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IMPACT OF PEACEKEEPER PROJECT
ON CHEYENNE WATER SUPPLY

NOVEMBER, 1983

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FINAL REPORT

IMPACT OF PEACEKEEPER PROJECT
ON CHEYENNE WATER SUPPLY

SUBMITTED TO THE

CITY OF CHEYENNE, WYOMING
BOARD OF PUBLIC UTILITIES

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NOVEMBER, 1983

BANNER ASSOCIATES, INC.

PROJECT NO. 2152-01

Introduction

This study was performed to analyze the effect of the proposed Peacekeeper (MX Missile) project on the capacity of Cheyenne's Crystal Lake Reservoir. Along with the previously mentioned reports, other informational sources referred to included:

- 1) Population projections and associated water demands provided by the Board of Public Utilities (BOPU)
- 2) Final Forest Service Environmental Impact Statement (EIS) on the Cheyenne Water Project
- 3) URS - BERGER reports on the Peacekeeper projects.

Banner had previously developed the "Crow Creek System Operation Study" computer program to analyze the relationship of various water supply/Cheyenne demand situations, and this program is also used in this analysis.

A series of reservoir operation studies were run to mathematically model Cheyenne's Crow Creek system by means of a computer algorithm. Reservoir operation studies are made to visualize the manner in which a project, or in this case a water supply system, will work. In operation studies, various assumptions are made relative to the water supply and the demand upon it. The water supply and demands are compared under anticipated operating criteria. The operation studies presented herein are simply accounting systems to balance water supplies and demands. In its final form the operation study is a numerical representation of Cheyenne's future water demands superimposed on the Crow Creek reservoir system, and it is modeled after historic runoff conditions experienced during the period 1933-1969.

As used in this study, the purpose of the Crow Creek model is to determine if the water supply needs of Cheyenne could be safely and adequately met through 1990 with and without the Peacekeeper project utilizing only the existing Lake Owen to Crow Creek pipeline. Another factor considered under the same conditions is the presently restricted capacity (15' below spillway level) of Crystal Reservoir. An additional factor that will be considered is the construction presently being done at Rob Roy Dam and Hog Park Dam which also necessitated draining of the reservoirs.

Crystal Lake Dam Restricted Capacity

Crystal Lake Dam and Reservoir were constructed on Middle Crow Creek in 1911. The dam is a gravity-arch dam of a concrete masonry type construction. The dam and reservoir were constructed to provide water supply to the City of Cheyenne, Wyoming.

In 1978, the U.S. Army corps of Engineers conducted a Phase I Inspection Report on Crystal Dam under the authority of the National Dam Inspection Act of 1972 (P.L. 92-367). The Corps determined the "...structural capacity of the dam is suspect for several reasons..." The Corps also conducted hydraulic and hydrologic evaluations that indicated that Crystal Lake Dam would be overtopped by a flood equivalent to 50% of the Probable Maximum Flood.

As a result of the Corps study, the reliability of a crucial link in Cheyenne's water supply system has been severely questioned. The Wyoming State Engineer, as a result of the Phase I study, has limited the amount of water Cheyenne can store in Crystal Lake Reservoir to that stored at a water elevation 15 feet below the spillway crest.

The Board of Public Utilities has adopted a four-step plan in order to rectify the Crystal Dam situation. The four steps are:

Step 1 - Hydrologic Investigation

Step 2 - Geologic Invesigation

Step 3 - Design of Renovation Facilities

Step 4 - Construction of Facilities

Step 1 involved a detailed hydrologic investigation to determine if additional water supply could be realized by enlarging Crystal Lake Reservoir. That study was performed by Banner Associates, Inc., and is entitled "Crystal Lake Reservoir Hydrologic Analysis". This study concluded that enlargement of Crystal Lake Dam and Reservoir, to increase water supply alone, is not cost-effective. The study stated that if reconstruction is necessary as a result of the findings of a geotechnical investigation, which is Step 2 of the plan, a modest enlargement of the dam height and reservoir capacity would be necessary for flood control.

Step 2 involved a geotechnical investigation to determine whether the existing dam is safe or whether to proceed with evaluation of foundation conditions for reconstruction. That study was performed by Woodward-Clyde. The final report has not been published as of November, 1983. However, a draft report was published in April, 1983. The draft report concluded that the dam need not be removed, but if it is to be maintained in operation some renovations of the dam and abutments are necessary. At present the existing spillway is not adequate to handle the Design Floods without overtopping. The final report is to be issued by Woodward-Clyde, in December, 1983. The report will address recommended spillway improvements and reservoir capacity. As part of the report, investigations included analyzing the possibility of enlarging Crystal Reservoir as a means to delay the construction of a second Lake Owen to Crow Creek pipeline. Initial analysis revealed that this enlargement is not effective and will not be recommended.

Step 3 will involve the development of construction drawings and specifications should the Board decide to rebuild, renovate, or enlarge Crystal Lake Dam and Reservoir. Step 4 will be the actual construction of new facilities.

