CHERRY CREEK BASIN WATER QUALITY AUTHORITY

1989 ANNUAL REPORT

June 7, 1990

CHERRY CREEK BASIN

WATER QUALITY AUTHORITY

Annual Report

Authority Members:

Arapahoe County
Arapahoe Water and Wastewater Authority
City of Aurora
Cottonwood Water & Sanitation District
Denver Southeast Suburban Water & Sanitation District
Douglas County
City of Greenwood Village
Inverness Water & Sanitation District
Meridian Metropolitan District
Parker Water & Sanitation District
Stonegate Center Metropolitan District
Town of Castle Rock
Town of Parker

Cherry Creek Basin Water Quality Authority
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INDEX

Page

CHERRY CREEK BASIN WATER QUALITY AUTHORITY
1989 ANNUAL REPORT SUMMARY

CHERRY CREEK BASIN WATER QUALITY AUTHORITY
1989 ANNUAL REPORT

CHERRY CREEK BASIN WATER QUALITY AUTHORITY
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Executive Summary

In 1984 the Colorado Water Quality Control Commission established a standard of 0.035 mg/l phosphorus for Cherry Creek Reservoir so that chlorophyll a levels in the Reservoir would not exceed 15 ug/l.

The Cherry Creek Basin Water Quality Authority ("Authority") is the 208 management agency for the Cherry Creek Basin ("Basin"). The Authority operates pursuant to special legislation, which created and authorized the Authority. See Section 25-8.5-101, et seq., C.R.S. The Authority also carries out special responsibilities for the Cherry Creek Basin, as provided by the Water Quality Control Commission. See 5 C.C.R. 1002-19 (1985). The Authority oversees the point source and nonpoint discharges in the Basin, conducts water quality monitoring and is implementing plans to improve the water quality of the Basin. This is a summary of the Authority's 1989 activities pursuant to its plans and regulations.

Construction of Shop Creek Drainage/Water Quality Control Project.

The Authority, in cooperation with the City of Aurora, constructed the Shop Creek Project. The Master Plan (1985) reflected that Shop Creek was the major contributor of nonpoint source phosphorus loads to the Reservoir. The Shop Creek Project, consisting of channel stabilization and a detention facility with infiltration followed by a series of wetlands, was constructed in 1989. By Agreement, the Authority will reimburse Aurora over four years for $463,000.00; the costs for the water quality elements of the Shop Creek Project. The Authority will monitor the Shop Creek Project to determine its effectiveness for nonpoint source phosphorus removal. Additional monitoring of the effectiveness of the project to remove other nonpoint source constituents is being funded by the Urban Drainage and Flood Control District.

Best Management Practices and NonPoint Source Control.

The Authority has recommended that each land use government within the basin adopt and enforce best management practices. The best management practices are designed to control nonpoint source pollution and erosion during construction, grading, and other activities which disturb the soil.

The Authority has adopted a Grading/Building Permit fee. The fee was imposed because the nonpoint source loads are increased by grading and the creation of additional permanent impervious surface areas. The fee is $0.03 per square foot of

building footprint and associated impervious areas or $50.00 for each single family residence, or $280.00 per acre. Each city and county, on behalf of the Authority, collects the fees at the time of building permit issuance.

The nonpoint source loadings from the four tributary inflows were monitored and modeled, to estimate that total 1989 loadings to Cherry Creek Reservoir were 5100 pounds of total phosphorus and 50,200 pounds of total nitrogen. The phosphorus load is substantially lower than phosphorus loads of 10,770 pounds, estimated by EPA as average for the Basin and the 9,520 pounds reported in 1988. The Master Plan and Control Regulation allocate 10,290 pounds of phosphorus for nonpoint sources, an allocation that assumed that 50% of the nonpoint source load had been contained. Although the Authority cannot accurately measure the amount of nonpoint source load that is not mobilized because best management practices prevent the typical erosion and runoff, they probably are a factor in the reduced phosphorus loads. The 1989 water year showed lower water inflows than 1988. The inflows in 1989 were very close to EPA's predicted average water inflow to Cherry Creek Reservoir, although the phosphorus loads were 58% of EPA's forecasted loadings for those flows.

In-Reservoir Control Options.

The Authority continued an evaluation of the in- reservoir control strategies. The in-reservoir phosphorus is combined within the water column and resuspendible bottom sediments containing phosphorus also mix with the water. These existing phosphorus loads within the Reservoir are substantial and can support algae growth in excess of the chlorophyll a goal. Based upon studies completed for the Authority, the Authority selected the following three in-reservoir control strategies for pilot studies and further consideration: dredging, alum addition and construction of wetlands at the Cherry Creek inflow to the Reservoir.

In cooperation with the Colorado Parks and Recreation Commission and the Department of Natural Resources, the Authority has established a fee of $3.00 per year for every vehicle entering the Cherry Creek Reservoir State Park.

Point Sources.

The Master Plan and Control Regulation allocated a total of 2,310 pounds of phosphorus to point source dischargers. In 1989, the Division issued compliance schedules to Cottonwood Water and Sanitation District and Denver Southeast Suburban Water and Sanitation District, for phosphorus discharges. Denver Southeast has commenced construction of a 1.0 MGD advanced wastewater treatment plant, scheduled to be complete and in operation by 1991. Phosphorus contributions from point source dischargers totalled 8,737 pounds in 1989; however, 7,790 pounds

were from one discharger. Each discharger in the basin is assessed a fee of $.05 per 1,000 gallons of sewerage discharged.

The Authority has commenced an internal review of wastewater treatment technologies to assess the phosphorus removal capabilities of each type of wastewater treatment process.

Master Plan Update.

In 1989, the Authority prepared an Update to the Master Plan. The Update contains new hydrologic data for Cherry Creek Reservoir and the groundwaters tributary to the Reservoir. The Update includes a discussion of in-reservoir treatment technologies. The control strategies termed as "in-reservoir" include dredging, alum treatments and construction of upstream wetlands. Pilot projects to test the feasibility and effectiveness of these control strategies are outlined.

The Master Plan Update has been submitted to the Denver Regional Council of Governments (DRCOG), the designated the 208 planning agency, and the Water Quality Control Commission for preliminary approval. The Master Plan Update will be incorporated into the DRCOG Clean Water Plan.

1989 Monitoring Program.

In 1989, the Authority monitored the Reservoir water quality, quantity and quality of inflows to the Reservoir, storm flows, and water quality detention ponds. The following are general findings of the 1989 monitoring:

(a) The number of storms in the Cherry Creek Basin was fewer and the magnitude of the 1989 storms was less than observed in 1987 and 1988.

(b) The total phosphorus removal rates for the Clarke Farms detention pond averaged 78%. No total phosphorus removal was reported for the Inverness ponds, ponds which had not been designed for water quality purposes.

(c) The growing season (July through September 1989) average concentration of total phosphorus was 0.045 mg/l and chlorophyll a averaged 5.6 ug/l. A three-year comparison shows:

Year	Phosphorus	Chlorophyll-a
(Adopted Standard/Goal)	.035 mg/l	15 ug/l
1982	.030 mg/l	10.7 ug/l
1984	.074 mg/l	15.3 ug/l
1985	.063 mg/l	4.2 ug/l
1986	.062 mg/l	4.0 ug/l
1987	.095 mg/l	8.3 ug/l
1988	.050 mg/l	32 ug/l
1989	.045 mg/l	5.6 ug/l

(d) Total nonpoint source loads to the Reservoir were 5100 pounds of phosphorus and 50,200 pounds of nitrogen.

CHERRY CREEK BASIN WATER QUALITY AUTHORITY
1989 ANNUAL REPORT

Background

The Clean Lakes Study of Cherry Creek Reservoir conducted in 1982 identified that euthrophication of the Reservoir could negatively impact the beneficial uses of the Reservoir (DRCOG, 1984). The Clean Lakes Study identified phosphorus as the major nutrient causing algal productivity and that euthrophication. Based on the Clean Lakes Study, the Colorado Water Quality Control Commission (CWQCC) established an in-reservoir total phosphorus standard of 0.035 mg/l to maintain the chlorophyll a levels in Cherry Creek Reservoir at concentrations no higher than 15 Ug/l (0.015 mg/l) as an average for the "growing season" (that is, during the months of July through September).

During 1985, the local governments (cities and counties and special districts), private interests, and representatives of the State and Federal Government developed a strategy to meet the Reservoir growing-season phosphorus standard and chlorophyll a goal. The control strategy was outlined in the Cherry Creek Basin Water Quality Management Master Plan (DRCOG, 1985a; 1985b).

The Cherry Creek Basin Master Plan was approved by the Colorado Water Quality Control Commission in 1985. Portions of the plan were adopted as the "Regulations for Control of Water Quality in Cherry Creek Reservoir" (Section 4.2.0, 5 C.C.R. 3.8.11), and effective December 30, 1985. The Master Plan was approved by the USEPA Region VIII office as the 208 Management Plan for the Cherry Creek Basin.

In 1985, an intergovernmental agreement was executed by the local governments within the Cherry Creek Basin, forming the Cherry Creek Basin Authority (Authority). The Authority was created to develop and implement the means to protect the water quality of Cherry Creek, while allowing economic development to occur.

In 1987, the Colorado Legislature's Water and Water Quality Subcommittee conducted hearings on several matters, including legislation to create a water quality management agency for the Cherry Creek Basin. That Subcommittee introduced legislation to the 1988 General Assembly which statutorily created and empowered the Cherry Creek Basin Water Quality Authority; it was approved by the House and Senate and signed by Governor Romer. See C.R.S. § 25-8.5-101, et seq.)

Purpose of the Annual Report

The primary purpose of the 1989 Annual Report Summary is to inform the Colorado Water Quality Control Commission (CWQCC) of the Authority's progress in implementing the Master Plan during 1989. Also, the "Regulations for Control of Water Quality in Cherry Creek Reservoir" (Section 4.2.8, 5 C.C.R. 1002-19) require that an annual report on the activities of the Authority and, particularly phosphorus control strategies, be submitted. The purpose of this 1989 Annual Report Summary is to fulfill those requirements.

I. 1989 LOADINGS, WATER QUALITY AND FLOW INFORMATION.

A. Point Sources.

1. 1989 Annual Loadings.

The "Regulations for Control of Water Quality in Cherry Creek Reservoir" established annual phosphorus allocations for each wastewater treatment plant in the Cherry Creek Basin. The phosphorus allocated to each plant was expected to be adequate for the wastewater treatment plant's 1985 capacity plus the next incremental expansion for the plant. The Master Plan and Control Regulations also set maximum phosphorus concentrations for dischargers of 0.1 mg/l for October through March and 0.05 mg/l for April through September, of each year.

The Master Plan designates the type of wastewater treatment for each facility. In 1989, three dischargers were using secondary treatment followed by rapid infiltration and five dischargers were using secondary treatment with slow rate land application. The NPDES permits for the dischargers generally require monitoring of the phosphorus discharged. Dischargers utilizing rapid infiltration have established monitoring wells below their infiltration ponds and downgradient of the ponds to monitor phosphorus concentrations.

