in the river valley and hopefully will stimulate feedback and discussion. Some of the information presented here is provisional since it is still undergoing refinement and expansion; hence, this document is made available in pdf format on the worldwide web at CSUArkRiver.colostate.edu and will be updated periodically. Portions of the detailed database and modeling tools also will be made accessible at this website.

Thorvaldson, J. and Pritchett, J., 2007. *Economic Impact Analysis of Reduced Irrigated Acreage in Four River Basins in Colorado.* Colorado Water Resources Research Institute Completion Report No. 207.

Abstract:

In this project, a rigorous economic accounting establishes the agricultural and economic demographics for four river basins in Colorado: the East Arkansas, East South Platte, Republican, and Rio Grande Basins. The IMPLAN software is utilized to develop an input-output model for each basin. Impact analysis is then performed on each model in order to approximate the economic effects of a reduction in irrigated acreage on each regional economy. The basins are analyzed separately because each basin has a unique economic base and idiosyncratic water demand/supply conditions. Indeed, the study finds that each basin is affected differently according to the basic demographics of the region, the diversity of the regional economy, the relative importance of irrigated agriculture in the regional economy, and the strength of the backward and forward linkages between irrigated agriculture and supplying and processing sectors. The impacts of the loss of irrigated crop sales are negative in nature and ripple throughout the entire regional economy, affecting every sector.

In terms of total impact, the East South Platte Basin experiences the largest total impact, which is not surprising considering that this basin is projected to experience the largest decrease in irrigated acreage. The South Platte Basin also has the largest multiplier, which can be explained by the greater size and diversity of the East South Platte Basin's economy. However, the East South Platte Basin experiences the lowest per capita impacts due to this basin's relatively high population density. Also, because of the greater diversity of the East South Platte Basin's economy, it may be better equipped to weather such an economic impact than the other economies under consideration. Substantial differences between the regions exist, both in terms of impacts and multipliers, leading to the conclusion that any policy or program intending to mitigate the negative impacts of lost irrigated acreage should not be a one-size-fits-all solution, but rather would be most effective if tailored specifically to the affected region.

Lewis, M.E. and Brendle, D.L., 1998. *Relations of Streamflow and Specific-Conductance Trends to Reservoir Operations in the Lower Arkansas River, Southeastern Colorado.* USGS Water-Resources Investigations Report 97-4239.

Abstract:

To provide for the better management of stream flow in eh lower Arkansas River, two main[stem reservoirs were constructed. John Martin Reservoir, constructed near Las Animas in 1948, and Pueblo reservoir, constructed near Pueblo in 1975, provide for flood control, irrigation, municipal water supply and recreation. Both reservoirs have the potential to alter specific conductance in the Arkansas River because of stream flow management. A change in specific conductance could affect eh intended use of eh water as an agricultural or domestic water supply. Step-trend analysis of stream flow and specific[conductance data for the Arkansas River was used for determining if the operation of pueblo Reservoir or John Martin Reservoir had affected stream flow or specific conductance in the lower Arkansas River. The nonparametric Mann[Whitney[Wilcoxon rank-sum test was used for trend analysis.

Streamflow and specific[conductance data collected at five streamflow gaging stations on the lower Arkansas River and at one station on the upper Arkansas River were analyzed for trends. The station in the upper basin was included in the analysis to differentiate between trends in the lower basin that were caused by differences I the quantity of quality of inflow from the upper basin or were caused by reservoir operations in the lower basin and from the three stations located between pueblo Reservoir and John Marin Reservoir were analyzed for tends that may have occurred after 1974 , which corresponds to the construction of p\Pueblo Reservoir. Data from the two stations located downstream from John Martin Reservoir were analyzed for trends that may have occurred after the implementation of a new reservoir operating plan in 1980.

Cain, D., 1987. *Relations of Specific Conductance to Streamflow and Selected Water-Quality Characteristics of the Arkansas River Basin, Colorado.* USGS Water Investigations Report 87-4041.

Abstract:

Areal, seasonal, and long-term variations in the specific conductance of surface and groundwater in the Arkansas River basin of Colorado were evaluated and relations of specific conductance to streamflow and to concentrations of dissolved solids and major ions were determined as part of an effort to develop a comprehensive hydrologic model of the basin. Mean specific conductance of surface and groundwater was smallest in the upper basin and increased downstream. Smallest mean specific conductance occurred during summer runoff, and largest mean specific conductance occurred during spring and fall low flows. Trends in specific conductance occurred at 18 of 31 surface-water stations and in flow-adjusted specific conductance at 14 of 24 surface-water stations. Logarithmic relations of specific conductance to stream flow were determined for 69 stations. Significant seasonal differences in the relations illustrate the effect of basin characteristics on the relation of specific conductance to streamflow. Relations of specific conductance to dissolved-solids concentration were determined for 28 surface-water stations and for groundwater in alluvial aquifers along the Arkansas River. Relations of specific conductance to concentrations of major ions were determined for 26 surface-water stations and for groundwater in alluvial aquifers along the Arkansas River. (USGS)

Lewis, M.E., 1998. *Relations of Main-Stem Reservoir Operations and Specific Conductance in the Lower Arkansas River, Southeastern Colorado.* USGS Fact Sheet 166-97.

Abstract:

An analysis of historical specific conductance in the Arkansas River changed as the result of main stem reservoir operations. Specific conductance upstream form Pueblo and at Las Animas tended to decrease following the construction of Pueblo Reservoir. Likewise, specific conductance down stream from john Martin Reservoir and Lamar decreased after implementation of the 1980 John Martin Reservoir operation plan the decreased in specific conductance at the site upstream form Pueblo is beneficial from a municipal – drinking- water supply pr\perspective because streamflow in the area provides drinking water to the greater Pueblo area. Although specific conductance increased at the site near Avondale, the increased after 1974 was to large enough to change the salinity hazard for irrigated agriculture . Although specific conductance decreased at Las Animas, downstream from John Martin Reservoir, and at Lamar. the decrease was not large enough t change salinity hazard for irrigated agriculture. The salinity hazard at all three sites remain high to very high (greater than 2,250 μS/cm).

Litke, D.W, 2002. *Lower Arkansas River Comprehensive Database and Data Assessment.* Project No. CO432.

Abstract:

Portions of the Arkansas River in Colorado and Kansas have been included on those State's 303(d) Lists of Impaired Waters. As a result, the States have committed to work jointly to adopt standards and to identify and implement management strategies to reduce constituent concentrations and loads. Available ground-water and surface-water quality data need to be compiled so that stakeholders can adequately assess factors that have affected historic and current water-quality. All of the current electronic sources of water quality data were inventoried and compiled into a single data base consisting of available water-quality information and related ancillary environmental data for the Arkansas River alluvial valley aquifer.

Butler, D.L., 2001. *Effects of Piping Irrigation Laterals on Selenium and Salt Loads, Montrose Arroyo Basin, Western Colorado.* Water Resources Investigations Report 01-4204.

Abstract:

Selenium and salinity are water-quality issues in the Upper Colorado River Basin. Certain water bodies in the lower Gunnison River Basin, including the lower Gunnison River and the Uncompahgre River, exceed the State standard for selenium of 5 micrograms per liter. Remediation methods to reduce selenium and salt loading in the lower Gunnison River Basin were examined. A demonstration project in Montrose Arroyo, located in the Uncompahgre River Basin near Montrose, was done during 1998-2000 to determine the effects on selenium and salt loads in Montrose Arroyo from replacing 8.5 miles of open-ditch irrigation laterals with 7.5 miles of pipe. The participants in the project were the National Irrigation Water Quality Program, the Colorado River Basin Salinity Control Program, the Uncompahgre Valley Water Users Association, and the U.S. Geological Survey. The placing of five laterals in pipe significantly decreased selenium loads in Montrose Arroyo. The selenium load at the outflow monitoring site was about 194 pounds per year less (28-percent decrease) in the period after the laterals were placed in pipe. More than 90 percent of the decrease in selenium load was attributed to a decrease in ground-water load. Salt loads also decreased because of the lateral project, but by a smaller percentage than the selenium loads. The salt load at the outflow site on Montrose Arroyo was about 1,980 tons per year less in the post-project period than in the pre-project period. All of the effects of the demonstration project on selenium and salt loads probably were not measured by this study because some of the lateral leakage that was eliminated had not necessarily discharged to Montrose Arroyo upstream from the monitoring sites. A greater decrease in selenium loads relative to salt loads may have been partially the result of decreases in selenium concentrations in ground water in some areas.

Ortiz, R.F., 2004. *Methods to Identify Changes in Background Water-Quality Conditions Using Dissolved-Solids Concentrations and Loads as Indicators, Arkansas River and Fountain Creek, in the Vicinity of Pueblo, Colorado.* Scientific Investigations Report 2004-5024.

Abstract:

Because no known methods are available to determine what effects future changes in operations will have on water quality, the U.S. Geological Survey, in cooperation with the Southeastern Colorado Water Activity Enterprise, began a study in 2002 to develop methods that could identify if future water-quality conditions have changed significantly from background (preexisting) water-quality conditions. A method was developed to identify when significant departures from background (preexisting) water-quality conditions occur in the lower Arkansas River and Fountain Creek in the vicinity of Pueblo, Colorado. Additionally, the methods described in this report provide information that can be used by various water-resource agencies for an internet-based decision-support tool.

Estimated dissolved-solids concentrations at five sites in the study area were evaluated to designate historical background conditions and to calculate tolerance limits used to identify statistical departures from background conditions. This method provided a tool that could be applied with defined statistical probabilities associated with specific tolerance limits. Drought data from 2002 were used to test the method. Dissolved-solids concentrations exceeded the tolerance limits at all four sites on the Arkansas River at some point during 2002. The number of exceedances was particularly evident when streamflow from Pueblo Reservoir was reduced, and return flows and ground-water influences to the river were more prevalent. No exceedances were observed at the site on Fountain Creek. These comparisons illustrated the need to adjust the concentration data to account for varying streamflow. As such, similar comparisons between flow-adjusted data were done. At the site Arkansas River near Avondale, nearly all the 2002 flow-adjusted concentration data were less than the flow-adjusted tolerance limit which illustrated the effects of using flow-adjusted concentrations. Numerous exceedances of the flow-adjusted tolerance limits, however, were observed at the sites Arkansas River above Pueblo and Arkansas River at Pueblo. These results indicated that the method was able to identify a change in the ratio of source waters under drought conditions. Additionally, tolerance limits were calculated for daily dissolved-solids load and evaluated in a similar manner.

Cain, D., 1985. *Quality of the Arkansas River and Irrigated-Return Flows in the Lower Arkansas River Valley, Colorado.* USGS Water-Investigations Report 84-4273.

Abstract:

Irrigation-return flows in the lower Arkansas River valley of Colorado were investigated using one-time data at 59 sites, monthly data at 4 sites, and intensive data in a small irrigated area. Specific conductance of return flows increased downstream, paralleling specific conductance of irrigation water. During July 1977, Arkansas River streamflow below Manzanola was mostly irrigation-return flow. A similar situation existed during periods of little precipitation in the early and late irrigation seasons during 1974 to 1978. Irrigation-return flows had a large effect on Arkansas River water quality during these times. (USGS)

Miles, D.L., 1977. *Salinity in the Arkansas Valley of Colorado*. Colorado State University Cooperative Extension/EPA Report IAG-D4-0544.

Abstract:

This report was prepared under and EPA interagency agreement between the Colorado Cooperative Extension Service and EPA region 8. The purpose of the project included activities directed toward the development and implementation of measures to improve water quality conditions, particularly salinity as it relates to agriculture as it relates to the Arkansas River Valley. This study, which was one of the first to be conducted in the Arkansas River Valley basin and was conducted to obtain a general understanding of salinity sources and affects. The primary data source used in the analysis were those published by the USGS during the period of 1964 -1974.

The report summarizes the water and salt balance of the main steam of the Arkansas from Canyon City to the Colorado Kansas State line. This was used to determine the primary sources of salts and quantified salt dissolution/precipitation for five major reaches for the study area.

Dash, R.G., 1995. *Irrigation Water Use for the Fort Lyon Canal, Southeastern Colorado, 1989-90.* USGS Water-Investigations Report 94-4051.

