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ST. VRAIN BASIN RECONNAISSANCE STUDY

prepared for

COLORADO WATER RESOURCES

and

POWER DEVELOPMENT AUTHORITY

COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY 1981

R. W. BECK AND ASSOCIATES • DAMES & MOORE

FEBRUARY 1986

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February 25, 1986

Mr. Uli Kappus, Executive Director
Colorado Water Resources & Power
Development Authority
Logan Tower Bldg., Suite 620
Denver, CO 80203

Dear Uli:

Subject: Final Report
St. Vrain Basin Reconnaissance Study

Transmitted herewith is the final report of the St. Vrain Basin Reconnaissance Study.

The report is the culmination of an extensive study process which we hope has paved the way for future study and development toward meeting the water-related needs of residents within the St. Vrain Basin.

Very truly yours,

BECK/D&M

James E. Alverson
Study Manager

JEA/rhm
Enclosure

EXECUTIVE SUMMARY

A. Introduction

The St. Vrain Basin Reconnaissance Study was authorized by the Colorado Water Resources & Power Development Authority (CWRPDA) in February 1983. This Study is the first comprehensive basin-wide study undertaken since the State Legislature created the CWRPDA in 1981. The initial objectives of the Study were: (1) to identify the needs of the St. Vrain Basin for future water resources development, and (2) to identify and evaluate, at a reconnaissance level of detail, the means available to meet those needs through the development of new water supplies and through the improved regulation and distribution of already developed waters, including imported waters.

The Study Area, which includes about 480 square miles, was established as the St. Vrain Basin exclusive of the Boulder Creek Watershed area and with minor adjustments reflecting present water service areas. It is located in the Front Range region of Colorado, approximately 30 to 50 miles north and northwest of Denver in Boulder, Weld and Larimer counties. The 1980 population of the Study Area, which includes the cities of Longmont and Lyons, is estimated to be 63,000. Under a medium-growth scenario, population is projected to increase nearly three-fold to 172,000 by year 2020. The principal cities are Longmont and Lyons. Adjacent areas lying to the north and south of the St. Vrain Basin, together with the Study Area, were designated as a Siting Area, in which potential water development projects to serve the Study Area could be sited. The Siting Area includes the Little Thompson River Basin and Carter Lake to the north, and the Boulder Creek Basin to the south. Water needs outside of the Study Area were not to be considered.

Step 1 of the Study, completed in August 1984, resulted in identification of water-related needs and physical, social, and economic characteristics of the Basin. Revised objectives for Step 2, begun in October 1984, were adopted, which are "To formulate and evaluate alternative water management plans which meet present and future demands for agricultural, municipal, and industrial water supplies in the St. Vrain Basin with consideration for other uses of the Basin's water and associated land resources." Non-structural measures were to be considered equally with structural measures, with considerable emphasis given to evaluation of potential social and environmental effects of alternative plans. The third and final step of the Study as originally planned, Reconnaissance-Level Evaluation of Candidate Alternatives, was deleted when the Step 2 scope was redefined and expanded.

A Management Committee, consisting of representatives of the Northern Colorado Water Conservancy District, the Colorado Water Conservation Board, and the CWRPDA, guided the Study. The Study was performed by an association of R. W. Beck and Associates and Dames & Moore, assisted by Leonard Rice Consulting Water Engineers, and W. B. Lord and Associates.

B. Public Information and Involvement Program

A comprehensive Public Information and Involvement Program (Program) was conducted as an integral part of the Study. The purposes of the Program were twofold: (1) to inform the public as to the objectives and progress of the Study, and (2) to provide opportunities for public input to the Management Committee and Study Team during the entire Study process. A Study Advisory Committee, comprised of 16 persons representing local and regional interests in the Study Area was formed to provide advice to the Management Committee and to serve as a liaison between the general public and the Management Committee.

The Study Advisors met eight times with the Management Committee and Study Team in formal sessions through December 1985, all of which were open to the general public and news media. The Advisors also participated in a public values assessment which was used to identify needs and values of the various interest groups in the Basin. The Advisors provided comments on draft task memoranda, Study reports, and preliminary alternative plans for water resource development.

C. Study Process

In general, the Study process included investigations, synthesis of alternative plans, and evaluations performed by the Study Team, with continual interaction, comment, and review by the Management Committee and by the Study Advisors. This process, although requiring a longer time span to complete the Study as compared to use of a more traditional approach, is more likely to engender a broad base of support for the Study findings and recommendations. The various community interests are carried forward with each element of the Study so that the end product does not contain unanticipated or unacceptable results from the perspective of the local water resources community.

Step 1 of the Study identified potential water management purposes including municipal, industrial, and agricultural water supply, enhancement of fish and wildlife, improvement or protection of water quality, water-based recreation (reservoir and stream corridor), flood damage reduction, and hydroelectric power generation. Major parts of the Step 1 effort included preparation of an inventory of Basin water resources, irrigated land acreage, population and other characteristics of the Basin. Future demands or water requirements (in the case of irrigated agriculture) were compiled for current conditions and forecast up to year 2020. A projection of electric power demand to year 2020 was also made, but this projection was based on an area to which such power might be marketed, rather than on needs of the St. Vrain Basin.

Provision of water supplies for present and future needs of the three sectors mentioned above was identified in Step 2 as the primary water management purpose to be served by the plans to be formulated. The other potential water management purposes were addressed to the extent they could reasonably be considered as ancillary features of plans formulated primarily for water supply purposes.

In Step 2, preliminary alternative water resource management plans were formulated by combining selected non-structural and structural elements to meet various target levels of water supply development. Some 98 structural elements and 26 non-structural elements were identified and evaluated on a preliminary basis. By combining various elements, ten preliminary alternative plans were formulated, of which six were subsequently evaluated. A computerized River Basin Simulation Model was used as a tool in analyzing the anticipated performance of the formulated plans.

D. Findings and Conclusions

1. Water Supply and Demand

Native surface water resources in the Study Area average about 118,000 ac-ft/yr as represented by the combined runoff of St. Vrain and Left Hand creeks where they enter the plains from the foothills zone. Imported water via the Colorado-Big Thompson Project has averaged about 31,000 ac-ft/yr since the latter 1950's. Ground water usage and potential are limited, and the present use of this resource is estimated to be about 9,000 ac-ft/yr.

For the municipal and industrial (M&I) sector, population and industrial growth are expected to result in increased water demand in the Study Area from about 18,000 ac-ft/yr presently to about 44,000 ac-ft/yr in 2020 under a medium population growth scenario for drought year conditions. The present firm annual water supply in the M&I sector is estimated to be about 18,000 ac-ft. If no further supplies are developed and demand-reduction measures are not implemented, the deficiency in year 2020 would be about 26,000 ac-ft/yr of firm supply. Longmont's entitlement to 8,000 ac-ft of Windy Gap Project supply could be utilized to partially satisfy this deficit.

If this entitlement to Windy Gap Project supply is utilized within the Basin, not considering the potential for reuse, it is estimated that an adequate drought-year supply will be available for M&I purposes until some point in the decade of year 2000 to 2010, assuming suitable cooperative arrangements are consummated to ensure distribution of supplies to all users. However, in the absence of further water resource development beyond utilization of the Windy Gap supply and conversion of agricultural water rights on urbanized lands to M&I use, drought-year supply capacity for M&I purposes would be inadequate by about 18,000 ac-ft/yr in 2020 for a medium population growth scenario. The Study placed considerable emphasis on identifying and evaluating measures to reduce municipal water demand, both in average hydrologic years and in drought conditions. The Study adopted a criterion of providing capacity for M&I water supply in combination with demand reduction sufficient to meet conditions anticipated during a 1 in 30-year drought. Plans developed by the Study identify and evaluate alternative means for meeting the projected M&I supply deficiency.

In the agricultural sector, based on estimated full irrigation water requirements, a deficiency in available supply presently exists in the range of about 70,000 to 140,000 ac-ft/yr, depending on hydrologic conditions, crop pattern, and growing season weather. Because of conversion of agricultural land to urban-type uses, this deficiency in agricultural water supply is forecast to decline to about 78,000 ac-ft in the year 2020 under a planned target of providing 85% of the calculated Blaney-Criddle requirement during a one in 10-year drought condition. This forecast assumes no further development of the Basin's water resources for agriculture, but with improved overall irrigation efficiency from the presently estimated 45% to 50%. Agricultural water requirements as presented herein are not to be construed as an economic demand for water, since the cost of providing new supplies to meet present and projected deficits appears to be greatly in excess of the economic return of such water in crop production. Instead, water requirements were calculated based on the empirical Blaney-Criddle approach to meeting the physiological water requirements of crops to provide full crop yields or slightly reduced yields during droughts.

2. <u>Potential Additional Water Resources Development</u>

The Study finds that about 13,000 ac-ft/yr of additional native St. Vrain Creek water can be developed under a junior water right as firm supply for M&I purposes. The storage capacity required to develop this supply under the M&I drought criterion adopted for this Study would be about 80,000 ac-ft. Estimated costs of constructing a reservoir of this capacity would be relatively high for any sites within the Study Area. Consequently, it is concluded that this water supply would be too costly for irrigated agriculture in the absence of significant subsidies.

The potential for development of large water supplies from ground water is considered negligible, due to prevailing geologic conditions in the Basin and the tributary nature of shallow alluvial aquifers.

3. <u>Hydroelectric Potential</u>

The potential for developing a significant amount of conventional hydroelectric power to produce revenues that would appreciably offset the cost of a water resources project does not exist due to limited streamflows. However, the potential may exist for a moderate sized pumped-storage peaking power development to be economically competitive with alternatives, but the Study did not thoroughly evaluate this potential. Further study would be necessary to identify and compare a potential project in the St. Vrain Basin with other potential pumped-storage projects in the region where such capacity could be marketed.

4. <u>Non-Structural Water Resource Management Measures</u>

The Study has identified a large array of non-structural measures that have considerable potential to increase efficiency of water use or to reduce the level of demand. Incorporation of selected non-structural measures in the alternative water resources plans is shown to offset a significant portion of forecast water demands. Several of these measures can be implemented at a substantially lower cost per acre-foot of water than the cost of development of new firm yield from either native or imported supplies. Also, institutional arrangements and water rights administration could be modified to improve the economical allocation of water and overall efficiency of use. Several of these potential measures have not been implemented previously elsewhere on a large scale and will require considerable cooperation among the various interests involved in water resources management and use.

5. <u>Issues in Water Resources Management</u>

During the approximately two-year Study process, a number of issues related to management and development of water resources in the St. Vrain Basin were identified and discussed with the Advisors Committee, the Management Committee, and other concerned citizens. Some issues seem to have been resolved by consensus whereas others require additional investigation, study, and dialog among the various interests in the Basin. Issues identified include the following:

a. Although a wide range of views regarding water resources management was expressed, a general consensus appears to have been reached that water availability for municipal, industrial, and agricultural purposes should be the primary consideration in water resources management. Important secondary purposes were mentioned previously.

b. The monetary cost of water resources management and development is a major issue, including the way in which the cost burden will be shared by various water user groups or interests.

c. Agricultural interests generally desire improved regulation of water supplies for crop irrigation. The Study findings indicate, however, that only non-structural measures for improving agricultural water management will be economical to implement. Since subsidies would be required, methods for financing arrangements for structural facilities is a crucial issue in the agricultural sector. Financial arrangements for facilities for M&I water supplies are also an important issue.

d. Social concerns impacted by water resources management are important to a large segment of the community, including the location of major storage reservoirs, availability of recreation, and flood control needs. Major reservoir locations immediately upstream from residential communities are a particularly sensitive social concern.

e. Conversion of a large number of shares of Colorado-Big Thompson Project water from agricultural to municipal and industrial use may be an economic and social issue.

f. Preservation of environmental resources and compliance of water development structural programs with the Boulder County Comprehensive Plan are significant issues.

g. The reuse of reclaimed wastewater for irrigation use and, by exchange, the augmentation of M&I supplies is an important issue.

h. The implementation and use of non-structural measures to reduce demands and improve the efficiency of water use for both the M&I and agricultural sectors will be an issue of increasing significance. This issue includes changes in existing water management institutions or establishment of new institutional structures which could facilitate implementation of various non-structural and structural measures.

6. Water Resource Management Plans

a. Estimated Yield and Costs of New Water Supply

Six water resources management plans were evaluated in the Study for which the estimated firm M&I yield developed by structural measures and new purchases, and estimated cost of water for each plan are tabulated below. Plans 1A and 1B address M&I supply fully and include only non-structural measures for agricultural supply, whereas the other four plans include a structural component for agricultural water management ranging from in-season regulation of existing supplies to development of limited quantities of new supplies, in addition to non-structural measures. Firm yields of the plans as shown in the table do not meet the full forecast deficit of 26,000 ac-ft in year 2020. In each case, the remaining deficit would be offset by demand-reduction measures.

Plan	M&I Firm Yield (ac-ft/yr)	Estimated M&I Water Cost (1985) ($/ac-ft)
1A	22,300	480
1B	17,400	320
2A	22,300	390
3A	22,300	480
3B	22,300	410
3C	24,000	600

Care must be exercised in comparing the above M&I water costs because where a structural agricultural component is included certain costs for joint-use facilities are allocated between agricultural and M&I supply. If the agricultural water supply features were eliminated, Plans 2A, 3A, and 3B would revert essentially to Plan 1A. Plan 3C would become a single purpose M&I water supply reservoir, together with purchase of C-BT Project shares and implementation of non-structural measures. Estimated costs of agricultural yield from structural measures are $360/ac-ft for Plan 3C, $480/ac-ft for Plan 2A, $590/ac-ft for Plan 3A and $700/ac-ft for Plan 3B.

b. Selection of Preferred Plan

The Study has identified and evaluated a number of plan elements which have significant potential to serve the water resources management needs of the Study Area. However, of the six alternative plans evaluated, none appears to be clearly optimal or suitable in total for detailed feasibility studies and eventual implementation, since significant uncertainties remain, particularly in regard to the technical and environmental feasibility of storage sites. Engineering and geotechnical investigations, including drilling, are needed to further evaluate the major dam and reservoir sites to reduce uncertainties, and more thorough analysis is needed of the more promising non-structural measures.

7. The Coffintop, Geer Canyon, and Boulder Creek Projects

The reconnaissance-level work performed in this Study indicates that development of the Coffintop Project would be more costly for municipal for water supply purposes than alternative storage projects, including reservoirs at the Little Thompson, Smithy Mountain, and North Sheep Mountain sites. Major social concerns also exist concerning development of the Coffintop Project. Since feasibility-level work has previously been performed at this site by others, it is concluded that no further study should be made of the Coffintop Project except if further study of projects at the Little Thompson, Smithy Mountain, and North Sheep Mountain sites should all indicate their respective project costs are significantly higher than the estimated costs developed in this Study. The Geer Canyon Project on Left Hand Creek would be costly and only limited potential exists on this stream for development of new water supplies. In addition, a large number of residences are located in close proximity downstream of the dam site which would result in a social concern. The Geer Canyon site was not included in any of the plans formulated by the Study.

Sites on Boulder Creek were reviewed at a reconnaissance level and it is concluded that because of potential costs and the over-appropriated situation of Boulder Creek water rights, that development of a storage project on Boulder Creek to serve the St. Vrain Basin would not be feasible.

E. Recommendations

Because there does not appear to be one clearly superior plan from among the six plans formulated and evaluated in the Study, none of the plans in total are recommended for feasibility studies. More study of certain plan elements is considered necessary prior to compiling a definite recommended plan for which full feasibility studies would then be undertaken. Decisions regarding implementation would be based on results of the feasibility studies.

1. First Priority Investigations and Studies

The recommended first priority investigations and studies are focused on determining a specific recommended plan to meet future demands for M&I firm water supply in the Study Area, and to determine specific measures for increasing irrigation water use efficiency. These investigations and studies are intended to result in a preliminary feasibility evaluation and a specific plan or set of structural and non-structural measures. The following categories of investigations and studies are recommended:

a. Engineering related to development of additional M&I firm yield, including engineering investigations of reservoir sites of Little Thompson No. 2, North Sheep Mountain, Smithy Mountain, and enlargement of Ralph Price Reservoir. The feasibility of developing storage at Dowe Flats and of raising Carter Lake as an alternative terminal storage reservoir for Longmont's Windy Gap Project entitlement would also be studied, as would a number of other related engineering investigations.

b. Engineering and analysis of measures to reduce municipal water demand and to increase irrigation water use efficiency.

c. Environmental and social impact studies related to effects of implementing pertinent water resource management measures.

d. Policy and institutional analyses.

e. Selection of a preferred major storage reservoir, from consideration of environmental, social, economic, financial, institutional, and engineering factors.

2. Preparation of Implementation Program

Following completion of first priority investigations, a program for conducting full feasibility studies should be prepared, which will lead to decisions regarding implementation of a recommended plan for water resources management. This program should include activities such as detailed scheduling for early action items (e.g. permitting and financing), identification of agencies that will be responsible as lead agencies for implementation of specific plan elements and development of a general financing plan to provide funding that will carry program implementation into the feasibility, EIS, and permitting stages. The financing plan would also identify the most likely funding approaches for engineering design and construction of structural features, and implementation of non-structural measures.

3. Needed Future Studies

To develop and implement a truly comprehensive water resources management program a number of additional future studies will be needed. Some of these studies do not have a fixed time-frame but others may be required during the EIS/permitting phase of any major structural element. Future studies may address topics such as a demand study of reservoir-based recreation, the potential (if any) of adverse water quality effects or soil toxicity resulting from use of reclaimed wastewater (secondary effluent) for irrigation, flood damage reduction studies, and evaluation of data on crop consumptive use of water as related to crop production. Information on the last item would help to define more specifically the amount of irrigation water that can be economically applied to crops in the Basin.

ST. VRAIN BASIN RECONNAISSANCE STUDY

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CHAPTER I

INTRODUCTION

A. Background and Objectives

The St. Vrain Basin Study was originally authorized by the Colorado Water Resources & Power Development Authority (CWRPDA) in February 1983. This Study is the first comprehensive Basin-wide study undertaken since the State Legislature created the CWRPDA in 1981.

The initial objectives of the Study as established in February 1983, and included in the Plan of Study of October 1983, were: (1) to identify the needs of the St. Vrain Basin for future water resource development, and (2) to identify and evaluate, at a reconnaissance level of detail, the means available to meet those needs through the development of new water supplies and through the improved regulation and distribution of already developed waters, including imported waters. The Study was initially planned to be carried out in three major steps:

- Step 1 - Identification of needs and characteristics of the St. Vrain Basin
- Step 2 - Formulation of water resource development alternatives
- Step 3 - Reconnaissance-level evaluation of candidate alternatives

The identification and evaluation of means to meet the future water resource needs of the St. Vrain Basin were initially limited to structural alternatives such as new reservoirs and appurtenant facilities, and the rehabilitation, expansion, or change in use of existing reservoirs and appurtenant facilities. Also, St. Vrain Basin water development alternatives were to be limited to consideration of already developed trans-mountain water and development of native flows in the St. Vrain Basin, inclusive of the Boulder Creek Watershed. Hydroelectric potential, both conventional and pumped storage, was to be evaluated as a possible means of generating revenues from the sale of power to aid in financing a potential project. However, partway through Step 1, as a result of public input, it was decided to substantially alter the scope and approach to the Study by including consideration of non-structural measures in meeting water management objectives. Also, the change in scope indicated more emphasis would be placed on evaluation of potential social and environmental effects of alternative measures designed to meet water-related needs.

Step 1 of the Study, completed in August 1984, resulted in the identification of water-related needs to the year 2020 and compilation of characteristics of the Basin related to water resources management. Step 2 of the Study was initiated in October 1984 with complementary objectives to Step 1 and a revised Plan of Study was prepared.

Revised objectives for Step 2 were adopted which are "To formulate and evaluate alternative water management plans which meet present and future demands for agricultural, municipal, and industrial water supplies in the St. Vrain Basin with consideration for other uses of the Basin's water and associated land resources." Step 3 was deleted when Step 2 activities were redefined and expanded.

B. Study Team and Management

A Management Committee, consisting of representatives from the Northern Colorado Water Conservancy District, the Colorado Water Conservation Board, and the CWRPDA, guided the Study. An association of two consulting engineering firms, R. W. Beck and Associates and Dames & Moore, was responsible for performing the Study. An interdisciplinary team of specialists was organized to conduct reconnaissance-level engineering, economic, financial, and environmental studies. The Study Team also participated in the Public Information and Involvement Program. Leonard Rice Consulting Water Engineers, Inc. participated as a member of the Study Team and was responsible for analysis of water rights and hydrology, and W. B. Lord and Associates provided assistance in the areas of municipal water demand and institutional analyses.

C. Public Information and Involvement Program

A Public Information and Involvement Program (Program) was conducted as an integral part of the Study. The purposes of the program were as follows: (1) to inform the public as to the objectives and progress of the Study, and (2) to provide opportunities for public advice to the Management Committee in the decision-making process. The Program included preparation and issuance of newsletters which informed the public of progress and upcoming Study activities. Public meetings were held in the Study Area to provide a public forum for discussion of the Study's components, including issues, evaluation criteria, alternatives, and analyses of formulated water resources management plans.

The Program was modified during the Study to include the following additional activities: (1) a series of interviews with community leaders, and (2) a public values assessment.

A Study Advisory Committee of persons representing local and regional interests in the Study Area was formed to provide advice to the Management Committee on the content and performance of the Study, and also to serve as liaison between the general public and the Management Committee. This Advisory Committee, comprised of 16 individuals from an equal number of organizations, represents a diverse range of economic, social and environmental interests potentially affected by water resource management and development in the St. Vrain Basin. The Advisors (as of the completion of the Study) are listed below with the name of the organization or interest group each represents:

- o Jim Cinea - City of Longmont
- o Jim Clark - Colorado Division of Water Resources
- o Ron Gosnell - Town of Lyons
- o Robert Helmick - Boulder County
- o Conrad Hopp - Boulder County Farm Bureau
- o Gary Mast - Denver Regional Council of Governments
- o Larry Nelson - U.S. Bureau of Reclamation
- o Barbara Poquette - St. Vrain and Left Hand Water Conservancy District
- o Dean Readmond - Dam Concerned Citizens, Lyons
- o Larry Quinn - Colorado Open Space Council
- o Ms. Mike Smith - League of Women Voters
- o Roger Tarum - U.S. Forest Service
- o David Walder - Sierra Club
- o Robert Wheeler - City of Boulder
- o Les Williams - St. Vrain Agricultural Water Users
- o Jack Zumwinkel - Allenspark Water Users

The Advisors met eight times with the Management Committee and Study Team in formal sessions through December 1985, all of which were open to the general public and news media. The Advisors also participated in a public values assessment which was used to identify needs and goals of the various interest groups in the Basin. In addition, they provided comments on draft task memoranda, Study reports, and water resource development alternatives.

A series of interviews was held in February 1984 with selected individuals to obtain opinions on issues, concerns, and needs related to water resource development in the St. Vrain Basin. People interviewed included members of the Advisory Committee, elected officials, agency personnel, and citizens representing special interests in the Study Area. Interviews provided valuable information regarding the focus of the Study, issues of concern to various groups, and potential alternative measures for water resource management and development. This information, together with information previously gained from Advisory and public meetings, was instrumental in focusing the revision of the Plan of Study for Step 2. The following paragraphs are a summary of major issues and comments discussed during the February 1984 interviews.

<u>Needs</u>: Clear definition and documentation of water-related needs in the Basin were emphasized as a major concern. Some of those interviewed cited various perceived needs, ranging from winter water delivery to increased irrigation efficiency. Several people expressed concern that Colorado could lose water rights to other states unless development plans progress quickly.

<u>Alternatives</u>: A concern voiced in several interviews was the apparent exclusion of non-structural alternatives in the Plan of Study. Suggestions for non-structural alternatives to be considered include Basin-wide management planning, innovative conservation programs, and reuse of water and exchange options.

Environmental Concerns: Potential adverse and beneficial effects of water development alternatives were identified as a major issue among area stakeholders (defined as those individuals and organizations having a stake in the outcome of the Study). Specifically, stakeholders were concerned about the potential impact of water development on recreation, water quality, and coldwater fisheries. In addition, other environmental and social issues discussed were related to safety concerns regarding dams and flood hazards in the Basin.

Economic Concerns: A number of economic issues were raised during the interviews. Several people commented that land developers have not had to bear enough of the economic burden of water development in the past. Capital costs and effects on area water rates were common concerns expressed about potential project construction. At the same time, several people remarked that cost should not be a sole determining factor in selection or elimination of otherwise attractive alternative measures or plans.

In summary, the interviews and other elements of the Program were instrumental in changing the direction and emphasis of the Step 2 studies. In response to concerns raised in the interviews regarding the lack of emphasis on non-structural alternatives, the Management Committee directed that Step 2 studies be modified to include greater emphasis on non-structural water resources management measures.

In Step 2, Advisory Committee members completed a formal opinion questionnaire intended to document the relative importance of water related issues such as water availability, flood control, recreation, environmental and social concerns, energy production, and financial considerations. Results of this survey are included as Appendix A to this report. They indicate that the Committee favored reservoir alternatives located in the foothills or on the plains rather than those located in high mountain areas. The consensus was that a well-managed water resources management program is definitely needed to conserve available water supplies. As a result of the questionnaire and the on-going Program, a better understanding of regional interests and values was obtained.

D. Siting and Study Areas

A Siting Area and a Study Area were established by the CWRPDA prior to commencement of the Study. These areas are shown in Fig. I-1. The Siting Area is the larger of the two, fully encompassing the Study Area.

The Study Area is the area to be served by the structural and non-structural measures developed in this Study. The Study Area includes the St. Vrain Creek Basin to its confluence with the South Platte River exclusive of Boulder Creek and an approximate 40-sq-mi area of the St. Vrain physical drainage basin in the vicinity of Firestone, Frederick, and Dacono. Also, a small portion of the City of Boulder in the vicinity of Boulder Reservoir is included in the Study Area.

The Siting Area is that area in which facilities such as new reservoirs may be sited and the rehabilitation, expansion, or change in use of existing reservoirs may be accomplished to serve the needs of the Study Area.

The physical boundaries of the Siting Area are defined as the area inclusive of the St. Vrain Basin, the Little Thompson River Basin and Carter Lake to the north, the Boulder Creek Basin on the south, the Continental Divide on the west, and the South Platte River on the east.

E. Study Process

As previously indicated, the St. Vrain Study was intended initially to be a three-step process beginning with the Basin description and identification of water-related needs in Step 1, the formulation and preliminary evaluation of alternatives (primarily structural) in Step 2, and a reconnaissance-level evaluation of several selected alternatives in Step 3. Emphasis was to be placed on identification, evaluation, and selection of sites for water resources development, primarily storage. However, within three months following initiation of of Step 1 work, it was evident that the Study required a broader analysis to incorporate consideration of a spectrum of water management purposes, and with much greater emphasis on non-structural measures and more thorough evaluation of social and environmental effects of alternative water resource management plans. Therefore, the range of identified management measures was expanded to meet those purposes and, subsequently, Step 2 activities were redefined and Step 3 of the original Plan of Study was eliminated.

In conducting Step 1 and Step 2 studies, specific tasks were completed as defined in the Plan of Study. Each of these specific tasks along with their respective purposes is summarized in Table I-1. The following discussion summarizes the scope of the major tasks and results of Step 1 and Step 2.

Step 1 - Identification of St. Vrain Basin Characteristics and Needs

As indicated in Table I-1, six specific tasks were completed for Step 1.

Step 1, completed in August 1984, includes: (1) an inventory of the physical, socioeconomic, environmental, hydrologic, and institutional characteristics of the Basin; (2) water and power demand projections through the year 2020; and (3) preliminary identification of the water management purposes to be addressed by the Study.

Several water management purposes were identified in Step 1. These range from regulation of trans-Basin diversions and irrigation supplies to enhancement of fish and wildlife and protection and improvement of water quality, and include flood damage reduction, hydroelectric power generation, and municipal/industrial water supply.

Step 2 - Formulation of Water Resource Development Alternatives

Step 2 of the Study began in October 1984 with the completion of a revised Plan of Study. Revisions were made in recognition of the revised Study scope which resulted from input from the public and from the Study Advisors. As indicated in Table I-2, 13 specific tasks including the Final Report were completed for Step 2.

The main emphasis of Step 2 was to formulate and evaluate up to six alternative water resource management plans. An important part of plan formulation was the need to identify and evaluate plan elements. Plan elements are the building blocks for the alternatives and include existing structural features, potential structural features, and non-structural elements, also referred to as "measures." Evaluations were performed on 98 structural elements and 26 non-structural elements to determine which plan elements could to some degree meet the adopted plan purposes and which would be suitable for plan formulation. A computerized River Basin Simulation Model (RIBSIM) was used as a tool in analyzing water yield aspects of performance of the formulated plans.

Information obtained in the previous tasks of Step 1 and Step 2 was used in the plan formulation process. Study team members with expertise in the areas of water resource planning, hydrology, water rights, economics, hydraulic design, and environmental and social analyses met in workshop sessions to formulate nine preliminary alternative plans representing a range of potential water resource development for the St. Vrain Basin. The alternative plans include combinations of structural and non-structural measures for meeting the municipal, industrial, and agricultural water supply needs of the Basin. Five of these plans were selected for evaluation in Task 2-9. A sixth plan was subsequently formulated by CWRPDA staff, following response from the public and Advisors to the results of Task 2-9.

Both prior to and following evaluation, the alternative plans were presented to the Study Advisors. Comments from the public and the Study Advisors were presented to the Study Management Committee and incorporated into the Final Report and Summary Report.

Table I-1

St. Vrain Basin Reconnaissance Study

STUDY TASKS

STEP 1:

Task		Purpose
1-1	St. Vrain Basin Description	Describe the Basin's physical, environmental, social, and economic characteristics
1-2	Hydrology and Water Resources Assessment	Determine availability of water within the physical and legal constraints of the Basin
1-3	Inventory of Water Entities and Uses	Identify existing water supply entities and facilities in the Basin
1-4	Water Demand Forecasts	Identify the future water demand for various sectors
1-5	Power Demand Forecast and Preliminary Market Assessments	Determine Power Demand Forecast and assess preliminary marketability
1-6	Identification of Water Management Purposes	Summarization of the results of Step 1 of the St. Vrain Basin Study

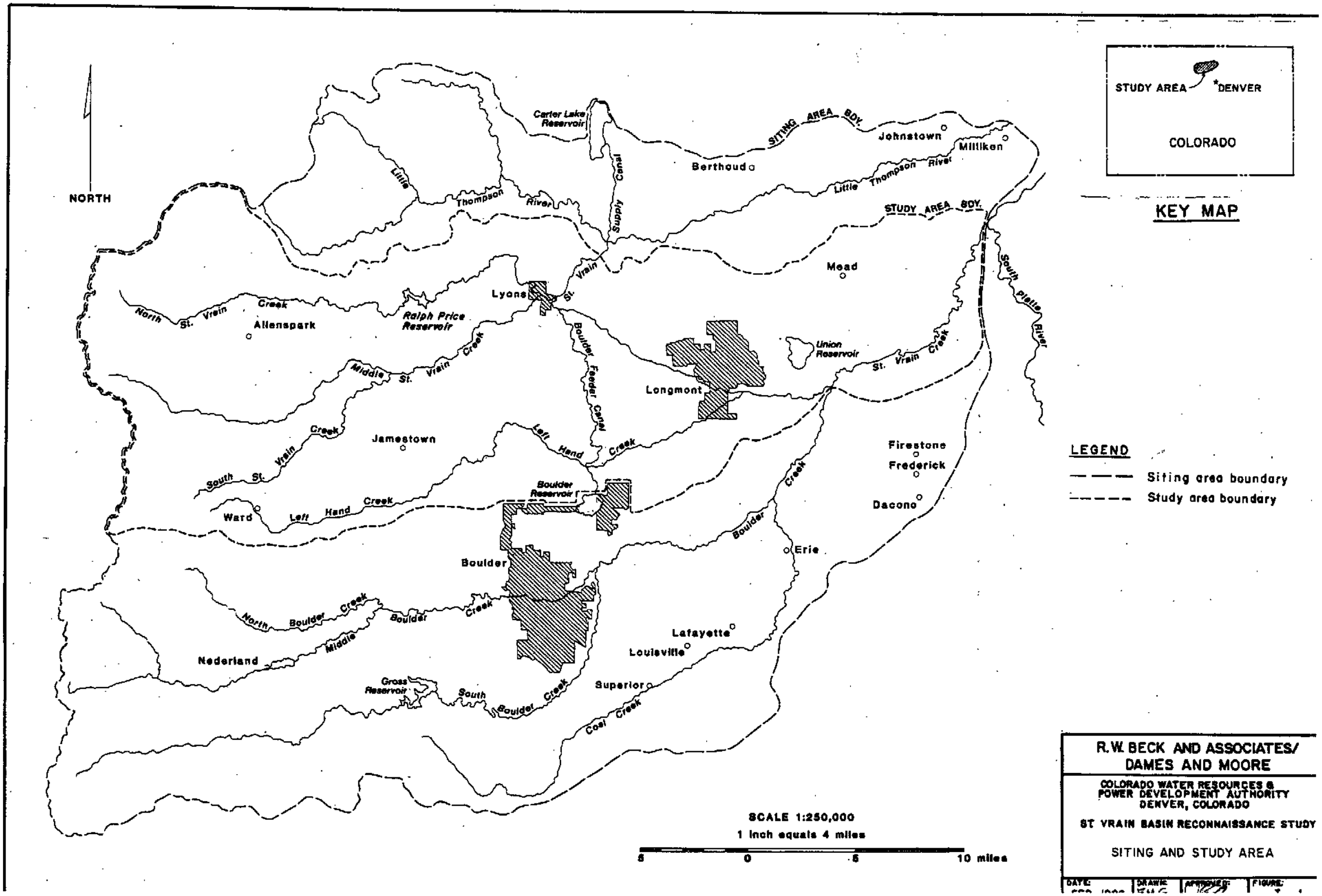
STEP 2:

Task		General Purpose
2-1	Finalize Plan of Study	Prepare Revised Plan of Study
2-2	Public Involvement and Information Program	Conduct a PII program including a survey to obtain information about the relative importance of water-related issues
2-3	Review and Finalize Plan Purposes	Translate future demands for water supplies and for other potential plan purposes into specific objectives
2-4	Calibrate River Basin Simulation Model	Adapt and calibrate the River Basin Simulation Model (RIBSIM) to simulate the St. Vrain Basin Water Supply System
2-5	Evaluation of Existing Water Supply Systems Operation	Quantify existing and future water supply deficits

Table I-1
(continued)

STEP 2: (continued)

Task		General Purpose
2-6	Identification of Plan Elements	Identify and list the plan elements to be considered for evaluation and formulation of alternative water resource management plans
2-7	Evaluation of Plan Elements	Provide a technical evaluation of the plan elements and selection of those elements which appeared to be most suitable for water resource management plan formulations
2-8	Formulation of Preliminary Alternative Plans	Formulate alternative water resource management plans using combinations of plan elements
2-9	Evaluation of Preliminary Alternative Plans	Evaluate the alternative plans formulated
2-10	Presentation of Preliminary Alternative Plans	Present preliminary alternatives and the evaluation of the preliminary alternatives to the public
2-11	Evaluation of Final Alternatives	Evaluate revised alternatives resulting from Task 2-10
2-12	Summary Report and Review of Final Alternatives	Prepare a Summary Report and present final Study results
2-13	Final Report	Prepare Final Report


NORTH
KEY MAP
STUDY AREA
DENVER
COLORADO
LEGEND
Siting area boundary
Study area boundary
SITING AREA BDY.
STUDY AREA BDY.
Carter Lake Reservoir
Supply Canal
Johnstown
Milliken
Berthoud
Little Thompson River
Little
Thompson
River
Mead
Lyons
St. Vrain
North St. Vrain Creek
Allenspark
Ralph Price Reservoir
Boulder Feeder Canal
Union Reservoir
St. Vrain Creek
Longmont
Middle St. Vrain Creek
South St. Vrain Creek
Jamestown
Left Hand Creek
Firestone
Frederick
Dacono
Boulder Reservoir
Ward
Boulder Creek
Erie
Boulder
North Boulder Creek
Middle Boulder
Nederland
Lafayette
Louisville
Superior
Gross Reservoir
South Boulder Creek
Coal Creek
South Platte River
SCALE 1:250,000
1 inch equals 4 miles
5
0
5
10 miles
R.W. BECK AND ASSOCIATES/
DAMES AND MOORE
COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY
DENVER, COLORADO
ST VRAIN BASIN RECONNAISSANCE STUDY
SITING AND STUDY AREA
DATE:
DRAWN:
APPROVED:
FIGURE:

CHAPTER II

BASIN DESCRIPTION

A. Introduction

This chapter presents a general description of the St. Vrain Basin characteristics and conditions. The description summarizes the physical, environmental and social characteristics as well as information pertaining to the governing entities in the St. Vrain Basin.

B. Physical Characteristics

1. Boundaries

The physical boundaries of the Siting and Study Areas are defined in Chapter I. These areas are shown in Fig. I-1.

2. Topography

The Siting Area (which includes the Study Area) can be divided into three separate topographic provinces. These provinces are the Front Range or the mountainous western portion of the area, the Hogback or foothill ridges rising up from the plains, and the plains area or piedmont composing the eastern portion of the area. Elevations within the Siting Area range from a high of 14251 feet at Longs Peak in the Front Range province to a low of 4740 feet at the confluence of the St. Vrain and South Platte rivers in the Plains province.

3. Climate

The rapid variance of topography in the St. Vrain Basin in conjunction with the Basin's mid-latitude location results in localized climatic extremes. The climate of the lowest portions of the Basin consisting of the Plains region, is classified as semi-arid and receives an average of about 13 inches of precipitation per year with the maximum and minimum precipitation generally occurring during the spring and winter months, respectively. Mean annual temperature for the City of Longmont, which is representative of the Plains region, is 48.6°F. The mountainous western area of the St. Vrain Basin can receive over 40 inches of precipitation per year with the majority of the precipitation coming from fall and winter snow storms. Mean annual temperature for the high mountain areas as represented by Allenspark (El 8500) is 40.5°F.

4. Geology

Regional features which are present within the Siting Area boundary are the Front Range, the Denver Basin and the Foothills Belt. The Front Range is a massive flat, fault-bounded arch approximately 185 miles long and 25 to 45 miles wide. The main body of the Front Range consists of Precambrian crystalline formations. Structural relief of the Precambrian surface ranges from approximately 14000 feet above sea level along the Continental Divide to approximately 8000 feet below sea level in the adjacent Denver Basin.

The Denver Basin is an asymmetrical structural basin. Its axis closely parallels and is located near the Front Range uplift. The deepest portion of the Basin is located near the City of Denver and is estimated to represent more than 13,000 feet of sediments. Along the western edge of the Denver Basin uplifted paleozoic, mesozoic and tertiary sediments are exposed and are known as the Foothills Belt.

5. Water Resources

Sources of water used in the approximate 480-sq-mi St. Vrain Basin come from native surface runoff, trans-Basin diversions, and groundwater. These sources are quantified briefly herein; however, a more detailed discussion is presented in Chapter III.

The long-term average native (virgin) surface water runoff of the St. Vrain Creek Basin exclusive of the Boulder Creek drainage is estimated to be 117,600 ac-ft per year (U.S. COE, 1977). This native surface water runoff of the St. Vrain Creek is estimated from the combined flow records of gaging stations located on St. Vrain Creek near Lyons and Left-Hand Creek near Boulder. Surface water runoff from areas below these gaging stations is not included in these estimates, but runoff from the lower basin represents a small volume on a long-term average basis.

Native surface water runoff during the 1953 to 1956 4-year drought period averaged 75,800 ac-ft per year, or approximately 64% of the long-term average. The largest peak discharge of record on St. Vrain Creek at Lyons prior to 1980 was 10,500 cfs on June 22, 1941 (U.S. COE, 1977).

Another source of water to the Basin comes from trans-Basin diversions. The Colorado-Big Thompson (C-BT) Project is a trans-Basin diversion project constructed by the Bureau of Reclamation in the 1940's and 1950's, and operated (except for power generation features) by the Northern Colorado Water Conservancy District. At the time the Study began, it was the only trans-Basin diversion conveying water to the Study Area; however, the new Windy Gap Project will deliver western slope water beginning in 1985 by use of the C-BT delivery system. Water users within the St. Vrain Basin divert from the C-BT system an average of approximately 31,000 ac-ft per year with approximately 13,500 and 17,500 ac-ft going to municipal and agricultural uses, respectively. Since the C-BT system is a supplemental water supply system, deliveries from the system are generally inversely proportional to native flow in the St. Vrain Basin, i.e. the highest deliveries of C-BT system water to the Basin occur in drought years.

Groundwater is also a source of supply for municipal, industrial, domestic, stock and agricultural use in the Basin. The primary aquifer in the Basin is in the valley alluvium of St. Vrain Creek and its plains area tributaries. The alluvium is recharged by precipitation, applied irrigation water, and leakage from canals and reservoirs. It is estimated that approximately 9,000 ac-ft per year may be used for irrigated agriculture in the Study Area and that lesser amounts of groundwater are used for rural residential and other uses.

C. Environmental Resources

1. Terrestrial Biology

The St. Vrain Basin encompasses a diverse array of vegetation types due to the wide range in elevation and corresponding changes in life zones. The Siting Area is divided into three regional zones, each zone characterized by generally similar sensitivities of the environmental resources. The three life zones identified are the mountain zone (elevations above 7000 feet), the foothills zone (elevations between 5500 and 7000 feet), and the plains zone (elevations below 5500 feet).

The mountain zone contains vegetation and wildlife habitat that is interrelated with the high scenic and recreational land use values. Vegetation in the mountain zone consists primarily of Douglas fir, lodgepole pine and aspen mountain forests. Riparian vegetation is usually characterized by willow and alder stands. Elk and mule deer, important wildlife species, use higher elevations of the mountain habitat during the summer.

The foothills zone is a transitional area between the mountain and plain zones. Vegetation in this zone becomes dominated by ponderosa pine in association with aspen and Douglas fir. Riparian vegetation consists primarily of willow and alder. Essentially the same wildlife species utilize the foothills zone as the mountain zone. Seasonal use by game species is important in this zone.

Much of the plains zone was originally represented by plains grassland with occasional sagebrush and mixed prairie species and now is mostly converted to agricultural production. Blue gramma, weed grasses and other mid- to tall-grasses dominate the native rangelands. Dense riparian vegetation dominated by cottonwoods grows along water courses and around some of the numerous lakes and reservoirs. Wildlife associated with this zone includes coyote, fox, mule deer, whitetail deer, and numerous species of birds and small mammals. Plant communities and open water provide suitable habitat for migratory waterfowl, shorebirds and raptors, including the peregrine falcon and bald eagle.

No plant species listed as threatened or endangered by the Federal government or the State of Colorado are known to occur within the St. Vrain Basin (U.S. Fish and Wildlife Service, 1983). However, butterfly weed is a candidate species for listing by the Federal government and has the potential to occur in the St. Vrain Basin. Several other plant species of special concern to the state have the potential to occur in the Study Area. These include Bell's twinpod and a little bluestem community. A total of 24 sites of critical plant associations and nine sites of rare plants are identified in Boulder County in the Comprehensive Plan (Boulder County, 1984). Wildlife species that are listed as threatened or endangered species by the Federal government that have the potential to occur in the St. Vrain Basin include the peregrine falcon and the American bald eagle. Peregrine falcon habitat exists along Boulder Creek from the middle north fork confluence downstream to the confluence of south Boulder Creek. Thirty-seven separate areas are identified as critical wildlife habitat in Boulder County in the Boulder County Comprehensive Plan (Boulder County, 1983).

2. Aquatic Biology

Aquatic habitats in the mountain zone include streams, alpine lakes, and a limited number of reservoirs. Habitats generally may be characterized by cold temperatures, low productivity and low suspended and dissolved solids levels. In addition, streams have high gradients, variable flows and limited substrate variability. Aquatic fauna consist mainly of trout species and invertebrates at low population densities.

The foothills zone aquatic ecosystems consist mainly of streams and a few reservoirs. Both streams and reservoirs in this zone generally would have habitat characteristics similar in some respects to mountain zone resources except the temperatures, productivity and solids levels would be slightly higher. Stream flow would be less variable, gradients would be lower and substrates more diverse than streams at higher elevations. The aquatic biota of the foothills zone would be expected to be dominated by cold water trout species. The fishery and invertebrate communities would be more diverse and populations would be more dense than mountain zone communities.

Warm water reservoirs and streams provide most of the aquatic habitat in the plains zone. These communities generally may be characterized by seasonal temperature variation, high productivity and high suspended and dissolved solids. Streams are typically low gradient streams with limited substrates and variable flows as a result of irrigation. Aquatic biota consist of a variety of warm water fishes dominated by the minnow species and many invertebrates adapted to sand and silt substrates.

Sport fisheries in the Siting Area are variable. The best sport fishing would typically be in the lakes and streams of the foothills zone and lower elevations of the mountain zone. The poorest sport fisheries exist in the lower portions of the various streams in the plains zone. The sport fisheries of the Little Thompson River, Left-Hand Creek and Four Mile Creek generally are considered of lower quality than those of St. Vrain and Boulder Creeks.

Two aquatic species of special interest occur in the area. A population of greenback cutthroat trout, a Federally endangered species, is known to occur in Como Creek, a tributary to North Boulder Creek. The johnny darter, which occurs in the foothills zone of St. Vrain Creek, is currently listed as a threatened species in Colorado by the Colorado Division of Wildlife.

3. Water Quality

Water quality in the St. Vrain Creek Basin is highly variable. The headwaters and upstream reaches have good to excellent water quality while there is significant deterioration in several water quality parameters downstream from Lyons. The upper reach, above the town of Lyons, is characterized by generally good water quality with low water temperature, high dissolved oxygen and rocky and gravel bottoms. This upper segment of the Basin generally maintains sustained flows.

A 1983 study of St. Vrain Creek indicated that the water quality of the stream at Lyons is good and meets the state stream standards of a Class I cold water fishery. Water quality below Lyons to Hygiene Road also appears to be capable of supporting a Class I cold water fishery; however, periods of low stream flow during the winter months appear to be the limiting factor in sustaining a fishery (DRCOG, 1983c).

The St. Vrain streambed through the Lyons and Longmont reaches is silted as a result of increased development along stream banks and the resultant increases in storm runoff. Agricultural withdrawals below Lyons have reduced flows considerably from those of the past. Water quality downstream of Longmont is generally poor due to agricultural return flows.

Non-point sources deliver significant quantities of pollutants to the St. Vrain Basin waterways; however, few data are available for quantifying the relative contribution of non-point to point source pollution. The data indicate that loading from non-point sources for total dissolved solids, fecal coliforms, fecal streptococci, and nitrates outweigh loadings from point sources. Ammonia and phosphate contributions from point sources exceed those from non-point sources. Significant loadings of organic materials (BOD) occur from both point and non-point sources. It is believed that agricultural irrigation return flows are the primary cause of the high total dissolved solids contributions from non-point sources. The high levels of microorganisms delivered to St. Vrain streams are believed to be a result of stormwater runoff (DRCOG, 1981).

Water quality data from the EPA STORET retrieval system were analyzed for five sampling stations in the upper and lower basins. Data summaries are shown in Table II-1. Measured pH levels increase as the St. Vrain Creek flows from the high mountain sources through the foothills down through the plains to Weld County. The increase in pH provides evidence of dissolved salt loading which buffers the water at higher pH levels. This is supported by data which show significant increases in conductivity from 28 to 1,300 mg/l as the stream flows from the high mountains downstream through the foothills to the plains.

Three main point wastewater discharges are located in the Basin. These are effluents from the municipal treatment plants for the City of Longmont, the Town of Lyons and the Niwot Sanitation District. The City of Longmont Wastewater Treatment Plant discharges to St. Vrain Creek just below the confluence with Left-Hand Creek. The plant currently operates at about 80% capacity with an average daily flow of 6.5 mgd. It is anticipated that the plant will be expanded to approximately 14 mgd by the year 2020. Ammonia concentrations are a concern during low flow periods in the winter months and are currently restricted in the Longmont National Pollutant Discharge Elimination System Permit.

The Town of Lyons Wastewater Treatment Plant discharges to St. Vrain Creek just below the confluence of North and South St. Vrain creeks. The plant currently operates at 29% capacity with an average daily flow of 0.085 mgd with no expansion anticipated at this time.

The Niwot Sanitation District's Wastewater Treatment Plant discharges into a tributary of St. Vrain Creek at a point about 4 miles northeast of Boulder Reservoir. The plant currently operates at 40% of capacity with no expansion anticipated at this time.

In addition, minor wastewater discharges include a few mine discharges and the Jamestown wastewater treatment facility into Left-Hand Creek. Currently, there are no land treatment systems and/or water rights exchanges using treated wastewater in the Study Area (Mugler, 1984, personal communication).