In order to monitor phosphorus concentrations from the slow rate land application sites, the dischargers have installed vacuum lysimeters below their land application areas in order to withdraw leachate samples for phosphorus analyses. However, those dischargers applying effluent at agronomic rates frequently do not report any leachate in the lysimeters. It is assumed that the effluent is fully utilized by the plants and evapotranspiration.

Ideally, the actual phosphorus loading occurring in the basin from point source dischargers would be calculated using the phosphorus levels detected in the samples

obtained from the land application or rapid infiltration monitoring sites minus background levels. Soils in the basin commonly contain significant amounts of phosphorus, so phosphorus may be leached from the soil during watering. The Authority is coordinating with its members and the Division so that Phosphorus within the soil and groundwater will not be included as part of the sample results reported pursuant to an NPDES permit.

Estimated phosphorus loadings from the existing and operating treatment facilities were derived by the Water Quality Control Division from the dischargers' monthly reports. Table 1 presents the calculated phosphorus loadings for each wastewater treatment plant, discharging during 1989. The phosphorus allocations for each wastewater treatment plant are shown also.

TABLE 1

POINT SOURCE PHOSPHORUS LOADINGS IN THE CHERRY CREEK BASIN
1989 Water Year

Wastewater Facility	1989 (1) Wastewater Phosphorus Concentration Mg/l	1989 (1) Phosphorus Loading (lbs/yr)	Allocated (3) Phosphorus Loading (lbs/yr)
Discharging Plants:			
Arapahoe	0.67	229.7	354
Cottonwood	0.49	376.9	213
Denver Southeast	6.39	7,790.0	365
Inverness	0.00	0	68
Meridian	0.06	1.2	114
Parker	0.34	339.2	533
Castle Rock (Mitchell Creek)			128
Plants Not Discharging:			
Castle Rock (Cherry Creek)	0	0	21
Castle Rock (McMurdo Gulch)	0	0	64
Castle Rock (Newlin Gulch)	0	0	86
Rampart Range	0	0	160
Stonegate	0		53
Totals	1.43		2,159

1) Flows and phosphorus loading for 1989 were calculated by the Water Quality Control Division from each discharger's monthly report.
2) The facility at Denver Southeast Suburban Water and Sanitation District was allocated up to 365 pounds (lbs) of phosphorus annually. The 365 lb phosphorus allocation is temporary and will be reduced to 213 lbs of phosphorus in 1990 or when Denver Southeast completes construction of a final build-out 1.4 MGD facility, whichever occurs first.
3) Section 4.2.4(1), 5 C.C.R. 1002-19.

Source: Updated from Richard P. Arber & Associates (1986) and In-Situ, Inc. (1987b), and ASI (1988).

The Authority is responsible for reviewing all site applications, compliance schedules and special permits for wastewater treatment plants to ensure the plants comply with the Cherry Creek Basin Master Plan. The Authority has a technical review committee which reviews each application and recommends point source and nonpoint source controls, as appropriate, to the Authority. The following actions were taken by the Authority regarding point source discharges:

(a) Havana Water and Sanitation District requested site approval for a new sewage lift station. All effluent from this District is treated and discharged outside the Cherry Creek Basin. The Authority recommended approval of the site application.

(b) Inverness Water and Sanitation District requested site approval to increase their slow rate land application sites to include common areas. Inverness has land applied their effluent on the golf course. The Authority recommended site approval to allow Inverness to use the common areas, as well as the golf course, for slow rate land application.

(c) Cottonwood Water and Sanitation District requested an extension of time to complete a rapid infiltration basin. Cottonwood requested that their compliance schedule be extended from September 1990 to January 1992 for completion of the basin due to ownership and title problems with the rapid infiltration basin site. The Authority recommended approval.

(d) Arapahoe Water and Sanitation District (now the Arapahoe Water and Wastewater Authority) obtained a permit to land apply treated sludge to twelve acres. Arapahoe presented information that the phosphorus contributed from the sludge would be minimal. The Department of Health had issued the permit; the Authority gave an after-the-permit recommendation of approval.

(e) Denver Southeast Suburban Water and Sanitation requested an extension of their compliance schedule for completion of their new AWT plant from March 1990 to December 1990. Denver Southeast noted that construction of the facility had commenced, but commenced later than anticipated while the District arranged financing for the wastewater treatment plant, including a loan from the State of Colorado. The Authority recommended that the extension be approved.

B. Nutrient Inflow Characteristics from Reservoir Tributaries and Precipitation.

1. 1990 Loadings.

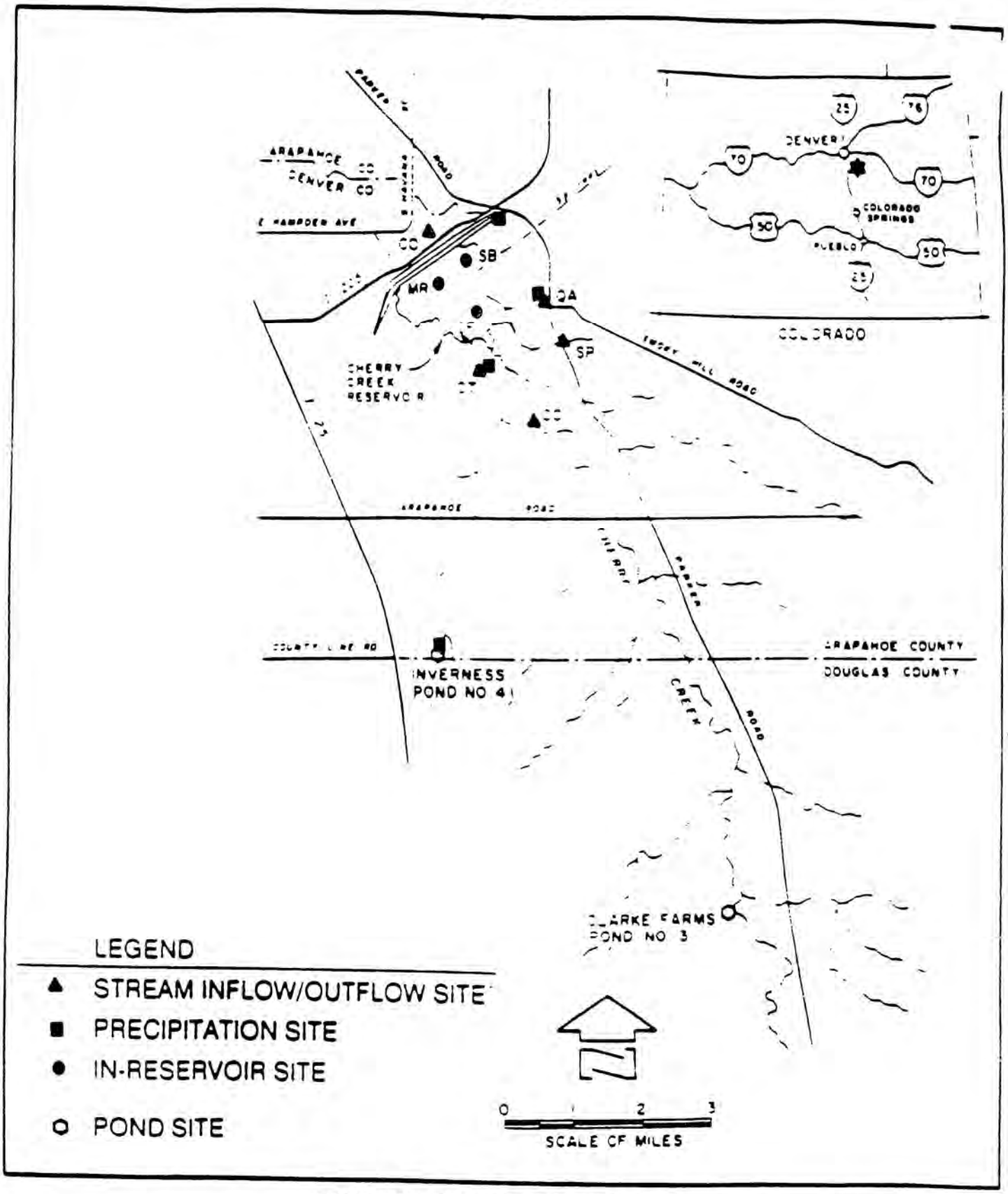
The locations for water quality monitoring in the Cherry Creek Basin are shown on Figure 1. The storm event and ambient water quality analyses for 1989 at the Reservoir inflow and outflow sites were modeled and the regression summaries relating concentrations of nutrients with streamflow were updated. These updated regression analyses were applied using the appropriate daily streamflow record to generate daily loadings total phosphorus and total nitrogen. The tributary inflows to Cherry Creek Reservoir from the four inflow monitoring sites totalled about 5880 acre feet for the 10 months of streamflow records collected during 1989. Reservoir outflow for the 12-month water year period, based upon records by the U.S. Army Corps of Engineers, totalled about 5070 acre feet, and measured by the U.S. Geological Survey (USGS) totalled about 5440 acre feet. The imbalance between inflows and outflows is due to the unmeasured evaporation losses and leakage from the Reservoir.

For 1989, the aggregate nutrient loadings to Cherry Creek Reservoir from the four tributary inflow sites totalled 5100 pounds of phosphorus and 50,200 pounds of nitrogen, respectively, based upon the regression function calculations. Outflow nutrient loadings were about 910 pounds of total phosphorus and about 10,500 pounds of total nitrogen. The difference between the nutrient inflows and outflows results from the reduced Reservoir releases. Even in an average water (runoff) year such as 1988, over half of the nutrient loadings into Cherry Creek Reservoir are retained in the Reservoir.

2. Comparison to Previous Loadings.

The loadings for 1989 can be compared to the 1982 Clean Lakes Study estimates (DRCOG, 1983) and those estimated by the USEPA (1977) for "average year" inflows. (See Table 2.)

FIGURE 1



GENERAL MONITORING PROGRAM
SAMPLING LOCATIONS

CHERRY CREEK BASIN

PROJECT NO. 970

TABLE 2

NUTRIENT LOADINGS, 1989

Source	Year	Inflows	Total Phosphorus	Total Nitrogen
DRCOG	1982	1090 ac-ft	4360 lbs	n/a
USEPA	"avg. year"	5310 ac-ft	10,770 lbs	49,820 lbs
In-Situ	1988	8960 ac-ft	9520 lbs	72,200 lbs
ASI	1989	5880 ac-ft	5100 lbs	50,200 lbs

Bulk precipitation falling on Cherry Creek Reservoir has been identified as a contributor of phosphorus. Three bulk samplers collected both wet and dry precipitation from the atmosphere. During 1989, an estimated 13.0 inches of precipitation fell directly on the Reservoir. The average total phosphorus concentration of the precipitation was 0.30 mg/l, compared to 0.47 mg/l in 1987 and 0.42 mg/l in 1988. For 1989, the phosphorus loading by precipitation to the Reservoir surface area of 850 acres was an estimated 750 pounds of total phosphorus. This compared with 690 pounds estimated by DRCOG (1983), 120 pounds estimated by USEPA (1979), and 1880 pounds estimated by In-Situ, Inc. (1989) for 1988.

