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Evolution of the Landscape along the Clear Creek Corridor, Colorado—Urbanization, Aggregate Mining, and Reclamation

By Belinda Arbogast,[1] Daniel H. Knepper, Jr.,[1] Roger A. Melick,[1] and John Hickman[2]

Preface

Economic forces, environmental concerns, and, ultimately, society as a whole, impact the common human pursuits for food, water, minerals, space, and energy. The mining that provides mineral resources is influenced by market demands, land ownership, property development, and choices of land use. In our western States, areas commonly developed as a result of mining, our Western culture, and the inevitable trend toward urban growth. Mining is often viewed in an "all or nothing" framework based upon the conflict between land degradation and conservation of natural resources. Yet, the conservation of natural resources can mean the extraction of mineral resources prior to other uses of the land.

We, as consumers, are also directly or indirectly responsible for the modification of the land so that we can earn a living, enjoy recreational activities, have a nice place to live, travel conveniently from place to place, and obtain the goods and services that are available. We may alter streams and remove vegetation in order to divert water for irrigation, municipal use, and recreation, build cities in flood zones, and obtain resources such as aggregate. Nature, in the form of floods, tornadoes, hurricanes, fires, and earthquakes may also destabilize a stream (Riley, 1998). "The entire country is an enormous working quarry, an operational network of exchange, movement and transmutation" (Corner, 1996, p. 12). But even though humans may misuse and damage the soil and water, they also can transform portions of the earth into gardens, open space, and parks.

In the semiarid climate of the Colorado Front Range, flood plains along major streams provided prime agricultural land that supported settlement of the region. Clear Creek, between Golden, Colorado, and its confluence with the South Platte River was one such stream. The discovery of gold in the alluvial deposits of Clear Creek spurred an additional interest in the flood plain. But the demand for sand and gravel for construction purposes initiated a sequence of events that exceeded previous interests in the flood plain and created the modified landscape and urban ecosystem that exists along Clear Creek today. The Denver metropolitan area in general, and the Clear Creek corridor in particular, provide illustrative examples of the effects of sand and gravel mining on an area over time. The valley corridor offers a landscape filled with a persistent visible and hidden reminder of it's past use.

Mining is a necessary step in the ongoing process of development, and it is important to recognize the inevitable change of landscapes associated with the process. The evolution of the Clear Creek landscape is analyzed as a series of compositions, both at the macro view (in the spatial context of urban structure and highways from aerial photographs) and micro view (from the civic scale where landscape features like trees, buildings, and sidewalks are included). Four types of reclaimed mine pits are repeated in various locations along Clear Creek: "hidden scenery," water storage facilities, wildlife/greenbelt space, and multiple-purpose reservoirs. Six sites are selected to illustrate the evolution of past land use and reclamation. Since the South Platte River and its other major tributaries are still undergoing this evolutionary process, the results of this investigation may be useful in understanding and planning their future. Land planners, industry, and the general public can use this publication to:

- *Assess the nature of incremental development of a landscape over long periods of time.*
- *Assess how development of a landscape affects the visual character of the landscape.*
- *Consider the social, environmental, and physical effects of aggregate mining in relation to competing uses of land.*
- *Examine changes in landscape features (including form and function) and character at different scales.*

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Introduction

During the USGS Infrastructure Resources Project (1996–2001), studies of the natural aggregate resources and reclamation practices in the Colorado Front Range urban corridor revealed that the extraction of sand and gravel along Clear Creek has a long and interesting history. Mining, reclamation, and conversion of land use have been accomplished in a wide variety of ways. In addition, some high-quality gravel resources have been covered by urbanization, and other currently available gravel resources may never be developed because of opposition to mining and the difficulty of the permitting process.

Of the major tributaries of the South Platte River, only along lower Clear Creek (defined for this report as between Golden and its confluence with the South Platte) has reclamation of its local aggregate resource mines been nearly completed. To understand how mining, reclamation, and the conversion of land use were accomplished, the sequential evolution of the landscape along Clear Creek over the last 100 years was investigated (fig. 1).

Assessing the impact of mining to the landscape is difficult given the complex interrelationships surrounding each of the six sites studied. This is compounded by the fact that we all see the same landscape differently. The houses, streets, waterfront, or vegetation may be common elements we recognize. It is their meaning, value, and association that differ in our perceptions. This report does not presume to present all of the different ways we view the downstream landscape of Clear Creek. It is more an attempt to simplify some of the elements of the landscape and present the development, growth, and modification of mine sites along a part of one stream corridor. This discussion includes the following: historical perspective, development traditions, ecology, and natural resources policy.

Geologic Setting

Clear Creek is one of several major east-flowing tributaries that empty into the South Platte River. Clear Creek heads at the Continental Divide in the Precambrian crystalline rocks of the Front Range west of Denver and exits the mountains onto the plains about 35 miles to the east at Golden, Colorado (fig. 2). West of Golden, Clear Creek is confined to a steep-walled canyon cut in Precambrian igneous and metamorphic rocks; the majority of the Clear Creek drainage basin is in these Precambrian rocks. Adjacent to the mountain front near Golden, Clear Creek has cut a steep canyon through early Tertiary lava flows, bisecting them into North Table Mountain and South Table Mountain. Between Golden and its confluence with the South Platte River, a distance of about 15 miles, Clear Creek flows across the plains, which are underlain by east-dipping upper Paleozoic, Mesozoic, and Tertiary sedimentary rocks. These sedimentary rocks are mostly soft siltstone and shale with some sandstone, conglomerate, and limestone.

During the Pleistocene Epoch, Clear Creek was swollen with meltwater from mountain glaciers to the west. Glacial meltwater transported coarse gravel and sand from the Precambrian crystalline rocks of upper Clear Creek to the plains east of Golden. As much as 33 feet of well-sorted and well-rounded gravels were deposited east of North Table Mountain and South Table Mountain, where the stream gradient flattened and the narrow valley walls gave way to a broad, open valley. These well-sorted and well-rounded gravels make up the Louviers Alluvium (Van Horn, 1972), a major source of aggregate along the Clear Creek drainage (Unit T1 of Schwochow and others, 1974a). Where preserved along the edges of Clear Creek valley, the upper surface of the Louviers Alluvium forms the Louviers terrace about 15 m above the level of the present-day Clear Creek (fig. 3).

During the Holocene, Clear Creek eroded and reworked gravel of the Louviers Alluvium and established a lower, less extensive flood plain. The deposits of this younger flood plain, the Piney Creek and Post-Piney Creek alluvium (Van Horn, 1972 and Trimble, 1979), were mined for aggregate along with the older underlying sand and gravel.

Historical Perspective and Purpose

Studies of natural aggregate resources and reclamation practices conducted as part of the Front Range Infrastructure Resources Project (FRIRP) raised questions about how an area and its landscape evolve through mining and reclamation to second or third land uses. In an earlier study, Arbogast (1999) identified nine categories (approaches) for designing post-mine sites based on broadly different functions of the reclaimed sites. This study was followed by an investigation of how human visual perception and culture influence the way different reclaimed mine sites are accepted or rejected by society (Arbogast and others, 2000). The present study builds on the previous studies and attempts to assess the history and evolution of the landscape of a single area that has gone through the mining/reclamation cycle: the Clear Creek valley between Golden and its confluence with the South Platte River. A U.S. Bureau of Mines report (Sheridan, 1967) described and photographed selected locations in the flood-plain areas of metropolitan Denver as they existed nearly 35 years ago. Downtown Denver is built upon thick deposits of sand and gravel and Sheridan attempted to illustrate the "loss of sand and gravel resources through preemption of ground by

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prior nonmineral use, feasibility of multiple use of aggregate-producing ground through reclamation, and prevailing mineral land use conflicts" (Sheridan, 1967, p. 17). Sheridan investigated the conversion of reclaimed mineral land to areas of industrial and commercial uses, churches, recreation, and transportation. Today, the area still illustrates the historic and current land conflicts between the aggregate industry and expanding urbanization of the Denver area. Our values and choices determine future landscape patterns:

> *The culture of a nation, by general consent, would, I suppose, be regarded as its greatest heritage, but a heritage perhaps equally worthy of being cherished is the land surface which a nation occupies. The culture to a large extent must have been influenced by the character of the land surface, and in any event culture and land surface are interwoven, and interact in countless directions difficult to unravel. For better or for worse a nation may endeavour to mould and to develop its culture along definite and pre-conceived lines. In whatsoever direction the national character and the nation's activities move, the land surface and the use to which it has been, and is being put, will be the mirror which reflects the devious paths which a people have trodden in search of self expression. (Stapledon, 1935, p. 1.)*

For a geologist, mining is the excavation and extraction of mineral resources. Because reclamation is part of mining, mining can also be viewed as the result of an intentional shaping of the terrain to meet certain human interests. Most of our present forms of reclamation are derived from our Western cultural vantage. With recognition of past resource use and reclamation design, one can achieve a better understanding of mining land use and consequently develop effective land-use policy decisions.

Scope and Methodology

This report identifies areas of land used and reclaimed by the mining industry from approximately 1900 through 2000 along Clear Creek, from the foothills near Golden northeast to the confluence with the South Platte River north of Denver. The immediate area downstream (north) along the South Platte is also examined because of the extensive amount of gravel-pit reclamation into water reservoirs. A discussion of mining as related to the larger regional landscape must include the consideration of how mining sustains us, the impact of various public policies, and the linear or areal extent of land use over time. Understanding the site history, ecology, and image are fundamental in site analysis (Lynch and Hack, 1986).

Multiple sources of information were used to reconstruct the evolution of the landscape along Clear Creek. Such sources include journal publications, maps, photographs (terrestrial and aerial), newspaper articles, interviews, and fieldwork. Existing data from a combination of industry, State, and Federal reports were used to determine the amount and type of land use in the study area. Looking at the Clear Creek corridor at different times and scales, and through different media provided the means for identifying a broad variety of landscape changes. Aerial photographs (1:50,000 and smaller scales) display patterns of water, human settlement, roads, and vegetation. Looking at the aerial photography, as well as working with larger scale maps and images (1:24,000 and larger)—from topographic maps to street scenes—allows the landscape to also be observed from an ecological and cultural vantage.

Landscapes must be experienced in place to be fully felt and known (Spirn, 1998). The authors recognize the three-dimensional environment of the stream corridor is being converted to a two-dimensional view by photography and mapping, thus limiting the results. Photographs have come to be accepted for use in judging landscapes although there is a loss of "real-life" experience, including smell, sound, action, and time. Local landscapes were examined for their personal sense of place (a unique character that includes various sensory qualities and cultural/historical/social background) (Saito, 1984) using on-site visits by the authors (Arbogast and Hickman) to correlate these views and add details.

The authors selected a 1901 USGS Denver topographic quadrangle map (1:125,000 scale) and standard 7.5-minute topographic maps (7.5-minute series, 1:24,000 scale) from 1937, 1941, 1957, and 1965 (revised 1980 and 1994) for tracking the development of the waterway and its connections. The area is approximately 176 square miles, entailing three 7.5-minute quadrangles: Golden, Arvada, and Commerce City (formerly Derby). The data were digitized, the three adjoining regions formed into a composite mosaic, and selected information field checked by rapid visual reconnaissance of the landscape from the air and on site from the ground for a sense of human scale. Additional information was utilized from the Colorado State Geological Survey to identify known mine sites.

The maps produced in this work provide a chronology of human settlement, appraise a specific natural resource, and assess landscape change over approximately 100 years (see map sheets 1 and 2). To merge, identify, and compare attributes more easily, the data were put into a Geographic Information System (GIS) database using ER Mapper™ and ArcView® software. The raster files were draped across a Digital Elevation Model to provide a visualization of the terrain.