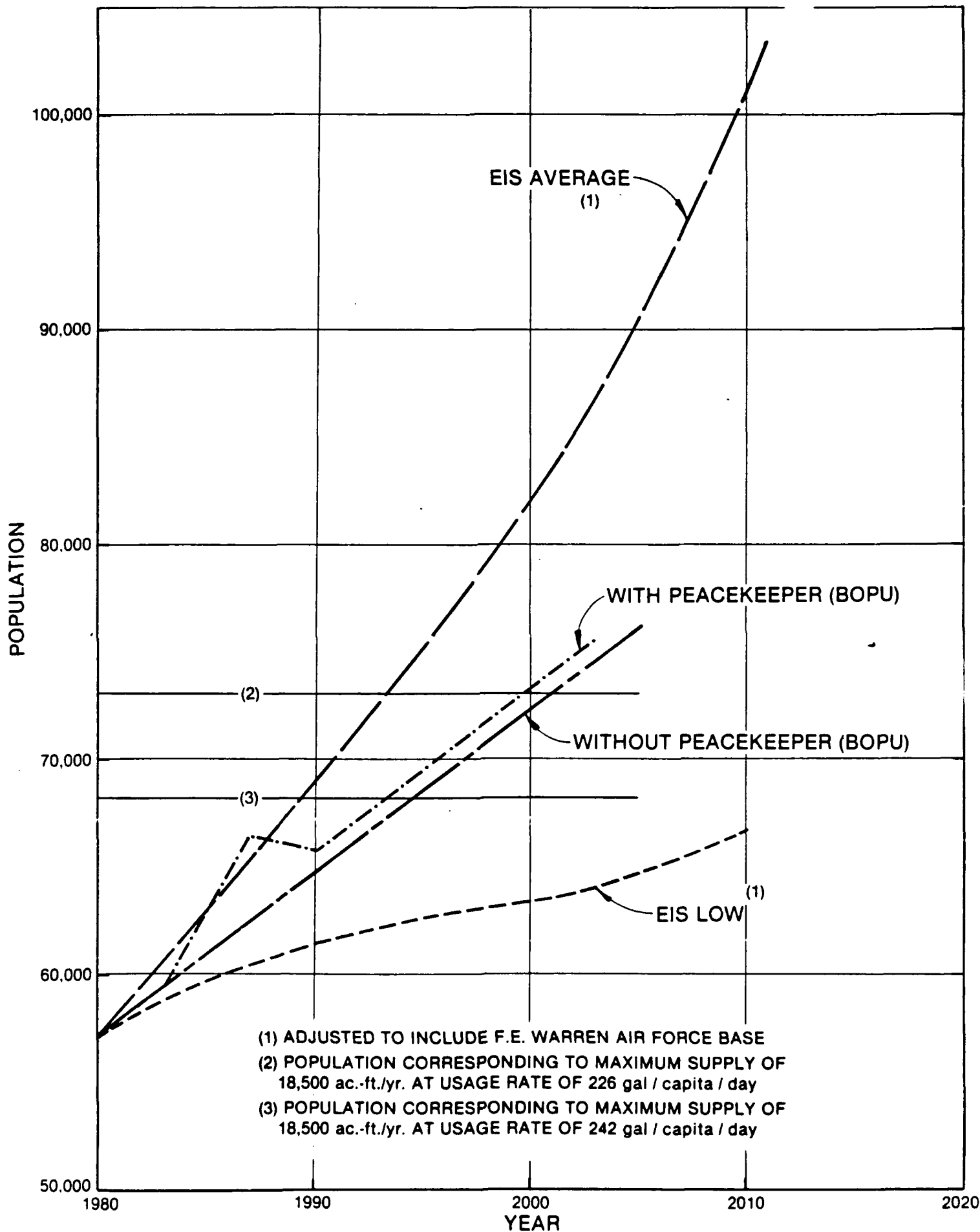
Water Supply Analysis

The ultimate Stage I & II development is 19,000 acre-feet per year, and this quantity eventually can be conveyed to the Crow Creek Reservoir from the Rob Roy Reservoir. However, the existing pipeline from Lake Owen to Crow Creek restricts the quantity of water that can be diverted to Crow Creek from Lake Owen to 12,810 acre-feet per year. In the operation studies, the pipeline was assumed to be running at full capacity the entire year.

Under normal conditions, it is better to maintain storage in Rob Roy than release Douglas Creek water to Crow Creek. This serves three purposes: 1) reservoir evaporation is less at Rob Roy, 2) available storage in the Crow Creek system increases in the spring months to receive Crow Creek runoff, and 3) if spills occur and Douglas Creek water has to be bypassed, it is better accomplished at Rob Roy so that replacement releases from Hog Park are not required. At high water demand times in Cheyenne, Douglas Creek water will be imported on a nearly uniform basis and used with very little retention time in the Crow Creek system.

Presently, Cheyenne does not use Brush Creek and South Crow Creek diversions, except in an emergency, because of the turbidity of this water. This water could be treated with modifications to the treatment process, but treatment represents increased operation costs which are not justified at present. Therefore, these operations studies do not consider diversion from Brush or South Crow Creek.

A major consideration in this analysis is the projected population and the per capita usage rates. The recommendations presented in this report are based on the information related to the Peacekeeper impacts as provided by the Board of Public Utilities. Population projections and usage rates from



the EIS are also tabulated for comparison purposes. Figure 1 shows a graphical representation of the projected populations from the two sources. Population projections presented in the EIS excluded Warren Air Base although it is part of the Board of Public Utilities service area and, thus, will influence water consumption. Therefore, the base EIS population in 1980 was adjusted upward to the Board of Public Utilities figure, and this adjustment is reflected in the population projections shown in Figure 1. Population projections provided by the Board of Public Utilities extended only as far as 1990. By linear regression analysis, it was determined that a straight-line population projection was being used for increases without the Peacekeeper project. Therefore, this straight-line projection was continued beyond 1990 for the Board of Public Utilities population projection. For population projections with the Peacekeeper project beyond 1990, it was assumed that the population with the Peacekeeper would parallel the population without the Peacekeeper, but at an increased base equal to the difference in population at 1990. Water usage rates provided by the Board of Public Utilities are approximately 226 gallons per capita per day (gpcd) throughout the years of projection. The EIS used a 1980 usage of 242 gpcd and decreased the usage by 2.42 gpcd per year (1% per year of the 1980 usage rate) to a 2010 usage rate of 169 gpcd. The reduction presented in the EIS assumed that conservation would decrease per capita usage. To illustrate a "worst-case" analysis, water usage at the EIS 1980 level and continuing at that rate (no conservation) was also tabulated. Table 1 shows the demand per year based on the various usage rates and using the population projection provided by the Board of Public Utilities.

TABLE 1

WITHOUT PEACEKEEPERBOPU

<u>YEAR</u>	<u>POPULATION PROJECTION</u>	<u>WATER¹ DEMAND</u>	<u>WATER² DEMAND</u>	<u>WATER³ DEMAND</u>
1980	57,123	14,450 Ac-Ft/Yr	15,480 Ac-Ft/Yr	15,480 Ac-Ft/Yr
1983	59,449	15,010 Ac-Ft/Yr	15,630 Ac-Ft/Yr	16,110 Ac-Ft/Yr
1987	62,492	15,790 Ac-Ft/Yr	15,760 Ac-Ft/Yr	16,940 Ac-Ft/Yr
1990	64,745	16,350 Ac-Ft/Yr	15,810 Ac-Ft/Yr	17,550 Ac-Ft/Yr

WITH PEACEKEEPER

1980	57,123	14,450 Ac-Ft/Yr	15,480 Ac-Ft/Yr	15,480 Ac-Ft/Yr
1983	59,449	15,010 Ac-Ft/Yr	15,630 Ac-Ft/Yr	16,110 Ac-Ft/Yr
1987	66,476	16,800 Ac-Ft/Yr	16,770 Ac-Ft/Yr	18,020 Ac-Ft/Yr
1990	65,779	16,690 Ac-Ft/Yr	16,060 Ac-Ft/Yr	17,830 Ac-Ft/Yr

¹Constant usage rate of 226 gpcd; Source: BOPU

²1980 usage rate of 242 gpcd and reducing by 1% of 1980 rate per year on assumption conservation will take place; Source: EIS

³Constant usage rate of 242 gpcd; Source: EIS 1980 usage rate

Based on these annual water demands, the computer operation studies were run setting constant yearly demands of 17,500 acre-feet and 18,000 acre-feet

The operation studies were also run with the same demands as above, but with Crystal Reservoir level restricted to 15' below the present spillway crest elevation (capacity at restricted level approximately 1950 acre-feet). In the studies, the Cheyenne demand was distributed on a uniform quarterly basis. The uniform quarterly demands, expressed as percentages are as follows (Noe, 1980):

<u>Period</u>	<u>% of Annual Demand</u>
October - December	21.29
January - March	19.53
April - June	24.61
July - September	34.57

The water supply is based upon historic records from 1933 to 1969. The USGS gaging station was abandoned in 1969. The operations study determines if there are deficiencies in the supply based upon these records. The program continues to operate by assuming that the deficiencies are made up from groundwater or surface sources, but prints out the deficits.

The operations study simulates the normal operation of the reservoir and groundwater pumping. Crystal Reservoir is maintained at a level as full as possible. Water released from Crystal to the Cheyenne water treatment and distribution system is replaced by releases from Granite Springs Reservoir. When water is available for storage, Crystal is filled first, then Granite is filled if additional water is available to enable greater operational flexibility. Water released from Lake Owen presently passes through Granite

Springs Reservoir. In the future, a small portion of that water will bypass Granite Springs Reservoir and flow directly into Crystal Reservoir. Groundwater is used in the operation study at a rate of 400 acre-feet per month during May through September.

