ALTERNATIVES TO ZERO DISCHARGE
Rocky Flats Plant

Task 17
of the
Zero-Offsite Water-Discharge Study

Prepared for:

EG&G Rocky Flats, Inc.
Plant Engineering
Civil/ Engineering - Environmental Restoration
P.O. Box 464
Golden, Colorado 80402-0464
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Prepared by:

Advanced Sciences, Incorporated
405 Urban Street, Suite 401
Lakewood, Colorado 80228

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EXECUTIVE SUMMARY

This report has been prepared for one of several studies being conducted for, and in the development of, a Zero-Offsite Water-Discharge Plan for Rocky Flats Plant (RFP) in response to Item C.7 of the Agreement in Principle (AIP) between the Colorado Department of Health (CDH) and the U. S. Department of Energy (DOE) (DOE and State of Colorado, 1989). The CDH/DOE Agreement Item C.7 states "Source Reduction and Zero Discharge Study: Conduct a study of all available methods to eliminate Rocky Flats discharges to the environment including surface waters and ground water. This review should include a source reduction review".

Specifically, this report addresses alternatives to zero discharge relative to water management at the RFP. Currently, there are ten on-channel ponds and two off-channel ponds that collect RFP surface-water runoff from approximately 2.25 square miles (mi^2) of the 10-mi^2 RFP site. Three terminal ponds (A-4, B-5 and C-2) are not adequately sized to operate without uncontrolled discharges during flood events such as that expected during the 100-yr, 72-hr design flood. Ponds A-4, B-5 and C-2 are now or in the event of a flood, would be on-channel impoundments, which means the water in these ponds may be subject to CDH water-quality stream standards, because these waters would be considered as waters of the United States. This study examines the preliminary feasibility of temporarily storing Sanitary Treatment Plant (STP) effluent, surface-water runoff, ground water, and runoff from the 100-yr, 72-hr flood from the RFP, and releasing it downstream under controlled conditions, or disposing of it on-site. Temporary water-storage facilities investigated in this report include new off-channel storage, using Great Western Reservoir and upgrading the existing terminal ponds. Off-channel storage may be particularly attractive, because water in these ponds probably would not be considered waters of the United States and may not have to meet CDH stream standards unless the water were released.

Operational studies were performed during this study for sizing the temporary water-storage reservoirs to store STP effluent, surface-water runoff, ground water and runoff from the 100-yr, 72-hr flood along with precipitation falling directly on the reservoir. The reservoir sizing was done for combinations of water-use demands both on- and off-site, as well as downstream releases after water treatment to meet stream standards.

Fifteen basic off-site and on-site water-release/water-use alternatives were assessed. These 15 alternatives were investigated for an off-channel water-storage reservoir, storage of water in Great Western Reservoir, and storage of water in the upgraded existing terminal ponds (A-4, B-5 and C-2). Additionally, the "no-action" alternative to zero discharge was assessed. The total number of alternatives considered was 46, 15 each for the three alternative storage reservoirs and the "no-action" alternative. Of the 15 basic alternatives, four were associated with off-site discharge at a new location such as Big Dry Creek, the South Platte River, or Clear Creek. Seven alternatives were associated with off-site discharge to an existing municipal sewer system. Two alternatives considered off-site discharge to water users such as landscape irrigation at the new Denver airport. One on-site alternative dealt with irrigation of pasture grass (other crops could be considered during future studies) at the RFP, while a second on-site alternative was spray evaporation in a lined pond at the RFP. This last alternative was really a zero-discharge concept which was examined in order to give a comparison to the other alternatives without having to refer to previous operational studies for zero discharge presented in the Task 21 report, ASI, 1991b).

Results of the reservoir operational studies are presented in this report. A preferred alternative for each of the three storage structures (off-channel, Great Western Reservoir, and the terminal ponds) was selected. The table that follows summarizes the preferred alternatives for each of the three storage structures. The terminal ponds, in general, cannot be built large enough to minimize uncontrolled releases, unless the rate of release is increased beyond the capability of some of the alternatives to use the water. In addition to the preferred alternative description, the

SUMMARY OF PREFERRED ALTERNATIVES

STORAGE ALTERNATIVE	ALT. NOS.	PREFERRED ALTERNATIVE DESCRIPTION	CONSTR. COSTS (Million $)	OM & R COSTS (Million $/Yr)
NEW OFF-CHANNEL RESERVOIR	6a	Off-channel storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 1.9 mi^2 (125.3 ac-ft/yr) with the 100-yr, 72-hr flood (425 ac-ft/yr), and ground water (10 ac-ft/yr) with April-through-October on-site spray evaporation in a lined pond (122.9 to 492.4 ac-ft/yr) (Zero Discharge).	4.5	0.7
GREAT WESTERN RESERVOIR	5b(a)	On-channel GWR storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 5.5 mi^2 (279.7 ac-ft/yr) with the 100-yr, 72-hr flood (1143 ac-ft/yr), and ground water (10 ac-ft/yr) with on-site irrigation of pasture grass (144 to 576 ac-ft/yr).	80.9	12.1
TERMINAL PONDS	4d(a)	Terminal ponds storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 1.07, 0.41, and 0.35 mi^2 (81.0, 39.2, and 34.8 ac-ft/yr) with the 100-yr, 72-hr flood (243, 106 and 76 ac-ft/yr) for Ponds A-4, B-5, and C-2 respectively, and ground water (10 ac-ft/yr) with a pipeline (187 to 374 ac-ft/yr) to the Denver Water Department Potable Reuse Plant, or with an irrigation water pipeline (164.6 to 658.3 ac-ft/yr) to the new Denver Airport.	146.0	21.9

summary table also includes the estimated construction and annual OM & R costs for each of the three preferred alternatives. The three preferred alternatives assume that the STP effluent volumes would be for the current RFP personnel population of about 6,300 people. Future increases or decreases in the RFP personnel population may demand that this alternatives be re-evaluated.

Additionally, the possibilities of combining parts of alternatives, especially the terminal ponds alternatives, have not been evaluated in this study. The possible combinations of such alternatives is very large. Decisions about RFP population, future water use, and water-treatment technologies would be helpful in reducing the number of possible alternative combinations.

Studies that are subordinate to the Zero-Offsite Water-discharge Plan that are affected by or would affect zero-discharge alternatives are: Water-Yield and Water-Quality Study of Walnut Creek and Woman Creek Watersheds (Task 4; ASI, 1990c); Confirmation of Rainfall/Runoff Relationships (Task 5; ASI, 1991g); Storm Runoff for Various Design Events (Task 6; ASI, 1991c); Treated-Sewage/Process-Wastewater Recycle (Tasks 11 and 13; ASI, 1991a); Surface-Water and Ground-Water Rights (Task 14; ASI, 1991h); Surface-Water Evaporation (Task 15; ASI, 1991e); Water-Yield and Water-Quality Study of Other Sources Tributary to Standley Lake and Great Western Reservoir (Task 16; ASI, 1990d); Temporary Water-Storage Capabilities (Task 21; ASI, 1991b); Ground-Water Recharge (Task 22; ASI, 1990e); Water Resource Management (Task 23; ASI, 1991f); Bypass Upstream Flows Around Rocky Flats Plant (Task 24; ASI, 1991d); Waste Generation Treatment (Task 27; ASI, 1991i); Augmentation Plan for Rocky Flats Plant (Task 28; ASI, 1991j); and Consolidation and Zero-Discharge Plan (Task 30; ASI, 1991k).

ALTERNATIVES TO ZERO DISCHARGE

Rocky Flats Plant

1.0 INTRODUCTION

1.1 BACKGROUND

This report has been prepared for one of several studies being conducted for, and in the development of, a Zero-Offsite Water-Discharge Plan for Rocky Flats Plant (RFP) in response to Item C.7 of the Agreement in Principle (AIP) between the Colorado Department of Health (CDH) and the U. S. Department of Energy (DOE) (DOE and State of Colorado, 1989). The CDH/DOE Agreement Item C.7 states "Source Reduction and Zero Discharge Study: Conduct a study of all available methods to eliminate Rocky Flats discharges to the environment including surface waters and ground water. This review should include a source reduction review".

1.2 SCOPE AND PURPOSE

This study will examine alternatives to zero discharge by assessing other methods of treatment/disposal of sanitary treatment plant (STP) effluent, surface-water runoff, and ground water flows at the Rocky Flats Plant (RFP). Many such alternatives, which have been proposed in the Rocky Flats Surface Water Management Plan (SWMP),(DOE, 1991), may require a more detailed evaluation along with other new alternatives to zero discharge. The proposal and Project Management Plan for this study (ASI, 1990a; 1990b) indicated that operational studies would be performed for selected storage reservoirs related to these discharge alternatives. Because of the preliminary nature of this study, selected reservoir operational studies were performed for several general categories of off-site and on-site water disposal alternatives to zero discharge, but without detailed analyses of each specific alternative outlined in the SWMP (DOE, 1991).

Conceptual alternatives to zero discharge presented in this report were taken primarily from previous reports and documents, such as the SWMP, preliminary alternatives analyses by Wright Water Engineers (WWE, 1990a; 1990b; 1990c; and 1990d) and the Temporary Water Storage Capabilities Study (ASI, 1991b). In most cases, these alternatives have been used as presented in the respective reports, except that more detailed analyses of the storage needed to provide continuous or time-dependent releases from the RFP were undertaken.

For purposes of this study, the zero-discharge alternatives were divided into two groups: (1) off-site alternatives, and (2) on-site alternatives. Off-site alternatives were those in which the water from the RFP would be transported off site via a hydraulic structure for treatment/disposal by an off-site user. On-site alternatives were those in which the alternative would be located on the RFP with discharge on the RFP. Sub-alternatives for the two primary alternatives might include off-site release via pipelines to major creeks and rivers downstream, or to municipal wastewater treatment plants in the Denver metropolitan area. On-site disposal may include evaporation, evapotranspiration, irrigation or land application.

Studies that are subordinate to the Zero-Offsite Water-discharge Plan that are affected by or will affect zero-discharge alternatives are: Water-Yield and Water-Quality Study of Walnut Creek and Woman Creek Watersheds (Task 4; ASI, 1990c); Confirmation of Rainfall/Runoff Relationships (Task 5; ASI, 1991g); Storm Runoff for Various Design Events (Task 6; ASI, 1991c); Treated-Sewage/Process-Wastewater Recycle (Tasks 11 and 13; ASI, 1991a); Surface-Water and Ground-Water Rights (Task 14; ASI, 1991h); Surface-Water Evaporation (Task 15; ASI, 1991e); Water-Yield and Water-Quality Study of Other Sources Tributary to Standley Lake and Great Western Reservoir (Task 16; ASI, 1990d); Temporary Water-Storage Capabilities (Task 21; ASI, 1991b); Ground-Water Recharge (Task 22; ASI, 1990e); Water Resource Management (Task 23; ASI, 1991f); Bypass Upstream Flows Around Rocky Flats Plant (Task 24; ASI, 1991d); Waste Generation Treatment (Task 27; ASI, 1991i); Augmentation Plan for Rocky Flats Plant (Task 28; ASI, 1991j); and Consolidation and Zero-Discharge Plan (Task 30; ASI, 1991k). Input from those subordinate tasks which have been initiated were used in this study where appropriate.

2.0 ALTERNATIVES ASSESSMENT COMPONENTS

2.1 PROPOSED ALTERNATIVES

As described above, two general categories of alternatives, off-site and on-site, have been defined for analyses in this study. Additionally the "no-action" alternative will be evaluated. Off-site alternatives include three broad categories of sub-alternatives. These sub-alternatives include: (1) Discharging RFP STP effluent, surface-water runoff, and ground-water flows at a new off-site location; (2) Conveying the RFP water to an existing treatment facility in the Denver metropolitan area; and (3) Locating off-site users for the RFP water and transporting the water to them.

On-site alternatives include two broad sub-alternatives which include: (1) providing state-of-the-art treatment of RFP-related water with discharge to Walnut Creek and/or Woman Creek; and (2) Disposal of RFP-used water on-site by a variety of physical processes including irrigation of crops and spray evaporation. State-of-the-art water treatment, considered for water-rights releases in the Temporary Water-Storage Capabilities Study (ASI, 1991b), also was used in this study but not for on-site alternatives.

These alternatives are described in detail in the following sections. Reservoir operational studies were done for each broad category of sub-alternatives for both off-site and on-site alternatives. A detailed description of the reservoir operational model used, along with detailed descriptions of the inputs may be found in the Temporary Water-Storage Capabilities Study (ASI, 1991b) and will not be repeated in this study. The data used for this study are summarized below and may be found in the Appendices A through C of this report.

2.2 RESERVOIR OPERATIONAL STUDY METHODS AND DATA

2.2.1 Reservoir Operational Study Methods

Uncontrolled discharge of STP effluent, surface-water runoff and ground-water flows from the RFP would not be acceptable if these water sources are to be conveyed to a specific new discharge point off-site, to an existing wastewater treatment plant in the Denver metropolitan area, or to another user because these waters would be untreated and could carry contaminants downstream. Generally, the flow rates which can be conveyed in pipelines, or other hydraulic structures, are limited by the economic and physical size of pipeline which can be constructed. Usually these pipelines or other hydraulic structures are of limited capacity, whereas, some sources of water, such as surface-water runoff, may have flow rates which far exceed the capacity of the pipeline or other hydraulic structure. Therefore, some kind of flow-equalizing facility would be needed to maintain a relatively constant flow rate or even to allow for periods of no flow in the hydraulic structure. Thus, the need for reservoir storage to accomplish this flow regulation.

Generally, a reservoir is operated to meet pre-specified target demands or releases for downstream users. To simulate the operation of the reservoir, the operating criteria are expressed in quantitative or mathematical terms. The principle of continuity, inflow to minus outflow from the reservoir should equal the change in storage in the reservoir and is used to size the reservoir for the appropriate alternative inflows, demands, and other inputs and losses. Generalized discussions of reservoir operational studies may be found in Linsley and others (1958), Riggs and Hardison (1973), and the U. S. Army Corps of Engineers (COE, 1981). Detailed analyses of reservoir operational studies at the RFP may be found in ASI (1991b). ASI used an in-house computer model to perform the water accounting for the reservoir operational studies presented in this study report.

Preliminary reservoir sizing was conducted for the alternatives to zero discharge assuming that STP effluent, surface-water runoff, ground water, and runoff from the 100-yr, 72-hr flood would be temporarily stored prior to discharge or reuse. The reservoir sizing resulted from performing reservoir operational studies using data and information discussed below. As with the reservoir operational studies done in the Task 21 Study (ASI, 1991b), the objective was to minimize uncontrolled releases.

Operational studies performed on the selected alternatives used many implicit and explicit assumptions. Some of these assumptions included: (1) the operational studies were performed monthly for 50 years which is adequate for this planning effort; (2) no seepage inputs or losses occurred from the water storage facilities during the operational studies; (3) if pumping was required into or out of the water-storage facility, adequate pumping capacity existed to pump all the monthly flow rates presented in this study; and (4) no uncontrolled releases occurred within the RFP that would have prevented the operation of the alternative under consideration.

Additionally, initial reservoir conditions were assumed but were generally specific to the alternative being considered. For the new off-channel reservoir and existing terminal ponds , the initial storage was assumed to be full to the maximum capacity. This initial condition as assumed in order to give a worst case to the uncontrolled discharge (zero discharge) end points during the reservoir operational studies. Great Western Reservoir was assumed to have an initial storage volume of 3,253 ac-ft, which is at the existing spillway crest. However, existing "stop logs" above the spillway crest provide a storage volume of 3,569 ac-ft prior to uncontrolled releases downstream. The following sections further describe the methods and conditions for the new off-channel reservoir, Great Western Reservoir, and the existing terminal ponds (A-4, B-5 and C-2) (Figure 1).

2.2.1.1 New Off-Channel Storage Reservoir

A new off-channel water-storage reservoir would receive water from STP effluent, surface-water runoff, ground water, and runoff from the 100-yr, 72-hr storm event. This off-channel reservoir was assumed to have a dike surrounding it. This dike would have 2 (horizontal) to 1 (vertical)-side slopes and a 10-ft top width. The height of the dike would be sufficient to form a reservoir about 20 ft deep. The resulting elevation-area-capacity curve for such a structure is nearly linear with depth. Surface water runoff from about 1.9 mi^2, collected by the terminal ponds, would be pumped to the proposed new off-channel reservoir such that the terminal ponds would be empty most of the time. The initial storage volume of the new off-channel reservoir was assumed to be at maximum capacity at the beginning of the 50-year operational period.

2.2.1.2 Great Western Reservoir

Great Western Reservoir would receive water from the RFP's STP effluent, surface-water runoff, ground water and runoff from the 100-yr, 72-hr storm. Great Western Reservoir was assumed to remain as an on-channel reservoir with a contributing drainage area of about 5.5 mi^2, which includes 1.9 mi^2 of RFP area, as well as an additional 3.6 mi^2 between Ponds A-4 and B-5 and the Great Western Reservoir dam (Figure 1). The existing elevation-area-capacity curves for Great Western Reservoir are given in Appendix C. These curves were used to perform the operational studies. Because Great Western Reservoir already exists and was assumed to not change for the operational studies, the size of the reservoir was fixed. The initial storage volume assumed for all the Great Western Reservoir operational studies was 3,253 ac-ft, which is the storage capacity at the existing spillway crest. The City of Broomfield has put wooden "stop logs" along the spillway crest to increase the storage from 3,253 ac-ft to 3,569 ac-ft before uncontrolled downstream releases would occur. It was assumed that these stop logs would remain in place during the operational studies. Therefore, an additional 316 ac-ft of storage was assumed to be available prior to any uncontrolled releases from Great Western Reservoir.

2.2.1.3 Existing Terminal Ponds

The existing terminal ponds (A-4, B-5 and C-2) would store surface-water runoff, ground water, and runoff from the 100-yr, 72-hr storm. Pond B-5, and perhaps Pond A-4, would store STP effluent. The present spillway and dam crest elevations of the terminal pond storage structures may have to be increased, based upon the operational studies. Each of the three terminal ponds was treated separately, that is, the contributing drainage areas were 1.07, 0.41 and 0.35 mi^2 for Ponds A-4 , B-5 and C-2, respectively. For purposes of operational studies for the three terminal ponds, it was assumed that there was a finite height to which each of the existing dams could be increased, and thus, the maximum possible storage at each site was assumed to be fixed by this physical constraint. For each pond, this physical constraint to storage volume and surface area was estimated by extending the existing elevation-area-capacity curves for each pond (Appendix C). The initial water-surface elevation in each of the terminal ponds was that estimated to completely store the 100-yr, 72-hour flood as described the in Task 21 Study (ASI, 1991b).

2.2.1.4 Location of Pond(s)/Reservoir(s)

The water-storage reservoirs that have been proposed for this study would need to be located in areas best suited to collect water from the input source(s) and distribute the water for its intended use. Additional items to consider in siting the locations of proposed water-storage reservoirs include topographic, geologic, land use, hydraulic, economic, environmental, and maintenance considerations. The existing on-channel terminal ponds located on North Walnut Creek (Pond A-4), South Walnut Creek (Pond B-5), and the off-channel terminal pond on Woman Creek (C-2) would be used as "collection" ponds for surface-water runoff from the RFP. This surface-water runoff then would be pumped to an off-channel water-storage reservoir. As an alternative to an off-channel reservoir, the existing terminal ponds were investigated as possible water-storage ponds. Additionally, Great Western Reservoir was investigated as a possible on-channel storage reservoir for RFP water.

It is not within the scope of this document or any other study performed for the Zero-Offsite Water-Discharge Study, to recommend the final location of any proposed water-storage facility. However, based upon a preliminary review of the area, it would be reasonable to locate proposed new off-channel facilities east or west of the Controlled Area (Figure 1), between South Walnut Creek and Woman Creek. These locations would be centralized and would allow for pumping from the existing terminal ponds with a minimum of piping. By choosing a flat site located along a ridge, construction could be simplified. The inflow of uncontrolled surface-water runoff would be minimized, and the need for an emergency spillway for the water-storage structure would be reduced. A smaller dam height also would reduce construction and O&M costs and liability.

The off-channel water-storage facility could consist of a single large pond or a series of smaller ponds. Multiple ponds would permit segregation of runoff water, ground water and STP effluent which may require different degrees of treatment. The STP effluent currently is collected in Pond B-3. Releases from Ponds A-4, B-5 and C-2 can be made in accordance with NPDES permit CO 0001333.

Great Western Reservoir could be used as a water-storage reservoir. This option would reduce the pumping of surface-water runoff from the terminal ponds to an off-channel water-storage reservoir but would increase the costs of pumping water back to the RFP for land application or other reuses. In addition, liabilities of accidental discharge of water would be increased unless major repairs/reconstruction were done at the Reservoir (Hydro-Triad, Ltd., 1981).

2.2.2 Reservoir Operational Study Inflow Data

Data used in the reservoir operational studies for the various alternatives included both reservoir inflow and outflow sources. Inflow data (Appendix A) included surface-water runoff estimates, STP effluent values, ground-water flow estimates, and precipitation falling directly on the reservoir. Outflow data (Appendix B) included evaporation from the reservoir, enhanced evaporation by spraying, demands for irrigation water, and demands for downstream release or other uses. Each of these inflow or outflow sources is briefly discussed below. Previous analyses (ASI, 1991b) provided details on much of these data. Therefore, only details on inflow data not presented in previous reports are presented in this study report.

2.2.2.1 Surface-Water Runoff

In an effort to estimate water-storage requirements at the RFP, it is necessary to estimate quantities of runoff that would be expected on a monthly and annual basis. However, insufficient long-term runoff data exist at the RFP to permit direct calculation or estimation of average annual or average monthly runoff. In the previous Task 4 study (ASI, 1990c), average annual and average monthly runoff was estimated for RFP watersheds for natural conditions with no site development in the form of buildings, roads and other impervious areas.

ASI (1991b) has generated 10 series of equally likely monthly synthetic flow sequences for a typical 1.0 mi^2 RFP drainage basin with 30 percent impervious area. These monthly flow sequences were generated using Monte-Carlo techniques available from Fiering and Jackson (1971), Yevjevich (1972), Kunkel (1974) and Shen (1976). The monthly synthetic flow sequences were based upon monthly flow data for abut 12 years collected by the U. S. Geological Survey (USGS) from Big Dry Creek at Littleton, Colorado (Ducret and Hodges, 1972 and 1975; Cochran and others, 1979 and 1983; and Mustard and others, 1987). ASI assumed that the underlying statistical distributions of the original USGS data were either normal, log-normal or gamma.

The results of the generated sequences (ASI, 1991b) suggested that the normal distribution preserved the monthly mean values within 35 percent of the original monthly streamflow data mean and preserved the variance within less than 1 percent of the original streamflow data variance. The results of the generated sequences also suggested that the log-normal distribution preserved the mean within 51 percent of the original streamflow data mean and the variance within 163 percent of the original streamflow data variance. The results of the gamma distribution resulted in numerous large monthly flow values which rendered the generated streamflows unusable for this distribution. Thus, the normal distribution appeared to preserve the mean and standard deviation of the original streamflows better than the log-normal distribution. Therefore, the 10 sequences of 50 years each generated from a normal distribution were selected for use in the reservoir operational studies of alternatives to zero discharge at the RFP. Sequence Number 3 (Appendix A), with a mean annual flow for the 50-year sequence of 76.9 ac-ft and a standard deviation of 28.1 ac-ft, was chosen at random from the 10 sequences for use in the reservoir operational studies for this report. The range of annual surface-water runoff volumes in Sequence Number 3 was between 25.8 ac-ft and 139.7 ac-ft from a typical 1.0 mi^2 drainage basin with 30 percent imperviousness (Appendix A-1).

The monthly surface-water runoff values for the typical RFP drainage basin area of 1.0 mi^2 were adjusted for other drainage basin areas by multiplying the 1.0 mi^2 monthly flows by a factor. This factor is calculated for any other drainage basin area by taking that drainage area to the 0.7574 power. This technique is discussed in the Task 4 study, (ASI, 1990c).

2.2.2.2 Sewage Treatment Plant Effluent

The quantity of STP effluent has been determined from data collected from 1986 through 1990 by EG&G. Appendix A-2 lists the monthly, annual, monthly average, and annual average effluent volumes for the 1986 through 1990 period. Volumes for the months of October, November, and December for 1990 are not actual measured volumes. At the time of this report, these values were not available, and the individual monthly averages were used to estimate the monthly totals for these three months. Using the five years of effluent data, the average annual effluent flow was 237.5 ac-ft. The five years of monthly STP effluent flows given in Appendix B were used as input to selected operational scenarios. In order to obtain 50 years of STP monthly inflows, the sequence of five years of actual volumes was repeated as needed.

