RESEARCH REPORT

IRRIGATION SYSTEM CONSOLIDATION

Submitted by

Michael Wayne Biggs

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Department of Civil Engineering
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ABSTRACT

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The historical development of irrigation systems in northeastern Colorado is traced from early attempts through present day development. A sample area near Fort Collins, Colorado, is analyzed to determine whether consolidation of separate canals is feasible and beneficial. The results of the study indicate that favorable benefit-cost ratios can be obtained from this type of project.

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I am particularly grateful to the following people for their comments, information and good will:

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Mr. W. G. Wilkinson	District 3 Water Commissioner
Mr. John Worthington	President, Highline Canal
Mr. Alex Fraser	President, New Mercer Canal
Mr. Glen Johnson	President, Larimer Co. Canal #2
Mr. Harvey Johnson	Former Mayor of Fort Collins
Mr. Tom Coffey	City Manager of Fort Collins
Mr. Harry John	J. T. Banner and Associates
Mr. George Weaver	President, Fort Collins Soil Conservation District
Mr. Mike Thomsic	SCS, Soil Conservationist
Mr. Floyd Brown	Former CSU Irrigation Specialist

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Chapter I

INTRODUCTION

Early Development

Present-day Colorado became American territory as part of the Louisiana Purchase in 1803. Preliminary exploration of the area indicated that the region was too arid to be of agricultural value.

The first settlements in the area were trading posts set up to deal with the Indian tribes and trappers for beaver furs. Gradually, the beaver trade diminished, and the settlers turned to mining for an occupation. Gold was discovered west of Denver in 1859, and a period of rapid growth followed during the 1860's. The large influx of gold seekers created markets that could not be supplied by the slow-moving freight trains from St. Louis. Food prices rose to exorbitant levels under these conditions.[13*] Many miners who had been unable to find easy wealth turned to farming as a means of livelihood. Many of the first attempts at irrigated agriculture were started by groups of farmers diverting water from the rivers and streams to irrigate a nearby portion of land. These canals were generally of low capacity, and they followed the contour of the land since no equipment was available for large-scale earthwork.

As the development of the irrigation system progressed, the early canals were enlarged and extended to irrigate new areas more distant from the rivers. In addition, later settlers were building new canal systems. These later canals usually served land which was more distant from the stream and passed through rougher terrain. As a result, these canals were much more expensive. Regardless of the lack of planning and experience, early irrigation was highly successful.

The period from 1870-1900 was an era of great expansion in the irrigation of the western states. Throughout this period, private enterprise was the main impetus for development. The early federal legislation related to the irrigation developments in the West tended to favor development by private enterprise. The first legislation in this area was the Act of July 26, 1866. This Act left the development of irrigation "to local customs, laws and decisions of courts." Through this Act, the federal government surrendered the control of non-navigable waters to the individual states.

The second federal act of importance was the Desert Land Act of 1877. Through this Act, a title could be obtained to 640 acres of arid land by conducting water onto the land and reclaiming the land within

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*These numbers refer to the references listed at the end of the text.

three years. A cost of \$1.25 per acre was charged for the land. Desert lands were defined as "lands exclusive of timber lands which will not, without irrigation, produce some agricultural crops." Approximately ten million acres of land were patented under this Act, and all have been developed by private enterprise. This Act was considered to be a very successful legislative achievement.

The Carey Act (1894) was expected to be a major milepost in the reclamation of the western states. The purpose of this law was to aid in the reclamation of desert lands in the public-land states. Under the provisions of this Act, each state was allotted one million acres of desert land, and the state was to enact supporting legislation to provide for the irrigation and reclamation of this land. The states were required to submit irrigation plans and maps to the federal government showing the proposed facilities. If these plans were approved, the lands were then reserved for use by the states. On the whole, the Carey Act was not very successful. Increasing construction costs were the main reason for its failure.

As the development of the irrigation systems progressed, water shortages became prevalent due to the large number of canals. In the period from 1890 to 1900, supplementary storage reservoirs were constructed to store off-season flows. Most of the easy, low-cost canal systems were completed by 1900, and over eight million acres were being irrigated in the western states.[15]

The pressure on the federal government to actively enter the reclamation program increased in the years following the Carey Act for two reasons: (1) to provide water storage to insure a dependable supply for existing irrigation projects, and (2) to provide a full supply for additional lands at greater distances from the watercourses which could be economically reclaimed.[15]

In 1901, the Congress held hearings on proposed legislation which would bring the Federal government into the reclamation field to undertake projects beyond the ability of private enterprise. These hearings were useful in that they provided necessary data concerning the irrigation potential of the western states and raised many pertinent questions. The eventual outcome of the hearings was the Reclamation Act of 1902. This Act provided for the establishment of a Reclamation Fund in the Treasury of the United States to receive all moneys from the sale and disposal of public lands in the western states. The Reclamation Fund was to be used for the examination, survey, construction and maintenance of irrigation works. Under this Act, an individual owner could not apply for water in excess of that needed to serve 160 acres. This 160-acre limitation is still in effect on all Bureau of Reclamation projects.

The major problem in the early years of operation under the Reclamation Act was a shortage of money. In order to partially alleviate this problem, in 1910 the Reclamation Fund was augmented by a ten million dollar loan.[15]

In 1924, Congress enacted the Fact Finders Act which established procedures for undertaking new reclamation projects. This Act provided for more lenient repayment of construction costs and transfer of the projects to the farmers for operation and maintenance. It also required the Secretary of the Interior to acknowledge that the project had adequate water and was feasible from an engineering standpoint.

The Reclamation Act of 1939 was important because it further modified the repayment requirements of water users to coincide with their crop income. In addition, this Act recognized the importance of power and municipal water in determining project feasibility and modified the rules of feasibility to provide for recognition of flood control and navigation benefits. In making allocations under the provisions of this Act, the Secretary of the Interior is permitted to classify navigation and flood control costs as non-reimbursable.

Subsequent legislation in the reclamation field has mainly been an extension or clarification of the Acts previously discussed.

Water Rights

The rapid development of the arid western states was largely due to their potential mineral wealth. Agricultural development was undertaken in all areas as a means of supporting the growing population and as an alternative for disappointed miners who had been unable to find wealth quickly and easily. One of the major developments of this situation was the formulation of a new system of water rights.

In regions where the water supply is less than the demand, legal doctrines have been established to control the use of surface waters. In most humid areas, water rights are determined in accordance with the common-law riparian rights doctrine. In the western United States, the riparian doctrine was found to be unsuitable for the unique situations caused by large scale mining and irrigation. The doctrine of appropriation was evolved to satisfy the distribution of water for consumptive use.