Total 1989 phosphorus and nitrogen concentrations were higher than for previous years (1987 and 1988) for the Cherry Creek inflow and the Cottonwood Creek inflow. These increases may be explained, in part, by the relatively small number of samples and the below normal precipitation occurring during 1989. Nitrate levels for the Shop Creek inflow were higher than nitrate levels for other tributary inflow sites. No explanation is available for the higher nitrate loadings at this site.

Time series plots of total phosphorus and total nitrogen loads at the four Cherry Creek inflow sites indicates that the 1989 period was not particularly unusual, even though flow was lower than the previous years.

C. In-Reservoir Water Quality.

1. 1989 In-Reservoir Concentrations.

Three sites in Cherry Creek Reservoir have been sampled to assess temporal as well as spatial changes in water quality and biological conditions - one site each in

the main body, the swim beach, and the Cherry Creek inflow arm. (See Figure 2.) Consistent with previous years' monitoring, in-reservoir sampling surveys are conducted by boat during open-water conditions and by coring through the ice during the winter. At each Reservoir sampling site, two sets of water quality samples are collected each time; one set is obtained from the middle of the euphotic zone (the depth is estimated in the field using a secchi disk) and a second set is obtained near the Reservoir bottom (1 to 1-1/2 feet above the Reservoir bottom).

Total phosphorus concentrations for 1989 in the Reservoir at all three locations, and for both sampled depths, averaged about 0.046 mg/l. The average growing season (July through September) total phosphorus concentration was 0.045 mg/l, above the phosphorus standard of 0.035 mg/l. Seasonal low concentrations of total phosphorus occurred during the months of November and December 1988. The growing season chlorophyll a concentrations during 1989 averaged 5.6 ug/l, which is substantially below the established goal of 15 ug/l.

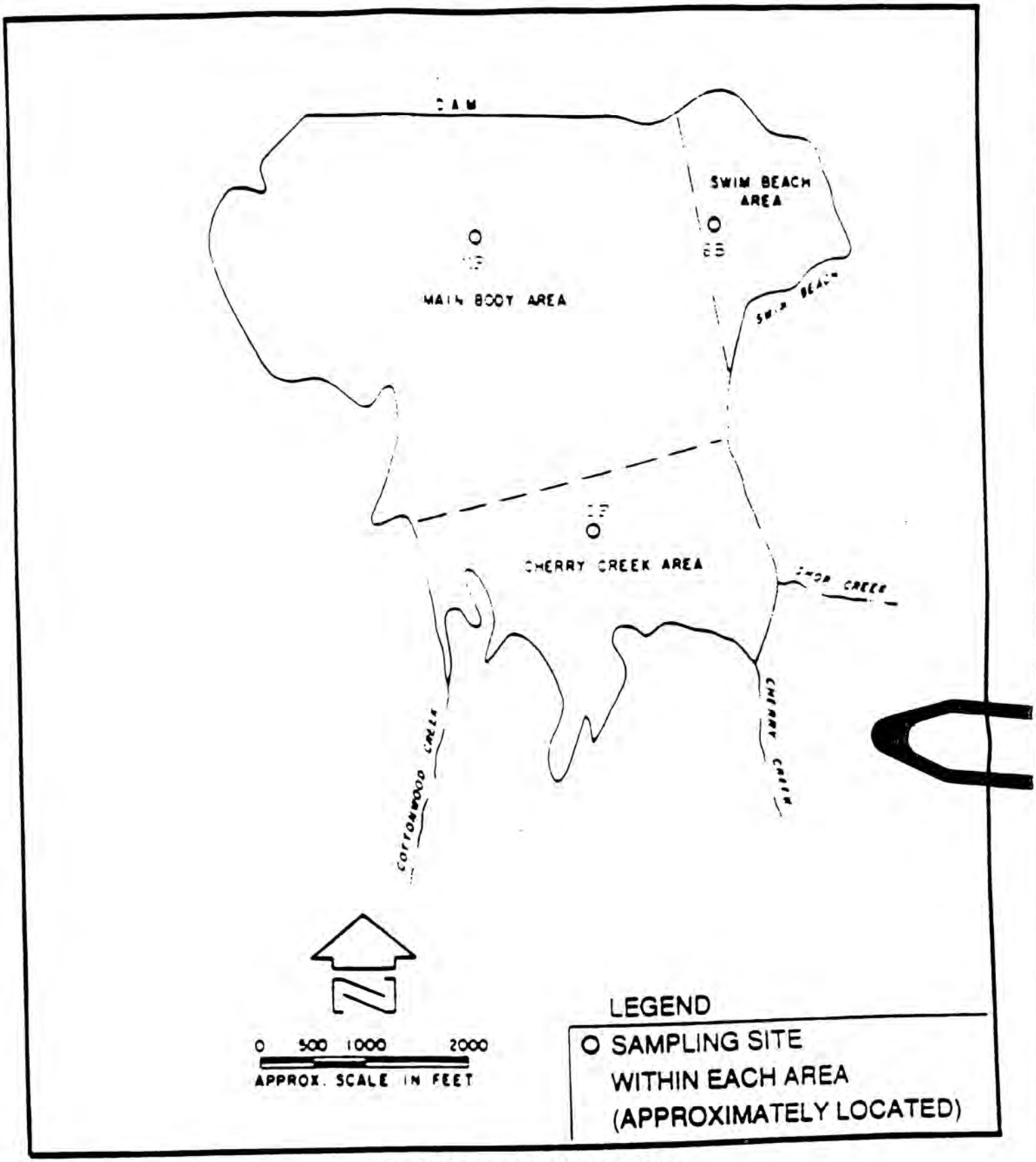
Total nitrogen concentrations for 1989 in the Reservoir averaged 0.78 mg/l, which is substantially lower than the average total nitrogen concentrations of the tributary inflow sites.

2. Phosphorus/Chlorophyll-a Relationships.

The average 1989 total phosphorus concentration during the growing season of 0.045 mg/l in the Reservoir was lower than average growing season phosphorus concentrations in 1987 and 1988 (0.095 mg/l and 0.060 mg/l, respectively). Also, in-reservoir total nitrogen concentrations during the 1989 water year were 0.78 mg, less than the 0.85 mg/l average for the 1988 water year and 1.45 mg/l average for 1987. Chlorophyll-a values for the 1989 growing season averaged 5.4 ug/l compared to 1988 and 1987 values of 32 ug/l and 8.3 ug/l, respectively.

The Clean Lakes Study utilized the Jones/Bachman model (1976) to predict the relationship between phosphorus and chlorophyll a in the Reservoir. The Jones/Bachman model predicted that an in-reservoir concentration of 0.035 mg/l phosphorus would result in a chlorophyll a concentration of 15 ug/l. Although the 1989 (growing season) average phosphorus concentration of 0.045 mg/l exceeded the standard, the resulting chlorophyll a concentration in the Reservoir of 5.4 ug/l was substantially below the chlorophyll a goal of 15 ug/l.

FIGURE 2



CHERRY CREEK RESERVOIR
SAMPLING SITES

CHERRY CREEK BASIN

PROJECT NO 970

FIGURE NO. 12

The phosphorus and chlorophyll a values for Cherry Creek Reservoir for the years of monitoring are as follows:

Year	Phosphorus	Chlorophyll-a
(Adopted Standard/Goal)	.035 mg/l	15 ug/l
1982	.030 mg/l	10.7 ug/l
1984	.074 mg/l	15.3 ug/l
1985	.063 mg/l	4.2 ug/l
1986	.062 mg/l	4.0 ug/l
1987	.095 mg/l	8.3 ug/l
1988	.050 mg/l	32 ug/l
1989	.045 mg/l	5.6 ug/l

Figure 3 depicts the chlorophyll a and phosphorus relationships for Cherry Creek Reservoir for 1982, 1984, 1985, 1986, 1987, 1988 and 1989 and compares those actual values to the values predicted by the Jones/Bachman model. The Jones/Bachman model did not accurately predict the phosphorus/chlorophyll a relationships for 1985, 1986, 1987 and 1988, all characterized as "wet years" - with greater than normal precipitation and, therefore, more runoff than 1982. 1989 was considered a below normal precipitation year. However, the phosphorus concentrations in the Reservoir did not produce the chlorophyll a that would have been predicted by the Jones/Bachman model.

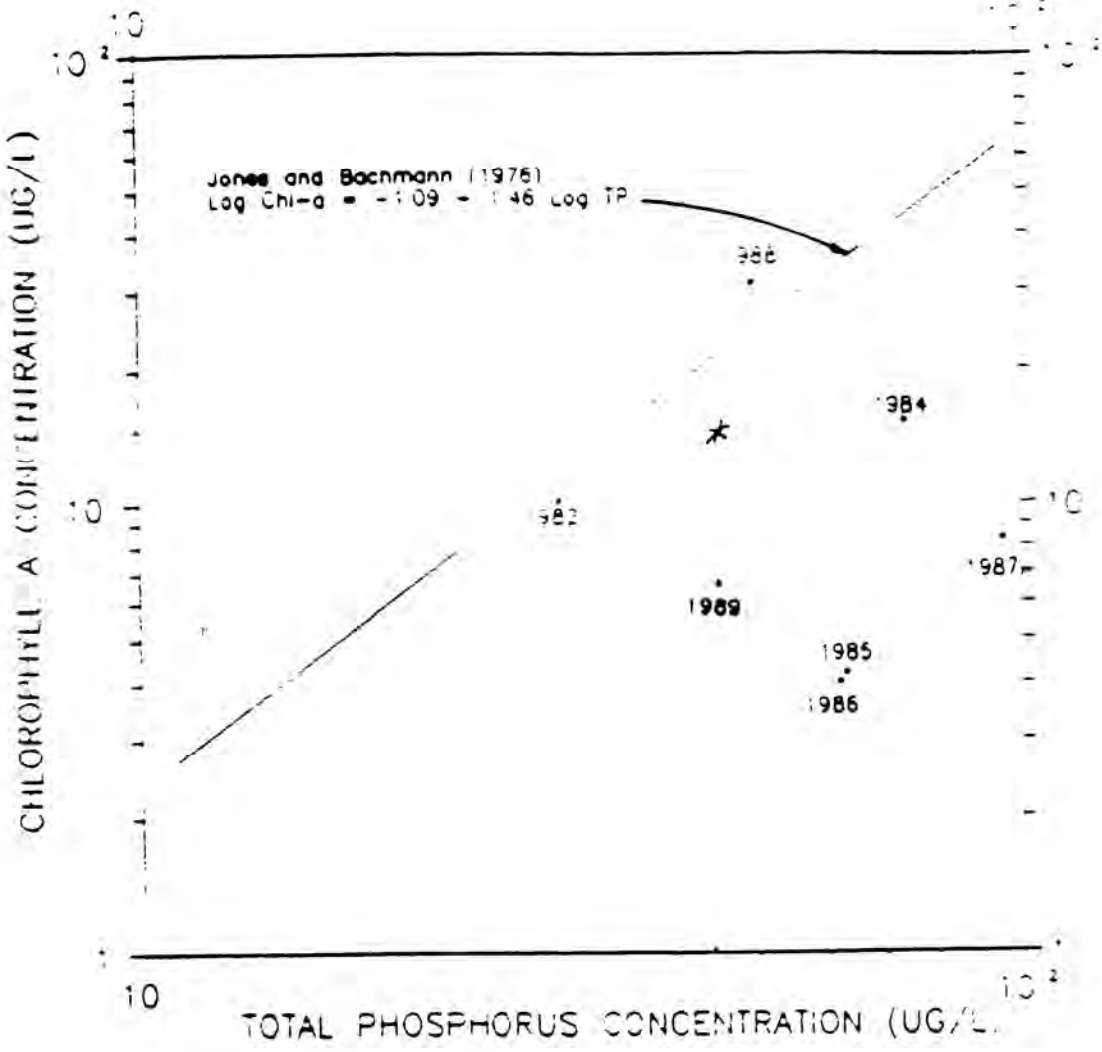
3. **1990 Algal Blooms and Species.**

Blue-green algae were numerically dominant throughout the 1989 water year in Cherry Creek Reservoir. However, the density (cells/mL) alone does not indicate the importance of a species in the algal community. Cell size varies greatly among the algal genera.