Current water quality planning efforts in the St. Vrain Basin are being undertaken by a task force comprised of state and local governmental interests, including the Denver Regional Council of Governments, the Larimer/Weld Counties Council of Governments, the City of Longmont, Boulder and Weld Counties, Colorado Division of Wildlife, EPA Region VIII, the Colorado Division of Water Quality, and the St. Vrain and Left-Hand Conservancy District. The task force is investigating whether current stream standards are being met, whether stream standards are proper or should be changed, extent of water quality problems and possible solutions, etc. In addition, water quality planning studies on St. Vrain Creek are presently being conducted by the City of Longmont and the EPA.

4. Stream Classification

Water quality classifications of the State of Colorado are based primarily on the uses for which a stream is presently suitable or intended to become suitable. These classifications include recreation (Classes 1 and 2), agriculture, aquatic life (Classes 1 and 2 warm and cold water), domestic water supply, and existing high quality waters (Classes 1 and 2). Class 1 designations indicate a higher quality within particular usage category than does Class 2. Figure II-1 shows the stream classifications of various streams within the Study Area.

5. <u>Recreation and Aesthetics</u>

The St. Vrain Basin offers a variety of recreational resources that are characteristic of the Front Range Region. Recreation opportunities and activities vary with location within the Basin. A portion of Rocky Mountain National Park occupies about 40 sq mi in the northwest corner of the Basin, together with the outlying Twin Sisters Area. Numerous trails in the park provide scenic views with typical activities including hiking, picnicking, camping and nature interpretation.

South of the National Park lies the Indian Peaks Wilderness Area administered by the U.S. Forest Service. This also contains spectacular high country scenery but is more remote from motorized access. The Indian Peaks Wilderness Area is the most heavily used wilderness area in the Rocky Mountain region (Tyler, 1984, personal communication).

Most of the western half of the Basin is within the Roosevelt National Forest which is managed by the U.S. Forest Service for multiple use. The mountainous forested terrain offers significant scenic enjoyment, wildlife, fishing and hunting opportunities. Also, the upper reaches of the north, middle and south branches of St. Vrain Creek are classified as important fishing streams.

Some scattered blocks of private land within the Front Range mountains support individual and organized recreation activities. In the area from the hogback eastward, most land is privately owned. Most users are local although the National Park attracts out-of-state visitors. The majority of recreational use occurs in the summer. There are significant winter activities such as cross country skiing and snowmobiling and big and small-game hunting in the fall.

The aesthetic quality of the western mountainous area of the Basin is characterized by spectacular alpine features, rugged terrain and commanding views of the surrounding country. Seasonal changes are marked, with some snow and ice visible all year, and alpine flowers providing colorful ephemeral displays in summer. Distinctive rock features, waterfalls, and vegetation patterns near tree line occur with rare, man-made modifications to the landscape. Below tree-line, the landscape becomes heavily forested with rugged mountains, dissected by deep, steep-sided valleys. The transition from forested mountains to open plains is marked by the Hogback ridges which form distinctive topographic landmarks.

The area is seen and experienced largely by local residents at lower elevations, those driving the highways, and by recreational users. U.S. Highway 36 (Boulder to Estes Park) and State Highway 7 (Lyons to Estes Park) are designated scenic highways by the State of Colorado.

D. Social Characteristics

1. Land Use

The Study Area encompasses approximately 320,000 acres (500 sq mi) of which approximately 82% is in Boulder County, 16% is in Weld County, and 2% is in Larimer County. The upper portion of the Basin west of Lyons includes approximately 190,000 acres which is primarily national forest lands and undeveloped private lands. A few small communities (Lyons, Allenspark, Ward and Jamestown) are present with scattered subdivisions that are presently under development. Rocky Mountain National Park and the Twin Sisters Area occupy about 40 sq mi in the northwest corner of the Basin. The City of Longmont and scattered subdivision developments in the lower basin (east of Lyons) comprise the largest percentage of urban development in the Study Area.

Cropland is the dominant land use in the lower basin with irrigated lands predominating over non-irrigated croplands. In 1980, approximately 71,000 acres of cropland in the Study Area were irrigated. It is estimated that an additional 10,000 acres would be prime irrigated land if water were supplied (SCS, 1979).

Regional land use policies of the counties are guided by county plans which consist of broad-based land use goals, policies and proposals intended to guide future development. The Boulder County Comprehensive Plan is the most detailed plan of the three counties in the Study Area (Boulder, Larimer and Weld). A significant component of the Boulder County Comprehensive Plan is the identification of natural and cultural factors which interact with various land use factors. Future water resource projects will be reviewed with regard to their consistency with the county plans of the various counties in which the projects are sited.

2. Socioeconomics

Boulder County makes up 82% of the Study Area and 64% of the Siting Area. The principal towns and cities of the county are experiencing considerable economic and population growth. This has been partially a result of the scientific research at the University of Colorado and at federal establishments in and near Boulder. Elsewhere the development of manufacturing plants has had significant influence on the local economy. Tourism likewise has played an important part in developing and stimulating the economy of the area. Table II-2 shows selected socioeconomic data for 1970 and 1980 for Boulder County. The population of Boulder County in 1980 was 189,625, an increase of approximately 44% from the 1970 census.

The Study Area population in 1980 is estimated at 63,000 people. Of these, approximately 43,000 people live in Longmont. Three thousand live in the upper basin west of Lyons inclusive of the 223 and 129 people who reside in Jamestown and Ward, respectively (DRCOG, 1983a, 1983b). General population, housing and socioeconomic characteristics for the four largest communities in the St. Vrain Basin are presented in Table II-3. Seventeen thousand people live in the rural portion of the lower basin inclusive of the 1,037 people who reside in Lyons. The three largest employment sectors for Longmont and Lyons were manufacturing, services and retail.

E. Institutional Setting

There are a number of institutions and agencies which may, to a greater or lesser extent, be involved in the planning, management or development of water resources in the St. Vrain Basin. They include cities and towns, water supply companies, special districts, counties, regional planning agencies, state agencies and federal agencies.

Municipalities in the Study Area include the City of Longmont and the towns of Jamestown, Lyons, Mead and Ward. Each of these municipalities is a water supplier for its respective urban area.

Two water supply companies and several ditch companies supply water to rural areas in the Basin. The Left-Hand Water Supply Company and the Longs Peak Water Association provide domestic water to rural residential customers in the eastern portion of the Study Area. Ditch companies provide water to all types of users. However, agriculture comprises the largest percentage of ditch company uses. Some ditch companies are privately owned; many, however, are mutual companies in which the water users are share holders and the company operates under the guidance of a board of directors.

Special districts in the area include water districts, water and sanitation districts, and water conservancy districts. The Little Thompson Water District provides water service to the rural residential area near Mead in the eastern end of the Basin. Other special districts in the Study Area are the Allenspark Water and Sanitation District, the Fairways Water and Sanitation District, the Left-Hand Water and Sanitation District, and the Olde Stage Water District.

Water conservancy districts are quasi-municipal corporations with the power to levy special assessments and tax property within the district for the purpose of financing water projects. There are three conservancy districts which encompass all or portions of the Study Area. They are the Northern Colorado Water Conservancy District (NCWCD), the Municipal Subdistrict of NCWCD, and the St. Vrain & Left-Hand Water Conservancy District (SV&LHWCD). The total area in the Northern Colorado Water Conservancy District is almost one and a half million acres and includes portions of Boulder, Larimer, Logan, Morgan, Sedgewick, Washington and Weld counties in Colorado. The NCWCD supplies water from the facilities of the C-BT Project for agricultural, municipal, and industrial purposes.

The SV&LHWCD was organized in 1971 to promote cooperation between municipal and agricultural water users in the St. Vrain Basin. District boundaries approximate those of the Study Area. It does not currently supply water or own or operate facilities.

The Study Area includes jurisdictions of two regional planning agencies: the Denver Regional Council of Governments and the Larimer/Weld Council of Governments. The regional planning agencies assist local governments by coordinating regional planning activities and by reviewing proposed development for conformance with adopted regional plans.

Four state agencies have a major role in water resources activities in Colorado. The Colorado Water Conservation Board and the CWRPDA are responsible for water planning and development activities in Colorado. The Division of Water Resources (State Engineer's Office) has the responsibility for administering water rights and water diversions in Colorado. The Department of Health, Water Quality Control Division, is responsible for water quality planning and enforcement activities in Colorado.

Other resource management agencies which are directly or indirectly concerned with water management in the Study Area include the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, the U.S. Environmental Protection Agency, the U.S. Department of Energy, the U.S. Forest Service, the U.S. Soil Conservation Service, the Colorado Division of Wildlife, the Colorado Division of Parks and Outdoor Recreation, and the Colorado Department of Highways.

(B0353C)

Table II-1

St. Vrain Basin Reconnaissance Study

WATER QUALITY DATA

		Upper Basin				Lower Basin	
Parameter	Units	South St. Vrain Creek Above Lyons	North St. Vrain Creek at Longmont Dam	St. Vrain Creek at Lyons	Longmont STP Effluent	St. Vrain Creek Below Longmont	St. Vrain Creek Near Mouth
DO	MG/L	9.6	9.5	9.6	3.6	9.6	9.5
PH	STANDARD	7.4	7.3	7.4	7.3	8.1	7.9
T ALK	MG/L	21.8	10.0	19.7		214.9	212.2
NO_2 & NO_3	MG/L	0.13	0.07	0.26	0.17	2.4	3.13
NH_3 & NH_4-	MG/L			0.08	19.00	2.0	1.18
T Hardness	MG/L	23.2	10.9	24.0		545.5	512.8
Calcium	MG/L	6.8	3.3	7.1		101.6	249.6
Magnesium	MG/L	1.5	0.7	1.6		70.9	63.7
Sodium	MG/L	3.1	1.9	3.4		98.7	107.4
Potassium	MG/L	0.6	0.4	0.6		5.2	5.2
Chloride	MG/L	1.1	0.7	1.4		17.2	29.5
Sulfate	MG/L	5.7	4.1	7.7		505.5	488.9
Fluoride	MG/L	0.2	0.14	0.2		1.1	1.0
Arsenic	UG/L	1.0		4.5		1.2	1.0
Barium	UG/L	200.0		200.0			
Berylium	UG/L	200.0			0.3	16.8	25.0
Cadmium	UG/L	3.0		0.0	5.0	0.2	0.2
Copper	UG/L	2.0		1.5	5.2	12.1	12.3
Iron	UG/L	51.3		120.0		1,274.3	1,014.5
Lead	UG/L	6.0		1.0	30.0	6.9	5.4
Manganese	UG/L	10.1		8.8		75.5	127.6
Zinc	UG/L	20.0		10.0	16.0		32.6
Selenium	UG/L	1.0		1.0	40.0	2.5	2.5
Mercury	UG/L	0.5		0.5	8.0	0.4	0.4
Fecal Coliform	/100 ml	0.0		40.5	540,000	2,288	8,908
TDS	MG/L	40.3	23.1	41.0		965.3	984.9
Conductivity	MICROHMS	60.9	27.9	70.0	964.2	1,331.1	1,281.0

(1) Blanks indicate no data available.
(2) Data represents average values, generally representing mid to late 1970's conditions.

SOURCE: EPA Storet System, Denver, Colorado.

(B0353C)

Table II-2

St. Vrain Basin Reconnaissance Study

BOULDER COUNTY

1970-1980 GENERAL POPULATION, HOUSING, AND SOCIOECONOMIC CHARACTERISTICS

	1970	1980	Percent Change
Population	131,889	189,625	43.8
Total Housing Units	44,307	74,638	68.5
Persons in Group Quarters	7,643	8,331	9.0
Total Households	40,870	68,964	68.7
Vacancy Rate (%)	7.8	7.6	-2.6
Average Household Size (no. persons)	3.04	2.63	-13.5
Median Household Income In 1980 Dollars	20,007	19,774	-1.2
Per Capital Income in 1980 Dollars	6,972	8,608	23.5
Civilian Unemployment Rate(1)	4.37	4.23	
Employment by Industry Classification			
Agriculture and Mining	1,317	2,644	100.8
Construction	2,923	6,595	125.6
Manufacturing	11,025	21,653	96.4
Transportation-Communication	2,669	5,136	92.4
Wholesale Trade	1,242	4,080	228.5
Retail Trade	8,254	16,503	99.9
Fin., Ins., and Real Estate	2,159	5,351	146.7
Services	19,807	32,250	62.8
Public Administration	3,076	4,950	60.9
Median Education (years)	12.8	14.2	

(1) The Civilian Unemployment Rate was 4.9% in September 1983 after peaking at 7.7% in January of 1983.

SOURCE: Denver Regional Council of Governments, 1983a. Regional Data Series: Profiles of 1970-1980 Socio-Economic Change by County and Census Tract.

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(B0353C)

Table II-3

St. Vrain Reconnaissance Study

GENERAL POPULATION, HOUSING AND SOCIOECONOMIC CHARACTERISTICS
FOR SELECTED COMMUNITIES IN THE ST. VRAIN BASIN

	Longmont		Change		Lyons	Jamestown	Ward
	1980	1970	No.	%	1980	1980	1980
Total Persons	42,942	25,012	17,930	71.7	1,137	223	129
Median Age	28	27	1	3.7	29	29	30
Persons in Households	42,621	24,777	17,844	72.0	1,130	223	129
Persons in Group Quarters	321	235	86	36.6	7	0	0
Total Households	15,483	8,062	7,421	92.0	454	92	68
Average Household Size	2.8	3.1			2.5	2.4	1.9
Owner Occupied Housing Units	9,983	5,383	4,600	85.5	300	60	40
Renter Occupied Housing Units	5,500	2,679	2,821	105.3	154	32	28
Median Value of Owner Occupied Units	66,500	53,001	13,499	25.5	59,400	62,200	29,800
Median Monthly Rent	248	176	72	40.9	193	269	153
Median Household Income	19,638	18,940	698	3.7	15,312	17,500	6,458
Per Capita Income	7,686	6,048	1,638	27.1	6,621	7,500	4,803
Civilian Labor Force	21,664	10,012	11,652	116.4	568	141	80
Civilian Unemployment Rate	4.57	4.86		6.16	2.12	21.12	
Industry(1)							
Agriculture and Mining	496	313	183	58.5	7	6	13
Construction	1,812	790	1,022	129.4	92	17	5
Manufacturing	5,907	2,908	2,999	103.1	125	39	11
Transportation-Communication	1,253	494	759	153.6	15	4	2
Wholesale Trade	925	253	672	265.6	19	5	2
Retail Trade	3,502	1,472	2,030	137.9	132	16	3
Fin., Ins. and Real Estate	900	344	556	161.6	18	3	3
Services	4,864	2,328	2,536	108.9	99	38	24
Public Administration	1,015	627	388	61.9	26	10	0
Occupation(1)	20,674	9,525	11,149	117.0	533	138	63
Managerial, Professional, Technical, Sales and Admin.	11,145	4,704	6,441	136.9	211	93	19
Service Occupations	2,225	3,418	-1,193	-34.9	97	8	12
Farming, Forestry, and Fishing	261	178	83	46.6	6	2	0
Precis. Prod., Craft, Repair, Operators, Fabricators, Labor	7,043	1,229	5,814	473.1	219	35	32
Median Education(2)	12.7	12.4	0.3	2.4	12.6	14.7	15.8

(1) Industry and occupation classifications of employed persons 16 years old and over by residence.
(2) Median education expressed as years of school completed.

SOURCE: Denver Regional Council of Governments. 1983b. Regional Data Series: Changes in Local Demographics, 1970-1980, for Places in the Denver Metropolitan Area.

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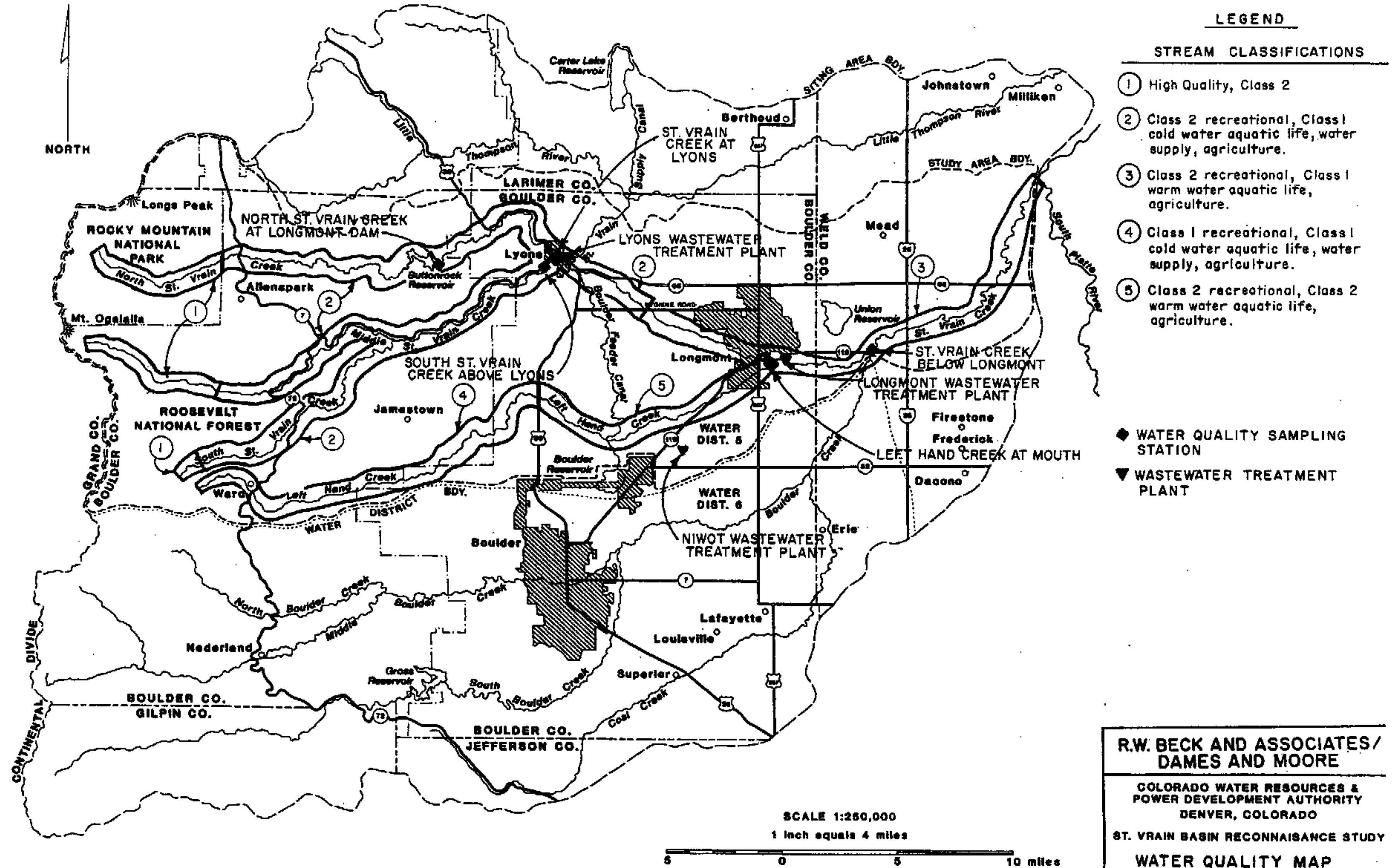

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DAMES AND MOORE

COLORADO WATER RESOURCES &
POWER DEVELOPMENT AUTHORITY
DENVER, COLORADO

ST. VRAIN BASIN RECONNAISANCE STUDY

WATER QUALITY MAP

DATE:	DRAWN:	APPROVED:	FIG:
FEB. 1986			II-1

CHAPTER III

HYDROLOGY AND WATER RIGHTS

A. Introduction

This chapter describes the surface and groundwater hydrology of the St. Vrain Basin. Also included is a description of trans-Basin imports to the St. Vrain Basin, a discussion of water administration and management and a summary of water rights in the Basin.

B. Surface Water Hydrology

1. General

St. Vrain Creek has a total drainage area of 976 sq mi at its confluence with the South Platte River. A significant portion of the total drainage area is from Boulder Creek, a major tributary to St. Vrain Creek, which has a drainage area of 496 sq mi.

The St. Vrain Basin is typical of South Platte River tributaries in Colorado. The Basin has an eastern aspect, with elevations ranging from approximately 4700 feet at the South Platte River to above 13000 feet along the Continental Divide. Precipitation generally increases with elevation; snowfall is the main source of runoff to the St. Vrain Basin. The St. Vrain Basin annually contributes a net 156,000 ac-ft, on the average, to the South Platte River. This volume is the gaged flow at the mouth, and includes the effect of trans-Basin imports and depletions caused by irrigated agriculture and municipal and industrial water uses. Trans-Basin imports are discussed later in this chapter, and water uses are discussed in Chapter IV.

The main tributaries of St. Vrain Creek within the Study Area are the North, South and Middle St. Vrain creeks and Left Hand Creek. Locations of U.S. Geological Survey (USGS) stream gaging stations are shown in Fig. III-1 and they are described in the following paragraphs. Data from those stations are shown in Table III-1.

2. North St. Vrain Creek

North St. Vrain Creek, which rises in the high mountains west of Allenspark, has a drainage area of 127 sq mi, ranging in elevation from 5300 feet at Lyons, to 14250 feet at Longs Peak. USGS Stream Gaging Station 7220, located 4 miles west of Lyons, operated from 1926 to 1953. In addition to depletions resulting from irrigation of a reported 300 acres above the gage, flows reported in Table III-1 at this gage were partly regulated by several small reservoirs.

Button Rock Dam which creates Ralph Price Reservoir is located on North St. Vrain Creek, about 8 miles upstream of Lyons. This reservoir has an active storage capacity of 15,750 ac-ft and is the largest reservoir in the Study Area. Button Rock Dam was completed in 1969, and has a height of 210 feet. The dam was constructed by the City of Longmont to supplement its municipal water supply as described in Chapter IV.

3. South St. Vrain Creek

South St. Vrain Creek has a drainage area of 85 sq mi, including Middle St. Vrain Creek, above its confluence with North St. Vrain Creek at Lyons. Elevations in this subbasin range from approximately 5300 feet at Lyons to 13223 feet at Mt. Audubon, near the Continental Divide. Middle St. Vrain Creek has a drainage area of 31 sq mi and joins South St. Vrain Creek at an elevation of 7040 feet, about 9 miles upstream of Lyons.

Formerly, there were two USGS stream gaging stations on South St. Vrain Creek. Station 7225, with a period of record from 1925 through 1927, 1929 through 1931, and 1955 through 1973, was located at about elevation 9400 feet, above the Left Hand Ditch Company diversion dam. Station 7234, with a period of record from 1976 through 1980, was located above Lyons.

4. Left Hand Creek

Left Hand Creek, with a drainage area of approximately 72 sq mi, has its source about 3 miles southwest of the Town of Ward. Elevations in this subbasin range from 4940 feet at the confluence with St. Vrain Creek, near Longmont, to over 11400 feet at Niwot Mountain. Left Hand Creek flows are enhanced by importation of South St. Vrain Creek water by the Left Hand Ditch Company, at a diversion point above the Town of Jamestown. An estimated annual importation of approximately 12,000 ac-ft from South St. Vrain Creek is included in the reported average annual Left Hand Creek discharge of 28,840 ac-ft shown in Table III-1.

Previously there have been two USGS stream gaging stations located on Left Hand Creek. Station 7245, with a drainage area of 52 sq mi, was located above the Left Hand Ditch Company ditch headgates. It operated off and on from 1930 through 1980 when it was discontinued by the USGS.

Gaging Station 7250, located at the mouth of Left Hand Creek, was in operation from 1928 through 1942 and from 1954 through 1955 when it was discontinued by the USGS. At that time, it was reported that approximately 12,000 acres of land above this station were irrigated, indicating that gaged flows are greatly affected by diversions and storage for irrigation.

5. Lower St. Vrain Creek

St. Vrain Creek between Lyons and the mouth, excluding Left Hand Creek, has a drainage area of 201 sq mi. The water yield of this drainage area is rather low in comparison to the mountain drainage basins, as average annual precipitation decreases from approximately 16 to 30 inches in the mountains to 12 to 16 inches in the plains.

There are four USGS stream gaging stations along lower St. Vrain Creek. All gages in this reach are affected by upstream diversions and importations for irrigation. Gaged flows are substantially regulated by reservoirs and are affected by trans-Basin imports.

Gaging Station 7240, St. Vrain Creek at Lyons, is located just downstream of the confluence of North and South St. Vrain creeks where the drainage area is 212 sq mi. There are several ditch diversions above the gage, but the St. Vrain Supply Canal, which imports Colorado-Big Thompson Project water into the St. Vrain Basin, is located just downstream. Therefore, this gage is a useful reference point for inflows to the plains portion of the Basin. Based on an 1895 to 1981 continuous period of record, the average annual gaged discharge at Station 7240 is 92,470 ac-ft. Calculation of virgin flows for the period 1951 to 1980 results in an estimated average annual discharge of 116,000 ac-ft. Note that the 1951 to 1980 period contains the 3 years of least runoff during the entire period of record. These are 1956, 1966, and 1977, in order of decreasing gaged flow.

Gaging Station 7251, St. Vrain Creek near Longmont, with 370 sq mi of drainage area, was in place from 1965 through 1968, while Station 7254.5, St. Vrain Creek below Longmont, reflecting a drainage area of 424 sq mi, has data from 1977 to 1981.

Gaging Station 7310, St. Vrain Creek at mouth (confluence with the South Platte River), drains 976 sq mi, including Boulder Creek. During the 1928 to 1981 period of record, the minimum and maximum recorded flows are 12 cfs and 11,300 cfs, respectively. The average annual discharge, which is greatly affected by diversions and storage, as well as trans-Basin imports, is approximately 150,000 ac-ft.

C. Groundwater Hydrology

1. Geology and Hydrology of the Study Area

The St. Vrain Basin is geologically diverse, but may be classified into three distinct hydrogeologic terrains, which are generally coincident with the three topographic provinces described in Chapter II: (1) the Precambrian igneous and metamorphic mountains west of the hogback ridges (mountains), (2) the upturned sedimentary strata exposed as hogback ridges, immediately east of the mountains (foothills), and (3) unconsolidated alluvial, eolian and glacial deposits which overlie sedimentary rocks in most of the area east of the hogback and limited areas in the mountains (plains).

The mountainous portion of the St. Vrain Basin is underlain by low permeability, igneous and metamorphic rocks, which yield limited domestic water supplies at best. The plains portion of the Basin is underlain by 8,000 to 10,000 feet of Cretaceous shales. This shale is an effective aquiclude, which prevents recharge to underlying Paleozoic and Mesozoic sandstones. The great thickness of the shale economically precludes drilling through it, even in areas where the underlying sandstones are good aquifers.

The Paleozoic and Mesozoic Formations, which underlie the Cretaceous shales, crop out along the north-south trending hogback, which flank the mountain front on the east. The hogback serves as a recharge area for these formations. The Pennsylvanian-Permian Fountain Formation, the Permian Lyons Formation and the Cretaceous Dakota Group, all consist of relatively thick sandstone sections. Domestic and small commercial water supplies are obtained from the sandstones locally. However, because these formations are so steeply dipping in the potential recharge zone along the hogback the area exposed for recharge is very limited and hence these sandstone aquifers will not sustain large yields to wells.

Unconsolidated glacial, alluvial, sheetwash and eolian deposits overlie the bedrock over much of the Basin. Glacial deposits are restricted to the upper parts of drainages and are not high-yield aquifers, due to their relative thinness (generally less than 50 feet) and the abundance of fine-grained material, which effectively lowers the permeability. Sheetwash and eolian deposits are also thin and permeability is low, due to their fine-grained texture. Yields from glacial, sheetwash and eolian deposits are generally limited to domestic supplies.

Alluvial deposits are probably the best aquifers within the Basin, consisting of floodplain and terrace deposits. These deposits consist primarily of boulders, gravel and sand with minor amounts of silt and clay. Alluvial floodplain deposits occur adjacent to streams within their floodplains. Where thick enough, these deposits will yield moderate to large quantities of water to wells. Yields in excess of 200 gpm have been reported from floodplain gravels in the St. Vrain Basin. Well yields from floodplain deposits are easily sustained, because they are hydraulically connected to the stream. Terrace deposits generally occur on elevated terraces and are most often above the water table. This means that terrace deposits are generally not saturated, as they are easily drained. Where saturated, terrace deposits will yield moderate amounts of water.

3. <u>Present Groundwater Development</u>

As of 1983, there are approximately 1,800 wells located within the St. Vrain Basin. Domestic and stock wells make up 94% of this total. Maximum potential annual withdrawal from the wells is about 37,000 ac-ft, based on reported well yields. Actual annual withdrawal is probably less than one-quarter of that or about 9,000 ac-ft. Domestic and stock wells account for about 63% of the total capacity. There are 28 irrigation wells on record at the State Engineer's Office, with an average reported yield of about 380 gpm.

4. Potential for Groundwater Development

Development of large scale groundwater supplies from aquifers within the St. Vrain Basin has very limited potential. The only aquifers which will consistently yield more than 50 gpm to wells are the alluvial floodplain deposits. These deposits are of limited areal extent.

All groundwater within the St. Vrain Basin is considered tributary by the State Engineer's Office and, therefore, development is subject to requirements for augmentation. However, wells could be developed in alluvial deposits as alternate points of diversion for existing surface water rights.

D. Trans-Basin Imports

Native runoff from the St. Vrain Basin has in recent history been supplemented by importation of water from other drainage basins. The two sources of trans-Basin water are the existing Colorado-Big Thompson Project and the Windy Gap Project, which began deliveries to the Basin in 1985. These two projects are described below.

1. Colorado-Big Thompson Project

The Colorado-Big Thompson (C-BT) Project was designed and constructed by the Bureau of Reclamation to divert, store and deliver surplus water from the headwaters of the Colorado River to the Big Thompson River on the eastern slope, for use within portions of the South Platte River Basin in Colorado. The Bureau of Reclamation presently operates and maintains all western slope facilities, and eastern slope facilities including power generation features up to and including Horsetooth Reservoir and Carter Lake. The NCWCD makes releases from Horsetooth Reservoir and Carter Lake in response to water orders and also operates and maintains all C-BT distribution features below these two terminal reservoirs. At the invitation of the U.S. Department of the Interior, the NCWCD is presently negotiating with the Bureau of Reclamation to assume full operation and maintenance responsibilities for the entire C-BT system.

a. Project Description

Construction of the C-BT Project began in 1938, and was completed in 1956. Water deliveries to the Big Thompson River began as early as 1947, with deliveries to the St. Vrain Basin as early as 1954. Full operation and official deliveries of C-BT Project water began in the 1957 irrigation season.

The C-BT Project consists of a series of reservoirs, conveyance facilities, and pumping plants which divert water from the headwaters of the Colorado River and deliver it to the Big Thompson River. Water is diverted at Willow Creek Reservoir and pumped to Lake Granby for storage. Willow Creek Reservoir water and water captured by Lake Granby is then pumped to Shadow Mountain Lake and Grand Lake. Water is subsequently delivered to the east slope, by gravity flow via Adams Tunnel, to Mary's Lake and then to Lake Estes. From Lake Estes, the water is conveyed to Flatiron Reservoir. At this point, a portion of the water is delivered north to Horsetooth Reservoir and the remaining portion is pumped south to Carter Lake. Hydroelectric generating plants operate at several locations within the eastern slope portion of the conveyance system.

Carter Lake Reservoir is the regulating reservoir for C-BT water deliveries to the St. Vrain Basin. When water users in the St. Vrain Basin call for C-BT water, the NCWCD releases water from Carter Lake into the St. Vrain Supply Canal. The canal delivers C-BT water to turnouts along the canal and to St. Vrain Creek. The St. Vrain Supply Canal becomes the Boulder Feeder Canal south of St. Vrain Creek and delivers water to those users south of the creek. In some cases, C-BT water users situated upstream of the delivery point of the supply canal exchange C-BT water for creek water with downstream users along St. Vrain Creek.

b. Water Delivery and Administration

The amount of water delivered each year to an owner of C-BT units varies according to the need within the service area for supplemental water. Each year, the NCWCD Board of Directors declares a quota for delivery of water to the owners of certified C-BT units, based upon demand forecasts. One unit of C-BT water is defined as 1/310,000th of the water supply annually made available by the C-BT Project. The quota has varied from 100% (1.0 ac-ft per unit) in a dry year, when the demand for supplemental water contained in storage is high, to around 60% (0.6 ac-ft per unit) in wet years, when the demand for supplemental water is lower. The average delivery per C-BT unit is about 0.7 ac-ft.

Actual C-BT deliveries have varied from 121,800 ac-ft in 1957, to 306,700 ac-ft in 1977, and have averaged approximately 218,500 ac-ft for the period 1957 through 1982. Deliveries to the St. Vrain Basin (including the Boulder Feeder Canal) have ranged from a low of approximately 8,300 ac-ft in 1957, to a high of approximately 51,000 ac-ft in 1977.

Within the St. Vrain Basin Study Area, approximately 25,300 C-BT units are owned by agricultural users and about 12,700 C-BT units are owned by domestic water suppliers. This ownership translates to a total water delivery to the Basin of about 38,000 ac-ft in a dry year or 26,600 ac-ft in an average year.

It is important to overall Basin water use that water delivered to owners of C-BT units can be used only once by that owner. That is, irrigation return flow from C-BT Project water must be allowed to return to the river system to benefit downstream water users.

2. Windy Gap Project

Windy Gap Project construction was completed in 1985 by the Municipal Subdistrict of the NCWCD following a 4-year construction period, and planning that began in the mid-1960's. Participating entities in the Windy Gap Project are the cities of Boulder, Estes Park, Greeley, Loveland, Longmont and the Platte River Power Authority. The City of Fort Collins was a participant initially, but subsequently has transferred its interest to other participants.

a. Project Description

The Windy Gap Project is a trans-Basin diversion scheme which utilizes unused conveyance capacity in the C-BT Project together with certain new facilities. The latter consist of a diversion dam on the Colorado River and associated pumping plant and pipeline facilities to convey diverted water to Lake Granby of the C-BT Project. Specifically, project facilities are the following:

- Windy Gap Reservoir--formed by a diversion dam located on the Colorado River, with 320 ac-ft active capacity
- Windy Gap Pumping Plant--four pumps, each rated at 150 cfs, for 600 cfs total capacity
- Windy Gap-Lake Granby Pipeline--a 9-foot-diameter pipeline approximately 30,000 feet in length
- Lake Granby Inlet Works--inlet facility to Lake Granby

b. Water Delivery and Administration

Water deliveries from Windy Gap began in mid-1985. Deliveries to the project participants will be based upon the number of units owned and allotted, according to the Water Allotment Contract. One unit is defined as 1/480th of the water supply annually produced by Windy Gap and made available by the Subdistrict. Presently, the cities of Boulder, Greeley and Longmont each own 80 Windy Gap units, Estes Park and Loveland each own 40 units, and the Platte River Power Authority owns 160 units.

With the existing project features, the yield of Windy Gap units will be variable, just as the yield of C-BT units can vary. Operation studies of the Windy Gap diversion dam, simulating 22 years of operations, indicate that an average yield of 48,000 ac-ft/yr can be developed by the project for delivery to the eastern slope. Diversions to the eastern slope are limited to not more than 90,000 ac-ft in any one year, and are not to exceed an average of 65,000 ac-ft per year in any consecutive 10-year period (Municipal Subdistrict, 1981).

It is understood that storage capacity located on the eastern slope will be necessary to even out fluctuations in both monthly and annual deliveries of Windy Gap water from the western slope, in order for this supply to be available on a firm yield basis delivered to meet a municipal monthly demand schedule. NCWCD staff have estimated that approximately 16,000 ac-ft of eastern slope storage capacity will be required to enable delivery of Longmont's entitlement on the above basis. Storage needs of other Windy Gap Project participants are not considered in this report. Additional western slope storage may also be necessary to ensure adequate inflow to Lake Granby for project deliveries under adverse hydrologic conditions.

Water delivered to the owners of Windy Gap units can be used for municipal, domestic, irrigation and industrial purposes. In addition, nothing "shall prevent the Petitioner (owner) from reusing Subdistrict water, by direct delivery, exchange or otherwise, provided the use thereof is for benefit of lands, facilities and service areas within the boundaries of the Subdistrict ..." (Municipal Subdistrict, 1981). This capability for reuse makes an acre-foot of Windy Gap Project water go further toward satisfying water demands of the unit owners, or, if the reuse right is sold, it would help to reduce the net cost of Windy Gap water.

Repayment of Windy Gap Project investment costs began in 1982, and is estimated to continue through 2014. It is likely that Windy Gap Project water will be used primarily for municipal and industrial purposes because the cost of this water is greater than can be justified for use in irrigated agriculture. It is expected that owners of Windy Gap units will vigorously pursue the sale of rights to reuse this imported water.

E. Water Administration and Management

Administration of water rights in the St. Vrain Basin by the State Engineer's Office and management of the Basin water resources by water user groups are two distinct functions described in this section.

1. Administration

The St. Vrain Basin lies in Division 1 of the State Engineer's Water Divisions. Water rights in Division 1 are administered by the Division 1 Engineer, whose office is in Greeley. Within Division 1 is Water District 5, the St. Vrain Creek Drainage Basin. The water rights within the District are administered by a Water Commissioner appointed by the Division 1 Engineer. The Water Commissioner has primary responsibility for the day-today regulation of waters in all of Water District 5. The St. Vrain Basin Study Area is located entirely within Water District 5 of Division 1.

The District 5 Water Commissioner administers the St. Vrain Basin under the statutes of the State of Colorado, which provide for a strict priority system. In administering the surface water rights system, the most senior rights usually receive a full water supply throughout the irrigation season.

Typically, based on the last 20 years, direct flow water rights with priority dates previous to and including June 30, 1864, are the most senior and receive a full water supply without need for supplemental water. Most owners of water rights with priority dates later than 1864 own some C-BT units or other supplemental supply.

Reservoir storage rights, which are junior to most of the direct flow rights, are typically in priority during the non-irrigation season and the spring runoff period. Upstream reservoirs are allowed by statute to fill out of priority, making releases later to satisfy downstream senior reservoirs in the event that such senior rights were not satisfied at the end of the storage season.

It is the responsibility of the Water Commissioner to see that all diversions for direct flow and storage are made in priority and in accordance with the terms of each individual water right decree. The Commissioner is also responsible for administration of C-BT Project water as long such water is within the St. Vrain Creek channel. Once diversion of C-BT water into a ditch has been made, responsibility for management of that diverted water is relinquished to the owner of the ditch.

2. Management

Agricultural, municipal and industrial water users are each responsible for managing their own water supplies. Agricultural water users are assisted by both the NCWCD and the St. Vrain and Left Hand Water Conservancy District. Chapter IV includes additional information on this topic. Municipal and industrial users may be assisted by the Municipal Subdistrict of the NCWCD.

Water use forecasting and planning is practiced only to a limited extent in the St. Vrain Basin, due in part to a lack of large storage reservoirs to allow control over runoff and water deliveries. The NCWCD does encourage irrigation scheduling based on crop needs, which is an important consideration in scheduling C-BT water delivery. Many ditch companies, however, do not own C-BT units or storage facilities and are, therefore, forced to rely on direct diversion from the river.

Ralph Price (Button Rock) Reservoir, owned by the City of Longmont, allows Longmont to use stored runoff in the winter or during dry summers. This is the only reservoir of substantial capacity in the Basin. Therefore, Longmont currently has more flexibility in water management than other water users.

The operation of the St. Vrain Basin water supply system is described in greater detail in Chapter IV.

F. Water Rights

1. General

The State Engineer's Tabulation of Water Rights, dated July 1, 1981, includes for the St. Vrain Basin approximately 420 decreed direct flow water rights totaling 3,846 cfs, and approximately 225 decreed storage rights totaling 221,416 ac-ft. Of these rights, 75 cfs and 115,586 ac-ft are conditional and 127 cfs and 104,420 ac-ft are for non-irrigation uses. The majority of these water rights occur on the main stem of St. Vrain Creek and on Left Hand Creek. There are also nine minimum streamflow filings in the St. Vrain Basin, eight of which have been decreed.

Straight-line diagrams, Figs. III-2 through III-5, present significant water rights in a format which allows for evaluation within their respective sub-basins. These diagrams were prepared from information gathered from USGS maps and the July 1, 1981 State Engineer's tabulation and consultation with the Water Commissioner.

Diversion records and call records for Water District 5 are kept by the State Engineer and Division Engineer, respectively.

2. Transfers and Exchanges

Because the St. Vrain Basin is over-appropriated, there have been a number of transfers and exchanges of water rights. These legal mechanisms allow for greater flexibility in beneficially using the waters of the St. Vrain Basin. A common type of exchange in the St. Vrain Basin is that in which a trade is made of upstream St. Vrain diversions for C-BT Project deliveries. A representative transfer is the 1981 City of Longmont transfer, wherein the historical consumptive use and other transferable portions of Longmont's interest in six irrigation ditches were transferred to alternate points of diversion and patterns of use. Such exchanges and transfers are one means by which water users can effect an increase in their water supply.

(B0353C)

Leonard Rice Consulting Water Engineers, Inc.

Table III-1

ST. VRAIN BASIN RECONNAISSANCE STUDY

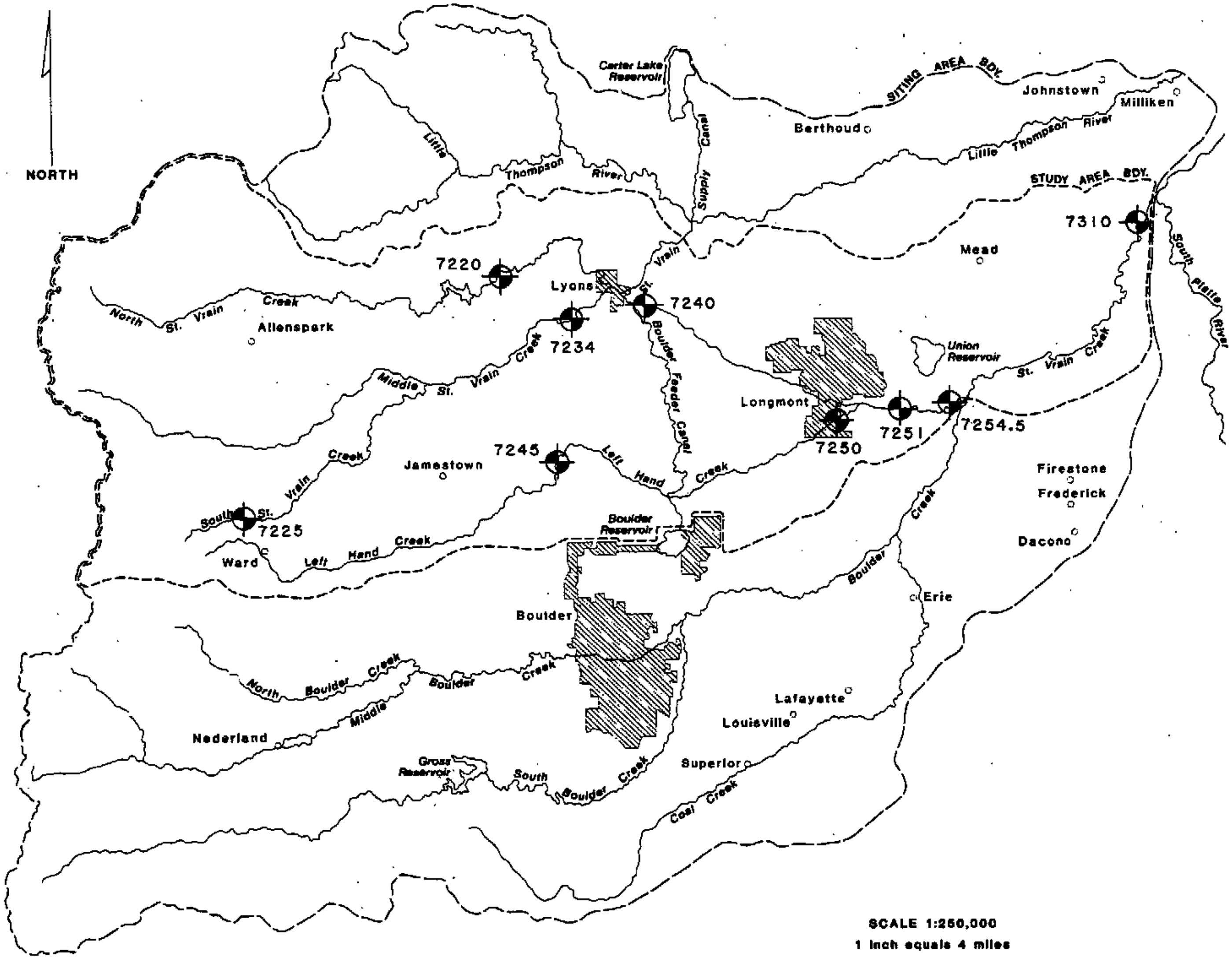
SUMMARY OF U.S.G.S. STREAMFLOW GAGES

U.S.G.S. Station	Stream	Location			Period Of Record	Elevation ft.	Approx. Drain. Area	Discharge Min. (cfs)	Discharge Max. (cfs)	Discharge Average cfs	Discharge Average ac-ft/yr
7220 (1)	North St. Vrain at Longmont Dam	R71W	T3N	S16	1926-1953	6,050	106	3.3	1,630	90	64,870
7225	South St. Vrain near Ward	R73W	T2N	S36	1925-1927 1929-1931 1955-1973	9,372	14.4	1	462	28	20,290
7234 (1)	South St. Vrain above Lyons	R70W	T3N	S19	1976-1980	5,400	81	3	932	62	45,010
7240 (1)	St. Vrain Creek at Lyons	R70W	T3N	S20	1887-1891 1895-1981 (2)	5,292	212	0	10,500	128	92,470
7251	St. Vrain Creek near Longmont	R68W	T2N	S7	1965-1968	4,890	370	12	1,810	68	49,200
72545	St. Vrain Creek below Longmont	R68W	T2N	S9	1977-1981 (2)	4,850	424	22	2,380	123	89,110
7310	St. Vrain Creek at mouth	R67W	T3N	S3	1905-1906 1928-1981 (2)	4,740	976	12	11,300	207	150,000
7245	Left Hand Creek near Boulder	R71W	T2N	S26	1930-1931 1948-1953 1956-1957 1977-1980	5,710	52	1	1,140	39.8	28,840
7250 (1)	Left Hand Creek at mouth	R69W	T2N	S10	1928-1942 1954-1955	4,940	72	0.4	812	13	9,340

Notes:

(1) Also has some water quality data

(2) 1981 - to present



R.W. BECK AND ASSOCIATES/
DAMES AND MOORE

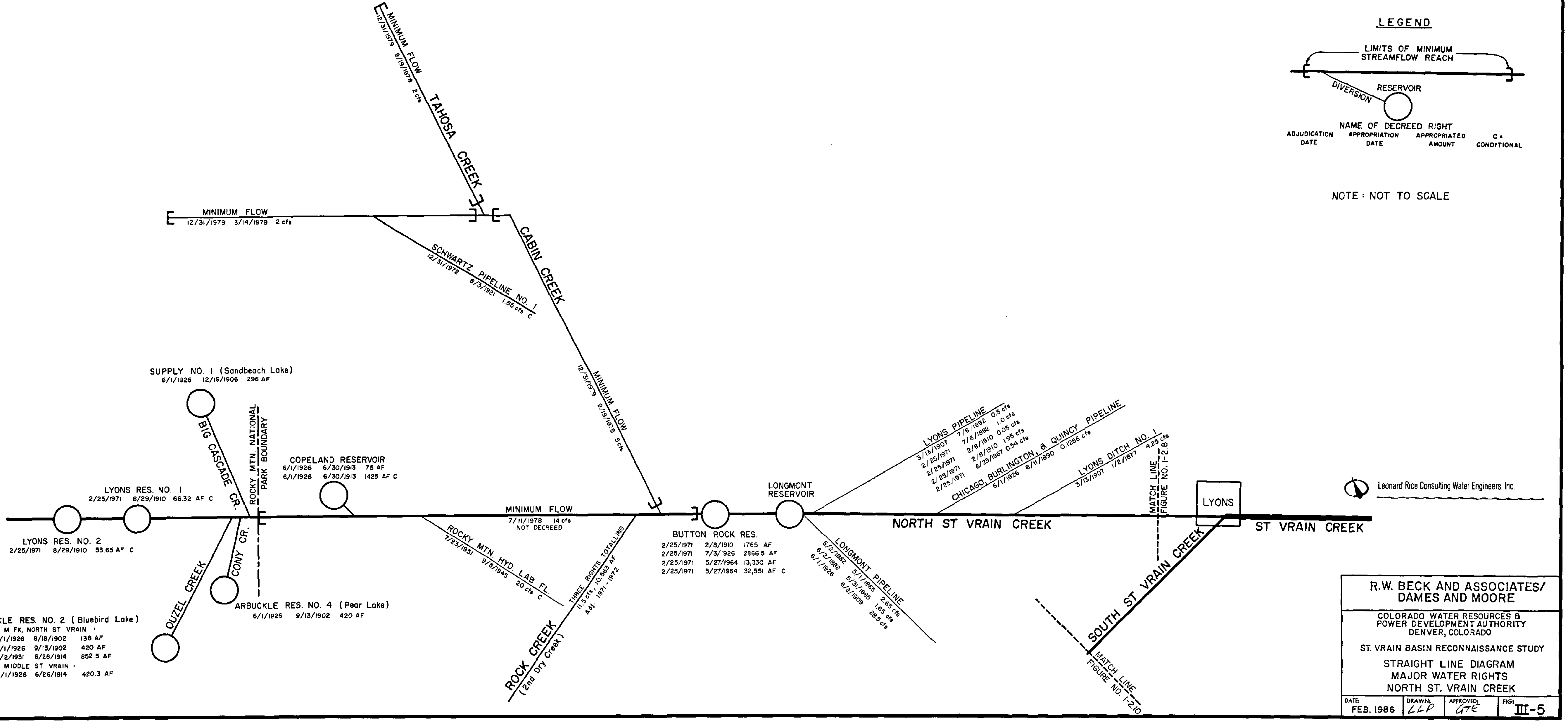
COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY
DENVER, COLORADO