Abstract:

The U.S. Geological Survey, in cooperation with the Bent County Board of County Commissioners, began a study to evaluate irrigation water use quantitatively for about 91,630 acres of farmland irrigated from the 103.7-mile-long Fort Lyon Main Canal in the Arkansas River Valley of southeastern Colorado. This report provides information from 1980 and 1990 for four hydrologic components of irrigation water use: Surface-water withdrawals, conveyance losses, ground-water withdrawals, and estimates of theoretical crop consumptive use. Surface-water withdrawals for the Fort Lyon Canal were 211,150 acre-feet (about 2.3 acre-feet per acre) during 1989 and 202,000 acre-feet (about 2.2 acre-feet per acre) during 1990. Conveyance losses occurred during the transport of water in the unlined Fort Lyon Canal. Conveyance losses were as much as 72 (acre-feet per day) per mile in the first division of the canal and generally decreased in the downstream canal divisions. Ground-water withdrawals for the Fort Lyon Canal were estimated to be 38,890 acre-feet (about 0.8 acre-foot per acre irrigated ground water) during 1989 and 33,970 acre-feet (about 0.7 acre-foot per acre irrigated by ground water) during 1990. Theoretical crop consumptive use was estimated to be 227,530 acre-feet (about 2.7 acre-feet per acre of cropland) during 1989 and 251, 130 acre-feet (about 2.9 acre-feet per acre of cropland) during 1990. The total crop irrigation requirement needed from irrigation withdrawals was 172,100 acre-feet (about 2.0 acre-feet per acre of cropland) during ` 1989 and 190,050 acre-feet (about 2.2 acre-feet per acre of cropland) during 1990. Crops cultivated in the five divisions of the canal were alfalfa, sorghum, corn, wheat, pasture, and spring grains.

Dash, R.G. and Ortiz, R.F., 1996. Water-Quality Data for the Arkansas River Basin, 1990-1993. USGS Open-File Report 95-464.

Abstract:

Water-quality data were collected and compiled for 59 surface-water stations in the Arkansas River Basin of Colorado. The purpose of the data collection was to describe selected water-quality characteristics of the Arkansas River from the headwaters downstream to the Colorado-Kansas State line. Data are presented for 19 Arkansas River stations, 31 tributary stations, 2 mine-drainage stations, and 7 trans-mountain diversion stations. Water-quality data presented in this report include instantaneous discharge; onsite measurements of specific conductance, pH, water temperature, and dissolved oxygen; analytical concentrations of bacteria, dissolved solids, major nutrients, trace elements, pesticides, radio-chemicals, and suspended sediment; and quality-assurance data for selected water-quality constituents. Sampling began in April 1990 and continued through March 1993 at the 59 surface-water stations. The basin-wide water-quality study was initiated in 1988 by the U.S. Geological Survey in cooperation with 14 local agencies and the Bureau of Reclamation.

Gates, T.K., Burkhalter, J.P., Labadie, J.W., Valliant, J.C., and Broner, I., 2002. *Monitoring and Modeling Flow and Salt Transport in a Salinity-Threatened Irrigated Valley.* Journal of Irrigation and Drainage Engineering, ASCE., 128(2): 87-99.

Abstract:

Saline high water tables pose a growing threat to the world's productive irrigated land. Much of this land lies along arid alluvial plains, where solutions must now be developed in the context of changing constraints on river management. Findings are presented from the preliminary phase of a project aimed at developing, through well-conceived data collection and modeling, strategies to sustain irrigated agriculture in the salinity-threatened lower Arkansas River Basin of Colorado. Extensive field data from a representative sub-region of the valley reveal the nature and variability of water table depth and salinity, irrigation efficiency and salt loading, and soil salinity. The shallow water table had an average salinity concentration of 3,100 mg/L and an average depth of 2.1 m, and was less than 1.5 m deep under about 25% of the area. Evidence reveals low irrigation efficiencies and high salt loading under each of six canals serving the sub-region. Water table depths less than 2.5–3 m contributed to soil salinity levels that exceed threshold tolerances for crops under about 70% of the area. Preliminary steady-state modeling indicates that only limited improvement can be expected from vertical drainage derived from increased pumping, or from decreased recharge brought about by reduced over-irrigation. Investments in canal lining, horizontal subsurface drainage, and improved river conditions also will need consideration.

Goff, K., Lewis, M.E., Person, M.A., and Konikow, L.F., 1998. *Simulated Effects of Irrigation on Salinity in the Arkansas River Valley in Colorado.* Ground Water, 36(1): 76-86.

Abstract:

Agricultural irrigation has a substantial impact on water quantity and quality in the lower Arkansas River valley of southeastern Colorado. A two dimensional flow and solute transport model was used to evaluate the potential effects of changes in irrigation on the quantity and quality of water in the alluvial aquifer and in the Arkansas River along an 17.7 km reach of the river. The model was calibrated to aquifer water level and dissolved solids concentration data collected throughout the 24-year study period (1971-95). Two categories for irrigation management were simulated with the calibrated model: (1) a decrease in ground water withdrawals for irrigation; and (2) cessation of all irrigation from ground water and surface water sources. In the modeled category of decreased irrigation from ground water pumping, there was a resulting 6.9% decreased in the average monthly ground water salinity , a 0.6% decrease in average monthly river salinity , and an 11.1% increase in groundwater return flows to the river. In the modeled category of the cessation of all irrigation, average monthly ground water salinity decreased by 25% / average monthly river ground water salinity decreased relative to historical condition for about 12 years before reaching a new dynamic equilibrium condition. Aquifer water levels were not sensitive to and of the modeled scenarios. These

potential changes in salinity could result in improved water quality for irrigation purposed downstream from the affected area.

Herrmann, S.J. and Mahan, K.I., 1977. *Effects of Impoundment on Water and Sediment in the Arkansas River at Pueblo Reservoir.* REC-ERC-76-19. University of Southern Colorado, Pueblo.

Abstract:

This report describes a two-year comprehensive study of the chemical quality of the waters impounded by Pueblo Dam. The primary objectives of this study was to determine the extent of which heavy metals are carried into Pueblo reservoir and there fate in the reservoir environment.

Lewis, M.E., 1999. *Simulated Effects of Water Exchanges on Streamflow and Specific Conductance in the Arkansas Upstream from Avondale, Colorado.* USGS Water-Investigations Report 98-4140.

Abstract:

The potential effects of future water-exchange scenarios on streamflow and specific conductance in the Arkansas River were simulated with two accounting models. The major processes in the models simulated the historical exchange potential in the Arkansas River and the operation of a native and nonnative Arkansas River water exchange. The potential effects of future exchange conditions were simulated using streamflow and specific-conductance data from the 1986-93 water – year study period. Hydrologic conditions during the study period were considered about average, compared to the long-term (1966-96) conditions. Therefore, the simulation results were indicative of the potential effects of future exchanges conditions on streamflow and specific conductance during periods of average hydrologic conditions.

Simulated specific conductance increased at all stations in response to the simulated exchanges. The median increase in the daily mean specific conductance at all stations range from a minimum of about 1 percent for a simulation of Aurora's maximum exchange demand and a 50-percent increase in Colorado Springs' historical exchange demand to about 7 percent for a simulation of the maximum exchange demand for both exchanges. The simulated increase in specific conductance resulted in an increased frequency of exceedance for the secondary drinking-water standard for dissolved solids of 500 milligrams per liter during low flow on this at a site located 9 miles downstream from Pueblo Reservoir. The simulated increase in salinity did not result in any changes in the historical irrigation salinity hazard for water in the Arkansas River.

Nolan, B.T. and Clark, M.L., 1997. *Selenium in Irrigated Agricultural Areas of the Western United States.* Journal of Environmental Quality, 26: 849-857.

Abstract:

A logistic regression model was developed to predict the likelihood that Se exceeds the USEPA chronic criterion for aquatic life (5µg/L) in irrigated agricultural areas of the western USA. Preliminary analysis of explanatory variables used in the model indicated that surface-water Se concentration increase with increased dissolved solids (DS) concentration and with the presence of upper Cretaceous, mainly marine sediment.

Ortiz, R.F., Lewis, M.E., and Radell, M., 1998. Water-Quality Assessment of the Arkansas River Basin, Southeastern Colorado, 1990-93. USGS Water Resources Investigations Report 97-4111.

Abstract:

This report describes the spatial and temporal variations in water-quality conditions in the Arkansas River Basin between April 1990 and March 1993. Discussions focus on the site-to –site variability of water quality in the main stem of the river in the upper basin (upstream from Pueblo) and in the lower basin (from Pueblo to the Colorado- Kansas State line). Water- quality data are presented by strawflower regime. In general, the data were separated into three stream flow regimes that are defined as: low flow (October-April), snowmelt runoff (May-June), and post-snowmelt runoff off (July- September)l For trace elements in the upper basin, data are further separated into an early snowmelt runoff period in April; therefore, the low-flow regime for trace elements in the upper basin is defined as October through March. The water quality perimeters that were assessed included those in 8 general categories these are 1. Dissolved oxygen pH, 2. Dissolved solids and major ions. 3. Trace elements, 4. nutrients, 5. radiochemical constituents. 6. Pesticides, 7.suspended sediment and 8. Bacteria.

Stoner, J.D., 1984. *Dissolved Solids in the Arkansas River Basin.* National Water Summary 1984 – Water-Quality Issues, pp. 79-84.

Sutherland, P.L, 2002. *Achieving a Sustainable Irrigated Agroecosystem in the Arkansas River Basin: A Historical Perspective and Overview of Salinity, Salinity Control Principles, Practices, and Strategies.* Proceedings, Central Plains Irrigation Association.

Abstract:

The report summarized the physical graphic features and agro ecology of the Arkansas River Drainage basin and there impact on there nature and sources of salt.

Troutman, B.M., Edelmann, P., and Dash, R.G., 2005. *Variability of Differences Between Two Approaches for Determining Ground-Water Discharge and Pumpage, Including Effects of Time Trends, Lower Arkansas River Basin, Southeastern Colorado, 1998-2002*. SIR 2005-5063.

Abstract:

In the mid-1990s, the Colorado Division of Water Resources (CDWR) adopted rules governing measurement of tributary ground-water pumpage for the Arkansas River Basin. The rules allowed ground-water pumpage to be determined using one of two approaches—power conversion coefficient (PCC) or totalizing flowmeters (TFM). In addition, the rules allowed a PCC to be applied to the electrical power usage up to 4 years in the future to estimate ground-water pumpage.

This report compared measured ground-water pumpage using TFMs to computed ground-water pumpage using PCCs by developing statistical models of relations between explanatory variables, such as site, time, and pumping water level, and dependent variables, which are based on discharge, PCC, and pumpage. When differences in pumpage (*diffP*) were computed using PCC measurements and power consumption for the same year (1998-2002), the median *diffP*, depending on the year, ranged from +0.1 to -2.9 percent; the median *diffP* for the entire period was -1.5 percent. However, when *diffP* was computed using PCC measurements applied to the next year's power consumption, the median *diffP* was -0.3 percent; and when PCC measurements were applied 2, 3, or 4 years into the future, median *diffPs* were +1.8 percent for a 2-year forward lag and +5.3 percent for a 4-year forward lag, indicating that pumpage computed with the PCC approach, as generally applied under the ground-water pumpage measurement rules by CDWR, tended to overestimate pumpage as compared to pumpage using TFMs when PCC measurement was applied to future years of measured power consumption.

Taylor, O.J. and Luckey, R.R., 1974. *Water-Management Studies of a Stream-Aquifer System, Arkansas River Valley, Colorado.* Ground Water, 12(1): 22-38.

Major, T.J., Hurr, R.T., and Moore, J.E., 1970. *Hydrogeologic Data for the Lower Arkansas River Valley, Colorado.* Colorado Water Conservation Board, Basic-Data Release No. 21.

Cain.D., Baldridge, D. and Edelmann, P., 1980. *Waste-Assimilation Capacity of the Arkansas River in Pueblo County, Colorado, as It Relates to Water-Quality and Stream Classification*. Water-Resources Investigation 80-82.

