2007 CLEAR CREEK WATERSHED REPORT

Exploring Watershed Sustainability

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EXECUTIVE SUMMARY

PROLOGUE: Research by numerous, reputable scientists, politicians, and environmental and social activists shows that management of our world's natural resources is at a decisive stage, and the alternatives offered by the concept of sustainability — respecting the perspectives of ecology, society, and economy — can create changes that will make it possible to answer the needs of the present without compromising the capacity of future generations to answer theirs. A certain level of development and natural resource consumption must continue in order for society to survive, but more sustainable guidelines and synergies must be implemented for society — and watersheds — to thrive. It is believed that the concerns about environmental issues such as peak oil and climate change are causing a societal shift toward the wiser use of natural resources in general. Focusing on sustainable solutions within the bounds of a watershed system is do-able and makes sense.

PURPOSE: This report documents and examines general watershed conditions and sustainable watershed management techniques that have been applied to the Clear Creek Watershed — an ecologically, socially, and economically diverse watershed just west of Denver, Colorado. This document is both a roadmap for the way forward and an example of real world techniques that might be applied by other watersheds throughout the arid mountain west. Our underlying thesis is: If cleaner water is good, there must be a viable market in producing sustainable results. Please note that this document is not intended to be a comprehensive water quality or hydrologic report.

WHAT WAS EXAMINED: In 2006, the Clear Creek Watershed Foundation (Foundation) was awarded a U.S. Environmental Protection Agency (EPA) Region 8 Regional Priorities Grant to research and develop sustainable watershed management tools for export to other watersheds throughout the arid Mountain West.

This report establishes the existing conditions of the Clear Creek Watershed in terms of its physical, biological, and human dimensions; threats to cleaner water; opportunities for sustainable management of natural resources; and descriptions of more sustainable conditions. Sustainability is defined in terms of the value sets of ecology, society, and economy. Each of these sets is examined in detail within our watershed context in an econometric fashion to determine to what degree current art and science can reflect cause-and-effect of certain actions or inactions.

This report also examines the applicability of multi-attribute utility analyses, cost-benefit analyses, and discourse-based valuations to impact decision-making in the realm of sustainable watershed management. The Foundation developed these valuations from a list of 41 completed projects with known results to determine relative benefit and cost in terms of watershed sustainability — ecology + society + economy. A discourse-based evaluation by watershed stakeholders was then conducted to quantify overall threats and opportunities in the watershed. Those results were then applied specifically to 80 new projects in order to better define partnerships, funding, and implementation strategies.

DISCUSSION: Sustainable watershed management includes considering the future impact of our actions — how can we meet the perceived needs of the present without impairing future generations from meeting their needs? For our deliberation, we use a

seven-generation timeframe for considering impacts on resources — from our great-grandparents' time forward to our potential great-grandchildren's time. We can learn from the past — factual data and human decisions and actions — to make a better future. In defining sustainable watershed management, we have come to use the following Venn diagram with a primary focus on water, but including the water-energy-mineral-forest-biology nexus.

SUSTAINABLE WATERSHED MANAGEMENT:

A community-based approach to improving and protecting the natural resources of a watershed by integrating ecological, social, and economic perspectives.

ecology + society + economy = sustainability

Ecology
- **management of natural resources with water quality and water quantity being the primary focus**
- **protection/enhancement of naturally-occurring ecological services (source/headwaters, storage, conveyance, wetlands)**

Society
- **respect for community values**
- **ongoing stakeholder participation and benefits**
- **local economic development that has an awareness of global and local sustainability opportunities**
- **maintaining a sense of history and place**

Economy
- **cost-efficient projects & economic opportunities with no net-loss of ecological services**
- **measurable results for environmental investments**
- **promotion of market-based investment in clean water**

THE BOTTOM LINE: Early efforts of the Foundation focused on orphan/ abandoned mine site remediation — not a mainstream topic in the corporate world or general public. Our market was limited to agencies specifically oriented to or charged with mine clean-up who might also seek local assistance. Broadening our focus from just cleaner water through mine remediation to overall watershed sustainability has expanded our horizons greatly, adding seven additional market areas to our portfolio. We have categorized the plethora of potential sustainable watershed projects into the following eight market areas:

- Orphan Mine Remediation
- Natural Resource Management
- Water/Wastewater Management
- Preservation/Promotion of Historical Mine Sites
- Alternative Energy/Transportation
- Waste Stream Reduction
- Subsurface Rights and Uses
- Outreach/Education

All of these categories have a direct relationship to the quest for cleaner water. Over the past 10 years, the value of water rights — regardless of water quality — have increased two- to ten-fold within over-appropriated watersheds in the State of Colorado, and perhaps the entire arid mountain west. The quest for cleaner water and the public's willingness to pay for cleaner water makes clean water even more valuable than gasoline.

MAJOR FINDINGS AND LESSONS LEARNED: Because the downward flow of water through a watershed carries with it the effects of nature and human activity, concern for a stream's health must include concern for the health of the entire watershed. Natural and manmade systems respond to cause and effect. In order for decisions to be made in favor of sustainable practices, compelling qualitative and/or quantitative data and information must be provided to decision-makers. These metrics can then be applied to various projects to document the spatial extent of the improvement practice.

- Societal perceptions of peak oil and climate change are leading toward a greater societal demand for cleaner water and sustainable watershed management.

- The Clear Creek Watershed is a rational model/framework of sustainable watershed management and the methodologies and lessons described in this report are transferable to other watersheds.

- Discourse-based valuation among watershed stakeholders using a multi-attribute utility analysis produces sustainability values to determine priorities and justify project funding and implementation.

- These values are satisfactory for regulatory and funding sources as evidenced by their willingness to partner on watershed projects.

- There is a plethora of projects and market areas to enhance watershed sustainability.

- There is, in fact, an extensive market for cleaner water at the watershed level.

- The demand for clean water impacts other areas/activities in the watershed (transportation, energy generation, etc.) in the water-energy-mineral-ecology-social nexus.

- Watershed management should be a "bottom up"/grassroots program; there should be appropriate receptors at the State and Federal level, but the program should not be managed from the top down.

The Foundation's goal is to encourage and facilitate the broader application of sustainable and regenerative watershed management practices by providing stakeholders (jurisdictions, agencies, developers, etc.) in the watershed with information and tools to make sustainability-focused decisions regarding environmental restoration/protection activities and development practices.

KEY DEFINITIONS

Best Management Practices (BMPs): Methods that have been determined to be practical and effective means of preventing or reducing pollution.

Clean Water Act (CWA): The federal law designed to protect surface water quality. Programs of particular importance to watersheds include: the NPDES (National Pollutant Discharge Elimination System) which regulates point-source dischargers through permit controls; the 303(d) List which identifies impaired water bodies requiring the development of TMDL (Total Maximum Daily Load) delineation that identifies contaminants and their sources; and the Nonpoint Source/319 Grant program which manages non-point sources through BMPs.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as *Superfund*: The federal law designed to respond to releases or threatened releases of hazardous substances that may endanger public health or the environment. Either through identifying PRPs (Potentially Responsible Parties) or through the trust fund created by taxing various industries, Superfund has been of particular importance to mining-impacted watersheds.

Concentration: The amount of material (such as metals) dissolved or suspended in a specific volume of water. The water volume can be stated as either volume or weight. For example, concentrations of metals in water are usually reported as *parts per million*, as in one gram of iron per million grams (one metric ton) of water, or *parts per billion*. Another example is *pounds of copper per gallon of water*.

Corporate Social Responsibility (CSR): Organizations, especially corporations, making decisions based on immediate, intermediate and long-term financial, social and environmental consequences. CSR has been an aspect of business considerations since the advent of the Industrial Revolution.

Culture of Cooperation: Efforts began in 1990 to bring people together from throughout the Clear Creek Watershed to share knowledge, attitudes, and values; and to resolve conflict. This continues to be essential for developing cooperative water quality improvement strategies and prioritizing projects. Through numerous forums, stakeholder input on projects is obtained and incorporated to define watershed priorities, and establish project partners, thus creating a nationally-recognized, watershed-wide *culture of cooperation*. Once stakeholders began fixing things on the ground, sustainable improvements began to be seen — project-by-project.

Ecological Services: Processes and functions of natural ecosystems that fulfill and sustain human life such as clean water, flood control, recreation. Historically considered "free" services, environmental economics is now beginning to identify the dollar value of these services provided from healthy watersheds for inclusion in land use decision making.

Flow: The volume of water that passes a spot on a creek/stream/river in a specific time period. Flows are commonly reported as *gallons per minute* or *cubic feet per second* (cfs). One cfs equals 449 gallons per minute.

Good Samaritan: An individual or organization willing to voluntarily remediate orphan mine sites for the public good, despite the fact that they are not legally required to remediate the mine sites. A Good Samaritan has no prior responsibility to a property and will not profit from cleanup of the property. Liability concerns under the Clean Water Act have resulted in efforts to develop legislation that would protect Good Samaritans.

Loading: The amount of material (metals) that flows by in a creek/stream/river during a specific period of time. Loadings can be reported as *pounds per day*. Loading is calculated by multiplying flow by concentration.

Mine Waste: The rock debris that is piled up adjacent to a mine adit or pit. These piles usually contain **waste rock** from the mine, **mill tailings** (left after metal-rich minerals have been separated from the ore in mill), or a mixture of both. Miners distinguish between waste rock and mill tailings, but they are commonly grouped together in environmental cleanup plans.

Non-Point Source (NPS) Pollution: Sources of water pollution that are hard to pinpoint because they do not come from a single pipe. Pollution from pipes is **point-source pollution**. NPS pollution can come from storm runoff from a new development, a cattle ranch, and mine wastes. It can also come from dispersed seeps of polluted ground water.

Orphan Mine Site: Sometimes referred to as abandoned, this is a mine site that has no identifiable PRP to clean it up.

Orphanage Remediation Concept: Treating pollutants resulting from multiple, individual orphan mine sites within a single drainage with a single "orphanage" remediation action rather than a separate treatment for each "orphan." This method of remediation is implemented by the Clear Creek Watershed Foundation whenever feasible as a cost-efficient and effective strategy for removing source-area metals and sediment loading that is a result of historic mining operations.

Potentially Responsible Party (PRP): An individual or company (such as owners, operators, transporters, or generators of hazardous waste) potentially responsible for, or contributing to, the contamination problems at a Superfund site.

Safe Drinking Water Act (SDWA): The federal law designed to provide safe drinking water through quality criteria for providers. Of interest in watershed management is the SWAP (Source Water Assessment and Protection) Program that focuses on identifying potential sources of contamination for drinking water supplies and mitigating them.

State Water Quality Standards: The yardstick by which the State assesses the status of the water body or stream segment. The State compares recent information regarding the physical, chemical, and biological condition of a stream segment with the associated water quality standards for that stream segment. Where technology-based effluent limits in discharge permits alone are not stringent enough to assure that water quality standards are met, these stream segments are designated "Water Quality Limited" and added to the 303(d) List. This list is produced every two years. The 303(d) list includes the identification of the specific component (such as nitrate, copper, sediment, or habitat) that further identifies the specific water quality problem for that segment. Agency-

calculated TMDLs are required for all components listed for each stream segment on the 303(d) List.

Sustainability: The actions within a system to maintain itself in perpetuity so that present needs are met without impairing the resources for future generations. Sustainability generally encompasses environmental or ecological, societal or community, and economic values.

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Economy
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Total Maximum Daily Load (TMDL): According to EPA, a TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. Water quality standards are set by States, Territories, and Tribes. They identify the uses for each waterbody, for example, drinking water supply, contact recreation (swimming), and aquatic life support (fishing), and the scientific criteria to support that use. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety to ensure that the waterbody can be used for the purposes the State has designated. The calculation must also account for seasonal variation in water quality.

Triple Bottom Line (TBL): A quantification that defines sustainability from an economic perspective by assessing not only the economic value of a resource, but also the ecological and social values and their economic worth to the organization. The TBL is becoming a practical tool for corporations to report a more balanced view of benefits and costs to shareholders in their annual reports.

Watershed: A watershed is a waterbody (stream or lake) and the landscape through which it flows. Somewhat like a bowl or funnel, a watershed is rimmed by higher ground that directs water from various sources (snowmelt, rainfall, smaller tributaries, etc.) toward the waterbody (lake, river, stream, etc.) in the valley below. A watershed is also a place in which people live, work and play. Wherever you are, you are in a watershed. Therefore the downward flow of water through a watershed carries with it the effects of nature and human activity. Because of this, concern for a river's health must include concern for the health of the entire watershed system.

Watershed Sustainability: A community-based approach to improving and protecting water quality and other watershed resources by integrating ecological, social, and economic perspectives in the use of shared critical natural resources: water, energy, minerals, land, biota, etc., in order to meet the needs of present and future generations.

For additional water quality and water law information, see these web links:

http://www.epa.gov/owow/watershed/wacademy/acad2000/protection/glossary.html

http://www.epa.gov/owow/nps/watershed_handbook/pdf/glossary.pdf

http://www.epa.gov/superfund/training/hrstrain/htmain/glossal.htm

http://www.epa.gov/superfund/training/hrstrain/htmain/glossmz.htm

PURPOSE OF REPORT

The legacy of an estimated 1,600 abandoned mine sites and ongoing transportation- and development-related impacts have impaired the water quality of Clear Creek and its tributaries. Incorporated in 1997, the nonprofit Clear Creek Watershed Foundation (Foundation) is dedicated to improving the ecological, recreational, and economic conditions in the Clear Creek Watershed through comprehensive and cooperative efforts with watershed stakeholders. Historically the Foundation has focused on improving the water quality of Clear Creek and its tributaries through mine remediation projects. Remediation work began in this watershed in the 1980s when the U. S. Environmental Protection Agency (EPA) established the Clear Creek/Central City Superfund Study Area and placed it on the National Priority clean-up list. Since then, numerous groups, agencies, and individuals have been working to improve the quality of Clear Creek. However, there is still progress to be made.

In 2006, the Foundation was awarded an EPA Region 8 Regional Priorities Grant to research the concept of *watershed sustainability* and the application of this concept in the Clear Creek Watershed as a model for the arid mountain west. We agree with Steve Johnson, EPA Administrator, who said, "We have a responsibility to sustain — if not enhance — our natural environment and our nation's economy for future generations."

Watershed sustainability — as the Foundation defines it — combines ecological, societal, and economic values in evaluating projects, investments, and outcomes — this is also known as the *triple bottom line*. Watershed sustainability seeks to maintain high ecological function and services value, while at the same time realizing multiple societal and economic benefits. For example — multiple mine site clean-ups and historic mining structures along a frontage road offer the potential for an historic mining corridor with educational and tourism benefits. Another example — numerous stabilized waste piles on south facing slopes near a transmission line offer the potential for renewable energy facilities. The multiple values generated by watershed sustainability thinking brings a more diverse set of public-private stakeholders to project partnerships and helps generate a broader base of support for watershed improvements that benefit the full range of natural resources, including water quality.

This report presents findings of the Foundation's research, including various *sustainable watershed management practices* for watershed protection and improvement. This is not a glowing report of sustainable success in the watershed, but a realistic assessment of existing conditions. Please note, however, that this document is not intended to be a comprehensive water quality or hydrologic report. The findings, lessons, and recommendations presented here are intended to help guide the Clear Creek Watershed and its stakeholders in making project decisions and investments over the next 10 years. Many tools and techniques for the integration of ecological, social, and economic perspectives in watershed management and land-use planning are presented for further research and discussion. Given the inherent nature of sustainability, it is impossible to completely separate the three topics of ecology, society, and economy — their overlap is inextricable; however for study and discussion purposes, we categorized our findings into those three topics in this report.

INTRODUCTION

Watershed — A Specific Physical, Biological, and Human Landscape. A watershed is typically thought of as a discreet geographic basin within which groundwater, rain, and snowmelt flow to a common waterbody. Therefore, watershed discussions have typically focused on water supply and water quality. More broadly, however, a watershed is also an ecological system comprised of forests, habitat, wildlife, fisheries, and natural beauty.

When people live, work, and play in that landscape, the definition becomes even broader to encompass socioeconomic and historical-cultural factors such as natural resource extraction, transportation, residential and commercial development, recreation, and structures and artifacts from the past. A watershed, in its broadest sense, then, is about the physical, biological, and human landscape encompassing a common water feature.

WHAT IS A WATERSHED?

While there are many definitions, scientist and geographer John Wesley Powell put it succinctly when he said that a watershed is:

> ***"...that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community."***

You can learn more about watersheds at the Conservation Technology Information Center's "Know Your Watershed" website at http://www2.ctic.purdue.edu/kyw/ and at EPA's Surf Your Watershed website at www.epa.gov/surf. For more on Colorado watershed organizations, go to the Colorado Watershed Assembly website at www.coloradowater.org.

The downstream flow of water from the headwaters to the confluence carries with it the effects of natural and human activities. Therefore, watersheds are integrated systems that respond to cause and effect and are affected by many sources.

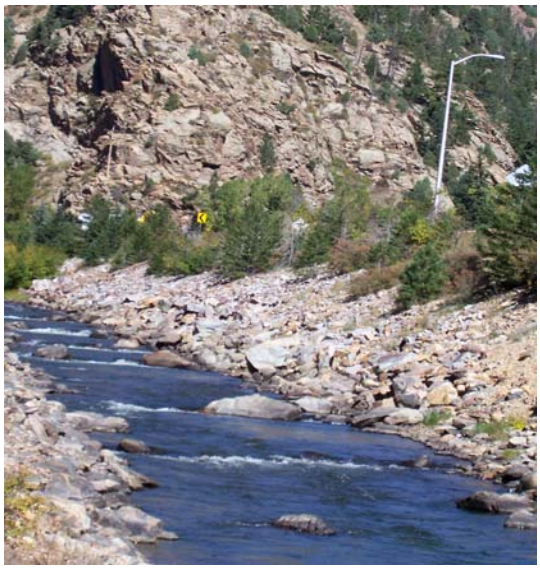
Our Watershed. Located west of Denver, the 575-square mile Clear Creek Watershed spans from 14,000-foot mountain peaks at its western edge on the Continental Divide down to the urbanized plains at its confluence with the South Platte River just north of the mile-high city of Denver. Often referred to as the *gateway to the Rockies*, the Clear Creek Watershed is the source of drinking for more than 300,000 people. Clear Creek also provides water for irrigation, recreation, and industry. 400 square miles of the watershed are located in the mountains west of Golden, and fully one-third of the Clear Creek Watershed lies within the Arapaho & Roosevelt National Forests. Please refer to the watershed map on page 11.

Torreys Peak. Photo courtesy of www.14-ers.com.

Clear Creek's headwaters begin in an area rimmed by four *14-ers* (mountains that are 14,000 feet in elevation or higher) — Grays and Torreys Peaks, Mt. Evans, and Mt. Bierstadt. Major tributaries that feed into Clear Creek include the North, South and West Forks; Leavenworth, Lion, Trail, Chicago, Soda and Ralston Creeks; Fall River; and Beaver Brook. The mainstem flows eastward along the Interstate-70 (I-70) corridor through several mountain communities, along approximately 12 miles of the Highway 6

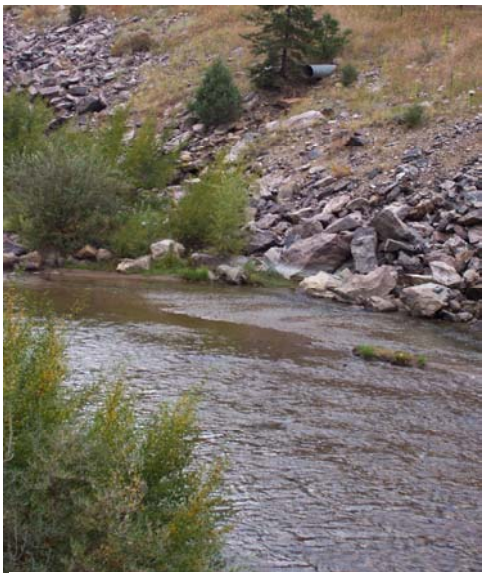
corridor through Clear Creek Canyon, and then back along the I-70 corridor through several Denver Front Range communities.

The cover photo of this report shows an attractive scene — Clear Creek west of Idaho Springs, looking west toward the Continental Divide — and some of the multiple demands of the valley floor — water conveyance, recreations/fishing, transportation/I-70, historic mining, and scenic value. But beneath this veneer of beauty lay serious water quality issues. Clear Creek is on the National 303(d) List of impaired waters due to the high concentrations of heavy metals including cadmium, zinc, and copper. The photos below show a realistic view of some of the obstacles that must be hurdled in order to achieve watershed sustainability.

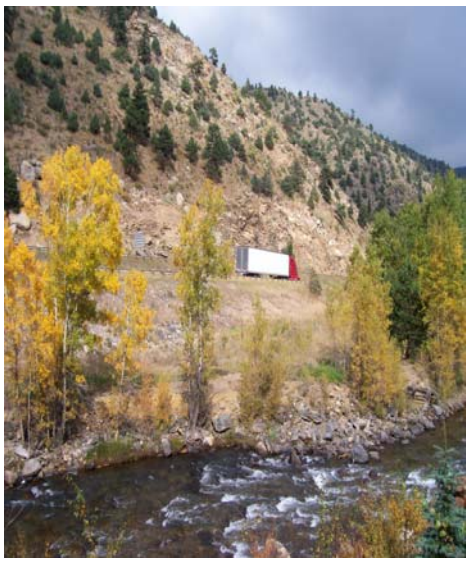


Channelized stream resulting in degraded ecological value.

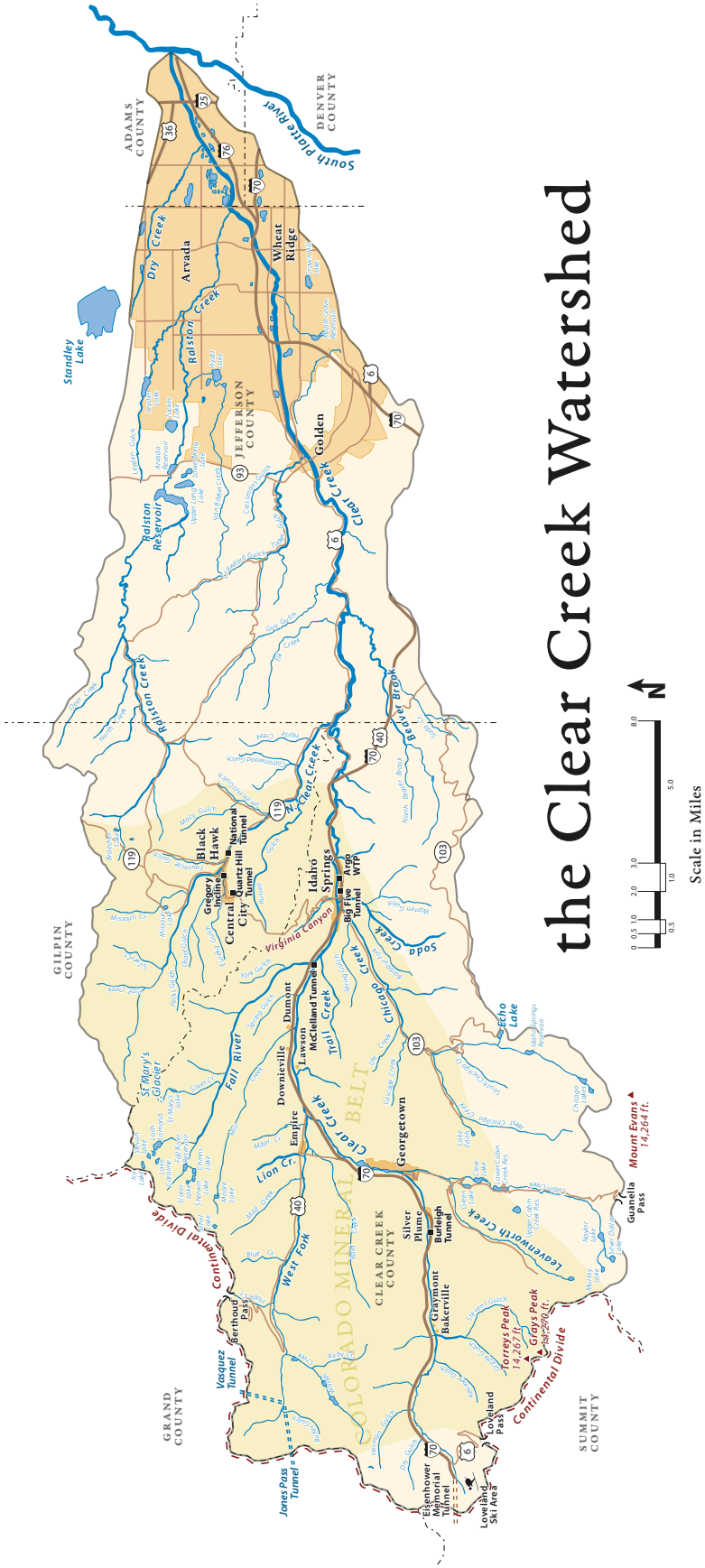
Road cuts through the sulfide ore body leaving behind actively eroding rock faces.



Sandbars have developed in Clear Creek as a result of 670 tons of traction sand and 13,800 gallons of magnesium chloride per mile used each year with no Recovery Plan.



I-70 road bed built on mill tailings containing hazardous metals including mercury, cyanide, cadmium, zinc, and arsenic.


the Clear Creek Watershed
ADAMS COUNTY
DENVER COUNTY
JEFFERSON COUNTY
GILPIN COUNTY
GRAND COUNTY
CLEAR CREEK COUNTY
SUMMIT COUNTY
South Platte River
Standley Lake
Arvada
Wheat Ridge
Golden
Ralston Reservoir
Ralston Creek
Dry Creek
Clear Creek
Black Hawk
Central City
Gregory Incline
Quartz Hill Tunnel
National Tunnel
Idaho Springs
Big Five Tunnel
Argo WTP
Virginia Canyon
Beaver Brook
Soda Creek
Chicago Creek
Fall River
Trail Creek
Dumont
Downieville
Lawson
McClelland Tunnel
Empire
Georgetown
Silver Plume
Burleigh Tunnel
Graymont
Bakerville
Echo Lake
Mount Evans 14,264 ft.
Guanella Pass
Leavenworth Creek
Torreys Peak 14,267 ft.
Grays Peak 14,270 ft.
Continental Divide
Loveland Pass
Loveland Ski Area
Eisenhower Memorial Tunnel
Jones Pass Tunnel
Vasquez Tunnel
Berthoud Pass
St Mary's Glacier
COLORADO MINERAL BELT
Scale in Miles
0 0.5 1.0 2.0 3.0 5.0 8.0
0.5 1.0

Why Apply Sustainability to the Boundaries of a Specific Watershed?

As EPA Deputy Assistant Administrator of Water, Ben Grumbles, puts it, "There is a basic dimension that…establishes our sense of place, our watershed or ecological address. No matter where you live, you live in a watershed and you have an impact on its health. Mountain watersheds are especially vital to those who live within their boundaries because they supply drinking water, provide for recreation, and sustain life. In arid and semi-arid western climates, watersheds are precious." In short, the oft cited phrase — *Think Globally, Act Locally* — is directly relevant to a watershed because people can identify with their local watershed, take meaningful action there, and see results. That is why the EPA and other agencies are promoting the idea that watersheds provide the best framework to manage and protect natural resources. Because it is part of a system, concern for a river's health must include concern for the health of the environmental, social, and economic aspects of the entire watershed. This philosophy supports a sustainable watershed.

"No matter where you live, you live in a watershed and you have an impact on its health."

The basic definition of sustainability is *the actions within a system to maintain itself in perpetuity so that present needs are met without impairing the resources of future generations*. The concept of sustainability is taking strong hold in our state. According to an April 2007 Denver Post article, "A consensus is growing in scores of Colorado communities to take solid steps toward balancing economic development, quality of life and protection of the environment…sustainability has moved from an esoteric idea just a few years ago to a way of life in Colorado."