Throughout most of the 1989 water year, the blue-green algal community was comprised of genera with relatively small cell volume. The green algal genera had cell volumes equal to or much larger than the more numerous blue-green algae. Therefore, the algal biomass as measured by volume in Cherry Creek Reservoir during 1989 was dominated by green algae.

Another measure of algal biomass is chlorophyll a. Chlorophyll a per unit volume varies among the algal divisions. Although the green algae and euglenoids have the highest amount per unit volume, the coccoidal blue-green algae have the lowest. Even though the coccoidal blue-green algae numerically dominated the phytoplankton of Cherry Creek Reservoir during the 1989 water year, the green algae

FIGURE 3



JULY-THROUGH-SEPTEMBER VALUES OF CHLOROPHYLL-a vs. TOTAL PHOSPHORUS

CHERRY CREEK RESERVOIR 1984 - 1989

were the greatest contributors to the algal biomass as measured by chlorophyll a.

Chlorophyll a content also differs among species within a division and is affected by cell volume and physiological status such as age, nutrient supply and illumination. These variables probably attributed to the relatively lower chlorophyll a values in 1989 was compared to 1988 chlorophyll a. Most of the 1989 algal density was comprised of small blue-green algae. The larger heterocystic blue-green algae were absent or had lower populations in 1989 than in 1988. Also, the numerically dominant green algae in 1989 was Kirchneriella lunaris. Larger green algae were more prevalent in previous water years.

Changes in chlorophyll a values vary seasonally as well as annually. Environmental factors which contribute to these variations include day length, solar radiation, absorption and scattering, temperature, and nutrient availability.

Secchi depths during the year probably were influenced by a combination of algal biomass and suspended solids. The relationship between each factor and the relatively shallow secchi depths measured in the Reservoir during 1989 cannot be determined. Therefore, mean Secchi depth would not be, by itself, an indicator of eutrophy in Cherry Creek Reservoir.

II. NONPOINT SOURCE CONTROLS AND MANAGEMENT.

A major drainage/water-quality control project for Shop Creek was constructed by the Authority and the City of Aurora in 1989. By an intergovernmental agreement between the Authority and Aurora, the parties agreed to share the costs of the Shop reek project. The Authority agreed to pay for the cost associated with water quality improvements, totalling about $464,000, and Aurora will pay for the drainage improvements of approximately $585,000. This is the first major basin project, as outlined in the Master Plan, to be constructed. The Authority considers it to be a prototype pilot project.

Water quality in Shop Creek should be improved by controlling in-channel erosion and settling out urban related stormwater sediments in the detention pond. The Shop Creek project has a detention pond, followed by rapid infiltration utilizing a sand filter. After filtration, the water will flow into a wetlands area. The wetlands were constructed to provide additional phosphorus removal. This project has a goal of removing a minimum of 50 percent of the phosphorus loading transported by Shop Creek, in order to improve the quality of Cherry Creek Reservoir.

The Shop Creek Project is more fully described as follows: The project involves improvements to a 3000-foot long reach of Shop Creek between Parker Road and the Perimeter Road around Cherry Creek Reservoir. The project includes a detention pond containing a permanent pool with a volume of 4-acre feet and a storm flow detention volume of 8-acre feet. The detention pond dam was constructed of a natural appearing soil cement mixture and will detain and then slowly release storm runoff downstream into Shop Creek. This flow detention process will allow for the settling out of sediments. Total phosphorus will be removed from the permanent pool, fed by base flows, and from the stormflow pool. The stream channel between the pond and the Reservoir Perimeter Road (downstream) was stabilized by the construction of five drop structures constructed in oval shapes with soil cement. The channel between each set of structures is relatively flat-sloped, promoting slow moving, braided stream channels and pools which were planted with suitable wetland species. The channel below the pool should have a stable flow regime, so the wetlands will remove additional phosphorus.

Drop structures of soil cement were constructed at the outlet of the culvert under Parker Road and on the downstream edge of a Perimeter Road to reduce channel erosion. Controlling erosion upstream will decrease the storm water runoff loads entering the Shop Creek facility.

The Shop Creek Project design received the Colorado Engineer's Design Award and won a national engineering design award. Monitoring of Shop Creek will commence in 1990 and the monitoring will evaluate the effectiveness of the project, and its components, for phosphorus removal.

A. Reductions of Phosphorus Loadings From Storms at Detention Ponds.

1. Inverness Pond No. 4.

The Inverness Pond is in the Inverness Business Park (near the intersection of Interstate 25 and County Line Road). The Pond is located on Cottonwood Creek, a major tributary to Cherry Creek Reservoir and is upstream from a tributary-inflow monitoring site. This Pond was created as an aesthetic amenity for a golf course (not as a storm runoff detention facility). It has a contributing drainage area of approximately 2620 acres, a volume of about 6.5 acre feet, a surface area of about 1.6 acres, and a mean depth of 4 feet. Inflow and outflow monitoring sites for the Pond were monitored. Data at this Pond were collected during the 1989 water year only for a 4-month period (October 1988 through January 1989). Only two storm events were sampled; runoff volumes from these storms were relatively small. Based upon regression functions relating nutrient

concentrations to streamflows at each monitoring site, daily loadings of total phosphorus and of total nitrogen were computed for the 4-month period of streamflow data collection at the Inverness Pond. The first four months of the 1989 water year indicate typically low total phosphorus inflows and corresponding low outflows at the Inverness Pond.

For the Inverness Pond on an annual basis, the effectiveness of phosphorus removal was reversed for the 4-month period of the 1989 water year. In other words, a slightly greater total phosphorus loading was released from the Pond than was contributed by the two pond inflows. The increase in phosphorus outflows could have been contributed from phosphorus in the Pond and its bottom sediments. In comparison, phosphorus removal efficiencies for the Inverness Pond were 15 percent for the 8 month monitoring period during 1987 and 20 percent for 1988. 1987 and 1988 had numerous storms and, subsequently, relatively higher flows. For the entire period of record for Inverness Pond (May 1987 through January 1989), the average total phosphorus removal rate was about 20 percent, based upon the monthly values.

The Authority determined in 1989, with the advise of its consultants, that adequate data had been collected to determine the phosphorus removal efficiency of the Inverness Pond and other similar structures. The Authority decided not to conduct additional monitoring of the Inverness Pond.

2. Clarke Farms Pond No. 3.

This Pond is in the Clarke Farms residential development, located along Jordan Road south of Lincoln Avenue (in the Town of Parker). The Pond is adjacent to Cherry Creek, a major tributary to Cherry Creek Reservoir and is upstream from another tributary inflow monitoring site. This Pond was created specifically for detention of storm runoff. It has a contributing drainage area of approximately 290 acres, a volume of about 20 acre feet, a surface area of about 4.3 acres, and a mean depth of 4.7 feet. Inflow and outflow sites were monitored. Field instrumentation at this Pond included two inflow sites and one outflow site; however, the outflow consisted of a perforated PVC standpipe permitting relatively slow drainage of storm runoff collected in the Pond. Also, a major part of the detained runoff percolated through the bottom of the Clark Farms Pond. In order to sample the percolating water, three wells were augured near the Pond bottom.

In general, flows during the 1989 water year were substantially less than flows during either the 1987 or 1988

water years. A total of ten storm events were sampled and the runoff volumes from these storms were small compared to the larger storm events encountered during the 1988 water year.

The Clarke Farms Pond continues to show relatively high total phosphorus removal rates because of the small direct discharges through the water quality stand pipe and the large amount of leakage to the nearby Cherry Creek alluvium. Total phosphorus removal rates for the April through September period during 1989 averaged over 75%, compared to over 74 percent for the same period in 1988. The consistency in total phosphorus removal at the Clarke Farms Pond is reflected in a total phosphorus removal rate of about 72 percent during the October 1987 through September 1989 period of record.

B. **Best Management Practices.**

The primary methods established to date for the control of nonpoint source pollution are best management practices (BMPs), designed to prevent erosion and pollution from new developing areas and along stream channels. Several land use entities in the Cherry Creek Basin (including the Towns of Castle Rock and Parker, the City of Aurora, Greenwood Village, and Arapahoe County) have all enacted BMP ordinances that require hay bales, rock drains, and other facilities to minimize sediment laden runoff flows from discharging to Cherry Creek tributaries. Therefore, all development within these land use entities have included these erosion control measures. Douglas County, the other major government with land use jurisdiction within the basin, has a draft BMP ordinance under consideration. These BMPs are thought to provide the substantial controls and reductions of phosphorus loadings into the Cherry Creek Reservoir.

Major projects in the basin in 1989 included construction of E-470 and State Highway 83. The Authority has specifically requested that the entities responsible for construction of these highways require their contractors to use best management practices.

C. **Septic (On-Site Sewage Disposal) Systems.**

On August 8, 1988, Tri-County entered into a contract with the Authority to perform Phase II of the septic study. The septic study has actually measured phosphorus concentrations from two septic systems in the Cherry Creek Basin. For the Master Plan, DRCOG assumed that septic leachate would have a phosphorus concentration of 0.058 mg/l phosphorus. Preliminary reports by Tri-County Health indicate that the septic system have reduced the phosphorus concentration in the effluent form 95% to 98%.

The samples are taken below the leachfields. Continued monitoring is necessary to verify phosphorus removals.

Tri-County Health has coordinated with the counties to require developments planning septic systems to establish septic management agencies. The septic management requires regular inspections of septic systems, pumping of the systems and replacements of defective or malfunctioning systems.

III. PUBLICATIONS

In 1989, the Authority produced a short video pertaining to the Cherry Creek Reservoir. The video discusses the eutrophication of the Reservoir and methods for reducing nutrient loads to the Reservoir. Copies of the video have been distributed. Representatives of the Authority have made presentations, utilizing this video to civic groups, homeowners associations and schools.