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Landscape as Culture: Development Patterns and the Grid

*We regard all landscapes as symbolic, as expressions of cultural values, social behavior, and individual actions worked upon particular localities over a span of time. Every landscape is an accumulation * * * methodically defining the making of the landscape from the past to the present * * *. (Meinig, 1979, p. 6.)*

Landscapes evolve and are shaped over time by the influences of weather, water, geology, organisms, and human culture. Human influences include:

- Early Settlement
- Public Policy
- Population Growth
- Transportation Networks
- Agriculture

Early Settlement

In understanding the culture of the Clear Creek landscape, it is important to begin with the native occupants of the area. During the 1700's, the hunting and gathering tribes indigenous to the eastern plains of Colorado included the Apache, Pawnee, and Comanche (Noel and others, 1994). The Arapaho and Southern Cheyenne replaced these tribes in the 1800's as settlement pushed eastern tribes west (fig. 4). The confluence of Clear Creek with the South Platte River was a favorite camping place and later became the site for an early trading post, Fort Convenience. It was an oasis in a land of wind and extreme temperatures.

Although Spanish explorers visited eastern Colorado in the mid-eighteenth century, another century would pass before other immigrants settled this area. The first name given to Clear Creek by the Spanish was Vasquez in 1859. Only a few ranchers lived in the area. Later, the "Creek was so clear and never known to be muddy till big rains and freshets [a great rise or overflow of a stream caused by heavy rains or melting snow] came down and the mills dirtied the stream and that give the name of Clear Stream or Creek" (Pioneer Association, 1918). By 1861, the first known map of the Colorado Territory shows 25 surveyed townships covering Clear Creek and other tributaries of the South Platte River. The Homestead Act of 1862 allowed settlers 160 acres. The Federal government required settlers to make improvements and live on the land for five years before receiving title (Noel and others, 1994). The Lee residence built in 1873 (fig. 5, sheet 1) exemplified the American dream of owning land.

Public Policy

The landscape of Clear Creek, and much of the West, was strongly affected by an act of Congress more than 200 years ago. The Land Ordinance of 1785, established a Federal land survey by regular, rectilinear geometry (the six-miles-square township, divided into 36 sections—the one-mile-by-one-mile "grid") to facilitate the settlement of large interior lands and serve economic life (Platt, 1996). Little attention was paid to the natural landscape patterns; canals, communication lines, and property boundaries were surveyed along straight edges disregarding the local topography. One hundred years later Major John Wesley Powell, head of the U.S. Geological Survey, suggested that land allocations match geographical features (Platt, 1996). The early twentieth century Department of Agriculture civil servant Hugh Bennett also envisioned a surveying system based on watersheds that would have fewer ecological effects on the landscape than the existing system (Kwasniak, 1996). Their land policy of political land reforms based on natural watershed divisions was rejected, but the concept has been reaffirmed because of the need for soil and watershed conservation studies.

The measurement grid influenced the American landscape, and its impact continues to this day (fig. 6). The natural boundaries of mountains, plains, and rivers were overlain by a grid of township, range, and sections. The scenic character of distant horizons is foreshortened and visually shaped by fences or hedgerows and dominated by buildings and roads. Cultural landscapes are broken into small parcels where the human presence is prominent and regional style (if there is one) frequently ignored. Development is typically piecemeal and dispersed while natural geographic features are obscure.

Transportation Networks

In addition to the land measurement grid, the other major built shape of the region is the vast linear system of transportation routes as shown in figure 7 (sheet 1). The earliest transportation systems followed rivers and streams, irrespective of the surveyed land grid. The path along Clear Creek became an important connection between Denver and Golden and on to the mountains, but the stream itself was too shallow and seasonal for navigation. By 1859 the first stagecoach arrived in Denver from the east (Noel and others, 1994), followed in the 1870's by railroad construction. The railroads aided the transportation of raw materials, goods, and people. Many major transportation routes followed north-south and east-west linear routes, with emphasis on the latter due to shipment of materials east. Transportation systems evolved from railroads in the early twentieth century to a road system designed for automobiles that mostly reflects the pattern of the measurement grid (fig. 8, sheet 1).

Colorado's streets and highways also developed in response to the location of physical features and natural resources. Gravel roads replaced dirt with an associated increase in use of stone, clay, sand, and gravel mining. Early road building materials included vitrified brick and granite blocks in downtown Denver streets.

The first trolley cars ran in Denver by 1889. In 1909, the city had 222 miles of tracks connecting the city and suburbs (Morson, 2000) (fig. 9). During the 1940's, Colorado's first limited-access highway was built from Denver to near

Golden: West Sixth Avenue. The north-south Valley Highway (Interstate 25, opened in 1958) and east-west Interstate-70 (mid 1960's) cross the Clear Creek corridor intersecting at an interchange referred to as the "Mousetrap." Interstate 76 parallels the creek, connecting Wheat Ridge to Commerce City, and it was built at a time when fewer interests competed for land use and the area was mostly blighted and in need of renewal. The interstate system now carries 24 percent of all traffic in the State (Garner, 1999) and is a dominant pattern of the urban landscape. Estimates range from approximately 30 percent of urban land in the United States is devoted to the automobile to as much as 75–80 percent in cities such as Los Angeles and Detroit (Hilpman, 1969; Trancik, 1986).

Thirty-seven percent of urban freeways in Colorado are congested, rating Colorado as the fifth most congested State in the nation (Flynn, 2001). The public understands traffic congestion is the price for urban growth, as well as a signal for the need for better transportation planning. By 1996, Colorado had 13,658 highway miles in urban areas; 1993 roadway congestion was estimated to be 100 vehicle hours of delay per 1,000 persons (U.S. Bureau of Census, 1998). In May 2000, the Denver area had 16.6 percent more automobiles on the road than licensed drivers (Myers, 2000). Land planners have said the true habitat for Americans is their car with streets no longer serving a social function for gathering and connecting neighborhoods (fig. 10).

At the local level, few want the aggregate pits that are needed for the materials of road building and maintenance. There are tradeoffs in resource protection, development, and reclamation of land. In November 1999, metro voters approved a $1.7 billion bond issue for highway projects and a proposal to allow the Regional Transportation District to borrow money to build a light-rail line from Denver along the southern I–25 corridor. In the same month, officials denied rezoning to allow quarrying near Eldorado State Park in Jefferson County and halted expansion of a gravel pit near Cherry Creek in Douglas County. Public concerns ranged from fears of noise to water pollution.

Suggestions to bring gravel in from outside the metro area may not work in certain locations. A gravel pit and train loading facility in Lyons, Colorado, were used full-time in the 1970's to haul gravel to an asphalt mixing plant near Clear Creek at Pecos Street. Economics in freight weights changed over the years so that other resources closer to Denver, such as Golden, were used instead and the train operation ceased. Today, it could be economically feasible to haul the Lyons gravel to Denver except for a catch—the new permit allows three unit trains per day; however, the hours of operation don't allow enough time to fill the trains. The residents of the rural area object to expanding the hours of operation.

Agriculture

Another historical land use along Clear Creek is agriculture and the man-made ditches that modify the landscape. Drainage ditches are a conspicuous cultural feature of the landscape. Many think of farmlands as natural landscapes, yet agrarian lands were not part of the original ecosystem (fig. 11, sheet 1). The waters of Clear Creek were diverted for irrigation as long ago as 1859 to grow wheat, corn, barley, and potatoes as food for miners (fig. 12). Eventually, vegetables and small fruit replaced wheat farming along Clear Creek. Clear Creek Valley acquired a reputation as one of the finest truck-gardening areas in Colorado. The agricultural land use again followed the grid.

One of the first post-industrial irrigated farms in Colorado is credited to a ditch built by David Wall along the north side of Clear Creek in 1859. Wall irrigated 2 acres opposite present-day Golden (Dark, 1939). According to Dark, four irrigation ditches (the Wanamaker, Swadley, Wadsworth, and Farmers High Line) were dug by 1861 and all the best ranches on Clear Creek and Ralston Creek were used for crops. The 1870's and 1880's saw the building of corporate ditches and canals on a large scale throughout the area; practically all of the available water was appropriated.

The permitting and diversion of water from Clear Creek without regard to prior ownership of land along the stream followed the Doctrine of Prior Appropriation in 1876—the first users were endowed with permanent rights to the water so long as they needed it and used it beneficially (Abbott, 1976). In simple words—first come, first served. Water rights are property rights to be bought and sold, with the State Constitution recognizing a preference of water uses (in the order of domestic, agricultural, and industrial). Yet, there is no ownership registry for water rights in the State; one must research the deeds at the county clerk's office (Colorado State University, 2000a). Farmers with water rights formed reservoir and irrigation companies, and some of these later were sold to municipalities in the late 1970's.

Despite the State increase in farmland through the 1950's (table 1), urbanization encroached upon cropland and grazing lands over the decades. A growth-control bill that would have provided funds to purchase open-space land with historic or archaeological importance and agricultural lands died in the Colorado Senate Agricultural Committee January 2000 (Sanko, 2000). Critics warned that suburban sprawl would just leapfrog around the preserved land and housing costs would escalate. County open-space plans advocate conserving such environmental resources through private land trusts, county actions (such as a County Right-to-Farm ordinance), the State Land Board, and State Division of Wildlife. There are advantages to maintaining farms and open space. For example, the planning department in Duchess County, New York, found that farms and other types of open space could actually subsidize local government by generating more in property taxes than the demand for services (National Park Service, 1995).

Population Growth

As late as 1820, only 7 percent of the United States population lived in cities and towns (Whitney, 1994). Three-quarters of Americans live in metropolitan areas today. Colorado is no exception in this trend. Beginning in 1860, the number of people in the Colorado territory grew over 30 years from a population of about 40,000 to approximately 400,000. By 1980, 1.35 million people were living inside the Denver urbanized area (U.S. Bureau of the Census, 1984). The spiraling Denver metro-area population is predicted to hit 3.2 million in 2020 (Myers, 1999). Table 2 and figure 13 (map sheet 1) illustrate the extensive growth impacting the lower Clear Creek valley. The area includes parts of the incorporated cities of Arvada, Commerce City (formerly known as Derby), Denver, Golden, Lakewood, Thornton, Westminster, and Wheat Ridge.

The settlement of Denver metropolitan cities has progressed outward from the South Platte River in a patchwork pattern covering aggregate resources and agricultural land alike. Views within the corridor (inside the flood plain looking out) range from limited, because of the low relief and vegetation, to spacious; views from the surrounding bluffs (outside looking into the flood plain) reveal the extent of urbanization (fig. 14).

Denver's economy is mostly related to manufacturing, government, and trade-service industries. Along the South Platte River downstream (north) from Denver, the economy is based on agriculture, livestock production, and energy (oil and gas) and aggregate extraction.

The Denver Regional Council of Governments has adopted a plan to limit growth to about a 700-square-mile area, but the regional body has no authority to implement its planning proposals. Most cities and counties have master plans that can be altered by officials. With changing public values and increased demands on limited resources, new laws may be enacted for cities and counties to jointly manage controversial growth. And as cities grow, they require extensive natural resources. Regardless, municipal infrastructure (including streets, curbs, bridges, storm-water and sewer systems) requires periodic maintenance and, thus, construction materials. The urban built area covered approximately 2 percent of the quality aggregate reserve in 1901. By 1990, urbanization expanded to cover 31 percent.