The Riparian Rights Doctrine - Under the riparian rights doctrine, the owner of land adjacent to a natural watercourse is entitled to receive the full natural flow of the stream, undiminished in quantity or quality. Landowners with riparian rights may use all the water necessary for domestic purposes and the watering of livestock. This system does not make the provisions necessary for consumptive uses, such as irrigation and mining.

Riparian rights are limited to riparian land, and, under most circumstances, they cannot be lost through non-use. The riparian doctrine does not specify any fixed point of diversion, and dams may be constructed to retain water if no injury results to the rights of other property owners.

The Doctrine of Appropriation - The economic base of the arid western states is dependent upon the consumptive use of water. The appropriation doctrine was instituted to serve these areas and the special problems introduced by the large-scale consumptive use of water. Under this system, both riparian and non-riparian landowners are allowed to file claims to divert water from streams or other bodies of water as long as their claims do not conflict with previous claims. In this manner, a system of priorities develops under which each appropriator has a recognized exclusive right to divert water from the stream up to the full amount of his decree, providing that there is sufficient water to satisfy all prior appropriators. The principal features of the doctrine of appropriation are summarized as follows:[9]

(1) It gives an exclusive right to the first appropriator. Later appropriations are provisional and justified only if all prior decrees are satisfied;

(2) It makes all rights conditional on beneficial use;

(3) Water may be diverted to both riparian and non-riparian lands;

(4) Diversion is permitted regardless of the diminution of the stream; and

(5) Continuation of the right depends on beneficial use. Non-use may result in the cancellation of the right.

In contrast to the riparian concept, the doctrine of appropriation requires administrative procedures. Action of administrative boards and courts is required in defining and adjudicating water right conflicts, and administrative procedures must be established for the filing and recording of claims. In addition, ditch riders and water masters are required in order to make certain that appropriators do not exceed the specified amount of their decree.

Chapter II

WATER SUPPLY

River Diversion

The four canals included in this study are the Arthur Canal, the Larimer County Canal #2, the New Mercer Canal and the Pleasant Valley and Lake Canal (Highline). All four of these canals divert water from the Cache la Poudre River near Fort Collins, Colorado. The location of the study area is shown in Fig. 1.

Since the volume of water available to these canals is highly dependent on the flow of the Cache la Poudre River, a wide variation in yearly diversions would be expected. The average annual runoff is about 288,900 acre-feet, and the peak flow usually occurs during the first half of June.[20] River hydrographs for 1954 and 1965 are shown in Fig. 2. The flow distribution for 1954 was one of the worst on record, while 1965 was above average. The wide variation in river discharge is clearly evident from comparison of these two hydrographs. Widespread water shortages have occurred in years of low runoff.

In order to use the available water more effectively, an extensive and complex system of water exchanges has evolved. This system relies more upon the accounting of water than upon the strict application of priorities. The basis for this development is the physical availability of plains storage reservoirs interconnected with the canals. In addition to this purpose, these reservoirs serve the purpose of storing surplus runoff that would otherwise be wasted and also serve an extremely useful function as flow regulators.

The major disadvantage arising from the use of these shallow plains storage reservoirs is the high evaporation rate (approximately 1.75 ac. ft./acre of surface/season). In many instances, the reservoirs are the source of seepage on lands near the canal systems.

Many of these plains storage reservoirs could be converted to upstream river storage sites. This would result in improved efficiency and conservation of water, since upstream storage would consist of deep reservoirs with proportionally smaller surface areas. Upstream dams could also be used to give flood protection to the city of Fort Collins. Consolidation of the plains storage reservoirs would also provide additional land for farming, ranching or urban development.

Preliminary Bureau of Reclamation studies have indicated that the consolidation of the storage reservoirs is not economically justifiable at the present time. Eventually, as the demand for water increases, the consolidation of these storage reservoirs will be more seriously considered.