ST VRAIN BASIN RECONNAISSANCE STUDY

GAGING STATION LOCATIONS

DATE:	DRAWN:	APPROVED:	FIGURE:
FEB. 1986	EQ		III-1

LEGEND
LIMITS OF MINIMUM STREAMFLOW REACH
DIVERSION
RESERVOIR
NAME OF DECREED RIGHT
ADJUDICATION DATE
APPROPRIATION DATE
APPROPRIATED AMOUNT
C - CONDITIONAL
R - REFILL
NOTES: I. NOT TO SCALE
NORTH ST VRAIN CR.
SOUTH ST VRAIN CR.
MATCH LINE FIGURE I-2.11
MATCH LINE FIGURE I-2.10
MATCH LINE FIGURE I-2.9
MATCH LINE FIGURE I-2.12
LYONS
LONGMONT
ST VRAIN CREEK
LEFT HAND CREEK
BOULDER CREEK
SOUTH PLATTE RIVER
ST VRAIN SUPPLY CANAL
SUPPLY DITCH
BOULDER FEEDER CANAL
BOULDER RES.
BAXTER LAKE RES.
DIVIDE RESERVOIR
IDE & STARBIRD NO. I RES.
HIGHLAND LAKE RES. NO. 2
HIGHLAND LAKE
KNOUTH RESERVOIR
HIGHLAND DITCH
PLEASANT VALLEY RES.
OLIGARCHY RES. NO. I (BURCH LAKE)
ROUGH & READY DITCH
PALMERTON DITCH
McCALL LAKE
LONGMONT SUPPLY DETENTION POND
INDEPENDENT RES.
LONGMONT SUPPLY DITCH
CHAPMAN & McCASLIN DITCH
OLIGARCHY DITCH
DENIO & TAYLOR DITCH
COFFMAN DITCH
RUNYAN DITCH
ZWECK & TURNER DITCH
UNION RESERVOIR (CALKINS LAKE)
McINTOSH LAKE
HIGHLAND NO. I (MULLIGAN) RES.
HIGHLAND NO. 3 (FOSTER) RES.
MARIE RESERVOIR
SANBORN RES.
THOMAS RESERVOIR
LIBERTY RESERVOIR
HOWLETT GULCH
ITLEY GULCH
DICKENS PRIVATE DITCH
DIXON MILL DITCH
287
25
SWEDE DITCH
SMEAD DITCH
MONTGOMERY PRIVATE DITCH
FOOTHILLS RESERVOIR FEEDER DITCH
SOUTH BRANCH ST VRAIN CREEK
FOOTHILLS RESERVOIR
GOSS PRIVATE DITCH
CLOUGH PRIVATE DITCH
WEBSTER & McCASLIN DITCH
TRUE & WEBSTER DITCH
DAVIS & DOWNING DITCH
CLOUGH & TRUE DITCH
JAMES DITCH
McCASLIN PRIVATE DITCH NO. I
CLOVER BASIN RESERVOIR
PELLA DITCH
PECK DITCH
N.W. MUTUAL LIFT INS DITCH
NIWOT DITCH
SOUTH FLAT DITCH
MASON MEADOW DITCH
SOUTH FLAT RES.
BECKWITH DITCH
ISLAND DITCH
CUSHMAN DITCH
GAYNOR RES.
LIBERTY PIPELINE
BONUS DITCH
COFFIN DAVIS DITCH
LAST CHANCE DITCH
HAYSEED DITCH (PUMPED)
HARDSCRABBLE DITCH
GOOSEQUILL DITCH
Leonard Rice Consulting Water Engineers, Inc.
R.W. BECK AND ASSOCIATES/ DAMES AND MOORE
COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY DENVER, COLORADO
ST. VRAIN BASIN RECONNAISSANCE STUDY
STRAIGHT LINE DIAGRAM MAJOR WATER RIGHTS ST. VRAIN CREEK
DATE: FEB. 1986
DRAWN:
APPROVED:
FIG. III-2



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ST. VRAIN BASIN RECONNAISSANCE STUDY

STRAIGHT LINE DIAGRAM
MAJOR WATER RIGHTS
NORTH ST. VRAIN CREEK

DATE:	DRAWN:	APPROVED:	FIG:
FEB. 1986	LLP	GTE	III-5


LEFT HAND CREEK
LEFT HAND PARK RESERVOIR
3/13/1907 8/5/1891 185 AF
2/25/1971 8/1/1961 1102.32 AF
WARD
CRYSTAL SPRING NO. 1
WARD DITCH PIPELINE
FROM SOUTH ST VRAIN CREEK (SEE FIG. 1-2.10)
LEFT HAND DITCH
GOLD LAKE
FROM LEFT HAND CREEK:
7/23/1951 12/31/1929 290.66 AF
7/23/1951 12/31/1929 145.34 AF C
FROM SOUTH
3/13/1907 9/1/1879 354 AF
3/13/1907 5/18/1904 82 AF
JAMES CREEK
ACME FLUMED DITCH & PIPELINE
2/25/1971 7/30/1934 10 cfs
JAMESTOWN
MINIMUM FLOW
GEER CANYON RESERVOIR
5/19/1978 12/31/1969 17,497 AF C
RED ROCK RANCH DITCH & PIPELINE
LAKE DITCH
ALLEN LAKE RESERVOIR
7/23/1951 12/2/1918 134.2 AF
7/23/1951 5/17/1927 569.5 AF
7/23/1951 12/31/1929 134.2 AF R
7/23/1951 12/31/1929 569.5 AF R
TOLL GATE DITCH (NORTH & SOUTH)
ALTONA DITCH
BADER DITCH (NO. 1 & 2)
FAIVRE SEEPAGE DITCH
TABLE MOUNTAIN DITCH
HALDI DITCH
JODER RESERVOIR
2/25/1971 7/10/1961 102.12 AF
2/25/1971 7/10/1961 102.12 AF Refill
MARGARET SPURGEON I RES.
2/25/1971 2/23/1961 247.56 AF
2/25/1971 2/23/1961 89.6 AF
2/25/1971 12/16/1961 247.56 AF C
2/25/1971 12/16/1961 89.6 AF C
12/31/1978 9/4/1977 9.89 AF C
CROCKER DITCH
LEFT HAND VALLEY INLET DITCH
LEFT HAND VALLEY OUTLET DITCH
LEFT HAND VALLEY RES.
7/23/1951 5/15/1945 10,572 AF
FENTRESS LAKE
2/25/1971 1/1/1900 71.28 AF
2/25/1971 5/10/1960 271.36 AF C
12/31/1972 1/1/1900 71.28 AF
12/31/1972 5/10/1960 ?
STAR DITCH
JOHNSON DITCH
FARMERS DITCH
HINMAN DITCH (SEE NOTE 2)
HOLLAND DITCH
STEELE BROS. RES. NO. 2
7/23/1951 12/2/1918 33.3 AF
7/23/1951 12/31/1929 33.3 AF R
STEELE BROS. RES. NO. 1
7/23/1951 12/2/1918 62.98 AF
7/23/1951 12/31/1929 62.98 AF R
BOULDER FEEDER CANAL
TO BOULDER RESERVOIR
LEFT HAND RESERVOIR
2/12/1883 4/15/1877 480 AF
SWEDE LAKE (Schureman Res.)
6/1/1926 12/31/1880 151 AF
6/1/1926 12/1/1918 72.2 AF
7/23/1951 12/2/1918 11 AF
7/23/1951 10/1/1950 14 AF
7/23/1951 10/1/1950 28 AF
LAGERMAN RESERVOIR
2/12/1883 9/3/1878 540.3 AF
COCHRAN DITCH
BAUM GOYN DITCH
LAGERMAN SUPPLY DITCH
BELCHER DITCH NO. 1
PACE PUMP PLANT DITCH
HORNBAKER DITCH
WILLIAMSON CAVEY DITCH
WAY DITCH
DICKENS R.C. DITCH
MATCH LINE FIGURE NO. 1-2.8
LONGMONT
ST VRAIN CREEK
LEGEND
LIMITS OF MINIMUM STREAMFLOW REACH
DIVERSION
RESERVOIR
NAME OF DECREED RIGHT
ADJUDICATION DATE
APPROPRIATION DATE
APPROPRIATED AMOUNT
C = CONDITIONAL
R = REFILL
NOTES: 1. NOT TO SCALE
2. NOT LISTED IN STATE ENGINEERS 1981 TABULATION
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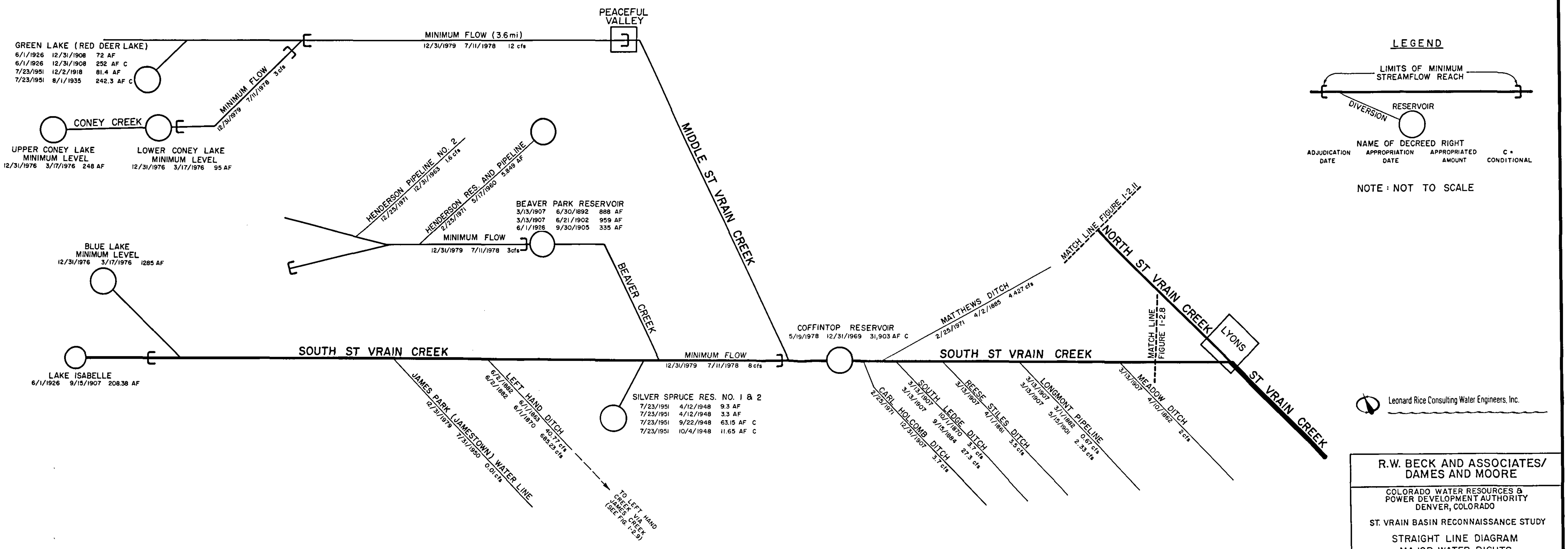
COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY DENVER, COLORADO
ST. VRAIN BASIN RECONNAISSANCE STUDY
STRAIGHT LINE DIAGRAM MAJOR WATER RIGHTS LEFT HAND CREEK
DATE: FEB. 1986
DRAWN: LLP
APPROVED: GTE
FIG: III-3



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COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY
DENVER, COLORADO

ST. VRAIN BASIN RECONNAISSANCE STUDY

STRAIGHT LINE DIAGRAM
MAJOR WATER RIGHTS
SOUTH ST. VRAIN CREEK

DATE:	DRAWN:	APPROVED:	FIG:
FEB. 1986	LLP	GTE	III-4

CHAPTER IV

WATER SUPPLY ENTITIES

A. Introduction

This section describes the organization, functioning and water supply systems, including water rights, of the various water supply entities of the St. Vrain Basin.

B. Water Conservancy Districts

There are three water conservancy districts in the St. Vrain Basin whose general purpose is to provide a means of financing and operating water projects to conserve water for municipal or agricultural water use.

1. Northern Colorado Water Conservancy District

The Northern Colorado Water Conservancy District (NCWCD) was formed in 1937, to promote, finance and contract for construction and administration of supplemental water supplies in Northeastern Colorado. NCWCD now operates the C-BT Project as described in Chapter III. The Project service area includes nearly 1,500,000 acres of land in the irrigated agricultural areas in the vicinity of the St. Vrain, Big Thompson, Cache La Poudre, Boulder, and South Platte rivers from near Platteville to the Colorado-Nebraska border.

The NCWCD is governed by a Board of Directors appointed by the District Court of Colorado. These represent the four judicial districts within the NCWCD boundaries. Funding for the district comes from a one-mill ad valorem tax on properties within the boundaries, and from revenues received for the rental of water.

The development of a supplemental water supply to users in the lower South Platte River Basin was the motivating factor in the formation of the NCWCD. In concert with formation of NCWCD, the C-BT Project was designed and constructed by the U.S. Bureau of Reclamation to divert, store and deliver the supplemental water supply.

2. Municipal Subdistrict of the Northern Colorado Water Conservancy District

Municipal Subdistrict No. 1 of the NCWCD (Subdistrict) was formed in 1970. Under provisions of the Water Conservancy Act, a subdistrict is an independent and separate conservancy district with the same legal standing and powers as the parent district. By statute, the Board of Directors of the Subdistrict is the same board as the parent district (NCWCD) and the staff of the NCWCD serves as the staff of the Subdistrict.

The Subdistrict was formed to develop the Windy Gap Project, described in Section III.

3. St. Vrain & Left Hand Water Conservancy District

The St. Vrain & Left Hand Water Conservancy District (SV&LHWCD) was formed in 1971, as a cooperative effort between municipalities and agricultural water users within the Basin.

The SV&LHWCD, whose boundaries are nearly identical to the Study Area boundary, is funded by a one-half mill ad valorem tax, in accordance with the Conservancy Act. Nine directors are appointed by the district judges of the three judicial districts within the boundaries.

The goals and objectives of the SV&LHWCD are: (1) to protect existing water rights from condemnation by municipalities, (2) to provide additional water storage capacity in the Basin for flood control, recreation and water supply, (3) to provide better management of existing water supplies through modernization of irrigation techniques, and (4) to meet State water quality and quantity standards.

To accomplish these goals, the SV&LHWCD reviews and comments on proposals for development activities. The SV&LHWCD has studied water storage projects for flood control, recreation and water supply. In 1981, the SV&LHWCD published a study for Geer Canyon and Coffintop Dam sites (Rocky Mountain Consultants, 1981). The SV&LHWCD has participated in studies related to instream flow maintenance, water quality and quantity problems and potential of St. Vrain Creek, as well as a study of irrigation management in the St. Vrain Basin (Rocky Mountain Consultants, 1983a-1983d).

C. Municipalities

1. Longmont

The City of Longmont is the largest municipal water supplier in the Basin, serving approximately 47,000 people in 1983. For the period November 1982 to October 1983, Longmont treated 11,650 ac-ft of water for residential and commercial, and 820 ac-ft for industrial purposes.

Longmont owns one new and two older water treatment plants. The older plants are located on Highway 66, about 1 mile east of Lyons. The north plant has a capacity of 10 million gallons per day (mgd), while the south plant has a capacity of 14 mgd. The new Burch Lake Water Treatment Plant located on Highway 66 has a rated capacity of 30 mgd.

Raw water is brought into the system through pipelines from North St. Vrain and South St. Vrain creeks, the St. Vrain Supply Canal and the Highland Ditch. The north pipeline diverts water from North St. Vrain, just downstream of Ralph Price (Button Rock) Reservoir, to the Longmont Power Plant west of Lyons, and then to the old water treatment plants. The south pipeline diverts water from South St. Vrain Creek, approximately 1 mile upstream of Lyons, for delivery to the old treatment plants. There is also a direct line from the St. Vrain Supply Canal, of the C-BT Project, to the old treatment plants. A recently completed pipeline delivers water from the Highland Ditch to the new Burch Lake Treatment Plant, and allows delivery of either Highland Ditch or C-BT Project water (via St. Vrain Creek) to the new treatment plant.

Longmont owns storage rights, direct flow rights, pipeline decrees, units of the C-BT Project, Windy Gap units and conditional decrees for well fields. Table IV-1 lists the absolute and conditional storage rights owned by the City and their estimated yields. Table IV-2 lists the direct flow ditch rights owned by Longmont, as of 1979. The total average yield of these rights, as reported in 1979, was approximately 8,000 ac-ft per year.

Longmont holds two pipeline decrees, one from South St. Vrain Creek and one from North St. Vrain. The south pipeline has two decrees, for a total of 3 cfs, with a reported average yield of 200 ac-ft per year. The north pipeline has one decree for 28.5 cfs, which yields an average 566 ac-ft per year. In addition, Longmont has transferred a total of 4.3 cfs from the Palmerton and Longmont supply ditches to the north pipeline. These earlier priority dates have had an average yield of 2,800 ac-ft per year (Rocky Mountain Consultants, 1979).

Longmont also owns 8,294 shares of C-BT Project water, whose average yield is approximately 5,000 ac-ft per year. In a dry year, the yield could be up to 8,294 ac-ft. Delivery of C-BT Project shares via the St. Vrain Supply Canal is currently limited to the irrigation season.

Longmont currently owns 80 units of the Windy Gap Project, which have an estimated average annual yield of 8,000 ac-ft. Initially, Windy Gap Project water will be available only during the irrigation season, since with Project facilities completed in 1985, such water is to be delivered through the existing C-BT Project system.

Acquisition of additional water rights by Longmont will occur over the years as new land is annexed to the City. Since 1976, newly annexed lands have been required to provide 2 ac-ft of direct flow and 1 ac-ft of storage water rights for each acre annexed, for eligibility to receive a treated water supply from the City.

The most pressing water supply problem facing Longmont at present is the shortage of water supply available for use during the winter season. It has been estimated that, under current population growth forecasts, the City will experience winter water supply shortages as early as 1990 (Rocky Mountain Consultants, 1979). It is possible that shortages may be reduced or postponed by annexation of storage rights, and by the anticipated delivery or sales of Windy Gap water and its reuses, and by the perfecting of existing conditional storage rights. However, Longmont will eventually require additional storage capacity or a winter deliver capability of C-BT or Windy Gap Project water to meet winter demands.

2. Town of Lyons

Lyons, located at the confluence of North and South St. Vrain creeks, supplied water to a 1983 population of approximately 1,300. The treatment plant, which receives water diverted from North St. Vrain Creek, delivered 310 ac-ft in the period November 1982 through October 1983.

In addition to a pipeline decree from North St. Vrain Creek, Lyons also owns portions of other direct flow water rights. The Town owns 275 units of C-BT Project water, and 300 ac-ft of storage capacity in Ralph Price Reservoir. Lyons' direct flow rights have been estimated to yield 780 ac-ft per year.

It is anticipated that Lyons will experience growth in the near future, which may require the addition of new water treatment facilities. It has been estimated that the future water needs approximate 725 ac-ft annually (Rocky Mountain Consultants, 1980).

3. Town of Mead

Mead, located in the lower St. Vrain Basin, serves treated water to a present population of approximately 400. The treatment plant, located near the Town, delivers approximately 90 ac-ft per year.

The Town owns an 81-ac-ft decree for Green Lake Reservoir on the Middle St. Vrain, as well as shares of the Supply Ditch and C-BT units. The average yield of these water rights is estimated at about 280 ac-ft per year.

Problems which will be faced by Mead as its population expands are mostly system-related, such as inadequate fire flows and storage of treated water (Engineering Professionals, 1981).

4. Jamestown

Jamestown, located on James Creek, a tributary to Left Hand Creek, presently serves approximately 250 people. The water system is reported to have delivered about 30 ac-ft per year in 1979 (W. W. Wheeler & Associates, Inc., 1982).

The Town owns two wells and an infiltration gallery. Shares of Left Hand Ditch Company have been used in a plan for augmentation in the decree for the wells (Case No. 79CW333), which entitles Jamestown to at least 12.5 ac-ft per year of out-of-priority depletions.

Current problems faced by Jamestown are related to summertime flow rate limitations and freezing of pipes in the winter. Jamestown is not expected to grow significantly during the planning period.

5. Town of Ward

Ward, located near the headwaters of Left Hand Creek, has a year-round population of approximately 120 people. Current water use is estimated at about 12 ac-ft per year.

The Town has a developed spring located west of town; there is no treatment facility. The only reported problem experienced by the Town is freezing pipes in the winter.

D. Water Companies

This section describes the two private water companies which provide water for rural domestic and other uses.

1. Longs Peak Water Association, Inc.

The Longs Peak Water Association, Inc. (LPWA), organized in 1960, supplies water to an area generally north of Highway 66 and west of Interstate 25. The service area is bordered on the north and east by the Little Thompson Valley Water District and on the south by Longmont.

The association currently serves a population of approximately 2,000, delivering approximately 570 ac-ft in calendar year 1983. Most of this water was used for domestic purposes.

The LPWA owns two treatment plants, each with a reported capacity of 1.5 mgd. Raw water is delivered to the plants from the St. Vrain Creek to the Supply Ditch, Rough and Ready Ditch, or Pleasant Valley Reservoir.

The LPWA owns three shares of the Supply Ditch, one share of Rough and Ready Ditch, one-half share of Pleasant Valley Reservoir, and two reservoirs near their treatment plant. In addition, LPWA owns 742 units of C-BT water. These water rights are estimated to yield about 720 ac-ft in an average year, with about 375 ac-ft of storage capacity.

The LPWA service area population is expected to increase. If C-BT deliveries were to decrease as a result of an extended drought, the LPWA customers might experience shortages.

2. Left Hand Water Supply Company

The Left Hand Water Supply Company (LHWSC) was formed in the early 1960's to provide a domestic water supply to rural users in Boulder and southwest Weld counties, covering an area of approximately 200 sq mi. Approximately 75 sq mi of this area are contained in the St. Vrain Basin Study Area.

The current population within the LHWSC service area is approximately 9,250 people. During the period November 1982 through October 1983, the LHWSC treated about 1,910 ac-ft.

The LHWSC diverts Left Hand Creek water, through Haldi Ditch, into Joder Reservoir. Their treatment plant, with a capacity of 7.0 mgd, is located near Joder Reservoir and Spurgeon No. 1 Reservoir, which have a total storage capacity of about 300 ac-ft.

Water rights owned by the LHWSC include 1,525 shares of Left Hand Ditch Company and 3,256 units of C-BT, with a total yield estimated at about 3,225 ac-ft.

The LHWSC is planning to build a new 2.5-mgd treatment plant near Niwot and is interested in acquiring storage rights in Left Hand Valley Reservoir. These two measures will help meet dry-year and wintertime demands as their service area population grows.

E. Water Districts

Water districts are formed under the laws of the State of Colorado, as quasi-municipal entities. The Little Thompson Valley Water District and the Central Weld Water District described in this chapter were formed to treat and distribute domestic water to rural water users.

The Little Thompson Valley Water District (LTVWD) and Central Weld Water District (CWWD), formed in 1962 and 1963, respectively, serve rural domestic users in parts of Boulder, Larimer and southwest Weld counties. They are discussed together since they share water treatment facilities, have the same source of water, and serve the majority of their users outside the Study Area.

The LTVWD serves an area bounded by the foothills on the west, Greeley on the east, Highway 34 in Loveland on the north, and St. Vrain Creek (east of Interstate 25) and the LPWA boundary on the south. Approximately 45 sq mi of Boulder County and Weld County served by the LTVWD are in the Study Area.

The CWWD serves an area from Interstate 25 on the west, St. Vrain Creek (in the Study Area) on the north, and the NCWCD boundary as the eastern and southern limits. Approximately 8 sq mi within the CWWD service boundary are located inside the St. Vrain Basin Study Area.

The present population served by the LTVWD within the Study Area is estimated at 2,500. For the CWWD, the population within the service area is estimated at 200. It is estimated that 600 ac-ft of the 4,665 ac-ft of water treated from November 1982 through October 1983 was for users in the St. Vrain Basin Study Area. Raw water is delivered from Carter Lake to the 7.0-mgd treatment plant owned by the two districts. The two districts own a total of

6,054 units of C-BT Project water (Denver Water Department, 1975), which yields about 4,240 ac-ft in an average year.

Population growth in these service areas is expected to continue. The present means of meeting future demands is by acquisition of additional shares of C-BT Project water.

F. Ditch Companies

Ditch companies are entities originally organized to appropriate water to be beneficially used for agricultural purposes. These companies, of which more than 20 operate within the Basin, now provide water to all types of users; however, agriculture still comprises the largest percentage of ditch company water use. This section will briefly describe the two largest ditch companies in the St. Vrain Basin.

1. Highland Ditch Company

The Highland Ditch Company (Highland) is the largest ditch system in the Study Area, serving approximately 25,000 acres of irrigated land located north and east of Longmont. There are 700 shares in Highland which share proportionately in the direct flow and storage yields of the company.

Water is diverted from the north bank of St. Vrain Creek, near Lyons, into Highland Ditch which feeds a ditch and lateral system of about 21 miles in total length. This system delivers water to and is supplemented by four reservoirs: Highland Lake and Highland Reservoir Nos. 1, 2 and 3. The storage capacity of these reservoirs totals approximately 7,000 ac-ft. In addition, Highland owns McIntosh Lake and Foothills Reservoir, which because of their locations outside of Highland's system, are used for exchange water or to satisfy calls of senior downstream diversion rights. (See Fig. III-2.)

Water rights owned by Highland are relatively junior, the earliest being a November 30, 1871 right for 205 cfs. Reported average-year and dry-year yields of the Highland Ditch direct flow rights have been about 22 ac-ft and 2.2 ac-ft per share, respectively (Rocky Mountain Consultants, 1983c).

Highland also owns storage rights totaling approximately 25,000 ac-ft. This includes refill rights and the reservoir rights for facilities which are used for exchange purposes. The yield of storage rights owned by Highland have been reported at approximately 11 ac-ft per share in an average year, and about 4.6 ac-ft per share in a dry year (Rocky Mountain Consultants, 1983c).

Because the total yield per share is very low, approximately 14,500 units of C-BT Project water are owned by the users of Highland Ditch water, as of 1983. Total average-year yield, including all sources, is estimated to be about 37,600 ac-ft.

2. Left Hand Ditch Company

In 1866, owners of all existing water rights on Left Hand Creek formed the Left Hand Ditch Company (LHDC), a corporation, combining their water rights in exchange for stock in the company. Presently, almost all water rights along Left Hand Creek are held by the LHDC. All stock is considered equal in priority. There are 16,900 shares in the LHDC, irrigating approximately 7,000 acres and serving the Left Hand Water Supply Company.

The LHDC imports water from South St. Vrain Creek into James Creek, a tributary of Left Hand Creek, thereby providing additional irrigation water. On Left Hand Creek there are about 16 major ditches, some with several headgates and delivery systems, which are the conveyance facilities of the LHDC water. The LHDC superintendent handles the distribution of water to these major ditches. Operation and maintenance of individual laterals is achieved either by the lateral owner or a hired ditch rider. The company also owns and operates several reservoirs along Left Hand Creek, as well as one reservoir, Lake Isabelle, on South St. Vrain Creek.

Water rights owned by the LHDC are numerous, combining the original direct flow and storage rights of the member ditches. The Left Hand Ditch diversion from the South St. Vrain Creek has a June 1, 1863 right for 41 cfs and a June 1, 1870 right for 685 cfs.

Reservoirs, totaling approximately 6,500 ac-ft capacity, are typically filled at the end of the irrigation season. In addition, there are currently 1,363 C-BT Project units owned by LHDC water users. Including all of the above sources, the yield of the LHDC water rights is estimated to be 22,000 ac-ft in an average year (W. W. Wheeler and Associates, 1982).

G. Other Water Suppliers

This section describes minor water supply entities within the St. Vrain Basin Study Area which serve small rural or mountain communities.

1. Allenspark

Allenspark, located in the mountains of western Boulder County, is served water by the Allenspark Water and Sanitation District. Approximately 100 year-round residents and 100 summertime only residents are served by the District, whose estimated 1983 consumptive use was approximately 9 ac-ft. Raw water comes from Willow Creek, a tributary to Rock Creek, which is tributary to the North St. Vrain Creek. The District is not expected to expand its service area nor serve a larger population in the foreseeable future.

2. Fairways Water and Sanitation District

The Fairways Water and Sanitation District serves a golf course and 13 homes east of Left Hand Valley Reservoir in Boulder County. It is estimated that this District used about 2 ac-ft in 1980, with purchased ditch water as the supply. The District is not expected to grow significantly (Denver Water Board, 1975).

3. Left Hand Water and Sanitation District

The Left Hand Water and Sanitation District serves a population of about 120 people in the "Lake of the Pines" subdivision, north of Boulder. The estimated 1980 usage is 35 ac-ft from a groundwater supply. This entity is not expected to grow because all future homes in the subdivision are to be served by the Left Hand Water Supply Company (Denver Water Board, 1975).

4. Olde Stage Water District

The Olde Stage Water District serves about 200 people in the mountains northwest of Boulder and south of Left Hand Creek. The estimated 1980 water usage is 35 ac-ft, supplied by wells completed in the Lykins Sandstone Aquifer. It is estimated that additional population growth will occur, but that the present supply will be adequate (Denver Water Board, 1975).

Table IV-1

ST. VRAIN BASIN RECONNAISSANCE STUDY

CITY OF LONGMONT

SUMMARY OF STORAGE WATER RIGHTS

Reservoir	Decreed Capacity ac-ft	Percent Longmont Ownership	20-year Average Yield ac-ft/yr	Minimum 5 Year Storage Carryover Yield ac-ft/yr
Bluebird	994	100	342(1)	92(1)
Copeland	75	100	40	15
Copeland Cond.(2)	1420	100	0	0
McCall	506	100	185(1)	101(1)
Pear	420	100	146(1)	89(1)
Button Rock	17,688	100	4,000	3,200
Button Rock Cond.(2)	32,551	100	0	0
Sandbeach	296	100	133	79
Liberty Cond.(2)	1,500	100	0	0
Clover Basin(3)	794	15	45	13
Independent(3)	164	33	28	28
Oligarchy No. 1(4)	2,130	32	271	21
Pleasant Valley(3),(5)	2,532	16	360	345
Total	61,070	—	5,550	3,983

(1) Yield if facilities were operable to full capacity.

(2) Cond. means conditional water right.

(3) Does not include shares acquired since 1979.

(4) Also known as Burch Lake.

(5) Also known as Terry Lake.

(Source: Rocky Mountain Consultants, Inc., Longmont Water Study, 1979)

TABLE IV-2

ST. VRAIN BASIN RECONNAISSANCE STUDY

CITY OF LONGMONT

SUMMARY OF DIRECT FLOW WATER RIGHTS

Ditch Name	Total Interests or Shares Owned
Beckwith	95.33
Clover Basin	41
Denio Taylor	316
Feltham[1]	All[2]
Longmont Supply[3]	152.2
Niwot	13.75
North Pipeline	All[2]
Oligarchy[3]	101.4
Oscar Beckwith	50% of ditch[2]
Palmerton[3]	6.5
Pella	220
Rough & Ready[3]	21.4
Smead[3]	25% of ditch
South Flat	324
South Pipeline	All[2]
Swede[3]	56
Upper Baldwin	12.5
Zweck & Turner	199/864[2]

Since 1979 Longmont Water Study.

(1) Feltham is owned entirely by Longmont and is used to irrigate parks. It is a 1 cfs right with an appropriation date of 7/12/-1902 and diverts from Spring Gulch, a tributary to St. Vrain Creek.

(2) These ditches are unincorporated and ownership is, therefore, not stated in terms of shares.

(3) These ditches were involved in the Longmont Water Transfer.

(Source: Rocky Mountain Consultants, Inc., Longmont Water Study, 1979 and City of Longmont, 1983)

CHAPTER V

WATER AND POWER DEMAND FORECASTS

A. Introduction

This chapter presents a forecast of water demand for municipal and industrial supplies, a forecast of potential water requirements for agriculture, and a forecast of power demand and associated need for hydroelectric generation by electric utilities in Colorado and adjacent regions. Both forecasts are made to the year 2020. Results of the forecasts are important to define the bounds of an overall water resource management plan.

B. Water Demand Forecast

1. General

This section presents the results of studies conducted to forecast future water demand in the St. Vrain Basin area identified in Fig. I-1, which includes water demands in the Left Hand Creek Basin. Water demands in the Siting Area and outside the Study Area are not considered herein. In the agricultural sector, water requirements as forecast herein are distinguished from water demand in that requirements are not related to the economic value of the water in terms of its cost, potential pricing, or willingness or ability of users to pay. In certain contexts, the term "water demand" is used where demands in the municipal and industrial sectors are aggregated with agricultural requirements, and where the three sectors are discussed together. However, throughout this report, agricultural water is forecast in terms of potential requirements rather than economic demand.

A rigorous analysis was made of water demand for the municipal and industrial sectors, and potential water requirements for agriculture, using more sophisticated techniques than generally used in reconnaissance studies. Forecasts are presented to year 2020 with high, medium, and low levels of demand estimated. Generally, the forecasts were developed based on historical trends and projected population growth and land use changes in the Study Area.

Several variables were used to forecast water demand and agricultural water requirements. In the agricultural sector, the total irrigated area, crop pattern, crop consumptive water use, population density, population location patterns, and system irrigation efficiency are considered along with population growth. In the municipal sector forecasts, household size, mean household income, price of water in Longmont, and housing patterns in Longmont are considered as influencing demand along with population. In the industrial sector forecasts, the manufacturing employment pattern with emphasis on technology-related growth is the key variable used along with population.

The total estimated water demand and agricultural water requirements for the Study Area is obtained by combining high, medium and low forecasts for each sector to obtain high, medium and low total water demand and requirement scenarios, respectively. Water demand and agricultural water requirements forecasts are given both for average weather conditions and dry/hot (drought) year irrigation season conditions for the agricultural sector and the municipal sector. For the industrial sector, only water demands for average weather conditions are presented because industrial demand in the Study Area is considered relatively insensitive to climatological variables and, also, is a small fraction of the total demand in the Study Area. Opportunities for serving other potential project purposes such as water quality, provision for water-oriented recreation, enhancement of fish and wildlife, and hydroelectric power production are also identified and quantified, as appropriate, in terms of potential water demand. Flood damage reduction is discussed briefly in terms of storage capacity for reduction of flood peaks.

2. Population Forecast

A number of different projections have been made by various organizations and entities for the population of the City of Longmont. These projections start at various base years, involve different assumptions, project to different future years, and were developed for a variety of purposes. The approach which has been applied in this Study to arrive at population projections to be used in the forecasting involved the review of other population forecasts and the categorization of those forecasts into high, medium and low categories. This review identified the fact that a recent study (Rocky Mountain Consultants, 1983b) generally typifies other projections existing in the literature. Therefore, the Rocky Mountain Consultants projections have been selected for use in this Study. Table V-1 presents the population projections for Longmont. Also shown is the relationship of the projections selected for use in this Study to those of other studies.

Population projections for the rural areas are based upon similar overall growth rates as those predicted for Longmont because no comprehensive projections were found in the literature for the rural areas. Although rural area growth rates are expected to be considerably lower than for Longmont, the error introduced by use of the Longmont rate is considered quite minor. Growth rates that are used approximate a 34% increase in population every 10 years in the high, 30% in the medium and 24% in the low forecast. Table V-2 gives the adopted projections for the various population groups for the Study Area.

Two important variables associated with population growth that affect the amount of irrigated land converted to urban use and thus ultimately affecting the agricultural water requirements in future years are: (1) population densities and (2) the ratio of irrigated acres to total acres converted to urban use. In Section B.3 below, Potential Agricultural Water Requirements, population densities of eight, six and four people per acre and irrigated land conversion ratios of 0.35, 0.55, and 0.75 are used for the high, medium and low projections, respectively.

The population densities selected are based on historical trends in and near the Study Area. The 1980 population densities of Longmont and Lyons are approximately six and two people per acre, respectively. The population density of rural areas is much less than two people per acre, whereas the density of Boulder has been as high as eight people per acre in the early 1970's. Longmont plans to annex various areas with densities covering this range. Therefore, the range of densities of eight, six and four people per acre is considered to represent the likely range of possibilities that will be experienced in the Study Area. In this estimate more weight is given to historical population densities for urban areas than those for rural areas because new population growth is expected to be associated with non-agricultural activities.

The actual irrigated land conversion ratio will depend on where new population growth occurs within the Study Area. Almost all annexation by Longmont will decrease irrigated acreage whereas conversely almost all annexation by Lyons will not decrease irrigated acres. Should most of the development occur around Longmont the ratio of irrigated acreage to total acreage converted will approach 0.75. However, should most of the development occur around Lyons this ratio will approach 0.35. The current ratio in the Study Area of irrigated acreage to total plains area acreage is approximately 0.55. Therefore, the irrigated acreage ratio range of 0.35 to 0.75 for lands converted to urban uses is considered to represent the range of possibilities of population distribution within the Study Area.

3. Potential Agricultural Water Requirements

a. General

The following subsections present estimates of potential agricultural water requirements for average and drought year irrigation season conditions. In this Study, potential agricultural water requirements are defined as the amount of water required for irrigation of cropland within the Study Area that is sufficient to satisfy potential crop consumptive use, without consideration of cost or pricing constraints on water use. Minor agricultural uses such as stock watering and domestic farmhouse use are not considered since they are not significant in terms of water quantity.

b. Forecast Approach

Primary factors which affect crop water requirements are crop pattern and the corresponding consumptive water use of that crop pattern, effective precipitation, acreage in production, and overall system irrigation efficiency. These factors are described in more detail in Section B.3.c. below. A reasonably rigorous approach was used in forecasting agricultural water requirements, utilizing monthly climatological data for a 30-year historical period and performing frequency analyses of results of calculated seasonal requirements. For a given irrigated area, the potential agricultural water requirement is determined by utilizing the following relationship:

$$\text{Diversion Requirement (ac-ft)} = \frac{(\text{Crop Consumptive Use (inches)} - \text{Effective Precipitation (inches)}) \times \text{Area (ac)}}{12 \times \text{System Irrigation Efficiency}}$$

Crop consumptive use is calculated by the modified Blaney-Criddle procedure by the use of a mathematical model which generally relates consumptive use with temperature, length of day, type of crop, and crop growth stage. Crop consumptive use is given by the following relationships.

U (Inches) = Crop Consumptive Use = F x K, where

F = Monthly Consumptive Use Factor = (Mean Monthly Temperature x Percent Daylight Hours)

KT = Climatic Coefficient = ((0.0173 x Mean Monthly Temperature) - 0.314)

K = Crop Consumptive Use Coefficient = KT x Monthly Growth Stage Coefficient

Monthly temperatures, and precipitation are basic climatological data used in the procedure. Monthly percentage of daylight hours is determined from Technical Release (TR) No. 21, Table 1 - Irrigation Water Requirements, Soil Conservation Service (SCS), April 1967, Revised 1970, (SCS TR 21, 1967). Growth stage coefficients are determined from curves in the TR 21 Appendix, for each particular crop. Effective precipitation is determined from Table 6 in TR 21. Thirty years, 1951 through 1980, of climatological records of monthly precipitation and mean monthly temperature for Longmont are utilized to calculate the estimated consumptive use of irrigation water by the above Blaney-Criddle procedure. A frequency relationship is then developed for the consumptive use of irrigation water on a seasonal basis, based on the 30 years of calculated data. Subsequently, monthly irrigation diversion requirements for the 30-year period are calculated by applying irrigation efficiency to this estimated consumptive use of irrigation water. Table V-3 presents consumptive use of irrigation water for various crops produced in the region for the period of record 1951 through 1980. Figure V-1 shows the frequency relationship for the consumptive use of irrigation water for the period of record, 1951 through 1980. These results are in general agreement with data presented in the Colorado Irrigation Guide (SCS, no date).

c. Conditions and Rationale Utilized in Forecasts

(1) Climatic Conditions

Important climatic conditions which affect potential agricultural water requirements are ambient temperature and precipitation during the growing season. Climatological data for the period of record 1951 through 1980 for Longmont are utilized for the calculation of potential agricultural water requirements.

(2) Current Irrigated Acreage

The number of acres of irrigated cropland within the Study Area is estimated to be 71,000 acres as of 1980, of which 40,000 acres are in Boulder County with the remainder in Weld County. There is no irrigated cropland in Larimer County within the Study Area. This acreage estimate is based on a quantified estimate of lands within the Study Area shown to be irrigated on the series of special maps published by the SCS which show important farmlands in various counties in Colorado (SCS, 1979). The primary sources of information used in preparing the maps are published land use maps, 1978 Landsat simulated color infrared prints, and personal communications with local planners and the SCS district conservationist. The estimate of 71,000 acres is also supported by the fact that Water District No. 5, which corresponds closely to the Study Area, reports for 1983 that 68,130 irrigated acres were supplied by ditches and 25,175 acres were supplied by ditch company reservoirs. Since nearly all the irrigated acres supplied by ditch company reservoirs are also supplied by the ditches, the 68,130 acres is considered likely to be a slight underestimate of the total number of irrigated acres in the Study Area (Palmer, 1984, personal communication). The 71,000 acres is also supported by data compiled by the Agricultural Stabilization and Conservation Service and estimates made by the U.S. Army Corps of Engineers in a 1977 study of the South Platte Basin which included the St. Vrain Basin (U.S. COE, 1977).

(3) Decline in Irrigated Acreage

Losses of agricultural land are linked to population growth in the Study Area. Since loss of agricultural acreage will occur due to an increase in population in the plains portion of the Study Area, population estimates for this area are utilized in estimating the decrease in agricultural acreage. In addition, it is also assumed that irrigated agricultural acreage would be urbanized in proportion to the ratio of irrigated acreage converted to total acreage converted to urban uses.

Based on the above assumptions, the number of irrigated acres would decline to approximately 65,000 acres, 62,000 acres, and 55,000 acres by the year 2020 for the high, medium and low forecasts, respectively. Table V-4 shows the forecast decline in irrigated acres over the planning period. The above reduction in the present acreage is based on population densities of eight, six and four people per acre and an irrigated land conversion ratios of 0.35, 0.55, and 0.75 for the high, medium and low projections, respectively.

(4) Crop Pattern

Since the Study Area includes approximately one-half of the cropland in Boulder County but only one-tenth of the cropland in Weld County (Colorado Dept. of Agriculture, 1983), the agricultural statistics of Boulder

County are used to estimate the crop pattern in the Study Area. Hay and corn have been the predominate irrigated crops in Boulder County since 1960, making up approximately 50% and 25%, respectively, of the total harvested irrigated acreage. The remaining 25% is made up of several crops with spring grains predominating. Weld County statistics were also reviewed and a similar crop pattern was found. Since crop patterns have changed little during the last 20 years, the crop pattern of 50% hay, 25% corn and 25% spring grain is utilized for the projections made herein.

(5) Crop Consumptive Use

Crop consumptive use is the amount of water used by plants in transpiration and building of plant tissue as well as that evaporated from adjacent soil and precipitation intercepted on plant foliage. Potential crop consumptive use represents the theoretical amount of water which the soil crop would consume if an adequate water supply were provided to the root zone. Estimates of potential consumptive use of irrigation water for the three primary crops grown in the Study Area as well as potential consumptive use of irrigation water for the estimated crop pattern of these three crops are presented in Table V-3. The values presented in Table V-3 are calculated by using the modified Blaney-Criddle method. These values are the consumptive use of irrigation water which includes correction of the crop consumptive use for effective precipitation, i.e., effective precipitation is subtracted from the crop consumptive use. Figure V-1 shows the frequency of occurrence of the seasonal consumptive use of irrigation water. From this figure, the consumptive use of irrigation water for a particular year having certain weather conditions can be estimated. The potential consumptive use of irrigation water for the period 1951-1980 is estimated at 21.4 inches for the one-in-ten drought year conditions and 18.4 inches for average weather conditions.

(6) Effective Precipitation

In order to determine the potential irrigation water requirements, effective precipitation must be subtracted from the crop consumptive use estimate. Effective precipitation is the amount of precipitation falling during the growing season which is available for consumptive use by crops, that is, stored in the soil root zone. It does not include water loss to deep percolation or surface runoff. Many factors influence the fraction of total precipitation that becomes effective including crop type, soil type and condition, field slope, and type and intensity of snow or rain storm. The average effective precipitation for the crop pattern in the Study Area over the growing season is 5.04 inches and was calculated using SCS methodology (SCS, TR 21, 1967) for the period 1951 through 1980.

(7) Irrigation Efficiency

The concept of irrigation efficiency must be considered in order to estimate the amount of irrigation water needed to satisfy crop requirements. For this Study, irrigation efficiency is defined as the percentage of diverted irrigation water that is stored in the soil and available for consumptive use by the crop. There are different designations for irrigation efficiencies, depending on the point of measurement. For example, if applied water is measured at the farm headgate it is called farm irrigation efficiency. If applied water is measured at the point of diversion it may be called project efficiency. Irrigation efficiency as used in this Study is overall system efficiency which takes into account water reuse within the Basin, on-farm efficiency and ditch efficiency. Water reuse is accounted for because the demand forecast refers to the amount of water diverted at ditch headgates which is affected by the amount of reuse. Another important factor is the proper timing of the application of irrigation water. Excess amounts of irrigation water over and above the potential consumptive use are currently applied in the early part of the growing season in areas supplied by some of the senior water rights. This practice has the effect of lowering overall efficiency.

A study of the South Platte River Basin (U.S. COE, 1977) indicates an average system irrigation efficiency of 43%. This estimate of current irrigation efficiency appears to be reasonable for the St. Vrain Basin based on discussions with Jim Hamilton, the District SCS conservationist for Longmont and with Bob Brandt of Rocky Mountain Consultants (Hamilton, 1984 and Brandt, 1984, personal communications). In this Study, a 50% system irrigation efficiency is used for all forecasts of future requirements. It is considered that improvements in system irrigation efficiency will occur as a result of the transfer of early season applications of irrigation water (by storage or other means) to later portions of the growing season and by the utilization of other measures such as lining of selected irrigation ditches, improved forecasting of streamflow, monitoring of soil moisture, and associated scheduling of irrigation applications. Thus, all forecasts assess the level of crop water requirements under the condition that water would be made available throughout the growing season either by storage or other means in accordance with crop growth stage requirements.

The above estimates of current irrigation efficiency are proven in the calibration of the hydrologic and water rights model (RIBSIM) developed in this Study. The RIBSIM model is described in Chapter VI. During calibration of the model, a 45% system irrigation efficiency has been found to closely correlate the current operation of the Basin.

d. Results of Potential Agricultural Water Requirements Forecast

Table V-5 presents potential agricultural water requirements for irrigation water for the high, medium and low forecasts for different conditions. Presented are water requirements for average weather conditions, for one-in-ten drought year irrigation season conditions and for one-in-ten drought year irrigation season conditions with application of 85% of the full consumptive use requirement to the crops. The condition of 85% consumptive use requirement of irrigation water applied to the crops is based on the fact that limited experimental data relating crop yield of corn to amount of irrigation water applied suggest that incremental increases in crop yield become substantially smaller as the full or maximum consumptive use of irrigation water is approached. From experimental data presented (Danielson, et al., 1977), the application of 85% of the full consumptive use of irrigation water is judged to be reasonable in a drought year.

Agricultural potential water requirements are predicted to steadily decline over the planning period with all cases considered, due primarily to the conversion of agricultural land to urban uses. Agricultural water requirements are forecast to decline over the planning period from 253,000 ac-ft per year to 219,000 ac-ft per year for the medium growth scenario subjected to 1-in-10 drought year conditions, with 100% of the full consumptive use applied. Water requirements for average weather conditions are approximately 15% lower than those for the 1-in-10 drought year irrigation season conditions.

It is important to note that the above potential agricultural water requirements reflect the quantity of water which would be required to satisfy the potential crop consumptive use. The actual demand for additional water in the Basin is also dependent upon the cost or pricing of water and the price irrigators would be willing or able to pay. The present water resources system in the Basin, even with C-BT Project imports, is not capable of supplying the calculated full amount (253,000 ac-ft) of present agricultural water requirements.