This study was designed to highlight new ideas emerging in the realm of sustainability thinking, apply them to the specific boundaries of a watershed, and to provide additional tools for watershed stakeholders and decision-makers to continue exercising their stewardship role.

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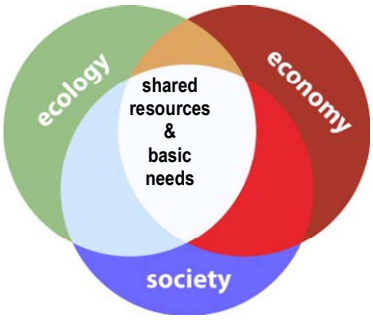

Ecology
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Society
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- maintaining a sense of history and place

Economy
- cost-efficient projects & economic opportunities with no net-loss of ecological services
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A Look Back. The Clear Creek Watershed is a storied place that has captivated the human imagination since the first reported passage by Spanish explorers while searching for the fabled "Seven Cities of Cibola" in the 1500s. While the banks of Clear Creek were the origins of the Colorado Gold Rush in 1859, tribes of Ute and Arapahoe lived in the area long before that, living off the bountiful natural resources of the area and benefiting from the spiritual and healing properties of the natural hot springs. The 1880 report *Idaho Springs—Its Mines and Mineral Waters* provides one of the earliest written descriptions of the mineral-energy-water-human nexus in the region:

Stanley Mine, circa 1900. This photograph shows waste piles that were subsequently buried under I-70 circa 1956 – 1958. This is only part of the 23 mill sites buried in or near the I-70 right-of-way. Photo courtesy of the Historical Society of Idaho Springs.

> *"No more desirable point than Idaho [Springs] can be found for the erection of concentrating and reduction works…Contiguous forests furnish an abundance of timber, and the water power of the different streams is practically unlimited…At every point there is something new. Some curious crag; some romantic dell with its ever constant brooklet…or some pleasing combination of the whole that attracts the attention, and indelibly impresses itself upon the memory."*

Although there was a great appreciation of the mining potential and the scenic amenities of the Clear Creek Watershed, the connection between natural resource depletion and negative impacts on the natural aesthetics and systems was not readily apparent at that time.

In 1983, because of mining-related water quality problems, the EPA established the Clear Creek/Central City Superfund Study Area and placed it on the National Priority clean-up list. This site was also listed by the Colorado Department of Public Health and Environment (CDPHE). In 1987 an intense study of mine tunnel drainage was completed, and many more studies followed. Thus began a large agency-led remediation effort on the active and abandoned mine sites in the area. Suffice it to say, the early relationship between the regulatory agencies and the local citizens was tense. The agencies had remediation technology and resources, while the locals had the historical knowledge of place. In order for complex water quality issues to be addressed and for clean-up efforts to be successful, common ground had to be found.

Established in 1990, the Clear Creek Watershed Forum was an informal organization which transcended the boundaries of any one agency, community, industry, or organization within the watershed. The role of the Forum was to bring people together from throughout the watershed to share knowledge, attitudes, and values; and resolve conflict. This was essential for developing cooperative water quality improvement strategies and prioritizing projects for this complex watershed. This was not an easy task given the diversity of stakeholders and interests — ranging from mountain-rural to urban, from agricultural and industrial to recreational and regulatory. Through numerous gatherings, stakeholder input on projects was obtained and incorporated to define watershed priorities and establish project partners, thus creating a watershed-wide *culture of cooperation*. Once stakeholders began fixing things on the ground, sustainable improvements began to be seen — project-by-project.

ANNOUNCING: AN INITIATIVE TO RECLAIM THE WATERSHED

The Clear Creek Basin is potentially one of the most valuable recreational and ecological resources along the Colorado Front Range…It provides approximately 165,000 people with their municipal drinking water supply [that 1992 estimate has increased to 350,000 in 2007]. It affords countless individuals from all over the Denver metro area with an easily accessible opportunity to experience nature…

Contaminated by metals from abandoned mines in the mountain canyons that it drains, dried up annually by the thirsty water users it serves, and channelized by the unceasing forces of urbanization, Clear Creek needs our help…

Clear Creek is an extremely complex watershed and any successful improvement program will need to be sensitive to existing water and land uses in the basin…

Constant input from and the enthusiastic participation of the residents of the Clear Creek Community will be the key to reclaiming and restoring Clear Creek.

–excerpted from the first Clear Creek Watershed Improvement Initiative Newsletter, Winter 1992

Incorporated in 1997 as the operating arm of the Clear Creek Watershed Forum, the Foundation is a non-profit organization dedicated to improving the ecological, aesthetic, recreational and economic conditions in the Clear Creek Watershed through comprehensive efforts with watershed stakeholders. This includes — but is not limited to — improving the water quality of Clear Creek and its tributaries through mine remediation projects. The Forum and the Foundation have since merged into one organization. More information on the organizational history/evolution and stakeholder involvement can be found at www.clearcreekwater.org.

Through numerous gatherings, stakeholder input on projects was obtained and incorporated to define watershed priorities and establish project partners, thus creating a watershed-wide *culture of cooperation*… The Foundation continues to cultivate the Clear Creek Watershed's well-established culture of cooperation by providing numerous opportunities for watershed stakeholder involvement and input…

Watershed Stakeholder Input is Key. The Foundation continues to cultivate the Clear Creek Watershed's well-established culture of cooperation by providing numerous opportunities for watershed stakeholder involvement and input on watershed threats and opportunities to mitigate these threats — most

visible are the Clear Creek Watershed Forums and project partnerships. The people who live, work, and play in the watershed are the primary shareholders of these assets who over the years have demonstrated a keen appreciation of Clear Creek Watershed's special sense of place and have served as stewards of these values.

Threats to the Clear Creek Watershed. Historical research has shown that some segments of the Clear Creek Watershed system have already been impaired by mineral loading — primarily because Clear Creek and its tributaries erode through the Colorado Mineral Belt. More current research shows that other sections are under different threats by various actual or potential activities. Based on stakeholder input obtained and refined during forums held in 2005, 2006, and 2007, the most imminent threats to water quality and the overall sustainability of the Clear Creek Watershed, listed in priority order, are:

1. proposed I-70 expansion
2. potential large-scale wildfire
3. metals loading
4. sediment loading
5. nutrient loading
6. toxic spills/incidents
7. drought
8. growth/development

The dollar values of the potential negative impact of these threats to the society, ecology, and economy of the Clear Creek Watershed range from millions to billions of dollars. However, our research and past remediation work shows that these threats are preventable, mitigatable, and/or treatable through the application of sustainable watershed management techniques. Refer to page 61 for a detailed description.

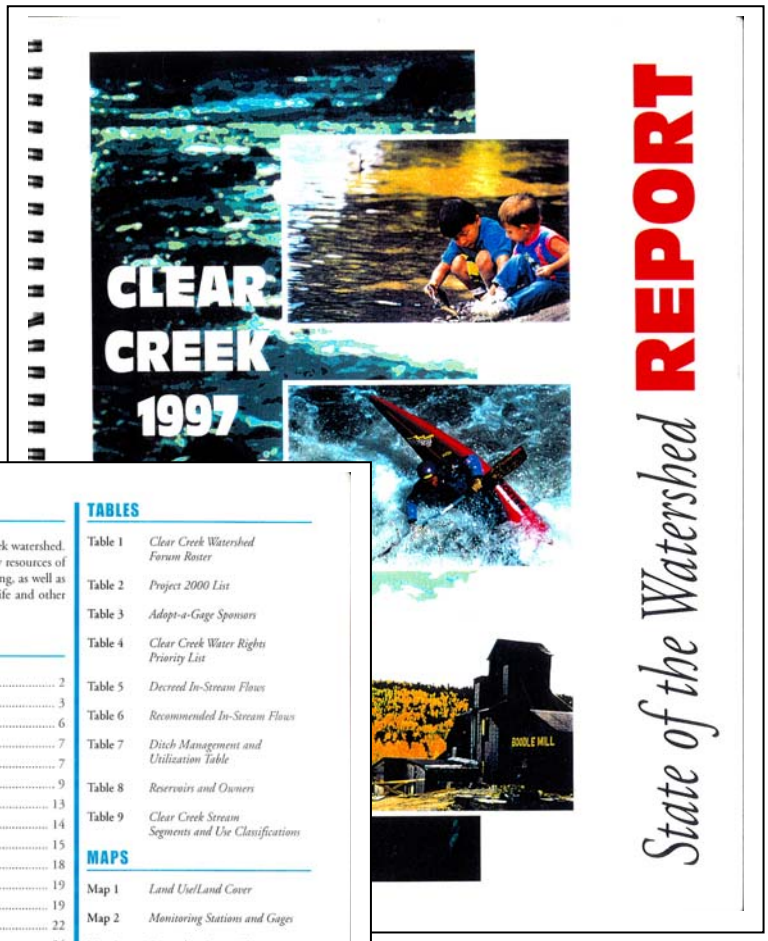
Opportunities for the Clear Creek Watershed. There are numerous sustainable watershed management project opportunities to reduce the impacts of these threats and enhance overall watershed sustainability. The process for ranking these opportunities is detailed in UTILIZING A VALUATION TECHNIQUE TO ASSESS THE TRIPLE BOTTOM LINE OF PROJECTS. The opportunities, which are discussed in APPLYING SUSTAINABLE WATERSHED MANAGEMENT TO THE CLEAR CREEK WATERSHED, fall into the following eight categories:

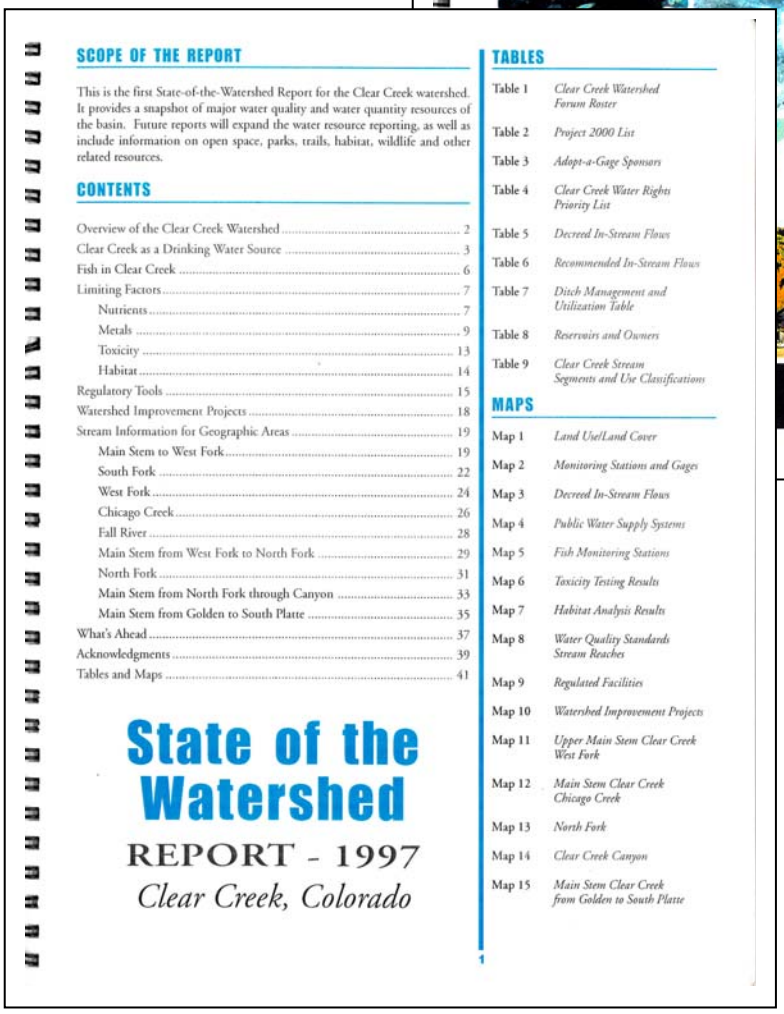
- Orphan Mine Remediation
- Natural Resource Management
- Water/Wastewater Management
- Preservation/Promotion of Historical Mine Sites
- Alternative Energy/Transportation
- Waste Stream Reduction
- Subsurface Rights and Uses
- Outreach/Education

The cost estimates of the potential projects also range from millions to billions of dollars; however, they would have positive impact on the society, ecology, and economy of the Clear Creek Watershed. As such, we classify them as sustainable watershed projects.

WATER QUALITY AND WATER QUANTITY IN THE CLEAR CREEK WATERSHED: AN OVERVIEW

A detailed analysis of water quality and water quantity for the Clear Creek Watershed was documented in the Clear Creek State of the Watershed Report, 1997. The first few pages are reprinted here for reference. The full 1997 Report is in PDF form at **www.clearcreekwater.org**. An updated companion volume to the 1997 report is being discussed.





SCOPE OF THE REPORT

This is the first State-of-the-Watershed Report for the Clear Creek watershed. It provides a snapshot of major water quality and water quantity resources of the basin. Future reports will expand the water resource reporting, as well as include information on open space, parks, trails, habitat, wildlife and other related resources.

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State of the Watershed

REPORT - 1997

Clear Creek, Colorado

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1

I. OVERVIEW OF THE CLEAR CREEK WATERSHED

Clear Creek's headwaters begin amidst the 14,000 foot peaks of Colorado along the Continental Divide near the Loveland Ski Area. Between the mountains and the plains, it flows through a handful of mountain communities and a majestic, undeveloped canyon in the foothills. It then becomes an urban stream providing scenery, trails, and habitat for wildlife as it flows through the north Denver metropolitan area on its way to join the South Platte River. Clear Creek is noted for its scenic grandeur, a rich mining heritage, limited-stakes gaming, and whitewater recreation. It is also an important source of water for a variety of uses such as agriculture, drinking water, and industry. Clear Creek is a stream with major water quality problems related to metals and concerns related to nutrients. The water quality problems are derived from natural sources, historic mining, municipal and industrial uses, and land use practices.

WATERSHED: *A watershed consists of two elements: a water body and the adjacent land from which water drains into that water body. In terms of water quality, the stream and the land are inseparable; water draining off the land carries with it the effects of nature and human activities.*

The Clear Creek watershed is often characterized as the upper basin and the lower basin. The upper basin consists of mountainous and foothills areas and encompasses two-thirds of the watershed. The lower basin is urbanized. Standley Lake is an important element of the Clear Creek watershed although it is located outside of the watershed. Water from Clear Creek is diverted into Standley Lake which supplies drinking water to several communities in the north Denver metropolitan area.

Communities

The counties and communities of the watershed are shown on Map 1, contained in Chapter X of this report. They include five counties and a dozen towns and cities. They range from picturesque mountain towns like Georgetown to gaming boom towns like Black Hawk and Central City to Golden, home of the Colorado School of Mines, to growing suburban areas like Arvada and Wheat Ridge. The Standley Lake cities, which tap Clear Creek water primarily for out-of-basin use, include Northglenn, Thornton, and Westminster. The largest land manager in the watershed is the U.S. Department of Agriculture (USDA) Forest Service. Fully one-third of the basin lies within the Arapaho-Roosevelt National Forest and is administered by the Clear Creek Ranger District. Other public lands are managed by the U.S. Department of the Interior Bureau of Land Management (BLM) and the State of Colorado Land Board. In 1995 the BLM lands in Clear Creek County were turned over to the county for disposition.

The Clear Creek Watershed Story

The Clear Creek watershed community has been described as a "culture of cooperation." It wasn't always that way. As recently as 1987, relationships between local community and business interests and the governmental agencies were strongly adversarial. Local interests felt that the state and federal regulatory presence was heavy-handed and they reacted angrily. This marked the low ebb of these relationships.

The turnaround in the relationship started with an honest attempt to listen and learn about each other's values - first, on the part of the regulatory community, such as the U.S. Environmental Protection Agency (EPA) and the Colorado Department of Public Health and Environment (CDPHE), and second, on the part of local people. Regulators learned to appreciate local values and wisdom—the special relationship with and knowledge of the land, the importance of personal relationships, and the unique rhythm and heritage of each community. At the same time, local people learned to appreciate what regulators could contribute: the technical knowledge and resources to address highly complex water quality issues.

Subsequently, through organizations like the Clear Creek Watershed Forum, the Upper Clear Creek Watershed Association, and the Upper Clear Creek Wathershed Advisory Group, relationships have been strengthened and a workable watershed effort has evolved. The groups bring together diverse watershed interests and create an atmosphere of cooperation.

The Clear Creek Watershed Forum is an informal organization which transcends the boundaries of any one agency, community, industry, or organization within the watershed. The role of the Forum is to bring people together from throughout the watershed to share information and to develop cooperative water quality improvement strategies and projects. The agenda of the Forum is locally-controlled by a Planning Committee made up of representatives from throughout the watershed. A roster of Forum participants is provided in Table 1, located in Chapter X of this report.

The Upper Clear Creek Watershed Association, which mostly represents dischargers in Clear Creek and Gilpin Counties, is a formal organization and part of the Denver Regional Council of Governments' regional planning effort. The Upper Clear Creek Watershed Advisory Group was formed to provide technical input on EPA and CDPHE cleanup projects. These groups spearheaded many efforts to improve cooperation in the basin. As an example of the cooperative spirit, stakeholders developed a list of 47 proposed watershed projects in 1993. So far 26 of these projects have been completed. To highlight just a few, they include the McClelland tailings cleanup, stream restoration through Idaho Springs, a joint stream monitoring program, and the publication and adoption of a "best management practices" (BMP) manual. The Project 2000 list, a list of projects expected to be completed by the year 2000, has now been developed. (See Table 2.)

II. CLEAR CREEK AS A DRINKING WATER SOURCE

Background

The watershed approach has fostered a remarkable spirit of cooperation and the use of common sense in addressing issues of water *quality*. The area of water *quantity* and *supply*, however, is much more competitive. Water from the Clear Creek watershed has been put to many uses over the last 137 years. Historically, it has been used for mining, agriculture, drinking water supplies, and industry such as flour mills, breweries, and manufacturing. Today, it provides drinking water for nearly 350,000 people and recreational opportunities for rafters, kayakers, fishermen, and gold panners. Clear Creek serves industrial purposes such as breweries and electrical production. The demand for Clear Creek water makes it one of the most over-appropriated streams in Colorado.

Stream Flow Characteristics

The discharge of Clear Creek has traditionally been measured by the U.S. Geological Survey at the Golden stream gage. The average peak flow is 1,255 cubic feet per second (cfs) and the average low flow is 28 cfs. About 75 percent of the annual flow is from snow melt and occurs in May, June and July. During late summer and winter, certain segments of Clear Creek are essentially dry.

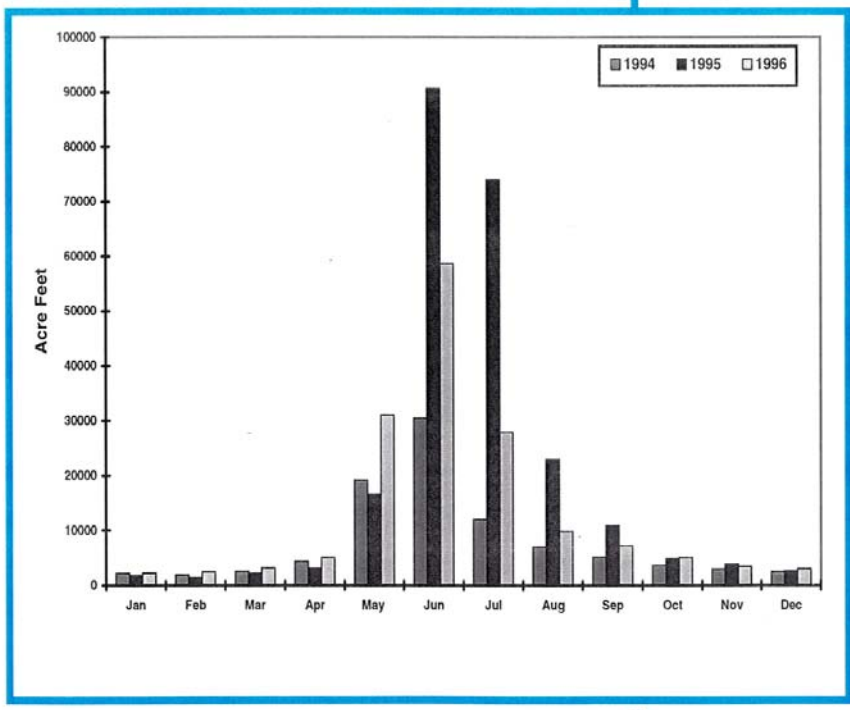
There are 18 stream flow gages on Clear Creek. Their locations are shown on Map 2 in Chapter X of this report. Funding for the operation of the gages comes through a successful "Adopt-a-Gage" program. (See Table 3 for a list of gage sponsors.)

CUBIC FOOT PER SECOND (CFS): *The rate of stream flow equal to one cubic foot (7.5 gallons) of water every second. One cfs flowing for one day results in a volume of water equal to about two acre-feet.*

ACRE-FOOT: *The volume of water required to cover one acre of land to a depth of one foot. An acre-foot is equal to about 325,825 gallons or the water required by two families of four for one year.*

Groundwater Characteristics

Groundwater is integral to the water quantity story of Clear Creek. In the headwaters portion of the watershed, groundwater accumulates in fractured rock and in alluvial deposits adjacent to Clear Creek. Metals from



CLEAR CREEK FLOW SUMMARY

This graph shows the total monthly flows at the Golden gaging station for 1994 through 1996. The spring of 1995 was a time of flooding and this is reflected in the June 1995 total flow which approached 91,000 acre feet.

natural and mining-related sources impact both groundwater and surface water as Clear Creek flows through the mineralized belt which crosses Clear Creek and Gilpin Counties. Extensive alluvial deposits of groundwater, as well as the deep aquifers of the Denver Basin, exist in the lower portion of the watershed.

GROUNDWATER: *Subsurface water which accumulates in underlying geologic formations as well as in fractured rock and alluvial (sand and gravel) deposits near stream beds. Groundwater and surface water are interconnected, in places readily flowing one to the other. In other places, this transfer of water may take more than 100 years. Areas of groundwater accumulation are called "aquifers" and can be tapped with wells for drinking water and other uses.*

Water Rights

The ability to use water from Clear Creek is determined by water rights. Water rights have a quantity and a priority date associated with them. There is generally adequate water in Clear Creek to satisfy all water rights during high flow. During low flow periods, when there is not enough water to satisfy all demands, the water users with the first or most senior water rights have first priority for water use.

Water rights are classified as direct flow water rights or storage rights. Direct flow rights generally run from April 1 through October 31 of any given year and involve taking water and using it immediately for activities such as irrigation. Storage rights, which generally run from October 31 through April 1, involve taking water and storing it in a reservoir for future use.

WATER RIGHTS: *The concept of Western water rights originated during the California gold rush. To keep peace among competing mining camps, a system was developed so that the miner who was the first to use the water had claim to that water. The second miner was next in line and so forth. This system was brought to Colorado during this state's mining boom and it became known as the Colorado Doctrine or the First-in-Time, First-in-Right Doctrine. This system of water rights became the law in 1876 when Colorado achieved statehood.*

In Colorado, a water right is a property right. The right can be sold or inherited. Water rights are generally measured in cfs or acre-feet. The current market rate for an acre-foot of high quality Clear Creek water with a senior water right is $8000 to $9000. The first water rights on Clear Creek were established in 1860.

HOW DOES A CALL WORK?: *When a senior water right is exercised, it is termed a "call"—for the simple reason that it is usually initiated with a telephone call to the water commissioner. Here's how the water commissioner works. Assume that water is being diverted to water rights holders with decrees dated 1860 and 1880. If someone with an 1870 decree puts in a call, the water commissioner will make sure that someone drives out to the field and physically shuts off the headgate of the 1880 water right holder and opens the headgate of the 1870 water right holder. Because there can be dozens of water rights holders and diversion structures on a stream, the call system can be quite complex.*

The seasonal pattern of water rights for Clear Creek tends to be distributed as follows:

During late summer and early fall—moderate flow—the controlling calls are from local water rights holders, e.g., those with 1860s and 1870s decrees such as the Church Ditch, Colorado Agricultural Ditch, and Farmers' High Line Canal which divert water to local communities and industry.

During spring—high flow—there can be calls from further down the South Platte River system because there is enough water to satisfy local senior water rights holders, e.g., those with 1860s decrees, as well as junior water rights holders, e.g., those with 1870s and 1880s decrees.

During winter —low flow—the calls on Clear Creek are controlled by storage decrees such as the Croke Canal, which diverts water to Standley Lake, and calls from the South Platte.

Table 4, provided in Chapter X of this report, shows the Clear Creek water rights and priority list for the lower basin.

In-stream Flow Rights

Flow Rights

Generally the most junior and smallest water rights are for in-stream flows. In-stream flow is the amount of water needed to "preserve the natural environment [and aquatic life] to a reasonable degree." For the past 20 years this has been generally interpreted as the flow necessary to sustain cold water fisheries, such as trout. Currently, this focus is being broadened to include warm water fisheries, e.g., smallmouth bass, black bullhead, and channel catfish, as well as endangered species. An in-stream flow appropriation gives the Colorado Water Conservation Board a water right. Calls from senior water rights holders can still deplete water from segments with in-stream flow rights; however, a more junior water right holder cannot encroach upon in-stream flow appropriations.

In-stream flow appropriations for selected stream segments start with flow recommendations, based on field analysis, from the Colorado Division of Wildlife (CDOW). CDOW provides recommendations to the Conservation Board which evaluates them against various criteria. If the Conservation Board agrees with CDOW's recommendations, they forward them to Colorado District Court, generally referred to as Water Court, for a decree which establishes an in-stream flow appropriation.

Tables provided in Chapter X of this report document those segments in Clear Creek which have decreed in-stream flow appropriations (Table 5) and where CDOW has made in-stream flow recommendations (Table 6). Map 3 displays the decreed minimum in-stream flows for Clear Creek.

Clear Creek Water Usage

Nowhere is the issue of water use highlighted more dramatically than by the network of canals and ditches which take water from Clear Creek and transport it to the various lower basin users. Table 7, included in Chapter X, lists the ditches and their management companies and major shareholders. Water from Clear Creek is used for a variety of purposes: aquatic life, recreation, water supply and agriculture. It is used both in-basin and trans-basin.

In-basin water use consists of water taken from Clear Creek for use within the watershed. About 40 percent of Clear Creek's annual flow is used in-basin. Trans-basin use involves diverting water from Clear Creek and transporting it through canals to another watershed. About 40 percent of Clear Creek's annual flow is used outside of the basin. Whereas some of the water used in-basin returns to Clear Creek, none of the trans-basin water is returned to Clear Creek. About 20 percent of Clear Creek water flows through to the South Platte River due to calls or lack of storage on Clear Creek.

Water Storage Facilities

Because of the variance in high and low flows and the time of year when water is in greatest demand, dams and reservoirs have been built in the Clear Creek watershed to capture some of the spring runoff for use during drier months of the year. There are a number of water storage facilities in the watershed, as well as outside of the basin, which receive water from Clear Creek. These are listed in Table 8, included in Chapter X of this report.

TRANS-MOUNTAIN DIVERSIONS

There are several trans-mountain diversions which flow through the Clear Creek watershed:

Gumlick and Vasquez Tunnels: These tunnels are part of the City of Denver's water system. Water from the Williams Fork in Grand County comes into the Clear Creek watershed through the Gumlick Tunnel, formerly known as the Jones Pass tunnel, near the Henderson Mine. Water is immediately diverted from the Gumlick Tunnel out of the watershed through the Vasquez Tunnel. From there, the water takes a roundabout route through Vasquez Creek (in the Fraser River system), Moffat Tunnel, South Boulder Creek, and Ralston Creek (in the Clear Creek watershed), to Ralston Reservoir. Water from Ralston Reservoir is then transferred to the Moffat Plant in Lakewood for treatment and distribution.