The Authority designed and printed decals for the Cherry Creek Reservoir passes. An informational brochure pertaining to Cherry Creek Reservoir and the Authority was prepared, printed and distributed to Cherry Creek Reservoir users and Basin residents. (copy enclosed)

IV. OPERATIONS AND FINANCES.

In 1989, the Authority collected revenue from several sources. The Authority adopted the following, which were collected in 1989:

1. Property Taxes. A .5 mill levy assessed on all properties in Arapahoe and Douglas County which are within the Cherry Creek Basin.

2. Wastewater Surcharge. A fee of 5 cents per 1,000 gallons of wastewater treated and discharged by each wastewater treatment plant written the Cherry Creek Basin.

3. Building Permit Fee and Grading Fee. Fees on grading and/or construction within the Cherry Creek Basin, as follows:

   (a) $280.00 per acre; or
   (b) $50.00 per residential unit; and
   (c) $.03 per square foot on business, all nonresidential buildings and all impervious surface areas.

Cherry Creek Basin Water Quality Authority

STATEMENT OF REVENUES, EXPENDITURES, AND CHANGES IN FUND BALANCES - BUDGET AND ACTUAL
GENERAL FUND

Year Ended December 31, 1989

	Budget	Actual	Variance Favorable (Unfavorable)
REVENUES			
Wastewater surcharge	$ 24,000	$ 15,720	$ (8,280)
Building permit fee	10,000	37,864	27,864
Property taxes	371,228	352,865	(18,363)
Specific ownership taxes	-	22,228	22,228
Recreation fee surcharge	100,000	159,630	59,630
Grading fee	-	12,515	12,515
Interest earnings	12,500	14,236	1,736
Total revenues	517,728	615,058	97,330
EXPENDITURES			
Accounting and auditing	7,800	5,526	2,274
Printing and publications	14,000	12,190	1,810
Consulting fees	12,500	22,523	(10,023)
District management	40,000	40,300	(300)
Insurance	6,500	6,770	(270)
Legal expense	19,500	43,584	(24,084)
Miscellaneous expense	250	226	24
Monitoring equipment	7,000	6,790	210
Monitoring expense	50,000	53,442	(53,192)
Public information program	-	35,160	(35,160)
Shop Creek Cost-Sharing Agreement - City of Aurora	118,553	150,000	(31,447)
Treasurer's fees	-	7,153	(7,153)
Septic tank study	20,000	-	20,000
Contingency	281,625	-	281,625
Total expenditures	577,728	383,664	144,314
Excess (deficiency) of revenues over expenditures	(60,000)	231,394	241,644
Fund balance - January 1, 1989	60,000	61,656	1,656
Fund balance - December 31, 1989	$ -	$ 293,050	$ 293,050

The Notes to Financial Statements
are an integral part of this statement.

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CHERRY CREEK BASIN WATER QUALITY AUTHORITY

1990 ANNUAL REPORT

CHERRY CREEK BASIN

WATER QUALITY AUTHORITY

Annual Report

Authority Members:

Arapahoe County
Arapahoe Water and Wastewater Authority
City of Aurora
Cottonwood Water & Sanitation District
Denver Southeast Suburban Water & Sanitation District
Douglas County
City of Greenwood Village
Inverness Water & Sanitation District
Meridian Metropolitan District
Parker Water & Sanitation District
Stonegate Center Metropolitan District
Town of Castle Rock
Town of Parker

Cherry Creek Basin Water Quality Authority
6200 South Syracuse Way
Suite 150, Carrara Place
Englewood, CO 80111

Substantial portions of this Annual Report were excerpted or derived from "The Cherry Creek Basin Annual Water - Quality Monitoring Report - 1990 Water Year" ASI, 1991.

INDEX

Page

CHERRY CREEK BASIN WATER QUALITY AUTHORITY
1990 ANNUAL REPORT SUMMARY

CHERRY CREEK BASIN WATER QUALITY AUTHORITY
1990 ANNUAL REPORT

CHERRY CREEK BASIN WATER QUALITY AUTHORITY
1990 ANNUAL REPORT SUMMARY

Executive Summary

In 1984 the Colorado Water Quality Control Commission established a standard of 0.035 mg/l phosphorus for Cherry Creek Reservoir so that chlorophyll a levels in the Reservoir would not exceed 15 ug/l.

The Cherry Creek Basin Water Quality Authority ("Authority") is the 208 management agency for the Cherry Creek Basin ("Basin"). The Authority operates pursuant to special legislation, which created and authorized the Authority. See Section 25-8.5-101, et seq., C.R.S. The Authority also carries out special responsibilities for the Cherry Creek Basin, as provided by the Water Quality Control Commission. See 5 C.C.R. 1002-19 (1985). The Authority oversees the point source and nonpoint discharges in the Basin, conducts water quality monitoring and is implementing plans to improve the water quality of the Basin. This is a summary of the Authority's 1990 activities pursuant to its plans and regulations.

Construction of Shop Creek Drainage/Water Quality Control Project.

The Authority, in cooperation with the City of Aurora, constructed the Shop Creek Project. The Master Plan (1985) reflected that Shop Creek was the major contributor of nonpoint source phosphorus loads to the Reservoir. The Shop Creek Project, consisting of channel stabilization and a detention facility with infiltration followed by a series of wetlands, was constructed in 1989. The Authority established three monitoring sites in 1990 to monitor the effectiveness of the Shop Creek Project. Those sites were upstream of the project, below the detention pond and downstream of the wetlands. The Authority is monitoring the Shop Creek Project to determine its effectiveness for nonpoint source phosphorus removal. Additional monitoring of the Shop Creek project was undertaken to determine removal of efficiencies of other nonpoint source constituents, which is being funded by the Urban Drainage and Flood Control District.

Best Management Practices and NonPoint Source Control.

The Authority has recommended that each land use government within the basin adopt and enforce best management practices. The best management practices are designed to control nonpoint source pollution and erosion during construction, grading, and other activities which disturb the soil.

Each city and county, on behalf of the Authority, is collecting the Grading/Building Permit fees adopted by the Authority in 1989, at the time of building permit issuance.

The nonpoint source loadings from the four tributary inflows were monitored and modeled, to estimate that total 1990 loadings to Cherry Creek Reservoir were 1,230 pounds of total phosphorus and 11,390 pounds of total nitrogen. The phosphorus load is substantially lower than phosphorus loads of 10,770 pounds, estimated by EPA as average for the Basin and the 5,100 pounds reported in 1989. The Master Plan and Control Regulation allocate 10,290 pounds of phosphorus for nonpoint sources, an allocation that assumed that 50% of the nonpoint source load had been contained. Although the Authority cannot accurately measure the amount of nonpoint source load that is mobilized because best management practices prevent the typical erosion and runoff, these practices are probably a factor in the reduced phosphorus loads. The 1990 water year showed lower water inflows than 1989. The inflows in 1990 were lower than EPA's predicted average water inflow to Cherry Creek Reservoir, and the phosphorus loads were approximately 11% of EPA's forecasted loadings.

In-Reservoir Control Options.

The Authority continued an evaluation of the in-reservoir control strategies. The in-reservoir phosphorus is combined within the water column as resuspendible bottom sediments containing phosphorus mix with the water. These existing phosphorus loads within the Reservoir are substantial and can support algae growth in excess of the chlorophyll a goal. Based upon studies completed for the Authority, the Authority selected the following three in-reservoir control strategies for pilot studies and further consideration: dredging, alum addition and construction of wetlands at the Cherry Creek inflow to the Reservoir. The Authority's 1990 reservoir monitoring program monitored the type of algae species present.

Point Sources.

The Master Plan and Control Regulation allocated a total of 2,310 pounds of phosphorus to point source dischargers. The Authority submitted a request to the Water Quality Control Commission to modify the effluent limitations from 0.05 mg/l to 0.2 mg/l phosphorus. In 1990, the Division issued compliance schedules to Cottonwood Water and Sanitation District and Arapahoe Water and Waste Water Authority, for phosphorus discharges. Cottonwood was granted a temporary permit modification to discharge at 0.2 mg/l, not to exceed their wasteload allocation of 213 pounds of phosphorus per year. Arapahoe has applied to the State for a facilities planning grant to develop plans for new facilities. Denver Southeast has completed construction of a 1.0 MGD advanced wastewater treatment plant, scheduled to be in operation during 1991. Phosphorus contributions from point source dischargers totalled 8,012.86 pounds in 1990; however, 6,738.80 pounds were from one discharger.

Each discharger in the basin is assessed a fee by the Authority of $.05 per 1,000 gallons of sewerage discharged.

Master Plan Update.

In 1989, the Authority prepared an Update to the Master Plan. The Update contains new hydrologic data for Cherry Creek Reservoir and the groundwaters tributary to the Reservoir. The Update includes a discussion of in-reservoir treatment technologies. The control strategies termed as "in-reservoir" include dredging, alum treatments and construction of upstream wetlands. Pilot projects to test the feasibility and effectiveness of these control strategies are outlined.

The Master Plan Update was approved in 1990 by the Denver Regional Council of Governments (DRCOG), the designated the 208 planning agency, and the Water Quality Control Commission. The Master Plan Update has been incorporated into the DRCOG Clean Water Plan.

1990 Monitoring Program.

In 1990, the Authority monitored: 1) the Reservoir water quality and quantity, 2) the quality of inflows to the Reservoir, including storm water flows, and 3) the effectiveness of water quality detention ponds. The following are general findings of the 1990 monitoring:

(a) The number of storms and magnitudes of the 1990 storms in the Cherry Creek Basin was slightly greater than those observed during 1989, but fewer and less than those observed in 1987 and 1988.

(b) The total phosphorus removal rates for the Clarke Farms detention pond averaged 72%. The removal rate for the new Shop Creek Pond was approximately 40%, and the wetlands downstream from the Shop Creek Pond removed an additional 57% of the phosphorus from the pond outflow. The total phosphorus removal for the first year of operation of the Shop Creek Project was approximately 74%.

(c) The growing season (July through September 1990) average concentration of total phosphorus in Cherry Creek Reservoir was 0.059 mg/1 and chlorophyll a averaged 8.6 ug/1. A yearly comparison shows:

Year	Phosphorus	Chlorophyll-a
(Adopted Standard/Goal)	.035 mg/l	15 ug/l
1982	.030 mg/l	10.7 ug/l
1984	.074 mg/l	15.3 ug/l
1985	.063 mg/l	4.2 ug/l
1986	.062 mg/l	4.0 ug/l
1987	.095 mg/l	8.3 ug/l
1988	.050 mg/l	32 ug/l
1989	.045 mg/l	5.6 ug/l
1990	.059 mg/l	8.6 ug/l

(d) Total nonpoint source loads to the Reservoir were 1,230 pounds of phosphorus and 11,390 pounds of nitrogen.