STP effluent quantities could have three alternatives, low, average, and high demand, based upon the scenarios presented in the Tasks 11 and 13 Study Report, (ASI, 1991a) and on the RFP population. For this study, we have assumed "low population" as a RFP personnel population of 3,000, "average population" as a population of 6,300, and "high population" as a population of 9,000. The STP effluent values in Appendix A-2 are for the average population of the RFP but can be adjusted to represent effluent flows for the high and low populations by multiplying the average STP monthly flows by the ratio of the low or high populations to the average population (ASI, 1991a).

2.2.2.3 Ground Water

The estimated amount of ground water that may be intercepted and stored on-site is estimated to be about 10 ac-ft per year (DOE, 1991). The Task 26 Study Report (ASI, 1991l) estimated that between 11.7 and 17.6 ac-ft of ground water per year may be pumped to control contaminant plume movement at the RFP. The findings of Task 26 were not available in time for use in this current study report. Therefore, the 10 ac-ft/yr value was used. The 10 ac-ft/yr value is generally small compared to the surface-water runoff and STP effluent components used in this study. The volume of ground water (10 ac-ft/yr) was uniformly distributed over the year and assumed to be invariant from year to year.

2.2.2.4 Precipitation

The amount of precipitation that would fall directly on a proposed water storage facility(ies) has been estimated using nearby climatological data. RFP on-site monthly precipitation data are limited. Appendix A-3 summarizes the data available from the RFP for this study. Average RFP precipitation as shown in Appendix A-3 is about 15.2 inches/year, based upon two record lengths. Because the monthly precipitation at the RFP was not adequate, the 43-year (1948 through 1990) record of precipitation data collected at the Cherry Creek Dam were used as input to the various operational studies analyzed for this report. Appendix A-3 also presents the monthly and annual precipitation values at Cherry Creek Dam. The 43 years of data have an average of about 15.3 inches/year. Comparison of the annual average values of precipitation at the RFP with those at Cherry Creek Dam, as shown in Table 1, indicate that the Cherry Creek Dam precipitation data are representative of the RFP. Therefore, the Cherry Creek Dam precipitation data were used in the reservoir operational studies. Because the operational studies analyzed 50 years of reservoir operation, the precipitation data for years 1948 through 1954 (7 years) were repeated in the data file to represent 50 years of precipitation.

2.2.2.5 Floods

The 100-year, 72-hour storm of 6.3 inches traditionally has been used as the design storm at the RFP (ASI, 1991b; DOE, 1986). Table 2 shows the runoff associated with the 100-year, 72-hour storm for drainage basins contributing runoff to the three terminal ponds (Pond A-4, Pond B-5 and Pond C-2) at the RFP (Figure 1). A detailed discussion of the existing terminal ponds and their ability to completely store the runoff from the 100-year, 72-hour storm is given in ASI (1991b). The total runoff from the 100-year, 72-hour storm is estimated to be about 425 acre-feet (ac-ft) as shown in Table 2. This runoff is from the 1.9 mi^2 area (Figure 1) which includes the RFP Controlled Area, the West Spray Field and T130 complex area, the Old Landfill area, and the Present Landfill area as well as the areas upgradient from the terminal ponds (Table 2). For drainage areas in the Buffer Zone, the U. S. Soil Conservation Service (SCS) runoff curve number (CN) was assumed to be about 77. Therefore, about 3.74 inches of the 6.3 inches of rainfall from the 100-year, 72-hour storm would run off. This runoff volume was used to estimate additional areas, such as the area between the terminal ponds and Great Western Reservoir, which might contribute flood flows as input to the reservoir operational studies.

The time of occurrence of the 100-year, 72-hour storm is uncertain. For purposes of this study, it was assumed that the storm would occur during the month of July. The probability that at least one 100-year, 72-hour storm would occur during the assumed 50-year flow sequence is about 30

Table 1

Comparison of Average Monthly and Annual Evaporation Data From Various Locations

	Precipitation (Inches)			Evaporation (Inches)	
	Average Values from Cherry Creek[1,5]	Average Values from RFP[2]	Average Values from the Climatic Atlas[3]	Average Values from Cherry Creek Dam[1]	Average Values from Fort Collins[4,5]
January	0.45	0.50	0.5	0.50	0.50[6]
February	0.53	0.65	0.5	0.62	0.62[6]
March	1.11	1.22	1.5	1.06	1.06[6]
April	1.47	1.71	2.8	2.90	3.43
May	2.62	2.88	3.0	4.71	3.96
June	1.88	1.69	2.0	5.77	4.53
July	2.31	1.38	2.0	6.48	5.07
August	1.62	1.19	2.0	5.69	4.41
September	1.09	1.61	1.0	4.57	3.43
October	1.02	0.99	1.0	3.52	2.29
November	0.71	0.81	1.0	1.61	1.26
December	0.53	0.53	1.0	0.70	0.70[6]
ANNUAL	15.34	15.16	16.0	38.13	31.26

1) Periods of Record - 1948 through 1990 (Precipitation) and 1948 through 1983 (Evaporation) (With 10 missing months).

2) Periods of Record - 1953 through 1976.

3) ESSA (1983).

4) Periods of Record - 1953 through 1990 (with 236 missing months).

5) These values were used to perform the reservoir operational studies.

6) Data from Cherry Creek Dam.

Table 2

Runoff Associated With The 100-Year, 72-Hour Storm[1)]

Pond	Area (ac)	Area in^2	Weighted CN	Runoff (in)	Runoff (ac-ft)
A-4[2)]	684	1.07	82	4.26	243
B-5	265	0.41	87	4.81	106
C-2[3)]	244	0.35	77	3.74	76

1) Using current basin conditions.

2) Including the West Spray Field and Present Landfill drainage basin areas.

3) Including the Old Landfill drainage basin area.

4) See text for estimate methodology.

percent if the storms are assumed to follow a series of trials similar to the tossing of a fair coin. Therefore, one runoff event from the 100-year, 72-hour storm was randomly placed within the 50-year runoff sequence. The randomly located storm was assumed to occur in July 1970 within the 50-year sequence of flows that would occur between January 1948 and December 1997.

In the cases where the terminal ponds are used to capture runoff which is conveyed to either an off-channel storage facility or to Great Western Reservoir, it was assumed that the 100-year, 72-hour storm runoff could be evacuated from the terminal ponds in 2 months. The evacuation rate to achieve this for all three terminal ponds is less than 1000 gallons per minute (gpm) (ASI, 1991b).

Table 3 summarizes the monthly and annual RFP reservoir operational study inputs. The data in Table 3 is a summary of the detailed data given above or in Appendix A.

2.2.3 Reservoir Operational Study Outflow Data

The reservoir operational study outflow data used for this report are presented in Appendix B and discussed below. These outflow data consist of reservoir evaporation, enhanced spray evaporation, demands for irrigation water, and demands for downstream release or other use.

2.2.3.1 Reservoir and Spray Evaporation

Evaporation of stored water will occur naturally from a water-storage reservoir surface. In addition, the evaporation rate can be increased by installation of an evaporation enhancement system at or adjacent to the water-storage facility. The Surface-Water Evaporation Study (Task 15) will include an in-depth analysis of the atmospheric processes that cause evaporation at the RFP along with a method of predicting pan evaporation at the RFP. However, because this information is not yet available, nearby (Fort Collins and Cherry Creek Dam) monthly reservoir and pan evaporation data were examined as potential data sources for monthly free water-surface

Table 3

MONTHLY AND ANNUAL SUMMARY OF RFP WATER INPUTS FROM VARIOUS SOURCES

(Ac-Ft Unless Otherwise Indicated)

Water Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Surface-Water Runoff ($1.0mi^2$)[1]	0.8	0.9	1.1	2.1	8.4	15.5	18.1	16.8	6.6	4.5	1.3	0.8	76.9
Surface-Water Runoff ($1.9mi^2$)[1]	1.3	1.5	1.8	3.4	13.7	25.3	29.5	27.4	10.7	7.3	2.1	1.3	125.3
Surface-Water Runoff ($5.5mi^2$)[1]	2.9	3.3	4.0	7.6	30.6	56.4	65.8	61.1	24.0	16.4	4.7	2.9	279.7
STP Effluent 3,000 Personnel[2]	7.8	8.3	10.0	10.8	10.9	10.7	11.0	10.9	9.9	8.6	7.5	7.6	114.0
STP Effluent 6,300 Personnel[2]	16.2	17.2	20.8	22.5	22.8	22.3	23.0	22.7	20.7	17.9	15.6	15.8	237.5
STP Effluent 9,000 Personnel[2]	23.1	24.6	29.7	32.2	32.6	31.9	32.9	32.5	29.6	25.6	22.3	22.6	339.6
Ground Water[3]	0.83	0.83	0.83	0.84	0.84	0.84	0.84	0.83	0.83	0.83	0.83	0.83	10.0
Precipitation (in)[4]	0.45	0.53	1.11	1.47	2.62	1.88	2.31	1.62	1.09	1.06	0.71	0.53	15.34
100-Yr, 72-Hr Flood[5]	--	--	--	--	--	--	425	--	--	--	--	--	425.

1) Source: ASI, 1991b (Sequence No. 3). 1 mi^2 values increased by the 0.7574 power of the drainage area (50-year Average).

2) Sources: ASI, 1991a; ASI, 1991b (1986-1990 Average).

3) Assumed to be 10 ac-ft/yr equally distributed throughout the year (ASI, 1991b).

4) As measured at Cherry Creek Dam (1948-1990 Average; ASI, 1991b).

5) See Table 2.

evaporation rates at the RFP site. Reservoir evaporation data have been collected by the COE at Cherry Creek Dam since 1948. This reservoir evaporation is estimated by the COE based upon a reservoir water balance, with evaporation and seepage being unknowns. Therefore, these reservoir evaporation values may slightly over-predict the actual reservoir evaporation. For the period 1948 through 1983, the Cherry Creek Dam average monthly reservoir evaporation is given in Table 1 and averages about 38.1 in/yr.

The average annual pan evaporation rate from the Fort Collins data for the period 1953 through 1990 is about 44.7 inches/year. To estimate free water-surface evaporation from pan data requires adjustment of the pan evaporation by multiplying pan evaporation by a pan coefficient. Typically, an annual pan coefficient of about 0.70 is assumed for reservoirs. Pan coefficients for the United States are published by the National Weather Service (Kohler and others, 1959; Farnsworth and others, 1982) and also have been published by ESSA (1983). For this area of Colorado, these references indicate an annual pan coefficient of about 0.70. This coefficient was used to convert the monthly and annual Fort Collins pan evaporation data to reservoir evaporation data. The average monthly reservoir evaporation for the period 1953 through 1990, based upon the Fort Collins pan data, is presented in Appendix B-1 and is summarized in Tables 1 and 4.

Reservoir evaporation at Fort Collins for the period 1953 through 1990 averages about 31.3 in/yr. Because no pan data were available for the months of January through March and December, Cherry Creek Dam reservoir evaporation data were used for these months to fill-in the Fort Collins evaporation data. Because the adjusted Fort Collins data are judged to be more representative of actual reservoir evaporation at the RFP, they were used in the reservoir operational model. This period of record was extended to 50 years by repeating the 1953 through 1957 evaporation data (5 years) at the beginning of the record and by repeating the 1953 through 1959 evaporation data (7 years) at the end of the record to obtain a 50-year records (1948 through 1997) parallel to the precipitation and runoff records.

Table 4

MONTHLY AND ANNUAL SUMMARY OF RFP WATER OUTPUTS FROM VARIOUS SOURCES (Ac-Ft Unless Otherwise Indicated)

Sources	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Reservoir Evaporation (in)[1]	0.50	0.62	1.06	3.43	3.96	4.53	5.07	4.41	3.43	2.29	1.26	0.70	31.26
Spray Evaporation 500 gpm[2]	10.6	9.5	11.1	13.1	15.1	17.9	20.0	20.7	17.8	18.3	12.2	11.7	178.2
Spray Evaporation 1,000 gpm[2]	21.1	19.1	22.1	26.7	30.3	35.7	39.9	41.3	35.6	36.7	24.5	23.5	356.5
Spray Evaporation 2,000 gpm[2]	42.2	38.2	44.2	53.4	60.6	71.4	79.8	82.6	71.2	73.4	49.0	47.0	713.0
Consumptive Use (Pasture Grass)(in)[3]	0.0	0.0	0.0	0.90	3.37	5.04	6.15	5.27	3.30	0.85	0.0	0.0	24.88
Pipeline Discharge[4]	39.7	35.7	39.7	41.6	43.6	43.6	43.6	43.6	43.6	41.6	39.7	39.7	495.7
Municipal STP Demand (4-Hours/Day)[5]	15.9	14.3	15.9	15.4	15.9	15.4	15.9	15.9	15.4	15.9	15.4	15.9	187.2
Municipal STP Demand (6-Hours/Day)[5]	23.8	21.5	23.8	23.1	23.8	23.1	23.8	23.8	23.1	23.8	23.1	23.8	280.5
Municipal STP Demand (8-Hours/Day)[5]	31.8	28.7	31.8	30.7	31.8	30.7	31.8	31.8	30.7	31.8	30.7	31.8	374.1

1) From Fort Collins (1953-1990 Average; ASI, 1991b).

2) Sources: Merrick & Company, 1990; ASI, 1991b.

3) Based upon 1953-1989 period using Blaney-Criddle (SCS, 1970).

4) Assumes 1 cfs flowing for 24 hours per day, 250 days per year.

5) Assumes 1.55 cfs flowing for the durations shown.

Enhanced evaporation by direct aerosol spray to the atmosphere can be accomplished through mechanical methods. Spray evaporation rates are a function of the size of the water droplets, wind speed, and relative humidity and temperature of the air into which the droplet is sprayed. The spray evaporation rates will be higher than the free water-surface evaporation rates. This will require a water distribution system, pump(s), pipe risers with nozzles, a reliable power supply, and a weather monitoring station. The use of this system will be intermittent due to changing weather conditions (wind drift), mechanical breakdown, etc. which will have an impact on the efficiency of the operation. It is estimated that by pumping water at a rate of approximately 500 gpm, for 250 days per year (providing for adverse weather conditions and mechanical breakdown), for 8 hours per day, approximately 178.2 ac-ft of water could be evaporated annually. Appendix B-2 presents the monthly and annual evaporation rates for pumping at 500 gpm, 1000 gpm, and 2000 gpm at ambient average monthly air temperatures and average monthly relative humidity (R.H.). These numbers were derived based upon the installation of an evaporation system, similar to the one described by Merrick & Company (1990). The monthly spray evaporation rates for pumping 500, 1000 and 2000 gpm also are summarized in Table 4.

If the enhanced spray evaporation is operated over a free water surface, the evaporation which would have occurred from the free water surface would be suppressed, because the vapor pressure gradient across the water surface would be small due to the high relative humidities at the air-water interface. Therefore, enhanced spray evaporation over an existing or proposed reservoir would include only the spray evaporation and those areas of the free water surface where spraying is not occurring. Thus, for spray evaporation systems, it was assumed that a lined shallow reservoir separate from other water-storage reservoirs would be constructed.

2.2.3.2 Irrigation

On-site irrigation demands could be met from water stored in on-site ponds. This could include spray or flood irrigation of landscaped areas, crop production, or tree planting projects. Trees may be planted to create wind breaks to aid in minimizing wind erosion or create wind barriers in specified areas, or simply to enhance the aesthetics of the plant site. The feasibility of using water in this manner has been questioned in recent years and may not be consistent with the philosophy of the zero-offsite water-discharge. This is exemplified by the discontinuation of spray irrigation into adjacent landscape areas from Pond B-3 in 1989.

Prior to the spring of 1990, the operation of spray irrigation from Pond B-3 was nearly continuous. In 1989, the North Spray Field was taken out of service (DOE, 1990). Concerns about the validity of spray irrigation as a water control technique, possible interaction with Individual Hazardous Substance Sites (IHSS's) and uncertainty over the definition of spray irrigation in accordance with "good engineering practices" resulted in cessation of all spray irrigation until these issues are resolved (DOE, 1990).

For purposes of this study, it was assumed that some form of spray or flood irrigation would be an alternative to zero discharge. The monthly quantity of water to sustain plant growth for a generic "pasture grass" crop was estimated using the modified Blaney-Criddle method (U. S. Soil Conservation Service (SCS), 1970) was calculated. The modified Blaney-Criddle method of estimating evapotranspiration, or consumptive use, was used because long-term solar radiation data are not available for the Denver area. Radiation methods of calculating consumptive use have been shown to be better than temperature methods such as the modified Blaney-Criddle method (Jensen and others, 1990). An alternative estimate of solar radiation would be to use clear-sky radiation and percent cloud cover. However, the cloud cover at the RFP may vary considerably from the cloud cover at the National Weather Service (NWS) station at Denver. Because the Colorado State Engineer accepts estimates of consumptive use based upon the modified Blaney-Criddle method, it was decided to use this method to estimate consumptive use in this study.

Air temperature data for calculating consumptive use was taken from the Fort Collins NWS climatological station which also was the source for the evaporation data in Appendix B-1. The period of record at Fort Collins was 37 years (1953 through 1989). Comparison of the Fort Collins monthly air temperature data with air temperature data from Cherry Creek Dam indicated that the Fort Collins data were representative of the Denver metropolitan area. The 37-year record of monthly and annual air temperature used in the modified Blaney-Criddle method of consumptive use calculations are presented in Appendix B-3. A summary of the 37-year consumptive use is shown in Table 4.

Other variables for estimating consumptive use for the pasture grass crop assumed to be irrigated at the RFP were taken from SCS (1970). Monthly and annual calculated consumptive use for pasture grass is presented in Appendix B-3, summarized in Table 4, and averages about 24.9 inches per year. It was assumed that the growing season for pasture grass at the RFP was from April 15 through October 15 of each year. In order to obtain 50 years of monthly consumptive use values, the 1953 though 1957 period of record (5 years) were repeated at the beginning of the record and the 1982 through 1989 period of record (8 years) were repeated at the end of the record. For calculation of irrigation requirement, the consumptive use shown in Appendix B-3 was reduced by the effective rainfall (SCS, 1970) and increased by an estimated irrigation efficiency of 80 percent. The irrigation efficiency was assumed based upon engineering judgement.

Previous estimates of potential evapotranspiration at the RFP were done by Koffer (1989). The annual potential consumptive use estimated by Koffer (1989) using the Penman method was about 39.2 inches using a single year of data which was the average of 24 years of record (1953 through 1976). The potential consumptive use for the period April 15 through October 15, estimated by Koffer (1989), was about 29.3 inches. Applying a season crop coefficient for pasture grass of about 0.78 (Jensen and others, 1990), gives a growing-season (April 15 through October 15) consumptive use for pasture grass of about 22.8 inches using the Penmen method. Based upon the comparison of the consumptive use results calculated for this report using the modified Blaney-Criddle method and the results calculated using the Penman method (Koffer, 1989), it is concluded that the modified Blaney-Criddle method should be adequate for use in estimating consumptive use for the demands in the reservoir operational study alternatives.

2.2.3.3 Other Demands

If off-site discharge via pipeline or other hydraulic conveyance is used to dispose of RFP water, the size of the pipeline is mostly dependent upon the flow rate. Although many flow rates are possible, for purposes of this study, it was assumed that the off-site flow rate would be 1 cubic feet per second (cfs). It was further assumed that the duration of the discharge from the on-site reservoir used to equalize the releases would be 24 hours per day for 250 days per year. These assumptions would result in an annual discharge volume of about 496 ac-ft/yr as summarized in Table 4.

For the options where RFP water is transmitted to existing municipal wastewater treatment plants in the Denver metropolitan area, the flow rate will be dependent upon the size of the existing municipal sewer system, the size of the treatment facility, and the times when the facility can treat excess water. For purposes of this study, it was assumed that a flow rate of 1.55 cfs flowing for between 4 and 8 hours per day, 365 days per year, would be a reasonable value for sizing a storage reservoir. The annual quantity of water leaving the RFP under these conditions would range from about 187 ac-ft/yr for a 4-hour duration, to 374 ac-ft/yr for an 8-hour duration. The monthly and annual discharge volumes for 4-, 6-, and 8-hour durations are summarized in Table 4.

2.3 DESCRIPTION OF ALTERNATIVES

Preliminary storage reservoir sizing, except for the "No-Action" alternative, was performed for six water-use alternatives which included a total of 45 sub-alternatives. The preliminary analyses of these alternatives, including approximate locations, sizes, construction costs and operation, maintenance and replacement (OM&R) costs, and environmental impacts are presented in the following sections. The six water-use alternatives include: (1) Alternative 1 - "No-Action" Alternative; (2) Alternative 2 - Off-site Discharge at a New Location; (3) Alternative 3 - Off-site Discharge to an Existing Wastewater Treatment Facility; (4) Alternative 4 - Offsite Discharge to a Downstream User; (5) Alternative 5 - On-site Evapotranspiration by Pasture Grass; and (6) Alternative 6 - On-site Spray Evaporation. These six water-use alternatives and their sub-alternatives are described in the following sections.

2.3.1 Alternative 1 - "No-Action" Alternative

This alternative to zero discharge would involve the continuing current practice of treating sanitary wastewater and storm runoff at one or more of the existing terminal ponds and release downstream under an NPDES permit. The costs for doing this were assumed to be zero because no new costs would be incurred. The environmental risks of the "No-Action" alternative include the potential discharge of contaminants off-site, especially during wetter-than-normal years when releases have to be made from the terminal ponds.

2.3.2 Alternative 2 - Off-Site Discharge at a New Location

This alternative includes a series of six sub-alternatives, two of which are further subdivided into 8 more sub-sub-alternatives. Four of these sub-alternatives were presented in the SWMP (DOE, 1991) as Option Nos. 1a through 1d. The fifth sub-alternative is new to this study and involves using Great Western Reservoir as the storage reservoir rather than a new reservoir. The sixth sub-alternative, also new to this study, involves using the existing terminal ponds as the storage reservoirs rather than a new reservoir. Figures 2 and 3 show the proposed sub-alternatives for off-site discharge to a new location. These sub-alternatives include: (a) a pipeline to the South Platte River along Big Dry Creek; (b) a pipeline to the South Platte River along 120th Avenue; (c) a pipeline bypass of Great Western Reservoir; (d) a pipeline to Clear Creek; (e) Great Western Reservoir as the flow-equalizing storage reservoir rather than a new off-channel reservoir applicable to sub-alternatives (a) through (d); and (f) the existing terminal ponds as the flow-equalizing reservoirs rather than a new off-channel reservoir applicable to sub-alternatives (a) through (d).

A reservoir operational studies were done to size in a preliminary a new off-channel reservoir for sub-alternatives 2a through 2d, for Great Western Reservoir for sub-alternative 2e, and for the existing terminal ponds for sub-alternative 2f. Results of the reservoir-sizing and operational studies for each of these sub-alternatives are presented in Section 3.0. For this alternative, the surface-water runoff for the new off-channel reservoir and the terminal ponds was assumed to come from 1.9 mi^2 of drainage area collected by the existing terminal ponds and pumped to the off-channel reservoir. For the Great Western Reservoir alternative, it was assumed that surface runoff came from 5.5 mi^2 of drainage area contributing to the Reservoir. Costs in this alternative include estimates for the storage reservoir and appurtenant facilities, such as pumping from the existing terminal ponds to the off-channel reservoir, along with the cost of transporting the water to its destination. The pipeline and other off-site costs were taken from DOE (1991) and were not independently estimated for this study.

2.3.3 Alternative 3 - Off-Site Discharge to Existing Wastewater Treatment Facilities

This alternative includes a series of nine sub-alternatives, two of which are divided into 14 more sub-sub-alternatives. Seven of these sub-alternatives were presented in the SWMP (DOE, 1990) as Option Nos. 2a through 2g. The eighth sub-alternative is new to this study and involves Great Western Reservoir as the storage reservoir rather than a new reservoir. The ninth sub-alternative, also new to this study, involves using the existing terminal ponds as the storage reservoirs rather than a new reservoir. Figures 4, 5, and 6 show the proposed sub-alternatives for off-site discharge to an existing municipal wastewater sewer system and/or treatment facility (WWTP) in the Denver metropolitan area. These sub-alternatives include: (a) Transport/Treatment at Arvada/Metro WWTP and Discharge; (b) Transport/Treatment at Westminster/Metro WWTP and Discharge; (c) Treatment at Superior/Rock Creek WWTP and Discharge; (d) Direct Pipeline and Treatment at Metro WWTP; (e) Surface Runoff and Wastewater Management by Northglenn; (f)

Surface Runoff and Wastewater Management by Westminster, (g) Broomfield WWTP; (h) Great Western Reservoir as the equalizing storage reservoir rather than a new off-channel reservoir applicable to sub-alternatives (a) through (g); and (i) the existing terminal ponds as the equalizing storage reservoir rather the a new off-channel reservoir applicable to sub-alternatives (a) through (g).