Table 2 is a listing of the years and the amount of deficits of supply to Cheyenne based upon the operation studies run. The maximum yearly deficit was 1720 acre-feet with the Peacekeepers population impact. A deficit of this magnitude can be made up by pumping of groundwater or diversion of South Crow Creek or Brush Creek water (with improvements to the treatment process).

By a review of Table 1, it can be seen that the water demands based on the Board of Public Utilities's population projections and usage rates could be met throughout the period to 1990 even with the Peacekeeper developmental impacts. Even when using the higher consumption rate presented in the EIS and assuming conservation does not take place, the deficits are infrequent and small enough to be made up through additional groundwater pumping.

In operation studies performed previously (WOODWARD-CLYDE CRYSTAL ENLARGEMENT STUDY), it was determined that an average water demand of 18,500 acre-feet per year is available from all sources to Cheyenne based on a storage of 3,410 acre-feet in Crystal Reservoir and using the existing Lake Owen to Crow Creek pipeline only. Based on that demand level and the Board of Public Utilities population projections and usage rates, a second pipeline would not be needed until the year 2000 with the Peacekeeper and approximately a year later if the Peacekeeper is not implemented (Refer to Figure 1). If the EIS 1980 usage rates are used, the second pipeline would be needed in 1993. It should be noted that if the adjusted average EIS population projections are used, the second pipeline would be needed in 1993

TABLE 2

WATER SUPPLY DEFICITS

Without Second Lake Owen to Crow Creek Pipeline

Cheyenne Demand of 17,500 Acre-Feet/Year (w/o Peacekeeper)

Active Storage (Ac-Ft)

<u>Year</u>	<u>3410</u>	<u>1950</u>
1957	0 Ac-Ft	70 Ac-Ft

Cheyenne Demand of 18,000 Acre-Feet/Year (w/Peacekeeper)

Active Storage (Ac-Ft)

<u>Year</u>	<u>3410</u>	<u>1950</u>
1956	600 Ac-Ft	1720 Ac-Ft
1957	380 Ac-Ft	380 Ac-Ft

and 1989, respectively, based on the usage rates of 226 gpcd and 242 gpcd. The present restriction on the level of Crystal storage had some effect but did not impact the results significantly.

Operation studies prepared for Woodward-Clyde indicated that based upon present per capita water use (242 gpcd) in Cheyenne service area and the EIS population projections, the second pipeline would be required in 7 to 10 years. This study reconfirmed that finding, and if the Board of Public Utilities's projections are used, the pipeline could be delayed somewhat longer even with the increased population due to the Peacekeeper (MX) project. Work performed for the Woodward-Clyde report also showed that an enlargement of Crystal Reservoir would not significantly delay the need for the second pipeline.

Additional data are attached regarding the operation studies for the simulation of the Crow Creek system. This also includes a narrative explanation of the row headings presented on the operation study summary sheets. Only summary sheets are provided for the studies due to the bulk of these studies. If further review of these studies is desired, the full printouts can be reviewed at the offices of Banner Associates, Inc., in Laramie, Wyoming.

Water Supply Available From Rob Roy to Crow Creek Due to Current Construction

This section of the report addresses the impacts resulting from the current construction activities at Rob Roy and Hog Park Reservoirs. These effects will result whether or not the Peacekeeper system is implemented although the impacts may increase due to the additional demands associated with the Peacekeeper project.

Due to construction activities, both Rob Roy and Hog Park Reservoirs are currently at dead pool levels, and completion of the Little Snake Stage II Pipeline is not expected until late in the 1985 water year. To analyze this situation and its potential effects on the Cheyenne supply, the operation study was performed by means of the Cheyenne Little Snake/Douglas Creek Exchange Operation Study developed by Banner Associates, Inc. Two scenarios were investigated: 1) The operation study begins at the lowest historical runoff condition. 2) The operation study begins at an average historical runoff condition. Operation studies were performed to simulate Rob Roy Reservoir assuming initial water level of the reservoir is at dead pool level. On the Hog Park portion of the study, it was assumed the reservoir began at dead pool level and Stage II flows were not available during the first two years. It should be noted that the contractor for the Little Snake Diversion Pipeline is contractually obligated to begin delivery of a portion of Stage II flows by the end of the 1984 water year (end of first year of operation study) or mitigate the effects. In the operation studies, it was assumed that during the first two years Douglas Creek depletions could not exceed the Stage I flows delivered by the Little Snake Diversion Pipeline to Hog Park Reservoir and the balance of the water storage in Seminole Reservoir. Since Hog Park Reservoir begins at dead pool storage, Hog Park storage has little effect on the supply yield during the first years of the study. Under the water accounting system being implemented for the Cheyenne Water System,

Cheyenne has a storage account for water in Seminole Reservoir that currently contains approximately 5,000 acre-feet.

The results of that operation study are shown in Table 3 and indicate the water supply available from Rob Roy to Crow Creek pipeline. In the first three years of the operation studies, additional Douglas Creek flows are available, but depletions from Douglas Creek were limited by the amount of Little Snake diversions being delivered to Hog Park Reservoir and by drawing against the Seminole storage account. It was assumed that the balance in the Seminole storage account would be drawn against in the first year. This was done to minimize groundwater withdrawal to meet Cheyenne's demand and to preserve storage in Granite and Crystal Reservoirs so it could be utilized more effectively. Table 3 shows that under both scenarios the full pipeline capacity of 12,810 acre-feet/year could be delivered beginning in the fourth year and would continue through the remainder of the study period (only the first five years are shown in the table).

To analyze the total effects on the Cheyenne demand, the supply sources of Crow Creek and groundwater were incorporated into the analysis. As with the Rob Roy supply analysis, the low and average historical runoff scenarios were used. Demands were based on the BOPU projected populations and usage rates with and without the Peacekeeper impacts. The initial storage condition of the Crow Creek system was based on the currently estimated Crow Creek system storage of approximately 5,600 acre-feet (NOE, November 1983). Runoff yields from the Crow Creek drainage were based on total historical inflow less the total average annual evaporation (870 acre-feet/year) from the Crow Creek reservoir system for the appropriate scenario. In the analysis, it was assumed that groundwater would be withdrawn up to a maximum rate of 5,000 acre-feet per year for the first two years and then return to the long-term yield of 2,000 acre-feet per year for all subsequent years.

TABLE 3

Water Supply Available from Rob Roy to Crow Creek Pipeline*

<u>Year</u>	Operation Study Start Condition**	
	<u>Lowest</u> <u>Historical Runoff</u>	<u>Average</u> <u>Historical Runoff</u>
1	4,610 + 5,000 (Seminole Account)	5,540 + 5,000 (Seminole Account)
2	5,910	7,040
3	7,870	9,670
4	12,810	12,810
5	12,810	12,810

*Based on Little Snake/Douglas Creek Exchange Study
 Rob Roy and Hog Park Reservoirs at Dead Pool Initially
 Stage II Flows Unavailable First Two Years

**All quantities are in acre-feet.

During the 1983 season, 5,000 acre-feet of groundwater was pumped. Continuing to pump at a rate of 5,000 acre-feet per year for an additional two years would be greater than what is considered to be a safe yield. In the analysis, the Cheyenne demand was first met by the Rob Roy supply and then groundwater up to the limits set for that year. Any deficits still remaining were taken from the Crow Creek system net inflows and available storage.