CHERRY CREEK BASIN WATER QUALITY AUTHORITY
1990 ANNUAL REPORT

Background

The Clean Lakes Study of Cherry Creek Reservoir conducted in 1982 identified that euthrophication of the Reservoir could negatively impact the beneficial uses of the Reservoir (DRCOG, 1984). The Clean Lakes Study identified phosphorus as the major nutrient causing algal productivity and that euthrophication. Based on the Clean Lakes Study, the Colorado Water Quality Control Commission (CWQCC) established an in-reservoir total phosphorus standard of 0.035 mg/l to maintain the chlorophyll a levels in Cherry Creek Reservoir at concentrations no higher than 15 ug/l (0.015 mg/l) as an average for the "growing season" (that is, during the months of July through September).

During 1985, the local governments (cities and counties and special districts), private interests, and representatives of the State and Federal Government developed a strategy to meet the Reservoir growing-season phosphorus standard and chlorophyll a goal. The control strategy was outlined in the Cherry Creek Basin Water Quality Management Master Plan (DRCOG, 1985a; 1985b).

The Cherry Creek Basin Master Plan was approved by the Colorado Water Quality Control Commission in 1985. Portions of the plan were adopted as the "Regulations for Control of Water Quality in Cherry Creek Reservoir" (Section 4.2.0, 5 C.C.R. 3.8.11), and effective December 30, 1985. The Master Plan was approved by the USEPA Region VIII office as the 208 Management Plan for the Cherry Creek Basin.

In 1985, an intergovernmental agreement was executed by the local governments within the Cherry Creek Basin, forming the Cherry Creek Basin Authority (Authority). The Authority was created to develop and implement the means to protect the water quality of Cherry Creek, while allowing economic development to occur.

In 1987, the Colorado Legislature's Water and Water Quality Subcommittee conducted hearings on several matters, including legislation to create a water quality management agency for the Cherry Creek Basin. That Subcommittee introduced legislation to the 1988 General Assembly which statutorily created and empowered the Cherry Creek Basin Water Quality Authority; it was approved by the House and Senate and signed by Governor Romer. See C.R.S. § 25-8.5-101, et seq.)

Purpose of the Annual Report

The primary purpose of the 1990 Annual Report Summary is to inform the Colorado Water Quality Control Commission (CWQCC) of the Authority's progress in implementing the Master Plan during 1990. Also, the "Regulations for Control of Water Quality in Cherry Creek Reservoir" (Section 4.2.8, 5 C.C.R. 1002-19) require that an annual report on the activities of the Authority and, particularly phosphorus control strategies, be submitted. The purpose of this 1990 Annual Report Summary is to fulfill those requirements.

I. 1990 LOADINGS, WATER QUALITY AND FLOW INFORMATION.

A. Point Sources.

1. 1990 Annual Loadings.

The "Regulations for Control of Water Quality in Cherry Creek Reservoir" established annual phosphorus allocations for each wastewater treatment plant in the Cherry Creek Basin. The phosphorus allocated to each plant was expected to be adequate for the wastewater treatment plant's 1985 capacity plus the next incremental expansion for the plant. The Master Plan and Control Regulations also set maximum phosphorus concentrations for dischargers of 0.1 mg/l for October through March and 0.05 mg/l for April through September, of each year.

The Master Plan designates the type of wastewater treatment for each facility. In 1990, three dischargers were using secondary treatment followed by rapid infiltration and four dischargers were using secondary treatment with slow rate land application. Denver Southeast Suburban Water & Sanitation District, one of the three dischargers using rapid infiltration, completed construction of an advanced waste treatment facility, expected to be operational in 1991. The NPDES permits for the dischargers generally require monitoring of the phosphorus discharged. Dischargers utilizing rapid infiltration have established monitoring wells below their infiltration ponds and downgradient of the ponds to monitor phosphorus concentrations.

In order to monitor phosphorus concentrations from the slow rate land application sites, the dischargers have installed vacuum lysimeters below their land application areas in order to withdraw leachate samples for phosphorus analyses. However, those dischargers applying effluent at agronomic rates frequently do not report any leachate in the

lysimeters. It is assumed that the effluent is fully utilized by the plants and evapotranspiration.

Ideally, the actual phosphorus loading occurring in the basin from point source dischargers would be calculated using the phosphorus levels detected in the samples obtained from the land application or rapid infiltration monitoring sites minus background levels. Soils in the basin commonly contain significant amounts of phosphorus, so phosphorus may be leached from the soil during watering. The Authority is coordinating with its members and the Division so that phosphorus within the soil and groundwater will not be included as part of the sample results reported pursuant to an NPDES permit. The present loading calculations include background phosphorus.

Estimated phosphorus loadings from the existing and operating treatment facilities were derived by the Water Quality Control Division from the dischargers' monthly reports. Table 1 presents the calculated phosphorus loadings for each wastewater treatment plant, discharging during 1990. The phosphorus allocations for each wastewater treatment plant are shown also.

TABLE 1

POINT SOURCE PHOSPHORUS LOADINGS IN THE CHERRY CREEK BASIN
1990 Water Year

Wastewater Facility	1990 (1) Wastewater Phosphorus Concentration Mg/l	1990 (1) Phosphorus Loading (lbs/yr)	Allocated (3) Phosphorus Loading (lbs/yr)
Discharging Plants:			
Arapahoe	0.57	643.70	354
Cottonwood	0.79	385.26	213
Denver Southeast	5.15	6,738.80	365 (2)
Inverness	0.00(4)	0	68
Meridian	0.00(4)	0	114
Parker	0.21	245.11	533
Stonegate	0.00(4)	0	53
Plants Not Discharging:			
Castle Rock (Cherry)		0	0 21
Castle Rock (McMurdo)	0	0	64
Castle Rock (Newlin)	0	0	86
Rampart Range	0	0	160
Castle Rock (Mitchell)	0	0	128
Totals	6.72	8012.87	2,159

1) Flows and phosphorus loading for 1990 were calculated by the Water Quality Control Division from each discharger's monthly report and revised or verified by each discharger.
2) The facility at Denver Southeast Suburban Water and Sanitation District was allocated up to 365 pounds (lbs) of phosphorus annually. The 365 lb phosphorus allocation is temporary and will be reduced to 213 lbs of phosphorus in 1991 or when Denver Southeast completes construction of a final build-out 1.4 MGD facility, whichever occurs first. The size of Denver Southeast's facility has been reduced to a 1.0 MGD facility.
3) Section 4.2.4(1), 5 C.C.R. 1002-19.
4) The facilities at Inverness, Meridian and Stonegate use slow rate land application and have not reported any leachate in their lysimeters.

The Authority is responsible for reviewing all site applications, compliance schedules and special permits for wastewater treatment plants to ensure the plants comply with the Cherry Creek Basin Master Plan. The Authority has a technical review committee which reviews each application and recommends point source and nonpoint source controls, as appropriate, to the Authority. The following actions were taken by the Authority regarding point source discharges:

(a) Cottonwood Water and Sanitation District requested temporary modification for its discharge permit, to allow discharges with a phosphorus concentration of 0.2 mg/l rather than 0.05 mg/l. Cottonwood's engineers provided information that discharges by Cottonwood at 0.2 mg/l would not result in exceedences of Cottonwood's phosphorus wasteload allocation.

(b) Arapahoe Water and Wastewater Authority applied to the State of Colorado for a facilities planning grant to construct additional facilities which are needed to meet the phosphorus requirements. The Authority endorsed the application.

(c) Denver Southeast Suburban Water and Sanitation requested a reduction in the size of their new AWT plant from 1.4 MGD to 1.0 MGD. The Authority recommended that the reduction be approved.

(d) Denver Southeast Suburban Water Sanitation financed construction of their new wastewater treatment plant with a loan from the State of Colorado. As the local 208 Management Agency, the Authority participated in the administration of the loan.

(e) Parker Water and Sanitation District requested a site approval amendment to increase their land application area onto 57 acres of a regional park. The Authority recommended approval of the site application amendment.

(f) The Authority also commented on subdivision applications and requests for 401 and 404 permits. The Authority's comments primarily required such projects to implement best management practices.

B. Nutrient Inflow Characteristics from Reservoir Tributaries and Precipitation.

1. 1990 Loadings.

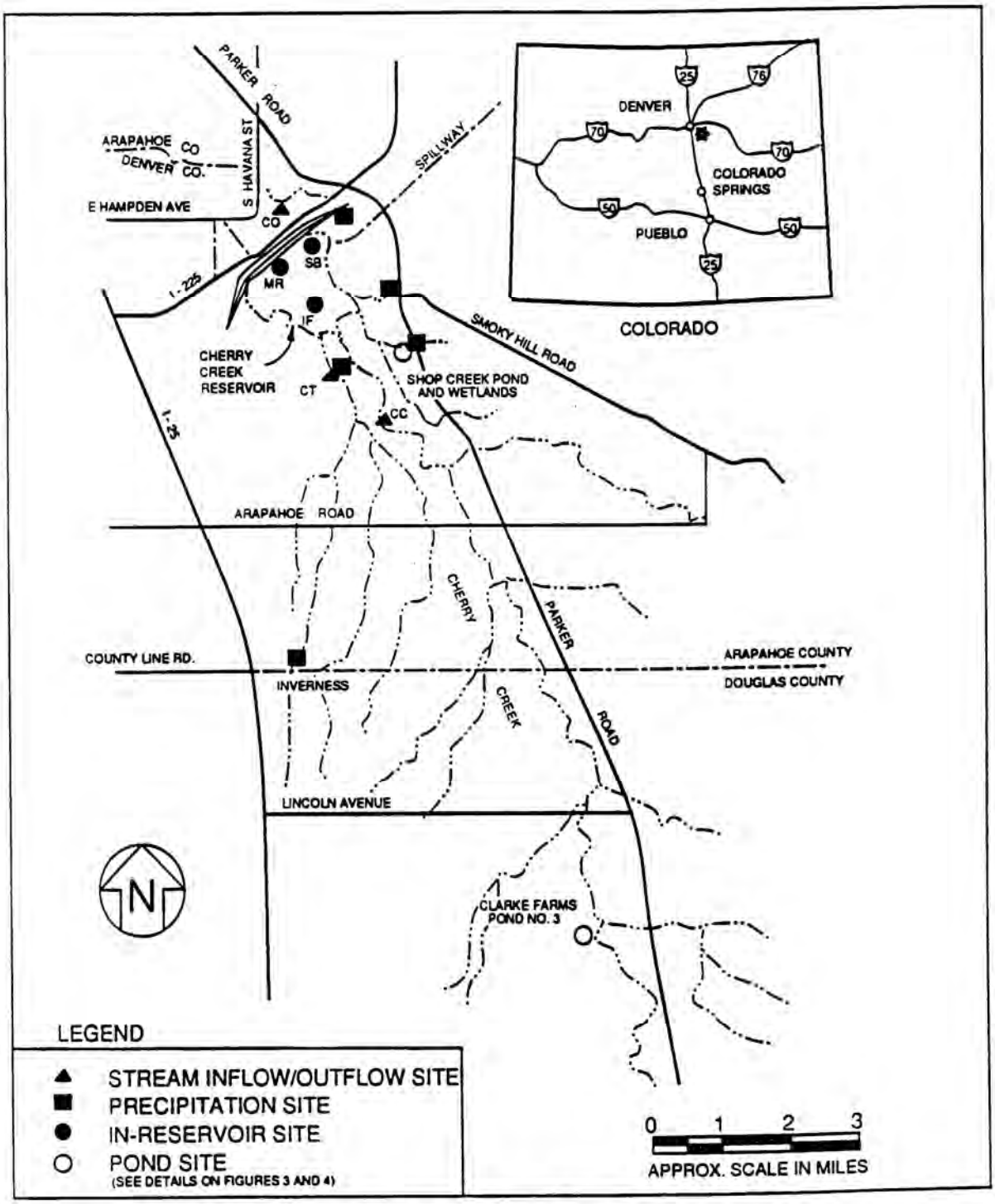
The locations for water quality monitoring in the Cherry Creek Basin are shown on Figure 1. The storm event and ambient water quality analyses for 1990 at the Reservoir inflow and outflow sites were modeled and the regression summaries relating concentrations of nutrients with streamflow were updated. These updated regression analyses were applied using the appropriate daily streamflow record to generate daily loadings total phosphorus and total nitrogen. The tributary inflows to Cherry Creek Reservoir from the three inflow monitoring sites totalled about 1,580 acre feet for the April through September period of streamflow records collected during 1990, as compared to 5,880 acre feet from four sites monitored for ten months in 1989. Reservoir outflow for the April through September water year period, based upon records by the U.S. Army Corps of Engineers, totalled about 1,760 acre feet, and measured by the U.S. Geological Survey (USGS) totalled about 1,380 acre feet. The imbalance between inflows and outflows is due to the unmeasured evaporation losses and leakage from the Reservoir, as well as the change in storage in the Reservoir.