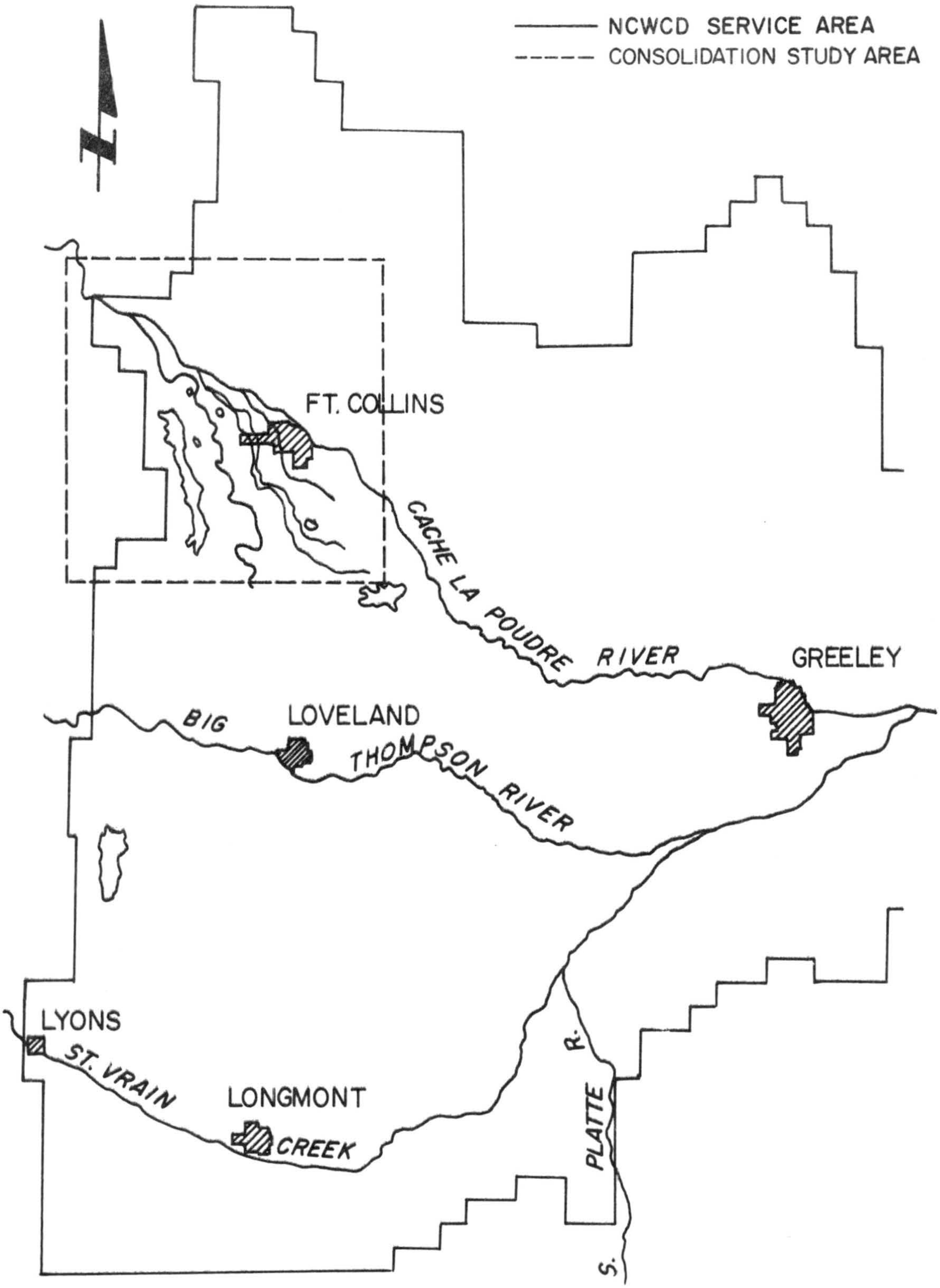


Fig. 1 - Location of Study Area

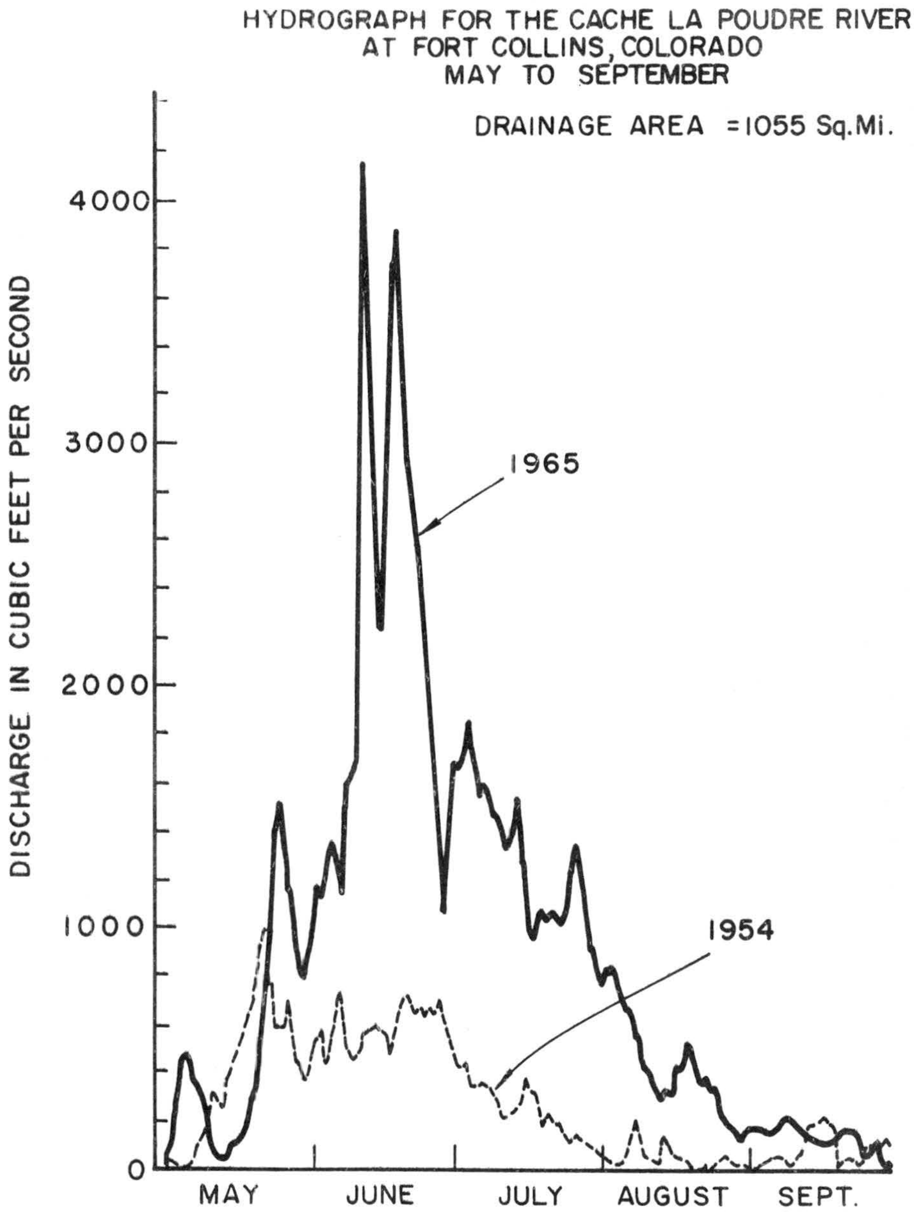


Fig. 2 - 1954 and 1961 River Hydrographs

TABLE I. WATER RIGHTS ON THE CACHE LA POUDRE RIVER

Company	Priority Number	Date	Decree	River Flow Required to Fill the Decree in CFS
Arthur	2	6- 1-1861	0.72	4.22
Highline	4	9- 1-1861	10.97	27.58
Highline 1st Enl.	11	6-10-1864	29.63	224.01
Larimer Co. #2	14	5- 1-1865	4.00	300.00(app.)
Arthur	19	7- 1-1866	2.16	335.13
New Mercer	25	10- 1-1867	7.03	391.89
Arthur	29	6- 1-1868	2.16	403.41
Arthur	32	6- 1-1869	1.67	481.25
New Mercer	33	9- 1-1869	4.17	485.42
Arthur 1st Enl.	38	4- 1-1871	31.67	693.51
New Mercer 1st Enl.	47	10-10-1871	8.33	1,047.84
New Mercer 2nd Enl.	49	7- 1-1872	15.00	1,085.22
Highline 2nd Enl.	51	7-10-1872	16.50	1,164.85
Arthur 2nd Enl.	52	7-20-1872	18.33	1,183.18
Larimer Co. #2	57	4- 1-1873	175.00	1,573.31
Arthur 3rd Enl.	66	9- 1-1873	52.28	1,682.77
Highline 3rd Enl.	92	8-18-1879	80.83	2,867.41
New Mercer 3rd Enl.	99	2-15-1880	136.00	3,340.36

All of the canals included in this study are unlined canals with decreed capacities ranging from 109 to 179 cubic feet per second. A complete list of canal decrees is shown in Table I. These canals were built by co-operative effort with interested individuals contributing most of the necessary labor. Due to the fact that they were constructed without elaborate equipment, the canals follow the contour of the land in a sinuous fashion. Typically, the canals have a physical width of about 20 feet, flow with depths up to five feet and velocities up to three feet per second for various flow conditions.