Noel and others (1994, p. 1) made the following statement about Colorado: "* * * the landscape remains more striking than the built environment. The land, not the people, predominates." How much longer will we recognize the natural land? Population growth is a fundamental driving force impacting the landscape and is fueled by immigration from other States. Environmental groups target urban sprawl and land-use planning as major problems for Colorado (Morson, 1999). The value of Colorado construction contracts increased from $3.2 million in 1990 to $6.5 million in 1997 (U.S. Bureau of the Census, 1998). Our culture, in combination with the physical environment, creates the urban landscape. The development of new and improved social services and manmade structures require construction materials; aggregate mining reflects that movement.

The majority of everyday human experience in urban landscapes is a culturally made one—consisting of small green spaces, human dwellings, commercial areas, transmission lines, and roads—artificial, linear, and hard edged, much as the grid pattern preordained. Farms and mines tend to have hard edges just as cities do in relationship to the environment because of section land boundaries. The shape tends to separate nature from urban settlement. Many landscape architects, planners, naturalists, and philosophers acknowledge the need for a careful mesh of the natural and human-built landscape (Simonds, 1983; Bell, 1999), but an increasing number of people swell cities and create conflict over land use. Large patches of native ecosystems are usually fragmented by human settlement and land planning decisions are usually based upon law, not ecology.

Landscape as Environment: An Ecological Perspective

A history of man and the land can never ignore its human dimensions without peril, and, ironically the chief obstacle to an environmentally informed history may now reside less in an ignorance of the natural world than in an ignorance of the nature of past human endeavors. (Cooter, 1978, p. 476.)

Stream Flow

Nearly three-fourths of the water running in Clear Creek comes from melting snow and only one-fourth of the flow results from rainfall runoff (Clear Creek Watershed Improvement Initiative (WIN), 1995). High flows typically occur in June and low flows are from January through March. Since peak municipal water demands are in July and August and there is insufficient water flow during that time, water supplies must be collected and stored. Regionally, surface waters supply 82 percent of water used daily in Colorado, while the remainder comes from ground-water aquifers (Helphand, 1991). The Clear Creek Watershed follows this pattern with surface waters providing 78 percent of fresh-water usage.

The average annual stream flow in Clear Creek at the west edge of Golden is about 160,000 acre-feet. Figure 15 shows the annual variability in stream flow over a 90-year study period. Total annual flows range from 66,630 acre-feet in 1954 to 306,000 acre-feet in 1914. The natural flow at this gauging station is affected by minor transmountain diversions from the Colorado River basin through Berthoud Pass ditch, several small reservoirs upstream from the station, and diversions for irrigation of about 5,200 acre-feet by the Welch and Church ditches (U.S. Geological Survey, 1999a). The long-term trend (based on figure 15) indicates a decrease in the amount of water available at Golden.

Typically, less than half of the water passing through Golden actually flows into the South Platte River, making Clear Creek among the most intensively managed streams in the country (Clear Creek WIN, 1995). This situation can be a concern because withdrawals of large amounts of water can result in less water to dilute stream pollutants in the lower reaches of the creek. According to the EPA (2000a), over 85 percent of the Clear Creek Watershed water is used as a drinking water supply for the metro area. From figure 16, the average amount of water withdrawn between Golden and Derby Gaging Stations is 87,300 acre-feet per water year.

The EPA (2000b) has assigned an overall index score (called the Index of Watershed Indicators—IWI) of 3 for the Clear Creek Watershed. On a scale of 1 to 6, the Clear Creek IWI score indicates less serious water quality problems and low vulnerability to stressors such as pollutant loadings. For comparison, the downstream Middle South Platte-Cherry Creek Watershed has an overall IWI score of 1 (better quality and low vulnerability). Metal loadings from active and inactive gold and silver mining sites and erosion caused by construction for growth in the mountains upstream from Golden are a major environmental concern for the Clear Creek corridor (EPA, 2000a). More than fifty percent of observations for ambient water quality data (toxic pollutants: copper, nickel, chromium, and zinc) exceeded selected reference levels for the years 1980 to 1990 (EPA, 1999). Conventional pollutants exceeded reference levels for 7 and 19 percent of the observations for ammonia and phosphorus, respectively (years 1990–1996). Water quality problems are usually minimal with sand and gravel operations because "* * * chemical characteristics of process waters are little altered by mining * * *" (Herricks, 1982, p. 202). According to the EPA (2000a), other environmental problems associated with Clear Creek include:

(1) Highway construction and maintenance runoff and spills to the creek from highway accidents

(2) Urban development and runoff

(3) Hydrologic modification—moderate volumes of impounded water

(4) Nutrient pollution from septic tanks and municipal point sources

(5) Industrial discharges

(6) Leaking underground storage tanks

What is evident from historical and contemporary photographs is the dramatic change in channel morphology and use of the flood plain and terrace over the past century (see fig. 17). Straight, built drainage and transportation lines replaced the sinuosity and natural meandering lines of the Clear Creek landscape.

Prairie Vegetation

Fire, droughts, and a variety of herbivores disturbed the pre-settlement grassland prairie. Without prior monitoring and inventories it is difficult to determine precise changes in the Clear Creek native vegetation over the last two centuries. There are no undisturbed riparian zones remaining in the Colorado Piedmont (Jonathan Friedman, oral commun., 2000). The upper reaches of Clear Creek west of Golden have been studied more than the downstream plains segment and there is some debate as to what type of grassland occupied the Clear Creek flood plain. Original pristine areas of vegetation along Clear Creek may have been comparable to regions along South Boulder Creek, the higher moisture remnant areas of Rocky Flats, or the Arikaree River Ranch Preserve (south of Wray). Most of the area had been transformed by the turn of the 20th century; Department of Agriculture aerial photographs show extensive farming and irrigation systems already in place by 1937. Whitney (1994) summarized the degradation of North America's mid-latitude grasslands as plowed out, grazed out, and mown out.

The limited deciduous tree canopy along Clear Creek now includes many non-native species. The natural vegetation was cleared and all but eliminated by agriculture and grazing. Stream terraces (a landform), stringers of trees or shrubs, and water reservoirs presently characterize the course of the Clear Creek flood plain. The stream contributes small areas of greenness (riparian zones) to a semi-arid landscape of dominantly tans and browns. In 1999, the EPA considered the Clear Creek Watershed to have experienced a moderate level of wetland loss since 1870.

Riparian areas, as mapped by the Colorado Division of Wildlife, "are those plant communities adjacent to and affected by surface or ground water of perennial or ephemeral water bodies such as rivers, streams, lakes, ponds, playas, or drainage ways" (State of Colorado, 2000, p. 2), and are shown on fig. 18 (map sheet 1).

> *Approximately 75% of the wildlife species known or likely to occur in Colorado are dependent on riparian areas during all or a portion of their life cycle. This is especially significant when we realize that riparian areas make up less than 1% of the landmass in Colorado. (State of Colorado, 2000, p. 1.)*

Only relics of tallgrass prairie remain in select moist areas and foothills along Clear Creek. The Clear Creek channel and flood plain probably would have contained many species common to midgrass prairie/riparian zones; shortgrass prairie would be spread throughout the valley floor (Jonathan Friedman, oral commun., 2000). Friedman comments that the region around lower Clear Creek cannot be historically termed a tallgrass prairie because the soil is not well developed due to blowing wind and a migrating stream channel. But the wet areas might have supported some prairie cordgrass (*Spartina pectinata*), and were probably dominated by switchgrass (*Panicum virgatum*) and Canada wild rye (*Elymus Canadensis*). Little bluestem (*Schizachyrium scoparium*) might have been found on gravelly slopes and heavier soils where moisture collects. Dry areas, except for very rocky soils, might have contained some shortgrasses: blue grama (*Bouteloua* gracilis), buffalo grass (*Buchloë dactyloides*), and western wheatgrass (*Agropyron smithii*). Examples of shortgrass prairie can be found in the Pawnee and Comanche National Grasslands of Colorado.

Scattered communities of peach leaf willow (*Salix amygdaloides*) and cottonwood (*Populus* spp.) most likely increased into small forests only with human settlement. The woody vegetation along the banks was important for humans (fig. 19). Native American people fed cottonwood bark to their horses over winter while early settlers collected wood for cooking fuel. In the early 1880's a resident of Wheat Ridge described the area:

> *People had places at least a half-mile square and knew their neighbors for miles in every*

*direction. Indians rode trails through their homesteads * * * The land had never been plowed and was covered with a fine short growth known as buffalo grass * * * but native birds were much more plentiful—quail, mockingbirds, orioles, bobolinks, lark canaries, humming birds and others. Blackbirds flew in flocks of thousands and would settle in cottonwood trees and all sing at the same time. (Jefferson County Historical Commission, 1985.)*

Species such as Prairie Gentian (*Eustoma exaltatum*) and Ute Ladies' Tresses orchid (*Spiranthes diluvialis*) are becoming rare. The orchid is listed as threatened by the U.S. Fish and Wildlife Service with only 6–20 occurrences in the State and globally (Colorado Rare Plant Technical Committee, 1999). The plant occurs in a Wheat Ridge greenbelt along Clear Creek where topsoil was previously scraped and stocked during an active sand and gravel operation. The hummocky area is subirrigated and provides saturated soil for the imperiled rare plant. Today, the Clear Creek corridor has patches of rare ecological value from reclaimed mine sites in this generally arid landscape: woodlands, wetlands, and surface water associated with flood plains (fig. 20, sheet 1).

The city of Wheat Ridge has funded the Wheat Ridge Open Space Biological Inventory. A survey for elements of biodiversity, including rare species and noxious weeds, began in 2000. A vegetative map was prepared listing plant communities through the city's Clear Creek conservation areas and the results published in 2001. For further information, please contact David Anderson of the Colorado Natural Heritage Program at:

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254 General Services Building
Fort Collins, CO 80523

Fish and Birds

The Colorado Division of Wildlife has conducted fish sampling of Clear Creek since 1980. There are no known significant wildlife studies of the area prior to that, and grassland invertebrates are poorly studied. One can historically assume that if the creek bed had been a constantly moving channel, with few permanent pools, then the fish compliment would have been limited.

A fish sampling of Clear Creek at Broadway, conducted in the early 1990's, found a tremendous variety of fish (15 different species) for such a small creek (Dave Nesler, oral commun., 2000). Nesler, with the Colorado Division of Wildlife, reports more introduced game fish than natives in Clear Creek. Bass and yellow perch (*Perca flavescens*—a warm water sport fish) escape from nearby ponds into the creek, competing with native green sunfish (*Lepomis cyanellus*) and orangespotted sunfish (*Lepomis humilis*). The sunfish prefers spawning nests over sand and gravel substrates. Nesler also states the Iowa darter (*Etheostoma exile*), a species considered at risk by the State, is located in two important areas locally: Well Borne Pond, near the confluence of Clear Creek with the South Platte River, and further west along Ralston Creek, a tributary of Clear Creek.

The Colorado Division of Wildlife lists 26 native species in danger of disappearing from Colorado's mountains, prairies, and wetlands (State of Colorado, 1996). Some of these species inhabit this study area. The reduction in shortgrass prairie habitat has led to the largest proportions and steepest population declines of any bird guild (species having similar ecological niches) in North America (Adams County, 1998a). Colorado's endangered species include the plains sharp-tailed grouse (*Tympanuchus phasianellus*) and whooping crane (*Grus Americana*). Threatened species include the bald eagle (*Haliaeetus leucocephalus*) and piping Plover (*Charadrius melodus*). On occasion, bald eagles can be seen at Clear Creek today, attracted to former gravel pits stocked with fish. A one-year study of 15 water-filled gravel pits near Ft. Collins, Colorado, revealed that they were used by a large variety of ducks, both dabblers and divers (Swanson, 1982).