Vidler Tunnel: The Vidler Tunnel is owned by Water Resources Company, Inc. The Vidler transports water from Dillon Reservoir into the Clear Creek watershed near Argentine Pass above Georgetown. From there it flows down Leavenworth Creek to South Clear Creek to the main stem of Clear Creek. Water is then diverted into the appropriate downstream canal depending on who has contracted to receive the water.

Berthoud Pass Ditch: The Berthoud Pass Ditch is owned by the City of Northglenn. It transports water from Current Creek (in the Fraser River system) to Hoop Creek (in the Clear Creek watershed). Water is then diverted downstream at the Church Ditch which leads to Standley Lake.

WATER SUPPLIERS

Dozens of businesses, industrial facilities, towns and cities rely on Clear Creek, or on groundwater aquifers in the watershed, for all or a portion of their water supply. Locations of some of these water supplies are shown on Map 4 in Chapter X. Major water users, from the top of the watershed down, who tap primarily surface water sources include:

--- Town of Silver Plume
--- Town of Georgetown
--- Town of Empire
--- City of Idaho Springs
--- City of Central
--- City of Black Hawk
--- City of Golden
--- Coors Brewing Company
--- City of Arvada
--- Consolidated Mutual Water Company (City of Wheat Ridge, etc.)
--- Public Service Company
--- City of Northglenn
--- City of Thornton
--- City of Westminster

Major water users, from the top of the watershed down, who tap groundwater sources include:

--- campgrounds in the Clear Creek Ranger District of the Arapaho & Roosevelt National Forest
--- facilities in Golden Gate State Park
--- St. Mary's Glacier Water & Sanitation District
--- Gilpin County Justice Center
--- trailer parks
--- campsites
--- restaurants
--- lodges
--- schools
--- private home owners

WATER QUALITY

Water quality monitoring has been ongoing in the Clear Creek Watershed since the early 1980s. Photo courtesy of www.clearcreekwater.org.

The perspective provided in this 2007 report provides a general overview of current water quality and quantity conditions for the Clear Creek Watershed from a sustainability viewpoint.

For over a century and a half, the water in Clear Creek and its tributaries has been used for mining, irrigation, recreation, industry, and drinking. Transportation, industrialization, and urbanization have taken their toll on the water — most apparent is water quality impairment primarily from toxic metals. The upper part of the Clear Creek Watershed — home of the 1859 Colorado Gold Rush — is traversed by the Colorado Mineral Belt and is an environment full of abandoned, or orphan, mines and naturally-occurring mineral sites.

Eleven of Clear Creek's 26 segments have been designated as having *impaired water quality* according to the State of Colorado's 303(d) List (2006). This list, which is updated every two years, is compiled by the CDPHE's Water Quality Control Division, and reviewed and approved by the State Water Quality Control Commission and the EPA. The 303(d) List includes the identification of the specific component (such as nitrate, copper, sediment or habitat) that defines the specific water quality problem for a given stream segment. Of the 16 segments of Clear Creek upstream of Golden, eight are impaired primarily due to the toxic metals of cadmium, copper, lead, and zinc; of the 10 segments downstream of Golden, three are impaired primarily due to aquatic life issues, bacteria, and organic sediment.

Water quality protection and improvement efforts by Clear Creek Watershed stakeholders have been ongoing since the designation of the Clear Creek/Central City Superfund Study Area in 1983, including an extensive network of water quality monitoring sites. (See map on page 22.) More than two decades of Federal, State, and local water quality monitoring makes Clear Creek one of the best-characterized watersheds in US EPA Region 8. Numerous parameters have been monitored over the years including nutrients, metals, turbidity, and flow. Biologists from the Colorado Division of Wildlife (DOW) have also conducted assessments of the fish populations in Clear Creek and selected tributaries.

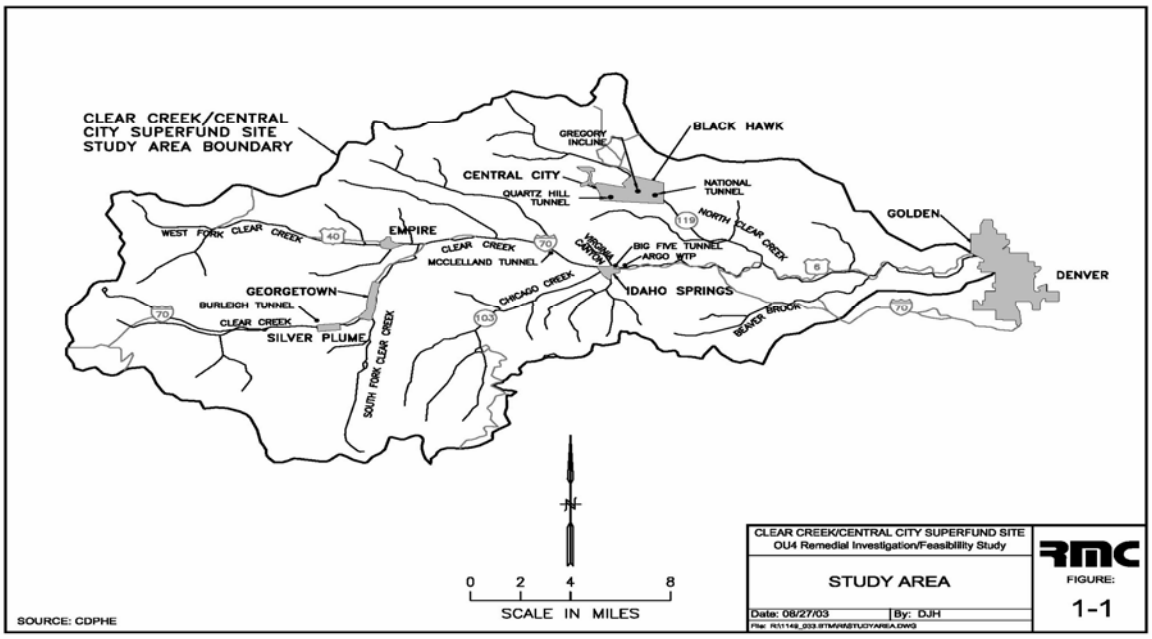
Since 1994, a dedicated, systematic water quality sampling and monitoring program has been operational. Through the *Clear Creek Watershed Management Agreement Monitoring Program,* water quality data on nutrients for up to 18 streamflow sites, eight wastewater treatment plants, and nine tributary sites have been collected. This effort has been cooperatively implemented by the Upper Clear Creek Watershed Association

(UCCWA), the Standley Lake Cities of Northglenn, Thornton, and Westminster; and the City of Arvada. The current members of UCCWA are:

1. Black Hawk
2. Black Hawk/Central City Sanitation District
3. Central City
4. Central Clear Creek Sanitation District
5. Clear Creek County
6. Clear Creek Ski Corporation (Loveland)
7. Colorado Department of Transportation (Eisenhower Tunnel)
8. Coors Brewing Company
9. Empire
10. Georgetown
11. Gilpin County
12. Golden
13. Henderson Mine
14. Idaho Springs
15. Jefferson County
16. Mt. Vernon Country Club Metropolitan District
17. Saddleback Metropolitan District
18. Shwayder Camp
19. Silver Plume.
20. St. Mary's Glacier Water and Sanitation District

Over the years, these data have demonstrated improved water quality due to voluntary mine waste clean-ups, improvements to wastewater treatment technologies, and various Superfund clean-up activities. Results of this monitoring program are published in the annual Clear Creek Watershed Agreement reports and presented to the CDPHE Water Quality Control Commission. In 2004, UCCWA received a 319 grant to produce the Clear Creek Watershed Management Plan which provides a framework to respond to anticipated TMDLs in the upper basin. In 2006 UCCWA formed a Regional Wastewater Study Group to focus long-range planning to optimize wastewater treatment.

CLEAR CREEK/CENTRAL CITY SUPERFUND SITE STUDY AREA LOCATION MAP



Clear Creek at its confluence with the South Platte River. Photo courtesy of Adams County Parks & Community Resources.

This effort is an essential element in order to measure water quality improvement progress or lack thereof over time. Continuation of this effort is necessary for sustainable watershed management. Various monitoring programs and aspects of the water quality for the Clear Creek Watershed are listed in APPENDIX 4.

By remediating mining-related water quality problems and promoting more sustainable watershed management projects, the Foundation and its partners have been providing on-the-ground revitalization for the Clear Creek Watershed communities and working toward ongoing water quality improvements for Clear Creek. To date, 35 major remediation projects have been completed with significant improvements to water quality, particularly along the I-70 corridor. See APPLYING SUSTAINABLE WATERSHED MANAGEMENT TO THE CLEAR CREEK WATERSHED for more details on this work, plus current and future projects.

Although none of the Clear Creek segments have yet been removed from the 303(d) List, there are clear indications that attainment of regulatory-specified targets is near on several mainstem segments.

Fishing in Clear Creek. Photo courtesy of www.clearcreekwater.org.

In APPENDIX 1: Aquatic Toxicity Investigations – An Overview and associated Table A-1: *Ceriodaphnia dubia* Acute-Toxicity Results, Upper Clear Creek Watershed and Figure A-1: Comparison of LC50% (Survival) for Aquatic-Toxicity Studies, key findings include:

- Overall comparative results for these studies (1989 to 2007) point towards an improvement in low-flow aquatic-toxicity conditions over time, as indicated by increasing…survival values at nine of the 14 sites having multiple samples for the indicator species, Ceriodaphnia dubia ("Daphnia").

- The Daphnia tests are an indicator of overall improvement of the health of the aquatic life system in the upper watershed.

- A spatial (upstream-to-downstream) comparison of LC50% survival values indicates a general profile of higher acute toxicity as one proceeds in a downstream direction. (See Figure A-1.)

- Soon after the Argo Tunnel treatment facility came on line (April 1998), a significant adit-discharge that was previously characterized by high trace-metals concentrations, resulted in reduced trace-metals loads into the mainstem of Clear Creek at Idaho Springs. Other remediation projects have also contributed to

reducing trace-metals loads to the watershed's streams. (See APPLYING SUSTAINABLE WATERSHED MANAGEMENT TO THE CLEAR CREEK WATERSHED.)

- Survey data reports the continuing need for improving conditions in the North Fork Clear Creek. New Superfund remedial projects have been funded and are beginning to be implemented [on the North Fork].

The overview also cites a Colorado Division of Wildlife perspective:

- According to Paul Winkle, Colorado Division of Wildlife (CDOW) aquatic biologist, "…the water quality of the mainstem of Clear Creek has improved considerably in recent years thanks, in large part, to treatment plants built in some of the mountain communities along the river and to government-citizen group habitat restoration efforts. As a consequence…Clear Creek is a viable trout fishery today." (*CDOW Fishing Guide, 2007*)

TABLE 1 below characterizes the toxicity changes cited in Appendix 1 and shows the impact of projects already put in place. See STUDY AREA LOCATION MAP on page 22 for locations.

TABLE 1: TOXICITY* CHANGES IN CLEAR CREEK • 1989 - 2007

Location	Prior Condition >> Current Condition	Proposed Future Remediation
Burleigh Tunnel	toxic » toxic	redesign Burleigh wetland
Woods Creek	toxic » good fishery	streambank improvement
Mainstem below Georgetown	good fishery » excellent fishery	groundwater recharge
Trail Creek	toxic » toxic	priority grant project for 2008
Clear Creek above Argo	fair fishery » good fishery	Maud(e) Munroe project
Clear Creek below Argo	toxic » fair fishery	instream improvements
North Fork below Gregory Gulch	toxic » worse toxicity	Superfund work in 2008
North Fork below Russell Gulch	toxic » improving water quality	Superfund work in 2008
Clear Creek downstream Golden	toxic » improving fishery	dependent on upstream water quality and downstream fishery improvements

* Toxicity refers to the quality of water necessary to sustain aquatic life colonies that are fundamental in the food chain of fish. In this instance, toxicity tests were conducted on the indicator species *Ceriodaphnia dubia*.

It is evident that improved water quality conditions are linked to the remediation of numerous orphan mine sites, which has reduced the trace metals loadings to Clear Creek and its tributaries. Improving trends validate the water quality protection and improvement strategy in place that will lead to restoring and maintaining water quality standards on impaired segments in the upper Clear Creek watershed.

Continued remediation is needed, primarily in the valley floors of the Clear Creek Watershed. This is where draining mine tunnels, historic mill sites, and the most potent highway residuals are located. This is also the area of greatest ecologic, social/historic, and economic value. These variables combine to make the perfect set-up for conflict among multiple purposes — national defense; transportation; historic preservation; clean water; and public health, safety, and welfare. Not all water quality problems are caused by human activity. Clear Creek and its tributaries cut through naturally-occurring ore bodies and materials in these zones either erode event-by-event or are fixed project-by-project. Human-caused and naturally-occurring water quality problems can be improved. In order to do that, however, one must understand the practical limits and excesses of system fluctuations. For instance, what are the historical fluctuations of flows in Clear Creek? Fortunately, streamfows in this watershed have been documented from pre-human intervention to the present. Read more in the WATER QUANTITY section below.

WATER QUANTITY

In addition to the impacts on water quality, there are constant impacts on the water quantity of Clear Creek — some occurring naturally and some due to human uses. In addition, ongoing demands on Clear Creek continue to make it one of the most intensively managed and over-appropriated streams in Colorado. Up-to-date water appropriation information, etc., can be obtained from the State Engineer and the local State Water Commissioner.

A review of the hydroclimatology of the Clear Creek Watershed provides valuable insight into the water quantity of the Clear Creek Watershed. Hydroclimatology is the hydrological response to climate shifts.

According to EPA, most people now understand that we have a climate problem, but few yet appreciate how big it is or what it will take to solve it. A recent EPA webcast called *Water, Energy, and Climate Change* explored the dimensions of this global problem and prompted discussions about what water quality managers at the federal, state, and local level, along with the watershed protection community, can do to rise

COLORADO WATER CHALLENGES

Colorado is a unique state when it comes to water. It receives much less rainfall and precipitation than many other eastern and some western states. Its water resources need to be understood and wisely managed so that what water the state does receive is available for all forms of life that depend on it.

The snow-capped Rocky mountains are the origin, or headwaters, of many streams that join to become rivers. These streams and rivers carry an average of 15 million acre-feet of water a year while in Colorado. They flow through 18 other states on their way to the oceans.

In an average year, 95 million acre-feet of precipitation, in the form of rain and snow, fall on Colorado. About 80 million acre-feet of that total evaporates, replenishes groundwater, or is used by plant life.

For more on river systems, the challenge of balancing water uses, river compacts, etc., log on to:

Colorado Foundation for Water Education at http://cfwe.org

Colorado Division of Water Resources at http://water.state.co.us

WATER WORDS

An acre-foot measures the volume of water. One acre-foot is 325,851 gallons, which is equivalent to a football field covered one foot deep with water.

A cubic foot per second (cfs) measures the flow rate of water. One cfs is 449 gallons per minute, which is equivalent to 30 to 40 garden hoses running at full capacity.

A typical family of four uses ½ of one acre-foot per year. This is equivalent to 162,926 gallons of water each year, or 446 gallons every day.

SOURCE: Colorado Water Education Foundation

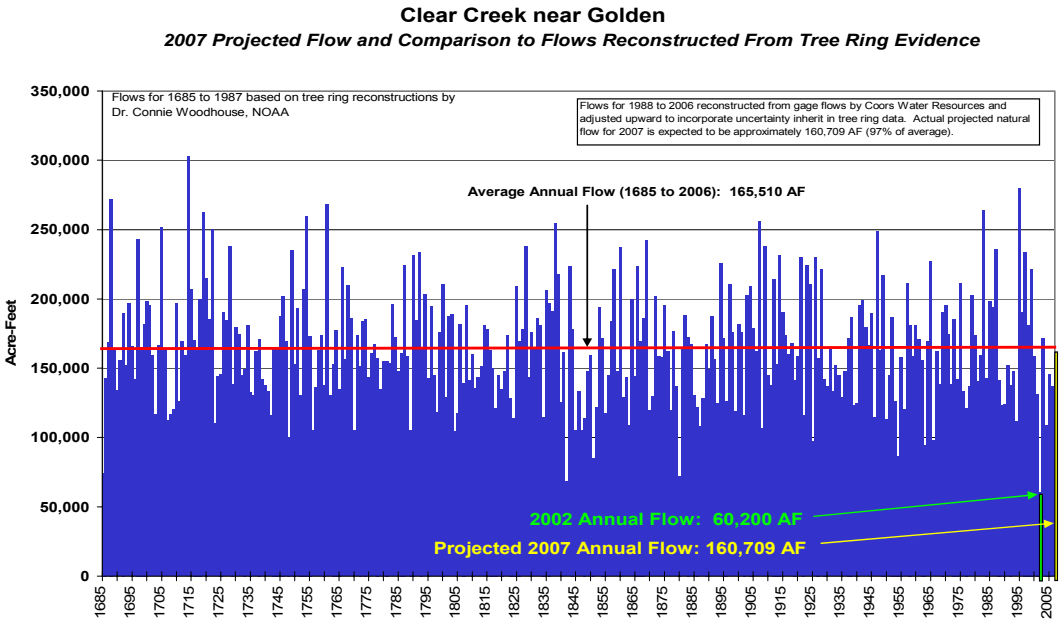
to the climate challenge. Major opportunities to simultaneously save water and energy, thereby reducing greenhouse gas emissions and limiting climate change, were discussed during the webcast. Watershed practitioners, utilities, community leaders, and agency officials can all benefit from becoming better informed about the profound implications of climate change on water resources and what we can all do now to protect our future water supplies. While global climate change seems daunting, dealing with such issues in the boundaries of a watershed makes real improvements attainable.

Climate change has become an important component of research being conducted by the US Geological Survey (USGS). Perceptions of earlier snowmelt occurrences in Colorado have been investigated and preliminary results were presented by David Clow, USGS Research Hydrologist, to the UCCWA in early 2007. Clow analyzed trends on the timing of the onset of snowmelt and streamflow runoff at a small number of sites for 1978 through 2005 using a new statistical technique. Results showed snowmelt and streamflow peaks advanced by an average of two weeks over the study period, and the observed changes were highly correlated with recent springtime warming trends. This earlier snowmelt places further demand on net storage. According to Clow, if these trends continue, there will be important implications for water resource management in Colorado.

The information presented in the hydrographs below provides valuable insight into the hydroclimatology of the Clear Creek Watershed. Annual flow rates and the mass storage potential for the years 1685 to 2007 developed from National Oceanic and Atmospheric Administration (NOAA) tree-ring analyses and measured stream flows are presented in the hydrographs.

HYDROGRAPH 1 is a graphical representation of Clear Creek annual flow rates (estimated for historical years prior to stream gaging) for the past 332 years (Coors Water Resources, 2007).

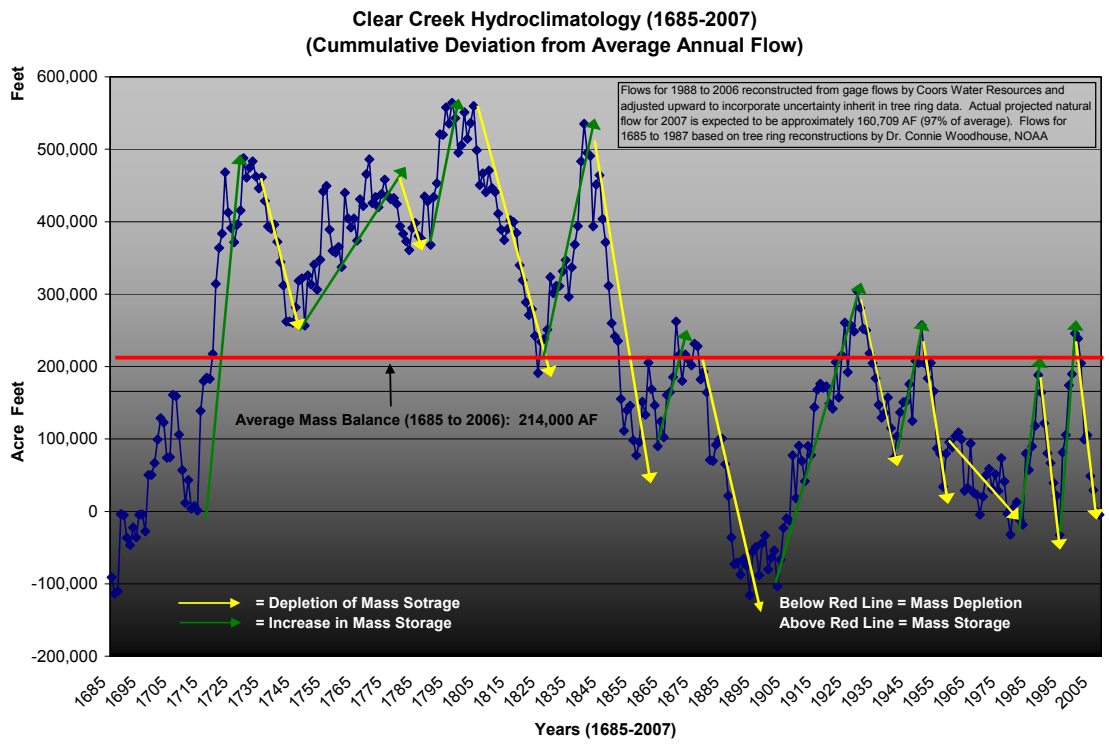
HYDROGRAPH 1: CLEAR CREEK ANNUAL FLOW RATES



This time-series plot illustrates that the flow rates of Clear Creek change drastically from year to year, with the variability tending to be a result of multiple environmental factors, including climate change. From these data, annual flow was determined. Hypothetically, this would allow decision makers to design projects that are dependent on water quantity of the annual predicted flows. However, it is more than likely that flows will continue to be significantly above or below this average each year — as plotted in the graph. The actual annual flow is rarely, if ever, equal to the average annual flow. Sustainable watershed planning and management would consider both flood and drought extremes when forecasting probable conditions for any given year. It is important to note that there is no direct cause and effect, thereby making flood-flows and drought difficult to predict. Note that some of the higher and lower flows occurred before significant human intervention, which commenced in about 1860.

HYDROGRAPH 2 provides an analysis of the water quantity that could be stored within the Clear Creek Watershed, also referred to as the *mass storage potential*.

HYDROGRAPH 2: MASS STORAGE POTENTIAL FOR CLEAR CREEK WATERSHED



The data plotted in HYDROGRAPH 2 is the cumulative deviation of the average annual flow data plotted in HYDROGRAPH 1, and depicts the historical increases and decreases in mass storage or depletion of the Clear Creek Watershed over the last 332 years. The yellow arrows illustrate declining trends in mass storage, while the green arrows depict increasing trends. The red line is the average mass storage potential. This hydrograph clearly illustrates that historically there was a period when the water available to be stored in the watershed was well above the estimated long-term average. However, over the past 100 years the overall trend has been a mass depletion. The plot shows the hydrologic shifts in mass as a response to climate shifts. It is critical to note

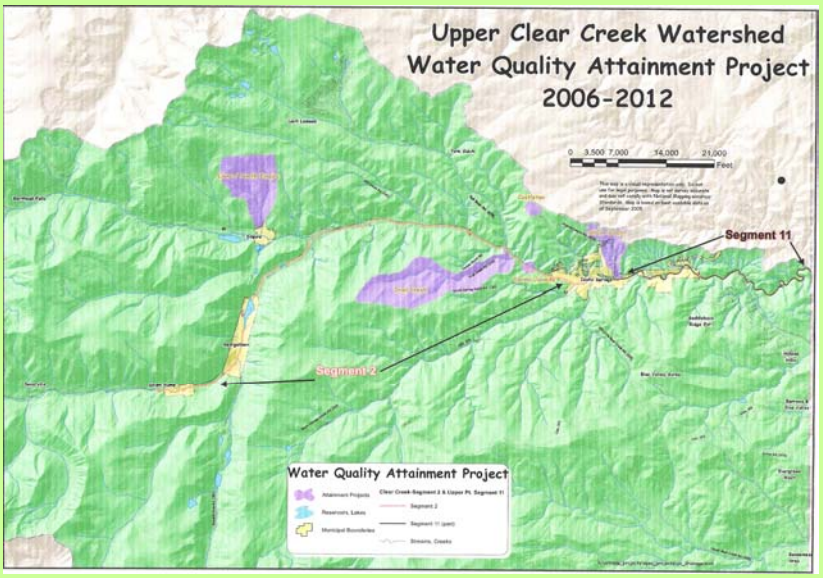
that there are no flat trends, this reflects the extremes of nature's variability. There is now greater net depletion than experienced in the prior 200 or so years; therefore, stakeholders, water users, and planners should be very concerned about drought planning and occasional dry flows. Note that some of the greatest droughts and high flow event years occurred prior to 1945. This record does not show that human activity has been a defining cause affecting streamflows in this watershed.

All of this information shows that the streamflows in the Clear Creek Watershed fluctuate from year to year, which in turn impacts water quality. In order to allocate water consumption without depleting the resource, municipalities and other decision makers need to take into account the highs and lows of both annual flow mass storage potential and runoff timing. Addressing these fluctuations in water quantity can result in better sustainable management of Clear Creek water resources, as climates have shifted from wetter, cooler periods of record to more recent drier, warmer periods.

Climate change and the hydrologic response to such change form the backdrop for all works done in the watershed. Short-term fixes may actually be long-term impediments. The point is that sustainable watershed management must consider long periods of record and project realistic expectations of the design life of projects. So often we hear "We want this fixed once and for all." There are no once and for all fixes. Sustain-ability must consider seven generations, but must be iterative and adaptable in design execution, operation, and maintenance of any project.

CLEAR CREEK WATERSHED STEWARDSHIP CONTINUES

The US EPA announced in August 2007 that the Clear Creek Watershed Foundation has been chosen as a finalist for a $544,090 Targeted Watersheds Grant. The proposal, one of 16 finalists in the nation, features a large-scale mine site remediation project to restore water quality in impaired stream segments. The proposal includes installation of traps for contaminated sediment, removal of mine waste piles, and development of an innovative metals trading program to fund maintenance of sediment traps.



Although we discuss the uniqueness of this watershed, we are aware and the reader should be aware, that there are commonalities in watershed management throughout the arid mountain west. Thus we wish to show a potential exportability of our findings and experience to other watershed groups facing similar issues.

ECOLOGICAL PERSPECTIVE

The Foundation defines *sustainable watershed management* as:

A community-based approach to improving and protecting the natural resources of a watershed by integrating ecological, social, and economic perspectives.

ecology + society + economy = sustainability

Ecology

- **management of natural resources with water quality and water quantity being the primary focus**
- **protection/enhancement of naturally-occurring ecological services (source/headwaters, storage, conveyance, wetlands)**

This section provides an overview of the following:

- The concept of *ecological services*.
- Methods of valuation.
- Examples of environmental valuation metrics.
- Examples of green calculators & other resources
- Jurisdictions and agencies conducting ecological services valuations.
- Examples of EPA and State programs advancing sustainability.

1. Environmental Economic Metrics

Ecological services are the goods and functions produced by ecosystems — such as wetlands and forests — that provide long-term human benefit. There are two types of ecological services, direct and indirect:

- **Direct** services are specific goods that we harvest or obtain from ecosystems such as timber, minerals/fuel, fish/wildlife, water, air, and recreational opportunities.

- **Indirect** services tend to be the less tangible functions of ecosystems such as water purification, flood control, nutrient cycling, carbon sequestering, and aesthetics.

Oftentimes the public and agencies discount the value of ecological services and/or take properly functioning ecological systems and services for granted. These services are essential to human health and well-being, but are often considered as free services, so

THE VALUE OF CLEAR CREEK

As water flows down Clear Creek, it begins to be subjected to human demands. Reservoirs have been constructed to store water and diversion structures have been built to deliver water supplies. Clear Creek diversions begin in earnest just above Golden. Water that once irrigated 75,000 acres of Colorado farmland has now been acquired by local municipalities and industries through court-approved change-in-use procedures.