Reservoir operational studies were done to preliminarily size a new off-channel reservoir for sub-alternatives 3a through 3g, for Great Western Reservoir for sub-alternative 3h, and for the existing terminal ponds for sub-alternative 3i. Results of the reservoir-sizing and operational studies for each of these sub-alternatives are presented in Section 3.0. For this alternative, the surface-water runoff for the new off-channel reservoir and the terminal ponds was assumed to come from 1.9 mi^2 of drainage area collected by the existing terminal ponds and pumped to the off-channel reservoir. For the Great Western alternative, it was assumed that surface runoff came from 5.5 mi^2 of drainage area contributing to the reservoir. Costs in this alternative are for the storage reservoir and appurtenant facilities, such as pumping from the existing terminal ponds to the off-channel reservoir, along with the cost of transporting the water to its destination. The pipeline and other off-site costs were taken from DOE (1991) and were not independently estimated for this study.

2.3.4 Alternative 4 - Off-Site Discharge to Water Users

This alternative includes a series of four sub-alternatives, two of which are further divided into 4 sub-sub alternatives. Two of these sub-alternatives were presented in the SWMP (DOE,1991) as Option Nos. 2h and 4a. The third and fourth alternatives are new to this study and involve Great Western Reservoir and the existing terminal ponds as the storage reservoir rather than a new reservoir. Figure 7 shows the proposed sub-alternatives for off-site discharge to a water user. These sub-alternatives include: (a) Denver Water Department Potable Reuse Plant; (b) Pipeline to the new Denver Airport; (c) Great Western Reservoir as the equalizing storage reservoir rather than a new off-channel reservoir applicable to sub-alternatives (a) and (b); and

(d) the terminal ponds as the equalizing storage reservoirs rather than a new off-channel reservoir applicable to sub-alternatives (a) and (b).

Reservoir operational studies were done to preliminarily size a new off-channel reservoir for sub-alternatives 4a and 4b, for Great Western Reservoir for sub-alternative 4c, and for the existing terminal ponds for sub-alternative 4d. Results of the reservoir-sizing and operational studies for each of these sub-alternatives are presented in Section 3.0. For this alternative, the surface-water runoff for the new off-channel reservoir and the terminal ponds was assumed to come from 1.9 mi^2 of drainage area collected by the existing terminal ponds and pumped to the off-channel reservoir. For the Great Western alternative, it was assumed that surface runoff came from 5.5 mi^2 of drainage area contributing to the Reservoir. Costs in this alternative are for the storage reservoir and appurtenant facilities, such as pumping from the existing terminal ponds to the off-channel reservoir, along with the cost of transporting the water to its destination. The pipeline and other off-site costs were taken from DOE (1991) and were not independently estimated for this study.

2.3.5 Alternative 5 - On-Site Evapotranspiration by Pasture Grass

This alternative has three sub-alternatives. In one sub-alternative, an off-channel reservoir will be sized for land application of RFP water to irrigate pasture grass. This sub-alternative is similar to, but not exactly the same as, Option 3b in DOE (1991). In the second and third sub-alternatives, Great Western Reservoir and the existing terminal ponds are used as an alternatives storage reservoir with water pumped for application to irrigate pasture grass. For purposes of this study, it was assumed that the method of irrigation was by center-pivot sprinkler system at some location on the RFP. While this location is undetermined, it most likely would be on one of the relatively flat pediments north or south of the Controlled Area. These sub-alternatives include: (a) on-site evapotranspiration by pasture grass; (b) Great Western Reservoir as the equalizing reservoir rather than a new off-channel reservoir applicable to sub-alternative (a); and

(c) the existing terminal pond as the equalizing reservoirs rather than a new off-channel reservoir applicable to sub-alternative (a).

Reservoir operational studies were done to preliminarily size a new off-channel reservoir for sub-alternative 5a, for Great Western Reservoir for sub-alternative 5b, and for the existing terminal ponds for sub-alternative 5c. Results of the reservoir-sizing and operational studies for each of these sub-alternatives are presented in Section 3.0. For this alternative, the surface-water runoff for the new off-channel reservoir and the terminal ponds was assumed to come from 1.9 mi^2 of drainage area collected by the existing terminal ponds and pumped to the off-channel reservoir. For the Great Western alternative, it was assumed that surface runoff came from 5.5 mi^2 of drainage area contributing to the Reservoir. Costs in this alternative are for the storage reservoir and appurtenant facilities, such as pumping from the existing terminal ponds to the off-channel reservoir, along with the cost of transporting the water to its destination. The pipeline and other off-site costs were taken from DOE (1991) and were not independently estimated for this study.

2.3.6 Alternative 6 - On-Site Spray Evaporation (Zero Discharge)

This alternative has three sub-alternatives. One of these sub-alternatives is similar to Option No. 3d in DOE (1991). The other two sub-alternatives use Great Western Reservoir and the existing terminal ponds as the storage reservoir rather than a new reservoir. These sub-alternatives include: (a) sizing of a new off-channel storage reservoir and a new on-site, lined spray evaporation area; (b) using Great Western Reservoir as the equalizing storage reservoir instead of a new off-channel reservoir, combined with a new on-site, lined spray evaporation area; and (c) using the existing terminal ponds as the equalizing storage reservoir rather than a new off-channel reservoir, with a new on-site, lined spray evaporation area.

Reservoir operational studies were done to preliminarily size a new off-channel reservoir for sub-alternative 6a, for Great Western Reservoir for sub-alternative 6b, and for the existing terminal ponds for sub-alternative 6c. Results of the reservoir sizing and operational studies for each of these sub-alternatives are presented in Section 3.0. For this alternative, the surface-water runoff for the new off-channel reservoir and the terminal ponds was assumed to come from 1.9 mi^2 of drainage area collected by the existing terminal ponds and pumped to the off-channel reservoir. For the Great Western alternative, it was assumed that surface runoff came from 5.5 mi^2 of drainage area contributing to the Reservoir. Costs in this alternative are for the storage reservoir and appurtenant facilities, such as pumping from the existing terminal ponds to the off-channel reservoir, along with the cost of transporting the water to its destination. The pipeline and other on-site costs were taken from Merrick & Company (1990) and were not independently estimated for this study.

3.0 RESULTS OF RESERVOIR OPERATIONAL STUDIES

Reservoir operational studies were performed for both off-channel and on-channel temporary water-storage facilities. These reservoir operational studies analyzed 50 years of reservoir operation considering the above-defined inflow and outflow sources presented previously in Sections 2.2.2 and 2.2.3 Thirty-five preliminary alternatives, including the "no-action" alternative and different combinations of inflow and outflow, were identified as described below. All of these alternatives examined reservoir operations assuming that STP effluent was discharged into the proposed water-storage facility, along with surface-water runoff, ground water and runoff from the 100-yr, 72-hr storm.

Fifteen alternatives investigated included a use of an off-channel water-storage reservoir, five alternatives investigated include use of Great Western Reservoir and 15 alternatives investigated included use of the existing terminal ponds. Of the fifteen off-channel water-storage alternatives, five assessed off-site discharge at a new location, seven assessed off-site discharge to existing wastewater treatment facilities in the Denver metropolitan area, two assessed off-site discharge to water users (such as irrigation at the new Denver airport), one assessed on-site irrigation of pasture grass, and one assessed zero discharge using on-site spray evaporation. The Great Western Reservoir and terminal pond alternatives also assessed the same relative distribution of off-site and on-site reuse or zero discharge.

An alternative-evaluation system was used to rank the water-storage capabilities of each alternative. Within the alternative evaluation system are weighing factors that influence the overall zero-discharge study. These factors were selected by a committee consisting of cognizant DOE and EG&G personnel. A discussion of how each of the categories were evaluated follows.

<u>Controlled Discharge</u> - Each alternative has been sized to a maximum size allowable which, in the case of the terminal ponds, has been restricted by the surrounding topography. If an uncontrolled discharge occurred from a storage reservoir, a score of "1" was given to that

alternative. If uncontrolled discharges do not occur within an alternative, a score of "5" was given to that alternative.

Waste Generation - Alternatives that are designed to reuse water for irrigation or spray evaporation and those designed to treat and release water downstream would generate wastes during treatment. Several alternatives would be treating various amounts of water and, thus, creating various amounts of waste. The alternatives were ranked based upon the amount of water that would need to be treated on an annual basis. The alternative which generates the greatest amount of waste was given the lowest relative score.

Risk - Each alternative presents a different level of risk that is associated with the possibility of dam failure. Because each alternative would be designed and constructed using state-of-art engineering techniques, the only variable between the alternatives, choice was whether the reservoir would be on-channel or off-channel. A score of "1" was given to those alternatives that would be on-channel, and a score of "5" was given to those alternatives that would be off-channel.

Cost - Each alternative was ranked on the relative cost of construction of a reservoir, bypass channels, treatment facilities, pumps, piping, and operation, maintenance, and replacement (OM & R) costs. The alternative with the highest construction and OM & R costs received the lowest score.

Design and Construction Schedule - The amount of design and construction required for each alternative is reflective of the cost of each alternative. Thus, the score that was given to the design and construction schedule was the same score that is given to the cost of the alternative. The alternative with the least amount of design and construction required received the highest score.

Flexibility - The flexibility of any proposed storage/reuse system would depend upon the system's capability to continue operating, without uncontrolled releases, in the event that mechanical failure would occur or a large unpredicted storm event would occur. The use of multiple ponds would be more flexible, because of the ability to move the water from one pond to another. If mechanical failure would occur with a system in one of the ponds, the other ponds can continue to operate. Most of the alternatives have been evaluated based upon the construction of a single pond. The flexibility of the single-pond alternatives can be increased by constructing multiple ponds. A score of "1" was given to the alternatives in which only one pond is considered. A score of "5" was given to the alternatives in which multiple ponds were considered.

Water Rights - The alternatives are scored in this category based upon whether or not the downstream water rights would be met by downstream release. Those alternatives in which it would be necessary to purchase water to meet downstream water rights were given a score of "1".

Air Emissions - None of the alternatives represents an advantage under this category. Air emissions are not an issue; thus, each alternative has been given a score of "5".

Wetlands/T&E - In the event that wetlands would be created, DOE may be obligated to maintain those wetlands throughout the period of reservoir operation and beyond. For this reason, it was not considered to be positive for any given alternative to create wetlands. The creation of wetlands also may cause additional long-term costs to maintain the wetlands. For example, during dry years, water may need to be purchased to maintain the newly created wetlands. Thus, the alternative which would create the least, or smallest, areal wetlands received the highest score.

New Off-Channel Storage

IHSS/SWMU - The creation of temporary water storage facilities on-site may also create additional SWMU(s). The alternative that would create the largest SWMU was given the lowest score.

Public Acceptability - Public acceptability was based on three of the above categories: (1) controlled discharge; (2) risk; and (3) IHSS/SWMU. These three categories are likely the most critical areas in which the public would be concerned. Thus, the scores that were given to the above three categories for each alternative were averaged to provide the score for public acceptability.

Preliminary conceptual-level cost estimates were performed on the earthwork required for dam construction and/or improvements, advanced water treatment for water-rights releases downstream at the prevailing stream standards, piping and pumping for makeup-water recycle and enhanced evaporation.

The costs developed are planning-level costs only and were derived from several sources. The "average bid price" as presented in "Bids Tabs Database" from the Urban Drainage and Flood Control District (1990), the draft Surface-Water Management Plan (DOE, 1991), and recent scope and estimate reports by Merrick & Company (1990) were used as a basis for these costs. Additionally, engineering judgements related to construction and OM & R costs also were used. Annual OM & R costs were assumed to be about 15 percent of the total estimated preliminary construction costs based upon engineering judgment. Unlike the one-time construction costs, OM & R costs are incurred each year of the project life.

3.1 NEW OFF-CHANNEL STORAGE RESERVOIR

Table 5 describes the 15 alternatives (2a through 2d, 3a through 3g, 4a and 4b, 5a and 6a related to a new off-channel reservoir to temporarily store STP effluent, surface-water runoff, ground water, and inflow from the 100-yr, 72-hr storm-event runoff. All 15 alternatives assume that the

Table 5

Reservoir Operational Alternatives (New Off-Channel Reservoir)[1)]

Alternative Number	Description
2a through 2d	Off-channel storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 1.9 mi^2 (125.3 ac-ft/yr) with the 100-yr, 72-hr flood (425 ac-ft/yr), and ground water (10 ac-ft/yr) with downstream releases through a pipeline (496 ac-ft/yr) to a nearby stream.
3a through 3g	Off-channel storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 1.9 mi^2 (125.3 ac-ft/yr) with the 100-yr, 72-hr flood (425 ac-ft/yr), and ground water (10 ac-ft/yr) with discharge to an existing Denver metropolitan area sewer system (187 to 374 ac-ft/yr).
4a	Off-channel storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 1.9 mi^2 (125.3 ac-ft/yr) with the 100-yr, 72-hr flood (425 ac-ft/yr), and ground water (10 ac-ft/yr) with a pipeline (187 to 374 ac-ft/yr) to the Denver Water Department Potable Reuse Plant.
4b	Off-channel storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 1.9 mi^2 (125.3 ac-ft/yr) with the 100-yr, 72-hr flood (425 ac-ft/yr), and ground water (10 ac-ft/yr) with an irrigation water pipeline (164.6 to 658.3 ac-ft/yr) to the new Denver Airport.
5a	Off-channel storage of STP effluent form 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 1.9 mi^2 (125.3 ac-ft/yr) with the 100-yr, 72-hr flood (425 ac-ft/yr), and ground water (10 ac-ft/yr) with on-site irrigation of pasture grass (144 to 576 ac-ft/yr).
6a	Off-channel storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 1.9 mi^2 (125.3 ac-ft/yr) with the 100-yr, 72-hr flood (425 ac-ft/yr), and ground water (10 ac-ft/yr) with April-through-October on-site spray evaporation in a lined pond (122.9 to 492.4 ac-ft/yr) (Zero Discharge).

1) Annual quantities shown in parentheses are the approximate 50-year averages and may vary from year to year.

Table 6

RESULTS OF NEW OFF-CHANNEL SIZING RESERVOIR OPERATIONAL ALTERNATIVES

ALTERNATIVE	INPUT ALTERNATIVE — ALL ALTERNATIVES INCLUDE 10 AF/YR GROUNDWATER, 125.3 AC-FT/YR SURFACE-WATER RUNOFF, 237 AC-FT/YR STP EFFLUENT, AND 425 AC-FT FROM 100-YR, 72-HR FLOOD					OUTPUT RESULT					
	DOWNSTREAM RELEASES WITH TREATMENT (496 AC-FT/YR)	DISCHARGE TO SEWER SYSTEM WITH TREAT-MENT (374 AC-FT/YR)	DISCHARGE TO AIRPORT (658 AC-FT/YR)	IRRIGATION OF 320 AC (576 AC-FT/YR)	ENHANCED EVAPORATION (492 AC-FT/YR)	NO UNCONTROLLED RELEASES	DEMAND WATER SHORTAGES	RESERVOIR VOLUME 300-400 AC-FT	RESERVOIR VOLUME 400-500 AC-FT	RESERVOIR VOLUME 500-600 AC-FT	RESERVOIR VOLUME 600-700 AC-FT
2a through d	●					■				■	
3a through g		●				■					■
4a	●					■				■	
4b			●			■	■ 182 1)	■			
5a				●		■	■ 153 1)		■		
6a					●	■				■	

● = INPUT ALTERNATIVE
= OUTPUT RESULT
1) TOTAL NUMBER OF MONTHS OF UNCONTROLLED RELEASES DURING 600-MONTH OPERATIONAL PERIOD

50-year average STP inflow is about 237 ac-ft/yr, surface-water inflow is about 125 ac-ft/yr, ground water inflow is about 10 ac-ft/yr and the runoff from the 100-yr, 72-hr flood is about 425 ac-ft which is assumed to occur in the month of July.

Water releases from the reservoir or demands on the reservoir were estimated as described earlier in this report. Several levels of releases and demands were considered in the operational studies for several of the 15 alternatives. If controlled releases were made downstream, as was the case for alternatives 2a through 2d, 3a through 3g, and 4a and 4b, it was assumed that the water could be treated to a quality consistent with the prevailing stream standards. This assumption also included those alternatives where water would be released to existing municipal sewer systems (Alternatives 3a through 3g). The rationale for treatment was based upon the fact that the STP effluent from the RFP would be part of the water inputs as well as runoff from known IHSS's. Therefore, it seems likely that treatment prior to release off site is mandatory from a risk potential standpoint.

Results of the monthly operational studies for the off-channel storage of STP effluent, surface-water runoff, ground water, and the 100-yr, 72-hr flood are shown in Tables 6 and 7. Analyses of the results in Tables 6 and 7 indicate that the volume of a reservoir large enough to minimize uncontrolled releases would range from about 346 ac-ft of storage to over 7,130 ac-ft depending upon the assumed release rate. For the off-site discharge at a new location (Alternatives 2a through 2d), the resulting reservoir volume was about 500 ac-ft with reservoir surface area of about 30 ac, assuming a 20-ft deep reservoir (Table 7).

For off-site discharge to an existing municipal sewer system (Alternatives 3a through 3g) the reservoir volumes ranged from abut 710 ac-ft to over 7,130 ac-ft with reservoir surface areas ranging from about 40 to 360 ac depending upon the rate at which water could be released to the existing sewers. For purposes of comparing alternatives the smallest reservoir volume and surface area, 706 ac-ft and 37 ac, respectively, were presented in Table 6. For off-site discharge to downstream users, in this case the Denver Water Department Potable Reuse Plant (Alternative

Table 7

Reservoir Sizes For New Off-Channel Reservoir[1)]

Alternative	Surface-Water Runoff and Ground-Water Inputs (ac-ft/yr)	STP Effluent Inflow (ac-ft/yr)	Water Demands (ac-ft/yr)	Inflow from 100-Yr, 72-Hr Flood (ac-ft/yr)	Releases With Treatment (ac-ft/yr)	Storage Reservoir Volume (ac-ft)	Storage Reservoir Surface Area (ac)
2a through 2d and 4a	135.3	237	0	425	496	546	29
3a through 3g and 4a	135.3	237	0	425	187	7130	364
	135.3	237	0	425	281	3840	197
	135.3	237	0	425	374	706	37
4b	135.3	237	329[4)]	425	0	1910	99
	135.3	237	658[5)]	425	0	324[6)]	18
5a	135.3	237	288[4)]	425	0	3570	184
	135.3	237	576[5)]	425	0	406[6)]	22
6a	135.3	237	246[2)]	425	0	5430	278
	135.3	237	492[3)]	425	0	546	29

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1) Assumes a rectangular reservoir, 20-feet deep.

2) Assumes 1,000 gpm pumping rate for an enhanced evaporation during the months of April through October of about 246.2 ac-ft/yr. The minimum surface area for such a system is about 23 acres (Merrick & Company, 1990).

3) Assumes 2,000 gpm pumping rate for an enhanced evaporation during the months of April through October of about 492.4 ac-ft/yr. The minimum surface area for such a system is about 23 acres (Merrick & Company, 1990).

4) Corresponds to 160 acres of irrigated area.

5) Corresponds to 320 acres of irrigated area.

6) Water shortages occurred for this reservoir size indicating that the reservoir was dry during part of the 50-year operational study.

4a), the reservoir size was the same as for either Alternatives 2a through 2d or Alternatives 3a through 3g depending upon the assumed rate of release to the Plant.

On-site water use by irrigation of pasture grass (Alternative 5a) assumed that 320 acres would be irrigated. The resulting reservoir volume was about 410 ac-ft with a surface area of about 22 ac. On-site spray evaporation (Alternative 6a) assumed a spray pumping rate of 2000 gpm in a separate 23-ac pond (Merrick & Company, 1990). The resulting off-channel storage reservoir volume was about 550 ac-ft with a surface area of about 29 ac. Alternative 6a is a zero-discharge alternative because water would not be discharged either to the surface- or ground-water systems.

Table 6 summarizes the output results of the smallest off-channel storage reservoirs from the 50-year operational studies. All reservoirs sizes resulted in no uncontrolled releases, based upon the assumed inputs. Alternatives 4b and 5a (irrigation alternatives) would result in water shortages in up to 30 percent of the 600 months over which the operational studies were performed. Therefore, the reservoir size presented for these two alternatives could not provide a dependable water supply. This could reduce the advantages of using RFP water as a water source off site. If irrigation was on site, there would be a cost savings by not operating the irrigation system if no water were available.

The construction, operation, maintenance and replacement (OM & R) costs of the new off-channel water-storage reservoir are generally proportional to the size of the reservoir. Total construction, and OM & R costs for the 15 off-channel reservoir alternatives are shown in Table 8. The single largest cost is associated with treatment of water for off-site release. Alternatives which release water off site (2a through 2d, 3a through 3g, 4a and 4b) were assumed incur this treatment cost because of both public perception of the water quality and to reduce risk. The construction costs of alternatives which had water treatment ranged from about $50 million (M) to over $100M. The lowest costs alternatives (5a and 6a) were associated with on-site water use either for irrigation of pasture grass (Alternative 5a) or spray evaporation (Alternative 6a).

Table 8

Preliminary Construction and OM & R Costs For New Off-Channel Reservoir Operational Alternatives

Alternative[9]	Estimated Construction Costs (Million $) Reservoir Earthwork	Piping and Pumping[2]	Pond Liner	Enhanced Evaporation[1]	New Advanced Water Treatment Plant[2]	Total	Annual OM & R Costs (15% of Total)[10]
2a[3]	0.9	14.9	0.6	0	62.5	78.9	11.8
2b[3]	0.9	9.3	0.6	0	62.5	73.3	11.0
2c[3]	0.9	4.0	0.6	0	62.5	68.0	10.2
2d[3]	0.9	5.8	0.6	0	62.5	69.8	10.5
3a[4]	1.1	2.5	0.7	0	47.1	51.4	7.7
3b[4]	1.1	1.6	0.7	0	47.1	50.5	7.6
3c[4]	1.1	8.6[7]	0.7	0	47.1	57.5	8.6
3d[4]	1.1	10.7	0.7	0	47.1	59.6	8.9
3e[4]	1.1	10.9	0.7	0	47.1	59.8	9.0
3f[4]	1.1	8.3[7]	0.7	0	47.1	57.2	8.6
3g[4]	1.1	12.3[7]	0.7	0	47.1	61.2	9.2
4a[4]	1.1	20.7[8]	0.7	0	47.1	69.9	10.4
4b[5]	0.7	17.5	0.4	0	82.9	101.5	15.2
5a[6]	0.8	9.0	0.4	0	0	10.2	1.5
6a[3]	0.9	0.6	0.4	2.6	0	4.5	0.7

1) Source: Merrick & Company (1990).
2) Source: DOE (1991).
3) Reservoir storage = 546 ac-ft, surface area = 29 ac.
4) Reservoir storage = 706 ac-ft, surface area = 37 ac.
5) Reservoir storage = 324 ac-ft, surface area = 18 ac.
6) Reservoir storage = 406 ac-ft, surface area = 22 ac.
7) Includes upgrading existing municipal STP.
8) Includes purchase of Denver Potable Water Reuse Plant.
9) See Table 5 for description.
10) 15% of Total Construction Costs.

Great Western Reservoir

Annual OM & R costs for the 15 alternatives ranged from about $0.7M to over $15M with the smaller annual costs being associated with the on-site alternatives rather than the off-site discharge alternatives.

Based upon alternative evaluation system discussed above, Table 9 indicates that Alternative 6a was selected as the preferred alternative for an off-channel water-storage reservoir. The environmental consequences related to this selected off-channel alternative would be minimal. Because it was proposed that these facilities be lined, wetlands would not be created. In addition, the location of the pond(s) will likely be such that present wetlands would not be affected by construction of such ponds. Also, because the reservoir(s) would not be located within a channel, the destruction of downstream wetlands will not be a concern due to not releasing water. The main environmental concern related to the selected alternative would be the creation of solid waste as a result of the treatment of the water discharged. The water that is treated will create solid waste that will need to be handled and disposed of in an environmentally safe manner.