Mammals

The grassy ecoregion in Colorado supported great herds of buffalo (*Bison bison*), and extensive prairie dog colonies provided prey for bald eagles and coyotes. The landscape along Clear Creek probably included buffalo wallows (Jonathan Friedman, oral commun., 2000) and trampled vegetation from the herds of buffalo. Bison wallows are depressions ranging from 10 to 16 feet deep and as much as 150 feet in diameter and might persist for decades after abandonment. The buffalo were virtually hunted out by the early 1870's. Beavers (*Castor Canadensis*) would have provided another major effect on the landscape. They constructed large numbers of dams on small, low gradient streams (Whitney, 1994). The beavers were trapped almost to extinction for the fashion of tall hats in big cities.

Gerhardt (2000a) reports "the number of prairie dogs on the Great Plains is down 98 percent from 100 years ago due to agriculture, development and other human activities" and Federal wildlife officials believe the black-tailed prairie dog (*Cynomys ludovicianus)* should be listed as a threatened species. The habitat most suitable for prairie dogs presently corresponds with the area surrounding cities that is shifting from agriculture to housing. Larger predators, such as gray wolf (*Canus lupus*), grizzly bear (*Ursus arctos*), and mountain lion (*Puma concolor*) were once common in the area.

One species designated as threatened under the Federal Endangered Species Act is the Preble's Meadow Jumping Mouse (*Zapus hudsonius preblei*). The rodent resides in moist lowlands of dense vegetation along the Colorado Front Range. The mouse needs willow and tall grass. However, it is unknown if the mouse occurs along Clear Creek; they probably do not do well along urban streams (Dave Webber, oral commun., 2000). A different compliment of wildlife resided along Clear Creek prior to permanent settlement. Today, riparian mammals include raccoons and deer that have adapted to a certain amount of habitat fragmentation and conversion.

Resource Use and Land Conservation

Extracting sand and gravel from riparian zones may cause environmental problems, but may also be accomplished without significant long-term damage if properly reclaimed. Matter and Mannan (1988, p. 7–8) wrote "Sand and gravel removal should be avoided within riparian zones because riparian areas are of high ecologic, economic, and aesthetic value and are becoming increasingly rare * * *." They also state, "Disturbed land can be reclaimed to provide fish and wildlife habitat if water is present." (Matter and Mannan, 1988, p. 1.) Potential problems due to sand and gravel extraction within riparian zones include (1) sedimentation, (2) changes in channel hydrology may significantly impact fish populations, (3) community types are in a relatively restricted riparian zone, and (4) a higher percentage of riparian species are less stress tolerant than upland species (Johnson, 1987). According to Batt (1996) prairie wetlands are generally fully restorable in form and function if the hydrological regime that created them in the first place is restored.

Industry and land planners can work to reclaim exhausted pits for open space and regeneration of local flora and fauna. The collaborative programs are important for biodiversity and human experience, and have produced exceptional results along parts of Clear Creek. Gravel pits in riparian zones offer three advantages in reclamation versus upland gravel sites: (1) species are generally adapted to a high degree of disturbance, including flooding and erosion, (2) they have a high proportion of early successional communities (including numerous ruderals with high seed output), and (3) ease of native plant re-introduction with re-invasion (Johnson, 1987). Roelle and Gladwin (1999) reported great success in the natural establishment of native woody riparian species in a former gravel pit near Fort Collins, Colo.

A possible model for reclamation of gravel pits along Clear Creek is the Cooley Gravel Co. project at South Platte Park. Located in Littleton, northwest of the intersection at Mineral Avenue and Santa Fe Drive, the 650 acre wildlife park contains well-designed natural areas reclaimed from aggregate mining (fig. 21). Resource use and future conservation is also forecast for a 17-mile section of the South Platte River northeast of Denver. The land is a mix of farms and mine pits that will be preserved for wildlife, including wild turkeys. There, most landowners and aggregate companies support the plan (Scanlon, 2000).

Landscape as Natural Resource: Economic Considerations

> *As prehistoric tribes settled into stationary communities, their numbers reshaped the land around them to meet their immediate needs and to make their lives more productive. The persistent demand for potable water prompted many settlers to establish their villages near rivers * * * the first thing they want to do is to divert its water to irrigate their cropland or to control its flow so that it doesn't wash away their homes. To achieve these water-management aims, settlers readily reconfigure the surface of the earth to construct irrigation canals, cisterns, reservoirs, dikes, and dams. * * * When prehistoric tillers of the soil achieved an agricultural surplus that exceeded their domestic needs, they were ready to trade. Commerce led in turn to travel, which necessitated transportation routes. By the third millennium B.C., resourceful individuals, recognizing that one of the most efficient ways to move people and goods from one place to another is to gouge out the earth between two bodies of water, developed navigable canals. To facilitate overland transportation, early engineers constructed roads, tunnels, and causeways. Through trade, markets were created for valuable materials that were mined from the earth, such as flint, copper, gold, and diamonds. (Bourdon, 1995, p. 53.)*

The U.S. Geological Survey (2001) reported Colorado produced 46.9 million metric tons of aggregate valued at $230 million, ranking 7th nationally in quantity for construction sand and gravel. By 1996, the Front Range counties sold or used approximately 34 percent of Colorado production due to the proximity of high-density urban areas where demand for construction material is great. The landscape, not unexpectedly, reflects that production. Modification of the landscape occurs due to aggregate mining and reclamation, as well as by the construction of roads and other infrastructure made with aggregate products. Table 3 shows the increase in United States and Colorado value of sand and gravel as related to new construction for the Nation.

Aggregate Heritage

Urban development and transportation are dependent upon the mining of stone and sand and gravel. In 1957, the Colorado Sand and Gravel Producers Association produced an air photomap to call attention to the diminishing availability of sand and gravel resources in the Denver area. The Colorado Geological Survey reported more than twenty years ago that all of the Front Range counties were loosing aggregate resources to urbanization (Schwochow and others, 1974a). To prevent further construction shortages, the State adopted a mineral resources policy in 1973, House Bill 1529, that considers commercial mineral deposits (meaning limestone, coal, sand, gravel, and quarry aggregate) essential to the economy and encourages resource conservation plans. The intent of the Colorado law was to preclude other land use (except agriculture) until the mineral had been extracted. The bill carried no penalties for noncompliance.

Reconnaissance maps of the Colorado Front Range, including the Clear Creek valley, show location and quality of natural aggregate at 1:500,000 scale (Langer and others, 1997) and 1:24,000 scale (Schwochow and others, 1974b). However, inventory maps do not, by themselves, protect a resource, aggregate, or flora. In 1935, Denver County supplied nearly 90 percent of the area's sand and gravel requirements (Adams County, 1983). By 1955, Denver County production had dropped to zero. Mining along Clear Creek occupied 846 acres in 1990 (table 4). By 2001, mining in the Clear Creek valley had virtually ceased. The last large gravel reserve in the Denver area extends from the confluence of Clear Creek with the South Platte River to 144th Avenue about 11 miles northeast along the Platte (in Adams County) (Schwochow, 1980). This gravel reserve was recognized by the Colorado Geological Survey and industry to be of strategic importance in the 1970's.

The valley below the mouth of Clear Creek continues to be mined and reclaimed for water reservoirs. Adams County Open Space Plan and the South Platte River Heritage Plan emphasize conservation areas, regional parks, trail connections, and multiple-use water storage facilities through the South Platte River corridor (Adams County, 1998a, 1998b). Reclamation of gravel mining areas is a crucial part of that plan development, with a key objective to demonstrate the potential for multi-purpose gravel mine restoration (Adams County, 1998b). Adams County itself is projected to realize the greatest proportion of population growth for the metro area over the next twenty years. This growth will contribute to the already existing pressure on the available aggregate resources.

Property rights, zoning policies, and open-space legislation may be at odds in determining land use. Environmentalists and business people may not be able to compromise if their perspective on environmental protection is "all or nothing." The middle course between extreme development and no growth does not come with easy decisions. Many interests compete for various phases of land use, resulting in a continued need for more scientific information and thoughtfulness. Mining (along with wetlands) occupies one of the smallest amounts of the major land uses in the study area (table 4). Only approximately 19 percent of the best quality surficial gravel deposits were mined in the Clear Creek aggregate reserve study area from the 1920's to the 1990's. The data presented are estimates only, affected by varying degrees of under enumeration and by changes in definition. Agricultural land and urban areas varied in definition from earlier censuses to later censuses

Urban growth impinges on agricultural and mining land. But it is the social changes associated with population growth that place difficult demands upon the State's natural resources. For example, a gravel pit opened on a relatively flat land surface (flood plain) and with a lack of surrounding vegetation will be visible despite the fact that the actual working surface is below the landscape horizon. Strategically placed berms and vegetation can lower the visual impact, but the exclusive use of land for mining and its subsequent conversion to some other use is where public issues often arise.

Water Heritage

Water shortages and severe flooding play a major role in the economic consideration of water and aggregate resources. The possibility of drought or flood shapes public policy as well as the landscape. Where floods impact urban or other built areas, public policy and opinion affect economic considerations and societal values. " 'That stream floods too often and it poses a danger to local inhabitants,' is a value judgment by someone about environmental performance. Similarly, an ordinance restricting development from wetlands reflects a societal value * * * " (Marsh, 1991, p. 126). Floods as far back as the 1880's, and the more recent 1965 and 1973 floods along the South Platte River and Clear Creek, washed buildings away, breached levees, and/or changed river channels. The Great Flood of 1896 is considered one of the worst natural disasters in Colorado history, twisting miles of railroad track up Clear Creek like pretzel dough (Gardner, 1996).

Early industry had little concern for preserving the landscape character of an area or conserving water resources. Over the past decades, the braided Clear Creek channel was confined and straightened to allow for the extraction of gravels and, presumably, to mitigate future flooding so that more of the flood plain could be used (fig. 22). McCain and Hotchkiss (1975) mapped the 100-year flood-prone areas for the greater Denver area, but residential building continues there even today.

Urbanization is the most significant land-use change that can occur within a watershed, and it can impact its hydrology (Riley, 1998). During urbanization, stream channels are incised or deepened, lateral movements contained, culverts installed, and land fill added to flood plains. According to Riley (1998, p.172):

> *Clear Creek * * * is a good example of the impacts a channel modification project can have on its tributaries. The degradation of the main channel of the [South Platte] river caused by channelization undermined the bridge abutments spanning the river; which are now being replaced at great cost. At the same time, the banks of the creek entering the river are collapsing because the creek channel bottom is dropping to conform to the gradient of the river it is entering. After the main channel has lowered its gradient, the tributary forms a "waterfall" where it joins the main channel, and the waterfall continues to advance up the tributary, progressively eroding the channel bed upstream.*

Vulnerability to urban runoff is high because 4.28 percent of the land area in the Clear Creek Watershed was above 25 percent imperviousness in 1990 (Environmental Protection Agency, 1999). Urbanization increases the amount of hard surface materials (roads, paved parking, roofs) covering the ground that, in turn, decreases infiltration of rainfall.

Water deficits are projected with declining water tables (Birdsall and Florin, 1985; Marsh, 1991; Frazier, 2000). Population growth has lead municipalities and private development interests to utilize exhausted sand and gravel pits for water reservoirs that are distinct and noticeable landforms (fig. 23, sheet 1). Reservoirs help water districts (1) store surface and shallow aquifer water and/or storm runoff that would normally flow back into creeks, (2) intercept treated wastewater return flows from metropolitan areas for augmentation and water exchanges, (3) regulate stream flows by storing excess water to be used in times of drought, (4) meet peak water supply demands, (5) avoid increased costs by buying junior water rights, and (6) control flooding. For reservoirs greater than 5,000 acre-feet, evaporation averaged 2.10 thousand acre-feet/year for the Clear

Creek watershed in 1990 (U.S. Geological Survey, 2000). There is a significant amount of additional evaporation if reservoirs less than 5,000 acre-feet (such as farm ponds, sedimentation ponds, and other types of industrial impoundments) are included (Russell Dash, oral commun., 2000).