Abstract:

The waste-assimilation capacity of a 42-mile reach of the Arkansas River in Pueblo County, Colo., was evaluated using a one-dimensional steady-state water-quality model. The model is capable of accurately predicting concentrations of carbonaceous biochemical oxygen demand, total ammonia, total nitrate and dissolved oxygen; predicted concentrations of total organic nitrogen and total nitrite are less accurate. Simulation capability for non-ionized ammonia was provided by defining its relationship to total ammonia. The model was used to simulate the water-quality effects of 63 combinations of wastewater treatment at the Pueblo Wastewater Treatment Plant and CF and I Steel Corporation. The mixing zone of the effluent from the Pueblo Wastewater Treatment Plant with the Arkansas River was determined to be 2.7 miles in length during the study. (USGS)

Cain,D. and Edelmann, P., 1980. *Selected Hydrologic Data, Arkansas River Basin, Pueblo and Southeastern Fremont Counties, Colorado, 1975-1980.* Open-File Report 80-1185.

Abstract:

Selected hydrologic data collected in 1975-80 as part of water-quality investigations by the U.S. Geological Survey in Pueblo and southeastern Fremont Counties, Colo., are presented in this report. The data, in tabular form, consist of streamflow-discharge measurements for 33 sites, channel-geometry measurements for 97 sites, travel time data for 12 sites, and field and laboratory water-quality analyses for 194 sites. Federal, state, and local officials may find these data useful in making decisions relating to the management of water resources of the area. (USGS)

Goddard, K.E., 1980. *Calibration and Potential Uses of a Digital Water-Quality Model for the Arkansas River in Pueblo County, Colorado.* Water-Resources Investigations 80-38.

Abstract:

The U.S. Geological Survey conducted a 1-year study to calibrate and demonstrate the use of a steady-state water quality model for a 42-mile reach of the Arkansas River in Pueblo County, Colo. Based on the calibration, the model is capable of accurately predicting concentrations of carbonaceous biochemical oxygen demand, total organic nitrogen, total nitrite, and total orthophosphate; predicted concentrations of total ammonia, total nitrate, and dissolved oxygen will be somewhat less accurate. Additional data are needed to determine the model 's capability to predict concentrations of coliform bacteria. Potential uses of the model were demonstrated by simulating the effects of different waste water discharges on streamflow quality, using water-quality and stream-discharge data provided by the Pueblo Area Council of Governments. Selected results for carbonaceous biochemical oxygen demand and total ammonia from three simulations illustrate the capability of the model. (USGS)

Burns, A.W., 1989. *Calibration and Use of an Interactive Accounting Model to Simulate Dissolved Solids, Streamflow, and Water-Supply Operations in the Arkansas River Basin, Colorado*. Water USGS, Resources Investigation Report 88-4214.

Abstract:

An interactive-accounting model was used to simulate the dissolved solids, streamflow, and water-supply operations in the Arkansas River basin, Colorado. The model calculates streamflow for incremental drainage areas by use of regression equations and time series of independent variables such as snowpack, precipitation, or gaged streamflow.

Burns, A.W., 1988. *Computer-Program Documentation of an Interactive-Accounting Model to Simulate Streamflow, Water Quality, and Water-Supply Operations in a River Basin.* Water-Resources Investigations Report 88-4012.

Abstract:

This report describes an interactive-accounting model used to simulate streamflow, chemical-constituent concentrations and loads, and water-supply operations in a river basin. The model uses regression equations to compute flow from incremental (inter-node) drainage areas. Conservative chemical constituents (typically dissolved solids) also are computed from regression equations. Both flow and water quality loads are accumulated downstream. Optionally, the model simulates the water use and the simplified groundwater systems of a basin. Water users include agricultural, municipal, industrial, and in-stream users , and reservoir operators. Water users list their potential water sources, including direct diversions, groundwater pumpage, inter-basin imports, or reservoir releases, in the order in which they will be used. Direct diversions conform to basin-wide water law priorities. The model is interactive, and although the input data exist in files, the user can modify them interactively. A major feature of the model is its color-graphic-output options. This report includes a description of the model, organizational charts of subroutines, and examples of the graphics. Detailed format instructions for the input data, example files of input data, definitions of program variables, and listing of the FORTRAN source code are Attachments to the report. (USGS)

Mueller, D.K., and Spruill, T.B., DeWeese, L.R., Garner, A.J., 1991. *Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Middle Arkansas River Basin, Colorado and Kansas, 1988-89.* Water-Resources Investigations Report 91-4060.

Abstract:

During 1988, a reconnaissance investigation was made of irrigation-drainage quality in the middle Arkansas River basin in southeastern Colorado and southwestern Kansas. This area was selected because high concentrations of selenium previously had been detected at several sites on the Arkansas River and its tributaries. This investigation was part of a program initiated in 1985 by eh U.S. Department of the Interior to evaluate the effects of irrigation drainage on water quality, bottom sediment, and biota in the Western United states. Water, bottom-sediment, and biota samples were collected at 14 surface-water sites—7 sites on the Arkansas River, 2 sites on tributary streams, and 5 sites on reservoirs. Ground-water samples were collected from five municipal wells completed in the Arkansas River valley alluvial aquifer.

Watts, K.R, 2006. *Hydrostratigraphic Framework of the Raton, Vermejo, and Trinidad Aquifers in the Raton Basin, Las Animas County, Colorado*. SIR 2006–5129.

Abstract

Exploration for and production of coalbed methane has increased substantially in the Rocky Mountain region of the United States since the 1990s. During 1999?2004, annual production of natural gas (coalbed methane) from the Raton Basin in Las Animas County, Colorado, increased from 28,129,515 to 80,224,130 thousand cubic feet, and the annual volume of ground water co-produced by coalbed methane wells increased from about 949 million gallons to about 2,879 million gallons. Better definition of the hydrostratigraphic framework of the Raton, Vermejo, and Trinidad aquifers in the Raton Basin of southern Colorado is needed to evaluate the long-term effects of coalbed methane development on the availability and sustainability of ground-water resources. In 2001, the U.S. Geological Survey, in cooperation with the Colorado Water Conservation Board, began a study to evaluate the hydrogeology of the Raton Basin in Huerfano and Las Animas Counties, Colorado. Geostatistical methods were used to map the altitude of and depths to the bottoms and tops (structure) and the apparent thicknesses of the Trinidad Sandstone, the Vermejo Formation, and the Raton Formation in Las Animas County, based on completion reports and drillers? logs from about 1,400 coalbed methane wells in the Raton Basin. There was not enough subsurface control to map the structural surfaces and apparent thicknesses of the aquifers in Huerfano County. Geostatistical methods also were used to map the regional water table in the northern part of Las Animas County, based on reported depth to water from completion reports of water-supply wells. Although these maps were developed to better define the hydrostratigraphic framework, they also can be used to determine the contributing aquifer(s) of existing water wells and to estimate drilling depths of proposed water wells. These maps of the hydrostratigraphic framework could be improved with the addition of measured sections and mapping of geologic contacts at outcrops along the eastern and western margins of the Raton Basin.

Wittler, J.M., Cardon, G.E., Gates, T.K., Cooper, C.A., and Sutherland, P.L., 2006. *Calibration of Electromagnetic Induction for Regional Assessment of Soil Water Salinity in an Irrigated Valley*. Journal of Irrigation and Drainage Engineering, ASCE, 132(5): 436-444.

Abstract:

Electromagnetic instruments are increasingly being used for in situ analysis and mapping of soil salinity in irrigated soils. This study develops calibration models for salinity assessment over regional scales on the order of tens of thousands of hectares. These models relate apparent soil electrical conductivity measured with the EM-38 electromagnetic induction meter (Geonics Ltd.) to traditional laboratory-measured saturated paste electrical conductivities (EC_e). The study area is located in the Lower Arkansas River Valley, Colo. and is divided into two regions. At each of 414 randomly selected calibration sites, an EM-38 reading was taken and multiple soil samples were extracted for analysis. The sites chosen have soil EC_e values ranging from 1 to 18 dS/m, gravimetric water contents (WC) from 0.02 to 0.4, and textures ranging from sands to clays. The best model for predicting soil EC_e in both study regions is bi-variate nonlinear and includes EM-38 vertical readings (EM_V) and WC as covariates. Uncertainty in the calibration equations is addressed and tests are conducted at 48 independent sites. Results indicate that, while uncertainty is considerable in regional scale surveys, electromagnetic instruments can be calibrated for rapid reconnaissance of soil water salinity, providing reasonably accurate identification of salinization categories.

Wright, W.G., 1999. *Oxidation and Mobilization of Selenium by Nitrate in Irrigation Drainage.* Journal of Environmental Quality, 28(4): 1182-1187.

Abstract**:**

Selenium (Se) can be oxidized by nitrate (NO_3^-) from irrigation on Cretaceous marine shale in western Colorado. Dissolved Se concentrations are positively correlated with dissolved NO_3^- concentrations in surface water and ground water samples from irrigated areas. Redox conditions dominate in the mobilization of Se in marine shale hydrogeologic settings; dissolved Se concentrations increase with increasing platinum-electrode potentials. Theoretical calculations for the **oxidation** of Se by NO_3^- and oxygen show favorable Gibbs free energies for the **oxidation** of Se by NO_3^-, indicating NO_3^- can act as an electron acceptor for the **oxidation** of Se. Laboratory batch experiments were performed by adding Mancos Shale samples to zero-dissolved-oxygen water containing 0, 5, 50, and 100 mg/L NO_3^- as N (mg N/L). Samples were incubated in airtight bottles at 25°C for 188 d; samples collected from the batch experiment bottles show increased Se concentrations over time with increased NO_3^- concentrations. Pseudo first-order

rate constants for NO^-_3 **oxidation** of Se ranged from 0.0007 to 0.0048/d for 0 to 100 mg N/L NO^-_3 concentrations, respectively. Management of N fertilizer applications in Cretaceous shale settings might help to control the **oxidation** and mobilization of Se and other trace constituents into the environment.

Zielinski, R.A., Asher-Bolinder, S., and Meier, A.L., 1995. *Uraniferous Waters of the Arkansas River Valley, Colorado, U.S.A: A Function of Geology and Land Use*. Applied Geochemistry, 10: 133-144.

Abstract:

The effect of local geology and land-use practices on dissolved U was investigated by analysis of surface water and some springs in the Arkansas River valley of southeastern Colorado. Water samples were collected during a 2 week period in April, 1991. The rate of increases of U concentration with distance downriver increased markedly as the rive flowed from predominantly undeveloped lands underlain by igneous and metamorphic rocks to agriculturally developed lands underlain by marine shale and limestone.

Zielinski, R.A., Asher-Bolinder, S., Meier, A.L., Johnson, C.A., and Szabo, B.J., 1997. *Natural or fertilizer-Derived Uranium in Irrigation Drainage: A Case Study in Southeastern Colorado*. Applied Geochemistry, 12: 9-21.

Abstract:

Drainage from heavily cultivated soils may be contaminated with U that is leached from the soil or added as a trace constituent of PO_4 based commercial fertilizer. The effect of decades-long application of U-rich fertilizer on the U concentration of irrigation drainage was investigated in a small ($14.2km^2$) drainage basin in southeastern Colorado. Results of this study indicated minimal impact of fertilizer-U compared to natural U leached lands indicated marked decoupling of the building up of dissolved NO_3 and U.

Watershed Assessments:

U.S. Department of Agriculture.,1981. *Arkansas River Basin Cooperative Study Report.* Cooperative Study Economic Research Service, Forest Service, Soil Conservation Service in association with the Colorado Conservation Board. Denver, Colorado.

U.S. Department of Agriculture., 1992. *Lower Arkansas River Basin Water Quality Study* Soil Conservation Service. Lakewood, Colorado.

U.S. Department of Agriculture, 2007. *Horse Watershed, Hydrologic Unit Code 11020008, Rapid Assessment.* RWA 11020008, Natural Resource Conservation Service, Lakewood, Colorado.

U.S. Department of Agriculture, 2007. *Lake Meredith Watershed, Hydrologic Unit Code 11020005, Rapid Assessment .* RWA 11020005, Natural Resource Conservation Service Lakewood, Colorado.