The amount of water that each ditch may divert is governed by Colorado water law, which is based on a doctrine of *prior appropriation* — the first person to divert water from a stream established a right or priority to that amount of water. These are called *senior water rights*. The seniority and historical consumptive use of a water right are important measures of its value when the right is transferred to a new user. The basic economic concept of supply and demand applies, and increased growth and development along the Front Range has increased demand for the limited supply of Clear Creek water, which has resulted in competition. The value of good senior rights for Clear Creek water currently ranges from $20,000 to $25,000 per acre-foot. This value has doubled from 1995 prices.

SOURCE: Coors Water Resources Group

their value is not taken into consideration by decision makers. Considering ecological services as free can lead to the misuse and over consumption of these precious commodities. Due to this tendency, environmental economists have developed various ecological valuation methods (i.e., placing real dollar values to ecological goods and services) over the past 30 years. It is important to understand the worth of these resources in order to make wise policy, planning, and regulatory decisions. Although sometimes discounted, these services are constantly in demand. They have high value even though we don't pay for them directly. Perhaps the questions we should be asking are: *What if we didn't have these services?* and *How much are we willing to pay for the water purification provided by healthy, functioning wetland systems and other naturally-occurring ecological services?* The following is a summary of the Foundation's study of valuation methods and application of those methods specifically to ecological services provided by the Clear Creek Watershed.

2. Methods of Valuation

Placing value on ecological services is a challenging and at times ambiguous process; however, the recent increased demand for actual dollar values of natural resources and ecosystem services has led to the development of several methodologies to estimate these costs. The following table lists the most commonly-used economic methods, their applicability, and their pros and cons.

TABLE 2: COMMON NATURAL RESOURCE/ECOSYSTEM VALUATION METHODS

Method	Applicable to	Description and Importance	Constraints and limitations
Market Price Method	Direct Use values, especially wetlands.	The value is estimated from the price in commercial markets (supply and demand).	Market imperfections (subsidies, lack of transparency) and policy distort the market price.
Damage Cost Avoided, Replacement Cost or Substitute Cost Method	Indirect Use Values: coastal protection, avoided erosion, pollution control, water retention	The value of organic pollutant or any other pollutant's removal can be estimated from the cost of building and running a water treatment plant (substitute cost).The value of flood control can be estimated from the damage if flooding would occur (damage cost avoided).	It is assumed that the cost of avoided damage or substitutes match the original benefit. But many external circumstances may change the value of the original expected benefit and the method may therefore lead to under- or over-estimates. Insurance companies are very interested in this method.
Travel Cost Method	Recreation and Tourism	The recreational value of a site is estimated from the amount of money that people spend on reaching the site.	This method only gives an estimate. Over-estimates are easily made as the site may not be the only reason for traveling to that area. Requires a lot of quantitative data.
Hedonic Pricing Method	Some aspects of Indirect Use, Future Use and Non-Use Values	This method is used when wetland values influence the price of marketed goods. Clean air, large surface of water or aesthetic views will increase the price of houses or land.	This method only records people's *willingness to* pay for perceived benefits. If people are not aware of the link between the environment attribute and the benefits to themselves, the value will not be reflected in the price. This method is very data intensive.
Contingent Valuation Method	Tourism and Non-Use values	This method asks people directly how much they would be willing to pay for specific environmental services. It is often the only way to estimate the Non-Use values. It is also referred to as a "stated preference method".	Various sources of possible bias in the interview techniques and controversy over whether people would actually pay the amounts stated in the interviews. It is the most controversial of the non-market valuation methods but is one of the only ways to assign monetary values to non-use values of ecosystems that do not involve market purchases.
Contingent Choice Method	For all wetland goods and services	Estimate values based on asking people to make tradeoffs among sets of ecosystem or environmental services.	Does not directly ask for willingness to pay; this is inferred from tradeoffs that include cost attribute. This is a very good method to help decision makers to rank policy options.
Benefit Transfer Method	For ecosystem services in general and recreational uses in particular	Estimates economic values by transferring existing benefit estimates from studies already completed for another location or context.	Often used when it is too expensive to conduct a new full economic valuation for a specific site. Can only be as accurate as the initial study. Extrapolation can only be done for sites with the same gross characteristics.
Productivity Method	For specific wetland goods and services: water, soils, etc.	Estimates the economic values for wetland products or services that contribute to the production of commercially marketed goods	The methodology is straightforward and data requirements are limited but the method only works for some goods or services.

SOURCE: www.ecosystemvaluation.org

Metrics have recently been developed for social and economic value sets that assist decision makers in determining the value of a potential project; however, little work has been conducted in developing useful ecological metrics per the valuation methods outlined in TABLE 2. A goal of the Foundation was to develop an ecological service metric that would be a beneficial tool for local stakeholders, elected officials, and government agencies. This tool would allow for more informed sustainability-based decisions considering the total economic benefit and costs of proposed projects.

One of the most cited research papers on ecological services *The Value of the World's Ecosystem Services and Natural Capital* by Robert Costanza, et al, addresses the need to value the services provided by ecosystems and develops a framework of average global values of annual ecosystem services. Over an intensive week-long conference held at the University of Santa Barbara in 1994, a group of scientists and economists used group deliberation and data obtained through an extensive literature review to determine global values in US dollars per hectare per year for these various services. These values were then developed into an ecological services matrix. The following table is excerpted from the original matrix and shows services and their values that apply to the Clear Creek Watershed. Note that the values have been adjusted to 2006 dollar values using annual inflation rates.

TABLE 3: GLOBAL VALUES FOR ECOSYSTEM SERVICES APPLIED TO THE CLEAR CREEK WATERSHED

ECOLOGICAL SERVICES	Forest	Wetland	Floodplains	Lake/Rivers
Gas Regulation		$181.17	$360.97	
Climate Regulation	$192.07			
Disturbance Regulation	$2.72	$6,182.87	$9,862.08	
Water Regulation	$2.72	$20.43	$40.86	$7,416.99
Water Supply	$4.09	$5,176.23	$10,352.46	$2,883.70
Erosion Control	$130.77			
Soil Formation	$13.62			
Nutrient Cycling	$491.74			
Waste Treatment	$118.51	$5,689.76	$2,259.83	$905.84
Biological Control	$2.72			
Habitat		$414.10	$597.99	
Food Production	$58.57	$348.71	$64.02	$55.85
Raw Materials	$187.98		$66.75	
Genetic Resources	$21.79	$144.39		
Recreation	$89.90	$781.88	$668.82	$313.30
Cultural	$2.72	$1,200.10	$2,398.77	
Total Value per hectare per year	**$1,319.94**	**$20,139.61**	**$26,671.19**	**$11,575.68**

SOURCE: *The Value of the World's Ecosystem Services and Natural Capital* by Robert Costanza, et al

TABLE 4 relates to the Foundation's efforts to develop a framework to assess the value of ecological goods/services found specifically in the Clear Creek Watershed, and then could also be applied to prioritizing proposed projects. The values found in these

metrics were developed using a range of different economic methods. These metrics give a description of the ecological good or service, the values obtained, the methodologies used, and reference sources. Note that these metrics present very basic values for ecological services/goods. There are countless variables that can be used when valuing ecological goods/services, and due to the Foundation's emerging valuation experience, many of the goods/services listed here may be under-valued.

TABLE 4: DOLLAR VALUES FOR ECOLOGICAL GOODS/SERVICES IN THE CLEAR CREEK WATERSHED

GOOD/SERVICE	VALUE	DESCRIPTION OF VALUE	METHODS	REFERENCE
Gold	**$626.90/oz**	Market price per ounce of gold as of January 2007	Market Value	National Mining Association www.mineralstox.com
Silver	**$12.88/oz**	Market price per ounce of silver as of January 2007	Market Value	National Mining Association www.mineralstox.com
Copper	**$2.60/oz**	Market price per ounce of copper as of January 2007	Market Value	National Mining Association www.mineralstox.com
Molybdenum	**$25.25/lb**	Market price per ounce of moly as of January 2007	Market Value	National Mining Association www.mineralstox.com
Zinc	**$1.75/lb**	Market price per ounce of zinc as of January 2007	Market Value	National Mining Association www.mineralstox.com
Uranium	**$72.00/lb**	Market price per ounce of uranium as of Jan 2007	Market Value	National Mining Association www.mineralstox.com
Crushed Stone (limestone/granite)	**$7.75/metric ton**	Average Market Price as of 2006	Market Value	USGS
Gravel and Sand	**$6.15/metric ton**	Average Market Price as of 2006	Market Value	USGS
Vanadium	**$8.08/pound**	Average Market Price as of 2006	Market Value	USGS
Fish	**$35/animal**	The fine assessed by CDOW for illegal poaching any species of fish.	Replacement Cost	Colorado Division of Wildlife http://wildlife.state.co.us/RulesRegs/ LawEnforcement/
Birds	**$50/animal**	The fine assessed by CDOW for illegal poaching of any bird.	Replacement Cost	Colorado Division of Wildlife http://wildlife.state.co.us/RulesRegs/ LawEnforcement/
Large Mammals	**$1000/animal**	The fine assessed by CDOW for illegal poaching of elk and mountain sheep.	Replacement Cost	Colorado Division of Wildlife http://wildlife.state.co.us/RulesRegs/ LawEnforcement/
Small Mammals	**$50/animal**	The fine assessed by CDOW for illegal poaching of beaver.	Replacement Cost	Colorado Division of Wildlife http://wildlife.state.co.us/RulesRegs/ LawEnforcement/
Min Potable Water	**$3.13/ 1000 gal**	The per 1000 gallon fee was determined by averaging the rate charged by Golden, Idaho Springs, and Georgetown to receive treated water.	Market Value	City of Golden, City of Idaho Springs, City of Georgetown
Max Potable Water	**$5981.88/ 1000 gal**	Based on an average value of price per liter of designer water. This is the price people are willing to pay for "pure" drinking water.	Willingness to Pay	Aquafina, Dasani, Fiji, Evian, and Refreshe Water Bottling Companies
Water Treatment	**$3.22/lb of metal removed**	Cost per pound of metal removed from Water	Market Value	Argo Water Treatment

SOURCE: *Clear Creek Watershed Foundation, 2007*

The complexity of the range of variables for developing economic valuations for ecological services is illustrated by the following example related to valuing local fisheries. For our study purposes, the value of a fish was determined to be $35, based on fines issued by the Colorado Division of Wildlife (CDOW) for catching a fish without a license. However, this value only scratches the surface of the numerous other variables that could go into determining a realistic value for a fish, such as:

1. the number people who fish each year,
2. how much they spend to fish for one day in Clear Creek,
3. travel costs to get to the fishing spot,
4. money spent by local fishing supply businesses to attract fisherman to the area,
5. cost to stock fish,
6. and so on.

According to the *2007 CDOW Fishing Guide*, a recent CDOW sampling yielded an estimate of between 30 and 300 pounds of brown trout and about 25 pounds of rainbow

GREEN CALCULATORS & OTHER RESOURCES

In an attempt to make ecosystem valuation easier to determine and more accessible to local decision makers who have limited research resources, numerous online green calculators, databases, and other helpful resources have been developed, including:

The Green Value Stormwater Calculator estimates the hydraulic and financial benefits of installing green stormwater solutions at new development sites.
http://greenvalues.cnt.org/calculator

The Ecosystem Services Database was developed by the University of Vermont and serves as a clearing house for literature on ecological valuation and provides dollar values for certain ecological services that have been studied extensively.
http://ecoinformatics.uvm.edu/projects/ecosystem-services-database.html

Better Site Design: A Handbook for Changing Development Rules in Your Community presents changes to community regulations that result in more environmentally-friendly development. It covers engineering principles, actual vs. perceived barriers, economic and environmental considerations, and presents case studies from across the country. This handbook is now available as a free PDF download at http://www.cwp.org/PublicationStore/bsd.htm.

The Low-Impact Development Photo Database was compiled by the Stormwater Quality Committee of the Colorado Association of Stormwater and Floodplain Managers. This is an online photo database of low-impact development approaches, which includes porous concrete, modular block pavement, porous landscape detention, grass buffers, green roofs, level spreaders and more. Logon www.casfm.org/stormwater_committee/LID-00.htm.

The Using GIS Tools to Link Land Use Decisions to Water Resources Protection web site, developed by the National Association of Counties, lists a variety of resources to help communities use geographic information systems (GIS) to evaluate water quality impacts of various land use decisions. Logon Using GIS Tools to Link Land Use Decisions to Water Resources Protection Web site. Included on the site is the recently updated County Water Quality Issue Brief.

Version 4.0 of the Better Assessment Science Integrating point and Nonpoint Sources (BASINS) software system has been released. BASINS 4.0 functions the same as BASINS 3.1 except it runs on a non-proprietary, open source, free GIS system (PDF) (2.0MB, 17 pages, About PDF), making the tool universally available to anyone interested in facilitating examination of environmental information, supporting analysis of environmental systems, and providing a framework for examining management alternatives for watersheds.

- **Background**
- **What's new in BASINS?**
- **BASINS 3.1**
- **Publications**
- **Download and additional information**

BASINS is a multipurpose environmental analysis system designed for use by regional, state, and local agencies in performing watershed and water quality-based studies. This system makes it possible to quickly assess large amounts of point source and non-point source data in a format that is easy to use and understand. Installed on a personal computer, BASINS allows the user to assess water quality at selected stream sites or throughout an entire watershed. This invaluable tool integrates environmental data, analytical tools, and modeling programs to support development of cost-effective approaches to watershed management and environmental protection, including TMDLs.

trout per acre in Clear Creek; so the overall population of each fish species also could be factored in. If all of these values could be obtained, the cost of a single fish would probably be orders of magnitude higher.

3. Jurisdictions That Have Conducted Ecological Services Studies

Ecological services valuation is becoming a key tool used by jurisdictions for city planning and management. Determining the value of ecological services and resources can aid decision makers in assessing property value, park services, and development impacts.

A prime example of this type of valuation was conducted by the City of Boulder, in collaboration with the US Forest Service Center for Urban Forest Research, to determine the dollar value of municipal trees (McPhearson et al 2005). In order to establish the economic value of a municipal tree in Boulder, a city-wide inventory was conducted to determine the number of park and street trees. Next, a dollar value for the following functions was assessed for each tree:

- Stormwater intercepted.
- Electricity saved annually from shading and climate effects attributed to trees.
- Annual CO2 sequestration and emissions reduction.
- Net annual air pollutants removed, released, and avoided.
- Estimated total annual benefits associated with aesthetics, property value increases, and other less tangible benefits

Based on values determined for each one of these variables, results determined that:

- The average annual net benefit is $56 per tree.
- For every $1 Boulder residents invest in tree care they will receive $3.64 in benefits.

These values are now used in city planning and assist in determining the benefits of investing in urban landscaping and park space. The City of Ft. Collins has since conducted a similar study, which is one of the larger-scale projects conducted by a jurisdiction in Colorado.

Not all ecological valuation studies have to be on such a precise level to obtain valuable information. For example, the Town of Vail determined the value of fish in their area by dividing the annual sales of all the fly fishing stores and outfitters in the city limits by the known number of fish in Gore Creek — information obtainable from USGS. This study was much simpler, but still gave the Town of a Vail a reasonable estimate on the value of fish, which can be used by city planners and elected officials. These examples provide insight into how economic valuation can be used at a local level to make more informed decisions regarding natural resources management.

4. Agencies That Have Performed Ecological Services Dollar Valuations

Valuing ecological services is a practice also used by federal and state agencies. The EPA has conducted several studies valuing the benefit of ecosystems including *Economic Benefits of Wetlands* and *The Best Watershed-Based Plans in the Nation*.

Ecological valuation is also used by the CDOW to determine the value of ecological services that impact recreational activities such as hunting, fishing, rafting, and hiking.

Natural Resource Damages assessment is an area where ecological valuation plays an essential role in determining the price to restore and cover interim lost services for natural resources that were injured as a result of events such as chemical spills or mining-related activities. This type of assessment is conducted by various agencies, including the State of Colorado (Department of Natural Resources, CDPHE, etc.) when dealing with Superfund cases. For such cases, the basic replacement cost is usually used and settlements are made out of court in order to get projects completed and natural resource impairment situations resolved.

5. Nonregulatory EPA and State Programs

The Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA) have programs aimed at both facility and non-facility water quality management within a watershed:

- Facility-focused programs regulate wastewater and drinking water treatment facilities.
- Non-facility programs (which are voluntary) promote best management practices (BMPs) aimed at nonpoint sources and drinking water sources.

With the vast majority of water pollution in the Clear Creek Watershed coming from nonpoint sources, the Foundation has championed the CWA's Nonpoint Source (NPS) Program and the SDWA's Source Water Assessment and Protection (SWAP) Program.

A valuable subsidiary nonpoint source-related program is Colorado's Addressing Water And natural Resource Education (AWARE) program, which helps local elected officials connect land use decision making with water quality protection. See the SOCIETAL PERSPECTIVE section of this report for more on AWARE.

As a non-facility-focused organization, the Foundation is championing the NPS, SWAP, and AWARE programs through the following measures:

EPA'S WATERSHED EDUCATION TOOLBOX

The US EPA has released the Nonpoint Source Outreach Toolbox, a comprehensive set of web-based resources designed to assist communities across the US conduct locally effective watershed education and outreach activities. Log on at http://www.epa.gov/owow/nps/tpplbox/.

- Links on the Foundation website.
- Displays in the Clear Creek Watershed Exhibit at the Idaho Springs Visitor and Heritage Center — viewed by 60,000 visitors annually.
- Watershed Sustainability PowerPoint presentation shown to elected officials and other decision-makers throughout the watershed, as well as other watershed groups.

6. Lessons Learned

- Although environmental valuation has been underway for decades, there is currently renewed interest in valuing ecological services and factoring these values into development decisions.

- Accurate ecosystem valuation is often an ambiguous task that involves complex economic modeling, time, and resources. Watershed groups typically do not have millions of dollars to spend on ongoing studies.

- None of the commonly used valuation systems are geared towards evaluating projects from the viewpoint of the triple bottom line; the Foundation's research shows that the Multi-Attribute Utility Analysis (MAUA) has potential for accomplishing this. The MAUA allows for more informed values without extensive and costly studies and/or exorbitant court costs. The MAUA is relatively easy to implement and update as priorities, conditions, and stakeholders in the watershed change. See UTILIZING A VALUATION TECHNIQUE TO ASSESS THE TRIPLE BOTTOM LINE VALUE OF PROJECTS for details on this topic.

- Nonregulatory federal and state water quality programs can provide information/education and outreach resources for watershed groups to use.

SOCIETAL PERSPECTIVE

The Foundation defines *sustainable watershed management* as:

A community-based approach to improving and protecting the natural resources of a watershed by integrating ecological, social, and economic perspectives.

ecology + society + economy = sustainability

Society

- **respect for community values**
- **ongoing stakeholder participation and benefits**
- **local economic development that has an awareness of global and local sustainability opportunities**
- **maintaining a sense of history and place**

In a watershed context, societal sustainability refers to the stakeholders' awareness of ecological/environmental issues, and actions taken to protect and restore the watershed. Hallmarks of this include some of the following:

- An informed community
- Active involvement by community leaders
- Initiatives that will result in behavioral change
- Programs/regulations or projects

This section provides examples of the following:

- Outreach/education philosophy
- Stakeholder forums (informed community)
- Watershed Advisory Boards (involved community leaders)
- Watershed-focused websites
- Social Marketing pilot project (behavioral change)
- Jurisdictional Best Management Practices that support watershed sustainability
    - County initiative (program)
    - Municipal initiative (project)

1. Outreach/Education Philosophy. Outreach and education projects are an important focus for the Foundation. Through collaborative partnerships, we work to provide the public with information on the history and current condition of the area, watershed science, sustainability techniques/tools, and natural resources in general. We believe that increasing awareness and concern for the health of this watershed will allow for more informed decisions to be made for sustainable watershed management — as well as individual practices — which will lead to beneficial change.

Efforts began in 1990 to bring people together from throughout the Clear Creek Watershed to share knowledge, attitudes, and values and thus develop cooperative water quality improvements strategies and projects. Not an easy task given the diversity of stakeholders and interests — ranging from mountain-rural to urban, from agricultural and industrial to recreational and regulatory. Through numerous gatherings, stakeholder input on projects has been obtained and incorporated to define watershed priorities and

establish project partners, thus creating a watershed-wide culture of cooperation. Once stakeholders began fixing things on the ground, sustainable improvements began to be seen — project-by-project. See the APPLYING SUSTAINABLE WATERSHED MANAGEMENT TO THE CLEAR CREEK WATERSHED section of this report for more information on past, current, and future watershed projects.

Through our outreach efforts, the Foundation continues to cultivate the well-established culture of cooperation by providing numerous opportunities for watershed stakeholder involvement. This effort is being accomplished through ongoing forums/meetings, tours/presentations (on request), outreach documents, websites, and the Watershed Exhibit at the Idaho Springs Visitor Center & Heritage Museum.

The Foundation's educational efforts include preparing and disseminating information to teachers relating to the 4th and 7th grade curriculum areas of Colorado Mining History, Natural Resources (especially mineral resources), and Watershed Science. See APPLYING SUSTAINABLE WATERSHED MANAGEMENT TO THE CLEAR CREEK WATERSHED for a detailed list of education/outreach projects.

ADVISORY COMMITTEES for CLEAR CREEK WATERSHED SUSTAINABILITY PROJECT

(formed in 2006)

STAKEHOLDER ADVISORY COMMITTEE

Crystal Gray Parks & Community Resources Director, Adams County

Neil Jaquet Director of Water Resources & Real Estate, Coors Brewing Company

Maryanne "Moe" Keller Colorado State Senator

Dennis Lunbery Mayor of Idaho Springs

Meredith Miller Vice President, Center for Resource Management

Ed Rapp, P.E. President, Clear Creek Watershed Foundation

George (Jerry) Sherk, D.Sc., J.D. Professor, Colorado School of Mines & University of Denver

Fabyan Watrous President, Jack Pine Mining Company & Clear Creek County Historic Public Lands Commissioner

Miles Williams Project Manager, Trout Unlimited/West Denver Chapter

Bruce Hutton Professor, University of Denver/Daniels School of Business

Peggy Stokstad Director, Clear Creek Economic Development Corporation

TECHNICAL ADVISORY COMMITTEE

Andrew Archuleta Abandoned Mines Lands Program Manager, US Forest Service/Arapaho-Roosevelt National Forest/Pawnee National Grassland

Jeff Crane Executive Director, Colorado Watershed Assembly

Mike Crouse Senior Hydrologist & President, Clear Creek Consultants

Gary Curtiss Environmental Protection Specialist, Colorado Division of Reclamation, Mining & Safety

Gary Frey Vice President, Trout Unlimited, West Denver Chapter

Mike Holmes Superfund Project Manager, EPA Region 8

Marcella Hutchinson Environmental Scientist, Watershed Coordinator & NPS Project Officer, Office of Ecosystems Protection and Remediation/EPA Region 8

Robert (R. L.) Jones Watershed Engineer Emeritus

Larry MacDonnell Environmental Attorney, Porzak Browning & Bushong

Bob McConnell Senior Scientist, Colo. Dept. of Public Health and Environment/Water Quality Control Division

Carl Norbeck Principal, The Sustainability Edge LLC

Timothy D. Steele, PhD President & Hydrologist, TDS Consulting Inc.

Tony Selle Data Team Leader/Office of Ecosystems Protection and Remediation/EPA Region 8

Gene Woolsey Professor Emeritus, Colorado School of Mines

Frank Young Director, Clear Creek County Open Space

2. Advisory Committees

At the outset of this project, two advisory committees were formed:

- A citizen-based Stakeholder Advisory Committee to oversee the community-based aspects of this project and to assist in spreading the ideas evolving from the project. They have met with the Foundation Team and the Technical Advisory Board on a regular basis.

- A broad-based Technical Advisory Committee to oversee the technical details of this project and to assist in peer to peer transfer of the ideas evolving from the project. They have met with the Foundation Team and the Stakeholder Advisory Board on a regular basis.

3. Stakeholder Forums

As discussed throughout this report, iterative stakeholder input is one of the most valuable communication techniques that has been established in the Clear Creek Watershed. Numerous forums, field trips, presentations, and bus tours have been held since the initial Forum in 1993. We highlight four of the forums here; the remainder are described on the Foundation website.

The First Forum — 1993 Held at a time when controversy and lawsuits surrounded several issues, this Forum brought together a cross section of nearly 100 elected officials, agency representatives, corporate participants, environmentalists, and interested citizens from throughout the watershed. Two key perspectives were highlighted at the 1993 Forum:

- In talking about *The Challenge*, Governor Roy Romer illuminated the importance of understanding and respecting various stakeholders' value sets. In Clear Creek these abound and include urban and mountain-rural lifestyle preferences, and upstream and downstream water user interests.

- Clear Creek County Commissioner Ed Rapp highlighted that shared experiences like the Forum were important in building watershed-wide relationships and trust, but that a local watershed group also has to be action-orientation and achieve practical on-the-ground results to be sustainable.

The 1993 Forum was notable for laying the groundwork for the culture of cooperation that eventually became Clear Creek's modus operandi, and for an approach that emphasized practical on-the-ground projects to restore and protect water quality and other watershed resources.

At this Forum, a shared vision also coalesced around the concept of a *Healthy Watershed*. In keeping with that vision, the Foundation's focus for over 10 years has been mine site restoration and water quality improvement.

Creating a Sustainable Future — 2005 Attended by a broad cross section of over 70 stakeholders, this Forum introduced the concept of watershed sustainability from two perspectives:

- ***Watershed Sustainability*** as a distinct domain that nests between the Macro/Global Domain and the Micro/Local Domain and focuses on the multiple natural resources and ecological functions of a watershed.

- ***Triple Bottom Line*** which encompasses the three values of ecology, society, and ecology, and how the three must be balanced in local decision making to provide the basis for a sustainable future for a watershed.

The keynote speaker was Senator Maryanne "Moe" Keller who presented her *Vision for the 21st Century*, which highlighted some of the threats and opportunities that are unique to Clear Creek with a focus on the I-70 corridor.

Creating an Action Plan for Clear Creek — 2006 Nearly 100 stakeholders attended this follow-up workshop on watershed sustainability. The focus of the day was to test the Multi-Attribute Utility Analysis (MAUA) model as a potential watershed sustainability ranking tool for prioritizing approximately 60 prospective projects, organized into eight groups, by their environmental, social, and economic value to the stakeholder group. Projects ranged from mine clean-ups to outreach and education.

The keynote speaker was Terry Minger, President of the Center for Resource Management, who addressed *The Role of Innovation in Watershed Sustainability*.

LEEDing the Way to Watershed Sustainability — 2007 A broad group of stakeholders participated in this session that highlighted a number of key perspectives important to advancing sustainability thinking in the Clear Creek Watershed. The 60 participants included hydrologists, geologists, biologists, tourism officials, builders, river rafters, wedding and event planners, industry representatives, and government officials.

- Clear Creek's two websites were rolled out:

  www.clearcreekwater.org
  Current information on watershed sustainability activities, historical watershed information, educational resources, and more.

  www.cwwtn.info
  A mutual aid network for waste water and drinking water treatment system professionals.

A diverse group of watershed stakeholders participated in the 2007 Clear Creek Watershed Forum.

- The US Green Building Council's Leadership in Energy and Environmental Design (LEED) green building rating system was highlighted as one program that provides specific guidelines for design, building, and operation of green buildings and performance measures.

- The Colorado Environmental Leadership Program (ELP) was highlighted as a recognition and reward program that offers benefits and incentives to members that voluntarily go beyond compliance with state and federal regulations and are committed to continual environmental improvement. It was noted that two major corporations in the Clear Creek Watershed have achieved recognition under this program: Silver Level — Coors Brewing Company and Bronze Level — Phelps Dodge/EMC2 (Henderson Mine operator).