3.2 GREAT WESTERN RESERVOIR

Operational studies were performed for Great Western Reservoir to evaluate if it could provide storage for the same 15 alternatives considered in the off-channel water-storage reservoir operational studies. Table 10 summarizes the basic alternatives for Great Western Reservoir operational studies. The basic differences in operational studies performed on Great Western Reservoir, as opposed to the off-channel reservoir, were: (1) the size of Great Western Reservoir was assumed to be limited to its present size, and (2) water would be pumped back to the RFP for on-site water-use alternatives. It is likely that releasing RFP's STP effluent to Great Western Reservoir and then pumping it back to the RFP would not be cost effective. However, for purposes of this study, RFP-generated STP effluent and surface-water runoff from 5.5 mi^2 of contributing drainage area (Figure 1) were assumed to be stored in Great Western Reservoir

TABLE 9

Alternative Evaluation And Ranking
New Off-Channel Reservoir

EVALUATION FACTORS	WEIGHTING FACTOR	ALT 2a - d		ALT 3a - g		ALT 4a		ALT 4b		ALT 5a		ALT 6a	
		S	W	S	W	S	W	S	W	S	W	S	W
CONTROLLED DISCHARGE	10	5	50	5	50	5	50	5	50	5	50	5	50
WASTE GENERATION	7	1	7	1	7	1	7	1	7	5	35	5	35
RISK	8	5	40	5	40	5	40	5	40	5	40	5	40
COST	6	2	12	3	18	2	12	1	6	4	24	5	30
DESIGN AND CONST. SCHEDULE	6	2	12	3	18	2	12	1	6	4	24	5	30
FLEXIBILITY	8	1	8	1	8	1	8	1	8	1	8	1	8
WATER RIGHTS	5	5	25	5	25	1	5	1	5	1	5	1	5
AIR EMISSIONS	10	5	50	5	50	5	50	5	50	5	50	5	50
WETLANDS/T&E	10	5	50	5	50	5	50	5	50	5	50	5	50
IHSS	10	3	30	1	10	3	30	4	40	2	20	3	30
PUBLIC ACCEPTABILITY	8	4.3	35	3.7	29	4.3	35	4.7	37	4	32	4.3	35
TOTALS			319		305		299		299		338		363
RANK			3		4		5		5		2		1

S = SCORE
W = WEIGHTED SCORE (SCORE X WEIGHTING FACTOR)

along with 1143 ac-ft from the 100-yr, 72-hr flood. Increasing the dam and spillway crest elevations of Great Western Reservoir may improve the estimates given below, however, it was assumed that no design changes would be made to Great Western Reservoir.

Results of the Great Western Reservoir operational studies are summarized in Table 11. For the off-site discharge at a new location (Alternatives 2e(a) through 2e(d)), some uncontrolled releases occurred for about 5 of the 600 months of simulation. Uncontrolled releases during these months generally were the result of the 100-yr, 72-hr flood which would cause water to discharge over the "stop logs" at the emergency spillway. This once-during-the-simulation uncontrolled release is not considered to be important, because the probability of at least one 100-yr, 72-hr flood during the 50-year operational study is about 40 percent, assuming that the occurrence of the flood follows the same probability distribution as that of tossing a fair coin.

For the off-site discharge to existing municipal sewer systems (Alternatives 3h(a) through 3h(g)), the uncontrolled releases occurred in 64 of the 600 months of simulation. These months generally were distributed throughout the period of simulation. Therefore, the existing Great Western Reservoir may release some untreated water downstream because a treatment plant generally could not treat the peaks associated with these 64 months of releases. A larger reservoir does not appear to be capable of storing the excess water released, which averaged about 356 ac-ft per year. The largest uncontrolled release was over 1300 ac-ft, nearly all in one month, as a result of the 100-yr, 72-hr flood.

Other alternatives associated with off-site discharge to downstream water users (Alternatives 4c(a) and 4c(b)), and on-site water uses (Alternatives 5b(a) and 6b(a)) resulted in essentially no uncontrolled releases. Therefore, Great Western Reservoir could be used as the water-storage structure for all but Alternative 3h , as shown in Table 10, without causing untreated water to be released downstream.

Alternatives 4c(b) and 5b(a) (irrigation alternatives) would result in water shortages in up to 11 percent of the 600 months over which the operational studies were performed (Table 4). Therefore, Great Western Reservoir may not provide a completely dependable water supply. This would reduce only slightly the attractiveness of RFP water as a water source off-site.

Table 10

Reservoir Operational Alternatives (Great Western Reservoir)[1)]

Alternative Number	Description
2e	On-channel Great Western Reservoir (GWR) storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 5.5 mi^2 (279.7 ac-ft/yr) with the 100-yr, 72-hr flood (1143 ac-ft/yr), and ground water (10 ac-ft/yr) with downstream releases through a pipeline (496 ac-ft/yr) to a nearby stream.
3h	On-channel GWR storage of STP effluent form 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 5.5 mi^2 (279.7 ac-ft/yr) with the 100-yr, 72-hr flood (1143 ac-ft/yr), and ground water (10 ac-ft/yr) with discharge to an existing Denver metropolitan area sewer system (187 to 374 ac-ft/yr).
4c	On-channel GWR storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 5.5 mi^2 (279.7 ac-ft/yr) with the 100-yr, 72-hr flood (1143 ac-ft/yr), and ground water (10 ac-ft/yr) with a pipeline (187 to 374 ac-ft/yr) to the Denver Water Department Potable Reuse Plant, or with an irrigation water pipeline (164.6 to 658.3 ac-ft/yr) to the new Denver Airport.
5b	On-channel GWR storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 5.5 mi^2 (279.7 ac-ft/yr) with the 100-yr, 72-hr flood (1143 ac-ft/yr), and ground water (10 ac-ft/yr) with on-site irrigation of pasture grass (144 to 576 ac-ft/yr).
6b	On-channel GWR storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 5.5 mi^2 (279.7 ac-ft/yr) with the 100-yr, 72-hr flood (1143 ac-ft/yr), and ground water (10 ac-ft/yr) with April-through-October on-site spray evaporation in a lined pond (122.9 to 492.4 ac-ft/yr) (Zero Discharge).

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1) Annual quantities shown in parentheses are approximate 50-year averages and may vary from year to year.

Table 11

RESULTS OF **GREAT WESTERN RESERVOIR** SIZING
RESERVOIR OPERATIONAL ALTERNATIVES

ALTERNATIVE	INPUT ALTERNATIVE: ALL ALTERNATIVES INCLUDE 10 AF/YR GROUNDWATER, 280 AC-FT/YR SURFACE-WATER RUNOFF, 237 AC-FT/YR STP EFFLUENT, AND 1143 AC-FT FROM 100-YR, 72-HR FLOOD					OUTPUT RESULT		
	DOWNSTREAM RELEASES WITH TREATMENT (496 AC-FT/YR)	DISCHARGE TO SEWER SYSTEM WITH TREAT-MENT (374 AC-FT/YR)	DISCHARGE TO AIRPORT (658 AC-FT/YR)	IRRIGATION OF 320 AC (576 AC-FT/YR)	ENHANCED EVAPORATION (492 AC-FT/YR)	NO UNCONTROLLED RELEASES	UNCONTROLLED RELEASES	DEMAND WATER SHORTAGES
2e(a through d)	●						■ 5 1)	
3h(a through g)		●					■ 64 1)	
4c(a)	●						■ 5 1)	
4c(b)			●			■		■ 66 2)
5b(a)				●		■		■ 5 2)
6b(a)					●		■ 4 1)	

● = INPUT ALTERNATIVE
= OUTPUT RESULT

1) TOTAL NUMBER OF MONTHS OF UNCONTROLLED RELEASES DURING 600-MONTH OPERATIONAL PERIOD

2) TOTAL NUMBER OF MONTHS OF SHORTAGES DURING 600-MONTH OPERATIONAL PERIOD

Terminal Ponds

The construction costs, and OM & R costs of Great Western Reservoir would be generally proportional to the location of the water use. Total construction, and OM & R costs for the 15 alternatives associated with Great Western Reservoir are given in Table 12. The two largest costs are associated with the purchase and upgrade of the Reservoir and treatment of water for off-site release. Alternatives which release water off site (2e(a) through 2e(d), 3h(a) through 3h(g), 4c(a) and 4c(b)) were assumed incur this treatment cost, because of both public perception of the water quality and of the need to reduce risk. The construction costs of alternatives which had water treatment ranged from about $119M to over $170M. The lowest costs alternatives (5b(a) and 6b(a)) were associated with on-site water use either for irrigation of pasture grass (Alternative 5b(a)) or spray evaporation (Alternative 6b(a)). Annual OM & R costs for the 15 alternatives ranged from about $11.2M to over $25M, with the smaller annual costs being associated with the on-site alternatives rather than the off-site discharge alternatives.

Based upon alternative evaluation system discussed above, Table 13 indicates that Alternative 5b(a) was selected as the best alternative for using Great Western as a water-storage reservoir. The environmental consequences related to the selected alternative is the generation of solid waste, and the water quality of Great Western Reservoir due to the inflow of STP effluent and other naturally occurring nutrients. The consequences of the decrease in water quality are such that Great Western Reservoir water quality may seriously deteriorate over time and as such become a large SWMU that may require remediation. As previously mentioned, if water is to be discharged, it must be treated which in turn will generate solid waste. This is an environmental concern in that the waste generated, must be handled and disposed of in an environmentally safe manner.

3.3 TERMINAL PONDS STORAGE

Alternatives 2f through 6c, as described in Table 14, would use the existing three terminal ponds (Ponds A-4, B-5 and C-2) as temporary water-storage facilities. The alternatives include storage

Table 12

Preliminary Construction and OM & R Costs For Great Western Reservoir Operational Alternatives

Alternative	Estimated Construction Costs ($ Million) Purchase and Upgrade GWR[2]	New Advanced Water Treatment Plant at GWR	C-2 Interceptor Pump and Pipeline to A-4 or B-5[2]	Piping and Pumping[2]	Enhanced Evaporation[1]	Total	Annual OM&R Cost (15% of Total)
2e(a)	70.0	62.5	0.3	14.8	0	147.6	22.1
2e(b)	70.0	62.5	0.3	9.2	0	142.0	21.3
2e(c)	70.0	62.5	0.3	3.9	0	136.7	20.5
2e(d)	70.0	62.5	0.3	5.7	0	138.5	20.8
3h(a)	70.0	47.1	0.3	2.4	0	119.8	18.0
3h(b)	70.0	47.1	0.3	1.6	0	119.0	17.8
3h(c)	70.0	47.1	0.3	8.6[3]	0	126.0	18.9
3h(d)	70.0	47.1	0.3	10.7	0	128.1	19.2
3h(e)	70.0	47.1	0.3	10.9	0	128.3	19.2
3h(f)	70.0	47.1	0.3	8.3[3]	0	125.7	18.9
3h(g)	70.0	47.1	0.3	12.3[3]	0	129.7	19.5
4c(a)	70.0	47.1	0.3	20.7[4]	0	138.1	20.7
4c(b)	70.0	82.9	0.3	17.4	0	170.6	25.6
5b(a)	70.0	0	0.3	10.6	0	80.9	12.1
6b(a)	70.0	0	0.3	2.0	2.6	74.9	11.2

1) Source: Merrick & Company (1990)
2) Source: DOE (1991)
3) Includes upgrading existing municipal STP.
4) Includes purchase of Denver Potable Water Reuse Plant.
GWR = Great Western Reservoir

TABLE 13

Alternative Evaluation And Ranking
Great Western Reservoir

EVALUATION FACTORS	WEIGHTING FACTOR	ALT 2e(a-d)		ALT 3h(a-g)		ALT 4c(a)		ALT 4c(b)		ALT 5b(a)		ALT 6b(a)	
		S	W	S	W	S	W	S	W	S	W	S	W
CONTROLLED DISCHARGE	10	1	10	1	10	1	10	5	50	5	50	1	10
WASTE GENERATION	7	1	7	1	7	1	7	1	7	5	35	5	35
RISK	8	1	8	1	8	1	8	1	8	1	8	1	8
COST	6	2	12	3	18	2	12	1	6	4	24	5	30
DESIGN AND CONST. SCHEDULE	6	2	12	3	18	2	12	1	6	4	24	5	30
FLEXIBILITY	8	1	8	1	8	1	8	1	8	1	8	1	8
WATER RIGHTS	5	5	25	5	25	1	5	1	5	1	5	1	5
AIR EMISSIONS	10	5	50	5	50	5	50	5	50	5	50	5	50
WETLANDS/T&E	10	5	50	5	50	5	50	5	50	5	50	5	50
IHSS	10	2	20	2	20	2	20	2	20	1	10	2	20
PUBLIC ACCEPTABILITY	8	1.3	11	1.3	11	1.3	11	2.7	21	2.3	19	1.3	11
TOTALS			213		225		193		231		283		257
RANK			5		4		6		3		1		2

S = SCORE
W = WEIGHTED SCORE (SCORE X WEIGHTING FACTOR)

Table 14

Reservoir Operational Alternatives (Terminal Ponds)[1)]

Alternative Number	Description
2f	Terminal ponds storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 1.07, 0.41, and 0.35 mi^2 (81.0, 39.2, and 34.8 ac-ft/yr) with the 100-yr, 72-hr flood (243, 106, and 76 ac-ft/yr), and ground water (10 ac-ft/yr) with downstream releases through a pipeline (496 ac-ft/yr) to a nearby stream.
3i	Terminal ponds storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface water runoff from 1.07, 0.41 and 0.35 mi^2 (81.0, 39.2, and 34.8 ac-ft/yr) with the 100-yr, 72-hr flood (243, 106 and 76 ac-ft/yr), and ground water (10 ac-ft/yr) with discharge to an existing Denver metropolitan area sewer system (187 to 374 ac-ft/yr).
4d	Terminal ponds storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 1.07, 0.41, and 0.35 mi^2 (81.0, 39.2, and 34.8 ac-ft/yr) with the 100-yr, 72-hr flood (243, 106 and 76 ac-ft/yr), and ground water (10 ac-ft/yr) with a pipeline (187 to 374 ac-ft/yr) to the Denver Water Department Potable Reuse Plant, or with an irrigation water pipeline (164.6 to 658.3 ac-ft/yr) to the new Denver Airport.
5c	Terminal ponds storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 1.07 0.41 and 0.35 mi^2 (81.0, 39.2, and 34.8 ac-ft/yr) with the 100-yr, 72-hr flood (425 ac-ft/yr), and ground water (10 ac-ft/yr) with on-site irrigation of pasture grass (144 to 576 ac-ft/yr).
6c	Terminal ponds storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 1.07, 0.41 and 0.35 mi^2 (81.0, 39.2, and 34.8 ac-ft/yr) with the 100-yr, 72-hr flood (243, 106 and 76 ac-ft/yr), and ground water 10 ac-ft/yr) with April-through-October on-site spray evaporation in a lined pond (122.9 to 492.4 ac-ft/yr) (Zero Discharge).

1) Annual quantities shown in parentheses are approximate 50-year averages and may vary from year to year.

of surface-water runoff, ground water, runoff from a 100-year (Figure 1), 72-hour flood, and STP effluent for a plant population of 6300 personnel in Pond A-4 or B-5. All of the alternatives assume the 50-year average STP inflow is about 237 ac-ft/yr, surface-water inflow is about 81.0, 39.2, and 34.8 ac-ft/yr, for Ponds A-4, B-5, and C-2, respectively; ground water inflow is about 10 ac-ft/yr, and runoff from the 100-yr, 72-hr flood is about 243, 106, and 76 ac-ft/yr for Ponds A-4, B-5, and C-2, respectively, which is assumed to occur in the month of July. The range of alternatives include the following release scenarios:

- Off-site discharge at a new location (Alternative 2f);
- Off-site discharge to an existing municipal sewer system (Alternative 3i);
- Off-site discharge to water uses (Alternative 4d);
- On-site evapotranspiration by pasture grass (Alternative 5c); and
- On-site spray evaporation (zero discharge) (Alternative 6c).

Water releases from the reservoir or demands on the reservoir were estimated as described earlier in this report. Several levels of releases and demands were considered in the operational studies. If controlled releases were made downstream, as was the case for alternatives 2f(a through d), 3i(a through g), and 4d, it was assumed that the water was treated to a quality consistent with the prevailing stream standards. This assumption also included those alternatives where water was released to existing municipal sewer systems (Alternatives 3i(a through g). The rationale for treatment was based upon the fact that the STP effluent from the RFP would be part of the water inputs as well as runoff from known IHSS's. Therefore, it seems likely that treatment prior to release off site is mandatory from a risk potential standpoint.

The present spillway and dam crest elevations of the storage structures at the three terminal ponds may have to be increased, based upon results of these operational studies. Each of the three terminal ponds was treated separately. The result was a series of 5 alternatives for each pond based upon Table 14.

For purposes of analyses of the terminal ponds, it was assumed that there was a finite height to which the existing dams could be increased, and thus, the maximum possible storage at each site was assumed to be fixed by this physical constraint. For each pond, these physical constraints to storage volume and surface area were estimated by extending the existing elevation-area-capacity curves for each pond (Appendix C).

Analyses of each of the terminal ponds is given below for a 50-year sequence (Sequence number 3 in Appendix A-1) of surface-water runoff. The results also are presented individually for each pond. However, care should be used in mixing the different alternatives for the three ponds, because interactions between ponds are not obvious and have not been analyzed in detail in this study. Detailed analyses of possible interactions would involve all 5 main alternatives with each other.

The initial water-surface elevation in each of the terminal ponds was assumed to be that required to completely store the runoff from the 100-year, 72-hour storm. The increase in elevation to store the surface-water runoff, ground water, and STP effluent under the constraints of various water demands and water-rights releases was estimated.

3.3.1 Pond A-4

Results of the Pond A-4 operational studies are shown in Tables 15 and 16. Analyses of these results indicate that it would be possible to increase the height of the existing Pond A-4 dam to completely store surface-water runoff, assumed ground-water contributions, runoff from the 100-year, 72-hour storm, and STP effluent for only two of the alternatives examined (Alternatives 4d and 5c). Both of these alternatives include controlled releases from Pond A-4 greater than 300 ac-ft/yr. The existing spillway crest must be increased by 77 ft to accomplish complete storage of these alternatives (Table 16).

Table 15

RESULTS OF TERMINAL POND A-4 SIZING RESERVOIR OPERATIONAL ALTERNATIVES

ALTERNATIVE	INPUT ALTERNATIVE (ALL ALTERNATIVES INCLUDE 10 AF/YR GROUNDWATER 81.O AC-FT/YR SURFACE-WATER RUNOFF, 237 AC-FT/YR STP EFFLUENT, AND 243 AC-FT FROM 100-YR, 72-HR FLOOD): DOWNSTREAM RELEASES WITH TREATMENT (290.2 AC-FT/YR)	DISCHARGE TO SEWER SYSTEM WITH TREATMENT (218.8 AC-FT/YR)	DISCHARGE TO AIRPORT (385.1 AC-FT/YR)	IRRIGATION OF 320 AC (337 AC-FT/YR)	ENHANCED EVAPORATION (285.6 AC-FT/YR)	OUTPUT RESULT: NO UNCONTROLLED RELEASES	UNCONTROLLED RELEASES	DEMAND WATER SHORTAGES	RESERVOIR VOLUME 3250 AC-FT	RESERVOIR VOLUME >3250 AC-FT
2f(a through d)	●						■ 14 1)			■
3i(a through g)		●					■ 233 1)			■
4d(a and b)			●			■		■ 8 2)	■	
5c(a)				●		■			■	
6c(a)					●		■ 22 1)			■

● = INPUT ALTERNATIVE
■ = OUTPUT RESULT
1) TOTAL NUMBER OF MONTHS OF UNCONTROLLED RELEASES DURING 600-MONTH OPERATIONAL PERIOD
2) TOTAL NUMBER OF MONTHS OF SHORTAGES DURING 600-MONTH OPERATIONAL PERIOD

Table 16

Reservoir Sizes For Terminal Pond A-4 For Selected Operational Alternatives[1)]

Alternative	Surface-Water Runoff and Ground-Water Inputs (ac-ft/yr)	STP Effluent Inflow (ac-ft)	Water Demands (ac-ft/yr)	Inflow from 100-yr, 72-hr Flood (ac-ft)	Water-Rights Releases With Treatment (ac-ft/yr)	Maximum Pond Volume (ac-ft)	Approximate Maximum Pond Surface Area (ac)	Increase in Spillway Crest Elevation[2)] (ft)
2f	91.0	237	0.0	243	290.2	>3250	--[3)]	--[3)]
3i	91.0	237	0.0	243	164.6	>3250	--[3)]	--[3)]
	91.0	237	0.0	243	218.8	>3250	--[3)]	--[3)]
4d	91.0	237	192.5	243	0.0	>3250	--[3)]	--[3)]
	91.0	237	385.1	243	0.0	3250	68	77
5c	91.0	237	168.5	243	0.0	>3250	--[3)]	--[3)]
	91.0	237	385.1	243	0.0	3250	68	77
6c	91.0	237	144.0[4)]	243	0.0	>3250[4)]	--[3)]	--[3)]
	91.0	237	285.6[5)]	243	0.0	3250[4)]	68	77

1) Assumes a reservoir based upon the elevation-area-capacity curves in Appendix C.

2) As measured from the spillway crest elevation to completely store the 100-yr, 72-hr flood.

3) Cannot build dam high enough to prevent uncontrolled releases.

4) Assumes 1,000 gpm pumping rate for an enhanced evaporation during the months of April through October of about 144 ac-ft/yr. The minimum surface area for such a system is about 23 acres (Merrick & Company, 1990).

5) Assumes 2,000 gpm pumping rate for an enhanced evaporation during the months of April through October of about 285.6 ac-ft/yr. The minimum surface area for such a system is about 23 acres (Merrick & Company, 1990).

A reasonable conclusion would be that Pond A-4 could minimize uncontrolled releases from its drainage basin if the spillway crest were increased by about 77 feet for alternatives that discharge a minimum of 340 ac-ft/yr. Pond A-4 does not have a liner and, therefore, would continue to result in uncontrolled seepage downstream. Additionally, the water quality in Pond A-4 could require special treatment for controlled releases off-site.

3.3.2 Pond B-5

Results of the Pond B-5 operational studies are shown in Tables 17 and 18. Analyses of these results indicate that it is not physically possible to increase the height of the existing dam to completely store surface-water runoff, runoff from a 100-year, 72-hour flood from the Pond B-5 drainage basin of 0.41 mi^2 as defined in Table 14, assumed ground-water contributions, and STP effluent, for the selected alternatives unless Ponds A-4 and B-5 were combined to form a single reservoir. This combined dam-and-reservoir scenario was not examined in this study.

In order to make Pond B-5 an effective operable component of zero-discharge, the RFP should be able to discharge a minimum of 290 ac-ft/yr from this pond. Based upon the 50-year operational studies, the increase in spillway elevation at Pond B-5 in order to have no uncontrolled releases, for a discharge of 290 ac-ft/yr would have to be about 40 feet above the crest to completely store the 100-yr, 72-hr flood.

A reasonable conclusion would be that Pond B-5 could minimize uncontrolled releases from its drainage basin if the spillway crest were increased by about 40 feet. This increase in spillway crest elevation, coupled with a minimum discharge volume of about 290 ac-ft/yr would allow Pond B-5 to be effective in minimizing uncontrolled releases. Pond B-5 does not have a liner and, therefore, would continue to result in uncontrolled seepage downstream. Additionally, the water quality in Pond B-5 could require special treatment for discharge.

Table 17

RESULTS OF **TERMINAL POND B-5** SIZING
RESERVOIR OPERATIONAL ALTERNATIVES

INPUT ALTERNATIVE: ALL ALTERNATIVES INCLUDE 10 AF/YR GROUNDWATER 39.2 AC-FT/YR SURFACE-WATER RUNOFF, 237 AC-FT/YR STP EFFLUENT, AND 106 AC-FT FROM 100-YR, 72-HR FLOOD

	INPUT ALTERNATIVE					OUTPUT RESULT			
ALTERNATIVE	DOWNSTREAM RELEASES WITH TREATMENT (111.1 AC-FT/YR)	DISCHARGE TO SEWER SYSTEM WITH TREAT-MENT (83.8 AC-FT/YR)	DISCHARGE TO AIRPORT (147.5 AC-FT/YR)	IRRIGATION OF 320 AC (129.0 AC-FT/YR)	ENHANCED EVAPORATION (110.3 AC-FT/YR)	NO UNCONTROLLED RELEASES	UNCONTROLLED RELEASES	DEMAND WATER SHORTAGES	RESERVOIR VOLUME >770 AC-FT
2f(a through d)	●						■ 600[1]		■
3i(a through g)		●					■ 600[1]		■
4d(a and b)			●				■ 380[1]		■
5c(a)				●			■ 445[1]		■
6c(a)					●		■ 586[1]		■

● = INPUT ALTERNATIVE
■ = OUTPUT RESULT
1) TOTAL NUMBER OF MONTHS OF UNCONTROLLED RELEASES DURING 600-MONTH OPERATIONAL PERIOD

Table 18

Reservoir Sizes For Terminal Pond B-5 For Selected Operational Alternatives[1)]

Alternative	Surface-Water Runoff and Ground-Water Inputs (ac-ft/yr)	STP Effluent Inflow (ac-ft)	Water Demands (ac-ft/yr)	Inflow from 100-yr, 72-hr Flood (ac-ft)	Releases With Treatment (ac-ft/yr)	Maximum Pond Volume (ac-ft)	Approximate Maximum Pond Surface Area (ac)	Increase in Spillway Crest Elevation[2)] (ft)
2f	49.2	237	0.0	106	111.1	>770	--[3)]	--[3)]
3i	49.2	237	0.0	106	63.0	>770	--[3)]	--[3)]
	49.2	237	0.0	106	83.8	>770	--[3)]	--[3)]
4d	49.2	237	73.7	106	0.0	>770	--[3)]	--[3)]
	49.2	237	147.5	106	0.0	>770	--[3)]	--[3)]
	49.2	237	290.0	106	0.0	0	0	40
5c	49.2	237	64.5	106	0.0	>770	--[3)]	--[3)]
	49.2	237	129.0	106	0.0	>770	--[3)]	--[3)]
	49.2	237	290.0	106	0.0	0	0	40
6c	49.2	237	55.1[4)]	106	0.0	>770[4)]	--[3)]	--[3)]
	49.2	237	110.3[5)]	106	0.0	>770[5)]	--[3)]	--[3)]

1) Assumes a reservoir based upon the elevation-area-capacity curves in Appendix C.