U.S. Department of Agriculture, 2007. *Purgatoire Watershed, Hydrologic Unit Code 11020010, Rapid Assessment.* RWA 11020010, Natural Resource Conservation Service, Lakewood, Colorado.

U.S. Department of Agriculture, 2007. *Rush Watershed, Hydrologic Unit Code 11020012, Rapid Assessment.* RWA 11020012, Natural Resource Conservation Service Lakewood, Colorado.

U.S. Department of Agriculture, 2007. *Two Butte Watershed, Hydrologic Unit Code 11020013, Rapid Assessment.* RWA 11020013, Natural Resource Conservation Service Lakewood, Colorado.

U.S. Department of Agriculture, 2007. *Upper Arkansas – John Martin Reservoir Watershed, Hydrologic Unit Code 11020009, Rapid Assessment..* RWA 11020009, Natural Resource Conservation Service, Lakewood, Colorado.

NEPA Environmental Assessments:

U.S. Department of Agriculture. 2001. *Six Mile-St. Charles Watershed Pueblo County Colorado* South Pueblo County Conservation District, Colorado State Soil Conservation Board and Natural Resource Conservation Service, Lakewood, Colorado.

U.S. Department of Agriculture. 2001. *Holbrook Lake Ditch Watershed Otero County Colorado*. East Otero Soil Conservation District, Holbrook Mutual Irrigation Company, Colorado State Soil Conservation Board, and Natural Resource Conservation Service, Lakewood, Colorado.

U.S. Department of Agriculture. 1996. *Highline Breaks Watershed Otero County Colorado*. West Otero Soil Conservation District, East Otero Soil Conservation District, Colorado State Soil Conservation Board, and Natural Resource Conservation Service, Lakewood, Colorado.

U.S. Department of Agriculture. 1996. *Limestone-Graveyard Creeks Watershed Prowers and Bent County Colorado*. Bent Soil Conservation District, Prowers Soil Conservation District, Colorado State Soil Conservation Board, Fort Lyon Canal Company, and Natural Resource Conservation Service, Lakewood, Colorado.

Miscellaneous References:

Environmental Protection Agency, 1986. *Secondary maximum contaminant levels (*section 143.3 of part 143, National secondary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100-149, pp. 587– 590.

Environmental Protection Agency, 2000. Watershed Analysis and Management (WAM) Guide for Tribes. EPA Watershed Analysis and Management Project.

Environmental Protection Agency, 2003. Getting in Step: A Guide for Conducting Watershed Outreach Campaigns. EPA, 841-B-03-002.

North American Lake Management Society (NALMS), 2007. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues,* 2nd Edition.

Regional Interagency Executive Committee, 1995. *Ecosystem Analysis at the Watershed Scale: A Federal Guide for Watershed Analysis*, version 2.2, Portland, Oregon.

State of Kansas, 2007. *Proponents Prehearing Statement of the State of Kansas.* Proposed Temporary Modifications for Selenium on Lower Arkansas Segment 1c Under Revised Water Quality Classifications, Standards and Designations for Multiple Segments in the Arkansas River Basin, Regulation #32 (5 CCR 1002-32).

Water Quality Control Commission, 2006. *Status of Water Quality in Colorado: The Update to the 2020 and 2004 305(b) Reports.*

Amweg, E.L., Stuart, D.L., and Weston, D.P., 2003. *Comparative Bioavailability of Selenium to Aquatic Organisms after Biological Treatment of Agricultural Drainage Water.* Journal of Aquatic Toxicology, 63: 13-25.

Breetz, H., et al., 2004. *Water Quality Trading and Offset Initiative in the U.S.: A Comprehensive Study.* Dartmouth College.

California Department of Water Resources, Salton Sea Ecosystem Restoration Program, 2005. *Salton Sea Ecosystem Restoration Plan: Upper Basin Selenium Source Control Report*.

Gunnison River Selenium Task Force (GRSTF), 2001. *Evaluation and Screening of Suggested Remediation Measures Lower Gunnison River/Uncompahgre River Area.*

California Department of Water Resources (DWR), 2005. *Treatment Technologies and Management Techniques to Limit Exposure to Selenium.*

Colorado Department of Public Health and Environment, 2007. *Regulation No. 32: Classification of Numeric Standards for Arkansas River Basin,* 5 CCR 1002-32.

City of La Junta, 2007. *Proponents' Prehearing Statement to the Water Quality Control Commission,* Rulemaking Hearing for the Consideration of the Adoption of Revised Water Quality Classification, Standards, and Designations for Multiple Segments in the Arkansas River Basin, Regulation #32 (5 CCR 1002-32) and in the Rio Grande Basin, Regulation #36 (5 CCR 1002-36). D0443669.8.

MSE Technology Applications, Inc., prepared for EPA and U.S. Department of Energy, 2001. *Final Report – Selenium Treatment/Removal Alternatives Demonstration Project; Mine Waste Technology Program,* Activity iii, Project 20.

Yergert, M., Austin, B., and Waskom, R., 2002. *Ground Water Monitoring in the Arkansas Valley.* Agricultural Chemicals and Groundwater Protection Fact Sheet 12.

Kuroda, P.K., Burchfield, L.A., and Essien, I.O., 1989. *Thorium, Uranium, and Plutonium Isotopes in the Arkansas River.* Journal of Radioanalytical and Nuclear Chemistry, 131(2): 369-375.

APPENDIX A

GLOSSARY OF TERMS

Glossary of Basic Water Quality Terms

Acre-foot - A volume of water equal to 1 foot in depth and covering 1 acre; equivalent to 43,560 cubic feet or 325,851 gallons.

Algae - Chlorophyll-bearing nonvascular, primarily aquatic species that have no true roots, stems, or leaves; most algae are microscopic, but some species can be as large as vascular plants.

Alkalinity – Generally, refers to the sum of the concentration of bicarbonate and carbonate of an aqueous solution.

Alluvium - Deposits of clay, silt, sand, gravel or other particulate rock material left by a river in a streambed, on a flood plain, delta, or at the base of a mountain.

Alluvial aquifer - A water-bearing deposit of unconsolidated material (sand and gravel) left behind by a river or other flowing water.

Ambient- Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants or completely enveloping. From a time series of measurements of a parameter at a given location the ambient value is the 85th percentile.

Amalgamation - The dissolving or blending of a metal (commonly gold and silver) in mercury to separate it from its parent material.

Ammonia - A compound of nitrogen and hydrogen (NH_3) that is a common by-product of animal waste. Ammonia readily converts to nitrate in soils and streams.

Anomalies - As related to fish, externally visible skin or subcutaneous disorders, including deformities, eroded fins, lesions, and tumors.

Anthropogenic - Occurring because of, or influenced by, human activity.

Aquatic guidelines - Specific levels of water quality which, if reached, may adversely affect aquatic life. These are non-enforceable guidelines issued by a governmental agency or other institution.

Aquatic-life criteria - Water-quality guidelines for protection of aquatic life. Often refers to U.S. Environmental Protection Agency water-quality criteria for protection of aquatic organisms. *See also* Water-quality guidelines, Water-quality criteria, and Freshwater chronic criteria.

Aquifer - A water-bearing layer of soil, sand, gravel, or rock that will yield usable quantities of water to a well.

Artificial recharge - Augmentation of natural replenishment of ground-water storage by some method of construction, spreading of water, or by pumping water directly into an aquifer.

Atmospheric deposition - The transfer of substances from the air to the surface of the Earth, either in wet form (rain, fog, snow, dew, frost, hail) or in dry form (gases, aerosols, particles).

Background concentration - A concentration of a substance in a particular environment that is indicative of minimal influence by human (anthropogenic) sources.

Bank - The sloping ground that borders a stream and confines the water in the natural channel when the water level, or flow, is normal.

Base flow - Sustained, low flow in a stream; ground-water discharge is the source of base flow in most places.

Basic Fixed Sites - Sites on streams at which streamflow is measured and samples are collected for temperature, salinity, suspended sediment, major ions and metals, nutrients, and organic carbon to assess the broad-scale spatial and temporal character and transport of inorganic constituents of streamwater in relation to hydrologic conditions and environmental settings.

Basin -*See* Drainage basin.

Basin and Range physiography - A region characterized by a series of generally north-trending mountain ranges separated by alluvial valleys.

Bedload - Sediment that moves on or near the streambed and is in almost continuous contact with the bed.

Bedrock - General term for consolidated (solid) rock that underlies soils or other unconsolidated material.

Bed sediment - The material that temporarily is stationary in the bottom of a stream or other watercourse.

Bed sediment and tissue studies - Assessment of concentrations and distributions of trace elements and hydrophobic organic contaminants in streambed sediment and tissues of aquatic organisms to identify potential sources and to assess spatial distribution.

Benthic - Refers to plants or animals that live on the bottom of lakes, streams, or oceans.

Benthic invertebrates - Insects, mollusks, crustaceans, worms, and other organisms without a backbone that live in, on, or near the bottom of lakes, streams, or oceans.

Best management practice (BMP) - An agricultural practice that has been determined to be an effective, practical means of preventing or reducing nonpoint source pollution.

Bioaccumulation - The biological sequestering of a substance at a higher concentration than that at which it occurs in the surrounding environment or medium. Also, the process whereby a substance enters organisms through the gills, epithelial tissues, dietary, or other sources.

Bioavailability - The capacity of a chemical constituent to be taken up by living organisms either through physical contact or by ingestion.

Biochemical - Refers to chemical processes that occur inside or are mediated by living organisms.

Biochemical oxygen demand (BOD) - The amount of oxygen, measured in milligrams per liter, that is removed from aquatic environments by the life processes of microorganisms.

Biodegradation - Transformation of a substance into new compounds through biochemical reactions or the actions of microorganisms such as bacteria.

Biomass - The amount of living matter, in the form of organisms, present in a particular habitat, usually expressed as weight per unit area.

Biota - Living organisms.

Blue-baby syndrome – methemoglobinemia - A condition that can be caused by ingestion of high amounts of nitrate resulting in the blood losing its ability to effectively carry oxygen. It is most common in young infants and certain elderly people.

Breakdown product - A compound derived by chemical, biological, or physical action upon a pesticide. The breakdown is a natural process which may result in a more toxic or a less toxic compound and a more persistent or less persistent compound.

Canopy angle - Generally, a measure of the openness of a stream to sunlight. Specifically, the angle formed by an imaginary line from the highest structure (for example, tree, shrub, or bluff) on one bank to eye level at midchannel to the highest structure on the other bank.

Carbonate rocks - Rocks (such as limestone or dolostone) that are composed primarily of minerals (such as calcite and dolomite) containing the carbonate ion (CO_3^{2-}).

Center pivot irrigation - An automated sprinkler system involving a rotating pipe or boom that supplies water to a circular area of an agricultural field through sprinkler heads or nozzles.

Channelization - Modification of a stream, typically by straightening the channel, to provide more uniform flow; often done for flood control or for improved agricultural drainage or irrigation.

Chlordane - Octachloro-4,7-methanotetrahydroindane. An organochlorine insecticide no longer registered for use in the U.S. Technical chlordane is a mixture in which the primary components are cis- and trans-chlordane, cis- and trans-nonachlor, and heptachlor.

Chlorinated solvent - A volatile organic compound containing chlorine. Some common solvents are trichloroethylene, tetrachloroethylene, and carbon tetrachloride.

Chlorofluorocarbons - A class of volatile compounds consisting of carbon, chlorine, and fluorine. Commonly called freons, which have been used in refrigeration mechanisms, as blowing agents in the fabrication of flexible and rigid foams, and, until several years ago, as propellants in spray cans.

Chrysene - *See* Polycyclic aromatic hydrocarbon (PAH).

Clastic - Rock or sediment composed principally of broken fragments that are derived from preexisting rocks which have been transported from their place of origin, as in sandstone.

Climate - The sum total of the meteorological elements that characterize the average and extreme conditions of the atmosphere over a long period of time at any one place or region of the Earth's surface.

Combined sewer overflow - A discharge of untreated sewage and stormwater to a stream when the capacity of a combined storm/sanitary sewer system is exceeded by storm runoff.