The present form of ownership is incorporated mutual companies with the water users as stockholders. Due to the proximity of the canals, many farmers have stock in more than one canal. This is especially true for farmlands which are served by the Larimer County Canal #2 and by the New Mercer Canal. Funds for the necessary upkeep and general maintenance are provided by annual assessments on a per share basis. In an effort to keep assessments low, maintenance has been held at a minimum. Usually, only enough maintenance is performed to enable the distribution of water for the coming season. As a result, the general condition of the systems is not good. Many structures are inadequate and some have been left isolated in the middle of the channels by the widening of canals. General erosion is evident in many areas. In addition, large trees are located near many of the canals. These trees use water, weaken the canal banks with their root systems and generally interfere with operation. Leaky sections of the canals are commonly ignored, resulting in the seepage to adjacent lands.

Table II shows the annual costs for water delivery for each of the four canals. The assessments for the year 1966 are used as a basis for determining costs. The total assessment for each canal can be considered to be the total cost for operation, maintenance and administration. On this basis, the combined operation cost for the four canals is approximately $26,300 per annum.

TABLE II. CANAL OPERATING COSTS

Company	Number of Shares	Assess. in 1966	Operation & Maint. cost	Annual Av. River Diver. in Acre-Ft	Ann. Cost of Work Per Acre-Ft of River Water
Arthur	1500	$ 3	$4,500	5,778	$ .78
New Mercer	148	29	4,300	4,717	0.91
Larimer Co. #2	157	30	4,700	7,102	0.66
Highline	256	50	12,800	14,119	0.91
Total			$26,300	31,716	$0.83 (Av.)

In order to compare the water supply characteristics of each canal, flow records for the 1951-1966 period have been compiled to determine the volume of flow. The original data was obtained from daily flow records of W. G. Wilkinson, District No. 3 Water Commissioner. It must be remembered that most of the irrigation water comes directly from the flow of the Cache la Poudre River. Consequently, the periods of high canal flows occur during the early part of June in conjunction with the peak river flows. The water must be used as it becomes available since there is no upstream storage and only limited plains storage. As a result, most irrigation water application does not coincide with optimum crop water requirements. In August and early September when many crops are reaching maturity, there is often a serious shortage of available irrigation (river) water.

These conditions led to the development of the Colorado-Big Thompson Project which annually supplies nearly 260,000 acre-feet of supplementary irrigation water to eastern Colorado.[18] The C-BT water is used primarily for irrigation in the latter part of the irrigation season. Approximately 6,400 acre-feet of C-BT water are used annually in the area served by the four canals.

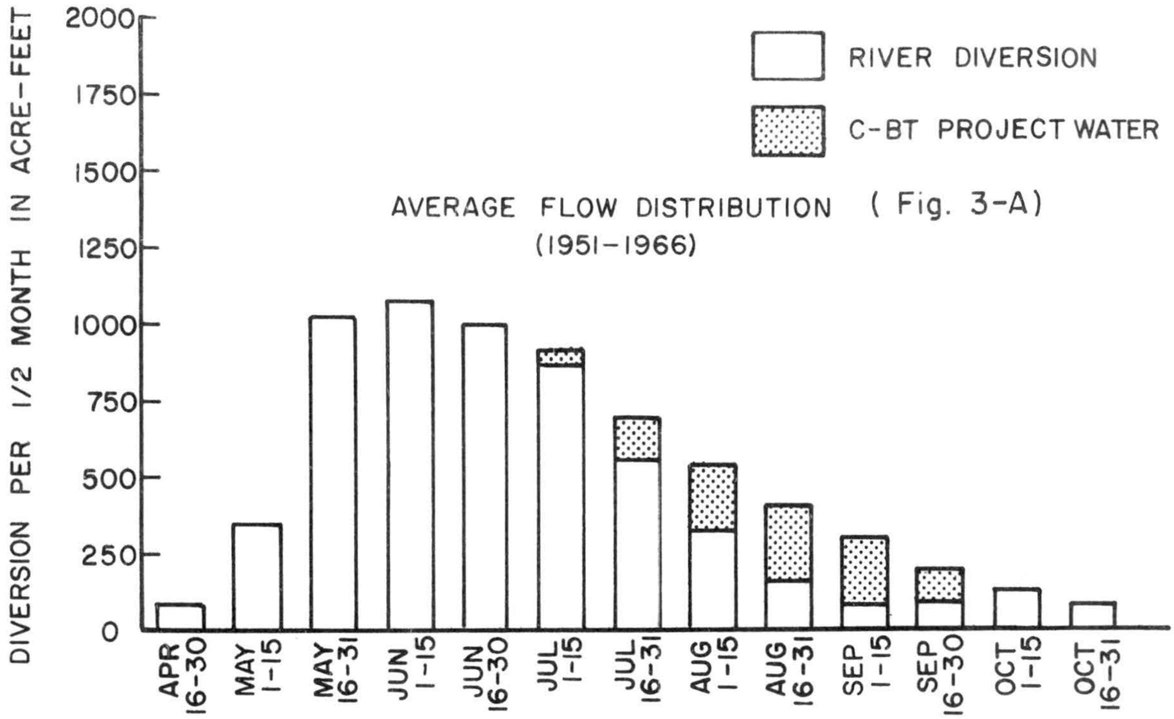
The major features of water supply for the canals are shown in Figs. 3, 4, 5 and 9. The graphs show the average flow conditions for the 16-year study period and the worst flow condition for the canal in the past 16 years. The flow data were compiled on a semimonthly basis in order to obtain the data for plotting these charts. The C-BT water is shown cross-hatched on these charts to separate it from river diversion water. Tables VI through XX, which are in the Appendix, summarize the canal diversion data.

Arthur Canal

The Arthur Canal holds seven decrees on the Cache la Poudre River. These decrees were filed between 1861 and 1873 and specify a maximum diversion of 108.99 cfs. Many of these decrees are among the earliest filed on the river, and hence, the Arthur Canal has a fairly dependable supply of water with a mean annual diversion of 5,778 acre-feet and an estimated variance of 750 acre-feet. In addition, the Arthur Canal carries an annual average flow of 970 acre-feet of C-BT water and approximately 140 acre-feet of rental water.