The results of the Cheyenne supply analysis under the construction impacts with and without the Peacekeeper system are shown on Tables 4 and 5, respectively. By utilizing the Seminoe storage account in the first year, no deficits to the Cheyenne demand occurred under either scenario. This was based on the assumption that 5,000 acre-feet per year could be pumped from groundwater for the first two years. If less than 5,000 acre-feet is pumped during the first two years, Granite and Crystal Reservoir could go dry and result in shortages to Cheyenne. Therefore, every attempt should be made to begin portions of Stage II deliveries by the second year of the study. The largest demand on Crow Creek storage occurred in the second and third years. As noted earlier, the assumption was made that Little Snake Stage II diversions would be unavailable the second year even though the flows are contractually obligated to be made. If the diversions are made or mitigative measures taken, the demand on the Crow Creek system would be even less than shown in Tables 4 and 5. The overall result is that with present storage available in the Crow Creek system and water in the storage account in Seminoe Reservoir, there should not be any problems meeting the Cheyenne demand with or without the Peacekeeper impacts.

TABLE 4

CHEYENNE DEMAND & SUPPLY SOURCES

(All quantities in acre-feet)

WITHOUT PEACEKEEPER

Scenario 1-1984 Sequence follows Lowest Historical Runoff Sequence

Year	Demand	Rob Roy Supply	Crow Creek System			Used	Groundwater
			Avail Storage	Avg. Annual Evap.	Inflow Less		
1984	15,241	9,610	5,600	560	560	631	5,000
1985	15,434	5,910	5,529	950	950	4,524	5,000
1986	15,626	7,870	1,955	8,360	8,360	5,756	2,000
1987	15,790	12,810	4,559	5,600	5,600	980	2,000
1988	16,009	12,810	9,179	6,150	6,150	1,199	2,000

Scenario 2 - 1982 Sequence Follows An Average Historical Runoff Sequence

1984	15,241	10,540	5,600	2,550	0	4,701
1985	15,434	7,040	8,150	7,900	3,394	5,000
1986	15,626	9,670	9,800*	2,920	3,956	2,000
1987	15,790	12,810	8,764	2,160	980	2,000
1988	16,009	12,810	9,800*	5,010	1,199	2,000

*Total Storage Capacity of Granite, Crystal, & North Crow Reservoirs Equals 9,800 Ac-Ft

TABLE 5

CHEYENNE DEMAND & SUPPLY SOURCESWITH PEACEKEEPER

(All quantities in acre-feet)

Scenario 1 - 1984 Sequence Follows Lowest Historical Runoff Sequence

<u>Year</u>	<u>Demand</u>	<u>Rob Roy Supply</u>	<u>Crow Creek System</u>			<u>Used</u>	<u>Groundwater</u>
			<u>Avail Storage</u>	<u>Avg. Annual</u>	<u>Inflow Less Evap.</u>		
1984	15,494	9,610	5,600	560		884	5,000
1985	15,938	5,910	5,276	950		5,028	5,000
1986	16,383	7,870	1,198	8,360		6,513	2,000
1987	16,800	12,810	3,045	5,600		1,990	2,000
1988	16,769	12,810	6,655	6,150		1,959	2,000

Scenario 2 - 1984 Sequence Follows An Average Historical Runoff Sequence

1984	15,494	10,540	5,600	2,550	0	4,954
1985	15,938	7,040	8,150	7,900	3,898	5,000
1986	16,383	9,670	9,800*	2,920	4,713	2,000
1987	16,800	12,810	8,007	2,160	1,990	2,000
1988	16,769	12,810	8,177	5,010	1,959	2,000

*Total Storage Capacity of Granite, Crystal, & North Crow Reservoirs Equals 9,800 Ac-Ft

Results and Conclusions

The results of these operation studies indicate that the second pipeline from Lake Owen to Crow Creek will not be needed through the period to 1990 with or without the Peacekeeper project based on the Board of Public Utilities population projections. The peak water demand with the Peacekeeper project would occur during construction projected in 1987. The operation studies indicated that even at this peak demand and the reservoir restricted to 15' below the spillway level, the Cheyenne demand could be adequately and safely met. Although the 15' restriction in reservoir water level had minimum impacts on the water supply, the Board of Public Utilities should restore Crystal Reservoir to full capacity so that the present system can be fully utilized to minimize any shortages that may occur.

The current construction activities at Rob Roy and Hog Park Reservoirs and Little Snake Diversion Pipeline should not present supply problems to Cheyenne if 5,000 acre-feet per year can be pumped from groundwater in the next two years. However, pumping at that sustained rate is considered to exceed the safe yield of the wells. Therefore, every attempt should be made to complete the Stage II Little Snake Diversion Pipeline on schedule to avoid possible deficits to Cheyenne.

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"Interim Report, Engineering Evaluation, Crystal Lake Dam; Laramie County, Wyoming" Woodward-Clyde Consultants; April 1983

"Cheyenne Stage II Water Diversion Proposal; Final Environmental Impact Statement" USDA Forest Service; December 1981

"Crow Creek Watershed Raw Water Delivery System Evaluation" prepared for URS-Berger; Banner Associates, Inc.; July 1983

APPENDIX

EXISTING SYSTEM MODEL WITH STAGE II IMPORTED WATER - CRYSTAL STORAGE = 3410 AF
 BOTH BRUSH CREEK AND SOUTH CROW DIVERSIONS UNAVAILABLE
 CHEYENNE DEMAND = 17,500 ACRE-Feet/YEAR
 GROUNDWATER USE = 2,000 ACRE-Feet/YEAR

CHEYENNE WATER PROJECT - CROW CREEK WATER SUPPLY AND DISTRIBUTION SYSTEM
 CRYSTAL RESERVOIR SIZING AND HYDROLOGIC INVESTIGATION