Although irrigation percolation and wastewater effluent replaces some of the water used, there are more demands for the resource than can be met at times. The Colorado Water Rights Determination Act of 1969 requires augmentation plans to replace out-of-priority diversions of surface/alluvial water and protect the rights of senior (older) water users. (Alluvial water is from channel and shallow aquifer seepage collecting in natural reservoirs in the alluvial deposits.) Stream depletions by pumping water from wells in alluvium can occur long after pumping stops.

"Free river days," where senior water right calls are light, allows diversion of surface and alluvial water for storage. In average and wet runoff years, free river water is available from Clear Creek below the intake of Croke Canal, typically during the late fall through early spring. The number of free river days per year is highly variable, depending on runoff, and is generally ruled by the water right calls on the South Platte River. The fewest number of free river days occurred during the drought of 1977 when there was a call on the South Platte River every day of the year. More than 350 free river days occurred in 1983 when only a few calls were made in July. The highest probability for free river days is generally the first two weeks of June (Gray Samenfink, oral commun., 2001).

The trend in ground-water storage was impacted by the passage of Senate Bill 120 in 1989. After 1980, gravel pits in operation that exposed ground water to the atmosphere are required to replace all out-of-priority depletions of ground water (Colorado Senate, 1996). Most of the sand and gravel pits utilized for water storage along Clear Creek are for surface diversion, not as ground-water reservoirs. Surface waters in reservoirs are managed so they can only divert surface water on a priority basis, and such reservoirs must bypass an amount of natural-flow water to account for evaporative losses.

Landscape as Place: The Local History of Mining and Reclamation

> *The American West, we argue, is the archetypal case of an American region yanked from its historical and myth-based sense of place into hyper-development and plugged-in modernity. Such a transformation forces startling contrasts between image and reality, between old and new. The most obvious contrast runs between a "cowboy economy" built on extracting natural resources and the post-World War II cosmopolitan florescence that, by the 1990's, had thrown the region's economy into the postindustrial services sector. Traditional life ways—logging, mining, drilling, farming, and ranching—contrast sharply with the new economy of services and information, ostentatious wealth, and tourism. This shift shows on the land, empty, awesome natural spaces now overlain uncomfortably with a landscape of sprawling cities, greenlawn suburbs, and ranchette estates—conventional American society in an unconventional place. (Riebsame, 1997, p. 12.)*

Natural resources have always played an important role in the development of Colorado. In the urban Front Range region, the discovery, development, and production associated with mining is what led to the settlement of the State by non-native American people. Precious and base metals initially drew miners, but as the region developed, sand and gravel mining became increasingly important. High-quality deposits of sand and gravel are found beneath stream terraces and flood plains along Clear Creek and the South Platte River. Sand and gravel mining efforts focused there initially. Paradoxically, as the demand for quality aggregate increased, more resource areas became unavailable for production due to development.

Gold Mining

The occurrences and discovery of gold and the development of mining in Colorado are well documented; for example, Henderson (1926), Davis and Streufert (1990), and Parker (1992). In 1849, placer gold was found in small quantities in the gravels along Ralston Creek (about 1 mile above the junction with Clear Creek), leading to a small population explosion along the flood plain (Henderson, 1926) (fig. 24, sheet 1). Another source credits a party of Cherokee Indians, returning from California in 1852, with finding gold in the banks of Ralston Creek, near its confluence with Clear Creek (Dark, 1939). By 1858, the town of Arapahoe City (gone by 1873; Scott, 1999) arose at diggings on the south bank of Clear Creek 2–4 miles east of the gap between North Table Mountain and South Table Mountain (fig. 2). Pioneers continued to settle the area because of its proximity to the mining towns of Central City and Idaho Springs farther upstream. The gravels of Clear Creek, from the mouth of the canyon in Golden downstream to the South Platte River, were worked again for gold in the 1890's and early depression years (fig. 25). A later attempt to mine the gravels in 1904 and 1905 with dredges failed because of boulders too big to move (fig. 26, sheet 1).

Cooley Gravel Co. was considered unique for combining the production of commercial aggregate with gold dredging in the Clear Creek Valley in the 1950's (Lenhart, 1953). According to Dark (1939, p. vii), "Although many people have washed gold from the sands of Clear Creek, no one has ever earned more than fair wages from the enterprise" in the valley. The precious metal was a by-product for a few sand and gravel plants and is still recovered along Clear Creek by hobbyists. While the exploration of metals lead to the Colorado Territory, it is the nonmetals that sustained the growth of the State. Where stream sand and gravel was once panned for gold, the aggregate resource eventually became a more valuable commodity (fig. 27).

Coal and Construction Material Mining

Coal was mined in Jefferson County for domestic use for about ten years. In 1880, three mines operated nearly within the city limits of Golden (Dark, 1939). The White Ash Mine tragedy in 1889 buried ten miners when water from Clear Creek filled the tunnels they were working in. The disaster marked the end of coal mining for the area.

Clay deposits, located next to the coal on both sides of Clear Creek, were an important economic resource. The clay is considered to be of excellent quality: it fires at a high temperature (2100°F) compared to other clays (1700°F), has a wide vitrification zone, and can be used as a base for any other color (Scott, 1990).

As early as 1867, workers produced dimension stone from a quarry near Morrison; the basaltic caprock of South Table Mountain in Golden was quarried in 1905 (fig. 28) (Murphy, 1995). By the 1870's, a firebrick and drain-tile factory (the establishment also produced sewer pipes and pavement tiles) and a pottery were located in Golden (Dark, 1939). The firebrick and facing brick was used in factories, kilns, home building, and distilleries (fig. 29, sheet 1). Denver Brick was established in 1860, Brannan Sand and Gravel in 1900 (Noel and others, 1994). By 1890, stone was laid in lime mortar of Portland cement imported from Germany due to the reliability and uniformity of the German product (Baker, 1927). Concrete replaced stone foundations, walls, and sidewalks, and asphalt supplanted paving stone on streets by the 1900's (Murphy, 1995).

Colorado did not regulate non-coal surface mining and reclamation until 1973. Construction material rules and regulations of the Colorado Mined Land Reclamation Board became effective in 1996. There are no comprehensive compilations of mining reclamation in the State, but examples can be gleaned from the literature. Some of Denver's most valuable real estate has a history of being used as agricultural land, then excavated for clay or sand and gravel, back filled with refuse, and then zoned industrial (Hansen, 1975). The site of the Denver Coliseum and adjacent parking areas was a sand-and-gravel pit prior to being used for waste-disposal in the late 1950's (Hilpman, 1969). Ruby Hill, the site of a former clay pit, was used for sanitary fill, and now is a public park, popular for winter sledding. The Colorado School of Mines used abandoned clay pits for student housing apartments. The students use to celebrate football touchdowns with a stick of dynamite tossed over a shoulder into the clay pit along Brooks Field in the 1940's (Scott, 1990). Mile High Stadium and Cherry Creek Shopping Center were built on refilled gravel pits.

Many landfills were created from exhausted mine sites in the past. However, using exhausted sand and gravel pits for sanitary landfills can present a few problems. The permeability rates are high for gravel, and waste disposal can lead to problems with ground-water contamination. Seals can be created out of vinyl or clay to contain any leachate, but sites can subside as the waste slowly decomposes. The State of Colorado closely regulates such land use today.

Aggregate Mining

After World War II, aggregate production and home building increased rapidly. The gravel along Clear Creek is of exceptional quality and produces high-grade concrete, rock, and sand (Schwochow and others, 1974a). Less than half of the original deposits along Clear Creek have been mined for sand and gravel, while the rest has been lost to suburban, commercial, and industrial growth (Schwochow and others, 1974a). In Arvada and Wheat Ridge alone, more than 2,000 acres of flood-plain gravel deposits were lost due to suburban expansion (Schwochow and others, 1974a). An area along Clear Creek from approximately Tabor Street to Harlan Street appears to have been mostly preempted from aggregate mining due to residential expansion.

The potential sources of relatively clean and sound gravel (for concrete aggregate) and locations of known industrial mineral mines, past and present, along the Clear Creek and South Platte River corridor are plotted on figure 30, map sheet 1. Approximately 3,360 surface acres of historical gravel mining operations have been identified in the Clear Creek flood plain and stream terrace deposits. Determining the exact location of early crushed-rock quarries and clay or sand and gravel pits can be difficult. A precise, accurate inventory of surface mining prior to 1972 does not exist and the location or exact amount of acreage that has been disturbed is unknown (Rold, 1977). Only with the establishment of the Mined Land Reclamation Board in 1972 did historical mining data for Clear Creek become more accessible. The 1937 USGS 7.5-minute series (topographic) maps do not show mine sites along Clear Creek as later editions do. A literature search may describe a mine as a point location, for example: "1 mi. southwest of Arvada" or "South Table Mt." (Argall, 1949) or at best list range, township, and section. On map sheet 1, symbols (circle, triangle, and square) are used to designate uncertain site size or location.

Site Analyses of Selected Sand and Gravel Locations

Sheridan reported the effects of urbanization, multiple use, and selected sand and gravel resource locations in the flood-plain areas of metropolitan Denver in 1967. Existing use and potential development were also reported (Sheridan, 1967). The three major land uses in the Clear Creek corridor—industrial, residential, and recreation—define areas; and the Creek itself serves as a community buffer—snippets of "natural" land separating urban areas. However, the land lacks integration and linkage (other than by highway) with the lands north and south of the creek.

Five of Sheridan's sites along Clear Creek were revisited in 2000 to document changes in the initial or proposed use of local mineral lands and to permit a view of the micro landscape. A photographic inventory was collected and scenery elements, such as prospect-refuge, form, line, color, or texture, were recorded. The planning, and changes in plans, at a site-specific scale often result in an unpredictable end use over time, different from the original conception. In addition to Sheridan's five sites, one additional site was examined along eastern Clear Creek near its confluence with the South Platte River to identify temporal shifts in mining activity (see map sheet 2 for site locations).

Taken as a whole, the pits produced by sand and gravel extraction are widely assumed to become eyesores and symbolize waste for many people. "However, without specific detailed knowledge or careful historic research, few people can detect the presence of the equally numerous reclaimed gravel pits throughout the state" (Rold, 1977, p. 72). Four models of landforms and uses are associated with mining reclamation in the metropolitan area (1) water storage for large suburban areas, (2) wildlife/greenbelt space, (3) multiple-use lakes (for example fishing, water skiing, and native habitat), and (4) "hidden scenery." The latter involves in-filling pits and quarries (with earth backfill, concrete rubble, or sanitary landfill) and covering the sites with light industrial, residential housing, simple revegetation, etc. This "hidden" landform is hard to detect; it becomes difficult to recognize as a past mine site. For this report, figure 31 (sheet 1) incorporates and distills the various end uses of gravel pits, turning the Clear Creek corridor into a series of four symbolic landforms.

Tolkien (from *The Hobbit*, 1994, p. 11) described a hole in the ground as refuge and comfort, "not a nasty, dirty, wet hole, filled with the ends of worms and an oozy smell, nor yet a dry, bare, sandy hole with nothing in it to sit down on or to eat * * *." Our visual pictures of sand and gravel pits may conjure up similar symbolism, but our perception of these environments changes with experience and knowledge or ethical beliefs. Most of these landscapes are viewed from roads that pass the sites. Parking the car and walking the sites, close up, opens new ways of viewing these environments. What has happened is the use of a resource by society and subsequent creation of four distinctive landforms clustered along Clear Creek.