2) As measured from the spillway crest elevation to completely store the 100-yr, 72-hr flood.

3) Cannot build dam high enough to prevent uncontrolled releases.

4) Assumes 1,000 gpm pumping rate for an enhanced evaporation during the months of April through October of about 55 ac-ft/yr. The minimum surface area for such a system is about 23 acres (Merrick & Company, 1990).

5) Assumes 2,000 gpm pumping rate for an enhanced evaporation during the months of April through October of about 110.3 ac-ft/yr. The minimum surface area for such a system is about 23 acres (Merrick & Company, 1990).

3.3.3 Pond C-2

Results of the Pond C-2 operational studies are shown in Tables 19 and 20. Analyses of these results indicate that if no STP is introduced into Pond C-2, the dam would have to be increased by 15 feet to completely store surface-water runoff and runoff from a 100-year, 72-hour flood from the Pond C-2 drainage basin of 0.35 mi^2, as defined in Table 14, and assumed ground water contributions. Analyses of Table 19 and Table 20 also indicate that if demands of 72 ac-ft/yr to 95 ac-ft/yr (Alternatives 2f, 3i, and 6c) occur, an increase in dam height of only 10 feet would provide adequate capacity to prevent uncontrolled releases based upon the 50-year operational study.

A reasonable conclusion would be that Pond C-2 could minimize uncontrolled releases from its drainage basin if the spillway crest were increased by about 10 ft for Alternatives 2f, 3i and 6c and about 15 feet for Alternatives 4d and 5c. Pond C-2 does not have a liner and, therefore, would continue to result in uncontrolled seepage downstream. Additionally, the water quality in Pond C-2 could require special treatment for discharge.

In summary, the construction, operation, maintenance and replacement costs to permit the terminal ponds to become part of a zero-discharge system are directly proportional to the increase in the existing spillway elevations. Table 21 summarizes the construction and annual OM & R costs for Ponds A-4, B-5, and C-2. For purposes of this study, the costs for all three terminal ponds will be combined for the one alternative that considers all three of the terminal ponds as an effective component of the Zero-Discharge study. The alternatives in which one of the terminal ponds dams could not be sized or constructed were dropped from further consideration. The costs for the single remaining alternative common to each of the terminal ponds is presented in Table 21.

Table 19

RESULTS OF **TERMINAL POND C-2** SIZING
RESERVOIR OPERATIONAL ALTERNATIVES

INPUT ALTERNATIVE: ALL ALTERNATIVES INCLUDE 10 AF/YR GROUNDWATER 34.8 AC-FT/YR SURFACE-WATER RUNOFF, AND 76 AC-FT FROM 100-YR, 72-HR FLOOD

OUTPUT RESULT

ALTERNATIVE	DOWNSTREAM RELEASES WITH TREATMENT (94.7 AC-FT/YR)	DISCHARGE TO SEWER SYSTEM WITH TREAT-MENT (71.4 AC-FT/YR)	DISCHARGE TO AIRPORT (125.7 AC-FT/YR)	IRRIGATION OF 320 AC (110.0 AC-FT/YR)	ENHANCED EVAPORATION (94.0 AC-FT/YR)	NO UNCONTROLLED RELEASES	UNCONTROLLED RELEASES	DEMAND WATER SHORTAGES	RESERVOIR VOLUME 125-200 AC-FT	RESERVOIR VOLUME 200-255 AC-FT
2f(a through d)	●					■		■ 392 1)	■	
3i(a through g)		●				■		■ 264 1)		■
4d(a and b)			●			■		■ 231 1)		■
5c(a)				●		■		■ 219 1)		■
6c(a)					●	■		■ 282 1)	■	

● = INPUT ALTERNATIVE
■ = OUTPUT RESULT
1) TOTAL NUMBER OF MONTHS OF UNCONTROLLED RELEASES DURING 600-MONTH OPERATIONAL PERIOD

Table 20

Reservoir Sizes For Terminal Pond C-2 For Selected Operational Alternatives[1)]

Alternative	Surface-Water Runoff and Ground-Water Inputs (ac-ft/yr)	STP Effluent Inflow (ac-ft)	Water Demands (ac-ft/yr)	Inflow from 100-yr, 72-hr Flood (ac-ft)	Releases With Treatment (ac-ft/yr)	Maximum Pond Volume (ac-ft)	Approximate Maximum Pond Surface Area (ac)	Increase in Spillway Crest Elevation[2)] (ft)
2f	44.8	0.0	0.0	76	94.7	177	13	10
3i	44.8	0.0	0.0	76	54.0	204	14	10
	44.8	0.0	0.0	76	71.4	204	14	10
4d	44.8	0.0	62.9	76	0.0	253	15	15
	44.8	0.0	125.7	76	0.0	253	15	15
5c	44.8	0.0	55.0	76	0.0	253	15	15
	44.8	0.0	110.0	76	0.0	253	15	15
6c	44.8	0.0	47.0[3)]	76	0.0	253[3)]	15	15
	44.8	0.0	94.0[4)]	76	0.0	127[4)]	12	5

1) Assumes a reservoir based upon the elevation-area-capacity curves in Appendix C.

2) As measured from the spillway crest elevation to completely store the 100-yr, 72-hr flood.

3) Assumes 1,000 gpm pumping rate for an enhanced evaporation during the months of April through October of about 47 ac-ft/yr. The minimum surface area for such a system is about 23 acres (Merrick & Company, 1990).

4) Assumes 2,000 gpm pumping rate for an enhanced evaporation during the months of April through October of about 94 ac-ft/yr. The minimum surface area for such a system is about 23 acres (Merrick & Company, 1990).

Based upon the alternatives evaluation system discussed earlier, Alternative 4d(a) (based upon discharging 675 ac-ft/yr downstream to a nearby stream) was selected as the best alternative for a RFP population of 6,300. Table 22 presents the results of the alternative evaluation. For the terminal ponds, it would be difficult to find an ultimate zero-discharge solution because the existing terminal pond dams could not be modified to store all the anticipated water from identified sources.

Adverse environmental consequences related to selected Alternative 4d(a) are those that the necessary increase in the size of the ponds would create larger wetlands to maintain, and waste would be generated due to the treatment of water for release downstream. In addition, these storage facilities are located on-channel. This creates an environmental risk of the dams failing and also may affect downstream wetlands.

3.4 "NO ACTION" ALTERNATIVE

As a comparison to the above alternatives, the "no action" alternative has been evaluated. The eleven factors that are used to evaluate alternatives throughout the zero discharge study are discussed in reference to this alternative.

In the event that RFP should choose the "no action" alternative, one occurrence would be the uncontrolled release of 237 ac-ft/yr of untreated STP effluent. In addition, 125.3 ac-ft/yr of surface-water runoff, 425 ac-ft/yr from the 100-year, 72-hour flood, and approximately 10 ac-ft/yr of recovered ground water would be released downstream untreated. Under the category of "Controlled Discharge", due to the uncontrolled discharge, this alternative would score a 1 which translates to a weighted score of 10.

Table 21

Preliminary Construction and OM & R Costs For Terminal Ponds Operational Alternatives

	Construction Costs (Million $)					
Alternative	Reservoir Earthwork	New Advanced Water Treatment Plant at A-4	C-2 Interceptor Pump and Pipeline to A-4 or B-5[1]	Piping and Pumping[2]	Total	Annual OM&R Cost (15% of Total)
4d	27.3	101	0.3	17.4	146.0	21.9
5c	27.3	0	0.3	9.0	36.6	5.5

1) Source: DOE (1991)

TABLE 22

Alternative Evaluation And Ranking Terminal Ponds

EVALUATION FACTORS	WEIGHTING FACTOR	ALT 2f(a-d)		ALT 3i(a-g)		ALT 4d(a)		ALT 5c(a)		ALT 6c(a)	
		S	W	S	W	S	W	S	W	S	W
CONTROLLED DISCHARGE	10	1	10	1	10	5	50	1	10	1	10
WASTE GENERATION	7	1	7	1	7	1	7	5	35	5	35
RISK	8	1	8	1	8	1	8	1	8	1	8
COST	6	0 1)	0	0 1)	0	1	6	2	12	0 1)	0
DESIGN AND CONST. SCHEDULE	6	0 1)	0	0 1)	0	1	6	2	12	0 1)	0
FLEXIBILITY	8	5	40	5	40	5	40	5	40	5	40
WATER RIGHTS	5	5	25	5	25	1	5	1	5	1	5
AIR EMISSIONS	10	5	50	5	50	5	50	5	50	5	50
WETLANDS/T&E	10	2	20	1	10	4	40	4	40	3	30
IHSS	10	3	30	2	20	4	40	1	10	3	30
PUBLIC ACCEPTABILITY	8	1.7	13	1.3	11	2	16	1	8	1.7	13
TOTALS			221		181		268		230		221
RANK			3		4		1		2		3

S = SCORE
W = WEIGHTED SCORE (SCORE X WEIGHTING FACTOR)
1) Alternative could not be constructed to control releases.

There would be no additional waste generated on-site for this alternative, because the water would not be undergoing any additional treatment than what is currently on-going. Under the category of "Waste Generation", this alternative would receive a score of 5 which translates to a weighted score of 35.

Risk in this task has been defined as the risk that is associated with the possibility of dam failure. Because no dams would be constructed or upgraded in an attempt to retain the above mentioned water, and downstream releases would occur so as not to apply additional stress on the current dams, the risks associated with this alternative are minimal. However, since dams do currently exist within the main drainages of the RFP, and these dams will be utilized as they are being utilized today, risk of dam failure is present. Therefore, under the category of "Risk" this alternative scores a 3 which translates into a weighted score of 24.

Under the categories of "Cost" and "Design and Construction Schedule", this alternative would score a 5 because there would be no cost or design and construction activities associated with this alternative. A score of 5 translates into a weighted score of 30 for each of these categories.

For this study task, the flexibility of a storage/reuse system depends upon the system's capability to continue operating, without uncontrolled releases, in the event that failure of the system may occur. Because no "system" to speak of would apply for this alternative, the "Flexibility" category is not applicable, and as such would score a 0.

The issue of water rights depends on whether or not the downstream water calls could be met without interference from RFP operations. Because downstream releases would not be prohibited, RFP operations should not interfere with the water rights of downstream users. Under the "Water Rights" category this alternative scores a 5 which translates into a weighted score of 25.

The creation of wetlands is considered a negative impact for this task due to the long-term maintenance and costs that may be associated with newly created wetlands. For this alternative, no new wetlands would be created and as such a score of 5 has been given to this category. A score of 5 translates into a weighted score of 50.

Activity that could create a new SWMU, or increase the size of a existing SWMU on-site is considered to be a negative impact. The discharge of untreated water downstream could result in the creation of new SWMU's along the flow path of the water and in any area in which the water may pond for any length of time. For these reasons, under the category of "IHSS/SWMU" this alternative is give a score of 1 which translates into a weighted score of 10.

The category of "Public Acceptability" for this task is based on three of the above categories: (1) controlled discharge; (2) risk; and (3) IHSS/SWMU. The average score of these three categories is 1.7 which translates into a weighted score of 14.

The overall total of the weighted scores for this alternative is 228. The totals of the weighted scores for the preferred alternatives for the New Off-Channel Reservoir, Great Western Reservoir, and the Terminal Ponds are 363, 283, and 268, respectively. In comparing the three preferred alternatives, it is apparent that the "No Action" alternative scores lower than any other alternative and as such was not considered further.

4.0 ALTERNATIVES EVALUATION SUMMARY

This study addresses alternatives to zero discharge relative to water handling at the RFP. Currently, there are ten on-channel ponds and two off-channel ponds that collect RFP surface-water runoff from approximately 2.25 square miles (mi^2) of the 10 mi^2 RFP site. Three terminal ponds (A-4, B-5 and C-2) are not adequately sized to operate without uncontrolled discharges during flood events such as that expected during the 100-yr, 72-hr design flood. Ponds A-4 and B-5 are located on-channel, which means the water in these ponds may be subject to CDH water-quality stream standards because these waters would be considered as waters of the United States. This study examines the preliminary feasibility of temporarily storing RFP's Sanitary Treatment Plant (STP) effluent, surface-water runoff, ground water, and runoff from the 100-yr, 72-hr flood from the RFP, and releasing it downstream under controlled conditions, or disposing of it on-site. Temporary water-storage facilities, investigated in this report, included new off-channel storage, using Great Western Reservoir, and upgrading the existing terminal ponds. Evaluation of off-channel storage may be particularly useful, because water in these ponds probably would not be considered waters of the United States and may not have to meet CDH stream standards unless the water were released.

Operational studies were performed for sizing the temporary water-storage reservoirs to store STP effluent, surface-water runoff, ground water and runoff from the 100-yr, 72-hr flood along with precipitation falling directly on the reservoir. The reservoir sizing was developed for combinations of water-use demands both on and off-site, as well as downstream releases after water treatment to meet applicable stream standards.

Fifteen basic off-site and on-site water-release/water-use alternatives were assessed. These 15 alternatives were investigated for an off-channel water-storage reservoir, storage of water in Great Western Reservoir, and storage of water in the upgraded existing terminal ponds (A-4, B-5 and C-2). Additionally, the "no-action" alternative to zero discharge also was assessed. The total number of alternatives considered was 46, 15 each for the three alternative storage reservoirs and the "no-action" alternative. Of the 15 basic alternatives, four were associated with off-site discharge at a new location such as Big Dry Creek, the South Platte River, or Clear Creek. Seven alternatives were associated with off-site discharge to an existing municipal sewer system. Two alternatives considered off-site discharge to water users such as landscape irrigation at the new Denver airport. One on-site alternative dealt with irrigation of pasture grass (other crops could be considered during future studies) at the RFP, while a second on-site alternative was spray evaporation in a lined pond at the RFP. This last alternative is really a zero-discharge concept which was examined in order to give a comparison to the other alternatives without having to refer to previous operational studies for zero discharge presented in Task 21 (ASI, 1991b).

Results of the reservoir operational studies are presented in this report. A preferred alternative for each of the three storage structures (off-channel, Great Western Reservoir, and the terminal ponds) was selected. Table 23 summarizes the preferred alternatives for each of the three storage structures. Based upon these study analyses, the terminal ponds, in general, cannot be built large enough to minimize uncontrolled releases unless the rate of release is increased beyond the capability of some of the alternatives to use the water. In addition to the preferred alternative description, the summary table also includes the estimated construction and annual OM & R costs for each of the three preferred alternatives. The three preferred alternatives assume that the STP effluent volumes are for the current RFP personnel employee level of about 6,300 people. Future increases or decreases in the RFP personnel population may demand that the alternatives be re-evaluated.

Additionally, the possibilities of combining parts of alternatives, especially the terminal ponds alternatives, have not been evaluated in this study. The possible combinations of such alternatives are very large. Decisions about RFP population, future water use, and water treatment technologies would be helpful in reducing the number of possible alternative combinations.

Table 23

SUMMARY OF PREFERRED ALTERNATIVES

STORAGE ALTERNATIVE	ALT. NOS.	PREFERRED ALTERNATIVE DESCRIPTION	CONSTR. COSTS (Million $)	OM & R COSTS (Million $/Yr)
NEW OFF-CHANNEL RESERVOIR	6a	Off-channel storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 1.9 mi^2 (125.3 ac-ft/yr) with the 100-yr, 72-hr flood (425 ac-ft/yr), and ground water (10 ac-ft/yr) with April-through-October on-site spray evaporation in a lined pond (122.9 to 492.4 ac-ft/yr) (Zero Discharge).	4.5	0.7
GREAT WESTERN RESERVOIR	5b(a)	On-channel GWR storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 5.5 mi^2 (279.7 ac-ft/yr) with the 100-yr, 72-hr flood (1143 ac-ft/yr), and ground water (10 ac-ft/yr) with on-site irrigation of pasture grass (144 to 576 ac-ft/yr).	80.9	12.1
TERMINAL PONDS	4d(a)	Terminal ponds storage of STP effluent from 6300 RFP personnel (237 ac-ft/yr), surface-water runoff from 1.07, 0.41, and 0.35 mi^2 (81.0, 39.2, and 34.8 ac-ft/yr) with the 100-yr, 72-hr flood (243, 106 and 76 ac-ft/yr), and ground water (10 ac-ft/yr) with a pipeline (187 to 374 ac-ft/yr) to the Denver Water Department Potable Reuse Plant, or with an irrigation water pipeline (164.6 to 658.3 ac-ft/yr) to the new Denver Airport.	146.0	21.9

5.0 ACKNOWLEDGMENTS

This study was conducted under the general supervision of Mr. Michael G. Waltermire, P.E., Project Manager, Advanced Sciences, Inc. Work involving this project task was under the technical direction of Dr. James R. Kunkel, P.E., ASI Principal Scientist. This study report was prepared by Ms. Theresa Santangelo-Dreiling and Dr. Kunkel, with assistance from Nick Massaro, ASI Draftsmen. The report was reviewed by Dr. Timothy D. Steele, ASI Manager, Physical Sciences Group. EG&G responsive reviewers of this report included:

R. A. Applehans, FE/PCSE
A. McLean, ER/NEPA
C. R. Rose, Consultant, ER/CWAD
F. A. Walker, FPM
J. R. McKeown, FE/PCSE

This report was prepared and submitted in partial fulfillment of the Zero-Offsite Water-Discharge Study being conducted by ASI on behalf of EG&G Rocky Flats, Inc. EG&G's Project Engineer for the Study was Mr. R. A. Applehans of EG&G's Plant Engineering/Civil-Engineering - Environmental Restoration (PE/CE-RE).

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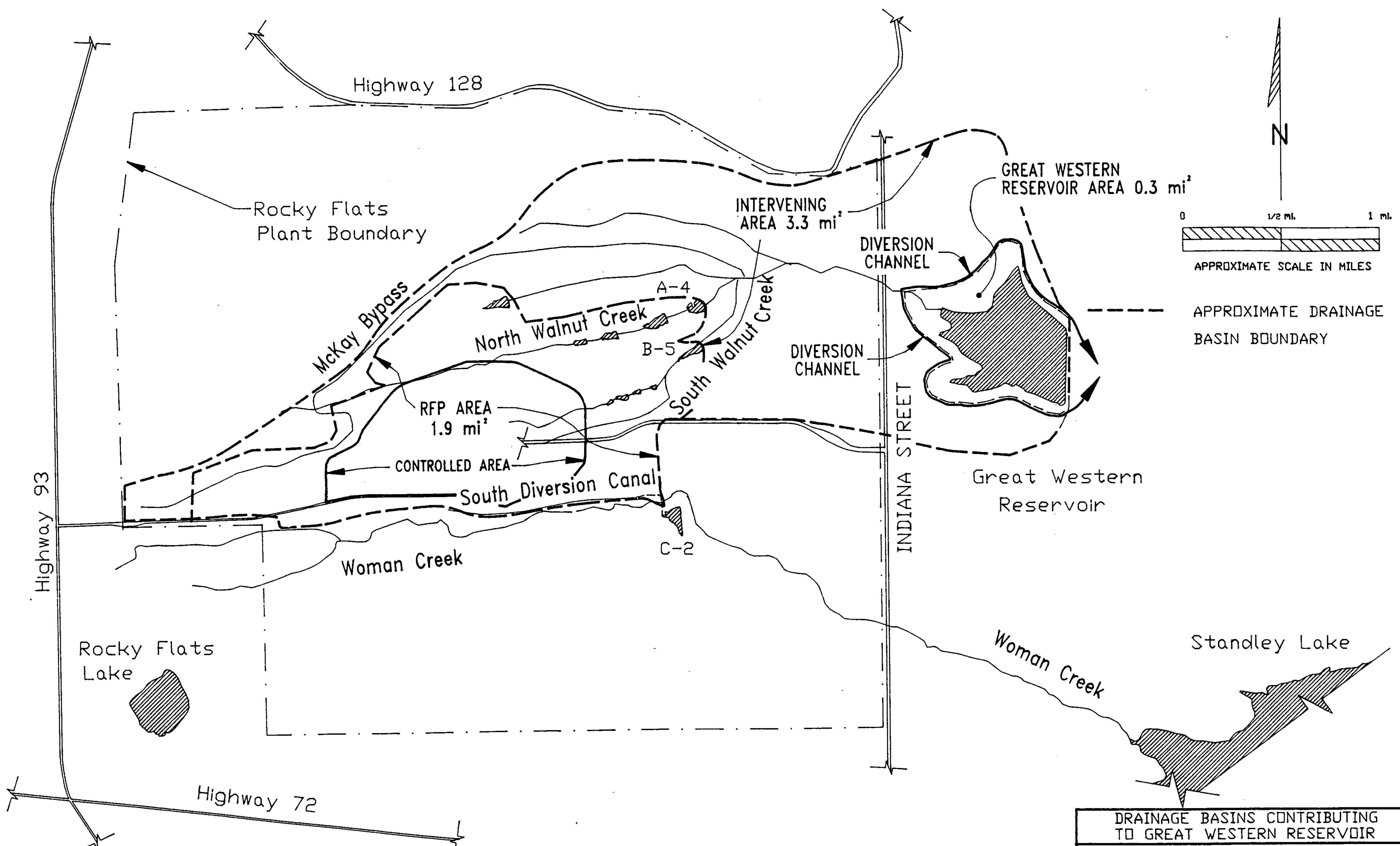
FIGURES

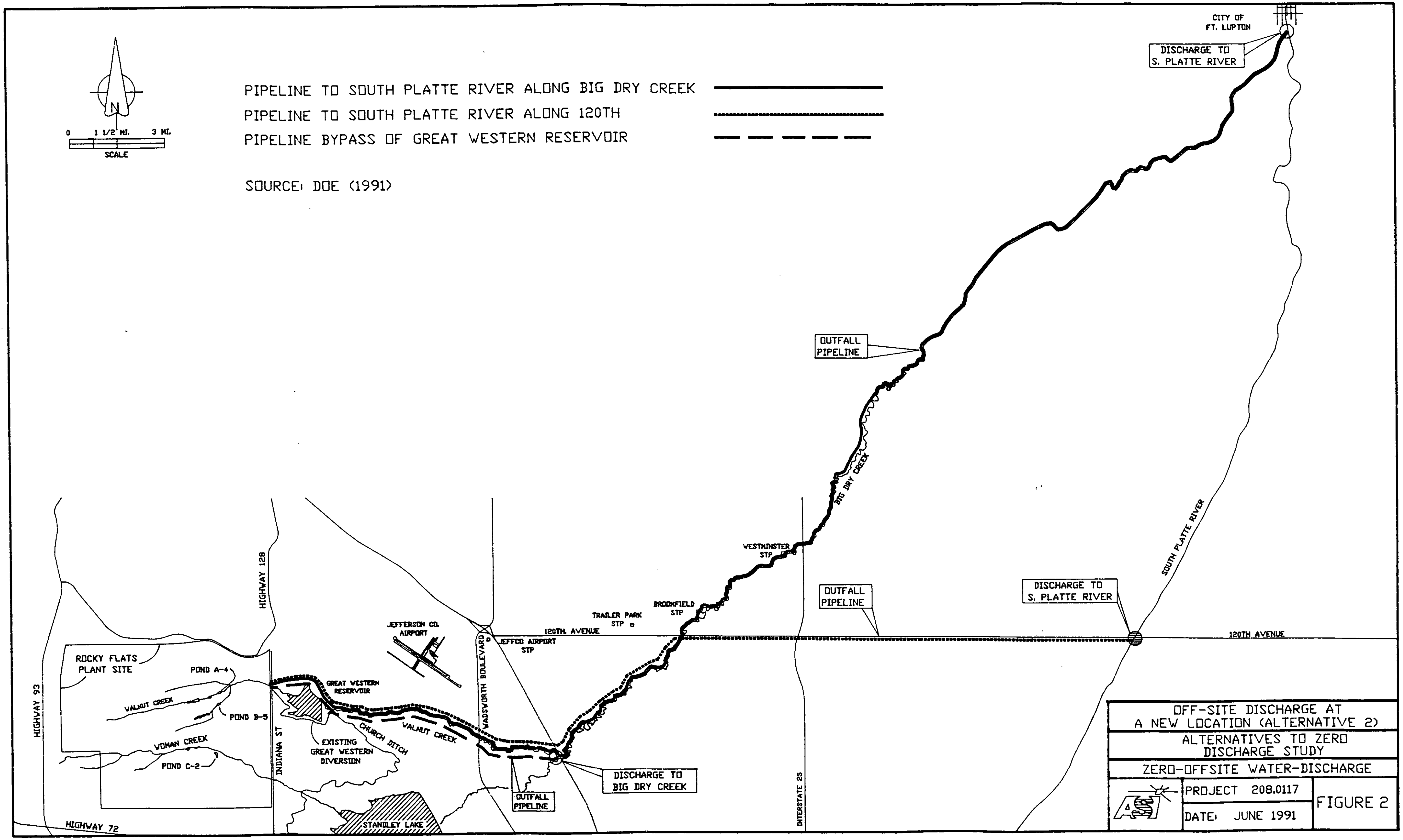


DRAINAGE BASINS CONTRIBUTING TO GREAT WESTERN RESERVOIR

TEMPORARY WATER STORAGE CAPABILITIES STUDY

ZERO-OFFSITE WATER-DISCHARGE

ASI	PROJECT 208.0121	FIGURE 1
	DATE: JUNE 1991	



OFF-SITE DISCHARGE AT A NEW LOCATION (ALTERNATIVE 2)