SUMMARY- 37 YEARS OF OPERATION	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	YEAR
CITY OF CHEYENNE WATER DEMANDS													
1 ESTIMATED DEMAND	1.24	1.24	1.24	1.14	1.14	1.14	1.44	1.44	1.44	2.02	2.02	2.02	17.50
BRUSH CREEK DIRECT DIVERSION													
2 INFLOW (EST)	0.05	0.04	0.03	0.03	0.03	0.08	0.29	0.36	0.21	0.07	0.03	0.02	1.24
3 DIVERSION TO CHEYENNE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 BYPASS	0.05	0.04	0.03	0.03	0.03	0.08	0.29	0.36	0.21	0.07	0.03	0.02	1.24
SOUTH CROW CREEK DIRECT DIVERSION													
5 INFLOW (GAGE 6-7550)	0.04	0.04	0.03	0.03	0.03	0.07	0.26	0.32	0.18	0.06	0.02	0.02	1.09
6 DIVERSION TO CHEYENNE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7 BYPASS	0.04	0.04	0.03	0.03	0.03	0.07	0.26	0.32	0.18	0.06	0.02	0.02	1.09
NORTH CROW RESERVOIR													
8 INFLOW (EST)	0.06	0.05	0.04	0.03	0.04	0.09	0.35	0.43	0.25	0.08	0.03	0.03	1.47
9 RELEASE TO CHEYENNE	0.17	0.16	0.15	0.15	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.91
10 EVAPORATION	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.04	0.02	0.20
11 SPILL	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.15	0.09	0.04	0.01	0.01	0.33
12 EOM STORAGE	1.27	1.15	1.03	0.91	0.80	0.74	1.05	1.31	1.44	1.44	1.43	1.42	.
CRYSTAL RESERVOIR													
13 INFLOW FROM GRANITE	0.55	0.59	0.59	0.50	0.54	0.49	0.92	1.18	1.08	1.12	1.11	1.11	9.80
14 S.F. MIDDLE CROW INFLOW (EST)	0.03	0.02	0.02	0.02	0.02	0.04	0.15	0.19	0.11	0.04	0.01	0.01	0.66
15 IMPORTED WATER INFLOW	0.49	0.48	0.49	0.49	0.44	0.49	0.48	0.49	0.48	0.49	0.49	0.48	5.79
16 RELEASE TO CHEYENNE	1.07	1.08	1.09	0.99	1.00	1.00	1.44	1.04	1.04	1.62	1.62	1.62	14.59
17 DEFICIT TO CHEYENNE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18 EVAPORATION	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.05	0.05	0.03	0.27
19 SPILL	0.00	0.00	0.01	0.01	0.00	0.02	0.07	0.68	0.55	0.03	0.00	0.00	1.37
20 EOM STORAGE	3.07	3.06	3.06	3.04	3.03	3.03	3.06	3.18	3.23	3.18	3.14	3.09	.
GRANITE SPRINGS RESERVOIR													
21 MIDDLE CROW INFLOW (GAGE 6-7545)	0.08	0.08	0.06	0.04	0.05	0.10	0.65	1.14	0.66	0.21	0.07	0.05	3.18
22 IMPORTED WATER INFLOW	0.60	0.58	0.60	0.60	0.54	0.60	0.58	0.60	0.58	0.60	0.60	0.58	7.02
23 RELEASE TO CRYSTAL	0.55	0.58	0.58	0.49	0.54	0.47	0.81	0.36	0.45	1.09	1.11	1.11	8.14
24 EVAPORATION	0.02	0.01	0.01	0.02	0.01	0.01	0.03	0.04	0.05	0.08	0.07	0.04	0.40
25 SPILL	0.00	0.01	0.01	0.01	0.00	0.03	0.12	0.82	0.63	0.03	0.00	0.00	1.66
26 EOM STORAGE	3.64	3.70	3.75	3.88	3.91	4.10	4.37	4.89	4.99	4.60	4.08	3.55	.
CITY OF CHEYENNE WATER SOURCES SUMMARY													
27 BRUSH CREEK DIRECT DIVERSION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28 SOUTH CROW CREEK DIRECT DIVERSION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29 CRYSTAL RESERVOIR RELEASE	1.07	1.08	1.09	0.99	1.00	1.00	1.44	1.04	1.04	1.62	1.62	1.62	14.59
30 NORTH CROW RESERVOIR RELEASE	0.17	0.16	0.15	0.15	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.91
31 GROUNDWATER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40	0.40	0.40	0.40	2.00
32 TOTAL SUPPLY	1.24	1.24	1.24	1.14	1.14	1.14	1.44	1.44	1.44	2.02	2.02	2.02	17.50

EXISTING SYSTEM MODEL WITH STAGE II IMPORTED WATER - CRYSTAL STORAGE = 1950 AF (15' BELOW SPWY RESTRICTION)
 EXISTING PIPELINE ONLY @ 17.7 CFS
 BOTH BRUSH CREEK AND SOUTH CROW DIVERSIONS UNAVAILABLE
 CHEYENNE DEMAND = 17,500 ACRE-FT/YEAR
 GROUNDWATER USE = 2,000 ACRE-FT/YEAR

CHEYENNE WATER PROJECT - CROW CREEK WATER SUPPLY AND DISTRIBUTION SYSTEM
 CRYSTAL RESERVOIR SIZING AND HYDROLOGIC INVESTIGATION

SUMMARY- 37 YEARS OF OPERATION	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	YEAR
CITY OF CHEYENNE WATER DEMANDS													
1 ESTIMATED DEMAND	1.24	1.24	1.24	1.14	1.14	1.14	1.44	1.44	1.44	2.02	2.02	2.02	17.50
BRUSH CREEK DIRECT DIVERSION													
2 INFLOW (EST)	0.05	0.04	0.03	0.03	0.03	0.08	0.29	0.36	0.21	0.07	0.03	0.02	1.24
3 DIVERSION TO CHEYENNE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 BYPASS	0.05	0.04	0.03	0.03	0.03	0.08	0.29	0.36	0.21	0.07	0.03	0.02	1.24
SOUTH CROW CREEK DIRECT DIVERSION													
5 INFLOW (GAGE 6-7550)	0.04	0.04	0.03	0.03	0.03	0.07	0.26	0.32	0.18	0.06	0.02	0.02	1.09
6 DIVERSION TO CHEYENNE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7 BYPASS	0.04	0.04	0.03	0.03	0.03	0.07	0.26	0.32	0.18	0.06	0.02	0.02	1.09
NORTH CROW RESERVOIR													
8 INFLOW (EST)	0.06	0.05	0.04	0.03	0.04	0.09	0.35	0.43	0.25	0.08	0.03	0.03	1.47
9 RELEASE TO CHEYENNE	0.17	0.16	0.15	0.15	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.91
10 EVAPORATION	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.04	0.02	0.20
11 SPILL	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.15	0.09	0.04	0.01	0.01	0.33
12 FLOW STORAGE	1.27	1.15	1.03	0.91	0.80	0.74	1.05	1.31	1.44	1.44	1.43	1.42	.
CRYSTAL RESERVOIR													
13 INFLOW FROM GRANITE	0.55	0.59	0.59	0.50	0.54	0.49	0.92	1.18	1.08	1.12	1.11	1.11	9.80
14 S.F. MIDDLE CROW INFLOW (EST)	0.03	0.02	0.02	0.02	0.02	0.04	0.15	0.19	0.11	0.04	0.01	0.01	0.66
15 IMPORTED WATER INFLOW	0.49	0.48	0.49	0.49	0.44	0.49	0.48	0.49	0.48	0.49	0.49	0.48	5.79
16 RELEASE TO CHEYENNE	1.07	1.08	1.09	0.99	1.00	1.00	1.44	1.04	1.04	1.62	1.62	1.62	14.59
17 DEFICIT TO CHEYENNE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18 EVAPORATION	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.03	0.02	0.19
19 SPILL	0.00	0.00	0.01	0.01	0.00	0.02	0.08	0.74	0.57	0.03	0.00	0.00	1.47
20 FLOW STORAGE	1.72	1.72	1.71	1.71	1.70	1.70	1.72	1.79	1.83	1.80	1.77	1.73	.
GRANITE SPRINGS RESERVOIR													
21 MIDDLE CROW INFLOW (GAGE 6-7545)	0.08	0.08	0.06	0.04	0.05	0.10	0.65	1.14	0.66	0.21	0.07	0.05	3.18
22 IMPORTED WATER INFLOW	0.60	0.58	0.60	0.50	0.54	0.60	0.58	0.60	0.58	0.60	0.60	0.58	7.02
23 RELEASE TO CRYSTAL	0.55	0.58	0.58	0.49	0.54	0.47	0.81	0.36	0.45	1.09	1.11	1.11	8.14
24 EVAPORATION	0.02	0.01	0.01	0.02	0.01	0.01	0.03	0.04	0.05	0.08	0.07	0.04	0.40
25 SPILL	0.00	0.01	0.01	0.01	0.00	0.03	0.12	0.82	0.63	0.03	0.00	0.00	1.66
26 FLOW STORAGE	3.64	3.70	3.75	3.88	3.91	4.10	4.37	4.89	4.99	4.60	4.08	3.55	.
CITY OF CHEYENNE WATER SOURCES SUMMARY													
27 BRUSH CREEK DIRECT DIVERSION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28 SOUTH CROW CREEK DIRECT DIVERSION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29 CRYSTAL RESERVOIR RELEASE	1.07	1.08	1.09	0.99	1.00	1.00	1.44	1.04	1.04	1.62	1.62	1.62	14.59
30 NORTH CROW RESERVOIR RELEASE	0.17	0.16	0.15	0.15	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.91
31 GROUNDWATER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40	0.40	0.40	0.40	2.00
32 TOTAL SUPPLY	1.24	1.24	1.24	1.14	1.14	1.14	1.44	1.44	1.44	2.72	2.02	2.02	17.50