Community - In ecology, the species that interact in a common area.

Concentration - The amount or mass of a substance present in a given volume or mass of sample. Usually expressed as microgram per liter (water sample) or micrograms per kilogram (sediment or tissue sample).

Confined aquifer (artesian aquifer) - An aquifer that is completely filled with water under pressure and that is overlain by material that restricts the movement of water.

Confining layer - A layer of sediment or lithologic unit of low permeability that bounds an aquifer.

Confluence - The flowing together of two or more streams; the place where a tributary joins the main stream.

Constituent - A chemical or biological substance in water, sediment, or biota that can be measured by an analytical method.

Consumptive use - The quantity of water that is not available for immediate reuse because it has been evaporated, transpired, or incorporated into products, plant tissue, or animal tissue. Also referred to as "water consumption".

Contamination - Degradation of water quality compared to original or natural conditions due to human activity.

Contributing area - The area in a drainage basin that contributes water to streamflow or recharge to an aquifer.

Criterion - A standard rule or test on which a judgment or decision can be based.

Crystalline rocks - Rocks (igneous or metamorphic) consisting wholly of crystals or fragments of crystals.

Cubic foot per second (ft^3/s, or cfs) - Rate of water discharge representing a volume of 1 cubic foot passing a given point during 1 second, equivalent to approximately 7.48 gallons per second or 448.8 gallons per minute or 0.02832 cubic meter per second.

Degradation products - Compounds resulting from transformation of an organic substance through chemical, photochemical, and/or biochemical reactions.

Denitrification - A process by which oxidized forms of nitrogen such as nitrate (NO_3^-) are reduced to form nitrites, nitrogen oxides, ammonia, or free nitrogen: commonly brought about by the action of denitrifying bacteria and usually resulting in the escape of nitrogen to the air.

Detect - To determine the presence of a compound.

Detection limit - The concentration below which a particular analytical method cannot determine, with a high degree of certainty, a concentration.

Diatoms - Single-celled, colonial, or filamentous algae with siliceous cell walls constructed of two overlapping parts.

DDT - Dichloro-diphenyl-trichloroethane. An organochlorine insecticide no longer registered for use in the United States.

Dieldrin - An organochlorine insecticide no longer registered for use in the United States. Also a degradation product of the insecticide aldrin.

Discharge - Rate of fluid flow passing a given point at a given moment in time, expressed as volume per unit of time.

Dissolved constituent - Operationally defined as a constituent that passes through a 0.45-micrometer filter.

Dissolved solids - Amount of minerals, such as salt, that are dissolved in water; amount of dissolved solids is an indicator of salinity or hardness.

Diversion - A turning aside or alteration of the natural course of a flow of water, normally considered physically to leave the natural channel. In some States, this can be a consumptive use direct from another stream, such as by livestock watering. In other States, a diversion must consist of such actions as taking water through a canal, pipe, or conduit.

Drainage area - The drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide.

Drainage basin - The portion of the surface of the Earth that contributes water to a stream through overland run-off, including tributaries and impoundments.

Drawdown - The difference between the water level in a well before pumping and the water level in the well during pumping. Also, for flowing wells, the reduction of the pressure head as a result of the discharge of water.

Drinking-water standard or guideline - A threshold concentration in a public drinking-water supply, designed to protect human health. As defined here, standards are U.S. Environmental Protection Agency regulations that specify the maximum contamination levels for public water systems required to protect the public welfare; guidelines have no regulatory status and are issued in an advisory capacity.

Drip irrigation - An irrigation system in which water is applied directly to the root zone of plants by means of applicators (orifices, emitters, porous tubing, perforated pipe, and so forth) operated under low pressure. The applicators can be placed on or below the surface of the ground or can be suspended from supports.

Drought - Commonly defined as being a time of less-than-normal or less-than-expected precipitation.

Ecological studies - Studies of biological communities and habitat characteristics to evaluate the effects of physical and chemical characteristics of water and hydrologic conditions on aquatic biota and to determine how biological and habitat characteristics differ among environmental settings.

Ecoregion - An area of similar climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.

Ecosystem - The interacting populations of plants, animals, and microorganisms occupying an area, plus their physical environment.

Effluent - Outflow from a particular source, such as a stream that flows from a lake or liquid waste that flows from a factory or sewage-treatment plant.

Electrical Conductivity – See Specific Conductance

Endocrine system - The collection of ductless glands in animals that secrete hormones, which influence growth, gender and sexual maturity.

Environmental framework - Natural and human-related features of the land and hydrologic system, such as geology, land use, and habitat, that provide a unifying framework for making comparative assessments of the factors that govern water-quality conditions within and among Study Units.

Environmental sample - A water sample collected from an aquifer or stream for the purpose of chemical, physical, or biological characterization of the sampled resource.

Environmental setting - Land area characterized by a unique combination of natural and human-related factors, such as row-crop cultivation or glacial-till soils.

Ephemeral stream - A stream or part of a stream that flows only in direct response to precipitation or snowmelt. Its channel is above the water table at all times.

EPT richness index - An index based on the sum of the number of taxa in three insect orders, Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), that are composed primarily of species considered to be relatively intolerant to environmental alterations.

Equal-width increment (EWI) sample - A composite sample across a section of stream with equal spacing between verticals and equal transit rates within each vertical that yields a representative sample of stream conditions.

Erosion - The process whereby materials of the Earth's crust are loosened, dissolved, or worn away and simultaneously moved from one place to another.

Eutrophication - The process by which water becomes enriched with plant nutrients, most commonly phosphorus and nitrogen.

Evaporite minerals (deposits) - Minerals or deposits of minerals formed by evaporation of water containing salts. These deposits are common in arid climates.

Evapotranspiration - A collective term that includes water lost through evaporation from the soil and surface-water bodies and by plant transpiration.

Fecal bacteria - Microscopic single-celled organisms (primarily fecal coliforms and fecal streptococci) found in the wastes of warm-blooded animals. Their presence in water is used to assess the sanitary quality of water for body-contact recreation or for consumption. Their presence indicates contamination by the wastes of warm-blooded animals and the possible presence of pathogenic (disease producing) organisms.

Fecal coliform - *See* Fecal bacteria.

FDA action level - A regulatory level recommended by the U.S. Environmental Protection Agency for enforcement by the FDA when pesticide residues occur in food commodities for reasons other than the direct application of the pesticide. Action levels are set for inadvertent pesticide residues resulting from previous legal use or accidental contamination. Applies to edible portions of fish and shellfish in interstate commerce.

Fertilizer - Any of a large number of natural or synthetic materials, including manure and nitrogen, phosphorus, and potassium compounds, spread on or worked into soil to increase its fertility.

Fish community - *See* Community.

Fixed Sites - *See also* Basic Fixed Sites and Intensive Fixed Sites.

Flood - Any relatively high streamflow that overtops the natural or artificial banks of a stream.

Flood irrigation - The application of irrigation water where the entire surface of the soil is covered by ponded water.

Flood plain - The relatively level area of land bordering a stream channel and inundated during moderate to severe floods.

Flowpath - An underground route for ground-water movement, extending from a recharge (intake) zone to a discharge (output) zone such as a shallow stream.

Flowpath study - Network of clustered wells located along a flowpath extending from a recharge zone to a discharge zone, preferably a shallow stream. The studies examine the relations of land-use practices, ground-water flow, and contaminant occurrence and transport. These studies are located in the area of one of the land-use studies.

Fluvial deposit - A sedimentary deposit consisting of material transported by suspension or laid down by a river or stream.

Freshwater chronic criteria - The highest concentration of a contaminant that freshwater aquatic organisms can be exposed to for an extended period of time (4 days) without adverse effects. *See also* Water-quality criteria.

Fumigant - A substance or mixture of substances that produces gas, vapor, fume, or smoke intended to destroy insects, bacteria, or rodents.

Furrow irrigation - A type of surface irrigation where water is applied at the upper end of a field and flows in furrows to the lower end.

Gaging station - A particular site on a stream, canal, lake, or reservoir where systematic observations of hydrologic data are obtained.

Geothermal - Relating to the Earth's internal heat; commonly applied to springs or vents discharging hot water or steam.

Granitic rock - A coarse-grained igneous rock.

Ground water - In general, any water that exists beneath the land surface, but more commonly applied to water in fully saturated soils and geologic formations.

Habitat - The part of the physical environment where plants and animals live.

Hardness – The sum of the concentration of calcium and magnesium expressed on a calcium carbonate basis.

Headwaters - The source and upper part of a stream.

Health advisory – Non-regulatory levels of contaminants in drinking water that may be used as guidance in the absence of regulatory limits. Advisories consist of estimates of concentrations that would result in no known or anticipated health effects (for carcinogens, a specified cancer risk) determined for a child or for an adult for various exposure periods.

Herbicide - A chemical or other agent applied for the purpose of killing undesirable plants. *See also* Pesticide.

Human health advisory - Guidance provided by U.S. Environmental Protection Agency, State agencies or scientific organizations, in the absence of regulatory limits, to describe acceptable contaminant levels in drinking water or edible fish.

Hydrograph - Graph showing variation of water elevation, velocity, streamflow, or other property of water with respect to time.

Hydrologic cycle - The circulation of water from the sea, through the atmosphere, to the land, and thence back to the sea by overland and subterranean routes.

Index of Biotic Integrity (IBI) - An aggregated number, or index, based on several attributes or metrics of a fish community that provides an assessment of biological conditions.

Indicator sites - Stream sampling sites located at outlets of drainage basins with relatively homogeneous land use and physiographic conditions; most indicator-site basins have drainage areas ranging from 20 to 200 square miles.

Infiltration - Movement of water, typically downward, into soil or porous rock.

Insecticide - A substance or mixture of substances intended to destroy or repel insects.

Instantaneous discharge - The volume of water that passes a point at a particular instant of time.

Instream use - Water use taking place within the stream channel for such purposes as hydroelectric power generation, navigation, water-quality improvement, fish propagation, and recreation. Sometimes called nonwithdrawal use or in-channel use.

Integrator or Mixed-use site - Stream sampling site located at an outlet of a drainage basin that contains multiple environmental settings. Most integrator sites are on major streams with relatively large drainage areas.

Intensive Fixed Sites - Basic Fixed Sites with increased sampling frequency during selected seasonal periods and analysis of dissolved pesticides for 1 year. Most NAWQA Study Units have one to two integrator Intensive Fixed Sites and one to four indicator Intensive Fixed Sites.

Intermittent stream - A stream that flows only when it receives water from rainfall runoff or springs, or from some surface source such as melting snow.

Intolerant organisms - Organisms that are not adaptable to human alterations to the environment and thus decline in numbers where human alterations occur. *See also* Tolerant species.

Invertebrate - An animal having no backbone or spinal column. *See also* Benthic invertebrate.

Irrigation return flow - The part of irrigation applied to the surface that is not consumed by evapotranspiration or uptake by plants and that migrates to an aquifer or surface-water body.

Karst - A type of topography that results from dissolution and collapse of carbonate rocks such as limestone and dolomite, and characterized by closed depressions or sinkholes, caves, and underground drainage.

Kill - Dutch term for stream or creek.

Land-use study - A network of existing shallow wells in an area having a relatively uniform land use. These studies are a subset of the Study-Unit Survey and have the goal of relating the quality of shallow ground water to land use. *See also* Study-Unit Survey.

Leaching - The removal of materials in solution from soil or rock to ground water; refers to movement of pesticides or nutrients from land surface to ground water.

Load - General term that refers to a material or constituent in solution, in suspension, or in transport; usually expressed in terms of mass or volume.

Loess - Homogeneous, fine-grained sediment made up primarily of silt and clay, and deposited over a wide area (probably by wind).

Long-term monitoring - Data collection over a period of years or decades to assess changes in selected hydrologic conditions.

Main stem - The principal course of a river or a stream.

Major ions - Constituents commonly present in concentrations exceeding 1.0 milligram per liter. Dissolved cations generally are calcium, magnesium, sodium, and potassium; the major anions are sulfate, chloride, fluoride, nitrate, and those contributing to alkalinity, most generally assumed to be bicarbonate and carbonate.