Site 1, the westernmost site, is a highly visible, simple, and planar terrain at Clear Creek and McIntyre Street (figs. 32 and 33, sheet 2). The site is referred to as a prospect-dominant landscape because the observer has an unimpeded opportunity to see the environment. By contrast, a refuge landscape is one where the individual has an opportunity to hide (Appleton, 1996). The visual scale of the main reservoir (Coors Lake B–4) appears smaller than what it really is. Not unexpectedly, rectilinear-shaped ponds do not fair well esthetically relative to other possible designs (Chenoweth and others, 1982). The space shares a common philosophical style with Andre Le Nôtre, the designer of 17th century Versailles. Both site 1 and the great French design have nature conforming to man, unite sky and surroundings with water reflection, reveal the whole project at one glance, align geometrically along an axis, and are designed on a vast scale in relation to the historic surroundings (Jellicoe, 1987).

With little relief and shadow from linear vertical elements, the wind and sun are experienced in their basic form throughout this space. Rabbitbrush (*Chrysothamnus nauseosus*) and non-native Russian olive (*Elaeagnus angustifolia*) provide texture along the channelized (straightened) creek itself and along the south rim of Coors Lake B–4. In the semi-arid climate of north-central Colorado, the grassland often crunches underfoot. Rail lines and roadways are in parallel proximity (fig. 34, sheet 2). Adolph Coors Brewing Co. (owner of the property) shifted the course of Clear Creek northward, adjacent to the transportation lines, in order to extract more gravel and yield more water storage space.

Today, most of the exhausted pits form a strictly utilitarian, hard-edge boundary zone of man-made reservoirs with land carpeted by low vegetation and having a distinct memory of prior land use from aggregate mining (fig. 35). Coors Lake B–4 and the adjacent Coors Lake B–3 are used for process water by the brewery. These reclaimed pits are the first clay-lined reservoirs used by industry in the State (constructed in the 1970's). The "A water" lakes, north of Applewood Golf Course, are not lined and supply the "Rocky Mountain spring water" used in producing Coors beer. The high-quality gravels underlying the golf course, formally the Rolling Hills Country Club, were never extracted.

The old gravel pits played an important role in water rights on Clear Creek. In 1987, a water agreement (known as the "Cosmic Agreement") ended years of negotiations and resulted in Coors Brewery no longer discharging effluent from their wastewater facility above Croke Canal. The cities of Westminster, Thornton, and Northglenn, along with the Farmers Reservoir and Irrigation Company, had concerns about the quality of the water that flowed into Standley Lake (the cities' main drinking water supply) by way of the canal. The agreement included: (1) moving the Golden discharge plant below the intake of Croke Canal, (2) Golden, Westminster, and Coors will compensate Thornton for the necessary water storage to accomplish an annual water exchange to guarantee that historic water deliveries from the Croke Canal are not diminished in the future, and (3) formally recognizing Golden's water rights in Clear Creek (Jeffco Publishing, 1987).

Sheridan (1967) states that housing in the north-central part of the site prevented extraction of the underlying gravel, and residents blocked expansion of nearby operations. Economically, this area produced some of the most desirable aggregate in the State, providing high royalties. Prior to that, gold was dredged from the stream bed. How many people who drive Colorado Highway 58 realize the multiple, distinctive past land uses of the site or participate in this unique landscape experience? Roadside viewpoints, turn-off parking, and signage describing the fascinating history of the site (including a former leather tannery) could be used to establish educational points of interest for local residents, as well as the thousands of tourists that pass through the area every year.

Two former aggregate mine sites just outside the area of site 1 are noteworthy. A Mobile Premix gravel pit west of Site 1, next to Coors Lake B–6, was backfilled and is now a technical center. North of Site 1, Fairmont Reservoir was the first sand and gravel pit in the State that was dammed for water storage (completed 1992). The current owner, Consolidated Mutual Water Co., provides water to part of the City of Lakewood.

The value of exhausted sand and gravel pits to wildlife was recognized as early as 1931 in the United Kingdom (Swanson, 1982). Site 2 (fig. 36, sheet 2) illustrates a combination of wildlife/greenbelt and recreation landforms. In this example, development allows an opportunity for more ecologically attuned small-scale projects and intimate space.

In the 1960's, the Brannan Sand and Gravel Co. pit was projected to become either the recreational center for a future housing development or a water storage and retention reservoir for Arvada; instead, it became a State wetland park—Ward Road Ponds. Such public parklands provide glimpses of scenery and residual habitat, an approximation of wild nature usually not available in urban environments. The western entrance provides a thickly vegetated wall plane and descent to the water surface with a sense of mystery (fig. 37, sheet 2). Unfortunately, the "wild" screen effect and sense of enclosure is lost once one proceeds to the east because of the open view of Interstate 70. The landscape is divided into refuge or prospect-dominant halves. The eastern pond appears more despoiled and would improve in aesthetic appeal if there were less litter.

The wildlife theme continues to the south in the area of the former Lee Sand and Gravel Co. pit, reclaimed as an important stream, trail, and greenway corridor in the Wheat Ridge Greenbelt—named Prospect Park. The City of Wheat Ridge leases the property for a nominal $1.00 per year from Adolph Coors Brewing Company (which retains water rights). Prospect Park combines leisure activities, preservation of wildlife habitats, and positive aesthetic appearance. The landscape is well-balanced and complex because: (1) both prospect and refuge are provided, (2) there is a sense of depth from foreground, middle ground, and background vegetation, (3) there is moving water, and (4) there are high slopes in the foreground from the stream channel and terraces. The site has soft, curvilinear surface forms that fit our visual perception of "natural." In fact, the area is not pristine and is still undergoing efforts to eradicate troublesome weeds such as (Margaret Paget, oral commun., 2000):

- Diffuse and spotted knapweed (*Centaurea diffusa* and *Centaurea maculosa*)
- Canada and Musk thistle (*Cirsium arvense* and *Carduus nutans L.*)
- Leafy spurge (*Euphorbia esula L.*)
- Purple loosestrife (*Lythrum salicaria*)—a severe threat to waterfowl habitat
- Yellow toadflax (*Linaria vulgaris*)
- Common teasel (*Dipsacus fullonum L.*)

These exotics are frequently clustered around areas of native plants and require mechanical removal. They invade the habitat of native species and reduce ecological diversity (fig. 38).

Remnant species from agricultural days include: black walnut (*Juglans nigra*), brome (*Bromus* spp.—a grass that creates serious fire hazard when dry), and hay (including wheat and rye). Native milkweed (*Asclepias* spp.) and cattails (*Typha latifolia*) thrive in the wet mud around Bass Lake providing refuge elements around a prospect-oriented water surface. Layers of shrubs and trees, including three-leafed sumac (*Rus trilobata*) and mountain mahogany (*Cercocarpus montanus*), provide vertical backdrops and a series of enclosed spaces. Planted species are irrigated to establish root systems.

Urban trails contribute to an extensive greenway system that links nine cities and provides citizens relief from surrounding negative environmental impact. Red foxes, white tail deer, raccoons, and mountain lions are known to frequent the corridor. These animals once roamed the surrounding urban areas. More than 180 bird species have been recorded in the Wheat Ridge Greenbelt (Gray, 1992). Songbirds attracted to the riparian areas include warblers, grosbeaks, tanagers, flycatchers, and vireos (Gray, 1992).

Bowl-shaped lakes and open space connect via paths and trails for bikers, pedestrians, and equestrians. The lakes are stocked and have steep gravelly banks. The slope makes it hard for weed control, angler access, and establishing nearshore fish habitat (Margaret Paget, oral commun., 2000) (fig. 39). As abandoned gravel pits, the lake bottoms are relatively flat and featureless; an uneven, rolling bottom would probably have been better for species richness and diversity (Crawford and Rossiter, 1982). Prospect Lake is aerated because of water stagnation and algae-caused fish kills in the past. No swimming is allowed and non-motorized boating is by permit only. Although Tabor Lake is three-quarters lined with clay to prevent leakage, water levels fluctuate because it has no direct flow. Lining the bottom of basins with topsoil (placed on the layer of clay) would provide a more suitable substrate for aquatic vegetation and invertebrates (Crawford and Rossiter, 1982). Bass and West Lakes are connected with a drainage pipe, and a dam separates the latter from Clear Creek (fig. 40, sheet 2). West Lake bears the visible marks of concrete workings on the southwestern edge. Riffles (regions of shallow, rapid current) and thalwegs (lowest points of the channel) have been installed in the flowing creek and a few boaters take advantage of the high spring discharge in the creek. Vegetation along the creek helps slow the water velocity and stabilize banks.

Despite the abundance of water in this urban setting, the park does pose a risk of wildfire (Margaret Paget, oral commun., 2000). In dry years, a large amount of vegetation accumulates in the park below luxury homes. Unfortunately, the land still undergoes disturbance despite the cessation of mining many years ago. The prevailing wind is from the west and eats away at the eastern edge of Tabor Lake. Equestrians take shortcuts or avoid using the asphalt trail, trampling newly planted shrub borders. Geese eat new seedlings and intensive human use has inevitable impacts on the land.

The topographic map of the Golden quadrangle (U.S. Geological Survey, 1994c) shows a gravel pit south of Highway 58 and west of Youngfield Street. In 2000, the property appears to be inactive and unreclaimed; there is no apparent grading equipment or processing plant and some vegetation has been naturally reestablished (fig. 41, sheet 2). Adjacent to this property on the north, but south of Clear Creek, is a small, active operation owned by Jefferson County (fig. 42).

Reclaimed land north of Highway 58 (the Mount Olivet pit) is being developed for light industry because of ready access to Interstate 70. By 1965, the Youngfield Street frontage was being backfilled and graded by Lee Sand and Gravel Co. for future business or residential use. The secondary land use of this property now includes a small shopping center.

Matthew Sheridan (1967) reported three attempts to obtain sand and gravel permits along Clear Creek at West 44th Avenue in the 1940's (fig. 43, sheet 2). All requests were denied resulting in the loss of underlying aggregate reserve to a housing development. Agricultural land use of the 1930's mostly changed to residential by the 1960's.

Just southwest of the intersection of Clear Creek with West 44th Avenue is Anderson Park. The park contains a recreation center, playing fields, and greenbelt within the City of Wheat Ridge (fig. 44, sheet 2). The high-quality aggregate resources could have been extracted as an interim land use with establishment of the park afterwards, but residents resisted mining in the area. The cut grass park and surrounding suburban lawns are examples of a managed urban habitat, environments perceived as pleasant and pretty, but requiring much more water than the native plants that are adapted to the semi-arid climate of the plains. Robins, grackles, mourning doves, house sparrows, mice, raccoons, and squirrels frequent the suburban area.

On the northeast corner of site 3 is Johnson Park, near the intersection of I–70 and Wadsworth Boulevard. The marshy area of the park, part of the Wheat Ridge Greenbelt, lends a rural atmosphere to a busy transportation corridor (fig. 45, sheet 2). Adjacent to the park are highway ramps and overpasses. Over the last ten years, sand and gravel operations have not caused stream-bed erosion that could cause problems with bridges over Clear Creek (Steve White, oral commun., 2001). However, I–25 highway construction downstream has led to noticeable amounts of channel degradation and scour from Golden to the confluence with the South Platte River. Due to the construction, 3–4 feet of the channel of Clear Creek degraded, exposing piles from previous bridge supports at the Federal Boulevard bridge over Clear Creek (Steve White, oral commun., 2001). To help prevent the erosion problems and restore the grade of the stream bed, drop structures (step-pool formations) were placed in Clear Creek.