EXISTING SYSTEM MODEL WITH STAGE II IMPORTED WATER - CRYSTAL STORAGE = 3410 AF

EXISTING PIPELINE ONLY @ 17.7 CFS

NORTH BRUSH CREEK AND SOUTH CROW DIVERSIONS UNAVAILABLE

CHEYENNE DEMAND = 18,000 ACRE-FEET/YEAR

GROUNDWATER USE = 2,000 ACRE-FEET/YEAR

CHEYENNE WATER PROJECT - CROW CREEK WATER SUPPLY AND DISTRIBUTION SYSTEM
CRYSTAL RESERVOIR SIZING AND HYDROLOGIC INVESTIGATION

SUMMARY- 37 YEARS OF OPERATION OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP YEAR

CITY OF CHEYENNE WATER DEMANDS

1 ESTIMATED DEMAND 1.28 1.28 1.28 1.17 1.17 1.17 1.48 1.48 1.48 2.07 2.07 2.07 18.00

BRUSH CREEK DIRECT DIVERSION

2 INFLOW (EST) 0.05 0.04 0.03 0.03 0.03 0.08 0.29 0.36 0.21 0.07 0.03 0.02 1.24
3 DIVERSION TO CHEYENNE 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
4 BYPASS 0.05 0.04 0.03 0.03 0.03 0.08 0.29 0.36 0.21 0.07 0.03 0.02 1.24

SOUTH CROW CREEK DIRECT DIVERSION

5 INFLOW (GAGE 6-7550) 0.04 0.04 0.03 0.03 0.03 0.07 0.26 0.32 0.18 0.06 0.02 0.02 1.09
6 DIVERSION TO CHEYENNE 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
7 BYPASS 0.04 0.04 0.03 0.03 0.03 0.07 0.26 0.32 0.18 0.06 0.02 0.02 1.09

NORTH CROW RESERVOIR

8 INFLOW (EST) 0.06 0.05 0.04 0.03 0.04 0.09 0.35 0.43 0.25 0.08 0.03 0.03 1.47
9 RELEASE TO CHEYENNE 0.17 0.16 0.15 0.15 0.14 0.14 0.00 0.00 0.00 0.00 0.00 0.00 0.91
10 EVAPORATION 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.02 0.02 0.04 0.04 0.02 0.20
11 SPILL 0.01 0.00 0.00 0.00 0.00 0.00 0.03 0.15 0.09 0.04 0.01 0.01 0.33
12 FLOW STORAGE 1.27 1.15 1.03 0.91 0.80 0.74 1.05 1.31 1.44 1.44 1.43 1.42 .

CRYSTAL RESERVOIR

13 INFLOW FROM BRUSH CREEK 0.59 0.61 0.61 0.52 0.57 0.52 0.90 1.02 1.01 1.17 1.15 1.15 9.82
14 S.F. MIDDLE CROW FLOW (EST) 0.03 0.02 0.02 0.02 0.02 0.04 0.15 0.19 0.11 0.04 0.01 0.01 0.66
15 IMPORTED WATER INFLOW 0.49 0.48 0.49 0.49 0.44 0.49 0.48 0.49 0.48 0.49 0.49 0.48 5.79
16 RELEASE TO CHEYENNE 1.11 1.11 1.12 1.02 1.03 1.03 1.48 1.08 1.08 1.67 1.67 1.66 15.06
17 DEFICIT TO CHEYENNE 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.02 0.03
18 EVAPORATION 0.02 0.01 0.01 0.01 0.01 0.01 0.02 0.02 0.03 0.05 0.05 0.03 0.26
19 SPILL 0.00 0.00 0.00 0.00 0.00 0.01 0.03 0.44 0.43 0.02 0.00 0.00 0.95
20 FLOW STORAGE 2.90 2.88 2.88 2.87 2.85 2.85 3.00 3.00 3.07 3.02 2.96 2.91 .

GRANITE SPRINGS RESERVOIR

21 MIDDLE CROW INFLOW (GAGE 6-7545) 0.08 0.08 0.06 0.04 0.05 0.10 0.65 1.14 0.66 0.21 0.07 0.05 3.18
22 IMPORTED WATER INFLOW 0.60 0.58 0.60 0.60 0.54 0.60 0.58 0.60 0.58 0.60 0.60 0.58 7.02
23 RELEASE TO CRYSTAL 0.59 0.61 0.61 0.52 0.57 0.50 0.85 0.40 0.49 1.15 1.15 1.15 8.58
24 EVAPORATION 0.02 0.01 0.01 0.01 0.01 0.01 0.03 0.03 0.05 0.07 0.07 0.04 0.37
25 SPILL 0.00 0.00 0.01 0.01 0.00 0.02 0.05 0.62 0.52 0.03 0.00 0.00 1.25
26 FLOW STORAGE 3.30 3.33 3.36 3.46 3.46 3.63 3.93 4.62 4.79 4.35 3.79 3.23 .