The Arthur Canal diverts from the river at an elevation of 5,010 feet above sea level and terminates in Nelson Reservoir at an elevation of 4,958 feet. The canal is approximately 8.2 miles long and has an average slope of nearly six feet per mile. There are approximately 1,920 acres of land under irrigation from the Arthur Canal with an average duty of water over the 16-year study period of 3.56 acre-feet per acre. Average flow conditions are plotted in Fig. 3-A. The farms under irrigation from the Arthur Canal have a much greater supply of water per acre than the other canals. For this reason, the Board of Directors on the Arthur Canal have not expressed an interest in consolidating the canals. In addition, much of the land served by the Arthur Canal is being developed as residential housing. As the city grows, most of the land served by the Arthur Canal will probably phase out of agriculture.

The Arthur Canal would probably not be included in a consolidated system for these reasons. In addition, expenses would increase on the



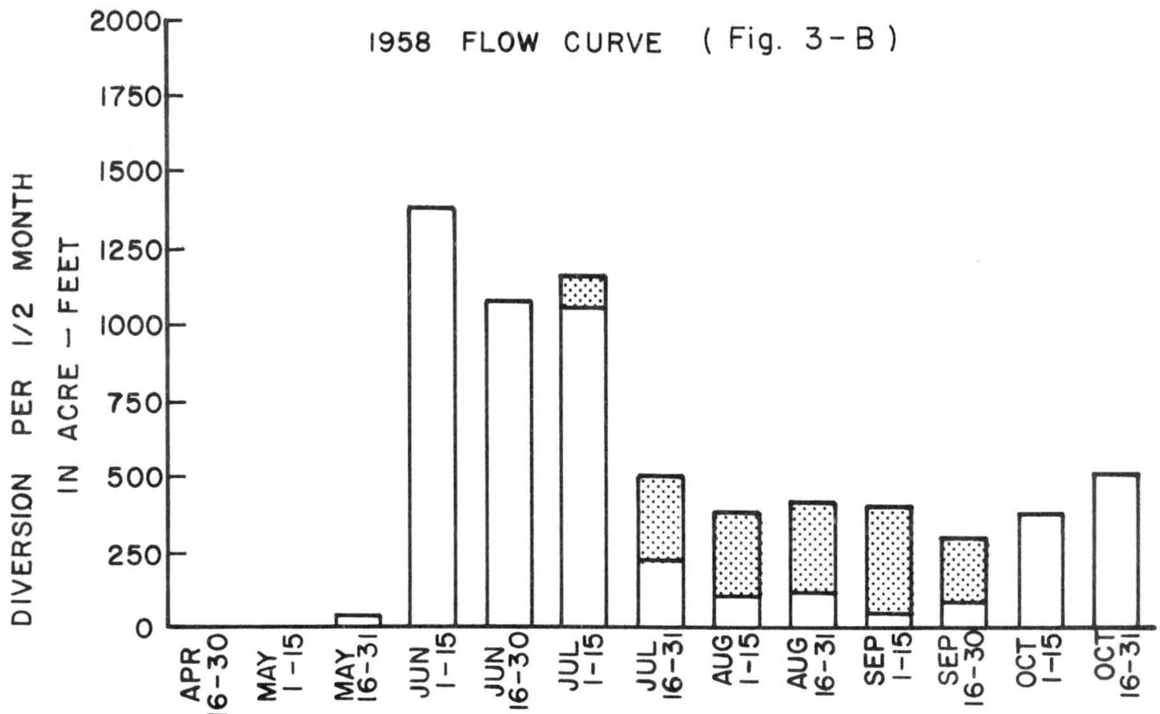


Fig. 3 - Temporal Flow Distribution - Arthur Canal

canal due to the large capital investment which would be required to update the equipment on the Arthur Canal while the value of the water savings would not offset the increased expenses.

The 1958 flow distribution curve for the Arthur Canal is plotted in Fig. 3-B. This condition represents the most severe flow condition of the 16-year study period. The flow conditions on the Arthur Canal ranged from a maximum total diversion of 8,380 acre-feet in 1960 to a minimum total diversion of 5,370 acre-feet in 1951.

New Mercer Canal

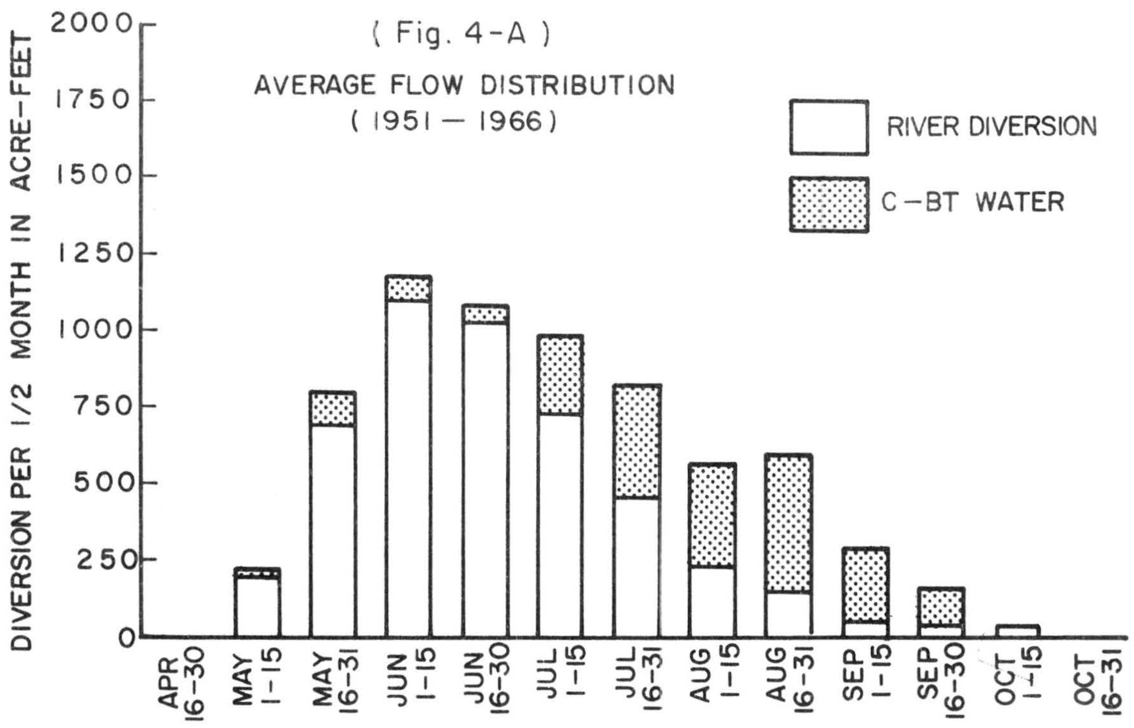
The New Mercer Canal holds five decrees for river flow. The decrees were filed between 1861 and 1880 and specify a maximum river diversion of 170.53 cubic feet per second. The last decree, filed on February 15, 1880, is for a flow of 136 cfs. In order to divert the full amount of the last decree, the river flow must be over 3,300 cfs. This decree is usually in effect about one week per year. Hence, the dependable flow for the New Mercer Canal is approximately 35 cfs. The mean river diversion for the 16-year study period was 4,717 acre-feet, with an estimated variance of 1,604 acre-feet. The large variance is due primarily to the effect of the river decree of 1880. Nearly 2,000 acre-feet of C-BT water is carried annually by the New Mercer Canal. Water rental accounts for an additional 239 acre-feet of water annually. The flow conditions on the New Mercer Canal ranged from a maximum total diversion of 8,672 acre-feet in 1957 to a minimum total diversion of 4,170 acre-feet in 1961.