Site 4 at the intersection of Clear Creek and Sheridan Boulevard illustrates "hidden" landforms, recreation, and water storage (figs. 46 and 47, sheet 2). The site is a mixed land use site with light industry and housing that provide architectural refuge. Dave Nesler (oral commun., 2000) sampled Clear Creek around Sheridan Boulevard and found a few fish species including the white sucker (*Catostomus commersoni*—an eastern slope native), longnosed Bace, and largemouth bass (a warm water sport fish introduced to Colorado in the 1870's).

Between Sheridan Boulevard and the South Platte River, the Clear Creek valley produced a great deal of the gravel used for development from 1950 to 1970 (Schwochow and others, 1974a). Areas "A" and "B" became sanitary landfills after the mining operations ceased (fig. 47, sheet 2). Upon completion of the landfill operations, area "B" became a mobile home park, not the hotel-motel-shopping center planned in the 1960's. Area "A" contains more mobile homes to the south (fig. 48, sheet 2) and an aggregate recycling plant north of I–76.

The land-use evolution of converting agricultural land into mine sites, which are then converted into water use, continues at area "A" (fig. 49, sheet 2). The reservoir adjacent to the east side of Sheridan Boulevard is utilized for jet skiing, and it appears exposed and industrial. Adjacent to the reservoir is an active concrete processing facility. Cooley Gravel Co. mined this area in the 1950's and 1960's for gold and silver as part of their aggregate extraction operations using a floating gold dredge with onboard processing facilities. Conveyers stacked processed aggregate and waste materials on different sides of the mined area. The parallel rows of tailings are still visible and provide bird habitat in the shallow ponds northeast of Interstate 76.

Site 5 at Clear Creek and Lowell Boulevard contains all four landforms associated with mining reclamation in the region: water storage, wildlife/greenbelt space, hidden scenery, and multiple-purpose lake (fig. 50, sheet 2). A series of ponds in this site drain naturally (Stearn, 1967), and the water surface appears smooth on calm days. On aerial photographs and topographic maps the individual shorelines of the ponds resemble static rectilinear forms, but on-site the clearly different and dynamic land uses become apparent. For example, areas "A" and "C" were mined in the 1950's and, as projected, became an 850 acre-ft municipal water supply and a water-oriented residential development, respectively, by the 1990's.

Near area "A," a wooden statue and metal plaque present another attribute of the landscape—local history (fig. 51, sheet 2). Jim Baker, a trapper scout and "the forgotten Mountain Man," homesteaded at 52nd Avenue and Tennyson Street in 1859. According to the plaque, he and his Native American wives ran a general store and operated a ferry and toll bridge across Clear Creek (at present day Lowell Boulevard) on the Denver Boulder Wagon Trail. Scott (1999) places Baker's Crossing a few blocks west, closer to Tennyson. Area "A" was purchased by the City of Westminster in 1989 to provide water. Since the preparation of the USGS topographic map of the area in 1994, the individual rectilinear ponds and pits at area "A" have been merged into a single water storage facility—Baker Reservoir. A combination of below-grade clay embankment and slurry wall liners and an above-grade earth dam were constructed for the project (McGraw-Hill, 1994). A perimeter drain system was designed for the potential rise of ground water in the vicinity. A pedestrian path arches around the reservoir providing a panoramic view of the surrounding landscape.

Aesthetic values of reclaimed mines and related structures (harsh plainness, sharp lines, and "man-made" appearance) along Clear Creek could be improved through the use of some classic design principles (Adams, 1983; Bell, 1999):

(1) Use rounded forms and irregular cuts that are compatible with the immediate adjacent terrain. Rounding the corners of the landforms and carrying vegetation across adjoining areas helps de-emphasize the flat surface plane.

(2) Terracing of the site (varying horizontal and vertical pitch) helps promote continuity between

the space and surrounding area; it would also help break the space down into human dimensions. Depressed floor planes, if not impinging on the water table or flood zone, could make exciting development space for sunken homes and sheltered courtyards.

(3) Use natural color combinations (to blend with the dominant background tone) for visible surfaces of the built structures. Vernacular building materials (locally available materials that include cobble, sandstone, and stucco) are encouraged.

Area "B," called "Aloha Beach," has a gated community, "sandy beach," boats, and little evidence of native flora and fauna (fig. 52, sheet 2). It is definitely a unique reclamation configuration for the Colorado climate and natural landscape. The northern pond was to be developed as a fishing area and the southern pond for swimming. The appearance of reclaimed area "C" nearby gives the street-side viewer an illusion of a more native-looking state. The Aloha Beach-type of reclamation can increase land values and attract premium residential areas. Area "C" was to be a private boating, swimming, and fishing facility (Sheridan, 1967) and is called Lake Sangraco.

Lowell Ponds State Wildlife Area, south of Interstate 76, has extensive riparian areas created out of reclaimed sand and gravel pits (fig. 53, sheet 2). The meandering open space in the area connects city bike trails with other transportation and water features. Light tree cover provides multiple vistas to visitors. On the northwestern corner of I–76 and Lowell Boulevard is an exhausted mine site backfilled with concrete rubble. Lafarge Corporation may recycle this resource, and the City of Westminster is looking at the site for water storage.

The majority of exhausted aggregate mines in Site 6 became "hidden" landforms (fig. 54, sheet 2). Some of the land mined in the 1950's became an unlined sanitary landfill. Today, site 6 contains active gravel-pit operations, industrial areas (including container storage, aggregate processing plants, fenced off lots, and office space—see fig. 55, sheet 2), and a large amount of ruderal habitats, which are the plant communities that border railroad lines, highways, construction sites, and dumps (Whitney, 1994). A structural pattern that creates order or establishes a rhythm is not apparent in this landscape. The viewer has difficulty finding a focal point or rest from the variety of activities going on, and doesn't experience refuge or prospect. Because the site is still active, developing, and evolving, the area may gain coherence and generate less negative visual impact with time.

Site 6 is a functional landscape with little green space. Greenbelts have been shown to increase the economic value of nearby properties (which can increase local tax revenues) and improve the appeal to corporate relocation. For example, because of the presence of a greenbelt in a Boulder, Colorado, neighborhood, property value was approximately $5.4 million greater than if there had been no greenbelt (National Park Service, 1995). The purchase price of the greenbelt was $1.5 million and produced about $500,000 in additional property tax revenue per year (Riley, 1998).

Screens of vegetation between unrelated objects (such as maintenance storage areas and utility easements) would enhance the visual composition in site 6. The easternmost gravel pit at the site is lined with shale 18 feet down, and is compacted for ongoing landfill operations. Methane vents in the landfill are visible from the I–76 highway. A number of pits were backfilled with construction rubble (asphalt and concrete), and the Brannan mine became a hazardous waste disposal site, highly engineered and monitored by the State.

Northeast of the Confluence of Clear Creek and South Platte River

The reclamation of sand and gravel pits along the South Platte River, near its confluence with Clear Creek, is included in this study because it reflects current thinking about the best use of exhausted pits and may also forecast the future development of the South Platte River downstream. The South Platte basin is only one of two river basins in Colorado considered to have significant developable water supplies available to meet future diversion demands (Colorado State University, 2000b). The other is the Colorado River Basin. The failure of proposals for large, expensive multiple-use water development projects (such as Two Forks Dam and Reservoir on the South Platte River canyon in the mountains west of Denver) has forced municipalities to look at alternative means of obtaining and storing water. The reclaimed sand and gravel pits along the South Platte River, northeast of its confluence with Clear Creek, provide huge storage systems and regulation for municipal and industrial water supplies for the Denver metropolitan area. Large, complex storage systems for farm irrigation are also in use downstream (north) of Brighton. Public water systems in a dry area with scattered trees in open grassland are our new millennium parks. Such parks are both paradoxical and ironic: the public objects to mining and the alteration of "natural" landscape character, yet citizens enjoy the reclaimed mine sites as recreation and wildlife space. The lakes along the South Platte River, northeast of its confluence with Clear Creek, are smaller versions of Aurora Reservoir to the south: anomalies in a prairie ecosystem. Completed in 1990 at a project cost of about $50 million, with a capacity of 51,680 acre feet, Aurora Reservoir cost approximately $967 per acre-ft. (Kim Stuart Able, oral commun., 2000).

In 1910, water from the Wannemaker Ditch Company cost about $1.50 per acre-ft (Jefferson County Historical Commission, 1985). Whitney (1983, p. 138) correctly forecast the competition for water where "* * * its price could leap from mere tens of dollars per acre-foot, to tens of *thousands* of dollars by the turn of the century." The cities of Denver, Thornton, Westminster, and Commerce City are working with aggregate operators to purchase exhausted sand and gravel pits; however, appraised values of such pits have skyrocketed. The mid to late 1990's saw an increase in cities competing for and condemning exhausted sand and gravel pits, because cities increasingly wanted such pits as water storage sites. The sites became "turn key" projects without environmental mitigation headaches and fewer costs to transport water, because the pits are short distances from the customer. (The term "turn-key" refers to the ease with which permits can be obtained to convert former gravel pits to water-storage sites as opposed to the difficulty to permit conventional dams.)

An example of the high cost of former sand and gravel pits is the CAMAS (now Aggregate Industries, Inc.) mine, whose owner settled for $58 million dollars (with options on water rights worth as much as $2,850 per acre-ft) with the City of Thornton under threat of condemnation. South Adams Water and Sanitation District and the Denver Water Board worked together to purchase one reclaimed water storage site only to have Thornton condemn the land 48 hours before the agreement was signed. The high demand and competition for Clear Creek water has pushed the value of winter water rights to $12,000 per acre-ft of consumptive use. This compares with $2,000 per acre-ft on the South Platte below its confluence with Clear Creek (Clear Creek Watershed Improvement Initiative, 1995). For further comparison, the City of Aurora has purchased water rights in the Arkansas and South Platte River Basins in the range of $3,500 to $10,000 per acre-ft (Kim Stuart Able, oral commun., 2000).

South Platte River Heritage Corridor Plan

Local sand and gravel producers say deposits mined from nearby areas along the South Platte River are being depleted and aggregate may have to be brought in by rail in the future (Patty, 2000). The Adams County Planning Department predicted " * * * it is probable that more gravel will be brought in from more remote pits, such as those on Boulder Creek and St. Vrain Creek, and from rock quarries in the mountains" (Adams County, 1983, p. II–4). Adams County has made an effort to address growth, utilize aggregate resources, and shape the form of the river corridor at a regional scale. A Mineral Conservation Overlay zone was established in 1979 to protect sand and gravel deposits. "Commercial deposits in the overlay must remain accessible or be mined before permanent improvements are placed on the land" (Adams County, 1983, p. II–5). The county also accepted the South Platte River Heritage Corridor Plan as part of their comprehensive master planning in March 1999. Key principles in the Heritage Plan include (Adams County, 1998b):

- Buffer along the river protecting natural resources and the flood plain
- Trail linkages and open space
- Preservation of certain agricultural lands
- Conservation of cottonwood groves and prairie dog towns
- Multiple use water storage

Virtually the entire South Platte River corridor has been environmentally impacted to some extent, and recreating presettlement landscapes is unfeasible (Adams County, 1998b). In urbanized environments "we usually have the opportunity to restore the dimensions of a bankfull channel within a narrow project width or right-of-way, even if we can't restore the historical floodplain" (Riley, 1998, p. 125). Implementing elements of the natural corridor (vegetation, for example) has been attempted along specific sites of Clear Creek with varying degrees of success. The bluffs overlooking the Clear Creek flood plain are mostly developed, while parts of those bluffs overlooking the South Platte River flood plain are still undeveloped. As one travels northeast along the South Platte River north of Denver, the area becomes less populated and more agrarian. Planned developments that cluster buildings, reduce impervious surfaces, and increase conterminous open space are not mandated. Instead, the conventional subdivision may prevail with large amounts of street paving and individual housing.