Maximum contaminant level (MCL) - Maximum permissible level of a contaminant in water that is delivered to any user of a public water system. MCLs are enforceable standards established by the U.S. Environmental Protection Agency.

Mean - The average of a set of observations, unless otherwise specified.

Mean discharge (MEAN) - The arithmetic mean of individual daily mean discharges during a specific period, usually daily, monthly, or annually.

Median - The middle or central value in a distribution of data ranked in order of magnitude. The median is also known as the 50th percentile.

Metabolite - A substance produced in or by biological processes.

Metamorphic rock - Rock that has formed in the solid state in response to pronounced changes of temperature, pressure, and chemical environment.

Method detection limit - The minimum concentration of a substance that can be accurately identified and measured with present laboratory technologies.

Micrograms per liter (µg/L) - A unit expressing the concentration of constituents in solution as weight (micrograms) of solute per unit volume (liter) of water; equivalent to one part per billion in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.

Midge - A small fly in the family Chironomidae. The larval (juvenile) life stages are aquatic.

Milligram (mg) - A mass equal to 10^{-3} grams.

Milligrams per liter (mg/L) - A unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water; equivalent to one part per million in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.

Minimum reporting level (MRL) - The smallest measured concentration of a constituent that may be reliably reported using a given analytical method. In many cases, the MRL is used when documentation for the method detection limit is not available.

Monitoring - Repeated observation or sampling at a site, on a scheduled or event basis, for a particular purpose.

Monitoring well - A well designed for measuring water levels and testing ground-water quality.

Monocyclic aromatic hydrocarbons - Single-ring aromatic compounds. Constituents of lead-free gasoline; also used in the manufacture of monomers and plasticizers in polymers.

Mouth - The place where a stream discharges to a larger stream, a lake, or the sea.

National Academy of Sciences/National Academy of Engineering (NAS/NAE) recommended maximum concentration in water - Numerical guidelines recommended by two joint NAS/NAE committees for the protection of freshwater and marine aquatic life, respectively. These guidelines were based on available aquatic toxicity studies, and were considered preliminary even at the time (1972). The guidelines used in the summary reports are for freshwater.

Nitrate - An ion consisting of nitrogen and oxygen (NO_3^-). Nitrate is a plant nutrient and is very mobile in soils.

Noncontact water recreation - Recreational activities, such as fishing or boating, that do not include direct contact with the water.

Nonpoint source - A pollution source that cannot be defined as originating from discrete points such as pipe discharge. Areas of fertilizer and pesticide applications, atmospheric deposition, manure, and natural inputs from plants and trees are types of nonpoint source pollution.

Nonpoint source contaminant - A substance that pollutes or degrades water that comes from lawn or cropland runoff, the atmosphere, roadways, and other diffuse sources.

Nonpoint-source water pollution - Water contamination that originates from a broad area (such as leaching of agricultural chemicals from crop land) and enters the water resource diffusely over a large area.

Nonselective herbicide - Kills or significantly retards growth of most higher plant species.

Nutrient - Element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phosphorus, and potassium.

Occurrence and distribution assessment - Characterization of the broad-scale spatial and temporal distributions of water-quality conditions in relation to major contaminant sources and background conditions for surface water and ground water.

Organic detritus - Any loose organic material in streams - such as leaves, bark, or twigs - removed and transported by mechanical means, such as disintegration or abrasion.

Organochlorine compound - Synthetic organic compounds containing chlorine. As generally used, term refers to compounds containing mostly or exclusively carbon, hydrogen, and chlorine. Examples include organochlorine insecticides, polychlorinated biphenyls, and some solvents containing chlorine.

Organochlorine insecticide - A class of organic insecticides containing a high percentage of chlorine. Includes dichlorodiphenylethanes (such as DDT), chlorinated cyclodienes (such as chlordane), and chlorinated benzenes (such as lindane). Most organochlorine insecticides were banned because of their carcinogenicity, tendency to bioaccumulate, and toxicity to wildlife.

Organochlorine pesticide - *See* Organochlorine insecticide.

Organophosphate insecticides - A class of insecticides derived from phosphoric acid. They tend to have high acute toxicity to vertebrates. Although readily metabolized by vertebrates, some metabolic products are more toxic than the parent compound.

Organonitrogen herbicides - A group of herbicides consisting of a nitrogen ring with associated functional groups and including such classes as triazines and acetanilides. Examples include atrazine, cyanazine, alachlor, and metolachlor.

Organophosphorus insecticides - Insecticides derived from phosphoric acid and are generally the most toxic of all pesticides to vertebrate animals.

Outwash - Soil material washed down a hillside by rainwater and deposited upon more gently sloping land.

Overland flow - The part of surface runoff flowing over land surfaces toward stream channels.

Part per million (ppm) - Unit of concentration equal to one milligram per kilogram or one milligram per liter.

Perennial stream - A stream that normally has water in its channel at all times.

Periphyton - Organisms that grow on underwater surfaces, including algae, bacteria, fungi, protozoa, and other organisms.

Pesticide - A chemical applied to crops, rights of way, lawns, or residences to control weeds, insects, fungi, nematodes, rodents or other "pests."

pH - The logarithm of the reciprocal of the hydrogen ion concentration (activity) of a solution; a measure of the acidity (pH less than 7) or alkalinity (pH greater than 7) of a solution; a pH of 7 is neutral.

Phenols - A class of organic compounds containing phenol (C_6H_5OH) and its derivatives. Used to make resins, weed killers, and as a solvent, disinfectant, and chemical intermediate. Some phenols occur naturally in the environment.

Phosphorus - A nutrient essential for growth that can play a key role in stimulating aquatic growth in lakes and streams.

Photosynthesis - Synthesis of chemical compounds by organisms with the aid of light. Carbon dioxide is used as raw material for photosynthesis and oxygen is a product.

Phthalates - A class of organic compounds containing phthalic acid esters [$C_6H_4(COOR)_2$] and derivatives. Used as plasticizers in plastics. Also used in many other products (such as detergents, cosmetics) and industrial processes (such as defoaming agents during paper and paperboard manufacture, and dielectrics in capacitors).

Physiography - A description of the surface features of the Earth, with an emphasis on the origin of landforms.

Phytoplankton - *See* Plankton.

Picocurie (pCi) - One trillionth (10^{-12}) of the amount of radioactivity represented by a curie (Ci). A curie is the amount of radioactivity that yields 3.7×10^{10} radioactive disintegrations per second (dps). A picocurie yields 2.22 disintegrations per minute (dpm) or 0.037 dps.

Plankton - Floating or weakly swimming organisms at the mercy of the waves and currents. Animals of the group are called zooplankton and the plants are called phytoplankton.

Point source - A source at a discrete location such as a discharge pipe, drainage ditch, tunnel, well, concentrated livestock operation, or floating craft.

Point-source contaminant - Any substance that degrades water quality and originates from discrete locations such as discharge pipes, drainage ditches, wells, concentrated livestock operations, or floating craft.

Pollutant - Any substance that, when present in a hydrologic system at sufficient concentration, degrades water quality in ways that are or could become harmful to human and/or ecological health or that impair the use of water for recreation, agriculture, industry, commerce, or domestic purposes.

Polychlorinated biphenyls (PCBs) - A mixture of chlorinated derivatives of biphenyl, marketed under the trade name Aroclor with a number designating the chlorine content (such as Aroclor 1260). PCBs were used in transformers and capacitors for insulating purposes and in gas pipeline systems as a lubricant. Further sale for new use was banned by law in 1979.

Polycyclic aromatic hydrocarbon (PAH) - A class of organic compounds with a fused-ring aromatic structure. PAHs result from incomplete combustion of organic carbon (including wood), municipal solid waste, and fossil fuels, as well as from natural or anthropogenic introduction of uncombusted coal and oil. PAHs include benzo(a)pyrene, fluoranthene, and pyrene.

Pool - A small part of the stream reach with little velocity, commonly with water deeper than surrounding areas.

Postemergence herbicide - Herbicide applied to foliage after the crop has sprouted to kill or significantly retard the growth of weeds.

Precipitation - Any or all forms of water particles that fall from the atmosphere, such as rain, snow, hail, and sleet.

Pre-emergence herbicide - Herbicide applied to bare ground after planting the crop but prior to the crop sprouting above ground to kill or significantly retard the growth of weed seedlings.

Public-supply withdrawals - Water withdrawn by public and private water suppliers for use within a general community. Water is used for a variety of purposes such as domestic, commercial, industrial, and public water use.

Quality assurance - Evaluation of quality-control data to allow quantitative determination of the quality of chemical data collected during a study. Techniques used to collect, process, and analyze water samples are evaluated.

Radon - A naturally occurring, colorless, odorless, radioactive gas formed by the disintegration of the element radium; damaging to human lungs when inhaled.

Recharge - Water that infiltrates the ground and reaches the saturated zone.

Reference site - A NAWQA sampling site selected for its relatively undisturbed conditions.

Relative abundance - The number of organisms of a particular kind present in a sample relative to the total number of organisms in the sample.

Retrospective analysis - Review and analysis of existing data in order to address NAWQA objectives, to the extent possible, and to aid in the design of NAWQA studies.

Riffle - A shallow part of the stream where water flows swiftly over completely or partially submerged obstructions to produce surface agitation.

Riparian - Areas adjacent to rivers and streams with a high density, diversity, and productivity of plant and animal species relative to nearby uplands.

Riparian zone - Pertaining to or located on the bank of a body of water, especially a stream.

Runoff - Excess rainwater or snowmelt that is transported to streams by overland flow, tile drains, or ground water.

Secondary maximum contaminant level (SMCL) - The maximum contamination level in public water systems that, in the judgment of the U.S. Environmental Protection Agency (USEPA), are required to protect the public welfare. SMCLs are secondary (non-enforceable) drinking water regulations established by the USEPA for contaminants that may adversely affect the odor or appearance of such water.

Sediment - Particles, derived from rocks or biological materials, that have been transported by a fluid or other natural process, suspended or settled in water.

Sediment guideline - Threshold concentration above which there is a high probability of adverse effects on aquatic life from sediment contamination, determined using modified USEPA (1996) procedures.

Sediment quality guideline - Threshold concentration above which there is a high probability of adverse effects on aquatic life from sediment contamination, determined using modified USEPA (1996) procedures.

Selective herbicide - Kills or significantly retards growth of an unwanted plant species without significantly damaging desired plant species.

Semipermeable membrane device (SPMD) - A long strip of low-density, polyethylene tubing filled with a thin film of purified lipid such as triolein that simulates the exposure to and passive uptake of highly lipid-soluble organic compounds by biological membranes.

Semivolatile organic compound (SVOC) - Operationally defined as a group of synthetic organic compounds that are solvent-extractable and can be determined by gas chromatography/mass spectrometry. SVOCs include phenols, phthalates, and Polycyclic aromatic hydrocarbons (PAHs).

Sideslope gradient - The representative change in elevation in a given horizontal distance (usually about 300 yards) perpendicular to a stream; the valley slope along a line perpendicular to the stream (near the water-quality or biological sampling point).

Siliciclastic rocks - Rocks such as shale and sandstone which are formed by the compaction and cementation of quartz-rich mineral grains.

Sinuosity - The ratio of the channel length between two points on a channel to the straight-line distance between the same two points; a measure of meandering.

Sole-source aquifer - A ground-water system that supplies at least 50 percent of the drinking water to a particular human population; the term is used to denote special protection requirements under the Safe Drinking Water Act and may be used only by approval of the U.S. Environmental Protection Agency.

Solid-phase extraction - A procedure to isolate specific organic compounds onto a bonded silica extraction column.

Solute - *See* Solution.

Solution - Formed when a solid, gas, or another liquid in contact with a liquid becomes dispersed homogeneously throughout the liquid. The substance, called a solute, is said to dissolve. The liquid is called the solvent.

Solvent - *See* Solution.

Sorption - General term for the interaction (binding or association) of a solute ion or molecule with a solid.

Source rocks - The rocks from which fragments and other detached pieces have been derived to form a different rock.

Species - Populations of organisms that may interbreed and produce fertile offspring having similar structure, habits, and functions.