CITY OF CHEYENNE WATER SOURCES SUMMARY

27 BRUSH CREEK DIRECT DIVERSION 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
28 SOUTH CROW CREEK DIRECT DIVERSION 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
29 CRYSTAL RESERVOIR RELEASE 1.11 1.11 1.17 1.02 1.03 1.03 1.48 1.08 1.08 1.67 1.67 1.66 15.06
30 NORTH CROW RESERVOIR RELEASE 0.17 0.16 0.15 0.15 0.14 0.14 0.00 0.00 0.00 0.00 0.00 0.00 0.91
31 GROUNDWATER 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.40 0.40 0.40 0.40 0.40 2.00
32 TOTAL SUPPLY 1.28 1.28 1.27 1.17 1.17 1.17 1.48 1.48 1.48 2.07 2.07 2.06 17.97

EXISTING SYSTEM MODEL WITH STAGE 11 IMPORTED WATER - CRYSTAL STORAGE = 1950 AF (15' BELOW SPWY RESTRICTION)
 EXISTING PIPELINE ONLY @ 17.7 CFS
 BOTH BRUSH CREEK AND SOUTH CROW DIVERSIONS UNAVAILABLE
 CHEYENNE DEMAND = 14,000 ACRE-Feet/YEAR
 GROUNDWATER USE = 2,000 ACRE-Feet/YEAR

CHEYENNE WATER PROJECT - CROW CREEK WATER SUPPLY AND DISTRIBUTION SYSTEM
 CRYSTAL RESERVOIR SIZING AND HYDROLOGIC INVESTIGATION

SUMMARY- 37 YEARS OF OPERATION	DEC	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	YEAR
CITY OF CHEYENNE WATER DEMANDS													
1 ESTIMATED DEMAND	1.28	1.28	1.28	1.17	1.17	1.17	1.48	1.48	1.48	2.07	2.07	2.07	18.00
BRUSH CREEK DIRECT DIVERSION													
2 INFLOW (EST)	0.05	0.04	0.03	0.03	0.03	0.08	0.29	0.36	0.21	0.07	0.03	0.02	1.24
3 DIVERSION TO CHEYENNE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 BYPASS	0.05	0.04	0.03	0.03	0.03	0.08	0.29	0.36	0.21	0.07	0.03	0.02	1.24
SOUTH CROW CREEK DIRECT DIVERSION													
5 INFLOW (GAGE 6-7550)	0.04	0.04	0.03	0.03	0.03	0.07	0.26	0.32	0.18	0.06	0.02	0.02	1.09
6 DIVERSION TO CHEYENNE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7 BYPASS	0.04	0.04	0.03	0.03	0.03	0.07	0.26	0.32	0.18	0.06	0.02	0.02	1.09
NORTH CROW RESERVOIR													
8 INFLOW (EST)	0.06	0.05	0.04	0.03	0.04	0.09	0.35	0.43	0.25	0.08	0.03	0.03	1.47
9 RELEASE TO CHEYENNE	0.17	0.16	0.15	0.15	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.91
10 EVAPORATION	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.04	0.02	0.20
11 SPILL	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.15	0.09	0.04	0.01	0.01	0.33
12 FOW STORAGE	1.27	1.15	1.03	0.91	0.80	0.74	1.05	1.31	1.44	1.44	1.43	1.42	.
CRYSTAL RESERVOIR													
13 INFLOW FROM GRANITE	0.59	0.61	0.61	0.52	0.57	0.52	0.90	1.02	1.01	1.17	1.15	1.15	9.82
14 S.F. MIDDLE CROW INFLOW (EST)	0.03	0.02	0.02	0.02	0.02	0.04	0.15	0.19	0.11	0.04	0.01	0.01	0.66
15 IMPORTED WATER INFLOW	0.49	0.48	0.49	0.49	0.44	0.49	0.48	0.49	0.48	0.49	0.49	0.48	5.79
16 RELEASE TO CHEYENNE	1.11	1.11	1.12	1.02	1.03	1.03	1.48	1.08	1.08	1.67	1.66	1.66	15.03
17 DEFICIT TO CHEYENNE	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06
18 EVAPORATION	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.02	0.18
19 SPILL	0.00	0.00	0.00	0.01	0.00	0.01	0.04	0.52	0.45	0.02	0.00	0.00	1.06
20 FOW STORAGE	1.64	1.63	1.63	1.62	1.62	1.61	1.61	1.70	1.75	1.71	1.68	1.64	.
GRANITE SPRINGS RESERVOIR													
21 MIDDLE CROW INFLOW (GAGE 6-7545)	0.08	0.08	0.06	0.04	0.05	0.10	0.65	1.14	0.66	0.21	0.07	0.05	3.18
22 IMPORTED WATER INFLOW	0.60	0.58	0.60	0.60	0.54	0.60	0.58	0.60	0.58	0.60	0.60	0.58	7.02
23 RELEASE TO CRYSTAL	0.59	0.61	0.61	0.52	0.57	0.50	0.85	0.40	0.49	1.15	1.15	1.15	8.58
24 EVAPORATION	0.02	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.05	0.07	0.07	0.04	0.37
25 SPILL	0.00	0.00	0.01	0.01	0.00	0.02	0.05	0.62	0.52	0.03	0.00	0.00	1.25
26 FOW STORAGE	3.30	3.33	3.36	3.46	3.46	3.63	3.93	4.62	4.79	4.35	3.79	3.23	.
CITY OF CHEYENNE WATER SOURCES SUMMARY													
27 BRUSH CREEK DIRECT DIVERSION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28 SOUTH CROW CREEK DIRECT DIVERSION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29 CRYSTAL RESERVOIR RELEASE	1.11	1.11	1.12	1.02	1.03	1.03	1.48	1.08	1.08	1.67	1.66	1.66	15.03
30 NORTH CROW RESERVOIR RELEASE	0.17	0.16	0.15	0.15	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.91
31 GROUNDWATER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40	0.40	0.40	0.40	2.00
32 TOTAL SUPPLY	1.28	1.27	1.27	1.17	1.16	1.17	1.48	1.48	1.48	2.07	2.06	2.06	17.94

CHEYENNE WATER PROJECT
CROW CREEK WATER SUPPLY AND DISTRIBUTION SYSTEM

CITY OF CHEYENNE WATER DEMANDS

R(1) Estimated Demand. The Cheyenne demand was distributed on a uniform quarterly basis. The uniform quarterly demands, expressed as percentages, are as follows (Noe, 1980):

<u>Period</u>	<u>Percent of Annual Demand</u>
October-December	21.29
January-March	19.53
April-June	24.61
July-September	34.57

BRUSH CREEK DIRECT DIVERSION

R(2) Inflow (Est.). Cheyenne operates a direct diversion on Brush Creek. The flow of Brush Creek above the diversion structure is estimated since a stream gage at this site is not available. The runoff at Brush Creek is assumed to be proportional, based upon drainage area, to the runoff at the South Crow Creek gage (6-7550). The area above the South Crow gage is 8,848 acres and above the Brush Creek diversion the area is 10,095 acres.

$$R(2) = 10,095/8,848 * R(5)$$

R(3) Diversion to Cheyenne. The estimated diversion capacity of the Brush Creek structure is 3.5 cfs. However, due to turbidity problems, Cheyenne has temporarily abandoned this facility. Each version of this program indicates with a notation at the top left corner of the printout whether this source was utilized.

The amount of diversion is equal to the diversion capacity, 3.5 cfs, or the inflow, R(2), whichever is less.

R(4) Bypass. All water not diverted must be bypassed, since storage is negligible at the Brush Creek diversion.

$$R(4) = R(2) - R(3)$$

SOUTH CROW CREEK DIVERSION

R(5) Inflow (Gage 6-7550). Cheyenne also operates a direct diversion on South Crow Creek. The USGS operated a stream gage above the diversion. Stream flow records are available for the period 1933-1969.

R(6) Diversion to Cheyenne. Like the Brush Creek diversion, the South Crow water is highly turbid, and the City has temporarily abandoned the use of this source of supply. The use, or nonuse, of this facility

for the version of interest is noted at the top left of the printout. When the structure is in use, a diversion capacity of 5 cfs is used. The amount of water diverted into the city system is equal to the inflow, R(5), or 5 cfs, whichever is less.