4. Municipal Water Demand

a. General

Municipal water use as defined herein refers to water delivered to users for residential and commercial supply and for public uses such as fire fighting, street cleaning and park watering, etc. The total municipal demand for surface water in the Study Area can be represented by the demand of the City of Longmont and domestic requirements of rural areas which include the towns of Lyons and Mead and other rural areas in Boulder, Weld and Larimer counties.

The general approach taken in this Study for forecasting water demand for Longmont is to relate water demand to certain variables, including population, household size, mean household income and price of water. The relationship of these variables to water demand was obtained by a review of the literature and by the utilization of historical data in the Study Area. Thus, by forecasting changes in these explanatory variables, future water demand can be predicted. Induced reduction in water demand as a result of price increases is explicitly included in the forecast for Longmont. Also, potential effects of other demand-reducing measures resulting from policy changes that could be instituted, especially during dry years, have been estimated but are not included in the forecasts since these measures are not considered representative for most years.

In this Study, water demand for rural areas is strictly correlated to population and per capita consumption. This correlation was adopted because the current per capita water demand for this portion of the population is relatively low. Also, historical data disaggregating water demand similar to that for Longmont are not available for the rural area.

b. Overview

(1) Current Conditions

Municipal water is supplied to the population of the Study Area by the water system of the City of Longmont and by a number of relatively small municipal systems and water districts.

Longmont supplies treated water for residential and commercial use to its residents which numbered approximately 43,000 in 1980. This represents a majority of the total population within the Study Area which amounted to approximately 63,000 in 1980. The water demand rate in 1983 for customers served by Longmont averaged approximately 239 gallons per capita per day which includes approximately 15 gallons per capita per day of industrial demand. Also, the above estimate includes a 15% allowance for system losses and public uses. In addition to public lands which are irrigated with treated water, certain other public lands within Longmont are irrigated with untreated ditch water and, therefore, not included in this forecast due to the small volume relative to Longmont's municipal water demand. Table V-6 presents Longmont's historical water demand data along with other statistics important in water demand forecasting.

Domestic water requirements of the rural area population totaling approximately 17,000 in 1980 are met by a number of small municipal systems and water districts. These include the municipal systems of Lyons and Mead, the Left Hand Water Supply Company (Left-Hand), Longs Peak Water Association, and the Little Thompson Water District as described in Chapter III. Table V-7 gives the 1980 population and current per capita water demand for these rural areas. The rural population of Boulder County is served by Left-Hand and Longs Peak Water Association. The rural population of Weld County is served by the Little Thompson Water District. Table V-8 shows the monthly municipal water use for the rural areas as well as for the City of Longmont.

In addition to the population served by surface water sources by the above entities, some residences located primarily in the foothills rely on groundwater. The 1980 population of these residences is estimated to be approximately 3,000 (DRCOG, 1983a). This portion of the population is not considered in the municipal demand forecast for surface water.

(2) Forecast Approach

City of Longmont

In this Study, residential water demand is correlated to household size, price, and household income. Other factors that could influence the forecast are lot size, housing values, and climate. Since income, lot size, and housing values are generally interrelated, these were not considered in the forecast. Weather was not included as an explanatory variable in the relationships developed in this Study. Thus, the relationships developed predict water demand for average weather conditions. Drought year demands are calculated using another technique as is discussed later in this section. Commercial water demand is correlated to population and water price. The relationships for predicting residential and commercial demand are given in Table V-9. Public water demand is estimated by including a 15% allowance over and above the total residential and commercial demand to account for system losses and public uses. This allowance is based on historical and expected values as indicated by Longmont's records.

Longmont's residential demand is divided into three categories consisting of single-family unmetered residences, single-family metered residences, and multi-family residences. The distinction between indoor and outdoor water demand is made because of its importance in showing differences between single and multi-family residences and in differences in sensitivity to price. The relationship between these explanatory variables and water demand was obtained by reviewing other studies and by using the 1980 Longmont data to adjust the demand relationships to local conditions (i.e. to calculate the constant term in the relationships given in Table V-9). In addition, 1976 data from Longmont were utilized to test whether the relationships accurately forecast historical demands. The 1976 and 1980 data were selected because the weather for these two years was nearest to normal of any of the years for which data were available, thus eliminating the need to incorporate weather into the forecasting relationships.

In order to estimate drought year demand for the City of Longmont, the concept of consumptive use of irrigation water in the agricultural sector is applied to the City of Longmont's outdoor use. The correlation is made between lawn watering and the irrigation of hay in the agricultural sector. By this approach an increase in outdoor use in a drought year of approximately 25% will result based on the percentage increase of alfalfa water use for a demand that is equaled or exceeded 3% of the years or a 1 in 30 chance. This is considered to be a reasonable level of protection for a municipality located on the Front Range.

Rural Areas

The demand forecast for this group of the population is based on a constant per capita demand over the planning period. Historical data describing this portion of the population are not disaggregated similar to the Longmont data. Therefore, the approach used for Longmont could not be utilized. A review of current per capita demand for the water entities serving this group shows that the per capita demand ranges from 110 gallons per day for the Little Thompson Water District to 210 gallons per day for the Towns of Lyons and Mead. Since most of the population in this group is located in areas served by Left-Hand, Little Thompson Water District and Longs Peak Water Association, a weighted average of 140 gallons per day is used in the forecast. The drought year demand for this group of the population is considered to be approximately similar to the demand for average weather conditions because of the low per capita demand and the small amount of outdoor water use due to minimal lawn watering. Therefore, no drought year estimates are made for this population group.

c. Conditions and Rationale Utilized in Forecasts

(1) Population

Section B.2 describes the population forecasts utilized in the demand forecasts presented herein. The high, medium and low population estimates are utilized to obtain the high, medium and low demand forecasts, respectively. These population forecasts are given in Tables V-1 and V-2.

(2) Household Size

Household size for Longmont is predicted to remain constant over the Study Period. This is based upon historical data which indicate, as shown in Table V-6, that mean household size decreased from 2.97 in 1970 to 2.63 in 1980 and has since remained constant.

(3) Median Household Income

Different income increases are utilized for the high, medium and low forecasts. Real income is assumed to increase at a growth rate of zero, 1% and 2% per year for the low, medium and high forecasts, respectively. These growth rates are intended to cover the range of potential real income growths for the Study Area during the planning period.

(4) Price of Water

Price of water is included as an explanatory variable in the demand relationship for metered single-family residences and for multi-family residences outdoor water demand. The 1983 price of water in Longmont was $1.05 per thousand gallons for metered service. In this Study demand forecasts are based on the premise that this price would not increase due to the cost of the Windy Gap Project in future years.

The exponential terms applicable to the water price (elasticity of demand) are derived from literature values. Based on the elasticity values reported in other studies, an elasticity term was selected for this Study to represent conservative estimates of water demands which may result in some overestimation of future water demands. This approach is considered reasonable in view of the substantial water demand reductions anticipated to occur as a consequence of initial metering.

(5) Reduction in Water Demand

Reduction in demand, sometimes termed "conservation," would be realized as a result of price increases and policy decisions made by water suppliers and/or political entities. The term "conservation" as used in this Study refers to reduced water demand only. It does not include certain broader concepts of conservation such as improved water reuse and increased storage of floodwaters and improved utilization of water within the St. Vrain Basin. In the forecasts, price-related demand reduction effects are explicitly included for Longmont as discussed above. In addition, it is estimated that a 25% reduction in water use may be achieved by policy-related measures which traditionally have been instituted during periods of water shortage (Flack, 1982). This additional degree of conservation is not accounted for in the municipal forecasts made herein because it would not be realized in most years. For the rural area forecasts, the effects of demand reduction are not considered since current per capita demand is low due to lack of significant outdoor demand associated with lawn watering.

(6) Effects of Metering

No data are yet available on annual water demand by single-family metered residences in Longmont. Consequently, for this forecasting study 1980 water use for unmetered households is reduced by 23% and 40% for indoor and outdoor demand, respectively, to allow for the effect of the $1.05 per thousand gallon charge presently in effect in Longmont. These two percentages are taken from a study that compares water demand in two nearly identical residential areas of the City of Boulder which differ primarily by the water rate charge (Burns et al., 1975). The 23 and 40% reductions used in this Study are also lower than those of an earlier Boulder study which indicate 35% and 50%, respectively, occurred as a consequence of metering (Hanke, 1970). This procedure is followed in order to calculate the constant term in the demand relationships for metered housing (Table V-9).

(7) Single-Family Unmetered Residences

Single-family residences in Longmont were unmetered until 1978. Beginning in that year meters were required on all new houses, but the meters were not used for water pricing. In June 1983 the City began charging metered single-family customers at a uniform rate of $1.05 per thousand gallons. Buyers of existing single-family residences are now required to install water meters so that the existing housing stock is converted to metered status as ownership change occurs. The current rate of sale of existing houses is 9% annually; therefore, the stock of unmetered houses declines at a rate of 9% or less annually. The single-family unmetered water demand relationships (Equations 1 and 2 in Table V-9) include both household income and household size as explanatory variables. The exponents for the two explanatory variables are both 0.4, an average of values reported in the literature (Morris and Jones, 1980; Morgan, 1973).

(8) Single-Family Metered Residences

The number of single-family metered residences is equal to the total number of single-family residences less the number of unmetered residences as shown in Equation 10 in Table V-9. The total number of single-family residences in Longmont grew at a slower rate than population during the 1970-1980 decade. In fact, it grew at a rate of 0.74 of the population growth rate. Therefore, Relationship 8 projects the number of single-family residences in Longmont.

The single-family metered water demand relationship also includes household income and household size as explanatory variables and with the same values for their exponents as are used in the unmetered case. In addition, both indoor and outdoor demand equations include water price as a third explanatory variable. The single-family metered demand relationships (Equations 3 and 4 in Table V-9) are adjusted to site specific conditions, i.e., the constant term is estimated at a price of $1.00 (nearly identical to the current price) and consumption of 77% and 60% of 1980 indoor and outdoor water demand values, respectively, for unmetered residences.

(9) Multi-Family Residences

The number of multi-family residences in Longmont has been increasing faster than the number of single-family residences in recent years. During the 1970-1980 decade, the number of master-metered units in Longmont increased 10% faster than the City's population according to Longmont Water Department records and reached a level of 559 units at the end of that period. Therefore, Equation 7 in Table V-9 projects the number of multi-family units in year N.

The multi-family indoor water demand relationship employs the same variables, function form and exponential values as those used for the single-family unmetered residences in recognition of the fact that these are master-metered units so that the marginal cost of water to residents is zero, as in the flat rate case. The multi-family outdoor water demand relationship (Equation 6 in Table V-9) follows the outdoor water demand relationship for single-family metered residences because outdoor water demand is controlled by the owner or manager who pays the water bill. This relationship is adjusted to local conditions by using 1980 multi-family data but without the assumed reduction due to metering because multi-unit residences were metered in 1980.

(10) Commercial Demand

The commercial water demand relationship (Equation 11 in Table V-9) relates demand to two explanatory variables; population and water price. The relationship is adjusted for site conditions of Longmont using 1980 data from Longmont. The price term employs the same elasticity (exponential) term as that employed for indoor residential use.

d. Results of Forecasts

Longmont water demand forecasts are shown in Table V-10 for average weather conditions. Table V-11 shows water demand for the rural area for average weather conditions. Table V-12 shows the drought year (1 in 30) municipal demand for the Study Area.

Municipal water demand for Longmont is forecast to steadily increase from 10,800 ac-ft per year in 1980 to approximately 24,700 ac-ft per year in 2020 for the medium population projection for the 1 in 30 drought year. Similarly, demand for the rural areas is estimated to increase from 2,700 ac-ft per year in 1980 to 7,600 ac-ft per year in 2020 for the medium population growth estimate. The total per capita demand for Longmont is forecast to decrease from 224 gallons per day in 1980 to 176 gallons per day in 2020 for the medium forecast, due primarily to the decrease in the number of single family residences with flat rate schedules. The decrease in per capita consumption for the high forecast is less than the medium forecast (to approximately 196 gallons per day) due to the difference in real income growth rates assumed for the high forecast.

5. Industrial Forecast

a. General

The forecasting approach taken is to relate industrial demand to manufacturing employment and to demand per employee for that employment. Manufacturing employment is in turn correlated to population growth in the Study Area. It it further predicted that the predominant type of industry that would locate in the Study Area is technology-related. Therefore, the forecasts do not include the possibility of any new water-intensive industry located in the Study Area because no evidence of this has been found. Water price considerations are not incorporated in the forecast due to the fact that water is not a major input to the types of industry presently in the Study Area, or likely to locate there in the planning period. Furthermore, industrial water demand is low relative to that of the agricultural and municipal sectors, and since most industrial demand associated with technology-related industries is not sensitive to climatological factors, refinements employing such factors are considered unnecessary.

b. Overview

(1) Current Conditions

Industrial water demand is the lowest volume of the three major categories of water demand in the Study Area. Major industrial water users include those supplied by the City of Longmont, those supplied by Left-Hand, and those industries that own direct water rights. A breakdown of the 1983 industrial water demand in the Study Area is shown in Table V-13. Industrial demand in the Study Area in 1983 was 1,900 ac-ft per year, which is a relatively minor amount as compared to the agricultural and municipal sectors. For the planning period, industrial demand is expected to remain only a fraction of the other sectors.

(2) Forecast Approach and Methodology

Future industrial water demand is divided into three separate categories. These are technology-related industrial demand such as Storage Technology Corporation (STC), non technology-related industrial demand such as Longmont Foods, and energy-related water demand such as Public Service Company of Colorado (PSC). The basic approach used in estimating technology-related and non technology-related industrial water demand is to relate the demand to employment in each of these sectors and to a demand per employee per day for that employment. The number of people employed in each of the sectors is projected based on ratios that relate employment to population. As explained above, water price considerations and climatological factors are not included in the forecast.

Water demand by the energy sector is projected to remain constant over the planning period since expansion of generating capacity at the St. Vrain power plant site is unlikely prior to 2020.

Industrial water demand, therefore, is based on the following relationships.

a) "Technology-Related" Water Demand
$HT(n) = HT\ (1980) + 0.00112 \times PI \times WF \times M \times PCD\ (HT) \times F(HT)$

b) "Non-Technology-Related" Water Demand
$NHT(n) = NHT\ (1980) + 0.00112 \times PI \times WF \times M \times PCD\ (NHT) \times F(NHT)$

c) PSC Water Demand
PSC Water demand is assumed constant during the planning period.

where:

HT(n)	= Total technology-related water demand for nth year
HT (1980)	= Technology-related water demand in 1980
NHT(n)	= Total non-technology-related water demand for nth year
NHT (1980)	= Total non-technology-related water demands in 1980
PI	= Population increases in the Study Area over the period (n-1980)
WF	= Fraction of the total population which makes up the workforce
M	= Fraction of total new jobs which are basic (manufacturing) jobs

F(HT) = Fraction of total new manufacturing jobs which are technology-related

F(NHT) = Fraction of total new manufacturing jobs which are non-technology-related

PCD (HT) = Per employee per day demand for technology-related industry

PCD (NHT) = Per employee per day demand for non-technology-related industry

c. Basic Conditions and Rationale Utilized in the Forecast

The conditions and rationale for these conditions utilized in projecting the industrial water demand for the high, medium and low forecasts are given below.

- o The total number of jobs in the Study Area is assumed to be equivalent to the number of employed persons who live in the Study Area. A review of vital statistics compiled by the City of Longmont shows that in 1981 86% of the total jobs in the Study Area were filled by persons living in the Study Area (City of Longmont, 1982). It is expected that this percentage will increase somewhat as industry continues to locate in the St. Vrain Basin.

- o The percentage of the total Basin population which makes up the workforce is assumed to remain constant at the current 50%. A review of 1980 Census Bureau data for the Study Area shows that 31,000 persons were employed out of a total of 63,000 persons residing in the area, or approximately 50% of the total (DRCOG, 1983a). This percentage is similar to values for Boulder County and Denver in 1980.

- o Of the total increase in overall employment estimated for the Study Area, 50% of these jobs are assumed to be basic jobs, i.e., jobs that produce goods and services that are sold outside the Study Area, and 50% service support jobs. The City of Longmont estimates that for each new manufacturing or basic employment job established, between 0.98 and 1.37 new service jobs will be created (City of Longmont, 1982). The value of 1.0 is chosen for this Study as a reasonable estimate.

- o All future basic jobs are assumed to be manufacturing jobs. This assumption that 100% of all future basic jobs will be in the manufacturing sector results in a maximum forecast of industrial water demand.

- o New manufacturing jobs in the Basin are anticipated to be approximately 80% technology-related, and 20% other manufacturing (Miller, 1984, personal communication). In the last few years, recent expansion of manufacturing in the Study Area has been primarily technology-related; for example STC and Mini-Scribe have both moved into the Study Area in the last few years. In addition, current plans call for the building of a major facility by Hewlett-Packard to the east of Longmont in Boulder County. Thus, it seems reasonable to assume that a large percentage of increased manufacturing employment in the Study Area will be technology-related.

- o Daily per employee water demand at technology-related facilities is estimated to be 100 gallons based on 365 days per year. This estimate is derived based on 1983 use at STC's facility located in Longmont.

- o Daily per employee water demand for future non-technology-related manufacturing is estimated to be 300 gallons based on 365 days operation per year. This estimate is based on 1983 usage at Longmont Foods Turkey Plant and is judged to be representative of future non technology-related manufacturing that would likely locate in the Study Area.

- o No future expansion of thermal power generating facilities is projected to occur in the Study Area prior to 2020. Thus, energy-related water demand is projected to remain constant over the planning period. The St. Vrain nuclear power plant site has additional acreage available for facility expansion. However, based on current power demand forecasts, expansion at this site is judged to be unlikely prior to 2020 (Van Volkenburg). In the forecasts, a 1,000 ac-ft per year demand supplied from the St. Vrain Basin is accounted for although there is a 3,100 ac-ft demand at the Fort St. Vrain nuclear power plant. The remaining 2,100 ac-ft per year which is currently supplied from outside the St. Vrain Basin, may at some future time be supplied from within the Basin. However, this would be accomplished by transferring water currently used for agricultural purposes by the plant owner to industrial use. Hence, total water demand within the Basin would not be affected.

d. Results of Industrial Demand Forecast

The forecast industrial water demand in the Study Area for the low, medium and high population growth is presented in Table V-14. The total projected industrial demand rises from its 1980 level of 1,770 ac-ft per year to levels of approximately 5,100, 5,900, and 7,200 ac-ft per year for the low, medium and high population growth scenarios, respectively. Although employment in technology-related industries is predicted to predominate in the future, technology-related and non technology-related demands are estimated to be approximately equal in 2020 due to the lower per employee daily water demand for the technology-related industries relative to the non technology-related industries.

6. Total Water Demand

The potential agricultural water requirements forecasts presented in Table V-5 and municipal and industrial water demand forecasts presented in Tables V-12 and V-14 are combined to estimate the total water demand for the Study Area. Drought year conditions along with medium population projections for 2020 are used herein for planning. Total water demand is estimated for high, medium, and low scenarios for varying conditions regarding the important variables such as population growth, income growth patterns, population density, etc. A scenario for a particular level of demand includes the summation of corresponding forecasts for the agricultural, municipal and industrial sectors. Table V-15 presents forecast total water demand for drought year conditions utilized in planning as undertaken in this Study.

Total water demand for the medium scenario is forecast to decrease from 268,000 ac-ft per year in 1980 to 257,000 ac-ft per year in 2020 when 100% of the full consumptive use is applied to the crops. If 85% of the full consumptive use were applied to the crops, the demand would decrease from 230,000 ac-ft per year in 1980 to 224,000 ac-ft per year in 2020 for the medium scenario. The decrease in total demand in the future should not be interpreted as meaning there is no further need to develop the Basin's water resources. This is because, as further discussed in Chapter VI, the estimated full demand requirements cannot be supplied by the water resources as now developed.

Municipal and industrial water demands are forecast to increase throughout the planning period while the potential agricultural water requirements decrease because of conversion of agricultural land to urban use. The decrease in potential irrigation water requirements is larger than the increase in municipal and industrial water demand for the medium and low scenarios, resulting in a decrease in forecast total water demand over the planning period. For the high scenario the increase in the municipal and industrial demand is larger than the decrease in potential agricultural water requirements and, consequently, the total water demand forecast shows an increase over the planning period.

7. Water Demand Considerations in Relation to Other Plan Purposes

a. General

A range of potential water management plan purposes was identified based on the technical analyses and evaluations conducted in this Study and upon the issues and concerns expressed by the Study advisors and others. The primary purposes of plans to be considered are to deal with water supply needs in the Basin. However, other purposes are identified that should be included in association with the primary water supply purposes. These other purposes are enhancement of fish and wildlife, provision of water-oriented recreation, improvement of water quality, flood protection, and hydroelectric power production.

The discussion of other plan purposes in this section is for the purpose of considering potential water quantity or storage capacity factors related to such plan purposes. It provides preliminary descriptions of benefits that may be attainable from flow management, primarily in conjunction with the primary water supply purposes addressed in the Study. This section does not provide a comprehensive discussion of potential measures for achieving other plan purposes and in particular does not identify non-structural measures.

b. Enhancement of Fish and Wildlife

Any implemented water supply management measure is likely to have some beneficial and/or adverse impact upon fish and wildlife. During later stages of project development (subsequent to this Study) impact analyses will be performed to identify expected impacts and to develop specific mitigation measures to alleviate such impacts as well as taking advantage of opportunities presented to enhance fish and wildlife.

One measure which can be addressed quantitatively at present commensurate with the reconnaissance level of detail of this Study, is flow augmentation in association with the construction of a reservoir(s) to maintain and improve fish life in St. Vrain Creek in the reach from approximately Lyons to Hygiene Road. This reach of the creek is considered important as a coldwater fishery. Instream flow studies (Rocky Mountain Consultants, Inc., 1983a; DRCOG, 1983b) concluded that flows 15 to 30 cfs year-around in the main stem of St. Vrain Creek along with habitat improvement structures would substantially improve the creek as a fishery. Utilizing the 30 cfs flow criterion along with monthly historical flow data recorded in St. Vrain Creek at Oligarchy Creek during 1954, which was a historical dry year, an estimate of approximately 12,000 ac-ft per year would be desirable to augment the historical dry-year flows to 30 cfs for every month during the year. The 1954 historical flows ranged from zero in September to an average of 47 cfs in July. This target amount can be considered in association with water management practices that will be studied in the Basin. It should be noted that this estimate will need to be reviewed in the future once specific alternative plans are identified in terms of reservoir locations and their capacity along with resulting flows downstream of the reservoir(s).

c. Water-Oriented Recreation

Generally, there are three basic types of opportunities for recreation that could be provided by a water resources management plan. First, opportunities would be provided in association with a potential reservoir (lake-type recreation) such as boating, picnicking and hiking. Second, stream corridor recreational opportunities could be provided such as trails for various activities. These types of opportunities should be investigated and incorporated into future studies (subsequent to the present Study). Third, a reservoir associated with a particular water resources management plan could provide more water available for flow augmentation downstream to improve stream corridor recreational opportunities. The consideration of 12,000 ac-ft per year of water to enhance fish and wildlife will also improve the fishing opportunities downstream of a potential reservoir by providing a better quality fishery.

d. Water Quality

Water quality considerations in the Study Area can be divided into two general categories. First, there are water quality considerations with respect to maintaining a cold water fishery from Lyons to Hygiene Road and second, considerations with respect to the impact of irrigation return flows below Longmont. The quality of St. Vrain Creek water at Lyons is good. Numeric stream standards have always been attained in the past. The amount of water considered for flow augmentation for fishery improvement which is 12,000 ac-ft per year would also have a beneficial impact on water quality. It is estimated that this flow augmentation would result in a reduction of approximately 20% in the total dissolved solids (TDS) levels to an average of approximately 200 mg/1 at Hygiene Road based on average water year flow conditions. However, the present concentration of TDS at this location is definitely not at a problem level. In addition, though, flow augmentation would result in water quality improvements downstream of Longmont where higher TDS levels are presently experienced. The augmented discharge of St. Vrain Creek would also result in improved receiving water conditions for Longmont's treated wastewater effluent. This improvement possibly could result in a lesser degree of treatment required in terms of ammonia removal, but this potential has not been investigated.

Along with flow augmentation possibilities considered in this Study, consideration of better management practices to control non-point sources of pollution from irrigation return flows are recommended by DRCOG to improve water quality below Longmont (DRCOG, 1983b). At present, consideration of flow augmentation for fishery improvement is also considered adequate for water quality improvements.

e. Flood Protection or Flood-Damage Reduction

This discussion is limited to consideration of storage of peak flows to reduce downstream discharges, as this approach is related to construction of reservoir storage for water supply purposes. A comprehensive flood damage reduction program would consider other structural and a number of non-structural measures also.

In order to estimate an amount of storage volume needed to detain excess runoff for the reduction of flood damages, a flood hydrograph was compiled that indicates discharge as a function of time associated with a particular storm event. A storm event of 6-hour duration with a 100-year recurrence interval was selected for this Study. The method used for the hydrograph calculation is an SCS method based on computing direct runoff by use of curves founded on field studies of the amount of measured runoff from numerous soil cover combinations. Assuming that all runoff above 1,000 cfs, the assumed bankfull channel capacity, would be stored in a reservoir generally located upstream of Lyons on St. Vrain Creek, approximately 10,000 ac-ft of capacity would be required. Therefore, 10,000 ac-ft of storage capacity is considered in plan formulation for this purpose. It should be noted that this volume does not represent a need for new water but rather dedicated space in a reservoir to temporarily store floodwaters.

Estimation of flood damages, and the relationship of damages to discharge, as well as all other economic aspects and potential non-structural measures related to flood damage reduction, are outside the scope of this Study.

f. Hydroelectric Power Production

Hydroelectric power production is considered in this Study in association with alternative plans incorporating storage reservoirs, and in pipelines where sufficient head and discharge would occur. There is no obligation on the part of this Study to identify new power resources to provide for projected deficiencies. Therefore, no new water supply is targeted for plan formulation with respect to hydroelectric power production. The potential marketability of power generated from a St. Vrain hydroelectric project is discussed in the next section.

C. Power Demand Forecast

1. General

The marketability of hydroelectric power from a St. Vrain project was discussed with principal Colorado utilities and several utilities in adjacent states. The market for such power would most likely come from utilities located within the state of Colorado because transmitting power, particularly peaking power, for substantial distances can adversely affect project feasibility. For this reason, the following power demand forecast and preliminary market assessment is focused on, but not limited to, the principal power suppliers in Colorado. However, potential markets in adjacent states, which are within reasonable transmission reach of the St. Vrain Basin, were also assessed. Needs of utilities east of Wyoming, Colorado, and New Mexico were not assessed as the western transmission system does not operate in synchronism with the transmission systems in the states to the east. Consequently, it is not reasonable at this time to consider the states to the east as part of the market for a St. Vrain project. In addition, the Western Area Power Administration (WAPA), a federal agency, was also contacted to obtain its plans for generation additions. Certain additions to existing federal hydroelectric capacity now being marketed by WAPA are in the planning stage, and such capacity additions have been included in the tabulation of area resources which will be available to serve future area loads. The following is a listing of the utilities and agencies contacted during the Study.

Colorado	Adjacent States
Public Service Company of Colorado	Utah Power and Light Company
Tri-State Generation and Transmission Assn.	Arizona Public Service Company
Platte River Power Authority	Salt River Project
Colorado-Ute Electric Association	Public Service Co. of New Mexico
City of Colorado Springs	Plains Electric G&T Association
Arkansas River Power Authority	Wyoming Municipal Power Agency
Western Area Power Administration	

The general service areas of these principal power suppliers are shown in Fig. V-2.

Although it is recognized that numerous smaller utilities exist within the state, the above listed Colorado utilities are considered to represent the most likely markets for power from a potential St. Vrain project due to the comparative size of these smaller utilities.

Because of the relatively limited streamflow available in the St. Vrain Basin, development of conventional run-of-river hydro generation would be limited in capacity to relatively small installations. Generation at such installations, if the power and energy output were competitively priced, could be marketed locally to utilities presently providing service in the immediate area. Specifically, the closest utilities include the Platte River Power Authority, Public Service Company of Colorado, and Tri-State G&T Association.

In the section that follows, the projected loads and resource plans for the Colorado utilities most likely to purchase Project power are presented to demonstrate the potential market for additional resources. Table V-16 shows a summary of findings and conclusions of the six Colorado utilities and WAPA.

The power demand forecast presented herein was conducted in December 1983, and therefore represents conditions prevailing at that time.

2. Colorado Utilities

a. Public Service Company of Colorado (PSC)

PSC, headquartered in Denver, is the state's largest investor-owned utility serving approximately 800,000 electric customers in 42 cities and towns including the Denver metropolitan area.

(1) Present Loads and Resources

In 1982, PSC, normally a summer peaking system, experienced a peak demand of 2,809 MW. The peak demand recorded for the summer of 1983 was 2,915 MW, an increase of 3.8% over 1982.

PSC categorizes its existing resources as follows:

	Capability (MW)
Baseload Capacity	2,410
Intermediate Capacity	242
Peaking Capacity	429
Net Purchases	164
Total Resource Capability ..	3,245

(2) Projected Loads and Resources

PSC prepares and updates a report each year entitled "Electric Load and Generation Resource Plan." The report dated June 1983 contains PSC's load projections and resource plans to year 2002. PSC states that it has not prepared projections and planning studies beyond 2002 and consequently is unable to furnish data to 2020.

The peak load and energy projections set forth in the June 1983 load and resource plan were developed by PSC using several data sources, but principally the Customer and Sales Forecast published by the PSC Corporate Planning Division. Both the peak and energy demand forecasts are based on econometric modeling, sales-per-customer analyses, assumptions of future economic activity, both nationwide and in the PSC service area, as well as other data sources described below.

PSC is projecting that its annual peak demand will grow from 2,809 MW in 1982 to 4,674 MW in 2002, which represents a 2.6% annual growth rate. For the period 1997 through 2002, PSC projects a growth rate of 2.1% per year. In the absence of extended projections from PSC for the years after 2002, continuation of a 2.1% annual growth rate is considered reasonable by the Study Team for extending load projections to the year 2020 for the purpose of this Study. On this basis, PSC's firm load in 2020 is estimated to be approximately 6,800 MW. If 15% is added to this figure for reserves (considered to be a prudent level of capacity reserves for planning purposes), PSC's capacity requirement in 2020 is estimated to be approximately 7,800 MW.

Firm load reduction estimates due to conservation and load management were developed by PSC from its direct load control program conducted in 1982. The results were developed using PSC's marketing load research and a benefit/cost study performed by PSC's System Planning Department. The load reduction estimates incorporated into PSC's annual peak load projections described above are 23 MW in 1984, increasing to 205 MW in 2002.

PSC anticipates increasing its generating capacity 560 MW by 1992 through the addition of the 485-MW Pawnee No. 2 generating unit and a 75-MW Fort St. Vrain nuclear plant uprating. Additional purchases from area utilities are estimated by that time to bring PSC's total effective resource capability to approximately 4,200 MW. Beyond 1992, PSC is planning to add baseload, coal-fired generating capacity, as yet unsited, and supplement its resources as necessary through capacity purchases from other utilities. Based on estimated resource requirements of 7,800 MW in 2020, PSC will require approximately 3,600 MW of resource additions, both baseload and peaking, from 1992 to 2020 plus replacement capacity for present generating units retired during that time period.

(3) Estimated Power Needs

PSC has indicated that it may be interested in obtaining 100 to 200 MW of additional peaking capacity by the late 1990's if economically attractive when compared to other alternatives. PSC now has in service approximately 400 MW of peaking capacity. On this basis it appears that PSC may be able to effectively utilize approximately 12% of its total load (excluding reserves) in peaking capacity or a total of 800 MW in 2020. Consequently, PSC may be interested in an additional 400 MW of peaking capacity by 2020, if economically priced.

b. Tri-State G&T Association (Tri-State)

Tri-State is an electric generation and transmission cooperative association headquartered in Denver. It operates on a nonprofit basis and provides wholesale electric service to 21 electric distribution cooperatives and four public power districts in the states of Colorado, Wyoming and Nebraska.

(1) Present Loads and Resources

Tri-State's annual peak demand requirements in 1982 was approximately 1,020 MW not including reserve requirements. The 1983 peak demand was approximately 930 MW, a reduction of 8% from the 1982 peak demand. Tri-State believes that a major reason for the load decrease in 1983 is the federal government's Payment In Kind (PIK) Program. The PIK program provides for payment in kind in lieu of crop production which reduces irrigation pumping requirements, a substantial component of the Tri-State load.

Tri-State's present power supply resources total 1,733 MW and consist of the following components:

	Capability (MW)
Baseload	
WAPA Allocation:	
Missouri River Basin	266
Colorado River Storage Project .	252
Purchases - Basin Electric	316
Craig Station	206
Laramie River Station	398
Peaking	
Republican River Station	195
Burlington Station	100
Total	1,733

(2) Projected Loads and Resources

Tri-State has projected demand and energy requirements to 2015 in a July 1983 loads and resources study. The utility furnished additional projections covering the Study period to 2020. Tri-State, in its expanded studies, projects total capacity requirements in year 2020 of 2,100 MW (including reserve requirements) compared to a total requirement in 1983 of approximately 1,280 MW. This represents an annual load increase of approximately 1.3% over the entire Study period.

Currently, the only resource additions planned by Tri-State for the period 1983 to 2020, in accordance with its July 1983 loads and resources study, are as follows:

	Capability (MW)	
Summer-Winter capacity exchange with Colorado-Ute	70	(beginning 1987)
Additional purchases from Basin Electric in accordance with existing contract	174	(increase over Study Period)
Total	244	

Consequently, together with existing resources of 1,733 MW, Tri-State currently plans to have available in 2020 resources totaling 1,977 MW.

(3) Estimated Power Needs

Tri-States' estimated capacity requirements of 2,100 MW in the year 2020 indicate that a deficit of 123 MW will exist at that time. However, Tri-State does not project capacity deficits to begin until 2014. Consequently, due to the speculative nature of projected capacity requirements 30 years in the future, Tri-State cannot realistically be included as part of a market for capacity from a potential St. Vrain hydroelectric project.

c. Platte River Power Authority (Platte River)

Platte River is a political subdivision of the state of Colorado and supplies electrical energy at wholesale to the four Colorado municipalities of Estes Park, Fort Collins, Longmont, and Loveland.

(1) Present Loads and Resources

Platte River experienced a peak demand of 201 MW in 1982 and approximately 224 MW in 1983, an increase of 11.4%. The prolonged cold weather experienced in December of 1983 is thought to be responsible, in some degree, for the higher peak demand in 1983.

Platte River's existing resources, including the 250-MW Rawhide Station, Unit No. 1, which commenced operation in 1984, are as follows:

	Capability (MW)
WAPA Allocation (Baseload)	235
Craig Station (Baseload)	149
Rawhide Station (Baseload)	250
Total	634

(2) Projected Loads and Resources

Platte River had estimated a peak demand for 1983 of approximately 200 MW, increasing to 620 MW by year 2000 and 2,400 MW by year 2020. These projections reflect annual load growth of approximately 7% and do not include reserves.

Platte River's load projections are based on requirements for electric energy for resale within areas presently served by the member cities and reflect a continuation of historical trend, geographic location, and growth potential of the areas and types of customer classes being served.

Platte River's Rawhide Unit No. 1, a 250-MW coal-fired generating facility, is located approximately 18 miles north of Fort Collins and started commercial operation in April 1984. Rawhide Unit No. 1 together with associated transmission facilities constitute the initial facilities of the Rawhide Energy Project. The Rawhide Energy Project is planned to ultimately include an additional two generating units of 250 MW each for a total capacity at the Rawhide site of 750 MW.

(3) Estimated Power Needs

Based on Platte River's latest load projections, its existing resources will serve its load through the mid-1990's. As one future resource alternative, Platte River is considering construction of a second Rawhide unit. Construction of a second Rawhide unit for operation in the mid- to late-1990's would provide sufficient capability to serve projected load only until the early 2000's. Peaking capacity, if available in the latter part of the 1990's, and if economically attractive, might defer a second Rawhide unit for a short period of time. Otherwise in the period 2000 to 2020, Platte River might be interested in 50 to 150 MW of peaking power, if available in an optimum location and if competitively priced. Platte River, with transmission facilities located in the Longmont-Loveland areas would be able to utilize power resources developed in the St. Vrain Basin with a minimum of transmission losses and capital expenditures.

d. Remaining Colorado Utilities

The remaining three Colorado utilities surveyed in this Study, Colorado-Ute Electric Association, City of Colorado Springs, and Arkansas River Power Authority, are considered less likely to be purchasers of power from a project developed in the St. Vrain Basin than all the utilities discussed previously because of lengthy interconnection requirements. A summary of projected loads and resources for each of these utilities is included, however, in Table V-16 so that this table reflects the findings of the overall survey conducted.

3. Western Area Power Administration (WAPA)

In December 1977, WAPA was established to administer federal transmission and power marketing activities which had previously been performed by the United States Bureau of Reclamation (USBR). The Loveland-Fort Collins area office of WAPA markets and delivers power generated principally in Colorado and Wyoming from federal hydro projects operated by the USBR. Allocations of WAPA power from the federal hydropower resources have been made to those Colorado utilities qualifying under preference provisions of federal Reclamation Law. The amounts of such allocations have been listed as resources when appropriate for the Colorado utilities discussed previously. In general, federal, state, and municipal entities and REA-financed electric cooperatives qualify to receive such allocations.

WAPA plans to reallocate its resources for the period after 1989 but, based on information presently available, it is assumed that the allocation of existing WAPA resources would remain essentially unchanged for this

Study after 1989. In addition, WAPA has announced that the USBR is planning certain capacity addition in Colorado and Wyoming which will add 169 MW of capacity by 1990 to the hydroelectric resources being marketed by the Loveland-Fort Collins area office. The capacity of these additions has been included as a future planned resource for the Colorado area. A portion of the 169 MW ultimately may be marketed to utilities other than those major Colorado utilities discussed herein but the ultimate utilization of these resources will not be known until WAPA's post 1989 marketing criteria, now being formulated, have been finalized. Therefore, in order to determine a conservative forecast of future resource requirements, the 169 MW is included as a planned resource for the Colorado utilities.

WAPA does not function as an electric utility in the true sense of the word since it does not have utility responsibility to serve the expanding electrical needs of customers in a defined area. However, WAPA does perform certain power supply coordination activities which can affect the systems of the utilities interconnected with WAPA and could be helpful in the marketing of power from a St. Vrain project. Additionally, WAPA has major transmission facilities in Colorado which could be important in the delivery of project power to a utility utilizing such power.

4. Utilities Providing Service in Adjacent States

In assessing the marketability of power from a project that might be developed in the St. Vrain Basin, studies have focused primarily on the long-range requirements of Colorado utilities and particularly those adjacent to the St. Vrain Basin. As noted earlier, any conventional hydro capacity developed in the Basin will be small, which can be easily absorbed by the immediately adjacent utilities if economically competitive. Also, the marketing of pumped storage peaking capacity inherently becomes more difficult as transmission distances and number of intervening utilities increase. Therefore, for the purposes of this Study, utilities outside of Colorado are not considered to be potential purchasers of project power.

5. Power Transmission

All of the Colorado utilities discussed herein are interconnected through the transmission system comprising the western transmission grid. In addition to facilities owned by the utilities discussed previously, the western transmission grid contains substantial facilities constructed and owned by WAPA to deliver allocations of hydro power to its customers from the USBR hydroelectric projects located in Colorado and adjacent states. As a matter of precedence, wheeling and interconnection agreements now exist between the parties which provide for delivery of power and energy by one party across transmission facilities owned by another. Consequently, we believe that arrangements could be made to deliver power and energy from a St. Vrain project to the various utilities discussed herein. The complexity and cost of such arrangements would depend, of course, on the amount of power involved and the timing of such deliveries with respect to system capability. Generally, additions are made to the transmission system from time to time by the party or parties creating the need for such additions.

The transmission system in the immediate vicinity of the St. Vrain Basin is comprised of transmission lines and substations owned by PSC, WAPA, Platte River, and Tri-State. Lines owned by these entities are then interconnected with the other in-state utilities and with utilities in adjacent states. If a pumped storage project were developed in the St. Vrain Basin, and the project output utilized by the adjacent utilities, pumping power could be provided from PSC's plants in the Denver, Boulder, and Brush areas, Platte River's capacity at Craig and Rawhide stations, and Tri-State's capacity at Craig and Laramie River stations. Purchases from greater distances would involve greater line losses and wheeling, and consequently higher costs.

Limitations in the existing transmission grid exist at the present under certain conditions. Transmission capacity south and west of Craig Station limits power flows at certain times. Such problems limit the ability of the existing transmission system to deliver power from the Colorado utilities to Utah, New Mexico and Arizona. The system from the Craig-Rifle area to the Denver area is generally heavily loaded. Transmission projects, however, are underway to relieve the existing problems and the interconnected utilities are continually planning together to make necessary additions to the system to serve the power supply needs of the area. As each new generation project is developed, detailed transmission power flow studies and stability studies are conducted to determine the effect of the new facility on the system and to determine what additional transmission facilities are required. Such transmission studies would be required for a St. Vrain project involving major generating facilities.

6. <u>Summary</u>

The marketability of output from a St. Vrain project has been discussed with the principal Colorado utilities and certain of the utilities serving in adjacent states. Based on such discussions and a review of the load projections and resource programs furnished by the utilities, there is no significant overall need for peaking power until the mid- to late-1990's.

A summary of projected loads and resources for the six principal Colorado utilities, together with related capacity deficiencies for each utility, are shown in Table V-16. In developing the capacity requirements shown in Table V-16, 15% was added to projected loads as a prudent provision for generation reserves. It is necessary for each utility to furnish its share of generating reserves to provide for scheduled outage of generating units for maintenance and for unforeseen emergency outages. For planning purposes, 15% for reserves is considered to be prudent and reasonable in the electric utility industry. The table indicates that by 1995 the six Colorado systems in total will require 188 MW of additional capacity beyond the capacity additions presently planned and sited. By the years 2000 and 2020 these total additional capacity requirements, both baseload and peaking requirements, increase to 1,763 and 9,154 MW, respectively.

Estimates of the amount of additional peaking capacity that could be effectively utilized by Colorado utilities in the 1995-2020 time frame are shown in Table V-17, indicating a total of 170 MW in 1995, increasing to 340 MW in 2000 and 940 MW in 2020.

(B0353C)

Table V-1

St. Vrain Basin Reconnaissance Study

LONGMONT POPULATION PROJECTION

	1980	1990	2000	2010	2020
High	42,940[3,4]	63,270[3,4]	85,020[3,4]	108,840[3,4]	139,320[3,4]
Medium	42,940[2,3,4]	60,300[1,2,3,4,5,6,7,8]	77,190[2,3,4,5,6,7,8]	94,100[1,2,3,4,8]	114,710[3,4]
Low	42,940[3,4]	54,220[3,4]	69,410[3,4]	84,600[3,4]	103,130[3,4]

(1) Ken Bruns, 1970 - values lower
(2) Denver Water Department, 1975 - values similar
(3) Corps of Engineers, 1977 - values lower
(4) Rocky Mountain Consultants, 1979 - values lower in high and medium scenarios, higher in high scenario
(5) Denver Regional Council of Government, 1982 - values higher
(6) City of Longmont, 1982 - values similar
(7) Boulder County, 1983 - values similar
(8) Denver Board of Water Commissioners, 1983 - values higher

Source of Information: Rocky Mountain Consultants, 1983b

(B0353C)

Table V-2

St. Vrain Basin Reconnaissance Study

STUDY AREA POPULATION PROJECTION

Rural Areas[1,2]

	1980	1990	2000	2010	2020
High	17,100	22,900	30,700	41,100	55,100
Medium	17,100	22,200	28,900	37,600	48,800
Low	17,100	21,200	26,300	32,600	40,400

Foothills[2,3]

	1980	1990	2000	2010	2020
High	3,000	4,000	5,400	7,200	9,700
Medium	3,000	3,900	5,100	6,600	8,600
Low	3,000	3,700	4,600	5,700	7,100

Total[4]

	1980	1990	2000	2010	2020
High	63,000	90,200	121,100	157,100	204,100
Medium	63,000	86,400	111,200	138,300	172,100
Low	63,000	79,100	100,300	122,900	150,600

(1) Includes the towns of Lyons and Mead as well as the rural population of Boulder and Weld Counties, excluding the foothills.
(2) These estimates assume the same overall rate of growth as Longmont.
(3) Includes the communities of Ward, Jamestown and rural residents in the foothills west of Lyons.
(4) Includes Longmont population estimates from Table V-1.

Table V-3

St. Vrain Basin Reconnaissance Study

CONSUMPTIVE USE OF IRRIGATION WATER
(inches)

Year	Alfalfa Hay	Corn Grain	Spring Grain	Crop Pattern
1951	20.11	14.42	6.33	15.25
1952	26.91	20.22	9.44	20.87
1953	24.04	18.51	7.76	18.59
1954	29.69	21.93	10.89	23.05
1955	25.61	19.05	9.00	19.82
1956	26.31	19.05	10.36	20.51
1957	21.32	16.08	6.06	16.20
1958	22.91	18.05	6.45	17.58
1959	23.36	17.41	8.60	18.18
1960	26.23	19.93	7.71	20.03
1961	18.64	14.09	6.20	14.39
1962	25.29	15.78	8.19	18.64
1963	28.03	20.30	9.20	21.39
1964	25.51	19.47	8.33	19.71
1965	18.63	12.76	6.07	14.02
1966	26.13	19.72	9.17	20.29
1967	17.95	13.08	3.44	13.11
1968	23.45	17.52	8.50	18.23
1969	23.24	18.42	4.63	17.38
1970	23.13	16.16	7.75	17.54
1971	23.78	17.48	10.17	18.80
1972	24.44	16.50	8.64	18.51
1973	23.56	17.84	7.89	18.21
1974	24.94	17.75	9.21	19.21
1975	22.70	16.02	6.48	16.98
1976	22.84	16.15	7.89	17.43
1977	29.23	22.14	10.49	22.77
1978	24.48	17.88	5.67	18.13
1979	21.79	15.84	5.40	16.21
1980	27.71	21.48	8.69	21.40
1951 - 1980 Avg.	24.07	17.70	7.82	18.41

(B0353C)

Table V-4

St. Vrain Basin Reconnaissance Study

IRRIGATED ACREAGE PROJECTION[1]
(Acres)

	1980	1990	2000	2010	2020
High	71,000	69,800	68,600	67,100	65,100
Medium	71,000	68,900	66,800	64,400	61,500
Low	71,000	68,100	64,300	60,300	55,300

(1) Irrigated acres decline relative to population growth in the study area based on the following equation:

$$\text{Project Acreage} = 71{,}000 - \frac{\text{population growth} \times \text{irrigated land ratio}}{\text{population density}}$$

The following conditions are utilized in the projections:

- o Population estimates are for the plains portion of the Study Area (see Table V-2).
- o Population densities are 8, 6 and 4 persons per acre on land converted to urban use for the high, medium and low projections, respectively.
- o The ratio of irrigated land to total land converted to urban use is 0.35, 0.55 and 0.75 for the high, medium, and low projections, respectively.
- o High, medium, and low acreage projections are related to the corresponding high, medium, and low population projections.

Table V-5

St. Vrain Basin Reconnaissance Study

POTENTIAL AGRICULTURAL WATER REQUIREMENTS FORECAST[1]
(ac-ft per year x 1,000)

	Average Weather Conditions (1951-1980)				
	1980	1990	2000	2010	2020
High	218	214	210	206	200
Medium	218	211	205	198	189
Low	218	209	197	185	170

	Water Requirements for the One-in-Ten Drought Year Irrigation Season Conditions, 100% Consumptive Use				
	1980	1990	2000	2010	2020
High	253	249	245	239	232
Medium	253	246	238	230	219
Low	253	243	229	215	197

	Water Requirements for the One-in-Ten Drought Year Irrigation Season Conditions, 85% Consumptive Use				
	1980	1990	2000	2010	2020
High	215	212	208	203	197
Medium	215	209	202	196	186
Low	215	207	195	183	167

(1) Water Requirements refer to irrigation water diverted at the ditch headgate.

Table V-6

St. Vrain Basin Reconnaissance Study

LONGMONT HISTORICAL DATA

Year	Population	Dwellings	Mean Household Size(1)	Water Demand(4) (ac-ft)	Water Demand(4) (gal/cap/day)(2)	Area (acre)	Median Household Income ($ x 1000)
1970	23,209	7,777	2.97	7,354	283	NA	NA
1971	24,823	8,429	2.95	8,463	304	NA	10,345
1972	27,182	9,341	2.92	8,112	268	5,279	11,040
1973	29,986	10,430	2.88	11,482	340	5,336	11,782
1974	32,538	11,457	2.83	9,637	265	5,427	12,575
1975	33,070	11,790	2.81	8,986	242	5,819	13,420
1976	34,187	12,342	2.78	9,107	238	6,003	14,322
1977	36,460	13,331	2.74	10,941	268	6,169	15,285
1978	39,020	14,452	2.69	12,533	287	6,251	16,313
1979	41,270	15,486	2.66	10,341	224	6,390	17,410
1980	42,942	16,341	2.63	11,266	234	6,691	18,507
1981	43,500	16,560	2.62	11,300	232	6,994	19,637
1982	44,000	16,736	2.63	NA	NA	NA	NA
1983	47,215(3)	NA	NA	12,470(3)	236	7,795(3)	NA

(1) Values calculated from population and dwelling units.
(2) Values calculated from water use (ac-ft) and population.
(3) Value actually for water year (November, 1982 - October, 1983).
(4) Values include some industrial water use.