- The preliminary results of the stakeholders' previous work with the MAUA model to rank 60 projects in eight groups was presented and its validity to watershed sustainability decision-making was demonstrated.

The two featured speakers of the day were Steve Andrews, co-founder of the Association for the Study of Peak Oil and Gas/USA who reported on his group's study of *Peak Oil & Gas* and its implications for local elected official's long-term decision making, and Clear Creek County Commissioner Harry Dale who addressed *Sustainable Land Management* with an emphasis on the special threat and opportunity posed by transportation infrastructure.

Steve Andrews, co-founder of the Association for the Study of Peak Oil & GAS/USA, reported on the implications of peak oil and gas.

This recent series of Forums is significant in updating and broadening the watershed's shared vision around the concept of a sustainable watershed. Consistent with this vision, the Foundation is now focusing on projects which optimize the triple bottom line.

4. Website Development

To best facilitate and promote accurate and timely information dissemination regarding watershed activities and sustainable watershed management, the Foundation has developed and launched two watershed websites:

The **www.clearcreekwater.org** website provides comprehensive information about the past, present, and future of the watershed and focuses on the non-facility type programs and projects such as the Nonpoint Source/319 Grant Program and the Gilson Gulch Restoration Project; and the Source Water Assessment and Protection (SWAP) Program and the SWAP exhibit being developed for the Clear Creek Watershed Exhibit.

The **www.cwwtn.info** (Colorado Water and Wastewater Treatment Network) website focuses on the facility type programs and projects such as water and wastewater treatment programs and the internet-based mutual support network. This interactive website was developed with a grant from Coors Brewing Company; with potential partnering with CDPHE/WQCD.

5. Working with Juristictions to Adopt Sustainability Regulations

Sustainable solutions require sustainable processes. This section combines two major sustainability tools — Community-Based Social Marketing and the Colorado AWARE Program — to further the advancement of practical, community-based sustainability applications. A similar Pilot Project using the techniques being discussed below is being initiated for the Clear Creek Watershed.

Community-Based Social Marketing. Pioneering work in social marketing has been conducted by Douglas McKenzie-Mohr and William Smith and is described in their book *Fostering Sustainable Behavior: An Introduction to Community-Based Social Marketing (1999).* Their research has documented that information-intensive campaigns to attain behavioral change do not work. Instead, it is important to engage stakeholders and to identify barriers and benefits for prospective techniques. Once this is known, a variety of tools of behavioral change can be applied. More information can be found at http://www.cbsm.com. Application of this concept in the Clear Creek Watershed through the AWARE Program is explored below.

Colorado AWARE (Addressing Water And natural Resource Education) Program. AWARE is a statewide program that informs local decision makers about the impacts of land use on water quality and advances the application of development-mitigating best management practices (BMPs). The program is funded by the Colorado Water Quality Control Division's Nonpoint Source Grant Program and led by the League of Women Voters of Colorado Education Fund. More information can be found at http://www.awarecolorado.org.

Case Study. As a member of the AWARE Advisory Committee, the Foundation recently it participated in a workshop in Loveland hosted by the Big Thompson Watershed Forum to apply community-based social marketing techniques in advancing the goals of AWARE. Representatives from Loveland, Estes Park, and Larimer County as well as developers attended.

The meeting was kicked off with a PowerPoint refresher of AWARE's 20-some BMP strategies for minimizing the impact of urban-edge development. Next, participants were given a Strategy Evaluation Sheet (see below) that listed all of the AWARE BMPs and were asked to write in:

STRATEGY EVALUATION SHEET

STRATEGY	Strategy already adopted	Why strategy might be implemented	Why strategy might NOT be implemented
Riparian buffers & setbacks			
Porous paving materials			
(List continues with 20 more BMPs)			

Participants then completed a somewhat similar exercise by multi-voting on the AWARE BMPs on a flip chart list based on which ones they would use/adopt and which ones were problematic. This was followed by a detailed discussion of the various BMPs and why some were prospective and others weren't.

This is one of the first times that a social marketing-type benefits/barriers analysis has been used to help develop a strategy for implementing a sustainability program in Colorado — specifically AWARE. Lessons learned included:

- It is an opportunity to get the right people from a watershed around the table: i.e., practitioners from the cities, counties, and the developer community.
- It provides a platform at which to review the entire list of BMPs (plus the participants all received the AWARE toolkit ahead of time).
- It is a way to learn which jurisdictions have already adopted specific BMPs from the list, and the discussion and fill-in sheets provide feedback on barriers to the implementation of the others.
- The multi-vote yields insight on benefits because is shows which BMPs the practitioners use versus those they avoid.
- This type of workshop becomes a behavior-changing tool in and of itself, i.e., if Loveland has adopted BMP "A," Larimer County should be able to do it also.
- It enables AWARE to ask participants: "What type of follow-up session would be useful to you to help you keep moving forward?"
- This approach has transferability to a wide range of community-based, non-governmental organizations, such as watershed groups.
- The process is context-based; although a watershed group may provide the forum and agenda, the process becomes stakeholder driven and allows participants to highlight and follow through on the BMPs most appropriate for their community.

Possibilities for applying other community-based social marketing techniques in the Clear Creek Watershed include:

- Updating the Clear Creek Watershed Exhibit to include ideas presented in this report, then showcasing the upgrades with open houses, continued watershed tours (using sustainable modes of transportation) and continued website updates/upgrades.
- Survey at the Watershed Exhibit and/or on our website asking about effectiveness of persuading individuals/groups to implement/champion watershed sustainability ideas in their watershed.
- Presentations at various watershed conferences (e.g., the *2007 Sustaining Colorado Watersheds Conference: Making Water Quality Connections*), and other events to share our research, conclusions, and recommendations for sustainable watershed management.

6. Best Management Practices (BMPs) That Support Watershed Sustainability

County in Watershed Undertaking a Sustainability Initiative. Starting from the perspective that watershed sustainability from a development viewpoint is primarily focused on expansion on the urban edges and into the lands between, the regulatory programs with the closest affinity relate to stormwater. Both the Colorado AWARE

Program (discussed previously) and the Jefferson County Stormwater Program have developed practical BMPs to guide this development. The Foundation believes that sustainable development within a watershed limits impacts on water quality through the application of appropriate BMPs.

Stormwater runoff is defined as "precipitation and snowmelt runoff from roadways, parking lots, (and) roof drains that is collected in gutters and drains [and is] a major source of nonpoint source pollution to water bodies." Stormwater runoff is considered a major source of nonpoint source pollution because the water encounters oils, greases, and other chemicals typically associated with urban areas and transports these pollutants to water bodies. To protect water quality, low-impact development (LID), and other stormwater BMPs can be implemented. These BMPs typically address the issue of stormwater runoff through one or more of the following measures:

- Implementation of rain gardens or porous trenches around rooftop driplines to promote infiltration and decrease urban runoff as well as erosion.
- Construction of sunken, curbless native vegetation bioswales in parking lots to break up large areas of impervious surfaces.
- Grading of parking lots towards vegetated swales, gardens, or bioretention areas.
- Decreasing the amount of impervious surfaces by utilizing open-grid pavement or pervious surfaces in areas of low volume traffic, parking overflow, and sidewalks.
- Construction of roadside checkdams along susceptible roads to decrease runoff velocity and promote infiltration.
- Construction of flow and sheet flow diffusers on culverts and around drainage areas to promote infiltration.

The Stormwater Management program developed by Jefferson County is a prime example of sustainability regulations implemented within a watershed. In order to protect and improve the quality of stormwater (also known as urban runoff), the Stormwater Management program has three main categories:

1. mountain stormwater BMPs,
2. required land disturbance permits, and
3. erosion and sediment control BMPs.

The mountain stormwater BMPs strive to use infiltration to reduce erosion and sedimentation problems using structures built during construction or post construction. These structures serve to reduce the velocity of stormwater and promote infiltration. Also listed are structures that residential households can implement at any time to curb erosion and sedimentation.

The required land permits are an attempt to keep stormwater and sediment discharge to a minimum during construction. Most land disturbing activities require a grading permit or a notice of intent. Additionally, for areas greater than one acre, a Construction Site Stormwater Permit must be obtained from the CDPHE.

Erosion and sedimentation BMPs attempt to keep soil from eroding at construction sites, as well as prevent the eroded soil from entering surface water bodies. Erosion control devices make physical contact with the soil to keep it from eroding while sediment

control devices trap or filter the sediment that has eroded and keeps it from being transported by runoff.

Although the Jefferson County Stormwater Management program was implemented as part of Stormwater Phase II Regulations under the Clean Water Act, it goes well beyond the letter of the regulations by being proactive in its outreach, implementation, and follow-up activities and is widely recognized as one of the more progressive programs in the state. For more information visit: http://jeffco.us/highways.

It should be noted that Clear Creek County has been addressing the unique water quality issues related to mountain development and stormwater in the upper part of the Clear Creek Watershed for years. In 1994, UCCWA published a guide to water quality protection and erosion control. Clear Creek County made some practical revisions to that document and adopted BMPs, including a mountain driveway BMP manual, as part of its building code. Shortly after, the Clear Creek County Land Use Division Site Development Department was formed, including the addition of a Site Development Inspector.

Municipality in Watershed Undertaking a Sustainability Initiative. While many of the towns and cities in the Clear Creek Watershed have implemented sustainability and *go green* initiatives, the Gilson Gulch Restoration Project, located on the east end of Idaho Springs, is a prime example of an on-the-ground sustainability pilot project within the Clear Creek Watershed. The Gilson Gulch Restoration Project is a project being implemented by the City of Idaho Springs in conjunction with the Foundation. Gilson Gulch is an intermittent tributary that flows through a residential area and then directly into Clear Creek.

Over the past 130 years the Gilson Gulch area was heavily mined. Due to these mining activities, numerous waste rock piles and draining mine adits were left behind. Runoff from frequent flash floods from spring snowmelt and summer thunderstorms flow through the waste-rock piles and from the mine areas, becoming heavily loaded with dissolved metals and sediments. Gilson Gulch is estimated to contribute over 50 tons of heavy metals per year into Clear Creek. As a result, it has become a high priority remediation site under the *Upper Clear Creek Watershed Plan ·September 2005/April 2006 Addendum: Remedial Action Priorities*.

REMEDIATING PAST MINING ACTIVITIES

The Colorado Division of Reclamation, Mining & Safety (DRMS) prepared a handbook entitled *Best Practices in Abandoned Mine Land Reclamation* to assist people in:

- **determining if an area has been impacted by past mining**
- **determining the extent of environmental problems caused by past mining**
- **providing options to address the environmental and safety problems caused by past mining, especially those posed by waste rock dumps, mill tailings piles, and hazardous openings**
- **providing a list of contacts to acquire additional information about reclamation practices and current regulations**

Find out more on Colorado mining practices by contacting the DRMS at www.mining.state.co.us.

The goal of the Gilson Gulch Restoration Project is to reduce the amount of metals and sediment loading into Clear Creek by implementing Abandoned Mine Land Reclamation BMPs in the area. This project is considered a sustainable watershed project because the construction aspects benefit the local residential development reducing risk of flood

(society/economy), while simultaneously reducing the loading into Clear Creek thereby improving aquatic life in Clear Creek (ecology) and protecting the drinking water source for 350,000 downstream water users (society/economy).

From a sustainability viewpoint, the end-use envisioned for the reclaimed mine sites in Gilson Gulch is of particular interest. A feasibility study conducted by Colorado School of Mines students indicates that a combination of solar, wind, and in-situ chemical renewable energy could generate power and be sold to Excel Energy and provide a substantial reduction in rates to provide sustainable power to operate the Argo Water Treatment Plant. See APPLYING SUSTAINABLE WATERSHED MANAGEMENT TO THE CLEAR CREEK WATERSHED, starting on page 61, for more on this potential project.

7. Lessons Learned

- In a watershed context, societal sustainability refers to the stakeholders' awareness of ecological/environmental issues, and actions taken to protect and restore the watershed.
- A broad-based outreach and education effort is an important building block in developing community support for watershed-related initiatives.
- Involvement of community leaders is important for moving sustainable watershed initiatives forward.
- A big-picture, shared vision needs to be developed and revised periodically to guide the activities of watershed-based groups.
- New tools such as community-based social marketing give watershed groups the ability to work with regulators and builders, in a supportive way, to advance BMPs that buffer the impacts of development on valuable ecosystems.
- Proactive programs with a behavioral change component, such as Jefferson County's Stormwater program, or on-the-ground projects, such as Idaho Springs' Gilson Gulch Restoration Project, indicate societal acceptance of sustainability.
- Sustainability efforts must become an ongoing part of a community's value set.

ECONOMIC PERSPECTIVE

The Foundation defines *sustainable watershed management* as:

A community-based approach to improving and protecting the natural resources of a watershed by integrating ecological, social, and economic perspectives.

ecology + society + economy = sustainability

Economy

- **cost-efficient projects & economic opportunities with no net-loss of ecological services**
- **measurable results for environmental investments**
- **promotion of market-based investment in clean water**

This section provides an overview of the following:

- Outdoor recreation and tourism activities.
- Examples of green building projects in watershed.
- Best management practices (BMPs).
- Motivation for green activities, ecological services valuations.
- Examples of EPA and State programs advancing sustainability.

1. Value of Clear Creek Watershed's Outdoor Recreation/Tourism Activities

The Clear Creek Watershed offers numerous recreational and cultural activities including skiing, hiking, camping, gold mine tours, fishing, hunting, rafting, the Georgetown Loop railroad, limited stakes gaming, and historical museums, districts and landmarks. These opportunities attract tourists from across the country and around the world, thereby making the tourism industry one of the most profitable business endeavors in the watershed. The Colorado Tourism Office determined that 22.5 million tourists came to visit Colorado in 2005 and spent $8.2 billion. Roughly 21% of these visitors came specifically to the North Central portion of Colorado, which includes the Clear Creek Watershed (Longwood's 2006).

Photo courtesy of Clear Creek Rafting.com

In 2006, rafting alone brought in 36,889 people to participate in commercial trips on Clear Creek, which had an economic impact in the area of $10 million dollars (Gernier and Werner 2006). This is a significant increase from the 600 rafters who came to the area in 1988 — before the Argo Water Treatment Plant and other major mine clean-up efforts. (See APPLYING SUSTAINABLE WATERSHED MANAGEMENT TO THE CLEAR CREEK WATERSHED/Project Highlights for more on the McClellan Project.) This indicates that improved water quality has significant positive impact on the rafting industry. Fishing and hunting also had significant economic impact in 2006, with these tourists spending roughly $8.9 million.

These values show that tourism has a major impact on the counties/communities within the Clear Creek Watershed and needs to be recognized in sustainable watershed management planning. The basis of the tourism industry depends on the pristine environment, abundance of ecological services and strong sense of cultural heritage that are provided by the watershed and its communities.

The Colorado Tourism Office conducted a survey in 2005 that asked tourists what their top priorities were in a vacation spot. The top three were:

- Sense of excitement
- Uniqueness in scenery and culture
- Sightseeing variety

All three of these priorities rely on the ecological, social and economic values of the watershed. By managing these values sustainably, the tourism industry has the potential to continue to grow and to become an even greater source of revenue.

2. Developers and Businesses Pioneering Green Building and Smart Growth Practices

Because watershed sustainability involves championing the protection of ecological values and ecological function, how development interfaces with the natural resource systems is of considerable importance. From energy and water conservation to the use of recycled materials to site design, *green building* and *smart growth* represent positive steps forward that can result in economic gain for communities. Green building is the practice of increasing the efficiency with which buildings use and harvest energy, water, and materials; thus reducing the buildings' impact to the environment and costs to operate. The philosophies behind smart growth focus on creating a town-centered community that reduces the need for auto transportation, implementing green building practices, and preserving open space and other environmental amenities. The reduction in the use of natural resources by these techniques results in overall lower operation and maintenance costs. Part of the green building movement is to include costs that are usually externalized – such as the impacts of stormwater runoff from the site on the nearby water body – when looking at the economics of the project. This is in step with the sustainable watershed management theory of valuing ecological services.

LEED-ing THE WAY!

So what is LEED anyway? The Leadership in Energy and Environmental Design (LEED) Green Building Rating System™ is the nationally accepted benchmark for the design, construction, and operation of high performance green buildings. LEED gives building owners and operators the tools they need to have an immediate and measurable impact on their buildings' performance. LEED promotes a whole-building approach to sustainability by recognizing performance in five key areas of human and environmental health: sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality. LEED provides a roadmap for measuring and documenting success for every building type and phase of a building lifecycle. To learn more about the LEED rating process, certification, etc., go to www.usgba.org.

It is important to keep in mind that green options usually involve a larger initial investment, but save money over the duration of the design life for the building, making them at least as cost effective as traditions options. For example, EPA's green roof was more expensive to install than a regular roof surface, but is expected to extend the life of the roof, reducing replacement costs over the life of the building. It is also expected to

help reduce heating and cooling costs as it provides superior insulation over a conventional roof.

In the following sections we highlight a number of builders and developers who have implemented or will soon be implementing sustainable building practices in commercial and residential projects in the Clear Creek Watershed and in surrounding Denver Front Range areas. The Foundation supports these efforts and chose to highlight these examples of sustainable development as a means to inspire other developers in the watershed to explore and implement green building and smart growth technologies.

As forward-looking as these green building examples are, it should be noted that the largest — Horizon City Center in Aurora — is only 500-acres compared with the 368,000 acres of the Clear Creek Watershed. Because one-third of the Clear Creek Watershed is forest land, sustainable development of the limited amount of mountain land that is actually developable is essential to the overall sustainability of the watershed. The greatest impact in watershed protection will be realized by green initiatives pursued by cities and counties, and watershed groups that are in a position to advance multi-jurisdictional problem-solving on issues that cross-cut jurisdictional boundaries.

Shadows Ranch is a successful wedding/event facility located at 1259 Alvarado Road in Georgetown. The owners/developers of this facility plan to incorporate environmentally-sound and sustainable practices into their existing structures, as well as into future construction plans. Some of these features include:

- Utilizing solar panels and wind turbines to provide alternative energy for the facilities
- Construction of Biolarims® consisting of tropical and wildflower gardens, used as a vegetative bio-filter to treat on-site water
- Utilizing geothermal hot spots for power and heat
- Creation of wetlands for on-site water treatment leading to a non-potable water source
- Green roofs and green roads to minimize impact on the environment

Photo courtesy of www.shadowsranch.com

At the start of this study project, the Foundation officially selected Shadows Ranch as the development project to demonstrate sustainable watershed management in the Clear Creek Watershed. The Foundation's selection letter to Shadows Ranch summarizes the wealth of opportunity at Shadows Ranch for sustainable watershed development:

> *"…We have been observers and supporters of Shadows Ranch and its plans for a sustainable facility expansion. Your commitment to natural wastewater treatment (wetlands), renewable energy (wind, solar, geothermal), and green architecture are all of great interest to us at the Foundation. We look forward to helping you develop one of the first true models of sustainable commercial development in [Clear Creek] County…We hope to illustrate, through Shadows Ranch, the advantages and synergies of pursing the "triple bottom line" of environment, economics and social values, in a commercial enterprise…"*

Signature Centre is in Denver West located at 14143 Denver West Boulevard, in the center of the Clear Creek Watershed. This office building was designed incorporating LEED™ green building practices and User Effective® elements to create a highly efficient, environmentally sustainable, and humanistic workplace. The five-story, 185,000 square-foot building has been certified LEED™ platinum and is framed by a one-acre park entrance. Some elements incorporated into its design include:

Photo courtesy of www.signaturecentre.com

- Under-floor HVAC system — shown to improve air quality and reduce absenteeism
- Individual temperature and lighting controls — improves employee productivity
- Energy efficient practices — reduces utility costs up to 50%
- Natural, non-toxic building materials

Wal-Mart Eco-Store in Aurora. Although not in the Clear Creek Watershed, this facility has many innovative elements worth noting. Wal-Mart has created two experimental environmental sustainable buildings one of which is located in Aurora, CO. The goal behind these buildings is to reduce the amount of energy and natural resources required to build and maintain the stores, reduce the amount of building material necessary for store construction, and substitute in renewable building materials whenever possible. Some examples of environmentally sustainable building practices implemented in the Aurora store, which can be seen on the self-guided tour, include:

- Stormwater runoff control by utilizing porous pavement in parking lots, infiltration beds under parking lots, and two 400-foot long bioswales
- Renewable energy sources including solar panels installed on roofs, and a 50-kilowatt wind turbine
- Water conservation including photo-voltaic-powered infrared sinks and waterless urinal
- Lighting control including use of high output fluorescent bulbs, high energy efficient LED lighting, automatic skylights with mirrored reflectors, and dimming controls.
- Waste-oil boiler burns used motor oil from the store's Tire & Lube Express and vegetable oil from the in-store deli
- Foundation made from 500 tons of recycled concrete from the old Denver Stapleton Airport

Wal-Mart Experimental "Eco-Store" photo courtesy of www.walmartstores.com

EPA Region 8's New Green Headquarters Although not located in the Clear Creek Watershed, the recently-completed new EPA Regional Headquarter building has numerous innovative elements worth noting, e.g., the "green roof." The goal of the design plans for the building was to reduce natural resource consumption and impacts to the natural environment. Located at 1595 Wynkoop Street in Denver, the building meets LEED Gold certification requirements and Energy Star building performance standards, the first federally-leased building in the nation to do so. The new EPA building includes the following green building practices:

SOURCE: http://epa.gov/region8/building/index.html

- Large atrium provides light source for entire structure
- Double L building design that allows for optimal energy efficiency
- Structural materials and concrete provide thermal mass that stores and releases heat slowly
- Sun shelves reflect daylight through windows on south facing side of the building
- Vertical fins on NE & NW exterior of building block high season sunrays
- High-performance glass insulates and filters sunlight
- Computer controlled blinds were installed on south facing windows to control glare and mitigate heat gain
- Under-floor air distribution system supplies air efficiently and reduces mixing required to condition workspaces
- High-performance, low energy chillers used to cool building
- Installation of air-side economizer capturers and cools outside air that is used to cool interior
- Green roof
- Energy Star computer monitors, lights, and copy/fax/print machines
- Use of light shelves on windows to distribute daylight throughout office spaces
- Purchased wind energy will offset 100% of the building's electric power needs
- Centralized district steam is used to heat the building

Harmony Village is a co-housing community located on 5.5 acres of land at 1001 Cottonwood Circle in Golden, CO. This community is located in the Clear Creek Watershed and consists of 27 clustered households designed to foster socially responsible use of resources. Examples include:

- Reduction of heating and cooling needs by incorporating sun tempering, natural ventilation, and low e windows into housing

Photo courtesy of www.harmonyvillage.org

- Conservation of water through water restrictors, low water toilets, and low water use grass
- Composting bins and recycling programs for plastic, tin, glass, cardboard, and newspaper
- Shared resources including a community garden, a common workshop, and a common house which includes a laundry, exercise equipment, and a game area

Horizon City Center — A LEED Neighborhood Development Pilot Project

Although not located in the Clear Creek Watershed, the recently announced Horizon Center has numerous site design features that reflect sustainable development and make it worth discussing here. The Horizon Center is a mixed-use development that will be located at the southeast corner of I-70 and the E-470 toll road, south of Denver International Airport. The development will cover 500 acres and consist of 2,800 residential units, 3 million square feet of commercial space, and 2 million square feet of retail space. Horizon is planned to be developed over the next 12 to 15 years and will eventually accommodate 26,000 people.

The Horizon Center is a pilot project for a new LEED rating system which focuses on entire neighborhoods rather than solely on individual buildings. The new LEED Neighborhood Development (ND) Rating System has several required elements, including:

- Smart location to reduce vehicle miles traveled, i.e., near rapid transit

INTERESTED IN A SUSTAINABLE LIFESTYLE?

The National Renewable Energy Laboratory is located in the heart of the Clear Creek Watershed in Golden. Visit www.nrel.gov to learn about NREL's research and development of renewable fuels and electricity that advance national energy goals to change the way we power our homes, businesses, and cars. And NREL practices what it preaches! The lab is now totally energy efficient — several of its buildings are among the most efficient of all comparable federal facilities; on-site electricity production from wind turbines and solar electric systems contributes 138,000 kilowatt hours annually to the lab's power needs; and the lab employs renewable energy to offset not only the total energy use of its buildings, but also the energy used by its vehicles, employee commuting, air travel, and other life-cycle energy consumption.

The Colorado Renewable Energy Society at www.cres-energy.org is a nonprofit membership organization that works for the sensible adoption of cost-effective energy efficiency and renewable energy technologies by Colorado businesses and consumers. They host an annual renewable energy conference and an annual Tour of Solar Homes — an opportunity to visit "real places for real people" that use the latest in renewable energy, efficiency, and green-built technologies.

The Colorado Energy Science Center at www.energyscience.org provides energy education programs and resources that promote economic and environmental benefits to homeowners, students and educators, and companies/organization. Their consumer section offers workshops for saving money and energy, living healthier, and protecting the environment at www.smartenergyliving.org.

The Rocky Mountain Sustainable Living Association is a non-profit organization committed to applying its vision and expertise toward a sustainable future for all. They are a solution-driven organization with the distinguishing quality to move people toward powerful and profound choices in an effort to stave off complacency about issues affecting our community. For more info, logon at www.sustainablelivingassociation.org.

You can also check out www.groovygreen.com which covers local, national, and international news, products, and the people fighting to make a difference in promoting sustainability. Through its website, Groovy Green hopes to get others involved — not just in community events — but also in national and international discussions or organizations that directly effect the green movement. Together we can all do a little more to reduce consumption, improve health, and find cleaner alternatives to power the gadgets, cars, and lives we lead today. This is the time for taking action in our lives.

- Proximity to water and wastewater infrastructure to reduce the infrastructure footprint, i.e., near existing service area
- An approved Habitat Conservation Plan
- Wetland and waterbody conservation to protect water quality, maintain natural hydrologic systems, and preserve habitat and biodiversity
- Preservation of prime farmland
- Designs around 100-year floodplain
- Other features can be adopted to earn points in the rating system such as: slope protection, habitat and wetland restoration and conservation, a 10-year conservation management plan with a guaranteed 10-year funding plan, and a far-ranging stormwater management program

3. Motivations for Residents, Builders, and Communities to Build Green

Commercial. Nationally, heating, cooling and powering office space accounts for more that 70 percent of total electricity usage and 40 percent of carbon dioxide emissions in communities. With the widespread concern about global warming, triggered in part by Al Gore's *Inconvenient Truth*, employers and employees are becoming more interested in greening the workplace. A recent survey indicated that one-third of workers would prefer to work for a sustainability-oriented business and employers have found that they can lease green buildings faster.

In response to the growing interest in energy and water conservation, the US Green Building Council created the LEED certification program in 2000. The program criteria cover factors such as energy and water efficiency, selection of building materials, and attention to the indoor environment. The LEED Platinum rating goes even further in terms of site location — near mass transit — to reduce the costs of commuting and congestion. LEED also has a certification program for building modification such as installing automatic shutoffs for lighting and computers and replacing old toilets with low-flow ones. There are currently 91 Platinum-certified buildings in the US and one in the Clear Creek Watershed — the Signature Center in Denver West (described previously). Surveys have documented that many developers view green building and LEED certification as a desirable and practical business practice.

Residential. The widespread awareness and interest in green practices in the commercial sector is as yet not matched in the residential sector. The key factors for a developer are up-front, maintenance, and marketability costs. The home purchaser is similarly short-term directed and primarily interested in price. Discussions with developers clearly indicate that currently considerably more momentum for green commercial building than for residential.

Local Jurisdictions. Local jurisdictions are also beginning to support *going green* — some in a way that will stimulate both the commercial sector and the lagging residential sector. Green initiatives across the US have been motivated by public recognition that leadership for "going green" is the role of state and local governments.