R(7) Bypass. All water not diverted is assumed to be bypassed.

$$R(7) = R(5) - R(6)$$

NORTH CROW RESERVOIR (Storage Capacity = 1,865 AF)

R(8) Inflow (Est.). The inflow to North Crow Reservoir is assumed to be proportional, with respect to area, to the streamflow of South Crow Creek (gage 6-7550). The drainage area above North Crow Reservoir is 11,947 acres.

$$R(8) = 11,947/8,848 * R(5)$$

R(9) Release to Cheyenne. Due to turbidity problems, the City utilizes North Crow Reservoir water during the late summer through early spring. It was assumed that North Crow water would be available from October through March. Also, it was desired to draw the reservoir down sufficiently to receive spring runoff. It was assumed that a drawdown of 1,000 AF during October through March would accomplish this at a uniform rate of 170 AF/month.

During October-March:

$$R(9) = .17 \text{ KAF (if adequate storage is available to meet total demand)}$$

$$R(9) = \text{PEOMNCR} + R(8) - 0.1 \text{ (if storage is inadequate to meet total demand)}$$

where: PEOMNCR = previous end-of-month storage in North Crow Reservoir in KAF

0.1 = dead storage in KAF

During April-September:

$$R(9) = 0$$

R(10) Evaporation. The reservoir evaporation is based upon the month's average reservoir surface area. The following evaporation rates were then multiplied by the average surface area to determine evaporation loss:

<u>Month</u>	<u>Evaporation Rate (AF/Acre)</u>
October	0.161
November	0.085
December	0.095
January	0.105
February	0.082
March	0.097
April	0.190
May	0.212
June	0.279
July	0.442
August	0.428
<u>September</u>	<u>0.267</u>
Total	2.443

R(11)Spill. Inflow in excess of demands and the reservoir's ability to store more water are passed through the reservoir's spillway.

$$R(11) = PEOMNCR + R(8) - R(9) - R(10) - 1.865$$

where: 1.865 = maximum reservoir capacity in KAF

R(12)EOM Storage. The end-of-month (EOM) storage is computed using the following formula:

$$R(12) = PEOMNCR + R(8) - R(9) - R(10) - R(11)$$

CRYSTAL RESERVOIR (Storage capacity varies with study)

R(13)Inflow from Granite. Water is released from Granite Reservoir, if available, to equal the amount of water released from Crystal not replaced by imported water or South Fork Middle Crow inflow.

$$R(13) = R(23) + R(25)$$

R(14)S. F. Middle Crow Inflow (Est.). The South Fork of Middle Crow flows into the Middle Crow between Granite and Crystal. Since gaging records are not available, an estimate was made of the streamflows of the South Fork Middle Crow. The estimate assumes the flows of the South Fork Middle Crow are proportional, with respect to area, to the flows of South Crow Creek. The total drainage area of the South Fork Middle Crow is 5,343 acres.

$$R(14) = 5,343/8,848 * R(5)$$

R(15)Imported Water Inflow. The U. S. Forest Service, as a mitigation measure for the Stage II project, could require that Cheyenne provide 8 cfs flow in the South Fork Middle Crow. Therefore, it is assumed that 8 cfs will be inflow to Crystal Reservoir from South Fork Middle Crow Creek.

$$R(15) = 8 * 1.983 * 0.001 * \text{NUNDAY}$$

where: 1.983 and 0.001 = conversion factors to convert
from cfs to KAF
NUNDAY = number of days in month

R(16) Release to Cheyenne. Cheyenne demands that are not met by diversions from Brush Creek or South Crow, releases from North Crow Reservoir, or groundwater pumping are met from Crystal Reservoir.

$$R(16) = R(1) - R(3) - R(6) - R(9) - \text{GPUMP},$$

or

$$R(16) = 0; \text{ whichever is greater}$$

where: GPUMP = groundwater supply; 0 during October-April,
.4 KAF during May-September

R(17) Deficit to Cheyenne. When all sources of supply, as fixed in the operation study, are inadequate to meet Cheyenne demand, deficits will occur. In the past these deficits have been made up through groundwater withdrawals.

$$R(17) = R(1) - R(3) - R(6) - R(9) - R(16) - \text{GPUMP}$$

R(18) Evaporation. The evaporation loss from Crystal Reservoir is based on the average surface area for that month. The average surface area was multiplied by the evaporation rates shown in the row explanation for R(10).

R(19) Spill. Inflow in excess of reservoir demands and its ability to store more water is passed through the spillway.

$$R(19) = \text{PEOMCR} + R(13) + R(14) + R(15) - R(16) - \text{MAXCRCAP}$$

where: PEOMCR = previous end-of-month storage in
Crystal Reservoir in KAF
MAXCRCAP = maximum Crystal Reservoir capacity
(see notation in upper left corner
of printout to see MAXCRCAP in effect)

R(20) EOM Storage. The end-of-month storage is computed by:

$$R(20) = \text{PEOMCR} + R(13) + R(14) + R(15) - R(16) - R(18) - R(19)$$

GRANITE SPRINGS RESERVOIR (Storage capacity = 5,321 AF)

R(21) Middle Crow Inflow (Gage 6-7545). The historic inflow to Granite Springs Reservoir has been recorded. The historic records were adjusted to reduce the inflow by an amount equal to historic Lake Owen imports.

R(22) Imported Water Inflow. The Stage I and II projects will divert an additional supply from Rob Roy and Lake Owen into the Crow Creek drainage.

$$R(22) = \text{Total Import} - R(15)$$

R(23) Release to Crystal. The City has expressed the desire to maintain Crystal Reservoir in a full condition as often as possible. In order to do this, a transfer from Granite equal to the net draft on Crystal Reservoir will be required.

$$R(23) = R(16) - R(14) - R(15), \text{ or } 0; \text{ whichever is greater if Granite storage is adequate; if storage is inadequate:}$$
$$R(23) = \text{PEOMGSR} + R(21) + R(22) - 0.2$$

where: PEOMGSR = previous end-of-month Granite Springs Reservoir storage in KAF
0.2 = Granite Springs Reservoir dead storage in KAF

R(24) Evaporation. The evaporation loss from Granite Springs Reservoir is based upon the average surface area for that month. The average surface area is multiplied by the evaporation rates shown in the row explanation for R(10).

R(25) Spill. Inflow in excess of reservoir demands and its ability to store more water is passed through the spillway.

$$R(25) = \text{PEOMGSR} + R(21) + R(22) - R(23) - 5.321$$

where: 5.321 = Granite Springs Reservoir maximum capacity in KAF

R(26) EOM Storage. The end-of-month storage is computed by:

$$R(26) = \text{PEOMGSR} + R(21) + R(22) - R(23) - R(24) - R(25)$$

CITY OF CHEYENNE WATER SOURCES SUMMARY

R(27) Brush Creek Direct Diversion.

$$R(27) = R(3)$$

R(28) South Crow Creek Direct Diversion.

$$R(28) = R(6)$$

R(29) Crystal Reservoir Release

$$R(29) = R(16)$$

R(30)North Crow Reservoir Release.

$$R(30) = R(19)$$

R(31)Groundwater.

$$R(31) = 0, \text{ October-April}$$

$$R(31) = 0.4, \text{ May-September}$$

R(32)Total Supply.

$$R(32) = R(27) + R(28) + R(29) + R(30) + R(31)$$