The New Mercer Canal diverts from the Cache la Poudre River northwest of Fort Collins at an elevation of 5,065 feet and flows in a generally southeasterly direction until it terminates at Mail Creek (elevation 5,025). The canal is about 12.8 miles long and has an average slope of 3.1 feet per mile.

The average flow distribution curve for the New Mercer Canal is plotted in Fig. 4-A. It should be noted that the New Mercer Canal uses C-BT water throughout the irrigation season. Peak demand for C-BT water usually occurs between August 15th and September 15th. The tremendous value of C-BT water to the New Mercer Canal is very evident from the graph.

Figure 4-B is a plot of the flows during 1961. It is readily observed that the volume of flow is far below average and that less C-BT water was available in 1961. It is also important to note that no water was used by this canal prior to June 15th.

Although the actual amount of water diverted by the New Mercer Canal and by the Arthur Canal is nearly equal, there is nearly three times as much irrigated land under the New Mercer Canal as there is under the Arthur Canal. The duty of water under the New Mercer Canal is about 1.19 acre-feet per acre. The New Mercer Canal delivers river water at an average cost of $0.91 per acre foot (based on operation and maintenance costs).



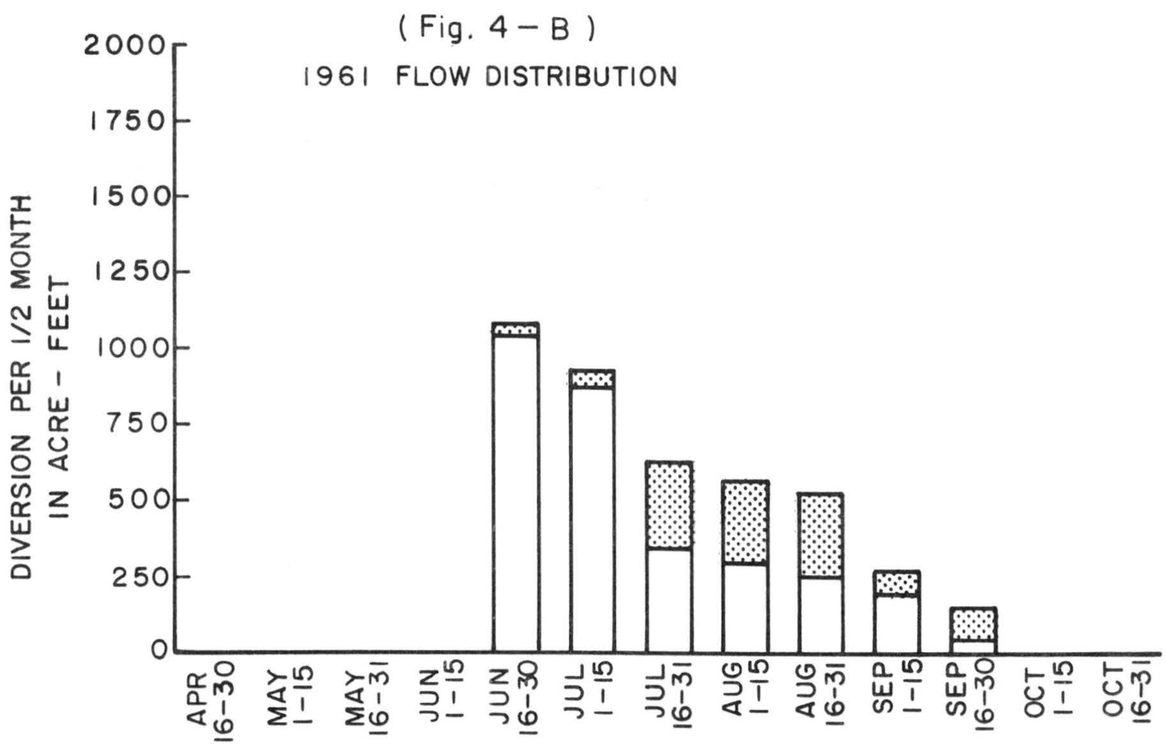


Fig. 4 - Temporal Flow Distribution - New Mercer Canal

Larimer County Canal #2

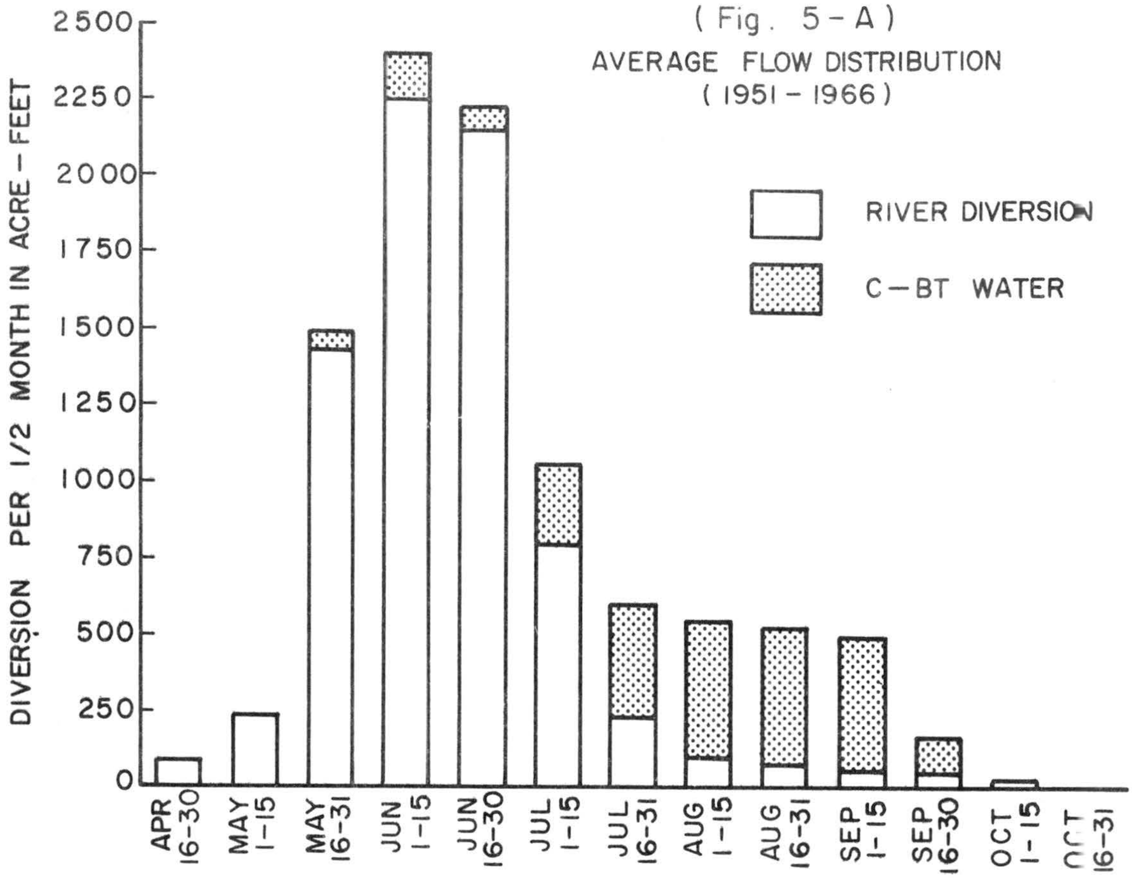
The Larimer County Canal #2 has only two decrees to obtain water from the Cache la Poudre River. A decree filed in May, 1865, permits the diversion of 4.0 cfs, and a decree filed in April, 1873, allows for a diversion of 175 cfs. The river flow required to fill the latter decree is 1,573 cfs; as a result, this decree is effective only for short periods of time when river flows are at a maximum. The resultant river flow distribution curve shown in Fig. 5-A rises to a rapid peak near June 15th and then decreases rapidly through July. After the end of July, the majority of flow in the canal comes from the C-BT Project.