Will the policymakers encourage the preservation of bluffs and vestiges of native grasslands, agricultural lands, and open views once urban development (high-intensity commercial and residential) begins? A land developer plans a $1.7 billion commercial and residential community in Brighton at the junction of Interstate 76 and planned extension of E–470 (Rebchook, 2000). This area is adjacent to Barr Lake and borders the northeast study area of the South Platte River Heritage Plan. A regional mall, 18-hole golf course, and business park are being considered. The developer and city manager of Brighton consider the lakes, parks, open space, great views, and "bucolic" land amenities an asset for growth (Rebchook, 2000). How much pressure and impact will that growth have on the very landforms considered attractive to the area? Will future mining be allowed in the Plan's designated areas in spite of potential intense residential opposition?

Choices between mining, residential development, and open space can be considered from a public cost point of view. In many cases, residential expansion resulted in an increase in services (at a higher cost than the property taxes generated) over industrial/commercial or farm/open space land. In 1988, for the City of Boulder, Colorado, the public cost for maintaining developed urban space was estimated to be over $2,500 per acre. The annual cost for maintaining open space in the city was $75 per acre (National Park Service, 1995). Some Adams County open space goals are "* * * to reclaim lands during and after mining in an effort to create habitat, restore vegetation, contribute to flood storage and provide recreational and educational opportunities. ***Encourage water storage facilities to be multi-purpose in use (water storage, passive recreation, and habitat restoration)" (Adams County, 1998b, p. 11). The most complex and ambitious part of this goal is multipurpose water storage. Clear Creek water facilities tend to be single-purpose but the demand for multiple-use gravel-pit lakes exists. Water planners found that a multiple-use policy could be better because, presumably, the benefits are greater for each dollar spent (Riley, 1998).

Michalski and others (1987) assessed the viability of fish and wildlife rehabilitation mixed with five other uses of pits and quarries (table 5). How does one design and administer a truly multiple-purpose lake to satisfy habitat restoration and recreation (whether passive or active) without additional stress on native habitat and wildlife? Small gravel pits (less than 5 acres in size) may provide angling when stocked with fish, but wildlife managers don't attempt to maintain proper fish community relationships in such pits (Knox, 1982). Is limited development (whether residential, agricultural, or industrial) a compatible use (from an ecological viewpoint) in riparian buffers? While agriculture is compatible with lakes and flood control, it may become an issue with habitat conservation and downstream water supplies. Multiple-use sites usually require large and physically diverse contiguous areas to start with, and their design and implementation require interdisciplinary teams in different levels of government and citizen involvement.

The U.S. Forest Service and U.S. Bureau of Land Management aim for a balanced perspective of recreation, rangeland, watershed, fish, timber, and wildlife, but controversy persists with the multiple-use concept in 2001. An example in the metro area is Cherry Creek Reservoir—a U.S. Army Corps of Engineers project, primarily used for flood control. The water quality of the reservoir is threatened from fertilizer chemicals containing phosphorus (from residential and agricultural runoff, and sewage treatment plants). The phosphorus encourages algae growth (which swimmers dislike), and as the prolific algae die, they decompose and deplete the water of oxygen (that fish need). Stein (2000a) reported the Cherry Creek Basin Water Quality Authority wants to chemically treat the reservoir with alum, but the Colorado Division of Wildlife and Department of Public Health and Environment oppose the plan. Biologists are concerned about the potential impact the treatment would have on gizzard shad and walleye bass in the reservoir (Stein, 2000a).

Barr Lake (originally a buffalo wallow; Gerhardt, 2000b) is another example of the problems of maintaining a viable multiple-use site. The State owns the 2,900-acre Barr Lake State Park; the Farmers Reservoir Irrigation Co. owns the water. Stein (2000b, p. 1A) notes "The park is managed by the state for wildlife and recreation, but that comes second to irrigation, which is why the lake was built in the 1880's." Canals from the South Platte River feed Barr Lake, located near Brighton, but the lake was reduced to mud flats due to irrigation water demands in the summer of 2000. Viewed on a regional scale, the drought problem and compatibility in multiple-uses takes an ironic twist. Roger Pielke, chief climatologist at Colorado State University, said, "I'm very concerned about the potential for extreme drought, worse than what we experienced in the 1930s. * * * If we go two or three more years without a good snowfall and without good rains, there is going to be a major threat to population growth in the state" (Frazier, 2000, p. 7A).

The coming years will tell if Adams County is able to follow through on the South Platte River Heritage Corridor Plan or if it will instead mirror the urban development, mining landforms, and pedestrian ways/open space linkages along Clear Creek. The ultimate goal would (1) relate land use and mining at three scales: site, region, and watershed, and (2) minimize the impact on stream structure, function, and dynamics.

There are two fundamental concepts in ecosystem design: structure (rocks, soils, plants, and animals; their association and community) and function (energy transformation, movement of matter in cycles—for example, water). Riley (1998) incorporates the terms in her concept of multi-objective floodplain management. She attempts to restore streams by returning (1) structure to a stream (riparian lands, meanders, and pools), (2) its functions (for example, wildlife habitat, flood storage), and (3) its dynamics (which determine its shape, dimensions, and meander).

Sand and Westerly Creeks, within Denver's closed Stapleton Airport, are an example of development plans to reestablish sandhills prairie and restore historic stream channels (Academy Editions, 1996). The proposed open space includes an extensive storm-water management system with indigenous riparian habitats and recreation facilities (integrating golf courses, bike trails, and active sports centers). The drainage and pond areas accommodate a system of wide and shallow swales; the main channel has meandering and braided subchannels with sand bars. Although the project's lakes are filled with storm water and designed to empty in a 48-hour period, many of the design guidelines are adaptable to land surrounding water storage lakes.

Summary—Land Use Change and Memory

> *In America one finds a number of marks and traces that are testimony to a particular schedule, sequence, or timing of human activity. These are the traces of social life and rhythm upon the land. Lines, elements, patterns, debris, and ruins register the passages of occupancy and labor over time. (Corner and MacLean, 1996, p. 97.)*

Development in the Denver suburban area is a controversial issue. Some would say our ancestors changed a desert into a garden, others just the reverse. Little land is left of a pristine nature despite the area's expansive landscape. Clear Creek has been transformed from a wide braided stream to a narrow confined stream, isolated from the flood plain (fig. 56, sheet 1). Powerful memories of its' mining history are evoked in rigid, rectilinear shapes or are camouflaged in a manner unrecognizable to future generations. Deciding which are deleterious or beneficial depends upon your viewpoint. Reclamation and resource planning cannot be assessed in only scientific terms; how one appreciates landscapes and the environment also affect land-use issues. The value of an area stems from its people and their wants: industry needs aggregate resources for building infrastructure, cities have increased demands for water resources and land for expansion, citizens view open space as beautiful landscapes or sources of recreational activities to enjoy, and scientists associate the land with opportunities for biodiversity and beneficial habitats. Ideally, we would read landscapes with all of their eyes.

The site photographs in this publication represent points in the process of change. Large-scale topographic features, such as mountains and terraces, appear "changeless" (they do change over geologic time), while a stream channel may vary dramatically within a human timescale. The landscape retains cultural artifacts (such as the linear geometry of roads and land parcels) for generations; at the same time the landscape is undergoing changes in land use and cover. It can be visually difficult to discern ecological change from human-induced change. Gravel-mining scars may appear as picturesque cliffs or may be hidden by a concrete bastion to the unknowing eye (fig. 57). The creek channel through much of the urban area has become artificial in attempts to make the streambed stationary for flood control, irrigation, and urban development.

Opposition to traditional dam building has brought about an increase in the use of lined sand and gravel pits for water storage. Distinct, strong-edged water reservoirs, reclaimed from off-channel excavations, serve a fundamental utilitarian purpose and form a regular composition along Clear Creek. There is little foreground or mid-ground; most of these reclaimed landforms appear as separate objects distinct from the urban scene. The horizontal floor planes align with roadways and most planted boundary edges have trees in single straight rows, serving as visual screens to camouflage the mining operation. One problem of the reclaimed landforms tends to be the isolation and lack of connection (other than vehicular) between the site and surrounding area; this is true of many urban sites.

Many former gravel mine sites reflect the rectilinear geometries of the grid system. Indeed, the grid defines mining properties, and efficient mining dictates that extraction proceeds to the regulated allowed distance from the property line. Consequently, the shape of the pits reflects the shape of the property. Nevertheless, mine and reclamation design palettes, including engineering practices and environmental considerations, could be expanded to find ways to keep a sense of place. Softer, irregular forms would aid in a sense of privacy and shelter, serving multiple functions. The linear parks formed for open space are important corridors knitting together urban and suburban space, industrial and natural space, water and land. Accommodating various, often conflicting, land uses is not always practical or efficient and should not develop without respect for environmental limitations. This isn't to imply designers and scientists shouldn't keep trying to integrate multiple uses; we need to recognize the process is complex and imperfect.

Some things haven't changed over decades; many people do not want to live near a pit operation yet may fail to appreciate aggregate for its' contribution to quality of life. On one hand, the disturbance created by mining affects the local landscape and population greatly. Noise, dust, and traffic are oft-cited problems. On the other hand, the region and the State benefits because mining is economically important, but that is usually not a factor in the thinking of the general public. The public (as consumers) is concerned when resources are in short supply and become more expensive. Reclamation of aggregate pits shows that little land is ultimately lost from urban use; there is just a delay in the availability of that subsequent land use. Reclamation projects can turn a generally unwanted form (mine pits) into a place people may enjoy. The public may not realize the triple use of sand and gravel mine sites; first for aggregate extraction, then for landfill, followed by subsequent third uses.

Mining is an affront to conventional urban values. As in many urban areas, the public response to mining has gone from NIMBY (Not In My Backyard) to NOPE (Not On Planet Earth). The question isn't whether there will be sand and gravel pits, but where the pits will be and how the sites should interact with the landscape. The effects of sand and gravel pits can be judged in relationship to (1) local values, which will differ from place to place, and (2) the landscape as a whole (not just as a single object within it). The urban community requires aggregate resource usage and subsequent land use; however, the individual may not want the noise, dust, or visual impact. Mining of aggregate resources is a short-term land use, with rapid urban-industrial development the cause and driving force of landscape degradation and depletion of natural resources.

Land planning, mine operations, society, and the urban environment simply reflect individual consumer's values, community culture, traditions, and scientific advances. Society will have to change if the current trend in landscape modification in response to aggregate mining in northern Colorado is to change. In the 1950's, J.B. Jackson posed the question, "Can anything so indefinable yet so precious as the atmosphere of a place survive the sudden impact of thousands of newcomers, millions of dollars invested in construction of every kind, and a transformed economy?" (Meinig, 1979, p. 221).

Settlement in the late 1800's followed the rush of miners to the stream beds of eastern Colorado, beginning the evolution of landscape modification in the Clear Creek corridor that continues today. The activity associated with mining is unrecognizable or leaves a visible imprint on the landscape. The rush continues to (1) find new resources before they are preempted, (2) write appropriate environmental guidelines, and (3) formulate dynamic reclamation designs to better serve the public good. The landscape heritage of Clear Creek is a reminder of what the future may hold for the South Platte River downstream of its confluence with Clear Creek.

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