For 1990, the aggregate nutrient loadings to Cherry Creek Reservoir from the three tributary inflow sites totalled an estimated 1,230 pounds of phosphorus and 11,390 pounds of nitrogen, respectively, based upon the daily loading calculations. Outflow nutrient loadings were about 540 pounds of total phosphorus and about 5,690 pounds of total nitrogen. The difference between the nutrient inflows and outflows results from the reduced Reservoir releases.

2. Comparison to Previous Loadings.

The loadings for the April through September 1990 period can be compared to the 1982 Clean Lakes Study estimates (DRCOG, 1983; 1984) and those estimated by the USEPA (1977) for "average year" inflows. (See Table 2.)

FIGURE 1



GENERAL MONITORING-PROGRAM
SAMPLING LOCATIONS

Project No. 970

CHERRY CREEK BASIN
MONITORING PROGRAM

Figure No. 1

TABLE 2

NUTRIENT LOADINGS, 1990

Source	Year	Inflows	Total Phosphorus	Total Nitrogen
DRCOG	1982	650 ac-ft	2620 lbs	n/a
USEPA	"avg."	3190 ac-ft	10,770 lbs	29,890 lbs
In-Situ	1988	4590 ac-ft	5650 lbs	37,500 lbs
ASI	1989	3250 ac-ft	2570 lbs	22,480 lbs
ASI	1990	1580 ac-ft	1230 lbs	11,390 lbs

Bulk precipitation falling on Cherry Creek Reservoir has been identified as a contributor of phosphorus. Three bulk samplers collected both wet and dry precipitation from the atmosphere. During 1990, an estimated 15.2 inches of precipitation fell directly on the Reservoir. The average total phosphorus concentration of the precipitation was 0.65 mg/l, compared to 0.47 mg/l in 1987, 0.42 mg/l in 1988, and 0.30 mg/l in 1989. For 1990, the phosphorus loading by precipitation to the Reservoir surface area of 850 acres was an estimated 1,900 pounds of total phosphorus. This compared with 690 pounds estimated by DRCOG (1983), 120 pounds estimated by USEPA (1979), 1880 pounds estimated by In-Situ, Inc. (1989) for 1988, and 750 pounds estimated by ASI for 1989.

Total 1990 phosphorus and nitrogen concentrations were generally less than or equal to those for previous years (1987, 1988 and 1989) for all sites. The Cherry Creek and Cottonwood inflow sites had total phosphorus loadings similar to those in 1989. The Shop Creek inflow site showed substantially less total phosphorus loadings, because of the newly constructed Shop Creek Pond/Wetlands Project.

Time series plots of total phosphorus and total nitrogen loads at the three Cherry Creek inflow sites indicates that the 1990 period was characterized by lower loadings of total phosphorus and total nitrogen, because of the relatively small releases by the USACOE.

C. In-Reservoir Water Quality.

1. 1990 In-Reservoir Concentrations.

Three sites in Cherry Creek Reservoir have been sampled to assess temporal as well as spatial changes in water quality and biological conditions - one site each in the main body, the swim beach, and the Cherry Creek inflow areas. (See Figure 2.) All in-reservoir sampling surveys for 1990 were conducted by boat during open-water conditions. At each Reservoir sampling site, two sets of water quality samples are collected each time; one set is obtained from the middle of the euphotic zone (the depth is estimated in the field using a secchi disk) and a second set is obtained near the Reservoir bottom (1 to 1-1/2 feet above the Reservoir bottom).

Total phosphorus concentrations for the 1990 water year in the Reservoir at all three locations, and for both sampled depths, averaged about 0.058 mg/1. The average growing season (July through September) total phosphorus concentration averaged 0.059 mg/1, above the phosphorus standard of 0.035 mg/1. Seasonal concentrations of total phosphorus were above the standard for the 1990 water year sampling period. The growing season chlorophyll a concentrations during 1990 averaged 8.6 ug/1, which is substantially below the established goal of 15 ug/1.

Total nitrogen concentrations for 1990 in the Reservoir averaged 0.6 mg/1.

2. Phosphorus/Chlorophyll-a Relationships.

The average 1990 total phosphorus concentration during the growing season of 0.059 mg/1 in the Reservoir was lower than average growing season phosphorus concentrations in 1987 and 1988 (0.095 mg/1 and 0.060 mg/1, respectively), but higher than in 1989 (0.045 mg/1). Also, in-reservoir total nitrogen concentrations during the 1990 water year were 0.6 mg, less than the 0.78 mg/1 average for the 1989 water year, the 0.85 mg/1 average for the 1988 water year, and the 1.45 mg/1 average for 1987. Chlorophyll-a values for the 1990 growing season averaged 8.6 ug/1 compared to, 1989, 1988 and 1987 values of 5.6 ug/1, 32 ug/1 and 8.3 ug/1, respectively.

The Clean Lakes Study utilized the Jones/Bachman model (1976) to predict the relationship between phosphorus and chlorophyll a in the Reservoir. The Jones/Bachman model predicted that an in-reservoir concentration of 0.035 mg/1 phosphorus would result in a chlorophyll a concentration of 15 ug/1. Although the 1990 (growing season) average

phosphorus concentration of 0.059 mg/l exceeded the standard, the resulting chlorophyll a concentration in the Reservoir of 8.6 ug/l was substantially below the chlorophyll a goal of 15 ug/l.

The phosphorus and chlorophyll a values for Cherry Creek Reservoir for the years of monitoring are as follows on Table 3:

TABLE 3

COMPARISON OF PHOSPHORUS AND CHLOROPHYLL-a VALUES 1982-1990

Year	Phosphorus	Chlorophyll-a
(Adopted Standard/Goal)	.035 mg/l	15 ug/l
1982	.030 mg/l	10.7 ug/l
1984	.074 mg/l	15.3 ug/l
1985	.063 mg/l	4.2 ug/l
1986	.062 mg/l	4.0 ug/l
1987	.095 mg/l	8.3 ug/l
1988	.050 mg/l	32 ug/l
1989	.045 mg/l	5.6 ug/l
1990	.059 mg/l	8.6 ug/l

Also, Figure 3 depicts the chlorophyll a and phosphorus relationships for Cherry Creek Reservoir for 1982, 1984, 1985, 1986, 1987, 1988, 1989 and 1990 and compares those actual values to the values predicted by the Jones/Bachman model. The Jones/Bachman model did not accurately predict the phosphorus/chlorophyll a relationships for 1985, 1986, 1987 and 1988, all characterized as "wet years" - with greater than normal precipitation and, therefore, more runoff than 1982. 1989 was considered a below normal precipitation year. The 1990 chlorophyll a values are below the Jones/Bachman predictions, continuing to indicate the inadequacy of this relationship to characterize the interactions between these two variables for Cherry Creek Reservoir.

3. 1990 Algal Blooms and Species.

Blue-green algae were numerically dominant throughout the 1990 water year in Cherry Creek Reservoir. Seasonal succession of algae in temperate lakes usually follows a definite sequence, with diatoms in the spring and fall, green algae dominating in summer, and blue green algae most numerous in the late summer and early fall. Blue-green algae also tend to be present for a greater part of the growing season in eutrophic lakes. However, the density

(cells/mL) alone does not indicate the importance of a species in the algal community. Cell size varies greatly among the algal genera.

Most of the algae density during 1990 was comprised of small blue-green algae. Large heterocystic blue-green algae were absent or had lower populations in 1990, than were found in 1988 and 1989. These algae dominate the phytoplankton in eutrophic lakes when temperatures and phosphate concentrations are relatively high and nitrogen levels limit green algae growth. It has been suggested that possibly nitrogen was not limiting during the summer months of 1990. Therefore, green algae, which are favored by high temperatures and relatively large nitrogen and phosphate concentrations, were numerous in the 1990 summer and fall phytoplankton communities.

Another measure of algal biomass is chlorophyll a. Chlorophyll a per unit volume varies among the algal divisions. Although the green algae have the high counts per unit volume, the coccoidal blue-green algae have the lowest. Even though the coccoidal blue-green algae numerically dominated the phytoplankton of Cherry Creek Reservoir during the 1990 sampling season, the green algae were the greatest contributors to the algal biomass as measured by chlorophyll a.

Changes in chlorophyll a values vary seasonally as well as annually. Environmental factors which contribute to these variations include day length, solar radiation, absorption and scattering, temperature, and nutrient availability. Also, because Cherry Creek Reservoir is a relatively shallow lake, wind and boat traffic stir the sediments and cause nutrients to be released from the sediments.

Secchi depths during the 1990 water year probably were influenced by a combination of algal biomass and suspended solids. The relationship between each factor and the relatively shallow secchi depths measured in the Reservoir during 1990 cannot be determined. Therefore, mean Secchi depth would not be, by itself, an indicator of eutrophy in Cherry Creek Reservoir.

II. NONPOINT SOURCE CONTROLS AND MANAGEMENT.

A. Reductions of Phosphorus Loadings From Storms at Detention Ponds.

1. Clarke Farms Pond No. 3.

This Pond is in the Clarke Farms residential development, located along Jordan Road south of Lincoln Avenue (in the Town of Parker). The Pond is adjacent to Cherry Creek, a major tributary to Cherry Creek Reservoir and is upstream from another tributary inflow monitoring site. This Pond was created specifically for detention of storm runoff. It has a contributing drainage area of approximately 290 acres, a volume of about 20 acre feet, a surface area of about 4.3 acres, and a mean depth of 4.7 feet. Inflow and outflow sites were monitored. Field instrumentation at this Pond included two inflow sites and one outflow site; however, the outflow consisted of a perforated PVC standpipe permitting relatively slow drainage of storm runoff collected in the Pond. Also, a major part of the detained runoff percolated through the bottom of the Clark Farms Pond. In order to sample the percolating water, three wells were augured near the Pond bottom.