The mean annual diversion for the Larimer County #2 Canal is 7,102 acre-feet with an estimated variance of 2,798 acre-feet. In addition, the Larimer County #2 Canal carries an annual average flow of 2,301 acre-feet of C-BT water and approximately 640 acre-feet of rental water. The flow volume of the Larimer County Canal #2 is the most erratic of the four canals. In years of high runoff, the canal has an abundance of water, while in years of drought the canal runs very low except for quantities of supplemental water. The irrigation flows in the Larimer County Canal #2 for 1954 are particularly interesting. The flow distribution curve for 1954 is shown in Fig. 5-B. Significant volumes of river flow occurred mainly between May 15th and June 15th. Approximately 65% of the water used by this canal in 1954 originated from the C-BT Project. This was the first year that C-BT water was available in this area, and its impact was felt immediately.

> "In the severely dry year of 1954, the (C-BT) project supplied 300,352 acre-feet of supplemental water and was credited with production of $22,000,000 worth of the $41,000,000 crop grown during the season. Without project water, the area would have suffered a catastrophe of far reaching proportions."[18]

The Larimer County Canal #2 diverts from the Cache la Poudre River at the same diversion structure as the New Mercer Canal. These two canals are parallel throughout their lengths with a maximum separation between them of about one-half mile. The Larimer County Canal #2 - New Mercer Canal diversion dam is in extremely poor condition as is shown in Fig. 6. The structure has serious cracks, and spalling of the concrete has occurred due to moisture and temperature extremes. A typical picture of the Larimer County Canal #2 cross section is shown in Fig. 7. This picture is typical of the banks on all four canals. The Larimer County Canal #2 carries a maximum flow of 175 cfs down to Warren Lake for storage; therefore, it is fairly uniform in cross section throughout its length. This canal terminates at Mail Creek at an elevation of 4,995 feet and has a length of 13.3 miles. The slope is approximately 5.2 feet per mile. The duty of water under this canal is 1.67 acre-feet per acre.

Improper energy dissipation techniques at the entrance to Warren Lake have led to large scale erosion. The width of the channel is approximately 30 feet, and the channel has scoured to a depth of