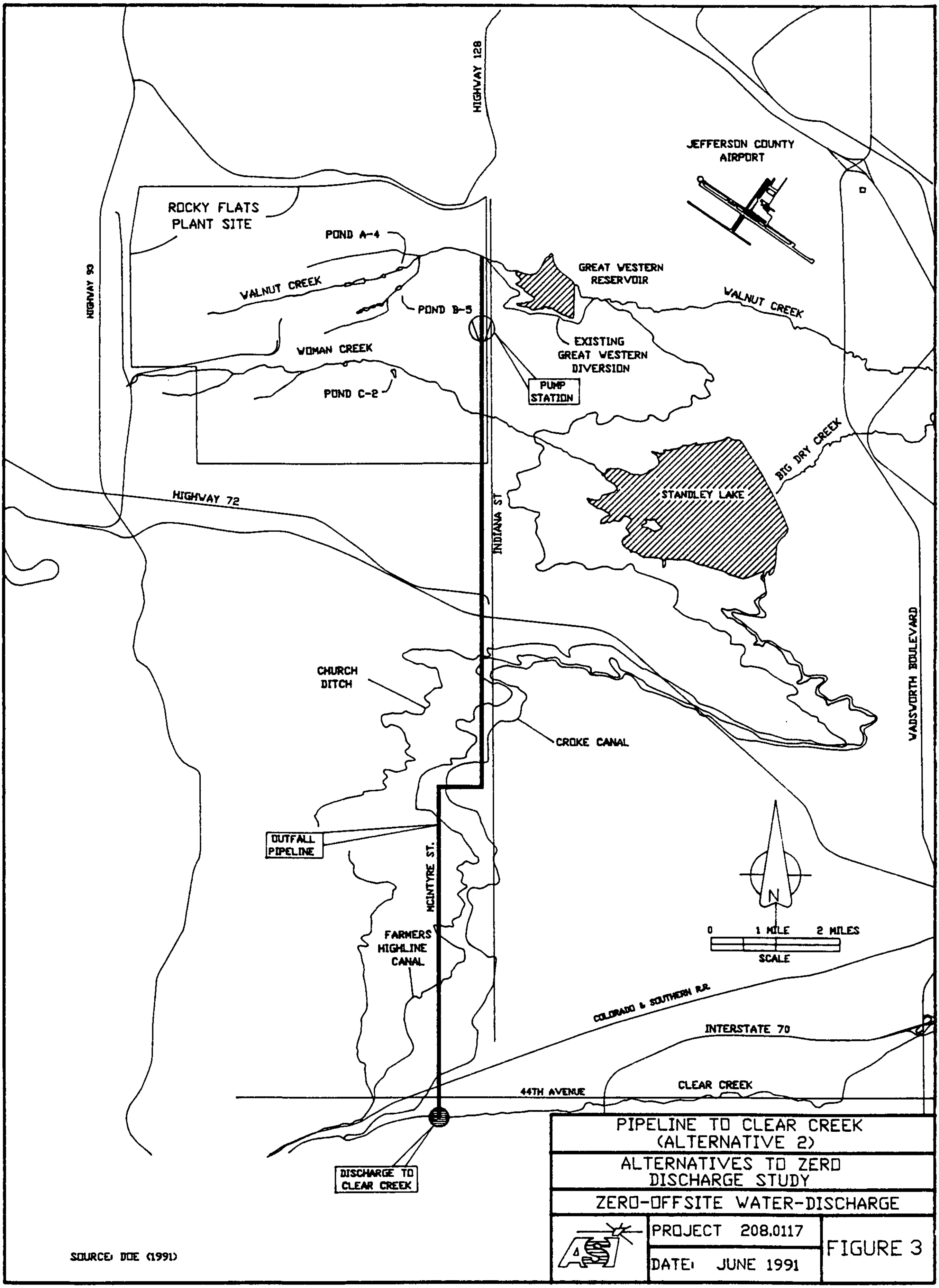
ALTERNATIVES TO ZERO DISCHARGE STUDY

ZERO-OFFSITE WATER-DISCHARGE

PROJECT 208.0117

DATE: JUNE 1991

FIGURE 2



PIPELINE TO CLEAR CREEK (ALTERNATIVE 2)

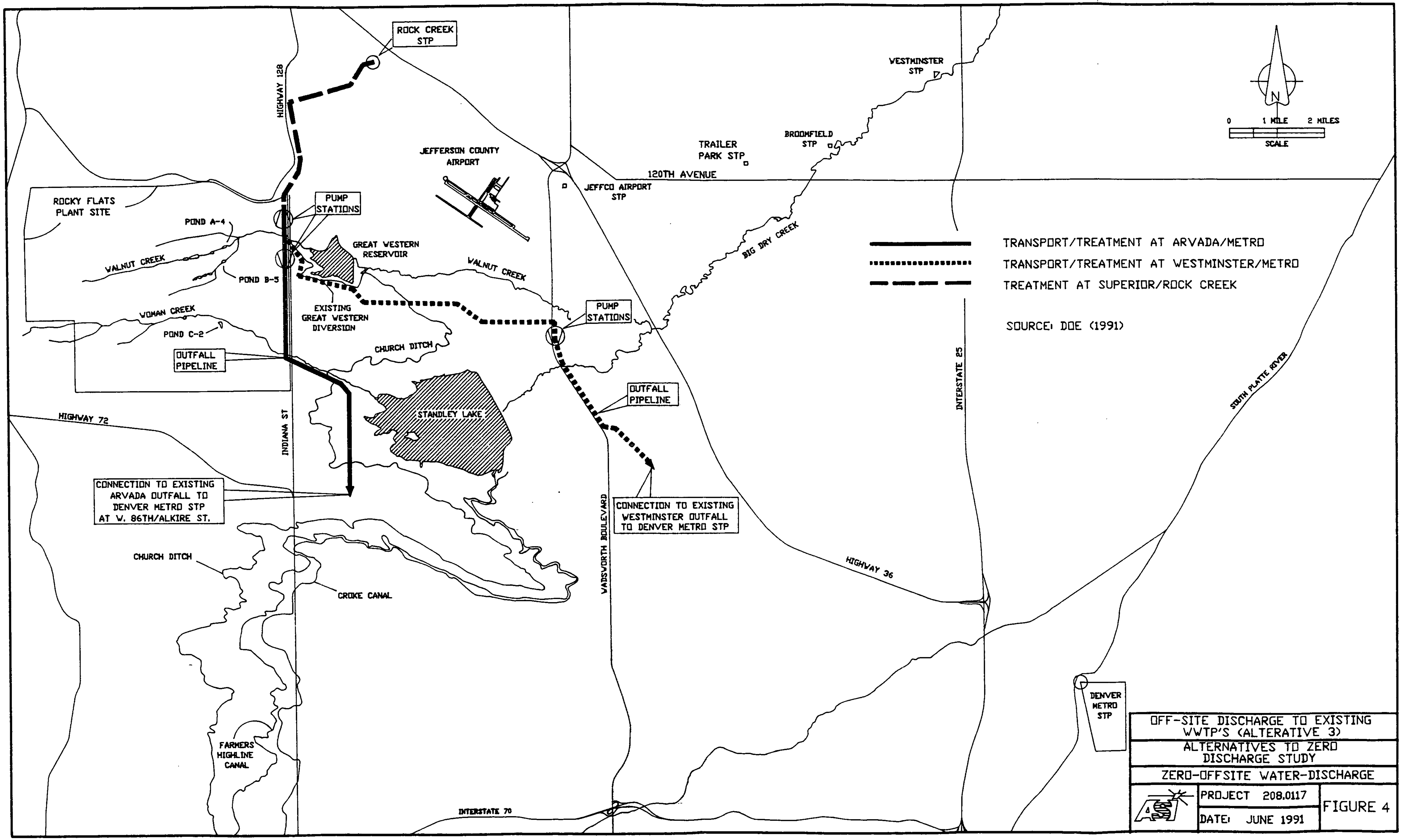
ALTERNATIVES TO ZERO DISCHARGE STUDY

ZERO-OFFSITE WATER-DISCHARGE

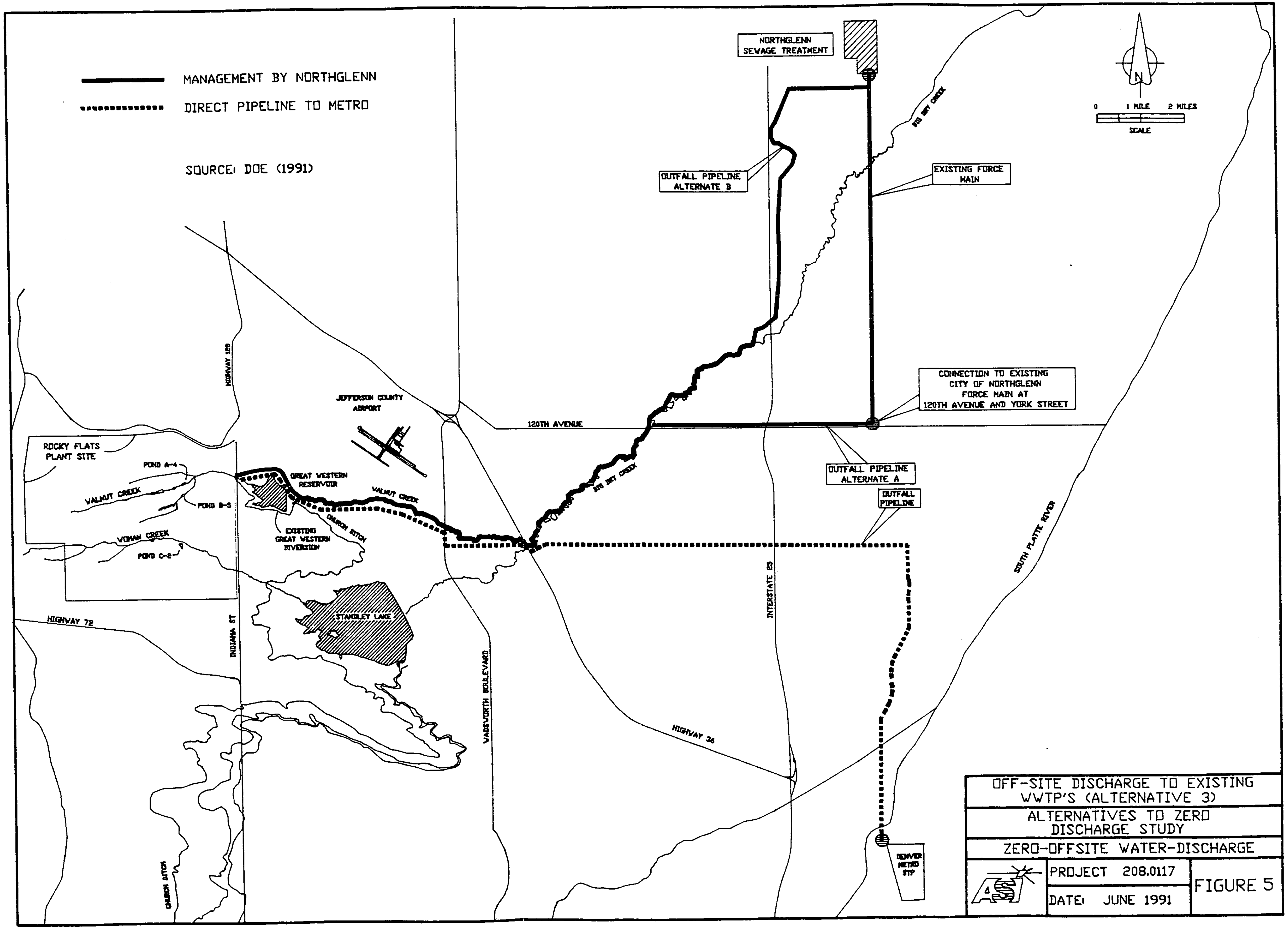
PROJECT 208.0117

DATE: JUNE 1991

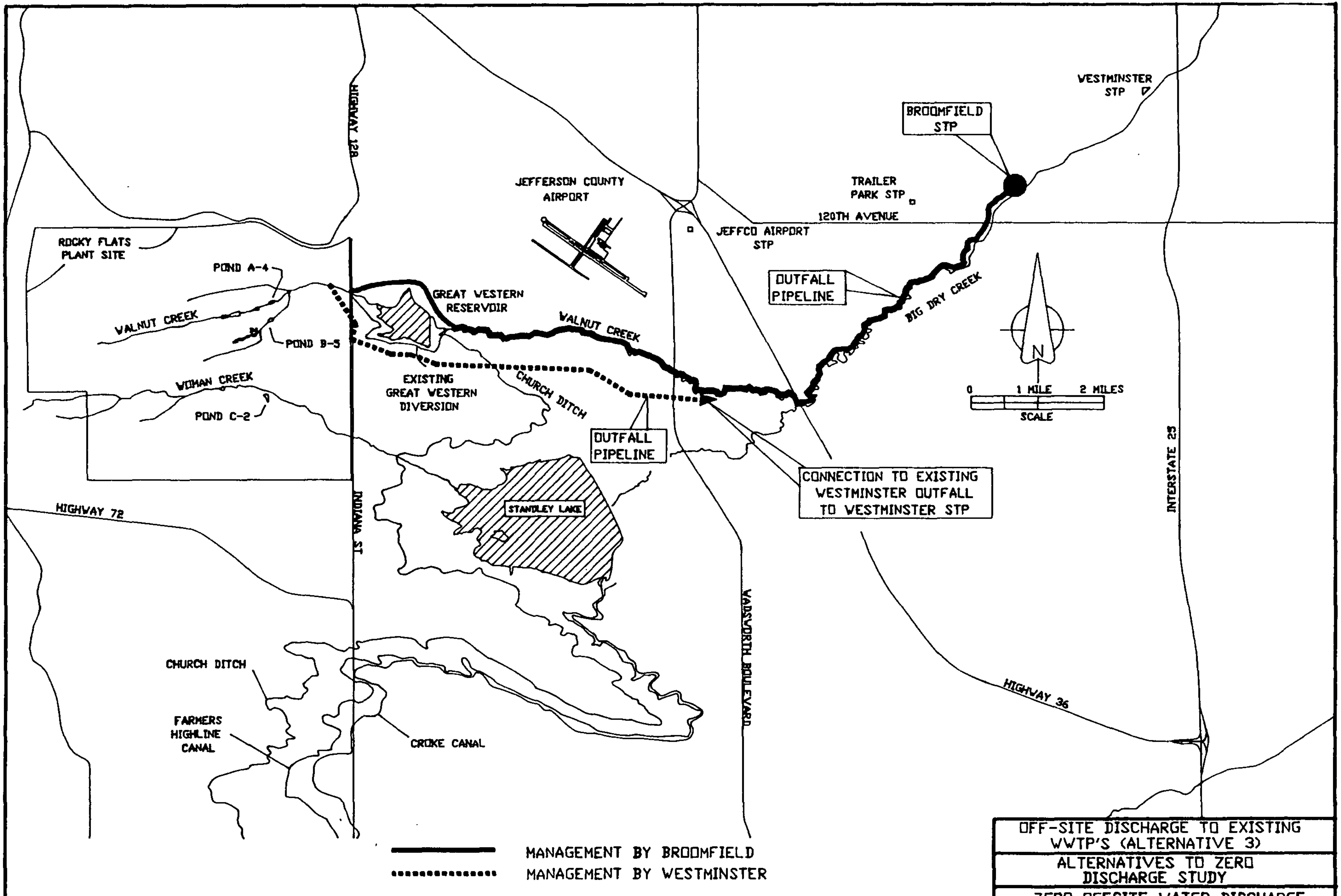
FIGURE 3



OFF-SITE DISCHARGE TO EXISTING WWTP'S (ALTERATIVE 3)	
ALTERNATIVES TO ZERO DISCHARGE STUDY	
ZERO-OFFSITE WATER-DISCHARGE	
PROJECT 208.0117	FIGURE 4
DATE: JUNE 1991	

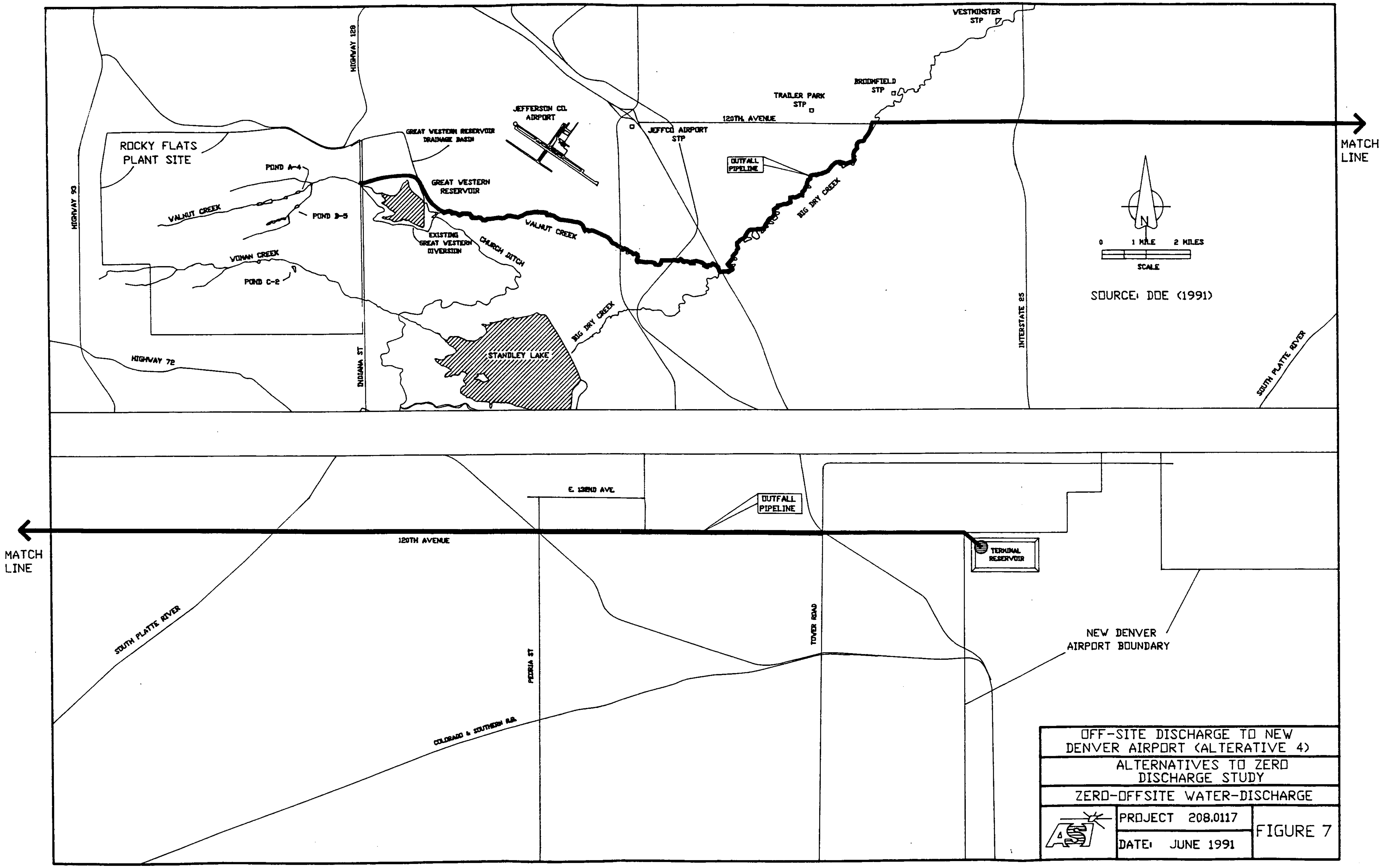


MANAGEMENT BY NORTHGLENN
DIRECT PIPELINE TO METRO
SOURCE: DOE (1991)
NORTHGLENN SEWAGE TREATMENT
OUTFALL PIPELINE ALTERNATE B
EXISTING FORCE MAIN
BIG DRY CREEK
0 1 MILE 2 MILES
SCALE
N
CONNECTION TO EXISTING CITY OF NORTHGLENN FORCE MAIN AT 120TH AVENUE AND YORK STREET
120TH AVENUE
OUTFALL PIPELINE ALTERNATE A
OUTFALL PIPELINE
JEFFERSON COUNTY AIRPORT
HIGHWAY 128
ROCKY FLATS PLANT SITE
POND A-4
POND B-5
POND C-2
WALNUT CREEK
WOMAN CREEK
GREAT WESTERN RESERVOIR
EXISTING GREAT WESTERN DIVERSION
CHURCH DITCH
STANDLEY LAKE
HIGHWAY 72
INDIANA ST
WADSWORTH BOULEVARD
INTERSTATE 25
HIGHWAY 36
SOUTH PLATTE RIVER
DENVER METRO STP
OFF-SITE DISCHARGE TO EXISTING WWTP'S (ALTERNATIVE 3)
ALTERNATIVES TO ZERO DISCHARGE STUDY
ZERO-OFFSITE WATER-DISCHARGE
PROJECT 208.0117
DATE: JUNE 1991
FIGURE 5



SOURCE: DOE (1991)

OFF-SITE DISCHARGE TO EXISTING WWTP'S (ALTERNATIVE 3)	
ALTERNATIVES TO ZERO DISCHARGE STUDY	
ZERO-OFFSITE WATER-DISCHARGE	
PROJECT 208.0117	FIGURE 6
DATE: JUNE 1991	


ROCKY FLATS PLANT SITE
POND A-4
POND B-5
POND C-2
WALNUT CREEK
WOMAN CREEK
HIGHWAY 93
HIGHWAY 128
HIGHWAY 72
INDIANA ST
GREAT WESTERN RESERVOIR DRAINAGE BASIN
GREAT WESTERN RESERVOIR
EXISTING GREAT WESTERN DIVERSION
CHURCH DITCH
STANDLEY LAKE
BIG DRY CREEK
JEFFERSON CO. AIRPORT
JEFFCO AIRPORT STP
120TH. AVENUE
TRAILER PARK STP
BROOMFIELD STP
WESTMINSTER STP
OUTFALL PIPELINE
INTERSTATE 25
SOUTH PLATTE RIVER
MATCH LINE
N
0 1 MILE 2 MILES
SCALE
SOURCE: DOE (1991)
E. 128ND AVE.
120TH AVENUE
OUTFALL PIPELINE
TERMINAL RESERVOIR
MATCH LINE
SOUTH PLATTE RIVER
PEORIA ST
TOWER ROAD
COLORADO & SOUTHERN R.R.
NEW DENVER AIRPORT BOUNDARY
OFF-SITE DISCHARGE TO NEW DENVER AIRPORT (ALTERATIVE 4)
ALTERNATIVES TO ZERO DISCHARGE STUDY
ZERO-OFFSITE WATER-DISCHARGE
PROJECT 208.0117
DATE: JUNE 1991
FIGURE 7

A

APPENDIX A

RESERVOIR OPERATIONAL STUDIES
INFLOW DATA

APPENDIX A-1

SEQUENCE NO. 3, NORMAL DISTRIBUTION TYPICAL RFP BASIN (D.A. = 1.0 mi^2, IMPERVIOUSNESS = 30 PERCENT)