Species diversity - An ecological concept that incorporates both the number of species in a particular sampling area and the evenness with which individuals are distributed among the various species.

Species (taxa) richness - The number of species (taxa) present in a defined area or sampling unit.

Specific conductance - A measure of the ability of a liquid to conduct an electrical current.

Split sample - A sample prepared by dividing it into two or more equal volumes, where each volume is considered a separate sample but representative of the entire sample.

Stage - The height of the water surface above an established datum plane, such as in a river above a predetermined point that may (or may not) be near the channel floor.

Statistics - A branch of mathematics dealing with the collection, analysis, interpretation, and presentation of masses of numerical data.

Stratification - Subdivision of the environmental framework. The Study Unit is divided into subareas that exhibit reasonable homogeneous environmental conditions, as determined by both natural and human influences.

Stream-aquifer interactions - Relations of water flow and chemistry between streams and aquifers that are hydraulically connected.

Streamflow - A type of channel flow, applied to that part of surface runoff in a stream whether or not it is affected by diversion or regulation.

Stream mile - A distance of 1 mile along a line connecting the midpoints of the channel of a stream.

Stream order - A ranking of the relative sizes of streams within a watershed based on the nature of their tributaries. The smallest unbranched tributary is called first order, the stream receiving the tributary is called second order, and so on.

Stream reach - A continuous part of a stream between two specified points.

Study Unit - A major hydrologic system of the United States in which NAWQA studies are focused. Study Units are geographically defined by a combination of ground- and surface-water features and generally encompass more than 4,000 square miles of land area.

Study-Unit Survey - Broad assessment of the water-quality conditions of the major aquifer systems of each Study Unit. The Study-Unit Survey relies primarily on sampling existing wells and, wherever possible, on existing data collected by other agencies and programs. Typically, 20 to 30 wells are sampled in each of three to five aquifer subunits.

Subsidence - Compression of soft aquifer materials in a confined aquifer due to pumping of water from the aquifer.

Substrate size - The diameter of streambed particles such as clay, silt, sand, gravel, cobble and boulders.

Subsurface drain - A shallow drain installed in an irrigated field to intercept the rising ground-water level and maintain the water table at an acceptable depth below the land surface.

Surface water - An open body of water, such as a lake, river, or stream.

Survey - Sampling of any number of sites during a given hydrologic condition.

Suspended (as used in tables of chemical analyses) - The amount (concentration) of undissolved material in a water-sediment mixture. It is associated with the material retained on a 0.45- micrometer filter.

Suspended sediment - Particles of rock, sand, soil, and organic detritus carried in suspension in the water column, in contrast to sediment that moves on or near the streambed.

Suspended-sediment concentration - The velocity-weighted concentration of suspended sediment in the sampled zone (from the water surface to a point approximately 0.3 foot above the bed) expressed as milligrams of dry sediment per liter of water-sediment mixture (mg/L).

Suspended solids - Different from suspended sediment only in the way that the sample is collected and analyzed.

Synoptic sites - Sites sampled during a short-term investigation of specific water-quality conditions during selected seasonal or hydrologic conditions to provide improved spatial resolution for critical water-quality conditions.

Tailings - Rock that remains after processing ore to remove the valuable minerals.

Taxon (plural taxa) - Any identifiable group of taxonomically related organisms.

Taxa richness - *See* Species richness.

Tertiary-treated sewage - The third phase of treating sewage that removes nitrogen and phosphorus before it is discharged.

Tier 1 sediment guideline - Threshold concentration above which there is a high probability of adverse effects on aquatic life from sediment contamination, determined using modified USEPA (1996) procedures.

Tile drain - A buried perforated pipe designed to remove excess water from soils.

Tissue study - The assessment of concentrations and distributions of trace elements and certain organic contaminants in tissues of aquatic organisms.

Tolerant species - Those species that are adaptable to (tolerant of) human alterations to the environment and often increase in number when human alterations occur.

Total concentration - Refers to the concentration of a constituent regardless of its form (dissolved or bound) in a sample.

Total DDT - The sum of DDT and its metabolites (breakdown products), including DDD and DDE.

Trace element - An element found in only minor amounts (concentrations less than 1.0 milligram per liter) in water or sediment; includes arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.

Tracer - A stable, easily detected substance or a radioisotope added to a material to follow the location of the substance in the environment or to detect any physical or chemical changes it undergoes.

Triazine herbicide - A class of herbicides containing a symmetrical triazine ring (a nitrogen-heterocyclic ring composed of three nitrogens and three carbons in an alternating sequence). Examples include atrazine, propazine, and simazine.

Triazine pesticide - *See* Triazine herbicide.

Tributary - A river or stream flowing into a larger river, stream or lake.

Tritium - A radioactive form of hydrogen with atoms of three times the mass of ordinary hydrogen; used to determine the age of water.

Turbidity - Reduced clarity of surface water because of suspended particles, usually sediment.

Unconfined aquifer - An aquifer whose upper surface is a water table; an aquifer containing unconfined ground water.

Unconsolidated deposit - Deposit of loosely bound sediment that typically fills topographically low areas.

Un-ionized - The neutral form of an ionizable compound (such as an acid or a base).

Un-ionized ammonia - The neutral form of ammonia-nitrogen in water, usually occurring as NH_4OH. Un-ionized ammonia is the principal form of ammonia that is toxic to aquatic life. The relative proportion of un-ionized to ionized ammonia (NH_4^+) is controlled by water temperature and pH. At temperatures and pH values typical of most natural waters, the ionized form is dominant.

Upgradient - Of or pertaining to the place(s) from which ground water originated or traveled through before reaching a given point in an aquifer.

Upland - Elevated land above low areas along a stream or between hills; elevated region from which rivers gather drainage.

Uranium - A heavy silvery-white metallic element, highly radioactive and easily oxidized. Of the 14 known isotopes of uranium, U238 is the most abundant in nature.

Urban site - A site that has greater than 50 percent urbanized and less than 25 percent agricultural area.

Volatile organic compounds (VOCs) - Organic chemicals that have a high vapor pressure relative to their water solubility. VOCs include components of gasoline, fuel oils, and lubricants, as well as organic solvents, fumigants, some inert ingredients in pesticides, and some by-products of chlorine disinfection.

Wasteway - A waterway used to drain excess irrigation water dumped from the irrigation delivery system.

Water budget - An accounting of the inflow, outflow, and storage changes of water in a hydrologic unit.

Water column studies - Investigations of physical and chemical characteristics of surface water, which include suspended sediment, dissolved solids, major ions, and metals, nutrients, organic carbon, and dissolved pesticides, in relation to hydrologic conditions, sources, and transport.

Water-quality criteria - Specific levels of water quality which, if reached, are expected to render a body of water unsuitable for its designated use. Commonly refers to water-quality criteria established by the U.S. Environmental Protection Agency. Water-quality criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.

Water-quality guidelines - Specific levels of water quality which, if reached, may adversely affect human health or aquatic life. These are non-enforceable guidelines issued by a governmental agency or other institution.

Water-quality standards - State-adopted and U.S. Environmental Protection Agency-approved ambient standards for water bodies. Standards include the use of the water body and the water-quality criteria that must be met to protect the designated use or uses.

Watershed - *See* Drainage basin.

Water table - The point below the land surface where ground water is first encountered and below which the earth is saturated. Depth to the water table varies widely across the country.

Water year - The continuous 12-month period, October 1 through September 30, in U.S. Geological Survey reports dealing with the surface-water supply. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1980, is referred to as the "1980" water year.

Weather - The state of the atmosphere at any particular time and place.

Wetlands - Ecosystems whose soil is saturated for long periods seasonally or continuously, including marshes, swamps, and ephemeral ponds.

Withdrawal - The act or process of removing; such as removing water from a stream for irrigation or public water supply.

Yield - The mass of material or constituent transported by a river in a specified period of time divided by the drainage area of the river basin.

Zooplankton - *See* Plankton.

APPENDIX B

STAKEHOLDERS LIST

APPENDIX B: STAKEHOLDERS AS OF 11/30/07

Category	Agency	Agency Region	Agency Division	Name
County/City/Regional Govt.	Eads Trustee	n/a	n/a	Cardon Berry
County/City/Regional Govt.	Eads Trustee	n/a	n/a	Bill Barlow
County/City/Regional Govt.	Colorado Springs Utility	n/a	Public Works	Brett Gracely
County/City/Regional Govt.		n/a	n/a	Gene Millbrand
County/City/Regional Govt.	Southeast Colorado Power Association	n/a	n/a	Jack Wolfe
County/City/Regional Govt.	Water Conservancy District	n/a	n/a	Jean Van Pelt
County/City/Regional Govt.	Lamar Water Board	n/a	n/a	L. Pruett
County/City/Regional Govt.	County Government RC9 D	n/a	n/a	Matt Heimerich
Engineering/Water Resources	Tetra Tech	n/a	n/a	Angela McElyea
Engineering/Water Resources	Tetra Tech	n/a	n/a	Brianna Shanklin
Engineering/Water Resources	Tetra Tech	n/a	n/a	Julie Vlier
Federal	USDA	n/a	NRCS	Charity Spady
Federal	USDA	n/a	NRCS	Cindy Schleining
Federal	National Park Service	n/a	n/a	Courtney Moore
Federal	National Park Service	n/a	n/a	Frances Pannebaker
Federal	USDA	n/a	Rural Development	Joe Kost
Federal	USDA	n/a	NRCS	John Knapp
Federal	U.S. Fish & Wildlife Service	Partners for Fish & Wildlife	n/a	Katy Fitzgerald
Federal	USGS	n/a	n/a	Lisa Miller
Federal	USGS	Colorado Water Science Center	n/a	Patrick Edelmann
Media	Pueblo Chieftain	n/a	n/a	Chris Woodka
Non-Profit	Lower Arkansas Valley Water Conservancy District	n/a	n/a	Bill Hancock

Category	Agency	Agency Region	Agency Division	Name
Non-Profit	Crowley County	Southern	n/a	Brooke Balenseifen
Non-Profit	Kiowa County	Southern	n/a	Bruce Fickenscher
Non-Profit	Natural Resources Conservation Service	n/a	n/a	Calvin Melcher
Non-Profit	Natural Resources Conservation Service	n/a	n/a	Charles Pannebaker
Non-Profit	Bent County	Southern	n/a	Christy Ridley
Non-Profit	East-Otero, West Otero, & Olney-Boone County Conservation District	Lower Arkansas Watershed	n/a	Connie Baker
Non-Profit	Prowers Conservation District	Lower Arkansas Watershed	n/a	Danielle Wollert
Non-Profit	Natural Resources Conservation Service	n/a	n/a	James Wittler
Non-Profit	Branson-Trichera Conservation District	Lower Arkansas Watershed	n/a	Jonnalea Tortorelli
Non-Profit	Otero County	Southern	n/a	Kate Langworthy
Non-Profit	Bent County	Southern	n/a	Kaye Kasza
Non-Profit	Crowley County	Southern	n/a	Kim Baltazar
Non-Profit	Las Animas County	Southern	n/a	Laura McCarver
Non-Profit	Baca County	Southern	n/a	Malinda Salzbrenner
Non-Profit	Baca Conservation District	n/a	n/a	Max Smith
Non-Profit	Baca County Conservation District	Lower Arkansas Watershed	n/a	Misty George
Non-Profit	Bent County Conservation District	Lower Arkansas Watershed	n/a	Nancy Appel