Sources of Information: City of Longmont, 1982.
City of Longmont Water Use Forms (unpublished).

(B0353C)

Table V-7

St. Vrain Basin Reconnaissance Study

RURAL AREA DATA

Area	1980 Population	Average Water Demand (gal/cap/day)
Lyons	1,100	210
Rural Boulder County[1] .	11,600	140
Mead	400	210
Rural Weld County[2]	4,000	110
Total	17,100	140[3]

(1) Served primarily by Left Hand Water Supply Company and Longs Peak Water Association.
(2) Served primarily by Little Thompson Water District.
(3) Value is weighted average.

Source of Information: DRCOG, 1983a.

Table V-8

St. Vrain Basin Reconnaissance Study

MONTHLY MUNICIPAL WATER USAGE
(ac-ft)

	Longmont 1970 - 1980		Lyons 1980 - 1983		Lefthand(1) 1980 - 1983		Longs Peak(1) 1980 - 1983		Little Thompson(1) 1980 - 1983		Non Longmont(1) Total 1980 - 1983	
Jan.	503	5.1%	21	7.2%	100	5.8%	36	6.6%	126	5.7%	283	5.9%
Feb.	452	4.6%	20	6.9%	101	5.8%	29	5.3%	125	5.7%	275	5.8%
March	485	4.9%	19	6.5%	101	5.8%	30	5.5%	126	5.7%	276	5.8%
April	582	5.9%	23	7.9%	135	7.8%	37	6.7%	163	7.4%	358	7.5%
May	886	9.0%	22	7.6%	134	7.7%	38	6.9%	171	7.8%	365	7.6%
June	1,338	13.6%	28	9.6%	205	11.8%	49	8.9%	250	11.4%	532	11.1%
July	1,463	14.9%	38	13.1%	231	13.3%	74	13.5%	297	13.5%	640	13.4%
Aug.	1,276	13.0%	35	12.0%	209	12.0%	67	12.2%	281	12.8%	592	12.4%
Sept.	990	10.1%	24	8.2%	174	10.0%	70	12.8%	224	10.2%	492	10.3%
Oct.	774	7.9%	23	7.9%	132	7.6%	45	8.2%	168	7.6%	368	7.7%
Nov.	540	5.5%	20	6.9%	104	6.0%	39	7.1%	133	6.1%	296	6.2%
Dec.	549	5.6%	18	6.2%	111	6.4%	35	6.4%	134	6.1%	298	6.2%
Total	9,838	100.0%	291	100.0%	1,737	100.0%	549	100.0%	2,198	100.0%	4,775	100.0%

(1) Water usage for these water supply companies and water districts are for their total service area which includes areas outside of the Study Area.

(B0353C)

Table V-9

St. Vrain Basin Reconnaissance Study

WATER DEMAND PROJECTION EQUATIONS FOR LONGMONT

Type of Use	Equation	Equation Number
Residential		
Flat rate single family		
Indoor	$Q_{FSI}/H_{FS} = 22.3\ Y^{.4}R^{.4}$	1
Outdoor	$Q_{FSO}/H_{FS} = 21.4\ Y^{.4}R^{.4}$	2
Metered single family		
Indoor	$Q_{MSI}/H_{MS} = 17.2\ P^{(-0.13-0.12P)}Y^{.4}R^{.4}$	3
Outdoor	$Q_{MSO}/H_{MS} = 12.9\ P^{(-0.38-0.12P)}Y^{.4}R^{.4}$	4
Multi-family		
Indoor	$Q_{MMI}/H_{MM} = 52.8\ Y^{.4}R^{.4}$	5
Outdoor	$Q_{MMO}/H_{MM} = 16.1\ P^{(-0.38-0.12P)}Y^{.4}R^{.4}$	6
Number of multi-family	$H_{MM} = 559\ (1+1.1G)^N$	7
Number of single-family	$H_{SFN} = 11,851\ (1+0.74G)^N$	8
Number of single-family flat rate	$H_{FS} = 0.91^N\ (11,851)$	9
Number of single-family metered	$H_{MS} = H_{SFN} - H_{FS}$	10
Commercial	$Q_C = 424,000\ (1+G)^N\ P^{(-0.13-0.12P)}$	11

Q = demand (thousand (1,000) gal/year)
Y = mean household size (persons)
R = median household income (thousand (1,000) 1980 $)
P = water price (1980 $/thousand (1,000) gal)
G = population growth rate (1/year)
N = calendar of years since 1980
Q_{FSI} = demand by flat rate single family residences for indoor use
Q_{FSO} = demand by flat rate single family residences for outdoor use
Q_{MSI} = demand by the metered single family residences for indoor use
Q_{MSO} = demand by the metered single family residences for outdoor use
Q_{MMI} = demand by the metered multi-family residences for indoor use
Q_{MMO} = demand by the metered multi-family residences for outdoor use
QC = demand for commercial use
H_{FS} = number of flat rate single family residences
H_{MS} = number of metered single family residences
H_{MM} = number of metered multi-family residences
H_{SFN} = number of single family residences

Table V-10

St. Vrain Reconnaissance Study

LONGMONT WATER DEMAND FORECAST

Year	Population[1]	Interval[2]	Growth[3] Rate	No. Single Family Flat Rate[4]	No. Single Family Metered[5]	Single Family Demand Flat Rate[6,14]	Single Family Demand Metered[7,13,14]	No. Multi-Family[8]	Multi-Family Demand[9,13,14]	Commercial Demand[10,13]	Total Demand[11]	
	(x 1000)	(yr)	(1/yr)	(x 1000)	(x 1000)	(gal/cap/day)	(gal/cap/day)	(x 1000)	(gal/cap/day)	(gal/cap/day)	(gal/cap/day)	(ac-ft/yr)
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
1980	43[15]	0	0	11.85[15]	0	156[15]	0	0.56[15]	11.5[15]	27.0[15,16]	224[15,16]	10.8[15,16]
1990	54	10	.023	4.61	9.42	56.7	74.1	0.72	12.8	26.7	196	11.8
1990	60	10	.034	4.61	10.58	53.1	80.7	0.81	13.4	26.7	200	13.4
1990	63	10	.039	4.61	11.14	51.5	84.3	0.85	13.9	26.7	203	14.3
2000	69	20	.024	1.80	15.05	17.3	96.1	0.94	13.1	26.7	176	13.6
2000	77	20	.030	1.80	16.58	16.8	102.3	1.07	14.4	26.9	184	15.9
2000	85	20	.035	1.80	17.96	16.5	109.0	1.19	15.7	26.5	193	18.4
2010	85	30	.023	0.70	18.96	5.5	98.4	1.18	13.3	26.7	165	15.7
2010	94	30	.026	0.70	20.29	5.6	107.3	1.30	14.9	26.4	177	18.6
2010	109	30	.031	0.70	22.70	5.4	116.4	1.53	19.1	26.4	190	23.2
2020	103	40	.022	0.27	22.33	1.8	95.5	1.46	13.6	26.6	158	18.2
2020	115	40	.025	0.27	24.43	1.8	109.4	1.66	16.2	26.8	176	22.7
2020	139	40	.030	0.27	28.25	1.8	122.6	2.05	19.4	26.9	196	30.5

(1) Population projections for years 1990-2020 are given in low, medium, high order.
(2) Column (A)-1980
(3) 2.72 xx (ln (column (B)/43)/column (C)) - 1.0.
(4) 11.85 x (0.91 xx (column (C))).
(5) 11.85 x ((1.0 + 0.74 x column (D)) xx column (C)) - Column (E).
(6) 663 x ((1.0 + real income growth rate) xx (0.4 x column (C))) x column (E)/column (B).
(7) (222 x indoor price elasticity + 225 x outdoor price elasticity) x ((1.0 + real income growth rate) xx (0.4 x column (C))) x column (F)/column (B).
(8) 0.56 x ((1.0 + 1.1 x column (D)) xx column (C).
(9) (682. + 281. x outdoor price elasticity) x ((1.0 + real income growth rate) xx (.04 x column (C))) x column (I)/column (B).
(10) 1160 x indoor price elasticity x ((1.0 + column (D)) xx column (C))/column (B).
(11) 1.15 x (column (G) + column (H) + column (J) + column (K)).
(12) 0.00112 x column (L) x column (B).
(13) Price = \$1.05/(gal x 1000).
Indoor price elasticity = 0.99.
Outdoor price elasticity = 0.98.
(14) Real income growth rate = 0.00/yr for low projections.
Real income growth rate = 0.01/yr for medium projections.
Real income growth rate = 0.02/yr for high projections.
(15) Actual values for 1980.
(16) Values exclude industrial water use.

Table V-11

St. Vrain Basin Reconnaissance Study

RURAL AREA WATER DEMAND FORECAST[1]
(ac-ft/yr x 1,000)

	1980	1990	2000	2010	2020
High	2.7	3.6	4.8	6.4	8.6
Medium	2.7	3.5	4.5	5.9	7.6
Low	2.7	3.3	4.1	5.1	6.3

(1) Values based on 140 gallons per capita per day, average weather conditions, and population forecast in Table V-2.

Table V-12

St. Vrain Basin Reconnaissance Study

MUNICIPAL WATER DEMAND IN A DROUGHT YEAR
(ac-ft per year x 1,000)

Year	Forecast	Longmont Water Demand Forecast for Average Weather Year(1)	Increase in Longmont Water Demand Forecast for Drought Year	Total Longmont Drought Water Demand Forecast	Rural Area Domestic Water Demand Forecast(2)	Total Municipal Drought Water Demand Forecast
1990	High	14.3	1.4	15.7	3.6	19.3
1990	Medium	13.4	1.3	14.7	3.5	18.2
1990	Low	11.8	1.3	12.8	3.3	16.1
2000	High	18.4	1.7	20.1	4.8	24.9
2000	Medium	15.9	1.4	17.3	4.5	21.8
2000	Low	13.6	1.3	14.9	4.1	19.0
2010	High	23.2	2.0	25.2	6.4	31.6
2010	Medium	18.6	1.6	20.2	5.9	26.6
2010	Low	15.7	1.4	17.1	5.1	22.2
2020	High	30.5	2.6	33.1	8.6	41.7
2020	Medium	22.7	2.0	24.7	7.6	32.3
2020	Low	18.2	1.5	19.7	6.3	26.0

(1) Values from Table V-10.
(2) Values from Table V-11. In this study rural areas are defined to include such towns as Lyons and Mead and other areas in Boulder, Weld and Larimer counties.

(B0353C)

Table V-13

St. Vrain Basin Reconnaissance Study

1983 INDUSTRIAL WATER DEMAND
(ac-ft per year)

Water Users	Water Suppliers: City of Longmont	Left Hand Water Supply	Self-Supplied (Direct Water Rights	Total
Technology-Related				
Storage Technology Corporation	100	--	--	100
Mini-Scribe	30	--	--	30
Others	70	--	--	70
				200
Non Technology-Related				
Martin Marietta	320	--	--	320
Longmont Food	300	--	--	300
Beech Aircraft	--	80	--	80
				700
Energy				
Public Service Co. of Colorado	--	--	1,000	1,000
Total	820	80	1,000	1,900

(B0353C)

Table V-14

St. Vrain Basin Reconnaissance Study

INDUSTRIAL WATER DEMAND FORECAST
(ac-ft per year)

Technology-Related Industrial Water Demand

	1980	1990	2000	2010	2020
High	70	680	1370	2180	3230
Medium	70	590	1150	1760	2510
Low	70	430	910	1410	2030

Non Technology-Related Industrial Water Demand

	1980	1990	2000	2010	2020
High	700	1020	1540	2140	2930
Medium	700	980	1390	1850	2420
Low	700	890	1250	1630	2090

Energy (PSC) Water Demand

	1980	1990	2000	2010	2020
High	1000	1000	1000	1000	1000
Medium	1000	1000	1000	1000	1000
Low	1000	1000	1000	1000	1000

Total Industrial Water Demand

	1980	1990	2000	2010	2020
High	1770	2700	3910	5320	7160
Medium	1770	2570	3540	4610	5930
Low	1770	2320	3160	4040	5120

PSC - Public Service Company of Colorado

Table V-15

St. Vrain Basin Reconnaissance Study

TOTAL WATER DEMAND
DROUGHT CONDITIONS[1]
(ac-ft per year x 1,000)

	Total Water Demand, 100% Consumptive Use				
Scenario	1980	1990	2000	2010	2020
High	268	271	274	276	281
Medium	268	266	263	261	257
Low	268	261	251	241	229

	Total Water Demand, 85% Consumptive Use				
Scenario	1980	1990	2000	2010	2020
High	230	234	237	240	246
Medium	230	229	227	227	224
Low	230	225	217	209	199

(1) Drought conditions are those occurring on a 1 in 10 year interval for the agricultural sector and on a 1 in 30 year interval for the municipal sector.

(B0353C)

Table V-16

St. Vrain Basin Reconnaissance Study

PROJECTED LOADS AND RESOURCES
COLORADO UTILITIES

Agency or Utility	1982	1985	1990	1995	2000	2005	2010	2015	2020	Average Growth Rate 1982-2020 MW/Yr	Average Growth Rate 1982-2020 %/Yr	Annual Load Factors 1982	Annual Load Factors 2020
							Loads-Demand (MW)						
Public Service Company of Colorado .	3,230	3,519	4,062	4,621	5,151	5,714	6,362	7,069	7,854	122	2.37	66.2	66.8
Colorado-Ute Electric Association ..	691	892	1,201	1,541	1,955	2,277	2,645	2,760	2,875	57	3.82	57.8	60.3
Tri-State Generation & Transmission	1,167	1,318	1,505	1,640	1,743	1,831	1,916	2,012	2,106	25	1.57	45.6	49.3
City of Colorado Springs	406	459	599	759	958	1,209	1,526	1,927	2,432	53	4.82	64.5	66.1
Platte River Power Authority	231	269	386	542	760	1,067	1,495	2,099	2,944	71	6.93	59.6	61.9
Arkansas River Power Authority	68	77	95	120	148	184	230	286	358	8	4.47	54.4	50.2
Total Loads(1)	5,793	6,534	7,848	9,223	10,715	12,282	14,174	16,153	18,569	336	3.11		
					Resources - Capacity (MW)								
Public Service Company of Colorado .	3,317	3,586	4,089	4,250	3,931	3,965	3,928	3,963	3,998				
Colorado-Ute Electric Association ..	743	892	1,201	1,191	1,191	1,191	1,191	1,191	1,191				
Tri-State Generation & Transmission	1,417	1,744	1,871	1,923	1,946	1,953	1,956	1,968	1,980				
City of Colorado Springs	456	514	658	914	914	904	893	893	893				
Platte River Power Authority	248	262	373	528	745	1,049	1,134	1,134	1,134				
Arkansas River Power Authority	89	101	78	60	56	50	50	50	50				
WAPA Planned Additions	--	112	169	169	169	169	169	169	169				
Total Resources(2)	6,270	7,211	8,439	9,035	8,952	9,281	9,321	9,368	9,415				
					Capacity Deficiencies (MW)								
Estimated Colorado Future Capacity (Surplus) or Deficiency(3)	(477)	(677)	(591)	188	1,763	3,001	4,853	6,785	9,154				

(1) Based on load projections as furnished by the utilities plus 15% reserves.
(2) Includes existing generation, WAPA allocations, planned and sited additions, and firm purchases and sales. Unsited future capacity additions are not included in resources.
(3) Estimated future capacity requirements not yet sited or specifically identified, representing base load, intermediate and peaking requirements.

(B0353C)

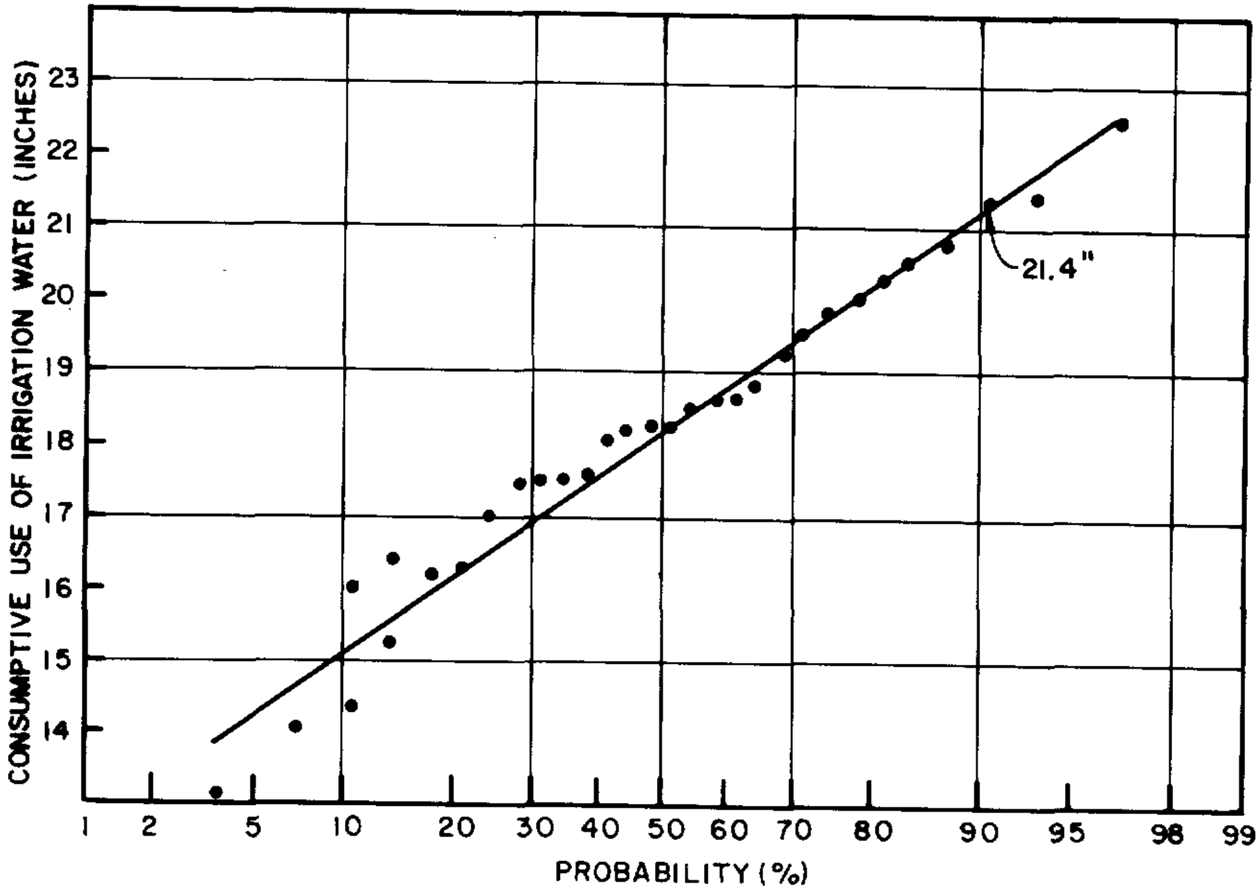
Table V-17

St. Vrain Basin Reconnaissance Study

ESTIMATED ADDITIONAL PEAKING POWER CAPACITY REQUIREMENTS
COLORADO UTILITIES

	Capacity (MW)			
	1995	2000	2010	2020
Public Service Company of Colorado	100	150	250	400
Colorado-Ute Electric Association	50	100	150	200
Tri-State G&T Association	0	0	0	10
City of Colorado Springs	0	30	80	150
Platte River Power Authority	20	50	100	150
Arkansas River Power Authority	0	10	20	30
Total (Colorado Utilities)	170	340	600	940

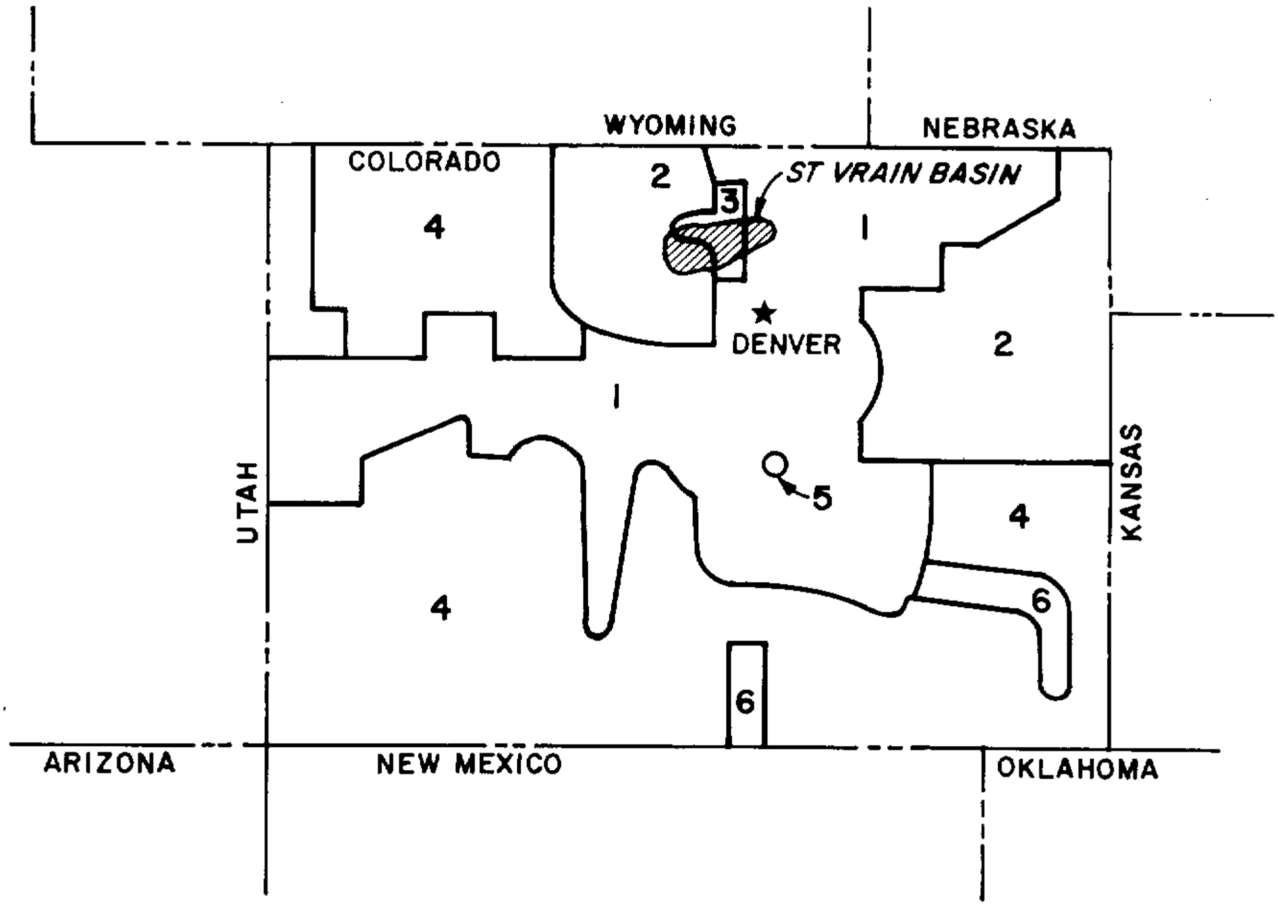
Notes:
(1) Based on loads and resource projections furnished by the utilities and on discussions with the utilities as to their opinions as to the need for peaking capacity. Peaking capacity requirements estimated to be in the range of 10 to 15% of annual peak load.
(2) Economic feasibility and compatibility with load pattern will determine actual acquisition of peaking resources in comparison to capacity estimates shown.



NOTE:
Based on years 1951-80.

R.W. BECK AND ASSOCIATES/ DAMES AND MOORE
COLORADO WATER RESOURCES & POWER DEVELOPMENT AUTHORITY DENVER, COLORADO ST. VRAIN BASIN RECONNAISSANCE STUDY **FREQUENCY DISTRIBUTION OF CONSUMPTIVE USE OF IRRIGATION WATER**

DATE:	DRAWN:	APPROVED:	FIG:
FEB. 1986	PJG	[signature]	V-1



LEGEND

1 Public Service Company of Colorado
2 Tri-State G & T Association
3 Platte River Power Authority
4 Colorado-Ute Electric Association
5 City of Colorado Springs
6 Arkansas River Power Authority

NOTE

1. Only Colorado service areas shown

R.W. BECK AND ASSOCIATES/
DAMES AND MOORE

COLORADO WATER RESOURCES &
POWER DEVELOPMENT AUTHORITY
DENVER, COLORADO

ST. VRAIN BASIN RECONNAISSANCE STUDY

GENERAL SERVICE AREAS
PRINCIPAL POWER SUPPLIERS
IN COLORADO

DATE:	DRAWN:	APPROVED:	FIG:
FEB. 1986	NRJ	JEA	V-2

CHAPTER VI

OPERATION OF THE ST. VRAIN BASIN WATER SUPPLY SYSTEM

A. Introduction

This chapter describes the River Basin Simulation Model (RIBSIM) used to simulate the operation of the water supply system in the St. Vrain Basin and the results of simulated operations. First, a discussion of the model calibration and results of calibration are presented. These are followed by evaluations of the water supply systems using existing water supplies to meet present water demands and future water supplies to meet forecast future demands.

B. Description and Calibration of RIBSIM

1. Model Description

RIBSIM is a general river basin simulation model designed for water supply studies using a monthly time step on a water year basis. RIBSIM operates using quantities of water; it does not model water quality. A river basin's water supply system can be modeled through the use of streamflow diversions, surface and subsurface agricultural return flows, as well as point municipal and industrial wastewater discharges, reservoirs, exports from reservoirs and gaged streamflows. Direct flow and storage water rights are operated by RIBSIM in a strict priority manner. RIBSIM has been successfully used in the evaluation of water rights in the Colorado River, and other basins, and has proven capable of modeling the complexities of the St. Vrain Basin.

RIBSIM utilizes three basic data files in its operation: (1) a water rights and stream network file, (2) a miscellaneous data file, and (3) a streamflow file. Following is a brief description of each data file.

a. Network File

The RIBSIM network defines the stream reaches (also called stream sectors), the direction of streamflows, and relative location of water rights, along with stream sectors and water rights information which does not change monthly. Streamflow sectors are defined as stream reaches with homogeneous flows. A flow sector begins and ends where there is a significant change in the flow regime, such as a tributary inflow. Water rights information in the network file includes water right priority, type, return flow locations and linkage of storage reservoirs to direct flow rights. Additional information includes constant monthly demands, return flow percentages and reference numbers to the miscellaneous file for variable monthly demands, return flow percentage and other monthly data information.

b. Miscellaneous Data File

The miscellaneous data file contains variable monthly data for water demands, consumptive uses and return flows. Also included are reservoir operating characteristics such as minimum and maximum monthly capacities, evaporation and seepage losses and area-capacity data. Data can be input as constant, i.e., the same 12 monthly values can be used for each year of the study period, or else a different value can be provided for each month of the year, resulting in a table with one value for each month of the study period. The miscellaneous data file is referenced by the network file during model operation.

c. Streamflows

The streamflow file is a table of monthly streamflows for each sector for each water year of the study period. The streamflows can be either virgin flows or gaged flows, depending on the purpose of the model run, but must be in units of ac-ft. Streamflows represent water initially available to the water rights in the respective stream sectors.

2. Model Operation

a. Diversions

RIBSIM is designed to process four types of direct flow diversions: (1) normal diversions (irrigation, municipal, industrial, domestic, etc.), (2) irrigation diversions as a function of calculated consumptive use, (3) non-consumptive diversions, and (4) streamflow monitors (gages). These are defined below.

A normal direct flow diversion can be an irrigation, municipal, industrial, domestic or any type of diversion right which diverts water from the stream and returns a percentage of the diversion back to the stream. A normal diversion demand is compared to available river flow at its headgate or node in the stream network. There are three conditions which may exist:

(1) Diversion demand is less than or equal to the available streamflows at the headgate and all nodes downstream. In this case, the demand, less return flows, is subtracted from the available streamflows for that sector and all other sectors downstream.

(2) Available flow at the headgate or at any node downstream is zero. In that case, no diversion will take place.

(3) Diversion demand is greater than the available flow at the headgate or at any node downstream, meaning the demand will only be partially satisfied. The diverted

amount is calculated as first being the smallest available amount at or downstream of the headgate. The diversion is processed and return flows are added to all downstream nodes. If water is still available at the headgate after return flows are added in, a check downstream for the smallest available amount is evaluated and processed, as above, and so on until the demand is either met or the smallest available amount is less than 0.5 ac-ft.

The second type of direct flow diversion is for irrigation rights which have demands calculated as a function of their potential consumptive use. This is achieved by specifying an average demand, which is defined by: (1) the average potential consumptive use of irrigation water for the ditch, and (2) a table in the miscellaneous data file with data for each month of the Study period, consisting of monthly ratios of actual potential consumptive use to the average potential consumptive use. When the irrigation water right is evaluated, the diversion demand is made equal to the average monthly demand multiplied by the corresponding consumptive use ratio for the particular month being processed. Once the demand has been computed, evaluation of the irrigation water right is the same as a normal direct flow diversion.

The third type of diversion is a non-consumptive diversion, equivalent to an instream flow right. The demand of the instream flow right is compared only to the flow corresponding to its headgate node.

The fourth type of diversion is a streamflow monitor, equivalent to a gaging station. This type of direct flow diversion reports the physical flow passing through the monitor node at the time the streamflow monitor is processed.

b. <u>Reservoirs</u>

RIBSIM can model on-stream and off-stream reservoirs. In accordance with its priority, storage demand is determined based on the decreed amount, reservoir capacity to fill in one month and the type of reservoir administration chosen. Reservoir demands can be constant, or calculated as a function of available capacity and administration, or can be varied in accordance with a monthly demand schedule. Once the demand has been determined, allocation of flow to the reservoir is processed similar to a normal diversion, as discussed above. Next, a reservoir protection option is operated if the reservoir is protecting out-of-priority diversions of an upstream water right. This is an exchange where the calling water right is below the reservoir and the protected right is above the reservoir. The export and import links are then operated as discussed later. Evaporation of the reservoir is then processed and the storage account is adjusted accordingly. To determine evaporation amounts, the model uses area-capacity data and monthly unit evaporation rates.

RIBSIM has three different options available to model reservoir administration.

(1) The reservoir may impound the decreed amount each year.

(2) The reservoir may store and restore throughout the year, without regard to the decreed amount.

(3) The reservoir may impound the difference between the decreed amount and the amount in storage at the beginning of the year. This option is generally the approach used by the State of Colorado in administering storage reservoirs.

For Options (1) and (3), the model keeps an account of the stored amount in the reservoir for each month of the year and compares the running total to the amount the reservoir is allowed to store. The amount the reservoir can store is dependent on both decreed amount and the capacity of the reservoir. Once the allowable storage amount for any given month is determined, the model checks for water availability and goes through the same procedure as described in the normal diversion section. Operation of Option (2) is similar, except the only constraint is the available capacity of the reservoir.

c. Export-Import Links

The purpose of an export link is to convey water, diverted in priority, from the point of diversion of the exporting water right to an importing water right. Export link data include maximum capacity of the link (ditch or pipeline) and the importing water right identification number. Examples of export links include delivery of water from a reservoir to supplement junior priority water rights or delivery of water from a diversion to a reservoir.

There are two combinations of priorities of export-import links which can occur. The first is when the exporting water right is senior to the importing water right. During operation of the senior, exporting right, the export link amount is held in a reserve account until the junior right is processed. When the junior right is processed, it looks to the river and diverts available flow up to its demand. If the junior right is shorted when it first looks to the river, the exporting senior right will deliver the shorted amount to the junior right. The junior right does not go through the iterations of determining available flow after its return flows are made, but instead, looks to the export link for supplemental water. If the junior right needs only a partial supply from the export link, the unused portion is either released to the river or stored, depending on whether the exporting right is a direct flow or storage right. If the exporting right is a direct flow right, the unused exported water will be released as available flow to the river. If the exporting right is a storage right, the unused portion of the export link will be left in storage.

The second case is when the exporting right is junior to the imported water right. When the senior, importing right is processed, it will operate normally and go through return flow iterations and divert all available flow up to its decree. When the junior export right is processed, an export will occur in the amount that the demand of the senior right was not satisfied. An example would be a direct flow irrigation right receiving supplemental water from a junior upstream reservoir during the low flow season.

d. Return Flows

RIBSIM allocates return flows from consumptive water rights to various locations downstream with variable monthly delayed return patterns. The source of these return flows is the recoverable portion of conveyance and on-site losses. The amounts are computed as shown below:

Conveyance Loss Return Flow = (Diversion Amount) x (% Conveyance Losses) x (% Conveyance Losses Returning to River)

On-Site Loss Return Flow = [(Diversion Amount - [(Diversion Amount) x (% Conveyance Losses)]] x (% On-Site Losses) x (% On-Site Losses Returning to River)

Conveyance and site loss return flows can then be further divided between surface and groundwater return flows. Surface returns are made in the same month of the diversion, while the groundwater returns can be lagged into later months (up to 24 months). The return flow locations can be anywhere along the stream network, either upstream, downstream or on a tributary.

3. Calibration to the St. Vrain Basin

The purpose of the calibration step is to refine model parameters, such as return flow locations and efficiencies, so that when the model is operated using actual historical diversions and streamflows, the modeled diversions and resulting modeled gage flows closely represent the historical diversions and actual USGS gaged flows. A 10-year period of record (1971-1980) was used for calibration. The goal of the calibration is to achieve a close representation of the actual operation of the St. Vrain Basin, so that when alternative plans are to be investigated, their relative performance can be quickly evaluated.

a. Inflows

Inflows used for modeling the St. Vrain Basin consist of three types: (1) virgin flows from the mountainous regions, (2) C-BT Project imported flows, and (3) return flows from the South Platte and Boulder Creek irrigated lands that drain into the St. Vrain River.

Virgin flows, defined as river flows which would have occurred without man's influence, were computed for St. Vrain Creek at Lyons (USGS Gage 7240) and for Left Hand Creek near Boulder (USGS Gage 7245). Virgin flows for St. Vrain Creek at Lyons were computed by adjusting the gaged flow changes of storage in Button Rock Reservoir, and for diversions made by the Supply Ditch, South Ledge Ditch, Longmont Municipal Pipelines and for diversions from upper South St. Vrain Creek made by the Left Hand Ditch Company. These monthly virgin flows were then used to derive virgin flows for North St. Vrain Creek and South St. Vrain Creek. The relative distribution of flows between North and South St. Vrain creeks is based on gaging records at USGS Stations 7220 on the North St. Vrain Creek and 7225 on the South St. Vrain Creek.

Virgin flows for Left Hand Creek, near Boulder, were developed using USGS records (Gage 7245) and records of diversions for the Left Hand Ditch Company. Water imported by the Left Hand Ditch Company from South St. Vrain Creek was subtracted from the gaged flow, and added into South St. Vrain Creek virgin flow as discussed above.

Inflows to St. Vrain Creek from Boulder Creek were gaged flows based on USGS gaging data for Station 7305, Boulder Creek, at mouth, near Longmont.

C-BT inflows to the St. Vrain Basin were made available to the ditches which own C-BT units. The amount of C-BT water made available was based on the actual quota declared by NCWCD, and on estimates provided by NCWCD.

Return flows from Boulder Creek and South Platte ditches, which return to St. Vrain Creek between the mouth of Dry Creek and Boulder Creek, and between the mouth of Idaho Creek and the mouth of St. Vrain Creek, were added as inflow to the Basin. These additional flows were estimated by determining potential irrigable land under ditches with headgates on the South Platte River or Boulder Creek and then computing return flows from those lands using a 45% efficiency and the same cropping pattern used in the St. Vrain Basin.

b. Network

Figure VI-1, accompanied by Table VI-1, is a schematic display of the water rights and stream network for the St. Vrain Basin and includes flow sectors, stream gages and water rights. Table VI-2 lists the water rights in the downstream order in which they appear in the file.

All major ditches along the main stem St. Vrain Creek which are administered by the Water Commissioner are included in this network. Other significant water rights on the south and north St. Vrain creeks are also included. Reservoirs diverting from the main stem St. Vrain Creek are also included, as is Button Rock Reservoir on the north St. Vrain.

C-BT inflows are modeled as inflow to separate tributaries to the St. Vrain Creek. These tributaries convey water upon demand to the St. Vrain Creek for further conveyance to the ditches requesting supplemental C-BT water.

The Left Hand Ditch Company (LHDC) irrigation ditches were modeled as one ditch on Left Hand Creek. LHDC reservoirs were modeled as one reservoir.

c. <u>Water Right Priorities</u>

RIBSIM operates the modeled water rights in priority. The priorities utilized for modeled water rights, listed in Table VI-1, are based upon the State Engineer reported adjudication and appropriation dates. In several cases where ditch diversions have been combined into one location, minor adjustments of the water rights priorities and/or diversion locations were necessary. These modifications do not affect the overall operation of the Basin. Note that listed priorities are relative only, i.e., the absolute value of a priority number is unimportant. A senior priority to use water is shown with a lower RIBSIM priority number; conversely, a higher RIBSIM priority number is a more junior water right.

d. <u>Water Demands</u>

To simplify input data requirements and still calibrate to historical use, each irrigation water right requests the lesser of the following amounts each month:

- o Decreed amount
- o Ditch capacity
- o Average historical monthly diversion

The decreed amount, taken from the State Engineer Tabulation of 1981, is limiting when historical diversions were greater than their decree, such as free river conditions. Ditch capacities are as reported by the Water Commissioner. It was assumed that diversions could not be greater than the reported ditch capacity. Monthly diversion records for 1971 to 1980 were taken from the State Engineer diversion records and analyzed to determine the average monthly diversion. Modeled ditch capacities are shown in Table VI-2.

Municipal demands for the City of Longmont are based upon water use data provided by the City. These data include monthly deliveries from the treatment plant, monthly diversions by the North Longmont Pipeline and monthly releases from Button Rock Reservoir. LHWSC demands are based on total annual water usage provided by Left Hand Water Supply Company, distributed in a monthly pattern based on that observed in the Longmont data.

Industrial water use for the calibration period is included in Longmont's historical use. C-BT deliveries to Ideal Basic Industries are combined with Longmont's C-BT water.

Monthly demands for reservoirs are based on their decreed amount. Each reservoir requests its decreed storage amount every month, but it cannot divert more than its entire decreed amount in any year. Each reservoir is also limited by its physical capacity, shown in Table VI-2 as "modeled capacity."

e. Efficiencies

The efficiencies and losses of municipal and agricultural uses modeled during calibration are illustrated using example diversions in Figs. VI-2 and VI-3.

f. Return Flows

RIBSIM models surface and subsurface return flows as returning to the river in several locations and under several delayed return patterns. Surface water returns from agricultural use are based upon the topography of the irrigated areas and areas surrounding the ditches themselves. Recoverable surface water returns are modeled to return to the river in the same month of diversion. The location of these return flows is site-specific and is based on discussions with the Water Commissioner.

Subsurface return flows from agricultural use are influenced by the soils and geology of the irrigated area and soils and geology between the irrigated parcel and St. Vrain Creek. The location of groundwater return flows are based upon the topography and location of irrigated parcels under the respective ditches.

RIBSIM has the capability to model delayed subsurface return flows, up to a 24-month delay. Two delay tables are included in the RIBSIM data base of the St. Vrain Basin. An analysis of return flows from certain ditches, using the "Glover method," had been performed by Rocky Mountain Consultants, Inc. in their work for the Longmont water transfer (Glover, 1974, and Rocky Mountain Consultants, 1982). This information was verified and used to develop one delay table for those ditches which irrigate lands overlying the St. Vrain alluvium. Those ditches which irrigate lands farther away from the river, such as the Highland and Supply ditches, have a much slower return flow pattern. The second delay table, utilized by RIBSIM to model return flows for these ditches, has a constant 4% returning to the river in each month for a 24-month period.

Municipal and industrial returns are based upon the locations of diversions, raw water treatment plants, and wastewater treatment plants. Return flows are assumed to return as surface water in the month of diversion. Conveyance losses were modeled as returning to the stream system with no depletions. Water delivered to users was modeled as having 80% returning during the winter months (October-March) and 58% returning for the summer months (April-September), from information provided by the City of Longmont (see Fig. VI-2).

3. Calibration Results

This section presents results of the model calibration runs. A 10-year average annual water balance of the Basin and comparisons of gaged flows versus modeled flows for St. Vrain Creek at Lyons and St. Vrain Creek at the mouth are presented.

a. Water Balance Check

To assure that the calibrated RIBSIM model accounts for all inflows, depletions and outflows, a water balance was computed for the entire Basin, using model results. The water balance was computed using the 10-year (1971-80) average annual flows and is summarized in Table VI-3. The difference between the computed outflow of 170,588 ac-ft to the modeled outflow of 170,593 ac-ft, is attributed to rounding errors, and is not significant.

b. Comparison of Gaged Flows

Figure VI-4 is a comparison of actual average monthly USGS gaged flows at Station 7240, St. Vrain Creek at Lyons, versus modeled flows at the same location. The model, on the average, accounts for approximately 99% of the actual total annual gaged flow. On a monthly basis the variation ranges between 71% of gaged flow in March and 105% in June.

Figure VI-5 is a similar comparison of actual average gaged flows versus modeled flows at USGS Station 7310, St. Vrain Creek at the mouth. On the average, the model accounts for 94% of the total annual gaged flow. The average monthly variation is between 82% in May and 108% in January.

The model is calibrated to within about ±5% at the confluence of North and South St. Vrain creeks, and to within about ±15% at the mouth of St. Vrain Creek, using USGS gaged flows as the basis for calibration. This is considered to be good accuracy for this reconnaissance level of study.

C. Description and Evaluation of the Existing Water Supply System

The existing St. Vrain Basin water supply system is composed of three independent components: (1) individual agricultural ditches and reservoirs developed to utilize native St. Vrain flows, (2) municipal water supply systems, and (3) the Colorado-Big Thompson Project. Although there is cooperation among the three types of water suppliers, they can and do function independently. Irrigation ditches and reservoirs which are operated by both organized ditch companies or by individual farmers have service areas ranging from 20,000 acres to less than 100 acres. Even on the large systems individual shareholders often operate in an independent fashion.

Municipal suppliers deliver from a few hundred to 15,000 ac-ft per year, relying in turn on a variety of supply options, such as municipal direct flow and storage rights, converted agricultural direct flow rights and storage rights, and imported C-BT Project water. Similarly, these municipal suppliers function as distinct, separate entities, not as a regional municipal water supplier.

The Colorado-Big Thompson Project is heavily relied upon by both agricultural and M&I water users; however, there is considerable flexibility in the operation of the C-BT system. Although this flexibility is being physically constrained by the heavy demands now being placed on the C-BT system by the St. Vrain and Boulder Creek users, it is still possible for delivery schedules and locations to vary greatly from one year to the next. Deliveries via the St. Vrain Supply Canal are made from April through October.

Although the various users can function independently, they are bound to operate under the water laws of the State of Colorado. The operation of the water supply system in the Basin is supervised by the District 5 Water Commissioner. The Commissioner manages the Basin to conserve water, yet satisfy all water rights without any unnecessary waste, or lost opportunity to use the existing water supply. For example, any time during the irrigation season when senior ditches no longer need irrigation water, they promptly notify the Commissioner, who then notifies the next junior water right owner(s) that they may divert.

During the winter months, the Commissioner has coordinated with the storage right owners in the Basin to allow the upstream junior reservoirs to fill first and the lower downstream Basin reservoirs to fill later. Ralph Price (Button Rock) Reservoir is an example of an upstream junior reservoir that benefits from this arrangement. This reduces unnecessary loss of storage water due to inadequate capacities of filler ditches for downstream reservoirs. In the case when downstream reservoirs have not filled after spring runoff, water stored out of priority by upstream reservoirs is then released to senior lower basin reservoirs.

D. Comparison of Existing Supply to Demand

A central question to be resolved by a water resources management study is a comparison of water supply to current and forecast water demands to provide estimates of surplus or deficit that should be considered in planning. Such a comparison was made for the St. Vrain Basin Study using the RIBSIM model as an analytical tool. With the model, hydrologic and climatologic conditions are simulated over a 30-year period so that variations in both supply and demand can be and are quantified, as are the differences (surpluses or deficits).

The concept of water supply may have several definitions. For purposes of this Study, the water supply available under the existing system is defined as headgate diversions supplied by the system, which are a function of Basin hydrology, physical facilities and administration. A comparison of headgate diversions versus existing water demands was made by a 30-year (1951-80) run of the calibrated RIBSIM model, herein termed the "base run." A second base run of RIBSIM was made using forecast demands for the year 2020, with incorporation into the supply side of certain changes that will occur, such as authorized projects and forecast land use changes. Water supply deficits indicated from this base run provide a basis for planning targets for plans subsequently formulated. In other words, this run of RIBSIM is intended to provide data for answering the question "How much additional water supply is likely to be needed by year 2020?"

Municipal and industrial (M&I) water demands are presented in Chapter V. Conveyance and treatment losses were added to define headgate demand (see Fig. VI-2). Agricultural water requirements were calculated using the Blaney-Criddle method to estimate consumptive use, as described in Chapter V. The water requirement for each ditch was then divided by an efficiency factor to arrive at estimated headgate requirement for that ditch (see Fig. VI-3).

It is important to note that RIBSIM does not optimize the allocation of water, nor does it actually allocate water. Rather, it utilizes input data regarding water use, such as priorities and diversion schedules, to simulate the allocation of water. Any comparison of supply to demand based on a model run is therefore dependent on the assumptions made in the data base.

1. <u>Existing Conditions</u>

Existing development in the Basin as of year 1980 was used as the basis for the existing condition.

a. <u>Municipal and Industrial</u>

The total existing M&I headgate demand is estimated at 18,000 ac-ft/yr. This demand was modeled as occurring every year of the modeling period. Total annual diversions made to satisfy these demands in the 1951-80 model run average 16,000 ac-ft, resulting in an average annual deficit of about 2,000 ac-ft. Table VI-4 shows these demands and diversions.

b. <u>Agricultural</u>

Based on estimates of crop consumptive use of irrigation water, requirements of the existing 71,000 acres of irrigated cropland were estimated, as described in Chapter V. An overall efficiency of 45% was used for all ditches in calculating the headgate requirement. The total calculated headgate requirement for the 37 ditches represented in the model ranges from 165,000 ac-ft in 1967, to 299,000 ac-ft in 1977. One in 10-year drought requirement is 253,000 ac-ft, based on 100% of the Blaney-Criddle calculated requirement. Total agricultural diversions made in the existing condition model base run, shown in Table VI-5, average 147,000 ac-ft per year.

2. <u>Future Conditions</u>

Water demand forecasts, using the medium growth scenario, described in Chapter V, were used to develop estimates of future water demands.

The RIBSIM model network was modified to reflect changes which are anticipated to occur between 1980 and 2020. These include delivery of Windy Gap Project water to Longmont, at an average of 8,000 ac-ft per year, the urbanization of an estimated 9,000 irrigated acres, and the transfer of agricultural water rights to municipal use. A 30-year simulation was made for the future condition case, with results as described below.

a. Municipal and Industrial

Future condition headgate demands for a 1-in-30-year drought are forecast to increase to a total of about 44,000 ac-ft by year 2020. The RIBSIM model results indicate average year diversions would total 36,600 ac-ft and that the 1 in 30-year drought deficit in year 2020 will be about 17,400 ac-ft, assuming delivery of Longmont's full allotment of Windy Gap Project water without reuse. As discussed subsequently in Chapter VII, this deficit was rounded to 18,000 ac-ft and used as an initial target requirement for plan formulation purposes. For plans that do not contemplate use of Windy Gap water within the Basin, the M&I drought year deficit for planning is 26,000 ac-ft.

Table VI-6 shows the annual diversions and calculated deficits for M&I use. The deficits are more serious from November through March, which indicates a need for storage facilities or for winter deliveries of Windy Gap and C-BT Project waters.

b. Agricultural

Agricultural water requirements at the headgate for year 2020 were calculated based on the medium projection of 62,000 acres of irrigated land, as described in Chapter V. In addition, irrigation efficiency is assumed to increase to 50% as a result of improved operation and maintenance of ditches in the next 35 years. The calculated year 2020 headgate water requirement is a function of climatological conditions and for a 30-year period of simulation ranges from 145,000 to 234,000 ac-ft, with an average of 190,000 ac-ft.

According to RIBSIM results, diversions made to satisfy these requirements, shown in Table VI-7, would average 120,000 ac-ft annually. These diversions are limited generally by available supplies, as simulated by the model. The annual deficit or difference between water requirements and diversions ranges from 8,000 ac-ft to 103,000 ac-ft, with an average of 42,000 ac-ft. Monthly deficits are generally greater during the latter part of the irrigation season.