A current example in the watershed is the City of Golden's recently completed 4-month sustainability initiative covering building, energy efficiency, renewable energy, water, economic health, education, communication, solid waste, recycling, and transportation. With the goal of reducing water use by 15 percent in 10 years and reducing energy use

by 25 percent in 10 years, the sustainability goals related to facilities requiring building permits is an example of local government's potential role in advancing green building. In the Golden system, the standards for both new buildings and major remodels offer a point system to meet sustainability standards. Residents and builders would have a menu of features to select from: energy-efficient windows, Energy-Star appliances, denser insulation, recycled building materials and low-flow toilets. Incentives such as permit fee reductions and rebates are being considered for those exceeding minimum standards.

Watershed Sustainability in the Context of Development. With all the attention that is focused on green building, there is considerably less attention paid to the land base and the ecosystems that are the source of land for development, water supplies, building materials, as well as ecosystem services, and the basic nature-related amenities ranging from fish and wildlife to outdoor recreation and scenic grandeur. Cities and counties naturally work within their boundaries, although some programs focus on broader environmental systems within their boundaries — notably parks and open space. Neither local jurisdiction — city or county — focuses on system-wide watershed sustainability from the viewpoint of ecosystem services and ecosystem functions that span the watershed. Watershed sustainability and watershed groups fill the gap by being multi-jurisdictional and multi-disciplinary with a focus on:

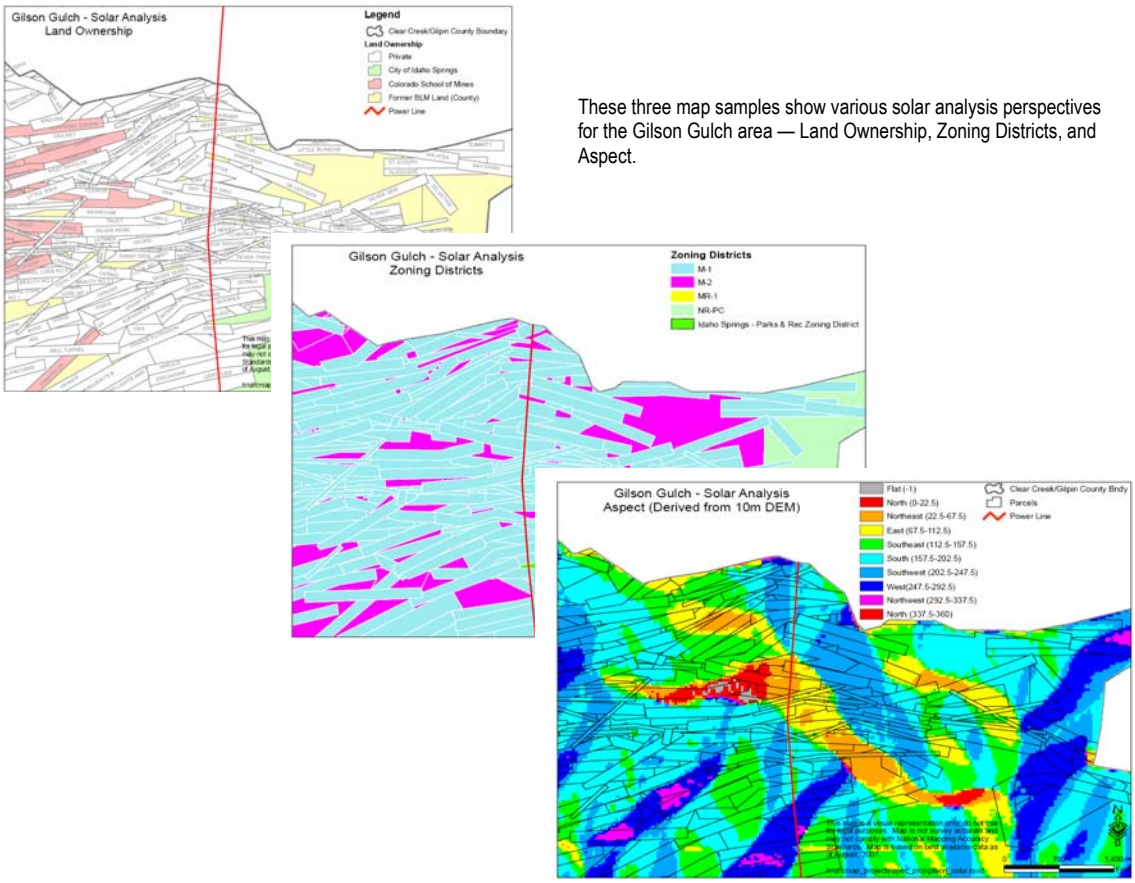
- Addressing local issues, such as clean-up of abandoned mine sites, which has both local and downstream implications
- Advancing the prospects for addressing major threats to the watershed that have both local and downstream implications, such as wildfire mitigation, and
- Championing ecosystem service valuation throughout the watershed and encouraging it to become part of the build green/smart growth paradigm.

4. Watershed Mapping and Modeling

Watershed mapping and modeling capabilities can be useful decision making tools for stakeholders. Current mapping programs available to the Clear Creek Watershed Foundation allow for detailed maps that give stakeholders a view of the various land uses, geology, topography, reduction/net loss of permeability, surface disturbance, and meteorological patterns that occur within the watershed. Watershed modeling programs are useful in predicting the impacts on water quality from such things as development, climate changes, and natural disasters. Using these tools will allow stakeholders to better understand the impacts of their watershed management strategies.

The basic data set used by the Clear Creek County GIS Department is LandSat data. Additionally, much of the basin has been flown to obtain greater definition for the Clear Creek County-owned GIS systems. Within the Clear Creek County GIS system, surface ownership and subsurface human-engineered structures (such as mine workings and water tunnels) have been linked. The terrain has been photographed through stereopairs from earlier generations of photogrammetry. Thus a running record of surface conditions exists and/or is attainable for comparative purposes. Where as many county courthouses have burned, this has not occurred in Clear Creek County. The county records are intact and are archived in an accessible vault; therefore, significant historical data are available for specific points of interest.

The GIS mapping capabilities available to the Foundation provide for more than 200 separate variable layers. These variables encompass all of the ecological, social, and economic data in a geographic format including: land use, land ownership, aerial photography, zoning, solar aspect, census/population, slope percentages, land parcels, topography, subsurface mines/tunnels/adits, and more. With these data sets, the surface and subsurface of the entire 575-square mile Clear Creek Watershed can be modeled in great detail for specific projects and/or issues — wildfire fuel reduction, alternative energy generation, development/transportation impacts, and so on — as shown in the map samples below.



These three map samples show various solar analysis perspectives for the Gilson Gulch area — Land Ownership, Zoning Districts, and Aspect.

The basic model used by the Foundation involves analysis of real sustainability data — ecological, social, and economic — over generational periods. Our records for these variables date from 1859 to the present. These models help direct project decisions and investments to restore and maintain overall watershed health and put into practical perspective the current mineral-energy-water-human nexus in this watershed.

Two other mapping and modeling programs that appear to have potential for use in the Clear Creek Watershed are:

IMRivers.com A new website that nonprofit River Network Partner groups can use to develop interactive watershed maps and make them available to the public. The maps can display multiple layers of information including data, photos, videos, and text. The

information can be about land use, pollution sources, clean-up and restoration activities, water quality, flows, natural history, recreational access, and more.

WARMF EPRI's Watershed Analysis Risk Management Frameworks (WARMF) is a decision-support model that can guide stakeholders to a consensus watershed management plan. The models embedded in WARMF can be used to determine how meteorology generates hydrology and nonpoint loads, how land use affects nonpoint loads, how point and nonpoint loads translate to water quality in rivers and lakes, whether the water quality is suitable for a particular intended use, and more.

5. Lessons Learned

- The Foundation supports projects that improve the quality of ecological services and preserve/enhance historical sites. These types of endeavors will continue to contribute to the tourism industry and are prime examples of how sustainable watershed management can enhance not just the environment of an area, but the social and economic values as well.

- Commercial green building is the vogue; residential green building lags behind, although communities are developing sustainability programs that will stimulate the residential sector. The Foundation, however, is impressed with residential developments such as McStain Neighborhoods (www.mcstain.com), Old Stapleton (residential and commercial), and Harmony Village.

- While there is some skepticism surrounding the motives/benefits of sustainable development/green building (i.e., *blue wash*), the Foundation believes that the general concept and specific applications of green building and smart growth have merit and positive benefit to the Clear Creek Watershed.

- Watershed sustainability and watershed groups operate inter-jurisdictionally and have the opportunity to champion ecosystem services and ecological functions in the green process.

UTILIZING A VALUATION TECHNIQUE TO ASSESS THE TRIPLE BOTTOM LINE VALUE OF PROJECTS

Over the years, the Foundation has maintained a stakeholder-generated, prioritized project list to guide its project investments. These project activities have informally incorporated many elements of triple bottom line thinking. With the evolution of watershed sustainability tools and techniques, more precise valuation tools have become available to engage stakeholders and to evaluate and prioritize projects.

1. Multi-Attribute Utility Analysis (MAUA) and Cost-Benefit Analysis

One of the goals of this project was to adapt and expand traditional and established analytical/valuation tools to facilitate evaluation of public and private watershed investments on the basis of all three triple bottom line value sets — environmental, societal, and economic. We also refer to this concept as sustainable watershed management. Our research shows that an effective way to attain actual, sustainability-based values and rankings for project decisions is to combine traditional ecosystem valuation techniques with deliberative-consensus building on a watershed level. The concept that stakeholder input provides real value for ranking social, environmental, and economic values, as well as threats and opportunities (projects) has been accepted in the Clear Creek Watershed. Building watershed-wide consensus through valuing the concerns of stakeholders is our established culture of cooperation.

The Value of Discourse-Based Valuation: In order for realistic values and sustainable watershed planning decision to be made at the local level, an iterative stakeholder-based process needs to be incorporated. Relatively recent social sciences research has determined that "…informed public discourse is also an appropriate method of determining economic values…derived in a forum of free and open discourse." This method, referred to as discourse-based valuation, has been used by the Foundation in the past because we believe that stakeholder input is one of the most valuable and accurate methods of economic valuation in the Clear Creek Watershed. Watershed stakeholders know their watershed.

Developing and Test the Multi-Attribute Analysis Model: To rank project opportunities for the Clear Creek Watershed, the Foundation developed a Multi-Attribute Utility Analysis Model (MAUA) that incorporates a combination of conventional valuation methodology and public-based discourse. A MAUA is a mathematical decision-making methodology that is commonly used in the engineering world to prioritize projects that have significantly different values and attributes. While not a new process, the application of a MAUA to watershed decision-making is unique. Using our developed MAUA model, proposed watershed projects are normalized on a single scale of sustainability benefit and are compared to the known sustainability benefit/cost ratio of a reference project. The reference project used by the Foundation is the Argo Water Treatment Plant (AWTP). The AWTP is used as a basis of comparison because the sustainability benefit in terms of ecological, economic, and societal values has already been established. Its economic value is based on its capital and annual costs, the ecological value is the pounds of metal removed per day from the watershed, and the societal value is put in terms of public health, safety, and welfare.

During a watershed forum held by the Foundation in February 2006, a large group of technical experts and local community leaders implemented a trial run of this method of valuation and prioritization. The following is an outline of the process conducted:

Step 1: Forum participants were divided into eight groups and assigned a sustainability project category where they ranked the ecological, societal, and economic values of each project in that category on a scale of 0 to 1000.

Step 2: Next, those projects were ranked against each other to determine which projects in that category had the most sustainable benefit on a scale of 0 to 1000.

Step 3: Each group presented to the overall forum their #1 ranked project from their focus category. Then the top projects from each of the eight categories were compared on a normalized scale of sustainability. The scale was set by the AWTP and had a relative scoring between 0 to 1000. The sustainability value of the AWTP was determined to be 500 when compared to other 25-year-life projects. This scale was referred to as the *Argo Scale*.

Step 4: The value determined for each project on the Argo Scale was the project's *sustainability benefit*. The sustainability benefit value was then divided by the estimated annual cost of each project to obtain a benefit versus cost ratio. The annual cost was determined by dividing the initial cost to implement the project plus annual operation and maintenance (O&M) costs by the lifetime expectancy of the project.

Step 5: In the final step, the benefit/cost ratio of the AWTP was set equal to one *Argo*. The Argo is merely a reference point used as the gold standard by which to compare, prioritize, categorize, and market projects within the Clear Creek Watershed. To determine the number of Argos for the projects considered for this analysis, their benefit/cost ratios were divided by the AWTP's ratio to determine the number of Argos the project is worth. Any project that is worth one or more Argos is a sustainability project that is in the public's interest to pursue. Projects that are worth less than one can be combined with other smaller projects to have an equal or greater benefit as the Argo.

TABLE 5, next page, shows the results from this trial run of the MAUA, listing the projects in order of prioritization. The table provides the following information:

Column 1 is the name of the project highlighted by a color that coincides with its project group.

Column 2 lists the number of points each project was given on the Argo Scale of 0 to 1000.

Column 3 is the cost to maintain and operate the project including its initial start-up cost averaged over the project's lifetime.

Column 4 is the benefit/cost ratio.

Column 5 is the number of Argos each project is worth.

The full paper describing the methodologies used to develop the Argo value is APPENDIX 2: Argo Water Treatment Plant as a Point of Reference for Evaluating Projects.

TABLE 5: CLEAR CREEK WATERSHED PROJECTS EVALUATED ON A TRIPLE BOTTOM LINE BASIS

PROJECT CATEGORIES:	
1.) Natural Resource Management	5.) Abandoned Mine Remediation
2.) Education and Outreach	6.) Alternative Energy Production and Transportation
3.) Water and Wastewater Management	7.) Waste Stream Reduction
4.) Preservation and Promotion of Historical Mining Sites	8.) Subsurface Rights and Uses

Projects	Argo Scale Value	Cost/year	Sustainability Cost Ratio	# of Argos
Argo Wastewater Treatment Plant	**500**	**$1,200,000**	**416**	**1**
George Jackson Historical Site	25	$3,600	69444	16.7
Orphan/Abandoned Mine Remediation	28	$4,000	50000	12
Shadows Ranch Constructed Wetland	23	$10,000	22500	5.4
Gem Site Regional Mine Waste Repository	30	$14,000	21429	5.1
McClellan Brownfield Project	20	$12,000	20833	5
Gilson Gulch Remediation	22	$23,000	14348	3.4
Mobile Watershed Lab	33	$25,000	13200	3.2
Conqueror Mines Complex	25	$23,000	10869	2.6
Mill Creek Water Production Demonstration	20	$19,000	10526	2.5
Lion Creek Drainage	30	$31,000	9677	2.3
Maude Monroe/Donna Juanita	23	$28,000	8035	1.9
Biocenter	28	$38,000	7237	1.7
Watershed Festival, Grade School Poster Contest, Watershed Placemats/Trivia Cards	25	$40,000	6250	1.5
Hazardous Spill Containment	330	$540,000	611	1.5
Wind Farm	1000	$1,800,000	555	1.3
Custom Mill	330	$700,000	471	1.1
Watershed Website, 4th and 7th Grade Mining /Natural Resource Curriculum	33	$75,000	4400	1.056
Gem Site Alternative Energy Production	28	$14,000	1964	0.5
Greenway Streambank Improvements/Interpretative Signage	200	$945,000	211	0.5
Integrated Trails/Greenway Projects	330	$1,200,000	275	0.066

From the information provided in TABLE 5, a review of the top 10 rated projects was conducted and the following hierarchy of project priorities was determined:

- Orphan/Abandoned mine remediation projects are a high priority. These projects tend to have low costs — particularly when conducted by Good Samaritan entities, produce a significant reduction of metals loading into Clear Creek, and have a large sustainable benefit/cost ratio. The average sustainability benefit-cost ratio of the projects in this category was on the order of 40 times that of the Argo Water Treatment Plant.

- Projects that promote and preserve historical mining sites also dominated the top with an average of 65 times the sustainable benefit-cost of the Argo Water

Treatment Plant. These projects are also relatively inexpensive to implement and simultaneously provide education to the public while remediating some of the historical sites in the watershed.

- Projects that promote outreach and education and projects that implement water and wastewater management programs also ranked high.

Each of these areas has significant marketability, and contributes to sustainable watershed management. Note that often the small, low-dollar projects provide significant sustainable benefit — more *bang for the buck*. These types of projects lend themselves to immediate community action, and implementing these projects can lead to a good societal result of accomplishment.

It is the long-term goal of the Foundation to use this method to enhance our watershed action plan to promote sustainability on a project-by-project basis in a market-based approach, rather then a forced regulatory framework. Using sustainable methods of watershed management provides an efficient and lower cost method of maintaining the water quality of Clear Creek. This tool for watershed management decision-making is being implemented in the Clear Creek Watershed and provides a template for other watersheds across the arid, mountain western United States to develop their own MAUA.

2. Lessons Learned

- To determine the net sustainability that the proposed projects are worth within a watershed, it is important to understand each projects ecological, economic, and societal variables. Looking at only one variable will lead to an inaccurate value for the overall sustainable potential of a proposed project; therefore in order to estimate the total sustainable impact, a full assessment of the three variables must be conducted.

- Discourse-based evaluation is a valuable method of determining values for watershed sustainability variables. Taking into account stakeholder perspectives allows for the determination of relatively accurate sustainable values that otherwise might be difficult to determine.

- A MAUA is a beneficial tool that has the capability to evaluate watershed sustainability variables to provide a prioritized list of watershed projects by utilizing benefit/cost data, statistical analysis, and discourse-based valuation.

- In order for the results of the MAUA to be accurate, it is important to have as detailed of a description of each project as possible, including costs to implement; O & M costs; and an understanding of possible ecological, societal, and economic impacts.

- Often the small projects can have high sustainability value and produce a sense of accomplishment within the community.

APPLYING SUSTAINABLE WATERSHED MANAGEMENT TO THE CLEAR CREEK WATERSHED

1. Threats and Opportunities in the Clear Creek Watershed

The Foundation believes that a more sustainable approach to land use/development and resource management in the overall watershed can mitigate future pressures and water quality degradation. Based on stakeholder input, the most imminent threats to the sustainability or triple bottom line of the Clear Creek Watershed are:

THREAT	POTENTIAL NEGATIVE IMPACT	COMMENT(S)
• proposed Interstate 70 expansion/ pavement	$ 10B	preventable
• potential large-scale wildfire	$ 1B	mitigatable
• metals loading	$100M	existing/treatable
• sediment loading	$ 20M	continuing/treatable
• nutrient loading	$ 1M	continuing/treatable
• toxic spills/incidents	$ 1M	emergency response
• growth/development	$1-10M	treatable "smart growth"
• drought	$1M-1B	water management & production improvement

Based on stakeholder input, there are numerous opportunities to improve watershed sustainability and reduce the impacts of these threats in the form of sustainable watershed management projects. The costs shown are both first and long-term costs believed to be in the public's interest. It is believed that a market exists or can be constructed that can pay for these substantial improvements to the watershed. For organizational and developmental purposes, the Foundation has grouped these projects into the following eight categories:

PROJECT OPPORTUNITY CATEGORY	COST ESTIMATE	EXAMPLES AND/OR COMMENTS
• Orphan Mine Remediation	$ 20M	de-listing 303d impaired waters
• Natural Resource Management	$100M	wildfire mitigation, increased water production
• Water/Wastewater Management	$ 20M	in-situ disposal systems
• Preservation/Promotion of Historical Mine Sites	$ 10M	Maude Monroe
• Alternative Energy/Transportation	$ 10B	wind/solar for monorail alternatives
• Waste Stream Reduction	$ 1M	increased recycling efforts
• Subsurface Rights and Uses	$ 1M	custom mill
• Outreach/Education	$ 1M	many projects, products, services

2. Sustainable Watershed Management Projects

The Foundation promotes and facilitates improved water quality through sustainable watershed management projects which integrate ecological, social, and economic perspectives. It is the Foundation's goal to get watershed projects done by facilitating cooperative partnerships and funding. In most instances the Foundation will be a partner, but in some cases we will be the lead organization.

As detailed in UTILIZING A VALUATION TECHNIQUE TO ASSESS THE TRIPLE BOTTOM LINE VALUE OF PROJECTS, over the past few years watershed stakeholders have identified roughly 80 actual and/or potential watershed-based sustainability projects which promote innovation, cooperation, and cost-efficiency. For organizational, project development, and marketing purposes, the Foundation has grouped these projects into eight categories. The categorized projects are listed below:

CLEAR CREEK WATERSHED PROJECT 2000 LIST
SOURCE: CDPHE/EPA 1997 State of the Watershed Report

COMPLETED

1. Orphan Site Demonstration Project
2. North Empire Creek Reclamation
3. Groundwater Contamination in Idaho Springs at Virginia Canyon
4. Upper Virginia Canyon Reclamation
5. Idaho Springs Big Five Stream & Bank Restoration and Bike Path
6. I-70 Erosion Problem Assessment
7. Waldorf Mine Clean-up
8. North Clear Creek Habitat Restoration
9. McClellan(d) Mine Drainage Treatment
10. ISDS Location and Failure Evaluation
11. Last two Segments of Clear Creek Trail
12. Gregory Incline, National and Quartz Hill Pipeline
13. Rafting and Recreation Plan
14. Loveland Pass Hazardous Spill Assessment
15. Long-Term Watershed Vision
16. Lower Basin Landfill Identification and Clean-up
17. Rockford Tunnel Reclamation
18. Clear Creek Canyon Acquisition
19. Clear Creek Habitat Restoration
20. Urban and Stormwater Assessment
21. Headwater Quality Characterization
22. Precipitation Characterization
23. Land Use Map Update
24. Emergency Response Plan
25. Wetlands Identification
26. Water Quality and Quantity Database
27. Pozo Reclamation
28. Georgetown Reservoir Study
29. Little Bear Mine Clean-up
30. Boat Chutes on three Low-head Dams at I-25 and I-76
31. Coordinated River Trails Plan with Stream Bank/Riparian Effort
32. Flood Control at Silver Plume
33. Argo Tailings Stabilization
34. Big Five Waste Rock Reclamation
35. Quartz Hill Tailings Clean-up
36. Boodle Mill Reclamation
37. Chase Gulch Tailings Clean-up
38. Gregory Gulch Flume Project
39. Superfund Drinking Water Project
40. Twins Inn Clean-up
41. Golden Gilpin Mill Site Clean-up

MARKET AREA 1: Orphan (Abandoned) Mine Remediation

Cutting through the Colorado Mineral Belt, the upper portion of the Clear Creek Watershed is a target-rich environment full of orphan mines and naturally-occurring mineral sites. As a *Good Samaritan* entity authorized in a 2003 EPA Action Memo, the Foundation has been conducting, facilitating, and expediting clean-up of the 1,600 or so remaining orphan mine/mill sites not listed as priorities in the Clear Creek/Central City Superfund Operable Units Record of Decision (ROD). This work supports Superfund remediation efforts. The ROD and other information is available on line at http://www.epa.gov/region8/superfund/co/ccclearcreek/ on the Region 8 website. The Foundation also conducts abandoned mine remediation work under a United States Forest Service (USFS) Administrative Order on Consent and Partnership Agreement.

By remediating mining-related water quality problems and addressing associated public health, safety, and welfare issues, the Foundation and its partners are providing on-the-ground revitalization for the Clear Creek Watershed communities. Historically, this mine

remediation work is perhaps what the Foundation is best known for. The Foundation is now also looking at land re-use options at mine clean-up sites to promote more sustainable remediation.

From its decade-plus of experience in this watershed, the Foundation has learned that defining, listing, and prioritizing the projects inevitably to funding and implementation. Remediation work in the Clear Creek Watershed is accomplished through innovative partnerships — both public and private. Project partners have included the DRMS, CDPHE, EPA, Henderson Mine, Coors, Clear Creek County, USFS, Silver Plume, Idaho Springs, and numerous individuals.

Projects Completed to Date:

- General Herkimer
- Little Sixes and other Waste Rock Piles
- Minnesota Mill Tailings
- McClellan(d) Mill Tailings
- Doctor Mine
- Gem Site
- Dibbens Mill Tailings
- Sydney Mill Tailings
- Urad
- Lion Creek
- Black Eagle Mill Tailings
- Little Bear Waste Pile
- Argo Tunnel Water Treatment Plant
- Argo Tailings Pipe
- Argo Tailings
- Golden Gilpin Tailings
- Chase Gulch #1
- Gregory Incline
  - Tailings
  - Collection Pipe/Blowout
- Gregory Gulch #1
  - Tailings (Eureka)
  - Tailings (Central City)
  - Tailings (Gold Rush)
- Gregory Gulch #2
  - Tailings (Prometheus)
  - Tailings (Viento Vista)
- National Tunnel
  - Waste Rock
  - Collection Pipe/Blowout
- Clay County Tailings
- North Clear Creek Tailings
- Boodle Mill Tailings
- Big Five
  - Tailings
  - Tunnel
- Burleigh Tunnel
- Virginia Canyon Groundwater
- Chase Gulch #2
- Waldorf Mine Drainage
- Alice Glory Hole Maintenance

Pending Superfund Projects:

- Burleigh Tunnel
- Golden Gilpin Tailings
- Gregory Incline Water Treatment
- National Tunnel Water Treatment
- Nevadaville Tailings
- Quartz Hill
  - Tailings
  - Water Treatment
- Gregory Gulch #3 Tailings
- North Clear Creek In-Stream Sediments

Pending Non-Superfund Projects Funded by Other Programs:

- Diamond Mine Drainage
- North Empire Waste Rock Pile (Conqueror Mine)
- Aorta Mine Drainage
- Empire Tailings (in town)
- Joe Reynolds Tailings
- Elida Tailings
- Red Elephant
- McClellan(d) Drainage
- Rockford Drainage
- Trail Creek Tailings
- Donna Juanita/Maude Monroe Tailings
- Alma Lincoln Tailings
- Two Brothers
- Franklin
- Gilson Gulch Restoration Project (see SOCIETAL PERSPECTIVE)
- Upper Virginia Canyon (Castleton Mine, etc.)
- West Gold Mine
- Lombard/Cumberland Gulch

MARKET AREA 2: Natural Resource Management

The goal of the projects in this group is to manage the natural resources in the watershed to protect Clear Creek from possible contamination or natural disasters. Natural resource management can range from reducing the effects of flooding/erosion and wildfire to preventing hazardous waste spills into the creek, all of which can have devastating effects on water quality.

- Clear Creek Watershed Econometrics Model
- Integrated Trails and Greenway Projects
- Stream Bank Restoration

  Trout Unlimited's Golden Mile Project

  The West Denver Chapter of Trout Unlimited (WDTU), the Foundation, and several other local entities are collaborating on an innovative effort entitled **The Golden Mile: On-Site Assessment and Design of Riparian and Aquatic Habitat Restoration**. The objective of **The Golden Mile** project is to restore the streambed and banks to create a more viable habitat for a substantial salmonid fishery within the Clear Creek Watershed near Golden, Colorado. As measured at the Golden gage over the past 25 years, stream flows for this particular segment of Clear Creek have ranged from a high flow of nearly 2,300 cubic feet per second (cfs) in June 1995 to a low flow of 28 cfs in December 2002. The width of this segment varies along its linear length from approximately 20' to 85', with additional variations per runoff. Restoration design is a precursor to WDTU's construction project which will improve the quality of aquatic life and increase local recreational/economic opportunities.