Category	Agency	Agency Region	Agency Division	Name
Non-Profit	Natural Resources Conservation Service	n/a	n/a	Patty Moore
Non-Profit	Kiowa County	Lower Arkansas Watershed	n/a	Pegi Hueller
Non-Profit	The Nature Conservancy	n/a	n/a	Ryan Boggs
Non-Profit	Kiowa County	Southern	n/a	Shawn Kelley
Non-Profit	NE Prowers County Region	Lower Arkansas Watershed	n/a	Sheri Moorman
Non-Profit	Prowers County	Southern	n/a	Shirley Montgomery
Non-Profit	SE Colorado RC&D	n/a	n/a	Tim Macklin
Non-Profit	Prairie Conservation District Region	Lower Arkansas Watershed	n/a	Trisha Kischefsky
Non-Profit	Natural Resources Conservation Service	n/a	n/a	Viola Melcher
Non-Profit	SE Land & Environment Prowers County	n/a	n/a	Virgil Cochran
Political	Ken Salazar U.S. Senator Colorado	n/a	n/a	Dwight Gardner
Political	State Representative	n/a	n/a	Jace Ratzlaff
Private Citizen	n/a	n/a	n/a	Fred Heckman
Private Citizen	n/a	n/a	n/a	John Morlman
Private Citizen	n/a	n/a	n/a	Kathy Del Rio
Private Citizen	n/a	n/a	n/a	Lauren Grasmick
Schools	Colorado State University	Cooperative Extension	Turf Grass Water Management	Anthony Koski
Schools	Colorado State University	Cooperative Extension	Livestock	Dean Oatman
Schools	Colorado State University	Cooperative Extension	Riparian Zone Management/ In-Stream Flows/Wetlands	Del Benson
Schools	Colorado State University	Cooperative Extension	Irrigation System Design, Operation and Maintenance	Israel Broner
Schools	Colorado State University	Cooperative Extension	Extension Director	Jean Justice

Category	Agency	Agency Region	Agency Division	Name
Schools	Colorado State University	Cooperative Extension	Extension Agriculture & Business Management	Jeffrey Tranel
Schools	Colorado State University	Cooperative Extension	Agricultural Operations/ Water Quality Impacts	Jessica Davis
Schools	Colorado State University	Cooperative Extension	Water Quality Monitoring / Non-point Source Pollution Control	Jim Loftis
Schools	Colorado State University	Cooperative Extension	Drinking Water Quality	Jim Self
Schools	Colorado State University			Jim Valliant
Schools	Colorado State University	Cooperative Extension	Water Management / Water Quality / Salinity Control	Joel Schneekloth
Schools	Colorado State University	Cooperative Extension	Family and Consumer Science	Lorri Arnold
Schools	Colorado State University	Cooperative Extension	Water Management / Water Quality / Salinity Control	Luis Garcia
Schools	Colorado State University	Cooperative Extension	Vegetable Crops	Michael Bartolo
Schools	Colorado State University	Cooperative Extension	Drinking Water Quality	Patricia Kendall
Schools	Colorado State University	Cooperative Extension	Water Resources	Reagan Waskom
Schools	Colorado State University	Cooperative Extension	Range Management	Roy Roath
Schools	Colorado State University	Cooperative Extension	Pesticides/ Herbicides	Sandra McDonald
Schools	Colorado State University	Cooperative Extension	Cropping Systems	Scott Brase
Schools	Colorado State University	Cooperative Extension	Fertilizers	Troy Bauder
State	State of Colorado, DOT	Region 2 - Engineering	n/a	Beatrice Haggard
State	La Junta City Government	n/a	n/a	Joe Kelley
State	State of Colorado, Dept. of Local Affairs	n/a	n/a	Lee Merkel
State	State of Colorado, Div. of Wildlife	n/a	n/a	Mike Smith
State	CDPHE	n/a	WQCD	Randy Ristau
TBD	Unknown	n/a	n/a	John Marlman
TBD	Las Animas	n/a	n/a	Kim Siefkas

Category	Agency	Agency Region	Agency Division	Name
TBD	Arkansas Valley Range Co.	n/a	n/a	Rick Kienitz
TBD	Bent County District	n/a	n/a	Tom Wallace
TBD	Agri-Resource Management	n/a	n/a	V. Hopkins

APPENDIX C

208 MANAGEMENT AGENCIES

APPENDIX C: Designated Management Agencies for Lower Arkansas Watershed Management Plan

AGENCY
Counties
Baca County
Bent County
Crowley County
El Paso County
Huerfano County
Kiowa County
Las Animas County
Otero County
Prowers County
Pueblo County

Cities/Towns
Aguilar
Andrix
Arlington
Avondale
Boone
Branson
Bristol
Campo
Cedarwood
Cheraw
Chivington
Cokedale
Crowley
Cucharas
Dehli
Deora
Eads
Edler
Ellicot
Fowler
Granada
Greenhorn
Gulnare
Hartman
Hasty
Hawley
Hoehne
Holly
John Martin
Kim
La Junta
La Veta
Lamar
Las Animas

Cities/Towns
Ludlow
Lycan
Manzanola
McClave
Model
Ninaview
Olney Springs
Ordway
Pinon
Pritchett
Rocky Ford
Rush
Rye
Sheridan Lake
Springfield
Stonewall
Stonington
Sugar City
Swink
Thatcher
Timpas
Toonerville
Towner
Trinchera
Trinidad
Two Buttes
Tyrone
Utleyville
Valdez
Vilas
Villegreen
Walsenburg
Westin
Wiley
Yoder

APPENDIX D

208 OPERATING AGENCIES

APPENDIX D: Summary of Wastewater Treatment Facilities

Facility
Crowley Correctional Facility
La Junta WWTP
La Junta, City of
La Junta, City of
Las Animas, City of
Las Animas, Muni P&L
Manzanola WWTP
Monument Lake Water Treatment Facility
Rocky Ford Sewage Lagoons (NE)
Trinidad Water Treatment Facility
Trinidad WWTP
Walsenburg
Walsenburg WWTP (Martin Lake)

APPENDIX E

BRAINSTORMING POTENTIAL MANAGEMENT STRATEGIES FOR THE LOWER ARKANSAS RIVER BASIN

Land Management

Promote Land Conservation

Develop priorities for land conservation:

1. Lands which are selenium hot spots,
2. Stream preservation corridors,
3. Floodplains, and
4. River corridor areas
    a. Promote river access
    b. Develop trail system for Arkansas River residents and visitors

Implementation mechanisms:

1. Acquisition of conservations easements through various programs
2. Support local districts and municipalities in efforts to conserve priority areas
3. Develop program for short-term and long-term conservation of lands. Landowners would "bid" their lands into a trust program for short-term or long-term.

Irrigation Management

Renovate and Maintain Historic Drainage Systems

Early farmers created a vast drainage network which has since become rundown or inoperable due to lack of maintenance. Renovating and maintaining the system would encourage drainage, reduce waterlogging, and could improve water quality. There is also potential for creating a market for providing maintenance services. An incentive must be provided for landowners to maintain their drainage ditches.

Drainage Water Reuse

Blending and cycling reuse of applied irrigation water on the farm; conserves water by reducing amount of drain water and the quantity of selenium and salinity transported off site.

Install Moisture Sensors

Moisture sensors could be installed in fields to prevent over irrigation. A local company could monitor and maintain the sensors, thereby growing the local economy.

PAM Application

Polymer that has proven to be effective in reducing erosion by preventing sediment transport in irrigation water. PAM is sprayed in solution in a dry canal. It seals and prevents seepage.

Sprinkler or Drip Irrigation

Implement irrigation efficiencies via sprinkler or drip irrigation.

Earthen Channel Lining/Replacement

Replace earthen line channels with PVC pipe or concrete lining to reduce seepage and leaching of selenate shales.

Active Land Management

Combination of measures, trials of alternative crop selection and changes in operation to improve water quality; Regular fallowing and crop rotation; manage the water table to increase its contribution to crop transpiration, decrease evaporative losses, and to prevent waterlogging.

Conduct Special Studies to Optimize Water Quality Benefits

Continue strong working relationship with federal agencies and state academia to better define key locations and opportunities to create irrigation efficiencies and water quality enhancement.

Habitat Improvements

Habitat Offsets

Creating and providing aquatic habitat for pollutant credits.

Tamarisk Eradication

Continue and expand tamarisk removal and potentially use tamarisk biomass for energy production.

Promote Public Access to the River

Integrate river corridor, access, hiking and biking trails along the river to promote awareness and recreational opportunities.

Sustainable Strategies

Carbon Trading/Biofuel Production

Canola is just one crop that provides for high uptake of selenium. In conjunction with this, it serves as an excellent biofuel. This type of sustainable program can be integrated with a carbon trading program in the watershed.

Solar Energy Production

Encourage shift of land use to solar energy production where feasible. Currently, solar is only feasible for those with large tax liability looking for tax breaks. Could work to encourage large-scale installers responding to Xcel RFPs to site locations in the Valley.

Harvest Energy from AFO Waste

AFO operators could harvest energy from animal wastes to produce electricity. Electricity could be used to power their operations or sold to other energy users in the area. Pilot economic feasibility studies have been conducted. Currently, manure is used in the valley for land application, however it is just a fairly expensive proposition for the feedlot owner and the farmer unless the sites are close to the feedlot.

Small-Scale Wind Farms

Small-scale wind installations are being used to power water pumping stations in Bent County. Implementing wind farms, in areas that are non-irrigable, non-productive (i.e. over laden by marine shales or highly saline soils), could employ more people and have the opportunity to sell energy at retail rates, while providing water quality improvements. Pilot scale installations will address the obstacle of not having availability to production tax credits given to large-scale wind facilities while quantifying water quality benefit.

Regulatory Management

Watershed-based Incentives

Create trading incentives for public and private entities to implement water quality controls, enhanced BMPs and other water quality incentives geared to reduce key constituents of concern (i.e. selenium, nutrients, sediment, etc.).

Ordinances

Create stormwater, land management or water quality policy and criteria that offer greater water quality benefits. Examples of ordinances may include requiring landowners that sell water rights to reseed lands prior to selling water.

Stormwater Controls

Coordinate with upper basin areas that are stormwater permittees to control sediment and nutrient loads on the river

Waste Management/Treatment

Harvest Energy from AFO Waste

AFO operators could harvest energy from animal wastes to produce electricity. Electricity could be used to power their operations or sold to other energy users in the area. Pilot economic feasibility studies have been conducted. Currently, animal waste is trucked out of the Valley.

Reduce Septic System Loads over Marine Shale Soils

Inventory septic systems and consider converting septic systems to conventional sewer systems or other technologies in areas promoting leaching of selenium.

Phyto-remediation

Use of plants to accumulate or volatize selenium and render it unavailable to fish and wildlife; Use of Indian mustard, canola, tall fescue, kenaf and birdsfoot trefoil show abilities for high uptake of selenium.

Bioremediation

Use of algae or bacteria to uptake or reduce selenium to the elemental (less toxic) form.

Constructed Wetlands

Flow through wetlands designed to provide a mechanical and biochemical filter capable of removing contaminants from water.

Hazardous Waste and Materials Pick-Up

Provide monthly pick-up of hazardous chemicals, paints, etc.; quarterly schedule for each county in conjunction with other community activities.

Funding

Identify Funding Mechanisms

Identify and develop new funding mechanisms to meet watershed goals. Implement a variety of federal, state, local, and private funding mechanisms to meet funding goals of an additional $2 million dollars annually.

Develop an overall business program and financing plan.

Grants are not the long term solutions. Market based solutions are most effective long term financial stability.

Participate with federally funded programs that support sustainable agricultural and habitat protection and restoration

Consider programs such as Conservation Reserve Program, Environmental Quality Incentives Program (EQIP), Partners for Fish and Wildlife, Wetlands Reserve Program, and Wildlife Habitat Incentives Program (WHIP) are federal programs appropriate to fund efforts in the watershed.

Collaborate with other private and public interest groups to leverage funding mechanisms to meet watershed goals

Coordinate with other public and interest groups to obtain additional funding, recognizing there may be opportunities to view problems as business opportunities.

Fund, design and construct high priority management strategies.

Implement targeted pilot and full scale projects targeted to reduce pollutant loads. Based on prioritization efforts and water quality enhancement, fund, design, and implement strategies.

Public Involvement

Retain a Watershed Coordinator

The Lower Arkansas Watershed Coordinator will foster community-based watershed management in the Lower Arkansas basin and be the point of contact to manage and facilitate watershed efforts.

Develop and Implement a Comprehensive Public Involvement Plan

The PIP will provide mechanisms to promote stakeholder involvement, encouraging, federal, state, and local interest. An open line of communication with other RC&D's will also be promoted.

Develop a Lower Arkansas River Watershed Website

Identify an agency to manage and serve as a repository for watershed geographic information system tools, resources information and maps.