Deficit for Planning Purposes. A frequency analysis was performed on the 30-year series of annual deficits, indicating that a deficit of about 78,000 ac-ft can be expected to occur on the average of once in 10 years, based on providing 85% of the Blaney-Criddle requirement. A discussion of the rationale of providing 85% of the Blaney-Criddle requirement in drought years is presented in Chapter V. As discussed subsequently in Chapter VII, Plan Formulation, a 10-year frequency of deficit is considered reasonable as an initial target for plan formulation for agricultural water supply.

E. Storable Flow Analysis

A preliminary analysis was made of flows legally and physically available for storage in the Basin on North and South St. Vrain creeks and on Left Hand Creek for a junior water right. More specific analyses were made subsequently for use in plan evaluation. The preliminary analysis utilized two scenarios of senior water right diversions in order to bracket storable flow quantities between conservative and more optimistic estimates. The conditional Narrows decree was assumed to be perfected with an agreement to not call out the new St. Vrain storage right. Because of downstream senior rights, storable flows on North and South St. Vrain creeks are not additive. That is, a right on one or the other branch could be developed, but not both of them.

The estimates of storable flow were determined using the RIBSIM model. A junior water right was placed near the mouth of the North St. Vrain and South St. Vrain creeks and on Left Hand Creek above any major diversions, in three separate 30-year model runs. This new storage right was assumed to be the most senior conditional right, since a 1985 storage right could conceivably yield no storage water if all senior conditional rights were perfected. It is important to note: (1) the model shows that the junior water right would divert all the water physically and legally available without any returns back to the system, and (2) that storable flows at other locations on the respective creeks may be more or less than estimated in this preliminary analysis.

In the conservative scenario, model results indicate that South St. Vrain annual storable flows range from 39,000 ac-ft to no storable flow, with a 30-year average of 7,000 ac-ft. The North St. Vrain annual storable flows range from 53,000 ac-ft to no storable flows with a 30-year average of 8,000 ac-ft. In Left Hand Creek, storable flows are estimated to be available in only 5 years out of the 30 years, which for all practical purposes amounts to no storable flow on the average.

A second scenario of storable flow runs was made using the 10-year diversion data base developed for calibrating the model. In this scenario, the average historical senior diversions were modeled and storable flows were determined for each of the previous analyzed creeks on this basis, rather than on maximum historical senior diversions, as used in the first scenario. The second scenario implies that excellent cooperation would occur among diverters in the Basin, to the extent that water users would recognize that the yield and performance of a new storage project is dependent on the frequency of their own placement of calls on the creek. Estimated storable flows for these models runs range from none in 1977 to 52,000 ac-ft on the South St. Vrain, from none to 70,000 ac-ft on the North St. Vrain, and none to 20,000 on Left Hand Creek. The 10-year averages of the estimated storable flows for this scenario are 24,000, 28,000, and 7,000 ac-ft for South St. Vrain, North St. Vrain, and Left Hand creeks, respectively.

Table VI-1, Page 1

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Listing of Water Rights Shown on Figure VI-1

Reference Number	Water Right Name	Return Flow[1] Location(s)	Export[2] Location(s)
1	Left Hand Ditch	-	60
	Left Hand Ditch Enlargement	-	60
2	South Ledge Ditch	24, 33	-
	South Ledge Ditch Enlargement	24, 33	-
3	Button Rock Reservoir	-	5, 6
4	North Longmont Pipeline	7, 33, 65	-
5	Button Rock Supply for Longmont	7, 33, 65	-
6	Button Rock Supply for Irrigation	(3)	-
7	Lyons Pipeline	10	-
8	Supply Ditch C-BT Reservoir	-	12
9	Longmont C-BT Reservoir	-	13
10	Divide Reservoir	-	11
11	Supply Ditch	64, 68	-
12	Supply C-BT Ditch	64, 68	-
13	Longmont Municipal C-BT	33, 65	-
14	Highland Ditch C-BT Reservoir	-	23
15	Rough & Ready C-BT Reservoir	-	26
16	Swede Ditch C-BT Reservoir	-	30
17	Oligarchy Ditch C-BT Reservoir	-	42
18	Clover Basin C-BT Reservoir	-	45
19	Peck, Davis & Downing, James C-BT Res.	-	47
20	Public Service C-BT Reservoir	-	66
21	Highland Reservoirs	-	22
22	Highland Ditch	64, 65, 68	-
23	Highland C-BT Ditch	64, 65, 68	-
24	Pleasant Valley Reservoir	-	25
25	Rough & Ready Ditch	57, 64, 65	-
26	Rough & Ready C-BT Ditch	57, 64, 65	-
27	Oligarchy Reservoir	-	41
28	Palmerton Ditch	37, 48	-
29	Swede Ditch	46, 64	-
30	Swede C-BT Ditch	46, 64	-
31	Smead & Montgomery Private Ditch	33	-
32	Foothills Reservoir	-	(4)
33	Goss Private Ditches 1 & 2	34	-
34	Clough, True & Webster, Clough Private	35	-
35	Webster & McCaslin Ditch	46	-
36	Weese, Baker & Weese Ditch	37	-
37	Longmont Supply Ditch	41, 52, 64	-
38	Chapman & McCaslin Ditch	39	-
39	Calkins Lake	-	67

Table VI-1, Page 2

St. Vrain Basin Reconnaissance Study

Listing of Water Rights Shown on Figure VI-1

Reference Number	Water Right Name	Return Flow[1] Location(s)	Export[2] Location(s)
40	McIntosh Lake	-	(5)
41	Oligarchy Ditch	48, 57, 65	-
42	Oligarchy C-BT Ditch	48, 57, 65	-
43	Clover Basin Reservoir	-	46
44	Clover Basin Ditch	64	-
45	Clover Basin C-BT Ditch	64	-
46	Peck, James, Davis & Downing	51, 64	-
47	Peck, James, D & D C-BT Ditch	51, 64	-
48	Denio & Taylor Ditch	49, 57, 58	-
49	Runyan Ditch	50	-
50	Zweck & Turner Ditch	52	-
51	Pella Ditch	52	-
52	Niwot Ditch	64	-
53	Hagers Meadow Ditch	54	-
54	South Flat, N.W. Mutual Ditch	64	-
55	Mason Meadow Ditch	56	-
56	Beckwith, Cushman Ditch	57, 64	-
57	Island Ditch	58	-
58	Dickens Private Ditch	64	-
59	Left Hand Ditch C-BT Reservoir	-	62
60	Left Hand Reservoir	-	61, 63
61	Left Hand Ditch Company	64	-
62	Left Hand C-BT Ditch	64	-
63	Left Hand Water Supply	64	-
64	Bonus Ditch	65	-
65	Last Chance Ditch	68	-
66	Public Service C-BT Ditch	(6)	-
67	GASP Augmentation Release (Calkins)	68	-
68	Gage at mouth of St. Vrain River (7310)	-	-

Notes:

(1) First downstream water right, listed by reference number, which can benefit from return flows.

(2) Listed water rights by reference number which receive exported water.

(3) Water is released to the river available for downstream irrigation water rights.

(4) Replacement reservoir for out-of-priority diversions for Highland Ditch.

(5) Replacement reservoir for out-of-priority diversions for Foothills Reservoir.

(6) No return flows, assumed 100% consumptive.

(B0353C)

RIBSIM INPUT: WATER RIGHTS LISTING

NETWORK NUMBER	STRUCTURE NAME	RIBSIM PRIORITY	DECREED CAPACITY	MODELED CAPACITY
20	LEFT HAND DITCH (SSV)	1000	40.8 cfs	41 cfs
30	LEFT HAND DITCH ENL(SSV)	2800	685.2 cfs	14.6 cfs
70	SOUTH LEDGE DITCH	4500	3.7 cfs	3.7 cfs
80	SOUTH LEDGE DITCH ENL	4700	27.3 cfs	0.5 cfs
110	BUTTON ROCK RESERVOIR	6700	17982 ac-ft	15500 ac-ft
130	N. LONGMONT PIPELINE	1500	32.8 cfs	21.3 cfs
136	LONGMONT BUTTON R SUPPLY	6703	NA	26.2 cfs
137	BUTTON ROCK IRR SUPPLY	6704	NA	2.4 cfs
140	LYONS PIPELINE	4900	4.04 cfs	0.5 cfs
150	DIVIDE RESERVOIR	4200	1800 ac-ft	900 ac-ft
151	SUPPLY DITCH	3800	92.2 cfs	35 cfs
152	SUPPLY CBT DITCH	3801	NA	50 cfs
153	LONGMONT MUNI. CBT	3601	NA	40 cfs
200	1883-90 ADJ HILAND RES	4300	4835 ac-ft	4035 ac-ft
210	1907 ADJ HIGHLAND RES	5100	779 ac-ft	779 ac-ft
220	1951 ADJ HIGHLAND RES	6100	7544 ac-ft	1441 ac-ft
230	HIGHLAND DITCH	3100	347.7 cfs	148.4 cfs
241	HIGHLAND CBT DITCH	3901	NA	150 cfs
250	PLEASANT VALLEY RES	4000	5064 ac-ft	2532 ac-ft
270	ROUGH & READY DITCH	2600	83.3 cfs	38.8 cfs
281	ROUGH & READY CBT DITCH	3601	NA	20 cfs
290	OLIGARCHY RES #1 1890	4400	1080 ac-ft	1080 ac-ft
300	OLIGARCHY RES #1 OTHERS	4800	1321 ac-ft	657 ac-ft
320	PALMERTON DITCH	1700	162.7 cfs	20 cfs
340	SWEDE DITCH	3000	24.6 cfs	14 cfs
351	SWEDE CBT DITCH	3501	NA	15 cfs
360	SMEAD & MONTGOMERY PVT	700	20.2 cfs	8.8 cfs
370	FOOTHILLS RES	5700	6745 ac-ft	4239 ac-ft
390	GOSS PRIVATE DITCH 1 & 2	1900	29.5 cfs	3 cfs
400	CLOUGH,T&W,& CL. PVT	600	30.1 cfs	8 cfs
410	WEBSTER & MCCASLIN DITCH	2100	13.2 cfs	2.5 cfs
420	WEESE,BAKER & WEESE D.	2000	6.8 cfs	2.2 cfs
430	LONGMONT SUPPLY DITCH	1600	50.7 cfs	20.1 cfs
440	CHAPMAN & MCCASLIN	400	98.1 cfs	4.4 cfs
450	CALKINS LAKE	5200	13219 ac-ft	12739 ac-ft
460	MCINTOSH LAKE	5400	4920 ac-ft	2460 ac-ft
470	OLIGARCHY DITCH	2400	237.5 cfs	36.2 cfs
494	CLOVER BASIN RES	5800	596 ac-ft	596 ac-ft
495	CLOVER BASIN DITCH	3700	23.6 cfs	5 cfs
500	PECK,JAMES,DAVIS&DOWNING	2500	63.8 cfs	27.5 cfs
501	PECK,JAMES,D&D CBT DITCH	2501	NA	10 cfs
510	DENIO & TAYLOR DITCH	2200	45.2 cfs	3.1 cfs
520	RUNYAN DITCH	900	10.8 cfs	3.7 cfs
530	ZWECK & TURNER DITCH	1400	82.6 cfs	9.4 cfs
540	PELLA DITCH	500	2.0 cfs	1.9 cfs
550	NIWOT DITCH	1800	36.9 cfs	7.2

RIBSIM INPUT: WATER RIGHTS LISTING

NETWORK NUMBER	STRUCTURE NAME	RIBSIM PRIORITY	DECREED CAPACITY	MODELED CAPACITY
570	HAGERS MEADOW DITCH	1200	2.7 cfs	2.0 cfs
580	S. FLAT, NW MUTUAL DITCH	1100	21.5 cfs	9.6 cfs
590	MASON MEADOW DITCH	295	5.5 cfs	1.0 cfs
600	BECKWITH,CUSHMAN DITCHES	299	27.7 cfs	8.6 cfs
610	ISLAND DITCH	1300	4.5 cfs	0.8 cfs
620	DICKENS PRIVATE DITCH	800	15.5 cfs	2.8 cfs
650	LEFT HAND RESERVOIRS	4100	13773 ac-ft	7514 ac-ft
655	LEFT HAND DITCH CO IRR	2802	NA	86.3 cfs
656	LEFT HAND CBT DITCH	2803	NA	50 cfs
660	LEFT HAND WATER SUPPLY	2801	NA	2.5 cfs
680	BONUS DITCH	300	23.2 cfs	12.5 cfs
690	LAST CHANCE DITCH	3400	96.9 cfs	32.8 cfs
900	PUBLIC SERVICE CBT DIT.	250	NA	10 cfs
1000	GASP AUG RELEASE (UNION)	3050	NA	65 cfs

Table VI-3

ST. VRAIN BASIN RECONNAISSANCE STUDY

AVERAGE TEN YEAR WATER BALANCE

MODEL RESULTS 1971-1980

	VALUES IN ACRE-FEET
A. INFLOWS	
1. North St. Vrain Creek	64271
2. South St. Vrain Creek	49019
3. Left Hand Creek	16857
4. C-BT Imports	31768
5. Dry Creek (includes Boulder Creek return flows)	5885
6. Boulder Creek	56244
7. Idaho Creek (Boulder and South Platte return flows)	27848
TOTAL	251892
B. DIVERSIONS	
1. Direct Flow (includes diversion of reservoir exports)	110547
2. To Storage	18354
3. C-BT Diversions	31768
4. Exports From Reservoirs (included in B.1 above)	-15123
TOTAL	145546
C. DEPLETIONS	
1. Crop, Municipal and Industrial Consumptive Use	78073
2. Reservoir Evaporation	3559
3. Change in Reservoir Storage	-328
TOTAL	81304
D. RETURN FLOWS	
1. Surface Returns	24516
2. Subsurface Returns	39726
TOTAL	64242
E. COMPUTED OUTFLOW	
1. Inflows - Diversions + Return Flows	170588
F. MODELED OUTFLOW	170593

TABLE VI-4

ST VRAIN BASIN RECONNAISSANCE STUDY

CURRENT MUNICIPAL AND INDUSTRIAL DEFICIT

ALL VALUES IN ACRE-FEET (1)

CURRENT MUNICIPAL AND INDUSTRIAL DEMANDS

DEMAND	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL
TOTAL	1408	1181	1191	1155	1084	1129	1257	1534	2111	2258	1997	1679	17984

CURRENT MUNICIPAL AND INDUSTRIAL DIVERSIONS

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL	ANNUAL DEFICIT
1951	652	452	532	526	485	543	1258	1537	2112	2261	2000	1680	14040	4000
1952	1411	611	622	633	566	602	1258	1537	2112	2261	2000	1680	15295	3000
1953	1411	1152	1163	1107	1001	1050	1258	1537	2112	2261	2000	1680	17734	0
1954	1411	1071	605	501	470	501	1258	1537	2112	2261	2000	1680	15410	3000
1955	1370	431	442	442	409	442	1258	1537	2112	2261	2000	1680	14386	4000
1956	1411	431	442	442	428	622	1258	1537	2112	2261	1879	641	13467	5000
1957	634	611	622	559	506	582	1258	1537	2112	2261	2000	1680	14364	4000
1958	1411	1152	1163	1107	1001	1050	1258	1537	2112	2261	2000	1680	17734	0
1959	1411	982	1060	1003	952	1020	1258	1537	2112	2261	2000	1680	17278	1000
1960	1411	972	1086	1059	990	996	1258	1537	2112	2261	2000	1680	17364	1000
1961	792	491	560	524	502	538	1258	1537	2112	2261	2000	1680	14257	4000
1962	1411	1182	1194	1138	1029	1081	1258	1537	2112	2261	2000	1680	17884	0
1963	1411	1005	1068	1002	465	548	1258	1537	2112	2261	2000	1680	16349	2000
1964	1411	431	442	497	484	571	1258	1537	2112	2261	2000	1680	14686	3000
1965	1152	431	465	497	457	533	1258	1537	2112	2261	2000	1180	13886	4000
1966	636	611	653	633	566	602	1258	1537	2112	2261	2000	1680	14550	3000
1967	1411	431	442	483	459	538	1258	1537	2112	2261	2000	1680	14614	3000
1968	1411	1032	1103	1037	951	1031	1258	1537	2112	2261	2000	1634	17370	1000
1969	1340	431	553	512	457	556	1258	1537	2112	2261	2000	1680	14699	3000
1970	1411	1182	1194	1158	1080	1092	1258	1537	2112	2261	2000	1680	17966	0
1971	1411	972	1018	1041	902	983	1258	1537	2112	2261	2000	1634	17131	1000
1972	1411	1152	1194	1138	1029	1081	1258	1537	2112	2261	2000	1680	17854	0
1973	1411	988	577	575	507	582	1258	1537	2112	2261	2000	1680	15490	2000
1974	1411	1152	1163	1127	1052	1061	1258	1537	2112	2261	2000	1680	17816	0
1975	1411	1152	1163	1127	1002	622	1258	1537	2112	2261	2000	1680	17327	1000
1976	670	611	622	622	589	622	1258	1537	2112	2261	2000	1680	14586	3000
1977	1411	611	622	622	589	622	1258	1537	2112	2261	2000	1680	15327	3000
1978	1370	431	454	622	524	591	1258	1537	2112	2261	2000	1680	14842	3000
1979	1402	719	622	602	538	571	1258	1537	2112	2261	2000	1680	15304	3000
1980	1411	1152	1163	1107	1001	1081	1258	1537	2112	2261	2000	1680	17765	0
AVERAGE	1275	801	800	781	700	744	1258	1537	2112	2261	1996	1626	15893	2000

CURRENT MUNICIPAL AND INDUSTRIAL DEFICIT

DEFICIT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL
AVERAGE	100	400	400	400	400	400	0	0	0	0	0	100	2000

NOTES: 1. Monthly deficits have been rounded to the nearest 100 ac-ft, annual deficits to the nearest 1000 ac-ft.

(B0353C)

TABLE VI-5

ST VRAIN BASIN RECONNAISSANCE STUDY

CURRENT AGRICULTURAL DEFICIT

ALL VALUES IN ACRE-FEET (1)

CURRENT AGRICULTURAL HEADGATE WATER REQUIREMENTS

DEMAND	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL
AVERAGE	4929	0	0	0	0	0	3718	25178	57356	65353	53234	32462	242230

CURRENT AGRICULTURAL DIVERSIONS

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL	ANNUAL DEFICIT
1951	4253	0	0	0	0	0	297	21143	41360	58848	28778	15353	170032	72000
1952	244	0	0	0	0	0	5315	21143	73711	51572	23811	14187	189983	52000
1953	3036	0	0	0	0	0	223	9313	61998	30022	20791	14229	139612	103000
1954	2236	0	0	0	0	0	12406	29169	22888	18353	11219	6801	103072	139000
1955	4829	0	0	0	0	0	9190	27103	29245	21958	13936	7228	113489	129000
1956	2768	0	0	0	0	0	3494	34234	50421	22345	14612	9638	137512	105000
1957	3026	0	0	0	0	0	0	0	56871	68875	38254	15568	182594	60000
1958	4465	0	0	0	0	0	2713	12082	58463	36018	18110	9134	140985	101000
1959	782	0	0	0	0	0	0	14095	67794	36184	19075	6572	144502	98000
1960	635	0	0	0	0	0	6282	13844	62518	35915	19028	8228	146450	96000
1961	2881	0	0	0	0	0	1859	8810	54618	46902	24317	7461	146848	95000
1962	0	0	0	0	0	0	9113	35225	44693	30651	19846	8024	147552	95000
1963	3042	0	0	0	0	0	11058	35466	32108	18695	17993	13380	131742	110000
1964	5840	0	0	0	0	0	3159	30364	34000	26970	12304	7527	120164	122000
1965	0	0	0	0	0	0	5018	23389	44807	49415	37023	8487	168139	74000
1966	0	0	0	0	0	0	3789	34263	32471	21956	11487	6918	110884	131000
1967	782	0	0	0	0	0	446	20992	13787	39540	28507	15217	119271	123000
1968	4910	0	0	0	0	0	0	20490	53066	30289	15128	10794	134677	108000
1969	4101	0	0	0	0	0	9729	15102	24701	52396	23714	12945	142688	100000
1970	0	0	0	0	0	0	2044	44822	37339	40043	22232	8104	154584	88000
1971	2785	0	0	0	0	0	0	33516	71614	33214	24620	5839	171588	71000
1972	0	0	0	0	0	0	3308	36934	47915	24545	15466	12953	141121	101000
1973	4148	0	0	0	0	0	0	6544	73356	43852	26485	9194	163579	79000
1974	3749	0	0	0	0	0	1896	43085	44924	34448	20097	11339	159538	83000
1975	3376	0	0	0	0	0	0	9313	56750	55797	27290	13980	166506	76000
1976	3480	0	0	0	0	0	4413	28937	42083	27381	21577	9152	137023	105000
1977	4149	0	0	0	0	0	3457	32498	34071	16689	13831	9297	113992	128000
1978	4116	0	0	0	0	0	6441	0	60101	56071	25023	14269	166021	76000
1979	2883	0	0	0	0	0	2825	10320	44807	57208	22016	17888	157947	84000
1980	4153	0	0	0	0	0	929	10068	81079	43820	21822	12473	174344	68000
AVERAGE	2689	0	0	0	0	0	3647	22075	48452	37666	21280	10739	146548	96000

CURRENT AGRICULTURAL DEFICIT

DEFICIT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL
AVERAGE	2200	0	0	0	0	0	100	3100	8900	27700	32000	21700	96000

NOTES: 1. Monthly deficits have been rounded to the nearest 100 ac-ft, annual deficits to the nearest 1000 ac-ft.

(B0353C)

TABLE VI-6

ST VRAIN BASIN RECONNAISSANCE STUDY

2020 MUNICIPAL AND INDUSTRIAL DEFICIT

ALL VALUES IN ACRE-FEET (1)

2020 MUNICIPAL AND INDUSTRIAL WATER DEMANDS

DEMAND	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL
TOTAL	3445	2989	3015	2933	2766	2873	3047	3776	5091	5440	4871	4105	44351

CURRENT MUNICIPAL AND INDUSTRIAL DIVERSIONS

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL	ANNUAL DEFICIT
1951	3302	1982	2026	2026	1893	1744	3036	3776	5080	5358	4728	3951	38902	5000
1952	3302	2012	2057	2435	2090	2637	3036	3776	5080	5358	4728	3951	40461	4000
1953	3302	1982	2026	2026	1893	2026	3036	3776	5080	5440	4728	3951	39266	5000
1954	3302	1982	2026	742	494	565	3036	3776	5080	5440	4761	2475	33679	11000
1955	1672	455	466	466	433	466	3036	3776	5080	5440	4871	3423	29585	15000
1956	1709	455	466	466	452	648	3036	3776	5080	5440	3622	1840	26992	17000
1957	1621	717	649	563	530	653	3036	3776	5080	5358	4728	3951	30662	14000
1958	3302	1982	2026	2026	1921	2057	3036	3776	5080	5440	4871	4053	39570	5000
1959	3302	1982	2026	2026	1893	1614	3036	3776	5080	5440	4810	3951	38936	5000
1960	3302	1982	2026	2026	1893	2057	3036	3776	5080	5440	4728	3951	39297	5000
1961	3302	1982	1614	1575	1453	1629	3036	3776	5080	5358	4728	3951	37484	7000
1962	3302	2847	2784	2509	2531	2707	3036	3776	5080	5440	4769	3951	42732	2000
1963	3302	1982	2026	1767	966	999	3036	3776	5080	5440	4871	3757	37002	7000
1964	1698	455	533	539	508	595	3036	3776	5080	5440	4871	2315	28846	16000
1965	1672	489	539	521	481	557	3036	3776	5080	5358	4728	3951	30189	14000
1966	3302	2012	2057	2057	2108	2377	3036	3776	5080	5440	4871	4053	40168	4000
1967	2757	1458	1570	1551	1076	562	3036	3776	5080	5440	4728	3745	34781	10000
1968	2769	1509	1613	1614	1467	1674	3036	3776	5080	5358	4728	3418	36041	8000
1969	2769	1587	1641	695	532	631	3036	3776	5080	5440	4728	3951	33866	10000
1970	3302	2012	2057	2057	1921	2057	3036	3776	5080	5358	4728	3951	39334	5000
1971	3232	1982	2057	2057	1921	2057	3036	3776	5080	5358	4728	3951	39234	5000
1972	3302	1982	2057	2385	2269	2670	3036	3776	5080	5440	4810	3951	40758	4000
1973	3302	1928	1623	1626	1458	1017	3036	3776	5080	5440	4728	3951	36966	7000
1974	3302	1982	2026	2026	1893	2057	3036	3776	5080	5440	4871	4053	39542	5000
1975	3302	1982	2026	2026	1027	999	3036	3776	5080	5440	4810	3951	37455	7000
1976	3302	1982	2026	2026	1893	2026	3036	3776	5080	5440	4871	4053	39511	5000
1977	3302	1982	2026	2026	1663	999	3036	3776	5080	5440	4871	3104	37306	7000
1978	1643	509	641	668	526	615	3036	3776	5080	5358	4728	3951	30531	14000
1979	3302	1982	2026	2026	1893	2026	3036	3776	5080	5358	4728	3951	39184	5000
1980	3302	1982	2026	2057	1921	2057	3036	3776	5080	5440	4728	3951	39356	5000
AVERAGE	2920	1672	1692	1621	1433	1493	3036	3776	5080	5413	4740	3713	36588	8000

MONTHLY MUNICIPAL AND INDUSTRIAL DEFICIT

DEFICIT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL
AVERAGE	500	1300	1300	1300	1300	1400	0	0	0	0	100	400	8000

NOTES: 1. Monthly deficits have been rounded to the nearest 100 ac-ft, annual deficits to the nearest 1000 ac-ft.

(B0353C)

TABLE VI-7

ST VRAIN BASIN RECONNAISSANCE STUDY

2020 AGRICULTURAL DEFICIT

ALL VALUES IN ACRE-FEET (1)

2020 AGRICULTURAL REQUIREMENTS (2)

DEMAND	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL
TOTAL	3291	0	0	0	0	0	2485	16804	38285	43623	35532	21667	161687

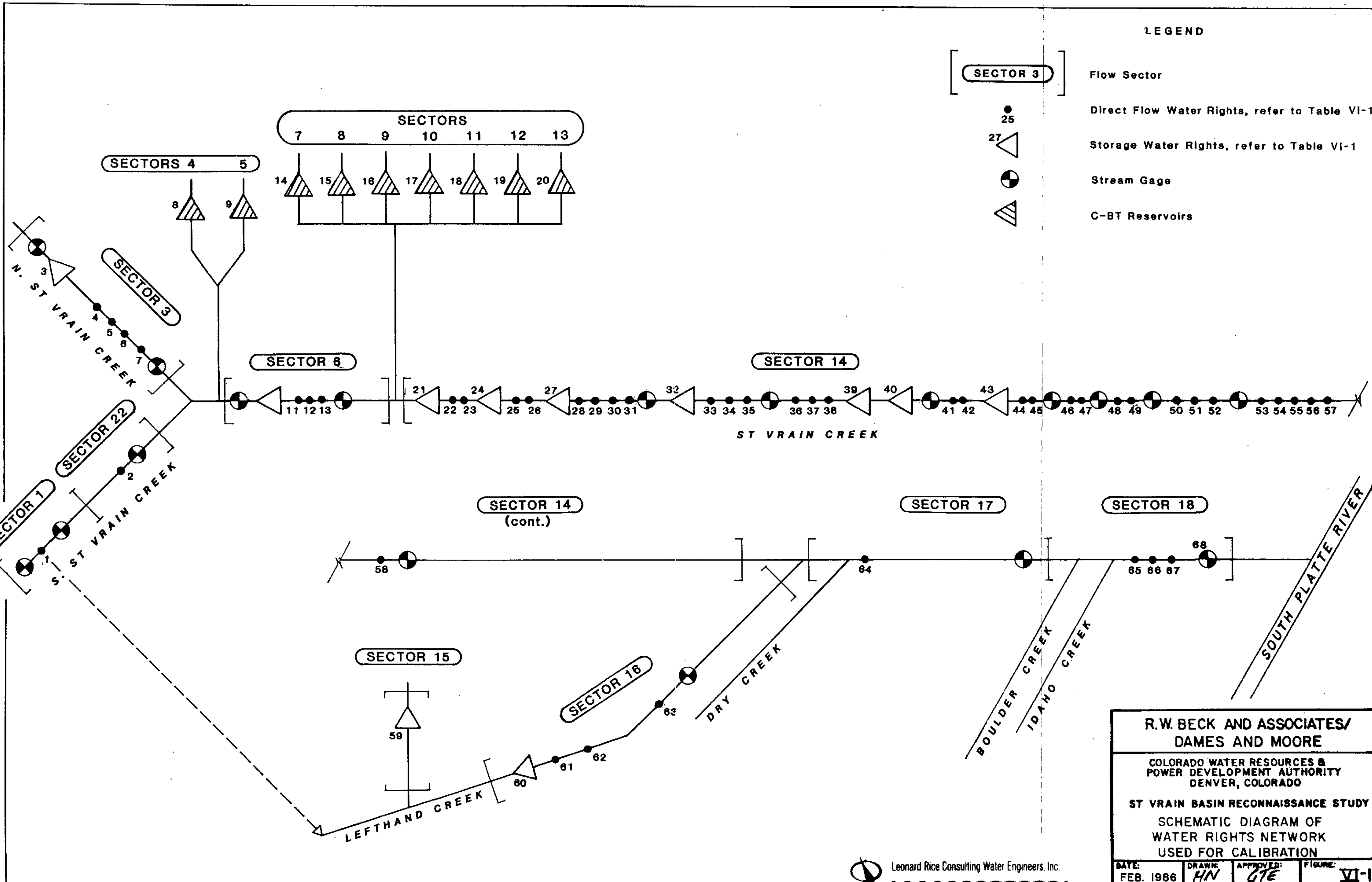
2020 AGRICULTURAL DIVERSIONS

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL	ANNUAL DEFICIT
1951	3398	0	0	0	0	0	199	14111	26011	40648	24316	18365	127048	13000
1952	165	0	0	0	0	0	3553	14111	46658	42350	21139	9996	137971	43000
1953	2541	0	0	0	0	0	149	6215	46522	31858	19810	11694	118790	45000
1954	1827	0	0	0	0	0	8773	25708	25727	17221	10615	5423	95293	103000
1955	3910	0	0	0	0	0	6309	23084	28172	20655	13463	7369	102962	75000
1956	2007	0	0	0	0	0	2335	22551	48618	22542	16115	9852	124021	53000
1957	2532	0	0	0	0	0	0	0	35731	43033	30076	14579	125950	19000
1958	3258	0	0	0	0	0	1814	8063	37465	32611	26269	9184	118663	38000
1959	521	0	0	0	0	0	0	9407	46519	37207	17608	5672	116934	43000
1960	424	0	0	0	0	0	4199	9239	41499	39977	17640	9221	122198	51000
1961	2546	0	0	0	0	0	1242	5879	34701	38428	20233	4980	108009	22000
1962	0	0	0	0	0	0	6162	23904	30452	33963	25194	9236	128911	30000
1963	2232	0	0	0	0	0	7738	32011	20814	28214	16317	12899	120226	58000
1964	5520	0	0	0	0	0	2112	21107	32209	30351	11562	6563	109423	78000
1965	0	0	0	0	0	0	3354	15801	27866	30955	30852	5994	114821	8000
1966	0	0	0	0	0	0	2534	26577	31202	24944	12503	6506	104267	74000
1967	521	0	0	0	0	0	298	14104	9198	25544	28630	19870	98166	12000
1968	4946	0	0	0	0	0	0	13845	40610	35380	16022	8688	119492	43000
1969	3291	0	0	0	0	0	6731	10079	16124	43670	22726	13215	115836	40000
1970	0	0	0	0	0	0	1367	28952	23220	37340	25705	8800	125383	27000
1971	1857	0	0	0	0	0	0	22320	48096	36285	21432	3898	133887	33000
1972	0	0	0	0	0	0	2211	26707	30791	33860	15660	9781	119010	39000
1973	3667	0	0	0	0	0	0	4368	47476	39105	30192	9102	133910	27000
1974	3287	0	0	0	0	0	1267	34093	28759	38679	22006	10156	138246	31000
1975	2732	0	0	0	0	0	0	6215	36428	40689	30958	13763	130787	17000
1976	3139	0	0	0	0	0	2957	19470	34867	34162	18590	6872	120056	32000
1977	3471	0	0	0	0	0	2311	29589	29769	17251	14089	9411	105890	93000
1978	3556	0	0	0	0	0	4342	0	38053	45059	25823	12620	129454	32000
1979	1922	0	0	0	0	0	1888	6887	28568	44373	17411	22616	123666	15000
1980	5069	0	0	0	0	0	621	6719	51181	43614	17088	10305	134597	52000
AVERAGE	2278	0	0	0	0	0	2482	16037	34110	34332	20668	10221	120129	42000

MONTHLY AGRICULTURAL DEFICIT

DEFICIT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL
AVERAGE	1000	0	0	0	0	0	0	800	4200	9300	14900	11400	42000

NOTES: 1. Monthly deficits have been rounded to the nearest 100 ac-ft, annual deficits to the nearest 1000 ac-ft.
2. This base run uses 85 percent of Blaney Criddle calculated demands at 50 percent overall efficiency to calculate agricultural headgate diversion requirements.


LEGEND
SECTOR 3
Flow Sector
Direct Flow Water Rights, refer to Table VI-1
Storage Water Rights, refer to Table VI-1
Stream Gage
C-BT Reservoirs
SECTORS 7 8 9 10 11 12 13
SECTORS 4 5
SECTOR 3
N. ST VRAIN CREEK
SECTOR 6
SECTOR 14
ST VRAIN CREEK
SECTOR 22
S. ST VRAIN CREEK
SECTOR 1
SECTOR 14 (cont.)
SECTOR 17
SECTOR 18
SOUTH PLATTE RIVER
SECTOR 15
SECTOR 16
DRY CREEK
BOULDER CREEK
IDAHO CREEK
LEFTHAND CREEK
Leonard Rice Consulting Water Engineers, Inc.
R.W. BECK AND ASSOCIATES/
DAMES AND MOORE
COLORADO WATER RESOURCES &
POWER DEVELOPMENT AUTHORITY
DENVER, COLORADO
ST VRAIN BASIN RECONNAISSANCE STUDY
SCHEMATIC DIAGRAM OF
WATER RIGHTS NETWORK
USED FOR CALIBRATION
DATE: FEB. 1986
DRAWN: HN
APPROVED: GTE
FIGURE: VI-1

HEADGATE DIVERSION: 100 ACRE-FEET

CONVEYANCE LOSSES	
19 % LOSS	19
19 % LOSS	19
	AC-FT

MUNICIPAL CONSUMPTIVE USE	
SUMMER 42.00 %	34.02
WINTER 20.00 %	16.20
OF DELIVERY	AC-FT

ON-SITE LOSSES	
58.00 % LOSS	46.98
80.00 % LOSS	64.80
	AC-FT

SEEPAGE		SURFACE	
0 %	0	100 %	19.0
0 %	0	100 %	19.0
	AC-FT		AC-FT

SUMMER
OVERALL EFFICIENCY = 34.02 PERCENT
HEADGATE EFFICIENCY = 42.00 PERCENT

WINTER
OVERALL EFFICIENCY = 16.20 PERCENT
HEADGATE EFFICIENCY = 20.00 PERCENT

SEEPAGE		SURFACE	
0 %	0	100 %	46.98
0 %	0	100 %	64.80
	AC-FT		AC-FT

SEEPAGE LOSSES				SURFACE LOSSES			
RECOVERABLE		IRRECOVERABLE		RECOVERABLE		IRRECOVERABLE	
0 %	0	0 %	0	100 %	19.0	0 %	0
0 %	0	0 %	0	100 %	19.0	0 %	0
	AC-FT		AC-FT		AC-FT		AC-FT

RECOVERABLE WATER = 19.00 ACRE-FEET

SEEPAGE LOSSES				SURFACE LOSSES			
RECOVERABLE		IRRECOVERABLE		RECOVERABLE		IRRECOVERABLE	
0 %	0	0 %	0	100 %	46.98	0 %	0
0 %	0	0 %	0	100 %	64.80	0 %	0
	AC-FT		AC-FT		AC-FT		AC-FT

RECOVERABLE WATER = 46.98 ACRE-FEET

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ST VRAIN BASIN RECONNAISSANCE STUDY

DISPOSITION OF MUNICIPAL
HEADGATE DIVERSIONS

DATE:	DRAWN:	APPROVED:	FIGURE:
FEB. 1986	PC	GTE	VI-2

HEADGATE DIVERSION: 100 ACRE-FEET

CONVEYANCE LOSSES	
19 % LOSS	19 AC-FT

CROP CONSUMPTIVE USE	
62 % OF DELIVERY	50 AC-FT

ON-FARM LOSSES	
38.00 % LOSS	30.78 AC-FT

OVERALL EFFICIENCY = 50.22 PERCENT

HEADGATE EFFICIENCY = 62.00 PERCENT

SEEPAGE	SURFACE
75 % 14.25 AC-FT	25 % 4.75 AC-FT

SEEPAGE	SURFACE
50 % 15.39 AC-FT	50 % 15.39 AC-FT

SEEPAGE LOSSES		SURFACE LOSSES	
RECOVERABLE	IRRECOVERABLE	RECOVERABLE	IRRECOVERABLE
95 % 13.5375 AC-FT	5 % 0.7125 AC-FT	85 % 4.037 AC-FT	15 % 0.7125 AC-FT

RECOVERABLE WATER = 17.58 ACRE-FEET

SEEPAGE LOSSES		SURFACE LOSSES	
RECOVERABLE	IRRECOVERABLE	RECOVERABLE	IRRECOVERABLE
95 % 14.6205 AC-FT	5 % 0.7695 AC-FT	85 % 13.08 AC-FT	15 % 2.3085 AC-FT

RECOVERABLE WATER = 27.70 ACRE-FEET

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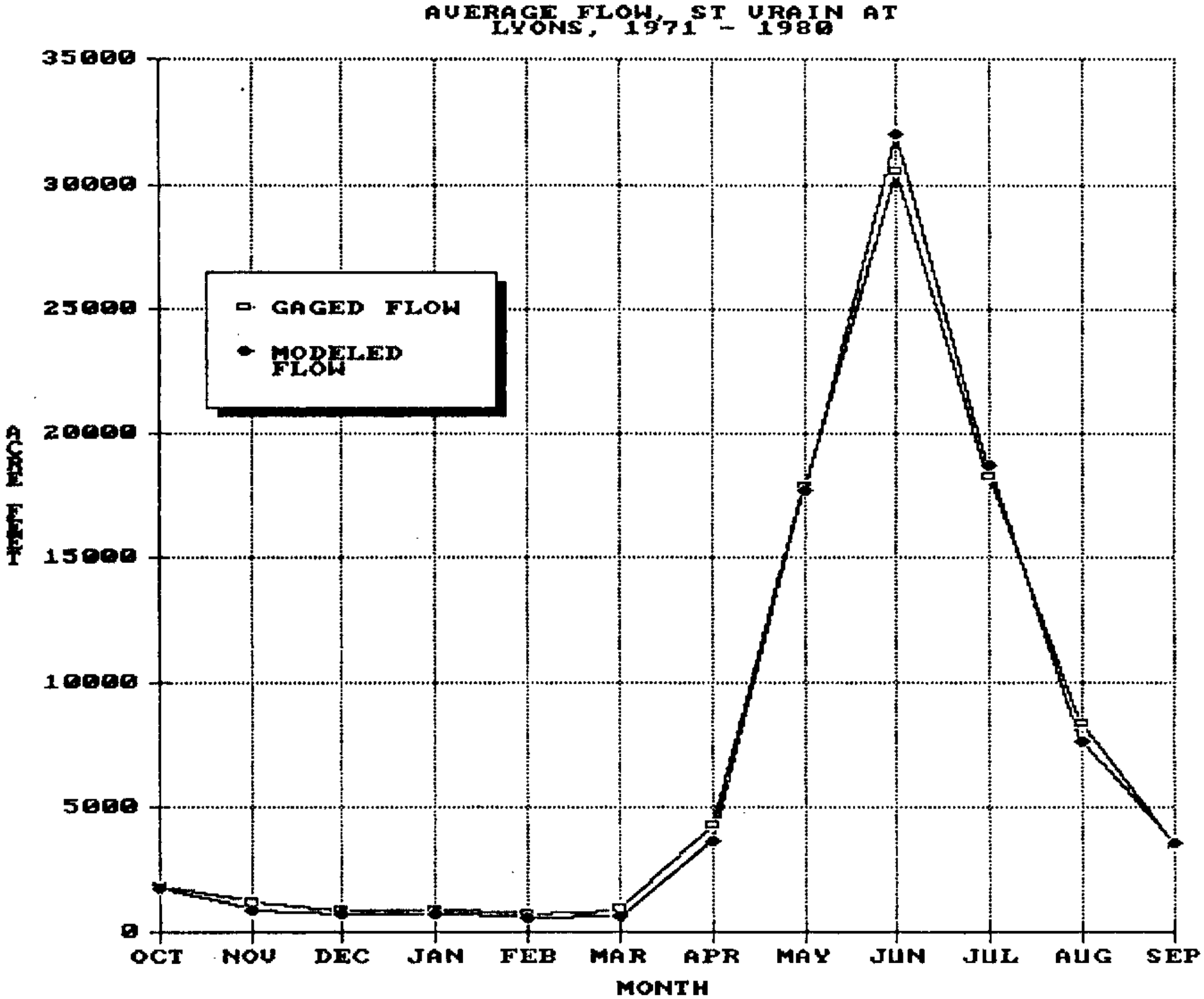
ST VRAIN BASIN RECONNAISSANCE STUDY

DISPOSITION OF IRRIGATION
HEADGATE DIVERSIONS

DATE:	DRAWN:	APPROVED:	FIGURE:
FEB. 1986	PC	GTE	VI-3



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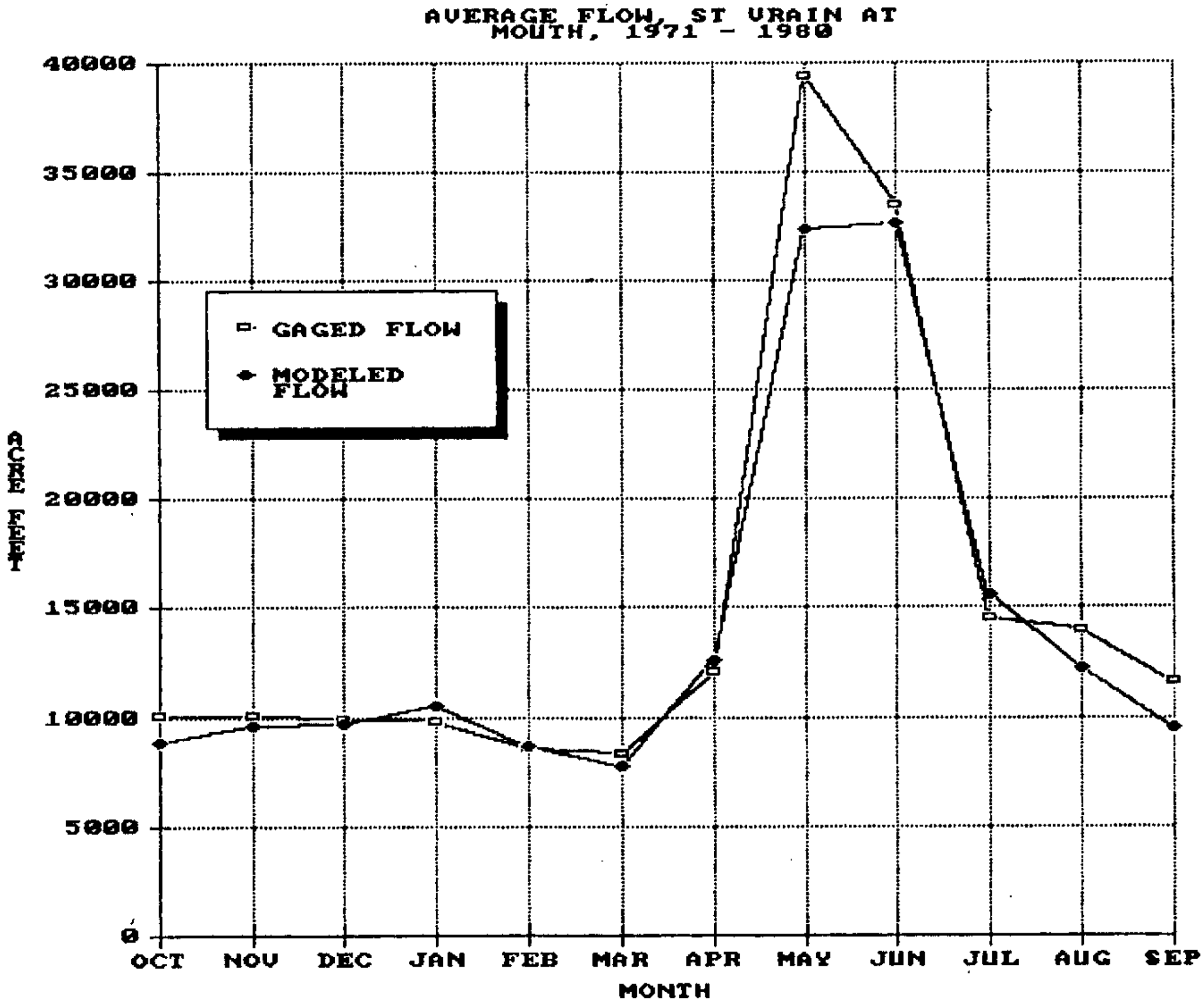
ST VRAIN BASIN RECONNAISSANCE STUDY

MODELED VS. GAGED FLOW
ST. VRAIN CREEK AT LYONS

DATE:	DRAWN:	APPROVED:	FIGURE:
FEB. 1986	PC	GTE	VI-4



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ST VRAIN BASIN RECONNAISSANCE STUDY

MODELED VS. GAGED FLOW
ST. VRAIN CREEK AT MOUTH

DATE:	DRAWN:	APPROVED:	FIGURE:
FEB. 1986	PC	GTE	VI-5

CHAPTER VII

PLAN FORMULATION

A. Introduction

Previous chapters collectively identify the water-related needs and describe the water supply system and other characteristics of the St. Vrain Basin, all of which form the basis for formulating water resource management plans. This chapter contains a discussion of the process used in formulating alternative water resource management plans, and presents the resulting plans. It describes the four major tasks that comprise the CWRPDA process; namely, the identification of water resource management plan purposes, identification of plan elements, evaluation of plan elements, and formulation of preliminary alternative plans.

B. Water Resource Management Plan Purposes

1. General

Water resource management plans for the Basin were formulated to address one or several of the purposes described in this chapter. Input and values of the Study Advisory Committee and from the public were instrumental in establishing these water resource management purposes. The processes utilized to obtain this input are described in Chapter I. Information compiled on Basin characteristics and water resources needs provided the factual base for selection of plan purposes. Ideally, a plan would meet as many purposes as possible while maximizing benefits and minimizing adverse impacts. In practice, there are limitations on the extent to which any plan can be developed and tradeoffs among the various plan purposes are inevitable.

Identified below are the primary and secondary purposes to be served by a St. Vrain Basin water resource management plan. In general, each plan includes at least one primary purpose, and may include one or more of the secondary purposes.

Primary Purposes

- o Augmenting and making better use of water supply for agricultural use
- o Augmenting and/or reasonably redistributing seasonal municipal and industrial water supplies to provide for the forecast water demand in year 2020

Secondary Purposes

- o Protecting water quality
- o Enhancing fish and wildlife resources

- o Developing reservoir-based, stream-based, and stream corridor recreation
- o Reducing flood damages
- o Generating hydroelectric power

2. Primary Purposes

a. Agricultural Water Supply

In Chapter VI the future supply and headgate requirement for irrigation water is discussed. Based on the medium growth scenario, the average agricultural headgate deficit in the year 2020 is forecast to be 42,000 ac-ft/yr. For a more severe condition, such as a drought with a 1 in 10-year frequency of occurrence, the year 2020 deficit is forecast to be 78,000 ac-ft/yr. This latter quantity is selected as a planning target. Measures considered to satisfy the target deficit may include developing new supplies and making better use of current supplies.

b. Municipal and Industrial Water Supply

Based on RIBSIM results presented in Chapter VI, the municipal and industrial drought year water supply deficit is forecast to be 26,000 ac-ft/yr in year 2020. This deficit is for a one in 30-year drought and assumes no deliveries of Windy Gap Project water for use in the St. Vrain Basin.

A primary plan purpose is to satisfy all or a portion of the forecast deficit amount by developing new supply or seasonally redistributing current supplies or both, and by use of measures to reduce water demand.