A total of four storm events were sampled and the runoff volumes from these storms were generally small compared to previous years' monitoring results.

Individual storm phosphorus-removal efficiencies were estimated using the concept of "regression efficiency", where rather than using an average or median value to describe the overall efficiency, regression analysis is used to obtain an overall nutrient-loading removal efficiency called a regression efficiency. The total-phosphorus regression efficiency for 15 storm events at the Clarke Farms Pond for data available between October 1987 and September 1990 indicates a phosphorus-removal regression efficiency of about 72% with a standard error estimate of 31 percent. Previous estimates of total-phosphorus removal rates using monthly averages indicated that about 26% of the April through September total phosphorus entering the Pond during the 1988 water year appeared in the outflow, and about 25% appeared in the outflow in 1989 for the same period.

2. Shop Creek Pond/Wetlands System

A major drainage/water-quality control project for Shop Creek was constructed by the Authority and the City of Aurora in 1989, and monitoring began in 1990.

The Shop Creek Pond is located West of Parker Road, South of Quincy Avenue in the City of Aurora. Shop Creek is a minor tributary to Cherry Creek Reservoir. This Pond was constructed to optimize the capture of phosphorus during storm events and to give primary attention to

trapping the fine sediments associated with suspended phosphorus. The Pond has a contributing drainage area of about 640 acres, of which 615 acres are monitored at the inflow site, a storage capacity of about 9.1 acre feet of which 4.8 acre fee is permanent (wet) storage, a surface area of about 1.8 acres, and a mean depth of 5.1 feet. Inflow and outflow sites were monitored.

A wetlands monitoring site was located about 1,400 feet downstream from the Shop Creek Pond outlet. The purpose of the wetlands is to provide entrapment of sediment, uptake of phosphorus, and to minimize washout from the wetlands of the phosphorus-rich organic humus.

A total of 13 storm events were sampled during the 1990 water year, and the resultant runoff volumes appeared to be generally small.

Based upon data from 7 storms between May and September 1990, the total phosphorus regression efficiency for the Shop Creek Pond is about 40% with a standard error of approximately 190%. The largest contributors to the standard error of estimate were the small storms with phosphorus loadings of less than 4 pounds. These small storms do not contribute significantly to the total phosphorus load. The total phosphorus regression efficiency would improve if only large storm events are measured in the future, therefore, this regression efficiency should be considered preliminary. Based upon data from 6 storms during the 1990 water year, the storm total-phosphorus regression efficiency for the Shop Creek wetlands is 57% with a standard error of 85%. The standard errors were high reflecting large variability in low data, probably because the pond and wetlands were immature and only a few storms were sampled.

The impact of detention time on removal of suspended phosphorus in the Shop Creek Pond was assessed by testing 4 inflow and 3 outflow samples. The average suspended particle settling velocity at the Shop Creek Pond inflow indicated a particle diameter of about 0.013 mm. Based upon the difference between the inflow and outflow average particle diameters, it appears that suspended particle removal is about 50% for all particle sizes. This sediment-removal percentage is not directly convertible to total-phosphorus removal because as much as 42% of the total phosphorus at Shop Creek is in dissolved form and because more phosphorus may be absorbed onto the finer suspended particles than onto the coarser suspended particles.

Trace metals at the Shop Creek Pond/Wetlands were also monitored. Concentrations of arsenic, chromium, and

cadmium were generally below laboratory detection limits, and, therefore, no removal efficiencies were calculated. Metals analyzed (Cu, Fe, Mn, Pb, and Zn) showed decreases in concentration downstream from the Shop Creek Project.

B. Best Management Practices.

The methods established for the control of nonpoint source pollution are best management practices (BMPs), designed to prevent erosion and pollution from new activities and stream channels. Several land use entities in the Cherry Creek Basin (including the Towns of Castle Rock and Parker, the City of Aurora, Greenwood Village, and Arapahoe County) have all enacted BMP ordinances that require hay bales, rock drains, and other facilities to minimize sediment laden runoff flows from discharging to Cherry Creek tributaries. Therefore, all development within these land use entities have included these erosion control measures. Douglas County, the other major government with land use jurisdiction within the basin, has adopted Chapter 70 of the Uniform Building Code which addresses erosion control measures. These BMPs are believed to provide substantial controls and reductions of phosphorus loadings into the Cherry Creek Reservoir.

Major projects in the basin in 1990 included construction of E-470 and widening of State Highway 83. The Authority has specifically required that the entities responsible for construction of these highways implement best management practices.

C. Septic (On-Site Sewage Disposal) Systems.

On August 8, 1988, Tri-County entered into a contract with the Authority to perform Phase II of the septic study. The septic study has measured actual phosphorus concentrations in the leachate from two septic systems in the Cherry Creek Basin. For the Master Plan, DRCOG assumed that septic leachate would have a phosphorus concentration of 0.058 mg/l phosphorus. Preliminary reports by Tri-County Health indicated that one septic system has reduced the phosphorus concentration in the effluent from 95% to 98%. The water quality samples were taken below the leachfields of two new septic systems which were located in different soil conditions, and results and final report are expected to be complete in spring of 1991.

Tri-County Health has coordinated with the counties to require developments planning septic systems to establish septic management agencies. The septic management requires regular inspections of septic systems, pumping of the systems and replacements of defective or malfunctioning systems.

III. IN-RESERVOIR CONTROLS

In 1990, the Authority published a feasibility plan, prepared by Camp Dresser & McKee Inc., for implementing in-reservoir phosphorus controls. The plan suggested three alternatives that may provide technical solutions for reducing the elevated phosphorus and chlorophyll-a concentrations in the Cherry Creek Reservoir. The three alternatives are construction of sedimentation ponds with wetlands; alum addition; and dredging. A brief discussion of each of these alternatives follows:

(1) Sediment Ponds with Wetlands. The construction of a sediment trap on the main stem, just upstream of the Reservoir, could be effective in removing sediments at a central location. Cherry Creek flows would pass through the sediment trap and then into a wetlands area that would provide treatment for nutrients before the flow reaches the reservoir. This alternative could be effective in removing sediments and nutrients.

(2) Alum Additions. Alum may be used to remove phosphorus from the water column during the time of major algae blooms. Alum would only be applied at selected times, not continuously. A pilot program with a limnocorral may be conducted to further ascertain the effectiveness of alum treatment.

(3) Dredging. Wet dredging, while the most difficult alternative, is potentially the most effective.

The Authority has ongoing consultations with the Corps of Engineers as well as state agencies regarding these inlake programs. Further studies and pilot projects need to be conducted before any of these programs can be implemented on a large scale.

IV. PUBLICATIONS

A. By the Authority.

In 1990, the Authority published a Feasibility Plan for Pilot Scale In-Reservoir Phosphorus Control at Cherry Creek Reservoir, prepared by Camp Dresser & McKee Inc., which developed a plan for implementing in-reservoir phosphorus controls.

The Authority also published in 1990 the Cherry Creek Basin Water Quality Management Master Plan (Revised 1989), which updated the 1985 Master Plan, and which revision was approved in 1990 by DRCOG and the Water Quality Control Commission.

B. By Others.

Steele, T. D., J. R. Kunkel, R. C. Averett, and W. F. Lorenz, 1991, Comparative Assessment of Nutrient-Biological Conditions in Selected Reservoirs in the Denver Metropolitan Area, Colorado, American Water Resources Association (AWRA). Proceedings of the Symposium on Urban Hydrology, November 4-8, 1990, Denver, Colorado (in press).

Wegener, K., J. R. Kunkel, and J. T. Wulliman, 1990, Shop Creek Stormwater Quality Enhancement Project, American Society of Civil Engineers (ASCE). Proceedings of the 1990 National Conference on Hydraulic Engineering, July 30 - August 3, San Diego, California (in press).

Wulliman, J. T., K. Wegener and J. R. Kunkel, 1990, Shop Creek Stormwater Quality Enhancement Project. Paper Presented at the Urban Nonpoint Pollution Session C7, American Water Resources Association (AWRA) 26th Annual Conference, The Science of Water Resources: 1990 and Beyond, November 4-8, Denver, Colorado.

V. OPERATIONS AND FINANCES.

In 1990, the Authority collected revenue from the following sources.

1. Property Taxes. A .5 mill levy assessed on all properties in Arapahoe and Douglas County which are within the Cherry Creek Basin.

2. Wastewater Surcharge. A fee of 5 cents per 1,000 gallons of wastewater treated and discharged by each wastewater treatment plant written the Cherry Creek Basin.

3. Building Permit Fee and Grading Fee. Fees on grading and/or construction within the Cherry Creek Basin, as follows:

   (a) $280.00 per acre; or
   (b) $50.00 per residential unit; and
   (c) $.03 per square foot on business, all nonresidential buildings and all impervious surface areas.

4. Recreation Fee. A fee of $1.00 per visit per vehicle for all recreationists entering Cherry Creek Reservoir State Park was collected. Recreationists could purchase an annual decal for Cherry Creek Water Quality for $3.00.

5. The Authority's statement of revenues and expenditures follows. (See Table 4.)

TABLE 4

Cherry Creek Basin Water Quality Authority

STATEMENT OF REVENUES AND EXPENDITURES
GENERAL FUND
YEAR ENDED DECEMBER 31, 1990

REVENUES	Annual Budget	Actual
Wastewater Surcharge	$ 20,000	$ 23,994
Building Permit Fees	23,000	52,961
Property Taxes	320,540	302,697
Specific Ownership Taxes	14,905	23,524
Recreation Fee Surcharge	130,000	124,375
Interest Income	12,000	37,236
Grading Fees	12,500	0
Miscellaneous Income	0	6,062
Total Revenues	$532,945	$570,849
EXPENDITURES		
Accounting and Auditing	$ 8,300	$ 8,794
Printing and Publications	12,000	396
Consulting Expenses	18,000	51,453
Decals	11,000	0
Management	30,000	32,171
Management--Special Projects	9,000	0
Office Expenses	500	0
Insurance	7,200	6,611
Legal-Special/Regulatory	6,500	12,236
-Regular/Internal	21,000	43,571
-Special Projects	10,000	19,103
Legislative Relations	300	0
Miscellaneous Expenses	5,000	3,152
Director's Expense	500	0
Contingency	25,000	0
Treasurer's Fees	6,709	6,380
Meetings and Seminars	1,500	0
Consultant-Technical Support	24,000	12,013
Septic Tank Study	5,000	10,500
Basin Wide Monitoring	64,000	76,353
Annual Report	5,000	0
Monitoring Equipment	7,000	6,790
Shop Creek	125,000	150,000
Public Information Program	15,000	9,823
Retired Debt	0	0
Conting-Capital Projects	329,189	0
Total Expenditures	$746,698	$449,346

Excess (deficiency) of revenues over expenditures	($213,753)	$121,503
Fund Balance-December 31, 1990	0	$414,554

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