  Protection and revitalization of this stretch of Clear Creek is planned to occur over two phases: Phase I: Restoration of **The Golden Mile** (Stage 1 and Stage 2) and Phase II: Future Upstream Actions. Stage 1 of the project focuses on restoration of the approximate one-mile of stream beginning at the up-stream end of the City of Golden's present kayak run extending to the upstream limit of the City's control of both the north and south banks of Clear Creek. In Stage 2, additional partner coordination will take place to continue restoration upstream to the vicinity of the Church Ditch diversion headgate. This reach of Clear Creek flows adjacent to Highway 6 and comprises land owned in parts by Golden, the Colorado School of Mines, Jefferson County Open Space and a Homeowners' Association.
- Wildfire Threat Mitigation (highlighted later in this section)
- Hazardous Spill Containment
- Monitoring Program (water quality and soil)
- Metals Trading (using Argo as an example) — The Foundation continues to advocate for the development/promotion of a *trading for credit* program to assist with remediation and maintenance costs at remediated sites.
- Orphanage Remediation Strategies for Orphan/Abandoned Mines not Covered by Superfund — The Foundation is pioneering the use of the orphanage approach which bundles similar mine waste sites in close proximity to each other under one plan/approval by EPA. This enables the bulk of funding to be invested on the ground.

MARKET AREA 3: Water and Wastewater Management

Another goal of the Foundation is to research and promote implementation of sustainable methods of water and wastewater treatment that are cost-efficient and ecologically sound. Construction projects such as traditional wastewater treatment plants can be extremely expensive and damaging to surrounding ecosystems; there are more passive systems that can be constructed that will create the same level of water quality with significantly lower cost and environmental impact. The Foundation aims to promote sustainable water and wastewater management throughout the watershed.

Completed Projects:

Colorado Water and Wastewater Treatment Network Website: To learn more about statewide water and wastewater treatment practices, **visit www.cwwtn.infot.** This is a newly formed interactive share-point website that is being hosted and maintained by the Foundation and sponsored by Coors Brewing Company. Since pure water is a key ingredient to the health and sustainability of our watershed, our goal is to protect water resources here and throughout Colorado. The purpose of this website is to provide Colorado water and wastewater professionals an avenue to exchange information and technical knowledge about their operations, to enable operators to help each other troubleshoot and problem solve with other professionals, and to provide increased training opportunities for all. Membership is free and members gain access to:

- information on water, wastewater and in situ treatment; as well as engineering, service and equipment supplier
- full interactive website access for your entire team
- your own facility web page
- shared knowledge and experience
- mentoring
- expert advice
- training opportunities
- member facility tours
- current industry news
- member contact and process information including photos and flow schematics
- library including books, publications, photos, forms, documents, and training materials
- quick links to water and wastewater related websites

Black Hawk/Central City Sanitation District (BHCCSD) Wetlands Project: As part of the construction of the relocated wastewater treatment facility, the BHCCSD originally planned on implementing a 0.6 acre wetland mitigation project. Instead, the BHCCSD made additional land available and teamed with CDPHE and EPA to implement over an acre of wetlands along the North Fork of Clear Creek near its confluence with the main stem. Throughout the year, the wetland treats about one cfs of North Clear Creek water, thereby supplementing Superfund efforts to control up-stream mine sediment and mine tunnel sources. The cost of this collaborative effort was shared by all three entities.

Pending Projects:

- Regional Wastewater Management Study — in progress by Arber Water, Wastewater & Reuse Engineers
- Shadows Ranch Wetland Demonstration Project
- Emerging Contaminants Study

MARKET AREA 4: Preservation and Promotion of Historic Mine Sites

The goal of the projects in this group is to enhance existing sites and create new locations (museums, landmarks, etc.) that provide information about this area's colorful

and vast mining heritage, as well as demonstrate some of the mine clean-up work that has already been done in the watershed. The sites will provide information on the history and future vision for the Clear Creek Watershed.

- Maude Monroe/Donna Juanita Historical Center/Living History Museum
- McClellan(d) Brownfield Project
- Endangered Place Designation(s)
- Clear Creek Heritage Corridor Designation (Continental Divide through Hidden Valley)
- George Jackson Historical Monument

MARKET AREA 5: Alternative Energy and Transportation

Promoting methods of renewable/alternative energy production and use is also a focus of Clear Creek Watershed Foundation. In March 2007, Colorado Governor Bill Ritter signed a bill that increases the state's renewable energy requirement to 20 percent by 2020. Sustainable means of energy production/use and transportation would result in less pollution in the Clear Creek Watershed, provide renewable forms of energy for future generations, provide economic development opportunities, and lessen dependency on non-renewable forms of energy. The CCWF is looking to support current alternative energy and transportation projects, as well as possibly implement pilot scale projects, especially on remediated mine land.

- Gem Site Repository & Alternative Energy Production Demonstration Project (see SOCIETAL PERSPECTIVE/Gilson Gulch)
- Hydropower Production Site(s)
- Wind Production Site(s) (Georgetown? Phoenix Mine?)
- Windfarm Lease of Shadows Ranch
- Green Building Practices
- Woodchip Usage Project (to facilitate energy production)
  NOTE: In 2007, Gilpin County finished construction of a new Road & Bridge Building which utilizes a bio-mass (wood-burning) boiler. This is an example of natural resource management, as well, by offering a use for the by-products of tree-thinning.
- Geothermal Electricity Production

- Regulation Assessment that Encourages Watershed-wide Alternative & Efficient Energy Systems
- Model Ordinance in Watershed that Promotes Sustainability
- Energy Conservation and Retrofits
- I-70 Mass Transit

MARKET AREA 6: Waste Stream Reduction

Projects that promote the concept of "reduce/recycle/reuse" could have huge positive impacts on the watershed by reducing pollution caused by waste products.

- Class A Biosolids Facility (Idaho Springs Transfer Station?)
- Biosolid Waste Stream Consolidation for Re-use as Soil Cover

MARKET AREA 7: Subsurface Rights and Uses

In Clear Creek County alone there are roughly 3,000 patented mining claims, more than half of which are currently abandoned and/or inactive. Mining was the founding industry for the area and the State of Colorado. CCWF wishes to support projects that protect the rights of current mine owners and explore various subsurface uses for inactive/abandoned mine property, including mining and water rights, and underground uses including storage, agriculture and science. The following is a list of pending projects and possible future projects:

- Henderson Molybdenum Mine Re-Use
- Underground Energy Storage
- Underground Explosives Storage
- Chicago Creek to Empire Junction Tunnel (deliver water to Empire Junction)
- Custom Mill to Support Local Mining
  NOTE: In 2007, the Clear Creek County Board of County Commissioners passed a resolution accommodating the development of custom mills in the county.
- Tourist Mines
- Protection of Mine Land Zoning and Mineral Rights
- Mine Safety
- Vocational Mining Skills Training Facility

MARKET AREA 8: Education and Outreach

Education and outreach projects are an important focus for CCWF. Through collaborative partnerships, we work to provide the public with information on the history of the area, what a watershed is, the current condition of Clear Creek Watershed, sustainability techniques/tools, and natural resources in general. We believe that this will allow for more informed decisions to be made to address watershed sustainability.

Completed Projects:

- Clear Creek Watershed Foundation Website Phase 1
- "Summer of Gold" Mining History for Students Phase 1 (as "Colorado Reader")

Pending Projects:

- Mobile Watershed Lab
- Clear Creek Watershed Foundation Website Phase 2 & Phase 3 (plus maintenance)
- Mining History Video for Kids (for 150th Anniversary of Colorado Gold Rush in 2009)
- Watershed Trivia Cards/Sustainable Watershed Management Board Game
- Educational Placemats
- "Summer of Gold" Mining History for Students Phase 2 (as Educational Workbook)
- 4th and 7th Grade Teacher Lesson Plans on Mineral Resources, Mining History, and Watershed Science (PDF on website, etc.)
- 4th and 7th Grade Classroom Loan Boxes on Mineral Resources, Mining History, and Watershed Science (advertise availability on website, etc.)
- Watershed Poster Contest for Elementary Schools in Watershed
- Watershed-Wide Photo Contest
- Create Clear Creek Watershed Environmental Leadership Program (based on CDPHE program)
- Clear Creek Watershed Festival
- Watershed Education Center (at Shadows Ranch)
- Ongoing Stakeholder Forums and Watershed Tours
- Watershed Speakers Bureau/Presentations
- Update Clear Creek Watershed Exhibit

3. Project Highlights

Each of the four projects highlighted in this section bring together the triple bottom line factors of ecology, society, and economy for sustainability projects in the Clear Creek Watershed. These projects illustrate sustainable watershed management.

- a legacy project — the McClellan — Brownfield to rafting
- a major opportunity for the watershed — the Maude Monroe — historical preservation
- a major threat to the watershed — potential large-scale wildfire — risk mitigation
- the transportation/energy issue — the I-70 dilemma — mode change

The First Sustainability Project. The McClellan Mill Site Clean-up, conducted in 1993, is an early example of incorporating sustainability principles into on-the-ground projects. The McClellan site is located immediately downstream from Dumont south of Clear Creek and I-70 along the frontage road. It consists of both mine drainage into Clear Creek and a mill site with tailings containing metals toxic to fish eroding into Clear Creek. The partners for this project included:

- Clear Creek County
- Clear Creek Watershed Forum (the precursor of the Foundation)
- US EPA
- CDPHE/Colorado Hazardous Materials and Waste Management Division (HMWMD)

- Coors Brewing Company
- Clear Creek rafting companies

These partners developed a plan that included localizing and capping the mill tailings to isolate them from the environment thereby rendering them essentially inert. A unique feature of the remediation was access to Clear Creek and a boat ramp on the river for rafts.

These before/after photos show improvements which continue to have ecological, societal, and economic benefits for the Clear Creek Watershed.

Originally envisioned as a public-private initiative that would address both the mine drainage and mill tailings issues by EPA, the project partners insisted on creating an outcome for highest and best use of the remediated surface for the future. The design maximized available ecologic, social, and economic benefit:

- **Ecologic Benefit:** The design involved stream and streambank work to enhance fish habitat and a wetland enhancement for water purification.

- **Social Benefit:** The surface provides recreation access to the finished surface and the stream.

- **Economic Benefit:** The access point was designed to accommodate commercial rafting. This industry has blossomed into a ten million dollar per year industry which did not exist prior to the project.

The Maude Monroe — A Sustainability Opportunity. The Maude Monroe is located immediately upstream from Idaho Springs between Clear Creek and I-70 and along the frontage road. It consists of a well-preserved historic mining structure comprised of a mine shaft, headframe, elevator and hoist. Perched on a high bank above the river, one concern has been that Clear Creek during a major storm event would wash away the bank and undermine the site.

The first — and essential — action was construction of a retaining wall along Clear Creek to stabilize the bank. This was made possible through a Supplemental Environmental Project (SEP) award from a fine levied for a tanker truck spill into Clear Creek.

Further possibilities for the site include restoration of the historic structure and development of a mining-related education center/living history museum for both school programs and tourists. Currently discussions are underway to evaluate the feasibility of this concept.

From the standpoint of the triple bottom line, the following enter into the project design:

- **Ecologic Benefit:** Stabilize the left descending bank with a retaining wall; clean-up of Cu, Ca, Mn, Al hotspots at the headframe and ore bin; treat water in the shaft.

- **Social Benefit:** Provide public parking with a porous surfaced lot on the right descending bank; provide access from right bank to left bank with a foot bridge; provide pathways and interpretive signage throughout the site; stabilize the site/structures for public safety.

- **Economic Benefit:** Use the site to stimulate eco-tourism throughout the county; capitalize on the upcoming 150-year anniversary (1859-2009) of the Colorado Gold Rush.

New retaining wall at the Maude Munroe to keep flood waters out of the mill waste pile.

<u>The Wildfire Threat — A Sustainability Challenge</u>. Potential wildfire conditions in Colorado's Front Range watersheds — including the Clear Creek Watershed — have been characterized as the *biological perfect storm* having these characteristics:

- Single forest species, i.e., doghair lodgepole pine
- Homogenous age of trees
- Repeated drought conditions
- Lack of traditional colder winters
- Mountain Pine Beetle infestation that weakens trees and is spreading from Grand and Summit Counties into the neighboring Boulder, Clear Creek, Gilpin, and Jefferson Counties

Typical burned landscape from the Hayman Fire. Photo courtesy of www.ieca.org

Starting with the caveat that a wildfire event could range from minor to major, the potential direct and indirect impacts to the Clear Creek Watershed (based on similar impacts for the Hayman Fire), could include the following:

- **Ecologic Impacts**
    - Degradation of water quality.
    - Reduction of water quantity yield.

  - Wildlife habitat and fisheries lost or degraded.
  - Impairment of aesthetic asset of the watershed.
  - Degradation of other ecological services of watershed.

- **Social Impacts**
  - Potential loss of human life.
  - Loss or damage to homes, businesses, and other community infrastructure.
  - Loss or damage to critical infrastructure, i.e., drinking water and wastewater treatment facilities.
  - Change in community character as some residents and businesses rebuild, some leave.

- **Economic Impacts**
  - Loss of forest asset (the Hayman burned 138,000 acres).
  - Cost to fight fire (the Hayman costs exceeded $200 million).
  - Disruption of personal and commercial travel along major east-west transportation corridor, i.e., I-70 and Eisenhower Tunnel.
  - Increased cost to treat or provide safe drinking water for 350,000+ northeast Denver residents and businesses, and 20,000 upper basin residents and businesses
  - Loss or damage to Loveland Ski Area.
  - Loss or damage to the Henderson Mine.
  - Loss or damage to Easter Seals Handicamp and Shwayder Camp.
  - Impairment of Rocky Mountain water for Coors Brewing Company.
  - Cessation of local outdoor recreation and other tourism activities.
  - Reduction of local tax revenues.
  - Ongoing costs to mitigate fire impacts

Stakeholders that could be impacted by a wildfire event include:

- Municipalities: Silver Plume, Georgetown, Empire, Dumont, Idaho Springs, Central City, Black Hawk, Golden, Arvada, the Standley Lake Cities (Northglenn, Thornton, and Westminster), and other ditch companies.
- Counties: Clear Creek, Gilpin, Jefferson, Adams, and Denver.
- Drinking water treatment facilities: Black Hawk, Central City, Golden
- Wastewater treatment facilities: Black Hawk/Central City Sanitation District, Central Clear Creek Sanitation District, City of Idaho Springs, St. Mary's Glacier Water & Sanitation District, Town of Empire, Town of Georgetown, Town of Silver Plume, City of Golden
- Major industries: Loveland Ski Area, Henderson Mine, Coors Brewing Company.
- Agencies: US Forest Service, US EPA, Colorado State Forest Service, Colorado Department of Transportation, Colorado Department of Natural Resources, Colorado Department of Local Affairs, Colorado Department of Public Health and Environment, Natural Resources Conservation District/USDA.

To mitigate the threat of wildfire, a number of goals, objectives, and tasks are being pursued:

- Encourage the engagement of all potentially affected stakeholders in prioritizing and accomplishing mitigation tasks.

- Thin the dense lodgepole stands on both Forest Service and private lands.
- Stimulate and facilitate involvement of the logging industry.
- Find and encourage end-users of beetle-killed timber (post and pole, mill operations, biomass, pellet, ethanol, particle board, etc.
- Encourage the US Forest Service to expedite their Environmental Assessment (EA) process to approve public-private forest management activities.
- Engage the Colorado State Forest Service to obtain on-the-ground expertise.
- Educate and assist residents on creating and maintaining defensible space.
- Provide training for local fire authorities, law enforcement officials, and first responders to increase effectiveness in managing fire events.
- Develop a Clear Creek Watershed Wildfire Mitigation Plan and website to post updates on project progress.

To accomplish these goals, cooperative efforts need to be pursued to overcome some of the inherent barriers:

- All stakeholders — upstream and downstream — need be persuaded to participate.
- Incentives need to be devised to involve the logging and end-user industries.
- The Forest Service needs to develop a process for expediting and overseeing public-private project approval.
- Adequate funding needs to be secured to get the job done.

The Foundation is partnering with USFS on the Yankee Hill/Mill Creek Fuel Reduction Program and with the Clear Creek County Office of Emergency Management on a County-Wide Community Wildfire Protection Plan. The aspects of these projects include — but are not limited to — fuel reduction, ingress and egress route protection, dry hydrant and water source protection, defensible space, increased/improved water production as a forest management prescription, GIS/mapping exercises, and education programs.

The Transportation Issue — I-70 Dilemma. There is great consternation among mountain communities concerning the manner in which the Colorado Department of Transportation (CDOT) is treating ecological and social issues in the December 2006 version of the Interstate 70 (I-70) Programmatic Environmental Impact Statement (PEIS). Local decision makers are convinced that the 15-year highway widening proposal — the old way of "wider and blacker" — is not survivable. Such a *cone zone* period is believed to so severely degrade the ecological, societal and economic fabric of place over a full generation that these communities might collapse. The communities base their evidence on experience gained from the first round of I-70 construction completed in the 1960s:

Ecologic Impacts:

- The original I-70 construction equipment parks and borrow pits remain as ecologic scars.
- CDOT is believed to be the largest industrial polluter in the watershed.
- Road cuts made through the Colorado Mineral Belt, not benign county rock.
- Ecologic impacts can be anticipated in the right-of-way. The valley floor where this expansion would take place contains the remnants of 23 mill sites with their buried concentrations of mercury, cyanide, and heavy metals. Horizontal

construction with bulldozers, pans and other heavy equipment threaten to re-surface toxic materials that have been contained and dormant. This is a direct threat to the 350,000 downstream water users and industries that have come to rely on clean water.

Social Impacts:

- The towns of Dumont, Downieville and Lawson were eliminated as viable communities and did collapse.
- Historic Idaho Springs gave up 14 of 44 city blocks.
- Georgetown and Silver Plume have been secluded and virtually bypassed, but are managing to hold on as a National Historic Landmark District that has been named by First Lady Laura Bush as a *Preserve America Community* and designated as one of Colorado's most endangered places.
- The original I-70 construction worker temporary housing remains as blighted mobile home parks throughout the valley.
- There are no continuous bypass service roads in existence; hence any disruption impacts schools and essential services.

Economic Impacts:

- The economic interruption to Western Slope communities and the Denver Basin has been estimated at 15 billion dollars each over the 15-year "cone zone" period. This is an economic impact with life cycle consequences that far exceed the first cost of $5 billion dollars.
- The cost to prevent the release of toxic materials located in the right-of-way is not included in cost estimates for highway expansion. It is believed that these costs render the wider highway approach infeasible.

The 2006 Draft PEIS glossed over these issues, insisting that the decision process legally does not need to consider impacts — cumulative or otherwise — incurred during the 15-year construction period. Instead, the focus is on the year 2025 (when this construction phase is complete) with an implied promise that a Context Sensitive Solution Process will make the area well after the year 2025. Were the impacts confined to Clear Creek County only as the highway "sacrifice zone," this ecological, social, and economic wasteland might be acceptable to the majority of voters in the state. This is not the case.

A New Way — A Sustainable Mode.

A sustainable approach to the I-70 transportation dilemma is to first install a state-of-the-art High Speed Surface Transportation System using vertical construction techniques to create an elevated parallel system, such as the CHSST system deployed in Japan. According to an April 2007 Denver Post editorial, "A 'maglev' line…would be a spectacular way to usher travelers into the Mile High City. It might also provide a technological key to unlocking the

Transportation and energy transmission in one packaged system — the high speed monorail.

gridlock on the Interstate 70 mountain corridor — which a recent study said costs the state $839 million a year in lost business and tourism as well as reductions in the quality of life that lures so many citizens to Colorado in the first place." Because this mode can be built over itself, the ecologic and social impacts of at-grade construction are virtually eliminated, with numerous benefits:

Ecologic Benefits:

- A guideway system provides a footprint that is 40 times less than an "at-grade" highway system.
- The materials from which it is constructed are primarily concrete and steel, not asphalt and crushed rock.
- The natural drainage, animal crossing, snow slides, etc., are accommodated under the guideway, not across the highway.
- The surface does not require sand or de-icers.
- The impervious surfaces are 20 times less than the highway of equivalent capacity, thus not requiring elaborate drainage structures.

Social Benefits:

- A guideway system is many times safer than a highway and less prone to delays.
- A guideway augmentation to an existing highway allows for choice.
- Construction proceeds off-line from the existing highway, thus one mode is a by-pass for the other.

Economic Benefits:

- A 500kv transmission line captured within the guideway super structure.
- There are economic benefits to the ecologic and social benefits, but a guideway provides economic benefit in its own right with a 75-year design-life versus a six-year design-life for pavement.
- The cost per mile of guideway is one-half the cost per mile of highway.
- The energy efficiency of the guideway is twice that of the highway.

Ultimately the decision is one of individual choice. The appeal of the highway is the illusion of freedom of the road, even though that may not be sustainable. The Clear Creek Watershed stakeholder valuation of threats and opportunities (2006 Forum) greatly favors a "monorail first" approach. However, issues remain:

1. How do you finance a guideway?
2. Where do you get the electrical energy to run a guideway in a sustainable manner?

The State of Colorado knows how to fund incremental widening of highways through HUTF and other mechanisms, albeit the sources are depleted for the foreseeable future. The State has not funded a transit system. A Task Force is currently convened to address this issue.

The power issue is beginning to be addressed by another state-wide Task Force looking at sustainable energy sources. The Foundation is pursuing its own sustainable energy program — *Brownfields to Brightfields*. The Foundation is taking action to turn some of the remediated orphan mine areas in the watershed into solar and wind energy farms.

In the ECONOMIC PERSPECTIVE/Watershed Mapping and Modeling section of this report (page 54) is a GIS analysis of south-facing slopes for solar power generation. It is believed that there are more than 30 megawatts of solar potential on those orphaned mine lands near Idaho Springs.

5. Lessons Learned

- The "sustainability lens" of viewing projects for their environmental, social, and economic importance can quickly highlight key opportunities and threats in the watershed that need to be addressed by a multi-jurisdictional consortium of stakeholders.

- Each of the 80 projects currently envisioned and taken through a scoping design phase is believed to enhance the sustainability of this geographic address.

- Our experience shows that once envisioned and described in sustainability terms, new projects can be seen in benefit/cost terms and will be funded and implemented.

- There is a ready market for cleaner water and sustainable energy production within the water-energy-mineral-forest-ecology nexus.

MAJOR FINDINGS

Because the downward flow of water through a watershed carries with it the effects of nature and human activity, concern for a stream's health must include concern for the health of the entire watershed. Natural and manmade systems respond to cause and effect. In order for decisions to be made in favor of sustainable practices, compelling qualitative and/or quantitative data and information must be provided to decision-makers. These metrics can then be applied to various projects to document the spatial extent of the improvement practice.

- Societal perceptions of peak oil and climate change are leading toward a greater societal demand for cleaner water and sustainable watershed management.
- The Clear Creek Watershed is a rational model/framework of sustainable watershed management and the methodologies and lessons described in this report are transferable to other watersheds.
- Discourse-based valuation among watershed stakeholders using a multi-attribute utility analysis produces sustainability values to determine priorities and justify project funding and implementation.
- These values are satisfactory for regulatory and funding sources as evidenced by their willingness to partner on watershed projects.
- There is a plethora of projects and market areas to enhance watershed sustainability.
- There is, in fact, an extensive market for cleaner water at the watershed level.
- The demand for clean water impacts other areas/activities in the watershed (transportation, energy generation, etc.) in the water-energy-mineral-ecology-social nexus.
- Watershed management should be a "bottom up"/grassroots program; there should be appropriate receptors at the State and Federal level, but the program should not be managed from the top down.

The Foundation's goal is to encourage and facilitate the broader application of sustainable and regenerative watershed management practices by providing stakeholders (jurisdictions, agencies, developers, etc.) in the watershed with information and tools to make sustainability-focused decisions regarding environmental restoration/protection activities and development practices.

APPENDIX 1: Aquatic Toxicity Investigations – An Overview

NOTE: *In the overview below, the term LC50 is used as the basis for determining progress towards achieving water quality standards. LC50 is a toxicity test. Such tests are used in commercial and government laboratories to ascertain the concentration of pollutants that are lethal to 50 percent of the test organisms that are subject to the pollutants for a predetermined time period. This value is expressed as the Lethal Concentration 50, or the LC50. LC50 means that 50 percent of the organisms die within the specified timeframe. Low LC50 values signify high toxicity (low survival of test species), whereas, high LC50 values signify low toxicity (high survival of test species). LC50 values are used, in part, to set water quality standards and, in turn, to assess whether water quality meets standards, or is improving.*

Ceriodaphnia dubia, or Daphnia, is an [cladoceran] indicator species commonly used for aquatic toxicity testing. Daphnia is a small, developing organism, low on the aquatic food chain. It is an ideal indicator species for testing water quality because the developing organism grows rapidly and is sensitive to the toxic pollutants; that is, it will exhibit a physiological response, such as, arrested development, abnormal growth, or death. Other species are ranked according to LC50s based on their sensitivity to the same pollutants.

Findings from the various aquatic-toxicity field investigations in the upper Clear Creek watershed and related reports have concluded the following:

- The number of LC50 (%) values obtained for field studies reported for 1989 (CDM, 1990), 1995 (Medine, 1995), 1999 (Medine, 1999), and 2003 (Integrated Laboratory Systems, Inc., 2005) have varied considerably. Few sites have consistently been sampled for all four studies, using *Ceriodaphnia dubia*, a cladoceran indicator species commonly used for aquatic-toxicity testing. Tabulated results from these investigations are given in Table A-1. The number of tests was eight for October 1989, 22 for October 1995, 12 for October 1999, and only three (all for North Fork Clear Creek) for August 2003. For the first three studies, LC50% values are expressed in terms of survival. That is, low LC50% values signify high toxicity (low survival); whereas, high LC50% values signify low toxicity (high survival). Acute-toxicity results from the most recent (8/03) study were expressed as LC50% mortality values; thus, these have been converted to LC50% survival values for purposes of this comparative analysis with the earlier three studies.
- The 1995 *Ceriodaphnia dubia* toxicity results were depicted graphically (USEPA and CDPHE, 1997, Map 6). However, the original data source reports LC50% values for 22 sites; whereas, this graphic depiction indicates a toxicity-ranking code for 33 locations. The source of these additional data currently is unknown.
- A spatial (upstream-to-downstream) comparison of LC50% survival values indicates a general profile of higher acute toxicity as one proceeds in a downstream direction (Figure A-1). At three sites upstream from the Argo Tunnel discharge, LC50% values are reported for the 1995 study as >100 percent, indicating the lowest toxicity. These consist of Woods Creek (a tributary of WFCC, site SW-34), Fall River (site SW-15), and Chicago Creek (site SW-08A). In contrast, high toxicity (low LC50% survival values) are indicated for mine-impacted streams or streamflows (Trail Creek, site SW-14; Argo Tunnel

discharge (prior to treatment), site SW-06; NFCC below BH/CC WWTP, site SW-39; and Russell Gulch confluence at NFCC, site SW-39). For this same (1995) survey, the lowermost mainstem Clear Creek sites indicated high toxicity (LC50% values of 6.25 at both sites SW-02A and SW-01)

- Overall comparative results from these studies point towards an improvement in low-flow aquatic-toxicity conditions over time (Table A-1), as indicted by increasing LC50% survival values at nine of the 14 sites having multiple samples for testing *Ceriodaphnia dubia*. Mixed results are indicated for three sites (Clear Creek upstream from Idaho Springs, site SW-13 and Clear Creek above the Argo discharge, site SW-05, with lower 1995 values; and NFCC confluence at Clear Creek, with LC50% survival values ranging between 4.79 and 14.17 for the four studies (see Table A-1 and Figure A-1)
- The 1999 study results for the mainstem Clear Creek indicate improvement in acute toxicity, in terms of increasing LC50% survival values when compared to earlier study results. This may well be indicative of the beneficial impacts of treatment of the Argo Tunnel discharges since April 1998.
- Mr. Paul Winkle, a CDOW aquatic biologist, has concluded that "… the water quality of the main stem of Clear Creek has improved considerably in recent years thanks, in large part, to treatment plants built in some of the mountain communities along the river *[stream]* and to government-citizen group habitat restoration efforts. As a consequence, says Winkle, Clear is a viable trout fishery today." (Weimer, 2007).
- This same report source (Weimer, 2007, p. 29) goes on to discuss the continuing need for improving conditions in the North Fork Clear Creek. This is the focus of the Superfund OU4 remedial projects currently underway or planned.
- Comparative results for annual fish-inventory and shocking studies by the CDOW have not been updated since Woodling and others (1998) and Woodling, J.D. and Ketterlin, J.K. (2002). According to Mr. Doug Jamison (CDPHE-HMWMD, oral commun., 7/12/07), a report using recent field-survey data is near completion by Dr. Woodling (now retired from CDOW).