3. Secondary Purposes

As described above, the primary plan purposes focus on Basin water supply needs of the agricultural, municipal, and industrial sectors. Also considered in the plan formulation process were certain secondary water resource-related purposes as described in Chapter V and listed above. These secondary purposes include enhancing fish and wildlife resources, developing water-oriented recreation, protecting the quality of water, reducing flood damages, and generating hydroelectric power. Plan formulation was focused on serving the primary purposes, with consideration given for also serving any or all of the secondary purposes as reasonable opportunities arise.

C. Identification of Plan Elements

1. General

In conformance with the CWRPDA process for formulating water resource management plans, a set of plan elements was identified and compiled from which overall plans were developed. The plan elements include structural and non-structural measures designed to meet one or several aspects of plan purposes previously identified. Structural plan elements are site-specific physical structures that have the capability to store, divert, convey water, or generate electric power as part of a water resources management plan, and include both new and existing structures. Non-structural elements are elements that primarily involve non-physical means of serving the water management purposes of the St. Vrain Basin, but some of these are physical, such as installation of water meters. In the previous section it was forecast that by the year 2020 combined water demand in the agricultural, municipal, and industrial sectors in a drought year condition will exceed the forecast supply by about 104,000 ac-ft. If this gap is to be closed, supply must be increased or demand must be reduced, or both. Structural elements are effective in increasing the supply component, whereas non-structural elements are effective primarily in reducing demand and increasing efficiencies of water use.

The compilation of plan elements is a result of information that has been collected from a number of sources and from original work. These sources include a map reconnaissance using USGS 7.5 minute quadrangles supported by field reconnaissance, and input received from the Study Advisors, the Northern Colorado Water Conservancy District, the CWRPDA and its consultants, USBR reports, through newspaper articles, and from the public-at-large.

2. Structural Plan Elements

Ninety-eight structural plan elements were identified. For ease in comparing like elements, structural elements were divided into two categories, potential elements and existing elements. These elements are listed alphabetically, by category, in Table VII-1. The listing includes a map designation number which is used to identify an element's location within the Basin in Fig. VII-1. A numerical listing of elements is provided in Table VII-2.

a. Potential Elements

Potential structural plan elements consist of potential (not yet constructed) physical structures that appear to have the capability of meeting to some degree one or more of the water management purposes of the St. Vrain Basin. These elements include storage, diversion, and conveyance facilities and each element is site-specific.

Table VII-1 includes a listing of the potential structural plan elements considered in the Study. The list includes 65 storage facilities, 14 diversion facilities, and one conveyance facility.

b. Existing Elements

Existing elements are those storage, diversion, and conveyance facilities currently in place, which may be utilized by enlargement or modification of their operation to improve water resources management and increase supplies of water available to meet project purposes.

Existing facilities in the St. Vrain Basin will continue to provide the basic infrastructure for provision of water supply for the various intended purposes. Alternative plans developed by this Study generally integrate potential elements with existing works. If ignored as elements in an overall plan, existing facilities would continue to satisfy their intended functions within their physical limitations, but would not add to the cumulative benefit of a water resource management plan. If, however, existing facilities can be rehabilitated to increase functional efficiency, or their current method of operation be changed to more effectively serve users as a whole, or can be structurally modified to increase storage or conveyance capacity, such actions can be of benefit to a Basin-wide plan.

Table VII-1 includes an alphabetical listing of the 18 existing structural plan elements that were identified for consideration and possible inclusion in a water resource management plan. Many other water facilities exist but are not included in Table VII-1 because their potential for enlargement, change in use, or rehabilitation is considered minimal. The table lists 15 existing storage facilities, two diversion, and one conveyance facility.

For the purpose of this Study only those reservoirs greater than 3,000 ac-ft decreed capacity and diversion works greater than 20 cfs capacity are listed; the rationale for this limitation is that elements with capabilities less than these values would not significantly contribute to an overall water resources management plan. A few exceptions exist where a plan element had been investigated by others prior to this study and is considered to have potential for contributing to a management plan. The largest existing storage facility, on the basis of decreed capacity, is Carter Lake Reservoir (112,200 ac-ft).

3. Non-Structural Plan Elements

The existing and potential structural plan elements that were considered in formulating water resource management plans would assist in increasing firm water supplies. A second category of plan elements considered is that of non-structural plan elements. If implemented, these elements would reduce water demand or increase efficiency of water use. Non-structural elements include actions that can be taken to more efficiently utilize the Basin's water resources without constructing major physical structures. Minor structural facilities may be incorporated in such elements, however, in addition to water supply and water demand management measures, non-structural elements include institutional changes such as changes in law, regulations, policies, and the organization and authority of water management entities.

Three general types of non-structural elements were identified; these include: (1) water supply management measures, (2) water demand management measures, and (3) institutional measures. A listing of non-structural plan elements, grouped by type, is shown in Table VII-3.

D. Evaluation of Plan Elements

1. General

Following identification of plan elements to be considered in plan formulation, a preliminary technical evaluation of the structural plan elements was performed as a selection basis of those elements which appear to be most suitable for water resources management plan formulation. Each element was evaluated based on consideration of its technical, environmental, and social characteristics. Characteristics considered generally include the element's location, capacity, structural dimensions, estimated average annual flow at the site, accessibility, potential interference with existing structures, relationship to the natural environment, and potential social impact if developed.

Each non-structural plan element was evaluated in terms of its effectiveness in meeting the defined plan purposes, its relationship to the existing environment, potential acceptance by the general public and key decision makers, and ease or difficulty of implementation.

2. Selection of Structural Elements

a. Approach to Storage Element Selection

Plan elements are the building blocks for forming water resources management plans. Because of the relatively large array of storage elements (98 in total), it was necessary to reduce the number of elements to a more manageable quantity prior to formulating plans. This was accomplished by first classifying and sorting the characteristics of each element according to several factors. For storage reservoirs, the factors include gross reservoir storage capacity, general location by sub-basin, and average annual flow at the site. As an approximate measure of potential project cost or efficiency of the site potential as a storage reservoir, the ratio of reservoir capacity to dam embankment volume was also determined for comparative purposes. Characteristics of diversion and conveyance-type elements were also tabulated for comparison.

In selecting plan elements, it is important to select an array of storage elements that can be combined into a broad range of formulated plans covering the water supply targets. To accomplish this objective, selected elements were distributed over the geographic sub-basins of the Siting and Study areas since it was considered desirable to have at least one and preferably two elements located in each of the major sub-basins. The major sub-basins are the Little Thompson River, North St. Vrain Creek, South St. Vrain Creek, Left Hand Creek, and the Boulder Creek drainage. In addition, for operational flexibility and short-term regulation, storage sites within the plains zone are also desirable.

The other major factor in the selection of storage elements was to provide a sizable range in reservoir capacities. This factor is important for two reasons. First, plans were to be formulated to cover a range of water supply objectives and other management purposes, and second, the potential to stage development of a plan over time indicates generally the need to include reservoirs of a range of capacities. In applying the factor to sites located within the mountain and foothill zones, reservoirs under 10,000 ac-ft in capacity are considered too small to effectively regulate water resources of the Basin. In the plains, capacities as low as 3,000 ac-ft are considered, because plains reservoirs generally function more for re-regulation or to serve smaller user groups. In this study, potential reservoirs of capacity up to 305,000 ac-ft have been identified.

Environmental and social attributes were compiled for each storage element and reviewed as to their due influence in element selection. Except to exclude sites located within Rocky Mountain National Park and Indian Peaks Wilderness, environmental and social factors were considered not to be overriding or exclusionary in the element selection process.

Having sorted storage elements by sub-basin and reservoir capacity, other attributes were then considered. These include a rough measure of site efficiency to provide storage space as indicated by the ratio of reservoir storage capacity to dam embankment volume. This ratio has been named herein the Dam Ratio. A measure of potential reservoir effectiveness in regulating the inflow to it is given by the ratio of storage capacity to estimated reservoir inflow, termed herein the Inflow Ratio. Inflow was considered without regard to water rights because of the general potential for water exchanges and transfers of storage decrees. Although accurate data on average annual flow are not available at most storage sites, estimates were made based on tributary drainage area and unit runoff factors. The Inflow Ratio is a general indicator only of the suitability of potential reservoirs and since it is not an absolute factor is useful only in conjunction with considerable judgment. Total inflow (as represented by streamflow) at a site is also a factor that is considered as a general guide in selection of storage elements. To regulate the water resources of the Basin as would be required for maximum development, reservoirs must be large enough cumulatively and appropriately situated within the Basin or Siting Area to impound most of the available or storable streamflow.

Constructibility was considered, based on available geotechnical and construction materials information, and potential access difficulty.

Another factor that was considered is the relative amount of relocation of buildings, highways, and other structures that would be required. Relocations reflect a potential major cost factor as well as social disruption. However, this factor by itself (minimum relocations) did not result in selection of any of the elements.

b. Selected Storage Elements

A total of 18 potential and existing storage elements were selected based on the criteria set forth above. Characteristics of the selected storage elements are presented in Table VII-4. The following paragraphs provide a brief description of each selected storage element, grouped according to sub-basin in which they are located.

(1) Little Thompson No. 2 Reservoir (Little Thompson River Basin)

The dam site is located about 4 miles south of Carter Lake on the Little Thompson River. An embankment type or roller-compacted concrete type dam is considered suitable for this site. The site, map designation 32, was identified by the USBR in past studies and by others.

This element could operate in conjunction with the C-BT and Windy Gap projects as well as regulate runoff of the Little Thompson River. Additional water could also be diverted from North St. Vrain Creek into the Little Thompson River above the reservoir to provide flexibility in developing St. Vrain Basin waters.

This element was selected for plan formulation for the following reasons:

- It is located in relatively close proximity to Carter Lake. Therefore, it has the ability to readily receive and regulate water that may be conveyed via the C-BT facilities system, such as Windy Gap Project water.
- Releases could be made to the Little Thompson River for subsequent diversion downstream or to the existing supply canal.
- To provide winter flow of water for M&I purposes, an intake and buried pipeline with pumping plant could be constructed from this reservoir to convey water to the main stem of St. Vrain Creek.
- The site can accommodate a reservoir of substantially large capacity.
- Based on very limited site reconnaissance there appear to be no technical factors that would preclude development.

(2) Smithy Mountain Reservoir (North St. Vrain Creek Basin)

The Smithy Mountain site is located on North St. Vrain Creek approximately 0.3 mile downstream from the existing Button Rock Dam. An embankment-type dam was considered at this site. This site, which carries map designation 59, if developed would inundate Button Rock Dam and Ralph Price Reservoir.

This element is selected for plan formulation for the following reasons:

- It would provide a relatively large capacity reservoir on North St. Vrain Creek, which is the largest producer of water of the sub-basins within the Study Area.

- Raising of Button Rock Dam by more than about 50 feet presents a complexity of problems from the engineering and constructibility viewpoints, so if greater capacity is needed, Smithy Mountain would represent an alternative.

(3) <u>North Sheep Mountain Reservoir (North St. Vrain Creek Basin)</u>

This site, map designation 94, is located on North St. Vrain Creek about 3 miles westerly from Ralph Price Reservoir (Button Rock Dam). An arch, concrete-gravity, rockfill or earthfill embankment dam could be suitable to the site, depending on height of the proposed structure and availability of materials.

This storage element is selected for the following reasons:

- It would provide large storage capacity.

- The site controls runoff from a substantial portion of North St. Vrain Creek.

- Only minimal relocations of facilities apparently would be required.

(4) <u>Ralph Price Reservoir (North St. Vrain Creek Basin)</u>

This existing earthfill dam is located on North St. Vrain Creek about 5 air miles west of Lyons. The map designation is 6.

The City of Longmont, the project owner, has long-range plans to increase storage in Ralph Price Reservoir by raising the existing dam. In the City's plan the enlarged reservoir would primarily function to supply City of Longmont winter water requirements. Very preliminary investigations by the Study Team indicate that a maximum raise of about 50 feet is practical, due to design aspects of the existing structure and site topography. Major problems involve the difficulties of raising a central core dam on the downstream side, since it is desired to keep the dam in service during construction, and the ravine on the left abutment downstream of the present dam. It appears feasible to raise the storage level about 50 feet without a major change in location of the dam. For a reservoir enlargement of more that 50 feet in height, the axis would have to be shifted downstream. A raise of 50 feet would increase storage capacity by about 12,500 ac-ft to a total of about 28,600 ac-ft, at a water surface elevation of 6450. Enlarging Ralph Price Reservoir was selected for inclusion in plan formulation because it is considered to be a reasonable project and is already planned by the owner of the dam.

(5) Tahosa Reservoir
(North St. Vrain Creek Basin)

This site, map designation 65, is located on Cow Creek (also known as Cabin Creek), a tributary of North St. Vrain Creek in its upper reaches. The site is about 3 air miles northeast of the Town of Allenspark. An embankment-type dam was considered at this site. The reservoir is small compared to the flow available at the site, and would probably be operated to assist in providing regulation for long-term cyclical drought periods.

This site was selected for plan formulation because it appears to be a physically excellent site with adequate flow of water. It is an intermediate sized reservoir which could fit well into plans for an integrated system of water resources development in the St. Vrain Basin.

(6) Coffintop Reservoir
(South St. Vrain Creek Basin)

This site, map designation 14, is located on South St. Vrain Creek, 1 mile upstream (southwest) from Lyons. A rockfill embankment or roller-compacted concrete type dam was considered at this site.

Others have completed extensive study of this element indicating a dam at this site would produce a large reservoir of 116,000 ac-ft capacity, with normal water surface elevation 5744. The reservoir would provide major regulation of South St. Vrain Creek, and a diversion from North St. Vrain Creek would be possible to increase the runoff that could be regulated.

This site was selected for consideration as a storage element in plan formulation because of its large capacity and location where, with additional diversion flows from North St. Vrain Creek, it could control runoff from a substantial portion of the St. Vrain Basin.

(7) Little South St. Vrain Reservoir
(South St. Vrain Creek Basin)

This site, map designation 75, is located on South St. Vrain Creek about 1.5 miles south of Riverside. An embankment-type dam was considered at this site.

This reservoir could provide a good degree of regulation of flow at the site. An embankment type or concrete-gravity dam could be considered at this site.

This site was selected for plan formulation because it appears to have reasonable physical characteristics and provides an alternative site on South St. Vrain Creek. Its capacity is moderate and the location seems suitable for further consideration.

(8) Geer Canyon Reservoir
(Left Hand Creek Basin)

This site, map designation 22, is located on Left Hand Creek about 5 miles north of the City of Boulder. A rockfill type dam was considered at this site.

This site is located so that it can regulate most of the runoff in Left Hand Creek, including existing and potential diversions to it from South St. Vrain Creek. The potential diversion point is located about 5 miles downstream from Riverside. A rockfill embankment type dam has been planned for this site by others. Substantial highway relocations would be required, and possibly some residences.

This site was selected for plan formulation because of its location and size where it can effectively control runoff originating in the Left Hand Creek Basin as well as diversions that may be supplied to it.

(9) Lykins Gulch Reservoir
(Left Hand Creek Basin)

This site, map designation 37, is located in a gulch about 2 miles north of the Geer Canyon site and about 5 miles south of Lyons. An embankment type dam was considered at this site. Natural runoff at the site is minimal and therefore it would be filled by diversions from South St. Vrain or Left Hand Creek or by pumping from Lake Ditch.

This site was selected for plan formulation primarily because of its location, together with a fairly substantial capacity. It does appear to be a marginal site, however, because it will be costly to supply water to it.

(10) Buckingham Reservoir
(Left Hand Creek Basin)

This site, map designation 95, is located on Left Hand Creek about 0.5 mile downstream of its confluence with James Creek. An embankment or concrete-gravity type dam is considered suitable at this site. This reservoir would provide regulation of flows in the Left Hand Creek Basin, including some carry-over storage for extended drought periods.

This site was selected for plan formulation because it provides an opportunity to regulate flows in the Left Hand Creek Basin, as an alternative to the Geer Canyon site. As with Geer Canyon, relocations would be a problem involving substantial cost and other potential difficulty.

(11) Sherwood Reservoir
(Boulder Creek Basin)

This site located on North Boulder Creek, map designation 56, and is situated about 2.5 road miles north of Nederland. An embankment-type dam was considered at this site. This site would provide regulation of North Boulder Creek runoff, but appears to be rather costly to develop due to topography.

This site was selected for consideration in plan formulation because it appears to be the best alternative available in the Boulder Creek drainage basin.

(12) Pleasant Valley (Terry Lake) Reservoir (Plains)

This existing embankment dam and reservoir, map designation 49, has a present actual capacity of about 3,200 ac-ft. This reservoir is included as a candidate for enlargement by increasing the normal water surface and dam elevation by 10 feet to a normal water surface elevation of 5103, which would provide an additional estimated capacity of about 4,000 ac-ft.

The reservoir is presently supplied by diversions through Rough and Ready Ditch, but an extension of Highland Ditch from the north could be made and additional water supplied to Pleasant Valley via that route. That would be feasible only if a new diversion canal were constructed from Little Thompson River as part of a storage project in that basin.

This storage element was selected for plan formulation because it appears reasonably possible to increase its capacity and because it is situated where it could receive water from a project on Little Thompson and subsequently deliver water to areas lying downstream from it.

(13) Foothills Reservoir (Plains)

This existing embankment dam and reservoir, map designation 21, is located in the plains zone about 3 miles southeast of Lyons. The existing reservoir has an estimated actual capacity of 3,345 ac-ft at its normal operating level of El 5199. The reservoir is presently supplied by diversion from the Boulder Feeder Canal, and releases water to St. Vrain Creek for subsequent diversion downstream.

A raise of about 20 feet appears practical which would increase the reservoir capacity by about 3,500 ac-ft. Buildings in the vicinity of the dam, however, would have to be removed to make way for the additional embankment.

This reservoir was selected for plan formulation because its location is favorable for supplying water and releasing it to provide short-term regulation.

(14) Highland No. 2 Reservoir (Plains)

This existing embankment dam and reservoir are situated in the upper plains area at El 5170 and has an estimated actual capacity of 3,400 ac-ft. Its map designation is 24.

Enlarging this reservoir by 3,300 ac-ft of additional capacity could be accomplished by raising the embankment elevation 20 feet. However, existing buildings on the south side of the reservoir would probably be affected and have to be purchased and removed.

This reservoir was selected for plan formulation because it is situated at a relatively high plains elevation and is close enough to the Little Thompson River to be supplied water from a new diversion canal. In this way it would function similarly to that described for Pleasant Valley Reservoir.

(15) Left Hand Valley Reservoir (Plains)

This existing embankment dam and reservoir, map designation 30, is located in the upper plains zone with normal water surface at El 5345. It is supplied water from Left Hand Creek via Crocker Ditch.

Additional capacity in this reservoir would provide improved in-season regulation of irrigation water. A raise of 20 feet would provide an additional 3,000 ac-ft capacity. Present actual capacity is estimated to be 3,400 ac-ft. A higher reservoir operating surface would require modifications to the ditch supplying the reservoir or a new diversion ditch from Left Hand Creek. Seepage potential from this reservoir is not known but could be higher than other elements because it is closer to the Hogback Ridge. The enlargement would affect at least two existing houses and several thousand feet of roads, both improved and unimproved.

This storage element was selected for plan formulation because increased storage here could be beneficially utilized to regulate irrigation supplies.

(16) Southwestern Portland Cement Co. Pits (formerly Martin-Marietta Pits)

This storage site, map designation 38, is located approximately 2 miles east of Lyons and 1 mile south of St. Vrain Creek. The Boulder Feeder Canal of the C-BT Project skirts the site to within a few hundred feet of Pit A. This pit is planned by the owner as a permanent water storage reservoir of capacity approximately 4,000 ac-ft, based on an area of 70 acres and average depth of 55 feet. The pit is excavated in Pierre shale which is considered to be relatively impervious.

This element was selected because of its proximity to the Boulder Feeder Canal and the owner's apparent intent to make it available for water regulation purposes.

A similar method of storage, using mined-out gravel pits in the area, is currently being studied by others. These gravel pits are generally located in pervious alluvium as contrasted to the limestone pits which are reported by others to be generally impervious and suitable for water storage without placement of linings or other measures to make them watertight. A preliminary report (Rocky Mountain Consultants, Inc.), June 1985, identifies the potential for approximately 10,000 ac-ft of gravel pit water storage along St. Vrain Creek from Lyons to Longmont.

(17) Dowe Flats Reservoir (Plains)

This storage site, map designation 18, is located between ridges of the hogback and is about 2 miles east of Lyons on a very small tributary drainage area. An embankment type dam was considered at this site. The location is strategic because the existing St. Vrain Supply Canal skirts around the upper portion of the site and water stored in this location would command by gravity most of the plains zone of the study area, including the City of Longmont water treatment facilities. However, it is not situated so as to regulate flow of St. Vrain Creek unless a diversion system were constructed, which might require pumping. Almost any capacity reservoir could be constructed here up to a maximum of about 119,000 ac-ft. Natural runoff at the site is very small due to the small tributary drainage area.

A significant concern is the presence of a hazardous waste disposal site located at the upper end of the reservoir at an elevation somewhat above the planned normal maximum water surface for the high dam. The potential threat posed by the existence of this toxic material to safe water storage has yet to be thoroughly investigated by others; however, potential detoxification measures are being studied.

This site was selected for plan formulation because of its strategic location, and its potential large capacity, as well as the landowner's expressed interest in cooperating with development of a reservoir at the site. However, it is considered that development of the reservoir must be conditioned on gathering sufficient information to fully understand the potential effects posed by the toxic material.

(18) Carter Lake Reservoir

Carter Lake Reservoir, map designation 11, is an integral feature of the Colorado-Big Thompson (C-BT) system and supplies western slope water to the St. Vrain and Boulder Creek areas. This reservoir was included for plan formulation because of its relationship to potential water resources developments that may be formulated as part of the St. Vrain Basin Study. Potential reservoirs on the Little Thompson River would operate in close coordination with Carter Lake. New outlet works could be incorporated as part of a Little Thompson storage reservoir project to expedite transfer of water from Carter Lake.

Enlargement of Carter Lake Reservoir by as much as approximately 23,000 ac-ft may be physically possible. To accomplish this, the three embankment type dams forming the reservoir would have to be raised 20 feet, and outlet works, drain zones and other features extended accordingly. Costs of necessary relocations have not been investigated but could be substantial.

Windy Gap Project waters will also be delivered through C-BT Project facilities, and the City of Longmont as a Windy Gap participant will probably take such supplies at Carter Lake or at the Pole Hill power plant. Because of the potential importance of Carter Lake to an overall water management plan in the St. Vrain Basin, the element was included in the selected list of elements.

c. Selected Diversion and Conveyance Elements

A total of eight diversion and conveyance elements were selected for consideration in plan formulation. In all cases, potential diversions were selected to enhance management of water resources by diverting flows from an unregulated sub-basin to a location where a major or intermediate sized reservoir would be located. Two existing diversion systems were also included as they would generally be incorporated into the operation of a future water resources management system. The selected diversion and conveyance elements are listed in Table VII-5, and are more fully described below.

(1) Little Thompson River Diversion to Highland Reservoir No. 2

This diversion element, map designation 98, would divert water from the Little Thompson River to Highland Reservoir No. 2 for reregulation to feeder canals.

This element can be used in conjunction with an upstream reservoir on the Little Thompson to store water for controlled regulation. The element would consist of a diversion dam and a canal approximately 12,000 feet long.

(2) North St. Vrain Diversion to Little Thompson River

This diversion element, map designation 8, would divert North St. Vrain water for storage in the Little Thompson River watershed. The element would include about 14,500 feet of tunnel and 7,500 feet of open canal, together with a diversion and intake structure.

This element was selected for consideration in plan formulation because such a diversion could enhance the attractiveness of a storage reservoir located on the Little Thompson River by increasing the flow that could be regulated there.

(3) Button Rock Diversion to South St. Vrain Creek

A tunnel of about 12,500 feet in length would be required to convey North St. Vrain water from Button Rock (Ralph Price) Reservoir to South St. Vrain Creek at a location upstream of storage element (map designation 14), the Coffintop Reservoir site. Adequate head is available for gravity diversion.

The purpose of this diversion element is to also regulate flows from North St. Vrain Creek if a major reservoir were constructed on Lower South St. Vrain Creek.

(4) North St. Vrain Diversion to South St. Vrain Creek

This diversion element, map designation 96, would include a diversion dam on North St. Vrain Creek at the Chimney Rock site (map designation 12) and a tunnel of about 8,300 feet in length. Estimated average annual flow at the diversion point is 62,000 ac-ft/yr. Gravity flow to a major storage reservoir site on lower South St. Vrain Creek would be provided by this element.

(5) South St. Vrain Diversion to Button Rock

This diversion element, map designation 60, would divert water by gravity from a point about 3 miles downstream from Riverside to Button Rock Reservoir via a tunnel of about 13,700 feet in length. This diversion point is below the confluence of Middle St. Vrain Creek with South St. Vrain Creek, and the estimated average annual flow at that point is 30,000 ac-ft/yr.

This diversion element was selected to provide flexibility in water resources management by enhancing the utility of a major storage reservoir on North St. Vrain Creek, or with an additional diversion facility to storage in the Little Thompson River drainage.

(6) South St. Vrain Diversion to Geer Canyon

This diversion element, map designation 81, would divert flow from South St. Vrain Creek into Geer Canyon in the Left Hand Creek drainage basin for regulation and subsequent use.

The diversion point would be located about 5 miles upstream from Lyons and would provide gravity flow via a tunnel 15,200 feet long to Geer Canyon at an elevation high enough to be stored in Geer Canyon Reservoir (storage element map designation 22). Estimated average annual flow in South St. Vrain Creek at the diversion point is 34,000 ac-ft/yr.

This diversion element was selected because of the flexibility it could provide in managing water resources of the Basin by providing for storage of South St. Vrain waters if a large reservoir were constructed in the lower portion of Left Hand Creek drainage.

(7) Brainard Diversion

The existing Brainard Diversion, map designation 72, currently conveys water from South St. Vrain Creek easterly to James Creek in the Left Hand Creek watershed. This is an old facility but is apparently in good condition and has a headgate hydraulic capacity of approximately 150 cfs. The estimated average annual flow in South St. Vrain Creek at the diversion point is 19,000 ac-ft/yr, of which approximately 10,000 ac-ft/yr is presently diverted to the Left Hand Creek Basin.

The facility consists of a concrete diversion structure and head gate and unlined ditch about 2,000 feet long. This element was selected for inclusion in plan formulation because it will continue to perform a useful function and has a potential for increased capacity.

(8) St. Vrain Supply Canal

This canal is a feature of the C-BT Project and conveys water from Carter Lake to St. Vrain Creek. It was included as a selected element because several of the storage elements being considered would or could utilize the supply canal. In addition, winterization of the supply canal to enable it to convey the City of Longmont's Windy Gap supply during winter months is an option to be considered. The supply canal could be used in conjunction with a storage reservoir on the Little Thompson River, although water from the supply canal would require pumping to such a reservoir. Gravity releases from the reservoir could be made back to the supply canal for conveyance to meet water demands in the area served by the canal.

3. Structural Elements Not Selected

The approach to selecting structural plan elements for subsequent consideration in plan formulation is described above. The approach results in selection of a list of 26 elements from the array of 98 elements considered. In this section, elements not selected are listed along with factors that influenced these choices. Seven such factors were taken into account. It may be noted that some of these additional factors apply also to several of the selected elements. However, the overall effectiveness of each selected element in serving its intended purpose(s) is considered better than a comparative element that was not selected.

The seven factors are as follows:

a. The storage capacity of the reservoir is relatively small or, in some instances, restricted by upstream development.

b. The average annual inflow, even with potential diversions, is relatively small.

c. Excessive relocations would be required relative to the magnitude of the project. This factor relates to the presence of structures such as roads, railroads, buildings, power lines, and other established features which would be inundated or otherwise affected by the element, and the resulting social impacts and relocation costs.

d. Location of the element in the National Park or Wilderness Area. Carrying out development in such areas is generally precluded.

e. Location of the element is at too low an elevation, or otherwise situated in a remote location, thereby presenting physical difficulties to readily serving the needs of the St. Vrain Basin.

f. Apparent adverse technical or geologic conditions exist, which may equate to excessive cost.

g. The facilities to impound or divert water appear relatively too costly for their intended purpose as compared to an alternative reservoir. That is, a significantly better element exists in the same sub-basin that would serve the same general purpose but perform better and/or at a lower cost.

Table VII-6 lists all 98 elements and indicates the factors which apply to each of the elements that were not selected. In addition, the table indicates those elements which are selected for plan formulation.

4. Social and Environmental Assessment of Structural Elements

a. Assessment Approach

The objective of the environmental and social assessment is to generally evaluate individually the 98 structural plan elements. This assessment indicates the relative sensitivity of plan elements (existing and potential structural elements) in regard to certain environmental and social parameters. The sources of information utilized for this assessment are:

(1) Information presented in Chapter II.

(2) The Boulder County Comprehensive Plan.

(3) Comments received from the Advisors during the Advisory Committee Meeting of January 7, 1985.

Data from the above sources were utilized to: (1) provide a general regional characterization of the structural elements located throughout the siting area, and (2) identify certain specific concerns associated with each structural element with respect to whether they eliminate or severely restrict the development of certain elements. The results of the above assessments are presented in tabular form in Tables VII-7 and VII-8.

It should be noted that the environmental and social characteristics of the elements were not used in an exclusionary manner to eliminate elements from further consideration other than elements located within Rocky

Mountain National Park and Indian Peaks Wilderness Area. Tables VII-7 and VII-8 identify certain considerations indicated as Environmental Resources, Open Space and Trails, and Social. The Environmental Resources and Open Space and Trails considerations identify potential conflicts that may exist with the Boulder County Comprehensive Plan if development of the elements were to occur. Social considerations generally estimate the likelihood for public opposition associated with the development of the elements. The likelihood of opposition is based on the type and size of reservoir and its relationship to population concentrations.

b. Results

The environmental and social assessment indicates the relative sensitivity of plan elements in regard to certain environmental and social parameters. The assessment was done on both a regional and site-specific basis.

The environmental and open space considerations were identified primarily from maps in the Boulder County Comprehensive Plan. It is probable that the greater the number of potential concerns identified, the higher the environmental sensitivity of the specific plan element. The concerns identified in Table VII-7 are not intended to be exclusionary in nature but rather used to provide guidance as to what might be important concerns to be further evaluated later.

The major conclusions from the environmental and social assessment are as follows:

- Three plan elements, Upper North St. Vrain Diversion, element number 68, North St. Vrain Diversion to Buck Gulch, element number 35, and Parks Alternative No. 2, element number 46, may be precluded from development due to their location in the protected areas of Rocky Mountain National Park and the Indian Peaks Wilderness Area and hence will not be considered further in this Study.

- Low potential for social concern is associated with elements which are existing, have relatively small capacity or are located in remote areas of the mountains or in the plains zone. High potential for social concern is associated with plan elements which have large capacity and are located above population centers or are located in protected areas.

- Plan elements located in the Little Thompson watershed have the best potential for development into a major storage project from a social viewpoint. Plan elements in the Boulder Creek watershed are considered likely to have the lowest potential for development into a major storage project from a social viewpoint. Plan elements located near and to the west of Lyons also have the potential for high public opposition.

- o Development of plan elements would have the least effects on terrestrial biology in the plains, and the greatest effects in the mountain zones.

- o Development of plan elements, in general, would have the least effects on water quality in the mountain zone and the most in the plains zone. Reservoirs in the plains zone are more shallow, and would therefore be more susceptible to increased water temperature during summer and to eutrophication.

- o Development of plan elements in the lower mountain and foothill zones located on St. Vrain or Boulder creeks could have the greatest effect on the sport fishery and species of special concern. Development of plan elements in the remainder of the study area are expected to have less effect on aquatic biology.

- o Development of plan elements would have the least effect on recreation and aesthetics in the plains and the greatest effect in the mountain zones.

5. Non-Structural Elements

Non-structural plan elements as previously presented in Table VII-3 are grouped into three general types: (1) Water Supply Management Measures, (2) Water Demand Management Measures, and (3) Institutional Measures. The following are the evaluations of each non-structural plan element considered for plan formulation.

a. Water Supply Management Measures

(1) Potential Transfers of Highland Ditch Company Storage Decrees

Several storage decrees held by the Highland Ditch Company are considered potentially transferable to a storage reservoir located on either North or South St. Vrain Creek. These reservoirs include Foothills, McIntosh, and several Highland senior decrees. The total amount of capacity estimated to be transferable for these decrees held by Highland Ditch Company is 5,000 ac-ft.

(2) Potential Transfers of Calkins and City of Longmont Decrees

The Calkins (Union) Reservoir decree is potentially transferable to a reservoir on either North or South St. Vrain Creek in amount of 2,500 ac-ft. In addition, several very small reservoirs owned by Longmont with a total volume of about 500 ac-ft estimated transferable include the McCall, Clover Basin, Independent, Burch, and Pleasant Valley decrees.

By transferring storage from the above-named reservoirs to a new facility, the existing capacity in these reservoirs would be available for use by an entity such as Longmont. The City possibly could benefit by using one or more of these reservoirs to store Windy Gap Project water, either raw water or, perhaps more likely, to store wastewater effluent in such reservoirs.

(3) Transfer of Points of Diversion of Senior Ditches

The objective of this non-structural element is to minimize diversion losses and hence minimize headgate diversion requirements of senior ditches by transferring their point of diversion to a well or well field. By implementing this measure all water presently lost in conveyance due to seepage would be saved and kept in the river for diversion by more junior ditches downstream.

A detailed site-specific analysis beyond the scope of this study is necessary to determine how many ditches and exactly which senior rights could be beneficially involved in this concept. Also, the amount of water that might be kept in the stream for use by more junior ditches would need to be estimated.

(4) Transfer of Historical Agricultural Consumptive Use to a New Storage Facility

For areas which are urbanizing the use of these transfers would provide a higher priority storage right than could be obtained by a new water right filing. This concept has also been implemented in several instances by Longmont and this practice will probably continue in the future as urbanization of irrigated lands continues. For example, by 1979 Longmont had considered that direct flow rights from seven ditches which it had acquired totaling approximately 1,700 ac-ft could be transferred to a new storage facility.

(5) Transfer of High Mountain Storage Decrees

This measure refers to three small reservoirs, Bluebird Lake, Pear Reservoir, and Sandbeach Lake, owned by Longmont which are located within Rocky Mountain National Park. It is understood that the City has been negotiating with the National Park Service for compensation in consideration of its abandonment of these reservoirs. In conjunction with such abandonment the storage decrees could be transferred to a new reservoir located outside the National Park.

(6) Ditch Lining and Phreatophyte Control

The objective of these measures is to reduce conveyance losses which would increase flow remaining in the stream due to reduction in headgate diversion requirements. It it considered that canal lining of the relatively senior ditches whose diversion points are relatively far downstream within the Basin may be beneficial to the overall Basin operation. In these cases, water saved due to any reduction in losses would then be available farther upstream where it potentially could serve more junior ditches.

Only little potential water saving could be obtained by eliminating phreatophytes. In the ditches in the study area most phreatophytes actually are cottonwood trees and they are generally considered to have significant aesthetic value. Furthermore, the amount of water they utilize may be relatively little.

(7) Satellite-Linked Hydrologic Instrumentation

Due to advancements in communications, basic hydrologic data can be gathered on a real time basis. These include streamflow, snowpack and weather data. The data obtained from such a system could be coupled with soil moisture and water demand data to assist in scheduling of irrigation applications to optimize water utilization.

The Northern Colorado Water Conservancy District has made a preliminary analysis of instrumentation required to provide the capability to make short-term runoff forecasts. The proposed system would utilize five stream gages (four new and one existing) and seven snowpack monitoring stations. Four of these would be new, whereas two existing SNOTEL and one SCS snow course would be incorporated into the system.

The Colorado satellite-linked water resources monitoring program that was funded by the CWRPDA would have a major role in implementing this concept for the St. Vrain Basin. There are two stations presently installed in the Basin, one at St. Vrain Creek at Lyons and one at the mouth near Platteville.

The combination of these measures (runoff forecasting and irrigation scheduling) is considered to be potentially beneficial to the improved management of water resources, and should reduce call severity. It should be investigated in greater detail and implemented if proven feasible. However provision of a reservoir to store and regulate water saved by such measures for use later in the irrigation season is probably necessary to fully realize the potential benefits of the instrumentation system and hydrologic model.

(8) Aquifer Recharge and Storage for Subsequent Streamflow Augmentation

It is considered that this potential measure has little potential to benefit the St. Vrain Basin. Suitable geological conditions of aquifer basins that could be filled and drained under controlled conditions do not exist in the Study Area.

(9) Improvement of Irrigation Efficiency

Improvement measures include improved irrigation scheduling, reduction or elimination of over-irrigation, conversion to sprinkler irrigation systems, use of on-farm soil moisture instrumentation to provide guidance for timing of irrigations, and more precise leveling of irrigated fields to improve the uniformity of distribution of irrigation water.

Most of the measures indicated for improving farm irrigation efficiency would be significantly beneficial only if a new storage reservoir were provided so that water saved could be stored and regulated for release at such times later in the irrigation season when crop demand is high and water supply generally is low. The economics of implementing such irrigation efficiency improvements is not analyzed in this Study. However, it appears that some potential measures including more precise leveling of irrigated fields, would have costs likely to substantially exceed their benefits in the St. Vrain Basin.

(10) Reduction of Water Quantity Provided to Irrigated Crops

Provision of less than the theoretical optimum water supply for crop consumptive use would result in some reduction in crop yield, but possibly relatively minor reduction compared to water savings. Consideration of supplying 85% of the irrigation water requirement calculated by the Blaney-Criddle procedure is discussed in Chapter IV. Future investigation of this measure is needed to establish functions of crop yield versus consumptive use and the economics associated with the concept.

(11) Weather Modification to Increase Watershed Yields

Weather modification by cloud seeding has been the subject of experimentation and evaluation for more than 30 years and while benefits of increased snowpack probably occur in certain locations a final evaluation of this general technique has not yet been made. The USBR developed a proposal in 1983 to undertake an extensive demonstration project involving cloud seeding in selected western slope areas of Colorado. If this demonstration is funded and undertaken it may provide some more specific answers to the potential feasibility of such measures on a continuing long-term basis. However, the USBR's proposal would require 8 or 10 years to reach with final conclusions on the effectiveness of the cloud seeding. Therefore, no firm evaluation can be given at the present time. However, it must be realized that some regions are situated more favorably than others with respect to moisture bearing winds, and eastern slope areas such as the front range in the St. Vrain Basin may or may not be well situated for cloud seeding to be significantly beneficial.

(12) Provision of Municipal Drought-Year Water Rights by Leasing Arrangements with Agricultural Interests

Measures involving leasing of agricultural rights by municipalities and utilizing such rights in drought years have considerable merit for the

St. Vrain Basin. However, the inverse of this concept is actually in practice in the St. Vrain Basin at the present time. In such cases, Longmont has obtained agricultural water rights which it leases back to agricultural interests for agricultural use in average and wet years. In dry or drought years, however, the City would utilize such water and agricultural interests would have to leave all or most land dependent on such rights uncropped for those years. This idea relates to direct-flow water rights and not to storage rights.

The concept of a municipality leasing water from a major ditch company to provide a reliable drought year supply provides for paying an annual fee for the right to divert senior agricultural water to satisfy municipal and industrial demands. The fee would be used to compensate the irrigators for the lost profit from the crop not produced. This concept would augment the traditional conservative and costly approach of providing large volumes of reservoir carry-over storage to provide sufficient capacity for critical drought conditions. It must be stressed that this approach would require storage for regulation/carry-over, but it would not require four to ten times carry-over storage capacity, which is probably typical for development of firm supplies from native flows in the St. Vrain Basin. The same concept could be utilized with a different payment arrangement, by which the municipality would accumulate a sinking fund from which payments would be made to agricultural water right holders only in those years when the municipality takes water.

The concept of leasing water during extreme drought periods is not new, since it has been practiced to a limited extent in Colorado. By means of basin instrumentation, irrigators in the Basin who have agreed to lease their water would know whether adequate water would be available to meet their irrigation requirements. A shortage formula could be developed that would then permit the irrigators to allocate their anticipated irrigation water. A likely result would be that some of the annual crops would not be planted but the perennial crops like alfalfa would continue to receive irrigation water during droughts so their root systems would not be damaged.

The potential advantage of leasing arrangements is that considerable savings may result to the M&I user by deferring reservoir construction and the irrigator would receive guaranteed cash payments each year, regardless of whether he produces a crop or not. Thus, monetary resources would be recycled in the community rather than being tied up in financing a storage facility. This cooperation between the M&I water user and irrigator would provide for a more efficient use of capital with both parties gaining considerable benefit.

(13) Modification of Reservoir Filling Sequences

This measure involves modification of the refilling sequence of larger reservoirs with headgates that have high hydraulic capacity and senior decrees. This modification would permit the smaller diverters to fill for a longer period of time since these headgates often have a lower hydraulic capacity and hence need a longer duration filling period. Earlier filling would avoid situations in which the high flow period is passed before smaller diverters are able to fill.

It is considered that little potential benefit in improved water management would result from this measure in the St. Vrain Basin. The reason is that this concept is already practiced to a considerable extent by the Water Commissioner and therefore little additional potential remains.

(14) Reuse of Municipal Wastewater

Two categories of water need consideration under this item as follows:

i. Windy Gap Project water owned by Longmont and the consumable portion of water from transferred agricultural rights. To realize maximum benefit to the City by reuse and sale of wastewater from this source will require a storage reservoir to which the wastewater can be pumped or conveyed by gravity. From such a reservoir, the City could make this wastewater available for reuse to purchasers at such times as they would prefer to have it. If the purchaser's diversion point lies upstream of the wastewater storage reservoir an arrangement to exchange waters would be necessary. If Longmont did not construct a reservoir in which to impound and regulate the reuse of this effluent, the water would probably be less saleable, since it would be discharged directly to the receiving stream.

ii. All other municipal wastewater, that is except Windy Gap Project water and consumable portion of transferred agricultural rights, becomes river water as soon as it is discharged back to the stream. This water is subsequently available for diversion and reuse by all legitimate diverters downstream.

(15) Dredging of Existing Reservoirs

Dredging is a potential way to increase usable capacity of existing reservoirs, or to restore them to their original capacity prior to sediment deposition. However, the cost of dredging and disposal of dredged material is likely to make this technique unattractive to reservoir owners. Preliminary indications are that current (1985) dredging costs for low-density material would be in the range of about $2,500 to $3,500/ac-ft or higher, not including costs of material disposal. If the dredged material were to have economic value, however, perhaps its disposal cost would be minimal.

b. Water Demand Management Measures

Water demand management measures are grouped into six plan elements for use in the formulation process. Elements 1 through 3 (as described below) consist of combinations of short-term measures which could be used to reduce municipal demands in a drought. Elements 4 through 6 represent long-term measures which could be used individually or in combination to permanently reduce municipal demands.

(1) Distribute Water Conservation Kits and Literature; Urge Voluntary Water Use Reduction

This short-term drought accommodation policy has been widely used and its effects are reported in the literature. It is inexpensive, only moderately effective, and short-lived. Nevertheless, it may be all that is required in many situations. If implemented in Longmont, it might be expected to reduce water use by 9%, or about 2,000 ac-ft/yr.

(a) Economic Effects

Approximately $50,000 in increased administrative costs and costs of conservation kits could be expected each year in which this policy was in effect.

(b) Environmental Effects

No environmental effects are expected. The 9% reduction in water use attributable to this element is well within the margin of water quantity presently wasted due to excessive lawn watering in Longmont; thus, no detrimental effects upon lawn appearance are anticipated.

(c) Social Effects

Negligible social effects are expected. The policy is entirely voluntary, is invoked only under drought conditions when community attitudes are favorable to water conservation, and is broadly acceptable for these reasons.

(2) Distribute Water Conservation Kits and Literature; Adopt Third Day Lawn Watering Restrictions; Adopt 25% Surcharge on Summer Water Use

This more stringent and more effective short-term drought accommodation policy is made up of components which have been implemented widely in the area (including Longmont) or which are reasonably predictable. It would produce a reduction in water use of about 3,000 ac-ft annually. However, most of this reduction would be achieved in the summer months, and would not address the anticipated winter shortage.

(a) Economic Effects

Administrative and other cost increases of $50,000 might be expected.

(b) Environmental Effects

The reduction in lawn watering attributable to implementation of this element is at the threshhold beyond which some decrease in attractiveness of urban lawns might be expected. To the value of this adverse environmental effect to lawn owners themselves must be added the external cost to others in addition to lawn owners.

(c) Social Effects

Both lawn watering restrictions and surcharges are disliked by the public, although restrictions are relatively acceptable during drought periods.

(3) Distribute Water Conservation Kits and Literature; Ration Water Use to 75% of Prior Year Use

This short-term drought accommodation policy has been widely used, particularly during the 1977 California drought, and its effects are largely predictable. A 25% reduction in water use would reduce 2020 annual demand by up to 5,000 ac-ft.

(a) Economic Effects

Administrative and enforcement costs might be expected to be about $100,000.

(b) Environmental Effects

Significant environmental costs are likely to be associated with this element because the reduction in water use approaches the amount presently attributable to overwatering. Therefore, the appearance of urban lawns could be expected to suffer somewhat (in drought years only), but insignificant long-term losses would be anticipated.

(c) Social Effects

Rationing is a highly unpopular policy, although less so in drought years. Therefore, this plan element involves more substantial negative social effects than do the other two drought accommodation elements.

(4) Implement Universal Metering

Longmont is presently converting its single family flat rate customer base to metering. However, it is doing so gradually, through a policy of requiring meter retrofits to existing flat rate residences as those residences are sold. All new construction is metered when built. The turnover rate for single family houses in Longmont now ranges from 7% to 9% annually. The long-run average has been assumed to be 9% for purposes of this Study. At this rate it will be many years before universal metering is accomplished. Immediate conversion could be required for all remaining flat rate residences. Although it would produce demand reductions of up to 7,000 ac-ft annually in the early years, its incremental effects would be imperceptible by 2020, when virtually all residences will have been converted under the existing policy.

(a) Economic Effects

No additional administrative costs would be incurred if this plan element were to be implemented. Capital costs of meter installation would be approximately $3 million.

(b) Environmental Effects

No environmental costs would be produced by this element.

(c) Social Effects

Survey research in Longmont has shown that substantial opposition to metering exists among flat rate customers. However, the same research has shown that metering is widely accepted once it is in place. Thus, the negative social effect of this element, although appreciable, can be expected to be quite temporary. Furthermore, the extent of the opposition will depend upon the rate structure in place at the time (metering can result in lower water bills under some rate structures), the extent to which a public information program convinces water users that their bills will not rise with metering, and the method chosen to pay for the conversion costs (opposition is strongest when flat rate customers themselves must pay the conversion costs).

(5) Adopt Increasing Block Pricing

Some cities have adopted increasing block pricing to discourage excessive water use. The effects of such a policy depend heavily upon the features of the policy adopted. In this case, the assumed rate structure begins at the current (1985) rate for the first 5,000 gallons per month and increases by the following increments for single-family residences.

Up to 5,000 gallons per month	0
5,000 to 10,000 gpm	10¢
10,000 to 15,000 gpm	20¢
15,000 to 20,000 gpm	30¢
Over 20,000 gpm	40¢

A similar rate structure was assumed for other categories of water users, except that the block limits were increased in proportion to their mean water usage.

(a) Economic Effects

The only significant costs associated with this element would be increased public information costs of $50,000. The effect on total revenue that would be realized by a water utility has not been estimated.

(b) Environmental Effects

This element would almost certainly produce a degradation in the appearance of urban lawns, although few lawns would be lost altogether.

(c) Social Effects

Rate increases are generally opposed by the public. However, those increases which penalize heavy consumers more than the average, and particularly those which do not penalize or even reward light consumers, are less strongly opposed.

(6) Building Code Requirements for Plumbing and Landscaping (New Construction)

Building code requirements for low water use plumbing are now widespread. Inclusion of low water use landscape requirements is less common, but growing. Depending upon the extent of low water use landscaping required, as much as 5,000 ac-ft of annual water demand could be eliminated by the year 2020.

(a) Economic Effects

Administrative costs of about $50,000 would be incurred.

(b) Environmental Effects

The current high proportion of grass lawn area would be reduced through conversion to non-water demanding landscaping if this element were to be implemented. Whether this represents a reduction, an increase, or no change in environmental amenities is a subjective judgment which would require further research to reveal.

(c) Social Effects

Building code requirements enjoy substantial public acceptability.

c. Institutional Measures

(1) Improved Water Management Through Market Processes

A private corporation could be formed to buy existing agricultural water rights and to lease water to agricultural, municipal, and industrial users on a firm or interruptible (drought years excluded) basis. This could achieve more efficient water use within and between sectors and between time periods. The economic gains from more efficient water use would accrue in part to the sellers of water rights and in part to the investors. Such a proposal is presently under consideration by a major investor.

In the absence of such a corporation, municipal and industrial water users could individually purchase water from existing agricultural users, including ditch companies. Such water can then be leased back to irrigators during normal years when it is not needed for municipal and industrial use.