** Typical RFP Basin (D.A. = 1.0 sq. mi., Imp. = 30 percent) **

SIMULATED DATA SEQUENCE NUMBER 3 DIS = 11

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANNUAL VALUE	YEAR
1.28	1.49	1.72	7.96	27.72	26.51	.00	10.33	.00	.00	2.04	1.13	80.18	1
.51	.59	.67	.00	.00	16.40	40.07	25.13	7.40	.00	.81	.46	92.04	2
1.48	1.74	1.99	3.10	25.64	19.04	28.17	12.80	.00	1.32	1.32	.73	97.33	3
.15	.18	.20	.03	3.56	.00	9.92	15.45	8.74	13.58	2.00	1.11	54.92	4
.05	.04	.05	.00	.00	21.10	19.73	10.31	12.70	14.42	1.78	.99	81.15	5
.00	.00	.00	.00	1.87	28.68	44.52	18.75	9.97	10.37	1.85	1.02	117.02	6
.42	.48	.54	.00	.00	.00	.00	23.19	.00	.00	1.20	.67	26.49	7
1.50	1.76	2.02	.19	5.96	.00	8.75	31.98	13.93	9.76	.93	.51	77.28	8
.51	.60	.69	4.79	15.19	43.00	21.42	21.20	7.92	.00	1.62	.90	117.83	9
.99	1.15	1.32	.00	.00	31.88	50.23	15.62	12.53	2.71	1.45	.80	118.68	10
.14	.17	.19	3.81	20.61	.00	43.16	.00	10.86	11.96	1.96	1.09	93.96	11
.10	.12	.14	4.14	.65	15.91	.00	38.92	4.75	6.05	1.84	1.03	73.66	12
.73	.85	.98	.00	.00	14.34	.00	7.68	14.80	.00	1.35	.75	41.48	13
.90	1.08	1.22	.00	.00	3.52	39.59	17.68	14.40	6.47	1.62	.89	87.39	14
.73	.85	.96	.00	.00	12.11	21.27	.00	5.60	.00	1.84	1.02	44.38	15
.98	1.14	1.30	3.13	.00	12.10	38.34	4.59	.90	11.71	.00	.00	74.20	16
1.25	1.46	1.68	5.87	23.11	7.60	.39	.00	4.20	5.21	1.48	.82	53.07	17
.07	.08	.10	.00	21.53	24.35	33.57	30.56	10.15	.00	1.96	1.08	123.44	18
.96	1.12	1.29	1.55	12.90	1.64	.00	.00	.82	1.26	1.26	.70	23.49	19
1.25	1.47	1.69	.00	.00	2.81	.00	9.71	13.94	.00	.00	.00	30.88	20
1.71	2.00	2.30	1.70	5.13	50.96	3.45	.00	3.63	.00	.30	.17	71.35	21
.71	.82	.94	6.58	12.72	11.75	42.88	9.51	6.78	17.92	2.82	1.56	114.98	22
.64	.74	.85	2.34	.00	31.43	26.57	21.44	9.20	2.93	2.99	1.66	100.78	23
.00	.00	.01	1.72	11.50	6.43	.00	4.60	10.19	3.25	1.15	.64	39.49	24
.26	.31	.35	.00	.00	.00	14.05	38.85	6.59	5.71	.00	.00	66.11	25
1.62	1.89	2.17	7.03	22.07	12.35	.00	.85	10.91	.00	1.47	.82	61.18	26
1.81	2.10	2.40	5.70	1.77	27.36	15.67	16.22	6.62	2.90	.00	.00	82.56	27
1.53	1.78	2.05	3.21	13.42	39.41	.00	27.50	9.31	.00	.46	.26	98.91	28
1.76	2.06	2.36	5.50	.52	4.44	1.00	14.50	.00	.00	1.05	.58	33.77	29
.98	1.15	1.32	.00	8.26	22.69	20.94	.00	3.83	11.68	1.94	1.08	73.87	30
1.23	1.44	1.65	7.74	31.48	34.27	16.86	19.88	9.51	.00	.20	.11	124.38	31
.00	.00	.00	.00	.00	21.93	28.05	14.42	9.19	.00	.01	.01	73.62	32
1.00	1.17	1.34	.95	12.75	27.22	16.14	56.20	4.63	15.24	1.94	1.08	139.66	33
1.07	1.24	1.41	.00	20.34	23.58	35.60	.00	1.07	.00	2.69	1.49	88.48	34
.56	.66	.74	1.15	11.59	3.32	42.02	6.31	11.90	9.55	2.19	1.22	91.24	35
.54	.63	.72	2.56	.00	8.68	27.89	51.75	3.67	.00	.00	.00	96.46	36
1.15	1.34	1.53	.00	3.43	.00	11.97	47.14	.00	.00	.56	.31	67.42	37
1.09	1.29	1.47	.04	.00	.00	21.63	8.50	13.29	.00	1.09	.61	49.00	38
.00	.00	.00	1.75	.00	13.97	.00	9.14	.00	.00	.62	.35	25.81	39
.23	.26	.31	1.17	11.21	38.26	.00	7.47	4.82	.00	.14	.07	63.95	40
1.39	1.61	1.85	4.04	11.67	9.65	.00	9.95	.00	6.23	1.58	.89	48.87	41
.82	.96	1.09	2.15	.00	23.20	26.67	22.03	7.53	1.78	2.02	1.13	89.37	42
1.34	1.56	1.78	4.84	13.72	.00	20.48	.00	.00	4.53	2.23	1.24	51.72	43
.86	1.02	1.17	3.40	.00	20.04	16.99	23.99	4.62	11.48	1.04	.58	85.19	44
.00	.00	.00	.16	.00	22.65	15.59	5.23	.00	14.62	2.48	1.38	62.11	45
.00	.00	.00	.00	10.16	3.23	24.29	23.67	5.41	7.83	2.36	1.31	78.27	46
1.42	1.66	1.90	5.16	30.83	.00	19.54	5.66	6.64	3.07	1.85	1.03	78.76	47
.97	1.14	1.30	1.04	.00	16.56	32.54	32.33	6.73	2.71	1.70	.95	97.97	48
1.11	1.30	1.48	.00	28.85	19.70	.00	31.72	9.45	7.02	.23	.13	100.99	49
.48	.56	.65	.00	.00	.00	22.66	38.36	12.24	.00	1.65	.92	77.52	50

.81	.94	1.08	2.09	8.40	15.48	18.05	16.82	6.63	4.47	1.34	.75	76.85	AVE.
.55	.64	.74	2.43	9.97	13.23	15.33	14.40	4.67	5.29	.83	.46	28.15	ST.D
.68	.68	.68	1.16	1.19	.85	.85	.86	.70	1.18	.62	.62	.37	C.V.
-.11	-.11	-.11	.83	.82	.50	.21	.77	-.10	.84	-.29	-.29	-.18	SKEW

TOTAL AVERAGE = 6.404
STANDARD DEV = 10.254
SKEW COEFFICIENT = 2.148

APPENDIX A-2

MONTHLY AND ANNUAL
SEWAGE TREATMENT PLANT EFFLUENT VOLUMES

Sewage Treatment Plant Effluent Volume
(Ac-Ft)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	15.04	16.27	18.26	23.02	22.10	23.32	23.02	19.95	18.57	18.72	16.57	18.72	233.55
1987	15.04	16.27	23.48	25.17	25.47	24.55	24.86	23.02	20.56	18.72	17.95	19.33	254.42
1988	20.87	21.64	24.09	23.85	24.80	22.99	24.98	27.62	23.88	15.93	12.74	13.07	256.44
1989	15.19	19.03	20.41	19.33	22.40	23.02	20.87[1]	20.87	20.87	18.11	15.04	11.97	227.10
1990	15.10	13.07	17.80	20.99	18.97	17.80	21.42	21.97	19.55	17.86	15.59	15.77	215.90
Avg:	16.25	17.25	20.81	22.47	22.75	22.34	23.03	22.69	20.68	17.87	15.58	15.77	237.48

1) Based upon an RFP population of 6,298.

Source: EG&G Rocky Flats, Inc.

APPENDIX A-3

MONTHLY AND ANNUAL PRECIPIATION

Monthly and Annual Precipitation at RFP
(Inches)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1971	.--	.--	.--	.--	.--	.22	1.11	.35	3.17	.55	.15	.40	.--
1972	.93	.08	.83	1.58	.97	.95	1.59	2.47	1.42	.91	2.00	1.05	14.78
1973	1.05	.15	2.04	4.73	4.71	.66	1.53	.54	2.74	.65	1.30	1.48	21.58
1974	1.12	1.11	.89	3.05	.08	1.99	1.00	.22	1.41	1.91	1.15	.38	13.20
1975	.38	.84	1.42	1.31	3.73	1.11	.83	1.22	.80	.68	.85	.21	13.38
1976	.13	.04	.34	2.16	1.93	.90	1.53	1.46	4.49	.66	.21	.10E	13.95E
1977	.06	.47	.08	1.80	.46	1.13	2.73	1.04	.12	.40	.34	.09	8.72
1978	.35	.33	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--
1979	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--
1980	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--
1981	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--
1982	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--	.--
1983	.02	.19	4.64	2.21	3.97	2.76	2.10	3.46	.01	.34	2.47	.42	22.59
1984	.36	.65	.84	1.42	.56	.91	.77	1.69	.16	3.68	.00	.28	11.32
1985	.41	.77	.64	1.69	2.92	1.73	3.38	.11	1.24	.00	1.26	.08	14.23
1986	.06	.93	.00	2.68	2.23	2.03	1.46	1.58	.84	.98	.98	1.26	15.03
1987	.43	1.19	1.35	.91	2.40	5.72	.57	2.09	.64	1.06	1.10	.71	18.17
1988	.27	.55	1.10	1.22	2.20	.95	1.66	1.60	1.36	.09	.40	.54	11.94
1989	.53	.11	.21	.51	2.20	.02	.55	1.96	6.03	.11	.11	.32	12.66
1990	.21	.17	1.64	1.32	1.43	.12	3.02	1.41	2.00	1.11	.64	.--	.--
Avg:	.42	.51	1.18	1.91	2.17	1.50	1.67	1.35	1.46	1.00	1.00	.54	15.18
1953-1976 Avg:	.50	.65	1.22	1.71	2.88	1.69	1.38	1.19	1.61	.99	.81	.53	15.16

Notes: -- means no data available.
E means estimated.

Source: EG&G Rocky Flats, Inc.

Monthly and Annual Precipitation at Cherry Creek Dam
(Inches)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1948	.97	.28	1.32	1.90	1.76	3.07	.84	2.13	.23	.21	.59	.27	13.57
1949	.67	.11	1.27	1.17	3.36	3.11	1.90	.56	.17	.86	.20	.13	13.51
1950	.43	.57	.35	2.69	1.82	1.45	3.08	.24	.58	.13	.81	.20	12.35
1951	.56	.55	1.30	1.66	2.34	1.40	.76	3.46	.53	1.26	.77	.21	14.80
1952	.00	.28	1.04	2.11	2.21	.08	.51	1.71	.37	.07	.76	.23	9.37
1953	.41	.55	.53	1.74	2.12	1.79	1.50	2.03	.08	.27	.20	.67	11.89
1954	.15	.08	.25	.70	.37	.50	2.31	1.05	.55	.11	.42	.50	6.99
1955	.05	.11	.21	.32	2.88	1.18	1.80	3.07	1.00	.16	.30	.05	11.13
1956	.17	.22	.35	.37	.82	.37	2.59	1.84	.00	.48	.31	.30	7.82
1957	.24	.55	.55	2.83	5.75	1.26	2.71	2.19	.78	2.24	.25	.07	19.42
1958	.35	.88	.74	1.77	4.86	1.12	1.88	1.17	1.73	.58	.50	.36	15.94
1959	.84	.62	1.70	.97	2.74	1.68	.70	.13	1.00	1.50	.77	.12	12.77
1960	.47	1.05	.51	1.17	2.15	.22	2.20	.20	.33	2.13	.09	.56	11.08
1961	.00	.46	1.76	.99	2.26	2.29	1.07	1.37	3.91	.63	.50	.10	15.34
1962	.40	.39	.28	1.11	.57	2.89	1.54	.76	.36	.30	.67	.17	9.44
1963	.85	.21	1.78	.02	.94	2.43	.70	4.70	2.32	.54	.73	.57	15.79
1964	.75	1.72	1.30	.61	2.49	1.06	1.76	.99	.76	.03	1.01	.54	13.02
1965	.75	1.26	1.29	2.53	2.12	10.07	5.08	3.11	2.99	.65	.20	.34	30.32
1966	.46	1.07	.50	.98	.66	1.12	2.90	.98	1.14	1.06	.45	.08	11.40
1967	.85	.29	.51	3.02	4.08	3.19	4.15	1.41	.81	1.31	.61	.97	21.20
1968	.46	.92	.70	1.80	1.09	.38	2.24	1.93	1.09	1.00	.99	.40	13.00
1969	.14	.19	1.15	.89	7.48	3.06	2.60	2.23	.22	4.37	.86	.62	23.81
1970	.13	.17	1.69	.57	1.74	1.74	2.20	.94	2.44	1.18	1.31	.02	14.13
1971	.25	1.06	.52	1.86	2.00	.08	1.40	1.35	2.61	1.09	.00	.61	12.83
1972	.53	.41	.67	1.39	.42	2.86	1.48	2.16	1.17	.52	2.22	.60	14.43
1973	.68	.12	1.05	1.75	7.32	.59	2.20	.89	2.93	1.50	.55	2.08	21.66
1974	.86	1.02	1.64	1.44	.08	2.78	2.54	.71	.73	2.01	.84	.65	15.30
1975	.38	.20	.55	1.13	3.03	2.52	3.30	2.15	.24	.09	1.50	.07	15.16
1976	.50	.17	.63	1.38	1.17	.88	3.11	1.25	2.55	1.69	.29	.44	14.06
1977	.16	.39	2.05	1.81	.28	1.58	3.22	2.84	.19	.44	1.15	.46	14.57
1978	.47	.66	.82	2.06	3.32	1.90	1.24	.27	.22	1.69	.51	1.11	14.27
1979	.40	.55	2.38	1.59	1.98	1.99	.44	1.30	.42	1.01	.95	2.34	15.35
1980	.70	.85	1.32	.92	2.38	.00	3.93	.65	.73	.10	.75	.02	12.35
1981	.50	.36	3.68	.57	3.95	.65	3.07	1.69	.46	1.21	.50	1.00	17.64
1982	.27	.45	.50	.42	4.15	2.48	2.71	2.23	2.37	2.18	.27	.51	18.54
1983	.05	.00	1.64	2.40	4.09	3.10	4.82	2.14	.24	.11	1.48	.21	20.28
1984	.07	.81	1.21	3.53	2.83	1.62	3.15	3.28	.55	3.84	.14	.33	21.36
1985	.48	1.01	.70	2.25	2.72	2.29	4.77	.31	3.13	.37	1.47	.30	19.80
1986	.25	.25	*1.11*	2.38	1.97	2.02	3.53	.37	.19	1.87	*.71*	*.53*	15.18
1987	*.45*	*.53*	*1.11*	*1.47*	6.53	2.90	.82	.20	.96	1.53	2.50	2.41	21.41
1988	.32	.99	1.19	.99	4.46	2.95	1.28	3.59	1.09	.06	.50	.86	18.28
1989	1.13	.27	.70	.74	1.67	1.61	2.70	1.46	1.34	.49	.37	.33	12.81
1990	.87	.00	3.14	1.32	1.82	.41	2.53	2.44	1.52	*1.02*	*.71*	*.53*	16.31
Avg:	.45	.53	1.11	1.47	2.62	1.88	2.31	1.62	1.09	1.02	.71	.53	15.34

Source: National Weather Service Annual Climatological Summaries.
Values in *italics* are average monthly values.

B

APPENDIX B

RESERVOIR OPERATIONAL STUDIES
OUTFLOW DATA

APPENDIX B-1

MONTHLY AND ANNUAL RESERVOIR EVAPORATION

Monthly and Annual Reservoir Evaporation at Fort Collins
(Inches)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1953	*.50*	*.62*	*1.06*	2.22	3.87	4.71	4.87	4.68	4.63	2.74	*1.26*	*.70*	31.86
1954	*.50*	*.62*	*1.06*	4.54	3.98	5.85	6.27	5.04	3.94	2.51	*1.26*	*.70*	36.27
1955	*.50*	*.62*	*1.06*	4.84	5.38	3.70	6.10	4.31	3.81	2.49	*1.26*	*.70*	34.77
1956	*.50*	*.62*	*1.06*	2.95	3.63	5.57	5.36	4.24	4.35	2.86	*1.26*	*.70*	33.10
1957	*.50*	*.62*	*1.06*	1.90	2.95	4.43	4.99	4.30	3.54	1.58	*1.26*	*.70*	27.83
1958	*.50*	*.62*	*1.06*	3.00	3.56	4.56	4.30	4.98	3.82	2.61	*1.26*	*.70*	30.97
1959	*.50*	*.62*	*1.06*	3.30	3.44	4.30	5.08	4.50	3.48	1.58	*1.26*	*.70*	29.82
1960	*.50*	*.62*	*1.06*	3.77	3.62	5.01	5.36	5.71	4.15	2.26	*1.26*	*.70*	34.02
1961	*.50*	*.62*	*1.06*	2.98	3.19	3.35	3.82	3.55	2.23	2.16	*1.26*	*.70*	25.42
1962	*.50*	*.62*	*1.06*	*3.43*	3.76	3.46	3.93	3.73	3.12	2.21	*1.26*	*.70*	27.78
1963	*.50*	*.62*	*1.06*	*3.43*	3.62	4.31	4.89	3.09	3.15	2.09	*1.26*	*.70*	28.72
1964	*.50*	*.62*	*1.06*	*3.43*	4.10	3.60	4.44	4.19	3.12	2.28	*1.26*	*.70*	29.30
1965	*.50*	*.62*	*1.06*	*3.43*	2.91	3.07	3.89	3.84	2.63	*2.28*	1.26	*.70*	26.19
1966	*.50*	*.62*	*1.06*	*3.43*	4.28	4.23	4.98	4.51	3.29	2.45	*1.26*	*.70*	31.31
1967	*.50*	*.62*	*1.06*	3.87	2.78	1.97	2.96	3.60	2.48	1.98	*1.26*	*.70*	23.78
1968	*.50*	*.62*	*1.06*	*3.43*	*3.98*	4.56	4.41	4.03	3.20	2.14	*1.26*	*.70*	29.89
1969	*.50*	*.62*	*1.06*	*3.43*	*3.98*	3.28	4.62	4.62	3.50	*2.27*	*1.26*	*.70*	29.84
1970	*.50*	*.62*	*1.06*	*3.43*	*3.98*	3.98	4.73	4.05	3.29	1.87	*1.26*	*.70*	29.47
1971	*.50*	*.62*	*1.06*	*3.43*	*3.98*	4.02	4.45	4.58	3.33	2.07	*1.26*	*.70*	30.00
1972	*.50*	*.62*	*1.06*	*3.43*	3.59	4.38	4.34	3.97	3.26	2.14	*1.26*	*.70*	29.25
1973	*.50*	*.62*	*1.06*	*3.43*	*3.98*	4.53	4.56	4.78	3.13	2.33	*1.26*	*.70*	30.88
1974	*.50*	*.62*	*1.06*	*3.43*	5.54	5.01	5.49	4.72	3.27	2.65	*1.26*	*.70*	34.25
1975	*.50*	*.62*	*1.06*	*3.43*	*3.98*	4.87	5.40	5.18	3.43	*2.27*	*1.26*	*.70*	32.70
1976	*.50*	*.62*	*1.06*	*3.43*	*3.98*	5.29	5.57	4.26	2.95	*2.27*	*1.26*	*.70*	31.89
1977	*.50*	*.62*	*1.06*	*3.43*	*3.98*	5.97	6.54	4.24	4.37	*2.27*	*1.26*	*.70*	34.94
1978	*.50*	*.62*	*1.06*	3.85	4.73	5.31	5.34	4.92	4.25	2.67	*1.26*	*.70*	35.21
1979	*.50*	*.62*	*1.06*	*3.43*	3.70	3.85	4.52	3.68	3.69	2.74	*1.26*	*.70*	29.75
1980	*.50*	*.62*	*1.06*	*3.43*	*3.98*	*4.54*	*5.08*	*4.40*	*3.40*	*2.27*	*1.26*	*.70*	31.24
1981	*.50*	*.62*	*1.06*	*3.43*	*3.98*	5.85	6.23	4.37	3.84	*2.27*	*1.26*	*.70*	34.11
1982	*.50*	*.62*	*1.06*	*3.43*	*3.98*	5.45	6.37	5.29	2.79	*2.27*	*1.26*	*.70*	33.72
1983	*.50*	*.62*	*1.06*	*3.43*	*3.98*	4.64	5.47	4.76	3.79	2.28	*1.26*	*.70*	32.49
1984	*.50*	*.62*	*1.06*	3.37	4.79	4.26	5.58	4.49	3.27	*2.27*	*1.26*	*.70*	32.17
1985	*.50*	*.62*	*1.06*	3.77	4.65	5.24	4.46	4.78	3.29	2.23	*1.26*	*.70*	32.56
1986	*.50*	*.62*	*1.06*	2.98	3.90	5.22	5.35	4.47	2.82	1.86	*1.26*	*.70*	30.74
1987	*.50*	*.62*	*1.06*	3.88	3.74	5.34	6.80	4.55	3.17	*2.27*	*1.26*	*.70*	33.89
1988	*.50*	*.62*	*1.06*	3.60	*3.98*	5.77	5.12	4.43	3.93	2.53	*1.26*	*.70*	33.50
1989	*.50*	*.62*	*1.06*	4.04	4.89	4.33	5.91	4.35	3.31	2.53	*1.26*	*.70*	33.50
1990	*.50*	*.62*	*1.06*	2.85	*3.98*	*4.54*	*5.08*	*4.40*	*3.40*	*2.27*	*1.26*	*.70*	30.66
Avg:	.50	.62	1.06	3.43	3.96	4.53	5.07	4.41	3.43	2.29	1.26	.70	31.26

Source: National Weather Service Annual Climatological Summaries.
Values in *italics* are average monthly values.

APPENDIX B-2

MONTHLY AND ANNUAL ENHANCED EVAPORATION BY SPRAYING

Enhanced Evaporation By Spraying Water[1)]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Average R.H.(%)	43	48	50	50	50	45	45	42	44	36	47	44	--
Average Air Temp (°F)	30.0	33.3	36.4	46.5	53.5	65.0	71.0	70.0	61.0	52.0	39.5	35.0	--
% of Pumped Water Evaporated[2)]	46.3	46.3	48.5	60.4	66.4	80.9	57.5	90.4	80.6	80.3	55.3	51.5	66.2
Evaporation (Ac-Ft) For Pumping Rate of 2000 gpm[3)]	42.2	38.2	44.2	53.4	60.6	71.4	79.8	82.6	71.2	73.4	49.0	47.0	713.0
Evaporation (Ac-Ft) For Pumping Rate of 1000 gpm[3)]	21.1	19.1	22.1	26.7	30.3	35.7	39.9	41.3	35.6	36.7	24.5	23.5	356.5
Evaporation (Ac-Ft) For Pumping Rate of 500 gpm[3)]	10.6	9.5	11.1	13.3	15.1	17.9	20.0	20.7	17.8	18.3	12.2	11.7	178.2

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1) Merrick & Company (1990).

2) Assumes: Droplet radius = 0.0007m, sprinkler height = 1 ft, droplet fall time = 0.25 sec, number of sprinklers = 400, area = 23 ac.

3) Assumes: Pumping rate for 8 hours/day.