Water-Quality Characteristics and Time-Trends

Findings from the various water-quality field investigations and modeling studies in the upper Clear Creek watershed and related reports have concluded the following:

- The seasonal and year-to-year variability of water-quality characteristics need to be taken into consideration when assessing any time trends and/or improvements resulting from wastewater-treatment-plant upgrades or mining-related remedial actions.
- Systematic monitoring data for flows and numerous water-quality variables are available at several surface-water sites and point-source discharges since February 1994. This monitoring program has provided a unique basis for assessing conditions and changes (Steele, Abel, and Fendel, 2004).
- Mining-related remedial actions are discussed elsewhere in this document. When the Argo Tunnel treatment facility came on line (April 1998), a significant adit-discharge characterized by high trace-metals concentrations has resulted in reduced trace-metals loads into the mainstem Clear Creek in Idaho Springs. Other remediation projects have also contributed to reducing trace-metals loads to the watershed's streams. Superfund (OU4) remedial projects have been funded and are beginning to be implemented.

- In spite of these beneficial actions, the watershed's streams have been impacted by below-normal streamflows for most years beginning in the 2000 water year (TDS Consulting Inc., 2006c) and continuing through the 2006 water year. Consequently, water-quality characteristics exhibit lower concentrations, due in large part to these lower flows. Especially in the case of trace metals, movement of sediments and water-sediment interactions affect resultant lower concentrations in streamflow. Only over a longer can the new benefits of remediation projects be quantitatively assessed, relative to noted streamflow conditions. In particular, the 2007 water year may produce again (finally) above-normal streamflows, and associated monitoring results can be compared to earlier data for comparable flow conditions in order to assess net beneficial remediation effects.

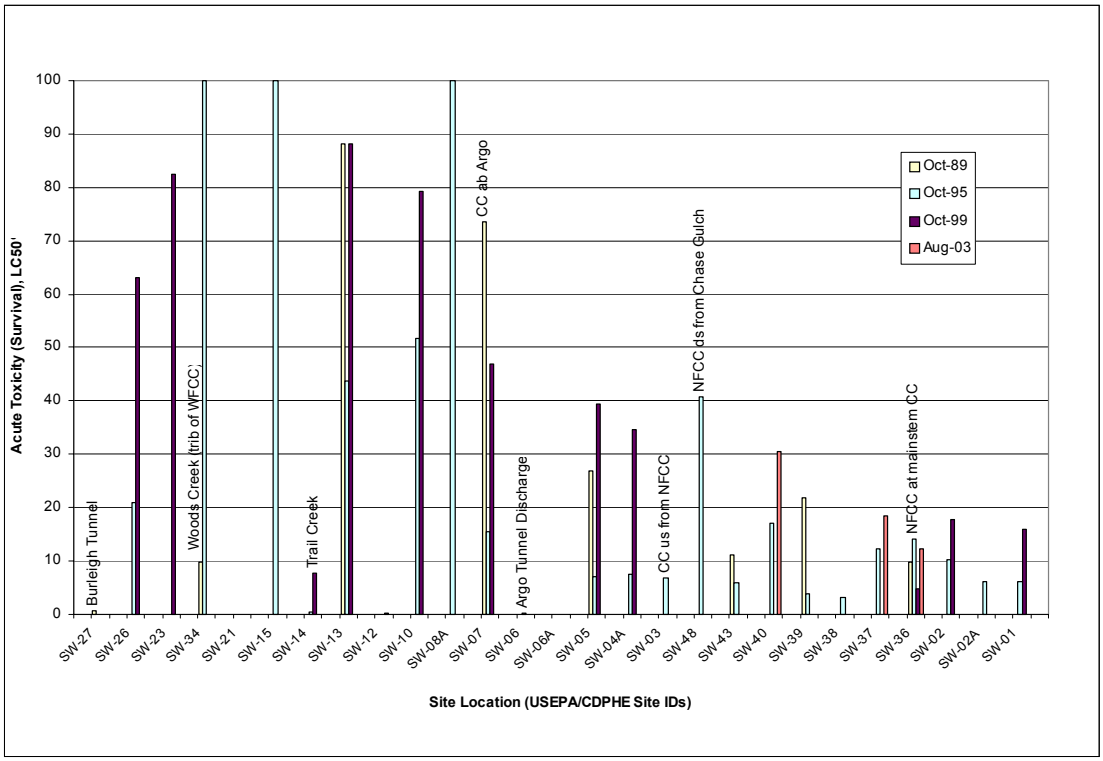
Recommendations

Continued monitoring for trace-metal concentrations and for aquatic-toxicity indicator species should be continued in order to assess long-term benefits of mining-related remediation projects and other improvements such as implementation of or upgrades to wastewater treatment plants. To the extent possible, consistency should be sought in aquatic-toxicity sampling and reporting methodologies and in iterative samples collected at selected monitoring sites throughout the watershed.

TABLE A-1: *Ceriodaphnia dubia* Acute-Toxicity Results, Upper Clear Creek Watershed

Ceriodaphnia dubia LC-50s (percent)		S-of-W Map 6 codes:		blue	>100		Note: State-of Watershed report (1997) indicates test results totaling 33 (see Map 6). Medine (1995) shows 22. Other data source?
				yellow	10-100		
				red	<10		
Site ID	*Description of Site*	*Oct-95*	*Oct-99*	*3-Aug*	*1995Color*	*TimeTrend*	*Comments*
SW-27	Burleigh Tunnel discharge						Mine-related discharge, toxic
SW-26	Clear Creek u/s from South Fork CC	21.01	63.21		yellow	*better*	
SW-23	Clear Creek u/s from West Fork CC		82.49		yellow?		*Shown on S-of W Map 6 as blue (no test)?* *UCCWA monitoring site CC-25*
SW-34	Woods Creek u/s from West Fork CC	100			blue		
SW-21	Clear Creek at Lawson streamgage						No toxicological tests are available *UCCWA monitoring site CC-26*
SW-15	Fall River @ Clear Creek confluence	100			blue		*UCCWA monitoring site CC-30*
SW-14	Trail Creek @ Clear Creek confluence	0.46	7.65		red	*better*	*UCCWA monitoring site CC-31*
SW-13	Clear Creek u/s from Idaho Springs	43.8	88.13		yellow	*mixed*	
SW-12	Big-Five Tunnel discharge (Id. Spgs.)		0.13				Mine-related discharge, toxic
SW-10	Clear Creek u/s from Chicago Creek	51.76	79.37		yellow	*better*	*UCCWA monitoring site CC-34*
SW-08A	Chicago Creek u/s from Clear Creek	100			blue		Not shown on Map 6 of S-of-W report *d/s from UCCWA monitoring site CC-35*
SW-07	Clear Creek above Argo Tunnel disch.	15.45	47		yellow	*mixed*	
SW-06	Argo Tunnel discharge	0.156			red		Mine-related discharge, toxic *UCCWA monitoring-site CC-99a*
SW-06A	Clear Creek just below Argo Tunnel Q						No toxicological tests are available
SW-05	Clear Creek below Argo Tunnel disch.	7.02	39.35		red	*better*	Further downstream on mainstem CC Looks as if indicated in red, Map 6
SW-04A	Clear Creek d/s from Id.Spgs. WWTP	7.55	34.68		red	*better*	
SW-03	Clear Creek u/s from North Fork CC	6.87			red		
SW-48	North Fork CC d/s from Chase Gulch	40.73			yellow		
SW-43	North Fork CC d/s from Gregory Glch	5.92			red	**worse**	
SW-40	NFCC d/s of National & u/s from BH	17.08		*30.5*	yellow	*better*	8/03 monitoring-site NCC-SW-16
SW-39	NFCC d/s of BH/CC WWTP	3.77			red	**worse**	
SW-38	Russell Gulch @ NFCC confluence	3.125			yellow		
SW-37	NFCC d/s from Russell Gulch	12.35		*18.4*	yellow	*better*	8/03 monitoring-site NCC-SW-6
SW-36	North Fork Clear Creek @ Clear Ck	14.17	4.79	*12.3*	yellow	*mixed*	*UCCWA monitoring-site CC-50* 8/03 monitoring-site NCC-SW-3
SW-02	Clear Creek just d/s from NFCC	10.15	17.68		yellow	*better*	
SW-02A	Clear Creek 1/2-mi d/s from Tunnel 2	6.25			red?		Should be red (1995 LC50% is <10) on Map 6?
SW-01	Clear Creek @ USGS gage in Golden	6.25	15.89		yellow?	*better*	Should be red (1995 LC50% is <10) on Map 6?
	Number of Ceriodaphnia dubia tests:	*27*	*12*	*3*	*22*	*14*	*See bibliography for reference sources.*
							Trend Summary: 9-better; 2-worse; 3-mixed

FIGURE A-1: Comparison of LC50% (Survival) for Aquatic-Toxicity Studies



APPENDIX 2: Argo Water Treatment Plant as a Point of Reference for Evaluating Projects

The Argo Value

by Shelby Frail, Clear Creek Watershed Foundation, Research Associate

I. Introduction: One of the goals of the Clear Creek Watershed Foundation was to create a watershed-scale tool that facilitates evaluation of public and private watershed investments on the basis of sustainability. Currently the Foundation has a list of roughly 60 possible sustainability projects in the upper basin that are categorized into the following eight affinity groups:

- natural resource management
- education and outreach
- water and wastewater management
- preservation and promotion of historical mining sites
- abandoned mine remediation
- alternative energy and transportation
- waste stream reduction
- subsurface rights and uses

These eight groups offer a range of projects that address sustainability of the Clear Creek Watershed by addressing cause and effects while also lending themselves to systems analysis. Using a multi-attribute analysis model the projects can be normalized by a group of stakeholders on one scale of sustainability benefit, be compared to the known sustainability benefit/cost of a reference project such as the Argo Water Treatment Plant, and have their benefit versus cost ratio put in terms of an "Argo." The "Argo" is the Foundation's point of reference that is used to compare, prioritize, and market projects within the watershed.

The following is a summary of the key definitions essential in understanding the "Argo Value," the methods used to implement the "Argo Value," results of a trial run, and final conclusions.

II. Definitions: To understand the prioritization of these projects the key terms, sustainability, watershed sustainability, multi-attribute analysis, the "Argo Value" and the "Argo," must first be clarified and expanded on.

Sustainability is defined as developing our resources so that they will meet the needs of today's society, as well as being able to provide for the needs of future generations (Mitsch and Jørgensen 2004). From an economist perspective sustainability can be defined quantitatively by the economic, ecological, and social values of the resource. These three values are thus referred to as the **"triple bottom line"** a term first coined by economist John Elkington (wikpedia.com). The goal of the Foundation is to develop a watershed management program that focuses on Clear Creek sustainability by supporting projects that provide the highest values for the variables of the "triple bottom line."

- **Economic value** is the most easily defined variable of the "triple bottom line" and can be thought of in terms of getting the most products for the dollar. Projects that generate revenue, enhance market-based motivation for investment, and promote no net loss ecological functions have high economic values.

- **Societal value** is based on the idea that certain projects can create an improved public discourse based on a better understanding of issues surrounding watershed management and the environmental state of Clear Creek. High societal value would be projects that promote education, develop awareness, and help create a sense of history.

- **Ecological value** is based on the value of environmental services. These services are defined as the benefits humans obtain from ecosystems functions, such as habitat, clean water, air, trees, and fish (Costanza et al 1997). Water quality is the key environmental service that the Foundation is reviewing and thus is the basis for defining ecological value. Projects that result in an improved water quality through the means of passive remediation, environmental investments, "smart" development, and pollution prevention all have ecological value.

Some of these values, such as clean water or education, are difficult to quantify but research has been conducted that showed that using group deliberation is an appropriate method of determining economic values for ecological and social services. The value set by the group can then be used to guide environmental policies and practices (Wilson and Howarth 2002).

Watershed Sustainability: The Foundation has developed a definition which incorporates the variables of the "triple bottom line" and the traditional definition of sustainability.

- **Watershed Sustainability**: A community-based approach to improving and protecting water quality and other watershed resources by integrating ecological, social and economic perspectives in the use of shared critical natural resources: water, energy, minerals, forests, biota.

From this point forward in this document ecological, societal, and economic values will be referred to as watershed sustainability variables to maintain the philosophy of the Foundation that in order to manage the watershed sustainably there must be balance of the these three perspectives.

Multi-Attribute Utility Analysis (MAUA): A MAUA is a mathematical decision-making methodology that is commonly used in the engineering world to prioritize projects that have significantly different values and attributes.

"Argo Value": The MAUA that the Foundation developed that incorporates a combination of conventional valuation methodologies and public-based discourse to rank project opportunities for the Clear Creek Watershed. Using the "Argo Value," proposed projects are normalized on one scale of sustainability benefit and are compared to the known sustainability benefit/cost ratio of a reference project. It is step by step process that is implemented by a group of stakeholders.

The "Argo Value" uses the Argo Water Treatment Plant (AWTP) as the reference project. The AWTP is used as a basis of comparison because the sustainability benefit in terms of the watershed sustainability variables has already been defined. Its economic value based on its capital and annual costs, its ecological value in terms of pounds of metal removed per day from the watershed, and the societal value is the impact it has on public health, safety, and welfare.

Since the AWTP was funded by tax-payer dollars it can be considered a sustainability project that is in the public's best interest.

An Argo: The result of prioritizing proposed project via the "Argo Value" is that the number of Argos each project is worth will be determined based its final benefit/cost ratio. An Argo is merely a statistical reference point that will be used as the "gold" standard in which to compare, prioritize, categorize, and market projects within the Clear Creek Watershed. The AWTP's benefit versus cost ratio is equal to one Argo and any project valued higher then one or more Argos is also considered to be the public's best interest. Projects that are worth less than one can be combined with other small project to have an equal or greater benefit as the Argo.

II. Methods: The following is a description of the steps involved in implementing the "Argo Value".

- **Step 1:** Members of a group are divided into 8 groups and assigned a sustainability category where they rank the ecological, societal, and economic values of each project on a scale of 0 to 1000.

- **Step 2:** Next each project within the category are ranked against each other to determine which one had the most sustainable benefit on a scale of 0 to 1000.

- **Step 3:** Rank all the projects on one normalized scale of sustainability. The scale was set by the Argo Wastewater Treatment Plant (AWTP) and had a relative scale of 0 to 1000. The sustainability value of the AWTP was determined to be 500 when compared to other 25 year-life projects. This scale will be coined the "Argo Scale".

- **Step 4:** The value determined for each project on the "Argo Scale" is the project's sustainability benefit. The sustainability benefit value is then divided by the estimated annual cost of each project to obtain a benefit versus cost ratio. The annual cost is determined by dividing the initial cost to implement the project plus annual O&M costs by the lifetime expectancy of the project.

- **Step 5:** The benefit/cost ratio of the Argo Wastewater Treatment Plant is equal to one Argo. To determine the number of Argos for the proposed projects, their benefit/cost ratio is divided by the Argo Wastewater Treatment Plant's ratio to determine the number of Argos the project is worth.

III. A Trial Run: During a past meeting held by the Clear Creek Watershed Foundation in February of 2006, a large group of stakeholders known as the Forum performed a trial run to implement this method of prioritization. The attendees of the meeting were organized into eight groups and assigned a project category. Each of the projects in the eight categories were then reviewed and ranked by the members of the groups. The first step of the review process was to rank the three variables of watershed sustainability, ecological, societal, and economic values, of each individual project on a scale of 0 to 1000. Each of the projects in all eight categories were then ranked on the Argo Scale to determine a value for the sustainability benefit that was used to calculate the benefit versus cost ratio. The sustainability benefit value was then divided by the estimated annual cost of each project to obtain a benefit versus cost

ratio. Finally, each projects ration is divided by the AWTP's ratio to determine how many "Argos" that it is worth.

Table 1 lists the final ranking of each project in the 8 categories as determined by the Forum. Column 1 is the name of the project highlighted by the color that coincides with its project group, column 2 of the table lists the number of points each project was given on the Argo Scale of 0 to 1000, column 3 lists the estimated cost per year to maintain the project, column 4 is the benefit divided by cost ratio, and column 5 lists the number of Argos each project is worth.

TABLE 1

1.) Natural Resource Management	**5.) Abandoned Mine Remediation**
2.) Education and Outreach	**6.) Alternative Energy Production and Transportation**
3.) Water and Wastewater Management	**7.) Waste Stream Reduction**
4.) Preservation and Promotion of Historical Mining Sites	**8.) Subsurface Rights and Uses**

Projects	Argo Scale Value	Cost/year	Benefit vs Cost Ratio	# of Argos
Hazardous Spill Containment	330	$540,000	**611**	1.5
Integrated trails/greenway projects	330	$1,200,000	**275**	0.66
Mill Creek Water Production Demonstration	200	$19,000	**10526**	25
Mobile Lab	330	$25,000	**13200**	32
Upper Clear Creek Watershed Festival, Poster Competition For Grade School, Placemats, Watershed Trivial Pursuit Cards	250	$40,000	**6250**	15
Watershed Website, 4th and 8th Grade Mining/Natural Resource Curriculum,	330	$75,000	**3300**	7.92
Shadow Ranch Constructed Wetland	225	$10,000	**22500**	54
George Jackson Historical Site	250	$3,600	**69444**	167
McClellan Brownfield Project	200	$12,000	**20833**	50
Mill Creek Water Production Demonstration	200	$19,000	**10526**	25
Maude Monroe/Donna Juanita	225	$28,000	**8035**	19
Greenway Streambank improvements/Interpretative Signage	200	$945,000	**211**	0.5
Good Samaritan Projects	275	$4,000	**50000**	120
Gem Site Regional Mine Waste Repository	300	$14,000	**21429**	51
Gilson Gulch Remediation	330	$23,000	**14348**	34
Conqueror Mines Complex	250	$23,000	**10869**	26
Lion Creek Drainage	300	$31,000	**9677**	23
Gem Site Alternative Energy Production	275	$14,000	**1964**	5
Wind Farm	1000	$1,800,000	**555**	1.3
Biocenter	275	$38,000	**7237**	17
Custom Mill	330	$5,000,000	**66**	0.16

Table 2 shows the ranking of all the projects against one another, listing the project with the highest number of Argos first down to the project with the least; however based on the rating conducted the number of Argos the low budget projects received is unrealistically high. This is

due to the sustainability benefit value these projects were given on the normalized Argo Scale. It is important to remember that scale ranges from 0 to 1000 and that ranking a project at value below 100 does not necessarily mean the project is worthless. Small projects are going to tend have a very low benefit when compared to a large project such as the AWTP, but the collaboration of several small projects will start to have a more comparable impact. For example the George Jackson Historical Site was ranked at 250 points on the which means that its benefit to the watershed is almost half that of the AWTP; however this a very small project that involves some interpretative signs being erected to give tourists a brief history of the area and does not really compete with AWTP that prevents 250,000 tons of metal from entering Clear Creek each year. Due to its high benefit value and its low annual cost it ended up being worth 167 Argos which realistically speaking is way too high. In order for the Argo Value to work efficiently it is important that the people involved in ranking thoroughly consider the sustainability benefit and use the whole scale of 0 to 1000, so that an accurate prioritization can be made.

To account for the overranking of the smaller budget projects, Table 3 was constructed to give a more realistic projection of what the outcome of the prioritization should look like. The sustainability benefit of any projects with an annual cost below $100,000 was then divided by 10. This significantly reduces the number of Argos that each project was worth and gives a better perspective of which projects should be actively pursued. Looking at the top 10 rated project in Table 3, abandoned mine remediation projects were a high priority. These projects tend to have low costs, but the reduction of metal loading into Clear Creek as a result of cleaning up abandoned mines sites has a large sustainability benefit versus cost ratio. The average benefit/cost ratios of the projects in this category were on average 40 times that of the AWTP. Projects that preserver and promote mining history also dominated the top with an average of 65 times the sustainability benefit versus cost of the AWTP. These projects are also relatively inexpensive to implement and provide education to the public along with remediating some of the hazardous sites in the county. Projects that promote outreach and education as well as projects that implement innovative and inexpensive methods of remediation were also ranked high within the top 10.

The prioritization of the projects outlined in this paper is not the final product; however it gives us the idea that the Foundation should be focusing on cost-effective remediation techniques and education. This was merely a trial run of the "Argo Value" and further research is being conducted under an EPA grant to quantify the values of the "triple bottom line". Economic and social values have already been well defined but it is the current goal of the Clear Creek Foundation to research the economic value of environmental services such as clean water, aesthetics, and healthy aquatic ecosystems. Once the "Argo Value" is more a more precise system, the projects will once again be ranked by a board of stakeholders and technical experts to determine the final ranking. The final prioritization of the project will then become part of the Clear Creek Sustainable Watershed Management Program.

III. Future Research and Modeling

This trial run of the Argo Value System has provided valuable insight into the areas of the prioritization process that requires further research. One area of focus is to refine the scope and definitions of each proposed project to make the prioritization process more accurate. Costs and benefit values for each project needs to be developed further in order to make the prioritization process more accurate. To better understand the cost and benefit of these proposed projects an analysis of projects that have all ready been completed will be conducted to give a basis of

comparison for new projects. These steps will help the prioritization conducted by our board to be more accurate and less time consuming.

Values for the three watershed sustainability variables must also be defined to allow the prioritization process to be more precise. Currently the Clear Creek Watershed is researching the economic valuation of environmental services. Environmental services are the products, such as clear water, air, timber, fish, etc., that are provided by natural ecosystems and are used for human benefit (Costanza et al 1997). These services are crucial in sustaining human health and well being; however they are usually considered free commodities that have no market value. Treating these products as if they are "free" can lead to overuse or misuse of natural resources, reduction in potential human welfare, and increase the cost of maintaining

TABLE 2

Projects	Sustainability Benefit Rank	Cost/year	Benefit vs Cost Ratio	# of Argos
Argo Wastewater Treatment Plant	500	$1,200,000	416	1
George Jackson Historical Site	250	$3,600	69444	167
Good Samaritan Projects	275	$4,000	50000	120
Shadow Ranch Constructed Wetland	225	$10,000	22500	54
Gem Site Regional Mine Waste Repository	300	$14,000	21429	51
McClellan Brownfield Project	200	$12,000	20833	50
Gilson Gulch Remediation	330	$23,000	14348	34
Mobile Lab	330	$25,000	13200	32
Conqueror Mines Complex	250	$23,000	10869	26
Mill Creek Water Production Demonstration	200	$19,000	10526	25
Lion Creek Drainage	300	$31,000	9677	23
Maude Monroe/Donna Juanita	225	$28,000	8035	19
IMBY Biocenter	275	$38,000	7237	17
Upper Clear Creek Watershed Festival, Poster Competition For Grade School, Placemats, Watershed Trivial Pursuit Cards	250	$40,000	6250	15
Watershed Website, 4th and 8th Grade Mining/Natural Resource Curriculum,	330	$75,000	4400	10.56
Gem Site Alternative Energy Production	275	$14,000	1964	5
Hazardous Spill Containment	330	$540,000	611	1.5
Wind Farm	1000	$1,800,000	555	1.3
Custom Mill	330	$700,000	471	1.1
Integrated trails/greenway projects	330	$1,200,000	275	0.66
Greenway Streambank improvements/Interpretative Signage	200	$945,000	211	0.5

TABLE 3

Projects	Argo Value	Cost/year	Benefit vs Cost Ratio	# of Argos
Argo Wastewater Treatment Plant	**500**	**$1,200,000**	**416**	1
George Jackson Historical Site	25	$3,600	**69444**	16.7
Good Samaritan Projects	28	$4,000	**50000**	12
Shadow Ranch Constructed Wetland	23	$10,000	**22500**	5.4
Gem Site Regional Mine Waste Repository	30	$14,000	**21429**	5.1
McClellan Brownfield Project	20	$12,000	**20833**	5
Gilson Gulch Remediation	22	$23,000	**14348**	3.4
Mobile Watershed Lab	33	$25,000	**13200**	3.2
Conqueror Mines Complex	25	$23,000	**10869**	2.6
Mill Creek Water Production Demonstration	20	$19,000	**10526**	2.5
Lion Creek Drainage	30	$31,000	**9677**	2.3
Maude Monroe/Donna Juanita	23	$28,000	**8035**	1.9
IMBY Biocenter	28	$38,000	**7237**	1.7
Upper Clear Creek Watershed Festival, Poster Competition For Grade School, Placemats, Watershed Trivial Pursuit Cards	25	$40,000	**6250**	1.5
Hazardous Spill Containment	330	$540,000	**611**	1.5
Wind Farm	1000	$1,800,000	**555**	1.3
Custom Mill	330	$700,000	**471**	1.1
Watershed Website, 4th and 8th Grade Mining/Natural Resource Curriculum,	33	$75,000	**4400**	1.056
Gem Site Alternative Energy Production	28	$14,000	**1964**	0.5
Greenway Streambank improvements/Interpretative Signage	200	$945,000	**211**	0.5
Integrated trails/greenway projects	330	$1,200,000	**275**	0.066

flows of ecosystems services in the long run (Ecological Economics 2002). The goal of the Foundation is to research methodologies that have been used and find examples of determined values for environmental services that would apply to the Clear Creek Watershed. Such values have been determined by organization, such as the Department of Natural Resources who use dollar values for ecosystem service in natural resource damage claims. Determining values for environmental services will aid in the prioritization process by providing a more numerical number for the ecological value each project will provide. This will allow for the ranking to be more accurate and reduce reliance on the technical members of the board to define ecological value.

Research will also be conducted to determine value for economic and social impacts of each project. Economic values will be based on potential tourists' dollars that would be generated as a result of improved water quality, improvements to recreational area, and development of historical sites. Modeling has been conducted in this area by Tourism Boards and other tourist based industries such as rafting. Also, the costs associated with treating water from Clear Creek by water treatment facilities will be assessed to determine how much of a reduction in this cost each project will have. Social values will determined by using models developed for marketing and business practice. Further research needs to be conducted to determine which social value models will best fit the needs of the watershed management plan.

IV. Conclusions

The purpose of creating the Argo Value model is to provide a means for a board of stake holder and technical experts to rate and evaluate sustainability projects proposed by the Clear Creek Watershed Foundation. After the final ranking has taken place, the Foundation will have a menu projects to present to private industries who wish to invest in the sustainability of the Clear Creek Watershed. The ranking of the projects using the Argo Value model, will allow the investors to choose projects that will provide the most sustainability for the amount they are willing to invest.

The ranking discussed in this paper is not the final prioritization of the projects, but merely a trial run to give the Foundation an understanding of the methods to be used in the Argo Value method. There is still further research being conducted by the Foundation to better understanding the watershed sustainability variables in order to make the model more precise. Research on the economic valuation of environmental services is being done to better understand how a price is put on clean water, healthy ecosystems, and other indicators of water quality. The Foundation is conducting further investigation into each project to better understand the costs associated with them and the overall benefit that could be obtained. This information will be used by the board member to better asses the overall sustainability each project will have.

It is the long-term goal of the Clear Creek Watershed Foundation to use this method, along with the projects it supports, to create a watershed management plan that will promote sustainability. Using sustainable methods of watershed management provides a low cost and efficient method of maintaining the water quality of Clear Creek and its tributaries. Ideally, this method of watershed management will be implemented in the Clear Creek Watershed and can be used as a template to for other watersheds across the arid Western United States to develop their own multi-attribute analysis model.

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