(2) Basin-Wide Cooperative Water Management Organization

Essentially the same idea could be pursued by an organization established somewhat along the lines of a mutual ditch company. In this case, the shares in the company would be awarded in proportion to the water rights conveyed to it by current water users, giving weight to both the magnitude or the rights involved and their seniority. However, in order to achieve efficiency gains, water would be leased on a cash basis to the highest bidders and not allocated in proportion to shares owned, as is the case with mutual ditch companies. This provision would ensure the flexibility necessary to achieve efficient water use. The economic gains from increased efficiency would be distributed in proportion to shares owned, in the form of cash dividends. In this way, owners of vested water rights would be assured of economic returns at least as great, and often considerably greater, than those which they receive under current institutional arrangements.

(3) Restructured Water Rights to Improve Efficiency of Use

Objectives similar to those which would be achieved by organizations in the preceding two options could also be achieved through legislative restructuring of water rights. State water laws could be amended to: (a) vest the right to use or sale of salvaged water in the salvager(s) of that water, and (b) provide for temporary condemnation of agricultural water rights by municipalities, given adequate notice and appropriate compensation. Agricultural water rights can now be condemned by municipalities, but only on a permanent basis. Water rights exchanges which would increase efficiency of use could be expected to occur as a consequence of such statutory changes.

(4) River Basin Authority with Regulatory Power

Colorado statutes presently permit the establishment of river basin authorities which are empowered to set and enforce standards for achieving efficient water use, as well as to tax and to construct and operate water management facilities. No river basin authorities have yet been established under this statute, but it is clearly a device which could achieve the same water use efficiency increased by regulatory means as could be accomplished by voluntary means under any of the three preceding options.

(5) Water Court Enforcement of Water Use Efficiency Goals

The existing water court system could also be used to achieve more efficient water use. Legislative action would be required to direct that beneficial use be more stringently interpreted to exclude waste. Existing statutes can be interpreted to do so, but the loose interpretation presently given to those statutes suggests that additional legislation may be required to effect change.

E. Formulation of Preliminary Alternative Plans

1. Plan Formulation Work Sessions

Following evaluation of the individual structural and non-structural plan elements, the Study Team and Management Committee representatives met in a series of work sessions to formulate preliminary alternative plans. Guidelines for preparing the plans were set up prior to the work sessions to outline the procedures and objectives of the sessions.

The work sessions were held on four consecutive days from February 5 through February 8, 1985. Participants representing the three engineering firms comprising the Study Team, and a representative of each agency included in the Management Committee participated in the work sessions. In addition, an independent economist/institutional analyst working on behalf of the CWRPDA participated in the sessions. The following paragraphs describe the water supply target objectives established prior to plan formulation and the resulting plans formulated during the work sessions.

2. Target Objectives and Plan Descriptions

Recognizing limitations in water supply quantities that can be developed, and the general economic value of water supply for different purposes, a range of quantified targets was established for use in plan formulation. Three target objectives were established based on the primary water resource management plan purposes identified previously in this chapter.

- o Target 1--To supply all municipal and industrial (M&I) water supply demands to year 2020.
- o Target 2--In addition to providing M&I water demands, provide storage capacity for in-season regulation of irrigation water supplies.
- o Target 3--Development of the water resources of the St. Vrain Basin to a reasonable maximum level.

Each target defines a different level of water resource development with the intent of satisfying different specific needs of the water demand sectors and plan purposes. The actual formulation of alternative plans to meet each target was accomplished by selecting plan elements and combining them to meet the target objectives. In order to do this, it was necessary first to enumerate the projected water supply deficiency for each target and to select elements that could provide the indicated water supply deficiencies.

While the approach used in plan formulation is as described above, the selection of plan elements for use in various plans illustrates the use of several concepts for achieving the Study's primary water supply purpose. These concepts include the following:

- The use of non-structural measures in conjunction with structural measures
- Off-stream reservoir storage
- Main stem reservoir storage
- Seasonal storage of irrigation supplies (no carryover storage)
- Regulation of trans-basin diversions for M&I use
- Reuse of reclaimed municipal wastewater for irrigation
- Development of irrigation supply by storage in major reservoir
- Development of irrigation supply by pumping streamflow from the lower end of the Basin to irrigation ditches or a storage reservoir located upstream

The three target objectives and the alternative plans formulated for each target, are described below. A total of nine plans were formulated on a preliminary basis, of which five were selected for evaluation.

a. <u>Target 1</u>

The objective of Target 1 is to supply all municipal and industrial water supply demands in the Study Area to year 2020. Regulation or augmentation of supplies for agriculture are not included in these plans. Five plans were formulated to meet this objective. For all Target 1 plans, non-structural elements were first selected to reduce water demands to the maximum extent practical and to improve operational efficiency of the Basin's water resource system. Different levels of such non-structural elements, however, were selected for various plans formulated to meet Target 1. Delivery and regulation of Windy Gap Project water was included in all plans except for Plan 1B. Any remaining deficits that could not be met by non-structural elements were then provided by structural elements or in some plans by purchase of C-BT shares or by conversion of agricultural water rights to M&I use.

All of the five plans considered include a pipeline system to convey water from Carter Lake Reservoir or from a reservoir on Little Thompson River to the Longmont water treatment plant. Such water may be that supplied either by the Windy Gap Project or the C-BT Project, depending on the particular plan. The pipeline system would be operable on a year-round basis and therefore would eliminate the need for winterization of the St. Vrain Supply Canal.

Regulation of wastewater effluent from Longmont to allow specific reuse of Windy Gap Project water is a feature of two of the Target 1 plans. The storage location selected for this regulation includes pits resulting from mining on the Southwestern Portland Cement Company property, and if needed, enlargement of Foothills Reservoir. For these plans, a pipeline system is also necessary to convey wastewater from the treatment plant to the storage facility.

Enlargement of Ralph Price Reservoir (Button Rock) is included in four of the five formulated plans. The reservoir appears to be a suitable site for regulation of agricultural rights that are converted to municipal use. A reservoir on Little Thompson River, excluding imports from other basins, was also considered for this purpose, but is judged to be somewhat less efficient in regulating converted agricultural rights, since it would have to rely upon exchange arrangements with C-BT Project shareholders.

Target 1 provides all M&I demand as forecast for year 2020 for the medium growth scenario as affected by 1 in 30 drought year conditions. This forecast amount of water is 44,000 ac-ft/year. The estimated present supply deficiency for this target is 18,000 ac-ft/year, accounting for full use of Windy Gap Water by Longmont. The supply deficiency would be 26,000 ac-ft/year for plans not accounting for the use of Windy Gap Water by Longmont. No regulation of agricultural supplies is provided in Target 1.

While the study focuses on certain facilities associated with the City of Longmont, it is inherent in plan formulation that additional municipal and industrial water supplies developed in Target 1 plans would be available to meet all the municipal demands in the Basin.

The five plans formulated to meet this target are characterized as follows:

- <u>Plan 1A</u>

  This plan employs a minimal level of non-structural elements to reduce water demand, along with reuse of Windy Gap Water and the purchase of C-BT Project water. The remaining deficiency would be supplied by conversion of agricultural rights to M&I use.

- o Plan 1B

  In contrast to Target Plan 1A, this plan employs a maximum level of non-structural elements to reduce demand along with purchase of C-BT Project water and conversion of agricultural rights to M&I use. This plan minimizes storage capacity required to meet Target 1 because it assumes Windy Gap Water will not be utilized by the City of Longmont.

- o Plan 1C

  This plan employs a maximum level of non-structural measures to reduce demand along with purchase of C-BT Project water and conversion of agricultural rights to M&I use.

- o Plan 1D

  This plan employs a moderate level of non-structural elements to reduce demand along with reuse of Windy Gap Water and conversion of agricultural rights to M&I use.

- o Plan 1E

  This plan employs a moderate level of non-structural elements to reduce demand along with the purchase of C-BT Project water and conversion of agricultural rights to M&I use.

Following consideration of all five plans, Plans 1A and 1B were selected for further evaluation. Plans 1C, 1D, and 1E were not considered to be as effective or as economical in meeting the target demands and are not described in detail in this report.

(1) Plan 1A Description

Plan 1A is designed to provide for forecast municipal and industrial water demand for year 2020 for the medium growth scenario, and for drought conditions expected to occur on an average of one year in 30. The estimated total amount of M&I demand forecast for year 2020 under these conditions is 44,000 ac-ft/yr. Present firm annual supply to meet the M&I demand is estimated to be 18,000 ac-ft, not including Windy Gap Project water. The structural and non-structural elements proposed in Plan 1A are designed to meet the 26,000 ac-ft of firm yield deficit forecast for year 2020. The elements of Plan 1A, and the amount of the total drought-year deficit each is designed to meet, are summarized as follows:

Structural Elements	Purpose
Pole Hill Diversion Little Thompson Dam and Reservoir Pipeline from Little Thompson River to Burch Lake Water Treatment Plant	Divert, regulate, and deliver Longmont's entitlement to Windy Gap Project water. These elements would deliver an estimated 8,000 ac-ft/yr of new firm supply.
Longmont Wastewater Pumping Plant Pipeline from Wastewater Pumping Plant to Southwestern Portland Cement Co. Pits and Foothills Reservoir SWPC Pits and Distribution Canal Raised Foothills Dam and Reservoir	Reuse of wastewater generated from the Windy Gap Project supply and the consumable portion of converted agricultural water rights. These elements would develop an estimated 6,600 ac-ft/yr of new firm supply.
Enlarged Ralph Price Reservoir	Regulate agricultural water rights converted to M&I use. This element would develop an estimated 5,400 ac-ft/yr of new firm supply.

Non-Structural Elements	Purpose
Purchase of C-BT Project water	Provide 2,300 ac-ft/yr of new firm supply.
Distribution of water conservation kits and literature, and urge voluntary water use reductions	Reduce demand by 2,000 ac-ft/yr.
Rate adjustment to pay for Windy Gap Project water	Reduce demand by 1,700 ac-ft/yr.
Hydrologic instrumentation of Basin	Improve system effectiveness of water resources facilities (not quantified).

Structural features of Plan 1A are illustrated in Fig. VII-2, and associated principal statistics are presented in Table VII-9.

Plan 1A includes a storage reservoir on the Little Thompson River for regulation of Longmont's 8,000 ac-ft/yr entitlement to Windy Gap Project water. To provide this amount on a firm basis, the reservoir of estimated 16,000 ac-ft of active storage capacity will be required. A pipeline from this reservoir will deliver the Windy Gap Project water to the Longmont Water Treatment Plant located adjacent to Burch Lake (hereinafter referred to as Burch Lake WTP). Windy Gap Project water will be diverted from the C-BT project from the afterbay of the existing Pole Hill Power Plant. It was assumed for this Study that water would be pumped from the Pole Hill afterbay; however, a gravity diversion may also be possible by piercing the existing dike forming the afterbay. Diverted water would then flow by gravity down the North Fork of the Little Thompson River for approximately 11 miles to the upper end of the proposed Little Thompson Reservoir. Diversion of Windy Gap Project water at Pole Hill avoids the more costly alternative of constructing an intake and outlet works from Carter Lake and a pumped conveyance system to the Little Thompson Reservoir. However, a power interference charge of about $130,000/yr, payable to the Western Area Power Administration (WAPA) would be required if water is diverted at Pole Hill. This is a charge related to lost power revenue by WAPA.

Another feature of Plan 1A is a system for reuse of wastewater supplied by the Windy Gap Project and the consumable portion of converted agricultural water rights. The wastewater reuse system includes a pumping plant located adjacent to the Longmont Wastewater Treatment Plant and a pipeline from that point westerly to a mined-out limestone pit presently owned by the Southwestern Portland Cement Company. Additional storage capacity for reuse purposes up to a combined total of 8,000 ac-ft will be provided by an enlargement of the adjacent Foothills Reservoir. Based on RIBSIM model results the reuse system will deliver an average annual volume of 5,900 ac-ft/yr, which would be exchanged for creek water normally diverted for agricultural use. The average annual volume is less than the system's firm yield of 6,600 ac-ft/yr, indicating water from this system will be of low priority under average conditions. That is, during the average year, demand will be satisfied from other supplies even through water would be available from the reuse system.

Wastewater effluent is used in many areas of the country for agricultural purposes. Water quality requirements vary with the type of soil, crop, and climate of the area. For example, effluent is being used in areas of Arizona, California, Texas, and Washington for irrigation of crops such as corn, hay, grain, alfalfa, sorghum, barley, wheat, pastures, cotton, citrus, maize, and cattle. (Texas Water Utilities Association, 1971.)

Plan 1A also includes enlargement of Ralph Price Reservoir by approximately 12,500 ac-ft, which would require raising the present normal maximum water surface elevation by 50 feet. This additional storage capacity is primarily for the purpose of regulating converted agricultural water rights obtained by the City of Longmont, but could also provide some capacity for other Study purposes such as flood control, water quality and fishery enhancement.

Non-structural elements in Plan 1A include the distribution of water conservation kits and literature to residential and commercial users, the urging (through publicity) of voluntary water use reductions, implementing a water rate adjustment to Windy Gap Project water, and hydrologic instrumentation of the Basin to monitor streamflows, snowpack, and weather data. The remaining deficit of 2,300 ac-ft/yr would be met by purchase of C-BT Project shares.

Regarding hydrologic instrumentation of the Basin, costs to provide instruments in the Basin for short-term runoff forecasting were prepared by the Northern Colorado Water Conservancy District in its letter to the CWRPDA dated November 5, 1984. The total estimated cost to provide five stream gage and seven snowpack instruments is $121,200. The effectiveness of the proposed instrumentation was not described in the subject letter.

(2) Plan 1B Description

Plan 1B, like Plan 1A, is designed to meet all M&I demand as forecast for year 2020 for the medium growth scenario and for drought conditions expected to occur on the average of once in 30 years. The amount of deficit in year 2020, assuming present sources will remain available, is forecast to be 26,000 ac-ft. Therefore, Plan 1B is formulated to provide an additional 26,000 ac-ft/yr of firm supply. A major difference from Plan 1A is that Plan 1B assumes Longmont's Windy Gap Project entitlement of 8,000 ac-ft would neither be utilized by the City nor by other entities within the Basin. It is assumed that this entitlement would be sold for use outside the St. Vrain Study Area. As with Plan 1A, Plan 1B does not provide any new irrigation water or improved regulation of present irrigation supplies.

The features of Plan 1B, and the amount of the total drought-year deficit each is designed to meet, are summarized as follows:

Structural Elements	Purpose
Pipeline from Carter Lake to Burch Lake Water Treatment Plant	Convey an additional 11,100 ac-ft/yr of new purchase C-BT water to the Study Area.
Enlarged Ralph Price Reservoir	Regulate converted agricultural water rights. This element would develop 5,400 ac-ft/yr of new firm supply.

Non-Structural Elements	Purpose
Increasing block pricing and low water demand landscaping on new construction	Reduce demand by 4,500 ac-ft/yr.
Distribution of water conservation kits and literature, and rationing of water use to 75% of prior year use during drought conditions	Reduce demand by 5,000 ac-ft/yr.
Hydrologic instrumentation of Basin	Improve system effectiveness of water resources facilities (not quantified).

The major source of new water in Plan 1B is through purchase of additional C-BT Project shares for M&I purposes. Such water would be conveyed to Longmont from Carter Lake via a pipeline as described below. This supply component would deliver about 11,000 ac-ft/yr in the drought year. To satisfy the remaining deficit, present agricultural rights would be converted to M&I usage in this plan.

Structural features of Plan 1B are illustrated in Fig. VII-3, and associated principal statistics are presented in Table VII-10. Structural features include a 36-inch-diameter gravity-flow pipeline, 9.5 miles long, from Carter Lake to the Burch Lake WTP, and enlargement of Ralph Price Reservoir by 12,500 ac-ft. The pipeline is sized to deliver the additional purchase of C-BT Project water, including wintertime deliveries, and would be capable of delivering water at a rate approximately 50% greater than the expected average monthly (December) flow rate to accommodate daily peaks caused by irregular demand. Enlargement of Ralph Price Reservoir would provide for regulation of converted agricultural water rights and additional capacity that may be used to provide for other project purposes such as flood control, water quality maintenance and fishery improvements.

Plan 1B incorporates maximum use of non-structural measures designed to reduce M&I water demand including increasing block pricing and requiring low water demand landscaping on new construction. Also, water use would be rationed in dry years and conservation kits and public media would be used to encourage reduced water consumption. As included in the four other selected plans, hydrologic instrumentation of the Basin is included as a non-structural measure in Plan 1B.

b. Target 2

The objective of Target 2 is to provide storage capacity for in-season regulation of irrigation water supplies in addition to providing the M&I water requirements specified in Target 1. Only one plan was formulated to meet this objective, and it is designated Plan 2A.

The structural and non-structural elements proposed in Plan 2A are designed to meet the 26,000 ac-ft/yr of M&I firm yield deficit forecast for year 2020, and to provide 23,500 ac-ft of storage capacity for in-season regulation of agricultural water. The elements, and the amount of the total deficit or plan purpose each is designed to meet, are summarized as follows:

Structural Elements	Purpose
Pole Hill Diversion Little Thompson Dam and Reservoir Pipeline from Little Thompson to Burch Lake Water Treatment Plant	Divert, regulate, and deliver Longmont's entitlement to Windy Gap Project water. These elements would deliver 8,000 ac-ft/yr of new firm supply.

Structural Elements	Purpose
Longmont Wastewater Pumping Plant Pipeline from Wastewater Pumping Plant to SWPC Pits and Foothills Reservoir SWPC Pits and Distribution Canal Raised Foothills Dam and Reservoir	Reuse of wastewater generated from the Windy Gap Project supply and the consumable portion of converted agricultural water rights. These elements would develop 6,600 ac-ft/yr of new firm supply.
North Sheep Mountain Dam and Reservoir	Dual purpose. Would provide 23,500 ac-ft of storage for in-season regulation of agricultural water, and regulate converted agricultural water rights to develop a firm M&I supply of 5,400 ac-ft/yr.

Non-Structural Elements	Purpose
Purchase C-BT Project water	Provide 2,300 ac-ft/yr of new firm supply.
Distribution of water conservation kits and literature, and urge voluntary water use reductions	Reduce demand by 2,000 ac-ft/yr.
Windy Gap Project water rate adjustment	Reduce demand by 1,700 ac-ft/yr.
Hydrologic instrumentation of Basin	Improve system effectiveness of water resources facilities (not quantified).

Structural features of Plan 2A are illustrated in Fig. VII-4, and associated principal statistics are presented in Table VII-11. Non-structural measures are the same as those proposed in Plan 1A, which include distribution of water conservation kits and literature, urging voluntary water use reductions, implementing a water rate adjustment to Windy Gap Project water, and hydrologic instrumentation of the Basin.

Only one element is included in Plan 2A that is not in Plan 1A; this is a reservoir of 30,000 ac-ft storage capacity at the North Sheep Mountain site upstream of Button Rock Dam on North St. Vrain Creek. North Sheep Mountain Reservoir would provide 23,500 ac-ft storage capacity for the in-season regulation function as well as 6,500 ac-ft storage for regulation of converted agricultural water rights to develop a firm yield of 5,400 ac-ft/yr. In Plan 1A, enlargement of Ralph Price Reservoir would serve the latter function. Little Narrows Reservoir located on South St. Vrain Creek was considered as an alternative storage site to the North Sheep Mountain site but was rejected. A preliminary construction cost estimate of the Little Narrows site indicates its cost would be substantially greater than the selected site.

The concept of in-season regulation as developed in Plan 2A is to provide a uniform percentage of the irrigation water requirement, as computed by the Blaney-Criddle method, for each month of each irrigation season, but not to provide any carryover storage. From year-to-year, the percentage of the Blaney-Criddle requirement delivered would vary, depending on the available water supply in each year. Reservoir capacity for this purpose, 23,500 ac-ft, was selected based on an analysis of historical seasonal distribution of irrigation supplies. With regulation, large amounts of water that are normally available early in the season would be stored and released for use later, primarily during August, September, and early October. All stored water for this purpose would be emptied from the reservoir at the end of the irrigation season.

c. Target 3

The objective of Target 3 is to develop the water resources of the Basin to a reasonable maximum level to provide capacity to meet all forecast M&I demand in year 2020 and a substantial additional supply for agricultural use. Three preliminary alternative plans were formulated to meet Target 3 objectives. A fourth alternative plan, designated Plan 3C, was added during the reformulation stage of the study, and is described in Chapter IX.

Since Target 3 plans aim toward reasonable maximum development of the water resources of the Basin they include development of more structural elements than do Target 1 and Target 2 plans. A substantial influence from non-structural elements to be implemented is included in these plans also. This target includes meeting all M&I demand as forecast for year 2020 for the medium growth scenario as affected by the 1 in 30 drought year conditions, which is forecast to be 44,000 ac-ft/yr. The estimated 1 in 30 year M&I deficiency for this target is 18,000 ac-ft/year, accounting for full use of Windy Gap water by Longmont. In addition to providing for M&I needs, this target calls for reasonable maximum development of remaining native water of the Basin for agricultural use and, in the case of Plans 3A and 3C, may also include in-season regulation of agricultural water.

The four plans formulated defined to meet Target 3 are characterized as follows:

o Plan 3A

This plan meets the M&I demand by employing Plan 1A. In addition, non-structural elements in the agricultural sector are implemented along with utilization of a pipeline to convey water by pumping from the lower reach of St. Vrain Creek (below the Boulder Creek confluence) to an upstream reservoir for short-term regulation. Water would be delivered directly to ditches from the pipeline when pumping, and releases made from the reservoir to ditches during non-pumping periods. Pumping from St. Vrain Creek to a reservoir at Dowe Flats is included for in-season regulation of presently developed agricultural supplies.

- Plan 3B

  This plan meets the M&I demand by employing the Target Plan 1A approach. In addition, non-structural elements in the agricultural sector are implemented together with development of storage capacity for reasonable maximum development of native water. This plan differs from plans 3A and 3C in that it does not include a pipeline to convey water from the lower part of the Basin to upstream locations.

- Plan 3C

  This plan provides storage for meeting the forecast year 2020 M&I demand, and, in the same reservoir, provides storage capacity for in-season regulation of agricultural water. Storage is accommodated by one main stem reservoir located at the North Sheep Mountain site. A pumped storage project is also provided utilizing North Sheep Mountain and Ralph Price reservoirs. Plan 3C was not formulated during the original formulation process, rather it was added by the Management Committee following public comment on the five alternative plans. Plan 3C is described and evaluated in Chapter IX.

- Plan 3D

  This plan also meets the M&I demand by employing Plan 1A. In addition, non-structural elements in the agriculture sector are implemented along with operation of a pipeline to convey water by pumping from the lower reach of St. Vrain Creek (below the Boulder Creek confluence) to upstream locations for direct use. No reservoir would be provided for in-season regulation. Deliveries would be made from the pipeline directly to various ditches along the route.

The plans initially selected for evaluation, Plans 3A and 3B, are described in greater detail below.

(1) Plan 3A Description

Plan 3A is designed to meet all M&I demand as forecast for year 2020 for the medium growth scenario, including drought conditions expected to occur on the average of once in 30 years. As previously discussed, the deficit forecast in year 2020 for M&I supply as compared to present capacity is 26,000 ac-ft/yr. Plan 3A is also intended to provide a reasonable maximum level of development of the water resources for the Basin for agricultural purposes. However, the estimated deficit in agricultural water supplies on a one in 10-year basis assuming demand corresponding to 85% of the Blaney-Criddle requirement is about 78,000 ac-ft/yr. This deficit is substantially greater than can be developed from native St. Vrain Basin resources.

The elements comprising Plan 3A, and the amount of the estimated total deficit each is designed to meet, are summarized as follows:

Structural Elements	Purpose
Pole Hill Diversion Little Thompson Dam and Reservoir Pipeline from Little Thompson to Burch Lake Water Treatment Plant	Divert, regulate, and deliver Longmont's entitlement to Windy Gap Project water. These elements would develop 8,000 ac-ft/yr of new firm supply.
Longmont Wastewater Pumping Plant Pipeline from Wastewater Pumping Plant to SWPC Pits and Foothills Reservoir SWPC Pits and Distribution Canal Raised Foothills Dam and Reservoir	Reuse of wastewater generated from the Windy Gap Project supply and the consumable portion of converted agricultural water rights. These elements would develop 6,600 ac-ft/yr of new firm supply.
Enlarged Ralph Price Reservoir	Regulate agricultural water rights converted to M&I use. This element would develop 5,400 ac-ft/yr of new firm supply.
Barbour Ponds Pumping Plant Booster Pumping Plant to Dowe Flats Pipeline from Barbour Ponds to Dowe Flats	Pump-back system. Pump from St. Vrain Creek and deliver an average of 19,300 ac-ft/yr for irrigation use.
Pipeline from St. Vrain Creek to Dowe Flats Dowe Flats Pumping/Power Plant	Pump and deliver 25,000 ac-ft of water to Dowe Flats Reservoir for in-season regulation of presently developed agricultural water supplies.
Dowe Flats Reservoir	Dual purpose. Store and regulate 30,000 ac-ft for the pump-back system, and 25,000 ac-ft for in-season regulation.

Non-Structural Elements	Purpose
Purchase of C-BT Project water	Provide 2,300 ac-ft/yr of new firm supply.
Distribution of water conservation kits and literature, and urge voluntary water use reductions	Reduce demand by 2,000 ac-ft/yr.
Windy Gap Project water rate adjustment	Reduce demand by 1,700 ac-ft/yr.
Establishment of a Basin-wide cooperative management organization to improve efficiency of water use	Improve system effectiveness of water resources facilities (not quantified).
Statutory change to provide for water salvage	Improve system effectiveness of water resources facilities (not quantified).
Reduction of conveyance losses and elimination of over-irrigation	Improve system effectiveness of water resources facilities (not quantified).
Hydrologic instrumentation of Basin	Improve system effectiveness of water resources facilities (not quantified).

Structural elements of Plan 3A are illustrated in Fig. VII-5, and associated principal statistics are presented in Table VII-12.

Plan 3A includes all structural and non-structural elements of Plan 1A and in addition provides a major facility to recirculate water pumped from the lower reach of St. Vrain Creek to a reservoir for distribution to certain irrigation ditches, and includes implementing additional non-structural elements. The intake and pumping plant site for the pump-back system is located about 0.5 mile below the confluence of Boulder and St. Vrain creeks and a booster pumping plant would be included at approximately the midpoint of the pipeline system, located about 1 mile south of Terry Lake. The pipeline, tentatively selected for 80 cfs capacity and 48 inches in diameter, would be approximately 15 miles in length, terminating at a new reservoir to be located at Dowe Flats.

The capacity of Dowe Flats Reservoir is preliminarily selected as 55,000 ac-ft which includes 30,000 ac-ft for the pump-back system and 25,000 ac-ft for in-season regulation of presently developed agricultural water supplies. Water for the latter purpose would be pumped directly from the Dowe Flats Pumping/Power Plant located on St. Vrain Creek to Dowe Flats Reservoir via a pipeline 54 inches in diameter and about 1 mile in length.

As an alternative to this pumping plant, a gravity diversion structure and pipeline could be constructed. However, to gain sufficient elevation for gravity operation the required pipeline length probably would make this system more costly than the pumping arrangement. The pump-back system, from Barbour Ponds Pumping Plant to Dowe Flats Reservoir, is planned to provide agricultural water to three ditch companies whose supplies at present consist of relatively junior rights and hence these companies experience water shortages almost perennially. These ditches are the Highland, Last Chance, and Rough and Ready. Deliveries to these ditches could be made when the system is in the pumping mode, or when not pumping, water from Dowe Flats Reservoir would be released back through the line by gravity for delivery directly to the ditches or to the Dowe Flats Pumping/Power Plant for power generating purposes and release to St. Vrain Creek.

Non-structural elements included in Plan 3A, in addition to those described in Plan 1A, are: (1) establishing a Basin-wide cooperative water management organization for the purpose of discussing and implementing ways and means to improve efficiency of water use; (2) implementing a statutory change to provide for water salvage; and (3) reducing conveyance losses and eliminating over-irrigation.

(2) Plan 3B Description

Plan 3B also provides for all M&I water demand as forecast for year 2020 for the medium growth scenario, including capability to supply full demand during the one in 30-year drought. In addition to providing M&I requirements, Plan 3B is intended to develop a reasonable maximum level of the water resources of the Basin. This level of development, however, will supply only a relatively small fraction of the forecast deficit in agricultural water.

To accomplish the assigned purposes, Plan 3B includes all structural features of Plan 1A, except that the 16,000 ac-ft capacity reservoir on Little Thompson River is replaced with a major storage facility of about 86,000 ac-ft of active capacity. The additional 70,000 ac-ft of capacity is used to regulate storable flows under junior water rights in the St. Vrain system and Little Thompson River. In the evaluation of Plan 3B, major storage sites at North Sheep Mountain, Smithy Mountain, and Coffintop were also considered for inclusion in the final plan. However, as discussed in Chapter VIII, the Little Thompson site was estimated to be the least costly alternative, and was therefore selected as the major storage site for Plan 3B. Non-structural elements included in this plan are the same as those cited above for Plan 3A.

The elements of Plan 3B, and the amount of the estimated total annual deficit each is designed to meet, are summarized as follows:

Structural Elements	Purpose
Pole Hill Diversion Little Thompson Dam and Reservoir Pipeline from Little Thompson Reservoir to Canal 3B	Dual purposes. Divert, regulate and convey 8,000 ac-ft/yr of firm yield for M&I use, and regulate and convey a firm yield of 13,900 ac-ft/yr for irrigation purposes.
North St. Vrain to Little Thompson Diversion Tunnel, Canal, and Diversion Works	Divert an average of 16,300 ac-ft/yr from North St. Vrain Creek to Little Thompson Reservoir.
Canal 3B	Deliver 13,900 ac-ft/yr of firm yield irrigation water to Highland Reservoir No. 2.
Pipeline from Canal 3B to Burch Lake Water Treatment Plant	Deliver 8,000 ac-ft/yr of firm yield M&I water.
Longmont Wastewater Pumping Plant Pipeline from Wastewater Pumping Plant to SWPC Pits and Foothills Reservoir SWPC Pits and Distribution Canal Raised Foothills Dam and Reservoir	Regulate for reuse wastewater generated from the Windy Gap Project supply and the consumable portion of converted agricultural water rights. These elements would develop 6,600 ac-ft/yr of new firm supply.
Enlarged Ralph Price Reservoir	Regulate agricultural water rights converted to M&I use. This element would develop 5,400 ac-ft/yr of new firm supply.

Non-Structural Elements	Purpose
Purchase of C-BT Project water	Provide 2,300 ac-ft/yr of new firm supply.
Distribution of water conservation kits and literature, and urge voluntary water use reductions	Reduce demand by 2,000 ac-ft/yr.
Windy Gap Project water rate adjustment	Reduce demand by 1,700 ac-ft/yr.
Establishment of a Basin-wide cooperative management organization to improve efficiency of water use	Improve system effectiveness of water resources facilities (not quantified).
Statutory change to provide for water salvage	Improve system effectiveness of water resources facilities (not quantified).

Non-Structural Elements	Purpose
Reduce conveyance losses and eliminating over-irrigation	Improve system effectiveness of water resources facilities (not quantified).
Hydrologic instrumentation of Basin	Improve system effectiveness of water resources facilities (not quantified).
Transfer of diversion points of selected senior ditches to wellfields	Improve system effectiveness of water resources facilities (not quantified).

In Plan 3B, water would be diverted from North St. Vrain Creek via a tunnel and canal system to the Little Thompson Reservoir. Releases of irrigation water from the reservoir would flow in a pipeline and be diverted at a point approximately 1 mile downstream from the dam into a new irrigation canal, named Canal 3B, which will convey this water to existing Highland Reservoir No. 2 where it will be utilized by existing ditch systems. The same ditches that benefit from Plan 3A would utilize the water developed in Plan 3B, namely Highland, Last Chance, and Rough and Ready ditches. Structural elements of Plan 3B are illustrated in Fig. VII-6, and associated principal statistics are presented in Table VII-13.

The diversion tunnel from North St. Vrain Creek to the Little Thompson River would be 9 feet in diameter and capable of conveying 600 cfs. Based on RIBSIM model results of 30 years of simulated monthly operation, this tunnel capacity would be sufficient to convey all monthly divertable flows from North St. Vrain Creek to the Little Thompson River, except for 1 month when historical flows were extremely high (38,600 ac-ft); this condition would result in only a slight loss of the potentially divertable flow.

The irrigation canal to existing Highland Reservoir No. 2, Canal 3B, would be concrete-lined and have a capacity of 110 cfs.

One of the non-structural elements considered in Plan 3B for increasing irrigation efficiency is transfer of points of diversion for a number of senior ditches in the St. Vrain system. Under this plan, diversion points would be transferred to wells or well fields located in or adjacent to the irrigated areas which would allow present use of the existing diversion ditches to be discontinued. In many cases, these diversion ditches are considered to be quite inefficient due to the pervious nature of the soils they pass through.

Table VII-1

St. Vrain Basin Reconnaissance Study

ALPHABETICAL LISTING OF STRUCTURAL PLAN ELEMENTS

1. Potential Elements

a. Storage

	Map Designation
Antelope Park Reservoir	1
Berts Corner Reservoir	82
Big Hollow Reservoir	83
Big John Reservoir	3
Bradley Ranch Reservoir	4
Buck Gulch Reservoir	5
Buckingham Reservoir	95
Chimney Rock Reservoir	12
Coal Creek Reservoir	13
Coffintop Reservoir	14
Cook Mountain Reservoir	15
Coulson Gulch Reservoir	17
Davidson Reservoir	91
Dowe Flats Reservoir	18
Dry Creek Reservoir	19
Erie Reservoir	20
Frederick Reservoir	90
Geer Canyon Reservoir	22
Harney Reservoir	87
Howlett Reservoir	27
Hydraulic Lab Reservoir	28
Last Chance Reservoir	29
Little Dry Creek Reservoir	88
Little Narrows Reservoir	93
Little South St. Vrain Reservoir	75
Little Thompson No. 1 Reservoir	31
Little Thompson No. 2 Reservoir	32
Little Thompson No. 3 Reservoir	33
Little Thompson No. 4 Reservoir	80
Longmont Sugar Plant Reservoir	76
Lookout Dam and Reservoir	34
Lower South St. Vrain Reservoir	36
Lykins Gulch Reservoir	37
Lykins Gulch Reservoir - Alternative No. 1	79
Nederland Reservoir	41
Nederland Reservoir - Alternative No. 1	42
Niwot Reservoir	89

Table VII-1
(continued)

	Map Designation
1. Potential Elements (continued)	
a. Storage (continued)	
North Sheep Mountain Reservoir	94
Oligarchy Reservoir	43
Orodell Reservoir	44
Parks Reservoir - Alternative No. 1	45
Parks Reservoir - Alternative No. 2	46
Pearl Reservoir	47
Pearl-Howlett Reservoir	48
Potato Hill Reservoir	50
Red Gulch Reservoir	51
Red Hill Gulch Reservoir	85
Rinn Valley Reservoir	86
Rock Creek Reservoir	92
Rowell Hill Reservoir	53
Rowell Hill Reservoir - Alternative No. 1	54
Sheep Mountain Reservoir	77
Sherwood Reservoir	56
Sixmile Canyon Reservoir	71
Smithy Mountain Reservoir	59
Southwestern Portland Cement Co. Pits (Formerly Martin-Marietta Pits)	38
Spring Gulch Reservoir	62
Steamboat Mountain Reservoir	63
Stone Canyon Reservoir	84
Table Mountain Reservoir	64
Tahosa Reservoir	65
Thorodin Reservoir	66
Tungsten Reservoir	67
Upper South St. Vrain Reservoir	69
Wondervu Reservoir	70
b. Diversion and Conveyance Elements	
Button Rock Reservoir to South St. Vrain Creek	7
Cabin Creek Diversion to Buck Gulch	9
Ditch or Canal Lining	73
Horse Creek Diversion to Buck Gulch	26
Little Thompson River Diversion to Highland Reservoir No. 2	98
Middle St. Vrain Diversion to Buck Gulch	40
North St. Vrain Diversion to Buck Gulch	35
North St. Vrain Diversion to Little Thompson River	8

Table VII-1
(continued)

	Map Designation
1. Potential Elements (continued)	
b. Diversion and Conveyance Elements (continued)	
North St. Vrain Diversion to South St. Vrain Creek	96
Roaring Fork Diversion to Buck Gulch	52
Smithy Diversion to South St. Vrain Creek	58
South St. Vrain Diversion to Buck Gulch	61
South St. Vrain Diversion to Button Rock	60
South St. Vrain Diversion to Geer Canyon	81
Upper North St. Vrain Diversion to Tahosa	68
2. Existing Elements	
a. Storage	
Beaver Reservoir	2
Boulder Reservoir	78
Button Rock Dam and Ralph Price Reservoir	6
Calkins Lake (Union Reservoir)	10
Carter Lake Reservoir	11
Copeland Lake	16
Foothills Reservoir	21
Gold Lake	23
Gross Reservoir	74
Highland No. 2	24
Highland No. 3 (Foster Reservoir)	25
Left Hand Valley Reservoir	30
McIntosh	39
Pleasant Valley (Terry Lake)	49
Silver Lake	57
b. Diversion and Conveyance Elements	
Brainard Diversion	72
Golden Age Mine Diversion	97
St. Vrain Supply Canal	55

Table VII-2

St. Vrain Basin Reconnaissance Study

NUMERICAL LISTING OF STRUCTURAL PLAN ELEMENTS

	Map Designation
Antelope Park Reservoir	1
Beaver Reservoir	2
Big John Reservoir	3
Bradley Ranch Reservoir	4
Buck Gulch Reservoir	5
Button Rock Dam and Ralph Price Reservoir	6
Button Rock Reservoir Diversion to South St. Vrain Creek	7
North St. Vrain Diversion to Little Thompson River	8
Cabin Creek Diversion to Buck Gulch	9
Calkins Lake (Union Reservoir)	10
Carter Lake Reservoir	11
Chimney Rock Reservoir	12
Coal Creek Reservoir	13
Coffintop Reservoir	14
Cook Mountain Reservoir	15
Copeland Lake	16
Coulson Gulch Reservoir	17
Dowe Flats Reservoir	18
Dry Creek Reservoir	19
Erie Reservoir	20
Foothills Reservoir	21
Geer Canyon Reservoir	22
Gold Lake	23
Highland No. 2	24
Highland No. 3 (Foster Reservoir)	25
Horse Creek Diversion to Buck Gulch	26
Howlett Reservoir	27
Hydraulic Lab Reservoir	28
Last Chance Reservoir	29
Left Hand Valley Reservoir	30
Little Thompson No. 1 Reservoir	31
Little Thompson No. 2 Reservoir	32
Little Thompson No. 3 Reservoir	33
Lookout Dam and Reservoir	34
North St. Vrain Diversion to Buck Gulch	35
Lower South St. Vrain Reservoir	36
Lykins Gulch Reservoir	37

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Table VII-2
(continued)

	Map Designation
Southwestern Portland Cement Co. Pits (Formerly Martin-Marietta Pits)	38
McIntosh	39
Middle St. Vrain Diversion to Buck Gulch	40
Nederland Reservoir	41
Nederland Reservoir - Alternative No. 1	42
Oligarchy Reservoir	43
Orodell Reservoir	44
Parks Reservoir - Alternative No. 1	45
Parks Reservoir - Alternative No. 2	46
Pearl Reservoir	47
Pearl-Howlett Reservoir	48
Pleasant Valley (Terry Lake)	49
Potato Hill Reservoir	50
Red Gulch Reservoir	51
Roaring Fork Diversion to Buck Gulch	52
Rowell Hill Reservoir	53
Rowell Hill Reservoir - Alternative No. 1 ...	54
St. Vrain Supply Canal	55
Sherwood Reservoir	56
Silver Lake	57
Smithy Diversion to South St. Vrain Creek ...	58
Smithy Mountain Reservoir	59
South St. Vrain Diversion to Button Rock	60
South St. Vrain Diversion to Buck Gulch	61
Spring Gulch Reservoir	62
Steamboat Mountain Reservoir	63
Table Mountain Reservoir	64
Tahosa Reservoir	65
Thorodin Reservoir	66
Tungsten Reservoir	67
Upper North St. Vrain Diversion to Tahosa ...	68
Upper South St. Vrain Reservoir	69
Wondervu Reservoir	70
Sixmile Canyon Reservoir	71
Brainard Diversion	72
Ditch or Canal Lining	73
Gross Reservoir	74
Little South St. Vrain Reservoir	75
Longmont Sugar Plant Reservoir	76
Sheep Mountain Reservoir	77
Boulder Reservoir	78
Lykins Gulch Reservoir - Alternative No. 1 ..	79

Table VII-2
(continued)

	Map Designation
Little Thompson No. 4 Reservoir	80
South St. Vrain Diversion to Geer Canyon	81
Berts Corner Reservoir	82
Big Hollow Reservoir	83
Stone Canyon Reservoir	84
Red Hill Gulch Reservoir	85
Rinn Valley Reservoir	86
Harney Reservoir	87
Little Dry Creek Reservoir	88
Niwot Reservoir	89
Frederick Reservoir	90
Davidson Reservoir	91
Rock Creek Reservoir	92
Little Narrows Reservoir	93
North Sheep Mountain Reservoir	94
Buckingham Reservoir	95
North St. Vrain Diversion to South St. Vrain Creek	96
Golden Age Mine Diversion	97
Little Thompson River Diversion to Highland Reservoir No. 2	98

Table VII-3

St. Vrain Basin Reconnaissance Study

LISTING OF NON-STRUCTURAL PLAN ELEMENTS

Water Supply Management Measures

1. Potential transfers of Highland Ditch Company Storage Decrees
2. Potential transfers of Calkins and City of Longmont Decrees
3. Transfer of Points of Diversion of Senior Ditches
4. Transfer of Historical Agricultural Consumptive Use to a new storage facility
5. Transfer of high mountain storage decrees
6. Ditch lining and phreatophyte control
7. Satellite-linked hydrologic instrumentation
8. Aquifer recharge and storage for subsequent streamflow augmentation
9. Improvement of irrigation efficiency
10. Reduction of water provided to irrigated crops
11. Weather modification to increase watershed yields
12. Provision of municipal drought-year water supplies by leasing arrangements with agricultural interests
13. Modification of reservoir filling sequences
14. Reuse of municipal wastewater
15. Dredging of existing reservoirs

Water Demand Management Measures

1. Distribute water conservation kits and literature
2. Urge voluntary water use reduction
3. Adopt third-day lawn watering restrictions

Table VII-3
(continued)

Water Demand Management Measures (continued)

4. Adopt 25% surcharge on summer water use
5. Ration water use to 75% of prior year use
6. Implement universal metering
7. Adopt increasing block pricing
8. Building code requirements for plumbing and landscaping (new construction)

Institutional Measures

1. Improve water management through market processes
2. Establish a Basin-wide cooperative water management organization
3. Restructure water rights to improve efficiency of use
4. Establish a river basin authority with regulatory power
5. Water Court enforcement of water use efficiency goals

Table VII-4

St. Vrain Basin Reconnaissance Study

SELECTED STORAGE ELEMENT CHARACTERISTICS

Storage Element Name	Map Designation	Maximum Capacity (ac-ft)	Subbasin	Inflow Ratio	Dam Ratio	Flow (ac-ft/yr)
Buckingham	95	35,000	Left Hand Creek	1.5	4.7	23,000
Carter Lake	11	135,200[1]	(C-BT Project Feature)	—	—	—
Coffintop	14	116,000	South St. Vrain Creek	3.3	11.6	35,000
Dowe Flats	18	119,000	Main Stem St. Vrain Creek	—	7.3	—
Foothills	21	6,845[1]	Plains	—	—	—
Geer Canyon	22	25,000	Left Hand Creek	1.0	4.1	25,000
Highland No. 2	24	6,700[1]	Plains	—	—	—
Left Hand Valley	30	6,400[1]	Plains	—	—	—
Little South St. Vrain .	75	37,000	South St. Vrain Creek	1.7	3.8	22,100
Little Thompson No. 2 ..	32	305,000	Little Thompson River	15.2	14.1	20,000
Lykins Gulch	37	20,000	Left Hand Creek	33.3	6.4	600
North Sheep Mountain ...	94	150,000	North St. Vrain Creek	3.0	6.7	50,000
Pleasant Valley (Terry Lake)	49	7,200[1]	Plains	—	—	—
Ralph Price	6	31,000[1]	North St. Vrain Creek	—	—	61,800
Sherwood	56	35,000	North Boulder Creek	1.0	7.0	35,000
Smithy Mountain	59	126,000	North St. Vrain Creek	2.0	4.9	61,800
Southwestern Portland Cement Co. Pits	38	4,000	Plains	—	—	—
Tahosa	65	15,000	North St. Vrain Creek	0.6	10.7	24,000

(1) Total capacity with enlargement.

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Table VII-5

St. Vrain Basin Reconnaissance Study

SELECTED DIVERSION AND CONVEYANCE ELEMENTS

Name	Map Designation	Estimated Average Annual Flow (ac-ft/yr)
Little Thompson River Diversion to Highland Reservoir No. 2 ...	98	20,400
North St. Vrain Diversion to Little Thompson River	8	59,000
Button Rock Diversion to South St. Vrain Creek	7	61,800
North St. Vrain Diversion to South St. Vrain Creek	96	62,000
South St. Vrain Diversion to Button Rock	60	30,000
South St. Vrain Diversion to Geer Canyon	81	34,000
Brainard Diversion	72	19,000
St. Vrain Supply Canal	55	--

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Table VII-6

St. Vrain Basin Reconnaissance Study

SELECTED AND NON-SELECTED STRUCTURAL ELEMENTS

	Map Designation	Factors Influencing Non-Selection(1)
1. Potential Storage Elements		
Antelope Park Reservoir	1	a,g
Berts Corner Reservoir	82	e
Big Hollow Reservoir	83	a,e
Big John Reservoir	3	b,g
Bradley Ranch Reservoir	4	c
Buck Gulch Reservoir	5	a,g
Buckingham Reservoir	95	Selected
Chimney Rock Reservoir	12	a
Coal Creek Reservoir	13	g
Coffintop Reservoir	14	Selected
Cook Mountain Reservoir	15	a,g
Coulson Gulch Reservoir	17	a,g
Davidson Reservoir	91	c,g
Dowe Flats Reservoir	18	Selected
Dry Creek Reservoir	19	g
Erie Reservoir	20	e
Frederick Reservoir	90	e
Geer Canyon Reservoir	22	Selected
Harney Reservoir	87	a,e
Howlett Reservoir	27	a,e
Hydraulic Lab Reservoir	28	g
Last Chance Reservoir	29	c,e
Little Dry Creek Reservoir	88	a
Little Narrows Reservoir	93	g

(1) Key to factors:
- a - Small storage capacity
- b - Small inflow
- c - Excessive relocations
- d - National Park or wilderness
- e - Low elevation or remote location
- f - Adverse technical or geologic conditions
- g - Facilities appear costly compared to an alternative within the same sub-basin

Factors are more fully explained in Section F.

Table VII-6
(continued)

	Map Designation	Factors Influencing Non-Selection(1)
1. Potential Storage Elements (continued)		
Little South St. Vrain Reservoir	75	Selected
Little Thompson No. 1 Reservoir	31	g
Little Thompson No. 2 Reservoir	32	Selected
Little Thompson No. 3 Reservoir	33	g
Little Thompson No. 4 Reservoir	80	c,g
Longmont Sugar Plant Reservoir	76	c
Lookout Dam and Reservoir	34	c
Lower South St. Vrain Reservoir	36	g
Lykins Gulch Reservoir	37	Selected
Lykins Gulch Reservoir - Alternative No. 1	79	a,g
Nederland Reservoir	41	c,f
Nederland Reservoir - Alternative No. 1	42	c,f
Niwot Reservoir	89	a,c
North Sheep Mountain Reservoir	94	Selected
Oligarchy Reservoir	43	a,e
Orodell Reservoir	44	a,c
Parks Reservoir - Alternative No. 1	45	c
Parks Reservoir - Alternative No. 2	46	b,d
Pearl Reservoir	47	a,e
Pearl-Howlett Reservoir	48	e
Potato Hill Reservoir	50	g
Red Gulch Reservoir	51	c
Red Hill Gulch Reservoir	85	a,g
Rinn Valley Reservoir	86	e
Rock Creek Reservoir	92	c
Rowell Hill Reservoir	53	c,g
Rowell Hill Reservoir - Alternative No. 1	54	c,g
Sheep Mountain Reservoir	77	g
Sherwood Reservoir	56	Selected
Sixmile Canyon Reservoir	71	g
Smithy Mountain Reservoir	59	Selected
Southwestern Portland Cement Co. Pits (formerly Martin-Marietta Pits)	38	Selected
Spring Gulch Reservoir	62	c,g
Streamboat Mountain Reservoir	63	c,g
Stone Canyon Reservoir	84	g
Table Mountain Reservoir	64	g
Tahosa Reservoir	65	Selected
Thorodin Reservoir	66	c
Tungsten Reservoir	67	c
Upper South St. Vrain Reservoir	69	a
Wondervu Reservoir	70	g

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