APPENDIX B-3

MONTHLY AND ANNUAL AIR TEMPERATURE AND CONSUMPTIVE USE

Monthly and Annual Air Temperature at Fort Collins
(Degrees Fahrenheit)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1953	36.9	31.4	41.1	41.6	52.7	67.6	71.4	68.3	62.2	51.3	39.9	31.0	49.6
1954	32.0	41.3	33.2	52.3	56.0	67.2	74.7	69.6	62.7	50.1	41.7	31.9	51.1
1955	22.7	23.7	34.5	48.4	57.8	62.1	73.0	71.2	61.0	51.2	33.2	30.2	47.4
1956	31.1	22.2	36.7	44.8	58.3	69.8	70.1	66.8	62.7	51.7	36.1	33.8	48.7
1957	21.0	36.8	37.7	40.0	52.4	64.8	71.7	69.8	58.4	50.4	34.0	36.9	47.8
1958	29.8	34.8	31.2	43.8	60.2	66.9	68.0	71.6	62.4	51.9	37.4	30.7	49.1
1959	27.1	26.1	37.7	43.1	54.7	67.9	71.0	71.3	58.0	45.8	35.7	34.2	47.7
1960	25.2	25.0	35.5	49.3	55.4	67.0	70.9	69.8	62.5	50.2	37.7	30.2	48.2
1961	29.2	35.1	36.5	45.7	56.0	65.2	69.7	70.0	54.7	48.2	33.9	26.6	47.6
1962	15.7	28.9	34.4	48.9	57.7	63.1	68.6	68.1	59.8	52.4	41.0	31.8	47.5
1963	16.9	36.7	36.1	48.3	58.6	66.8	73.4	69.0	64.0	54.7	40.0	25.8	49.2
1964	29.6	28.2	31.9	45.5	57.9	63.6	73.8	67.0	59.7	50.6	37.8	30.7	48.0
1965	33.5	28.0	27.1	49.0	55.5	63.3	70.7	67.3	52.9	53.2	42.3	31.8	47.9
1966	25.8	25.9	41.7	44.9	58.9	64.8	74.8	67.8	61.7	49.1	37.7	29.8	48.6
1967	32.0	34.9	42.8	49.1	52.9	60.5	70.1	67.8	60.2	52.2	37.6	25.0	48.8
1968	28.7	34.7	40.8	42.7	53.0	67.2	70.6	66.9	58.9	50.7	35.8	28.9	48.2
1969	30.8	32.9	31.8	51.7	57.9	60.2	72.5	71.6	62.2	40.2	37.7	32.4	48.5
1970	30.1	37.6	33.3	42.5	58.7	64.7	71.2	71.6	58.3	45.1	39.2	30.6	48.6
1971	29.4	30.3	37.7	46.9	54.4	67.8	69.1	70.4	56.0	48.2	37.6	29.3	48.1
1972	26.9	37.1	45.2	48.5	56.5	67.6	68.5	68.5	60.1	49.3	32.6	22.5	48.6
1973	26.6	31.7	37.8	42.4	55.8	66.8	68.9	71.2	58.6	51.8	36.0	31.2	48.2
1974	24.7	35.4	41.8	47.2	60.4	66.5	72.4	66.5	58.1	51.6	38.1	29.5	49.4
1975	30.0	30.0	36.9	43.3	53.3	63.5	71.7	69.2	59.3	51.2	36.5	32.8	48.1
1976	28.3	37.0	37.0	48.6	56.2	64.9	72.5	68.4	60.5	46.8	37.1	33.2	49.2
1977	25.4	36.4	38.7	50.0	59.7	71.3	72.9	68.2	64.6	51.8	38.5	33.9	51.0
1978	23.7	27.9	42.5	49.6	54.0	66.4	72.4	68.1	63.2	50.5	35.9	22.6	48.1
1979	16.9	32.0	40.5	48.5	53.8	64.9	71.9	67.1	63.8	52.7	31.0	31.6	47.9
1980	23.7	29.9	35.4	46.2	54.4	69.2	73.6	69.3	62.6	48.9	39.2	38.8	49.3
1981	33.1	34.5	40.3	54.2	54.7	68.7	72.1	68.6	64.6	49.2	42.7	32.7	51.3
1982	28.2	31.6	40.9	47.2	55.2	61.8	71.0	71.8	59.5	48.3	33.9	30.0	48.3
1983	33.6	36.7	38.0	41.0	52.5	62.5	71.9	73.8	62.6	51.4	36.7	18.6	48.3
1984	25.3	34.2	38.1	42.7	59.0	64.2	72.5	70.9	59.7	45.1	39.4	31.6	48.6
1985	24.5	26.4	41.2	51.9	59.6	66.1	71.3	69.6	57.6	48.6	28.8	26.0	47.6
1986	36.2	35.7	46.5	49.1	56.3	68.3	71.1	69.3	58.8	48.6	37.8	29.5	50.6
1987	31.2	35.2	37.3	51.0	58.3	67.1	71.7	68.2	60.3	50.2	38.6	28.0	49.8
1988	24.4	32.6	38.3	48.8	58.4	70.2	71.7	70.9	60.1	53.2	39.8	27.8	49.7
1989	32.2	21.6	41.2	50.5	58.3	64.0	72.8	68.4	60.2	50.1	41.1	27.2	49.0
Avg:	27.6	31.6	37.8	47.0	56.4	65.8	71.5	69.3	60.3	49.9	37.3	30.0	48.7

Source: National Weather Service Annual Climatological Summaries

Monthly and Annual Consumptive Use at Rocky Flats Plant[1)2)]
(Inches)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1953	.00	.00	.00	.64	2.84	5.37	6.12	5.09	3.54	.91	.00	.00	24.51
1954	.00	.00	.00	1.17	3.30	5.29	6.80	5.32	3.61	.86	.00	.00	26.35
1955	.00	.00	.00	.96	3.57	4.38	6.44	5.62	3.38	.91	.00	.00	25.26
1956	.00	.00	.00	.78	3.65	5.79	5.86	4.83	3.61	.93	.00	.00	25.45
1957	.00	.00	.00	.57	2.80	4.85	6.18	5.36	3.04	.87	.00	.00	23.67
1958	.00	.00	.00	.74	3.95	5.24	5.45	5.69	3.57	.94	.00	.00	25.58
1959	.00	.00	.00	.71	3.12	5.42	6.04	5.63	2.99	.68	.00	.00	24.59
1960	.00	.00	.00	1.01	3.22	5.26	6.02	5.36	3.58	.86	.00	.00	25.31
1961	.00	.00	.00	.83	3.30	4.93	5.78	5.40	2.58	.78	.00	.00	23.60
1962	.00	.00	.00	.99	3.56	4.55	5.57	5.06	3.22	.96	.00	.00	23.91
1963	.00	.00	.00	.96	3.69	5.22	6.52	5.22	3.79	1.07	.00	.00	26.47
1964	.00	.00	.00	.82	3.59	4.64	6.61	4.87	3.20	.88	.00	.00	24.61
1965	.00	.00	.00	.99	3.23	4.59	5.98	4.92	2.37	1.00	.00	.00	23.08
1966	.00	.00	.00	.79	3.74	4.85	6.82	5.01	3.47	.81	.00	.00	25.49
1967	.00	.00	.00	1.00	2.87	4.11	5.86	5.01	3.27	.95	.00	.00	23.07
1968	.00	.00	.00	.69	2.88	5.29	5.96	4.85	3.10	.89	.00	.00	23.66
1969	.00	.00	.00	1.14	3.59	4.07	6.34	5.69	3.54	.48	.00	.00	24.85
1970	.00	.00	.00	.68	3.71	4.84	6.08	5.69	3.02	.65	.00	.00	24.67
1971	.00	.00	.00	.89	3.07	5.41	5.66	5.47	2.74	.78	.00	.00	24.02
1972	.00	.00	.00	.97	3.38	5.37	5.55	5.13	3.26	.82	.00	.00	24.48
1973	.00	.00	.00	.68	3.27	5.22	5.63	5.62	3.06	.93	.00	.00	24.41
1974	.00	.00	.00	.90	3.98	5.16	6.32	4.78	3.00	.93	.00	.00	25.07
1975	.00	.00	.00	.72	2.92	4.62	6.18	5.25	3.15	.91	.00	.00	23.75
1976	.00	.00	.00	.97	3.33	4.87	6.34	5.11	3.31	.72	.00	.00	24.65
1977	.00	.00	.00	1.05	3.87	6.09	6.42	5.08	3.88	.93	.00	.00	27.32
1978	.00	.00	.00	1.02	3.02	5.15	6.32	5.06	3.68	.88	.00	.00	25.13
1979	.00	.00	.00	.97	2.99	4.87	6.22	4.88	3.76	.98	.00	.00	24.67
1980	.00	.00	.00	.85	3.07	5.67	6.57	5.27	3.59	.81	.00	.00	25.83
1981	.00	.00	.00	1.28	3.12	5.58	6.26	5.15	3.88	.82	.00	.00	26.09
1982	.00	.00	.00	.90	3.19	4.33	6.04	5.73	3.18	.78	.00	.00	24.15
1983	.00	.00	.00	.62	2.81	4.45	6.22	6.11	3.59	.92	.00	.00	24.72
1984	.00	.00	.00	.69	3.76	4.75	6.34	5.56	3.20	.65	.00	.00	24.95
1985	.00	.00	.00	1.15	3.85	5.09	6.10	5.32	2.94	.79	.00	.00	25.24
1986	.00	.00	.00	1.00	3.35	5.50	6.06	5.27	3.09	.84	.00	.00	25.11
1987	.00	.00	.00	1.10	3.65	5.27	6.18	5.08	3.28	.86	.00	.00	25.42
1988	.00	.00	.00	.98	3.66	5.87	6.18	5.56	3.26	1.00	.00	.00	26.51
1989	.00	.00	.00	1.07	3.65	4.71	6.40	5.11	3.27	.86	.00	.00	25.07
Avg:	.00	.00	.00	.90	3.37	5.04	6.15	5.27	3.30	.85	.00	.00	24.88

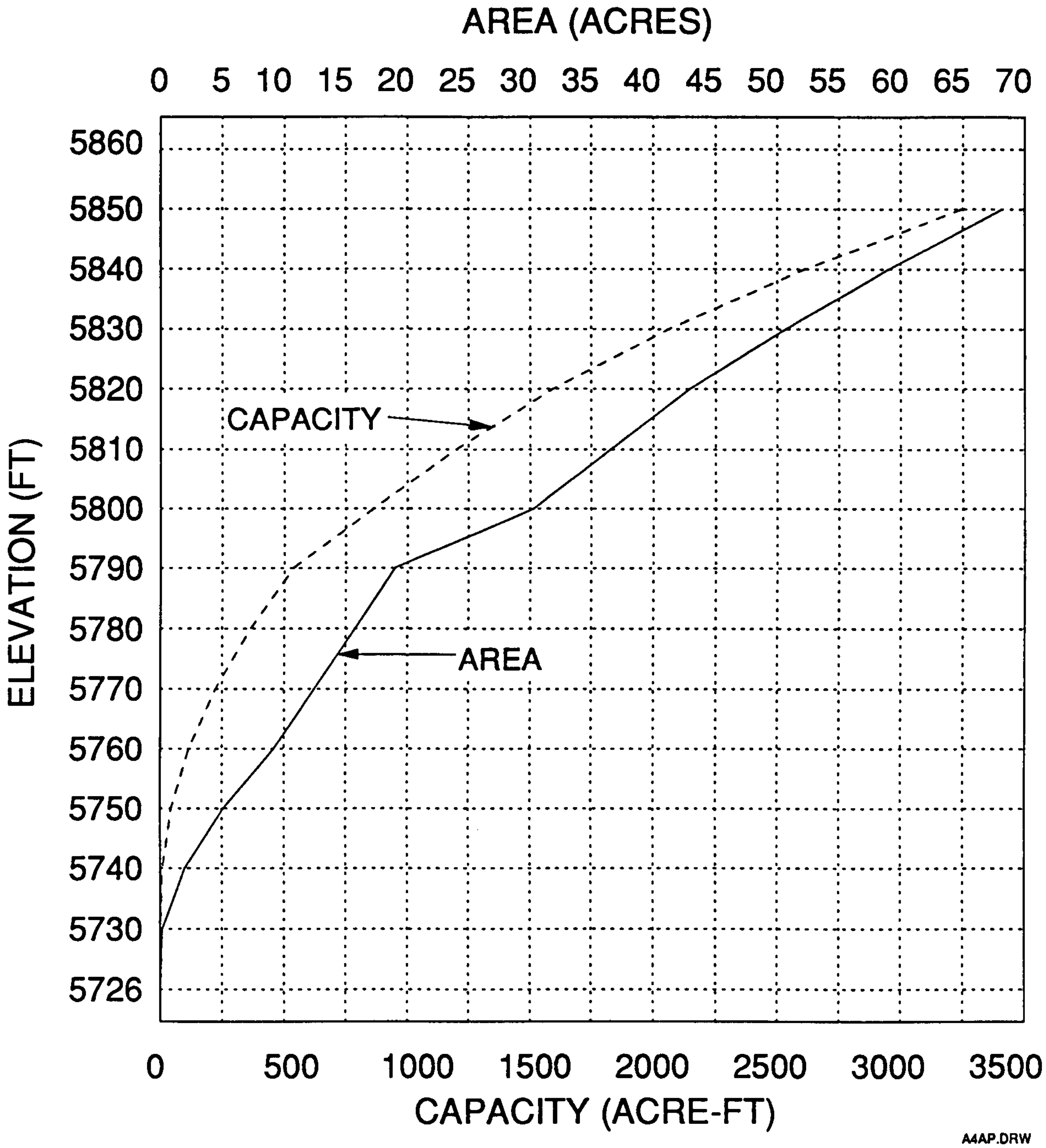
1) Based upon the modified Blaney-Criddle method (SCS, 1970).
2) Values for pasture grass.

C

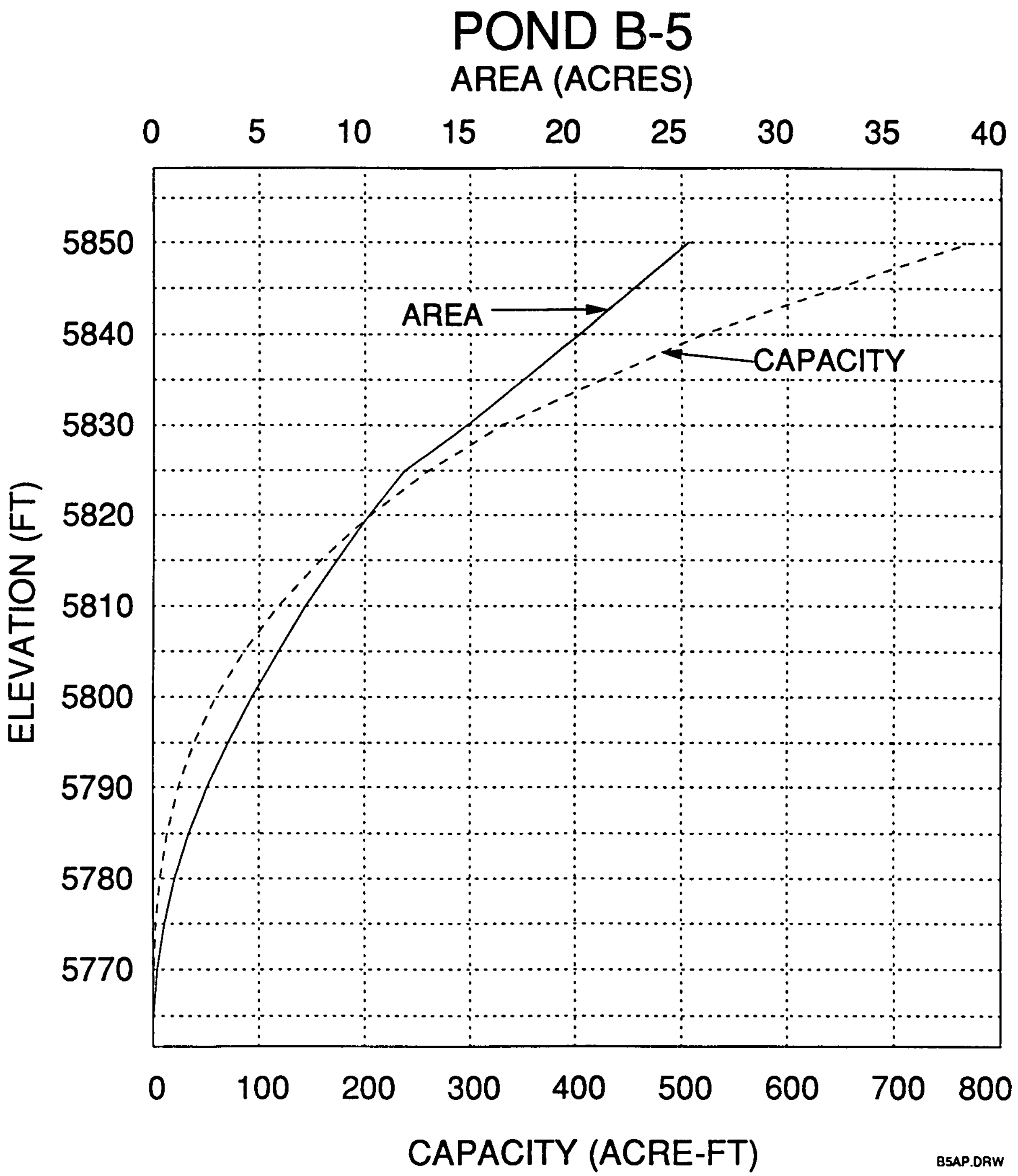
APPENDIX C

ELEVATION-AREA-CAPACITY CURVES
POND A-4, POND B-5, POND C-2, AND
GREAT WESTERN RESERVOIR

POND A-4



POND A-4 ELEVATION-AREA-CAPACITY CURVES		
ALTERNATIVES TO ZERO DISCHARGE		
ZERO OFFSITE WATER DISCHARGE		
	PROJECT: 208.0117 DATE: JUNE 1991	FIGURE C-1

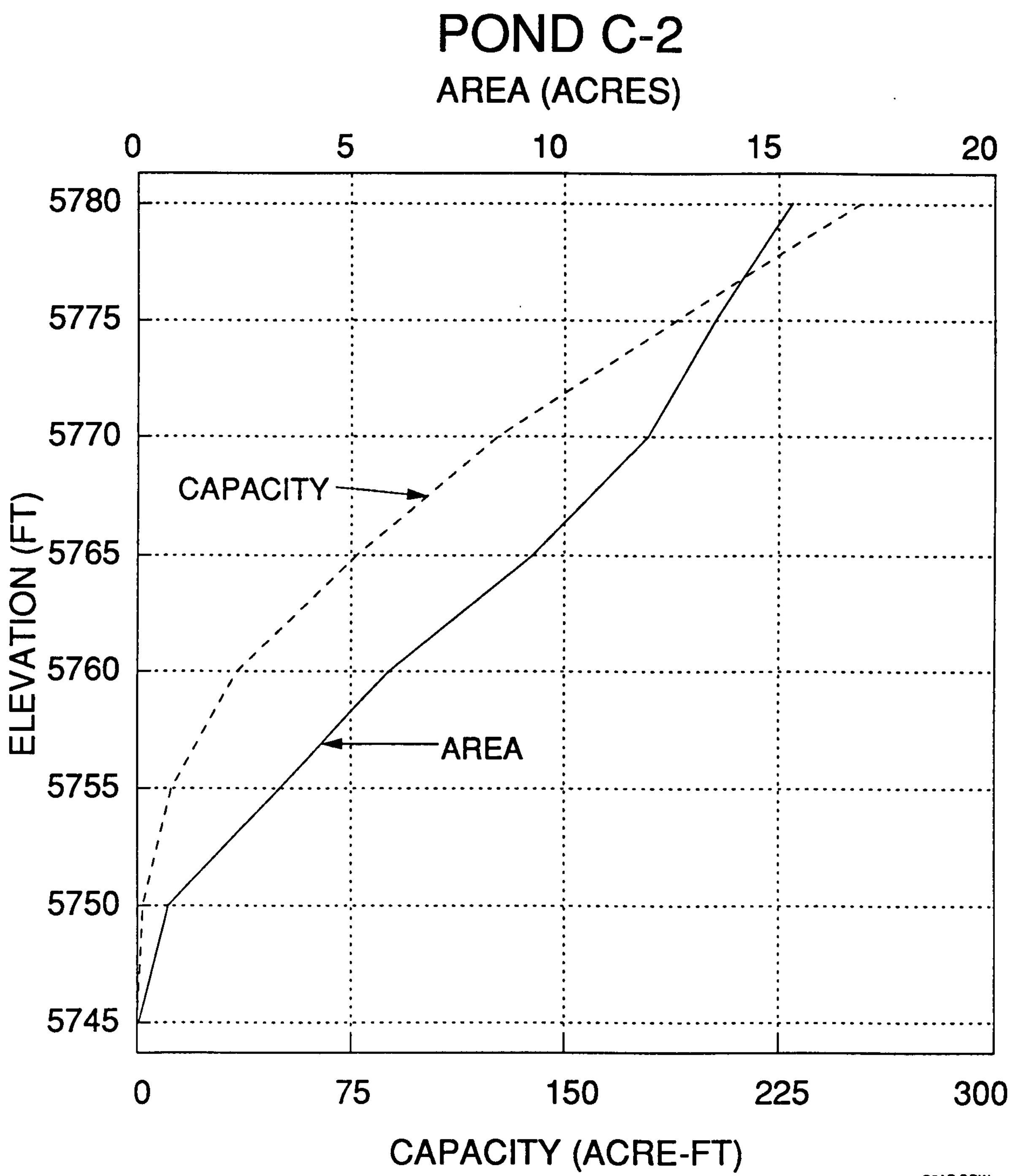


POND B-5
ELEVATION-AREA-CAPACITY CURVES

ALTERNATIVES TO ZERO DISCHARGE

ZERO OFFSITE WATER DISCHARGE

	PROJECT: 208.0117	FIGURE C-2
	DATE: JUNE 1991	



C2AP.DRW

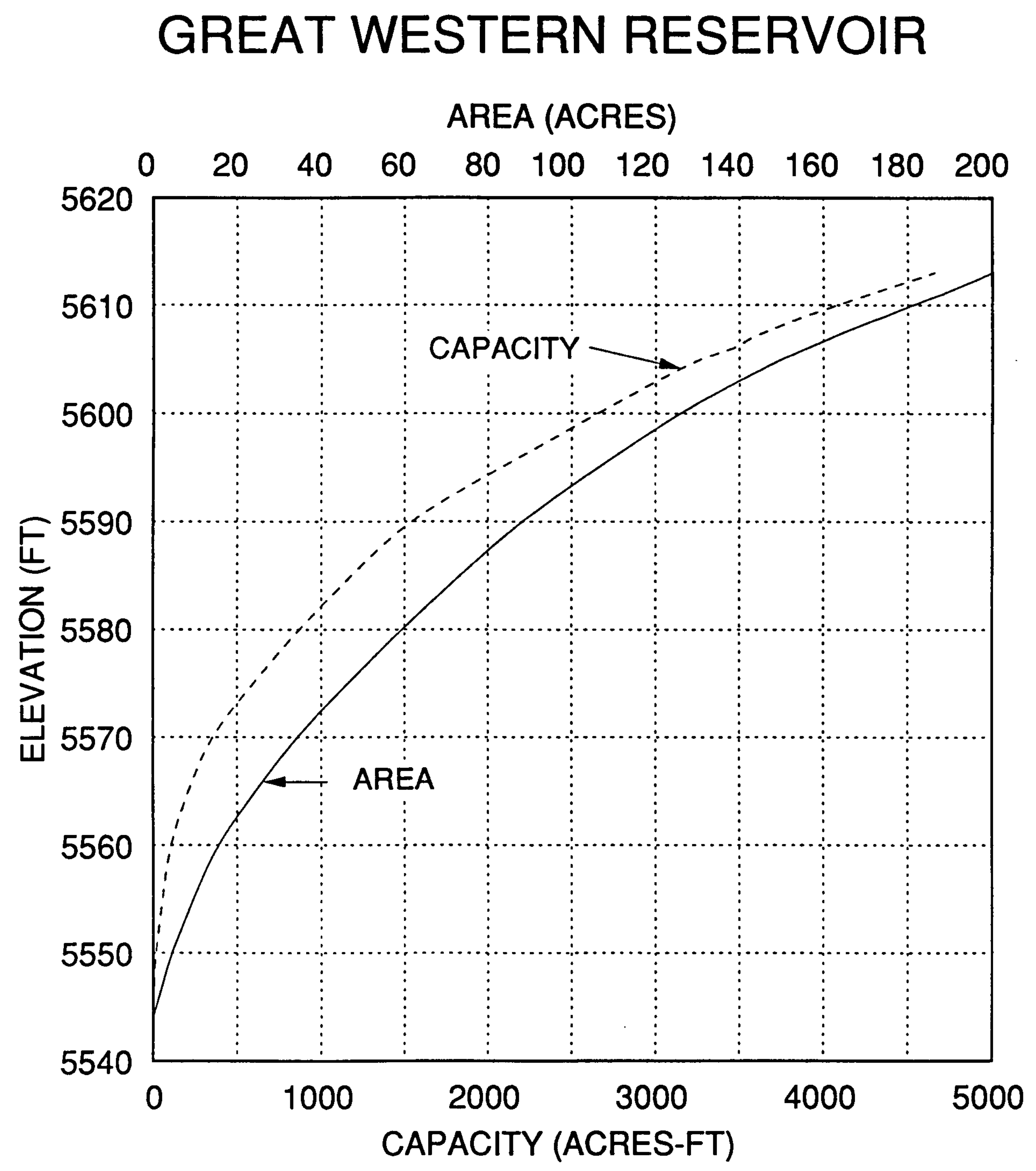
POND C-2
ELEVATION-AREA-CAPACITY CURVES

ALTERNATIVES TO ZERO DISCHARGE

ZERO OFFSITE WATER DISCHARGE

PROJECT: 208.0117
DATE: JUNE 1991

FIGURE C-3



GWAP.DRW

GREAT WESTERN RESERVOIR ELEVATION-AREA-CAPACITY CURVES		
ALTERNATIVES TO ZERO DISCHARGE		
ZERO OFFSITE WATER DISCHARGE		
ASI	PROJECT: 208.0117 DATE: JUNE 1991	FIGURE C-4