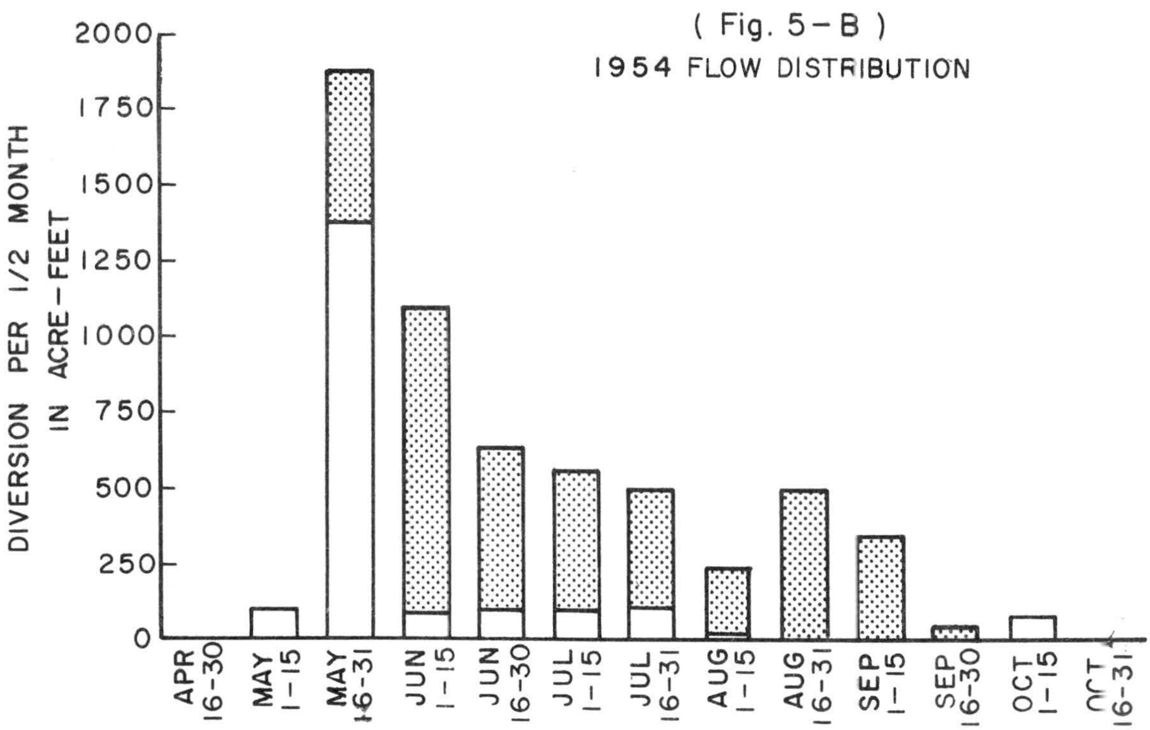


Fig. 5 - Temporal Flow Distribution - Larimer Co. Canal #2

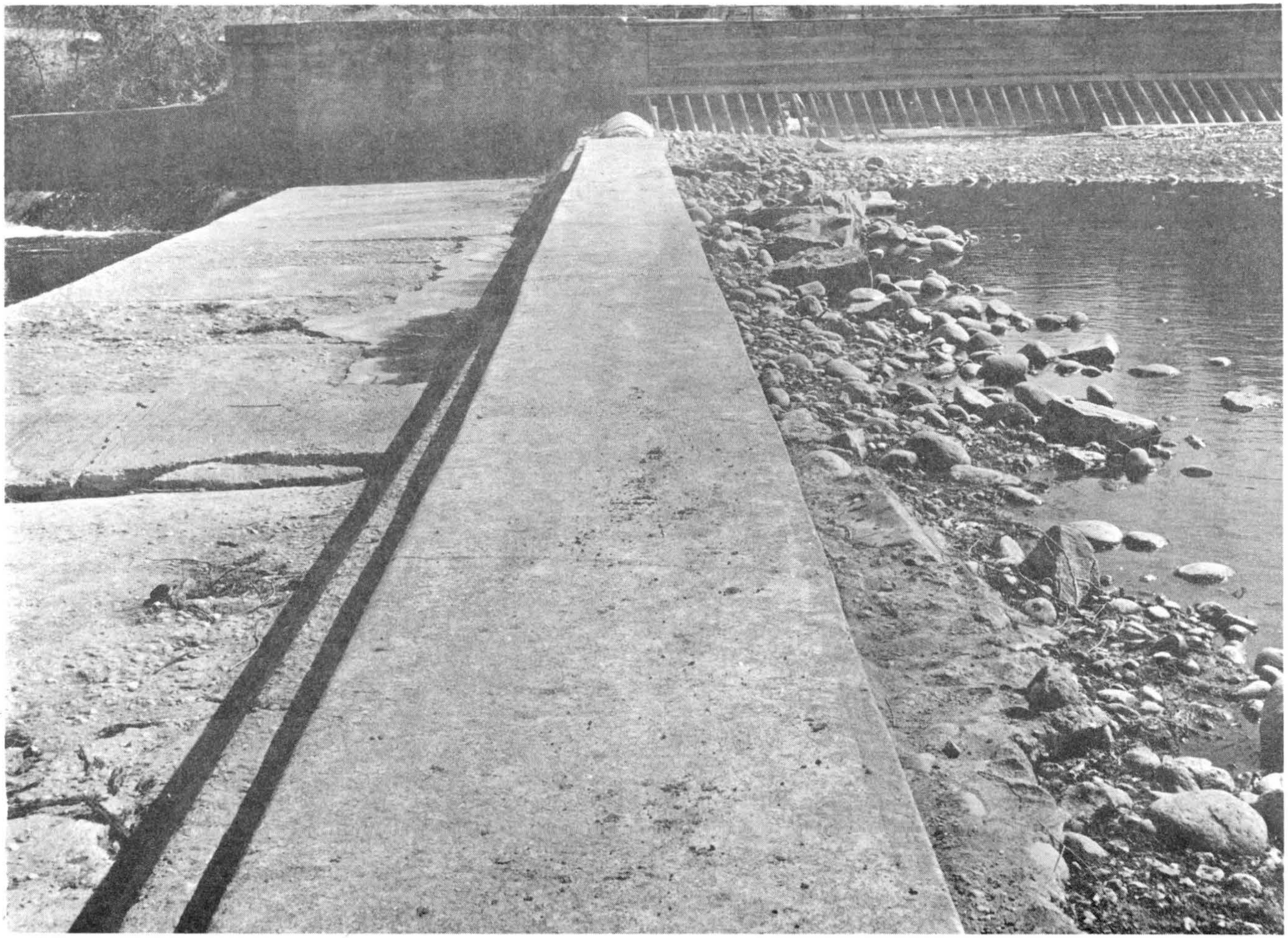


Fig. 6 - New Mercer - Larimer Co. Canal # 2 - Diversion Structure

Fig. 7 - Larimer Co. Canal #2 - Typical Cross Section

Fig. 8 - Larimer Co. Canal #2 - Warren Lake Channel Erosion

about 25 feet. Figure 8 shows the magnitude of the erosion at the entrance to Warren Lake.

Highline Canal

The earliest decree on the Highline Canal dates back to September, 1861. In all, four decrees are held by the Highline Canal. The maximum river diversion is about 138 cubic feet per second. This canal diverts from the Cache la Poudre River at an elevation of 5,190 feet above sea level and flows southeasterly. The canal does not enter (at the present time) any of the residential areas of Fort Collins. The canal terminates at Fossil Creek, 19.7 miles from its diversion point at an elevation of 5,100 feet. The slope of the canal is 4.57 feet per mile. The last decree on the canal was filed on August 18, 1879, for about 81 cfs. This decree is not very effective since the river flow must be 2,870 cfs before it can be filled. The base flow for the Highline Canal arises from the first two decrees. The Highline Canal has a mean annual river diversion of 14,119 acre-feet with a variance of 1,920 acre-feet. In addition, the Highline Canal carries about 1,156 acre-feet of C-BT water and 962 acre-feet of rental water. The Highline Canal is the only canal which consistently carries large volumes of rental water.

Approximately 6,140 acres are irrigated under the Highline Canal. The duty of water is 2.66 acre-feet per acre. The flow distribution curves for the Highline Canal are shown in Fig. 9. From Fig. 9-A, it should be noted that the Highline carries significant volumes of water throughout the entire irrigation season. The peak flows of C-BT water are used between July 15th and September 15th.

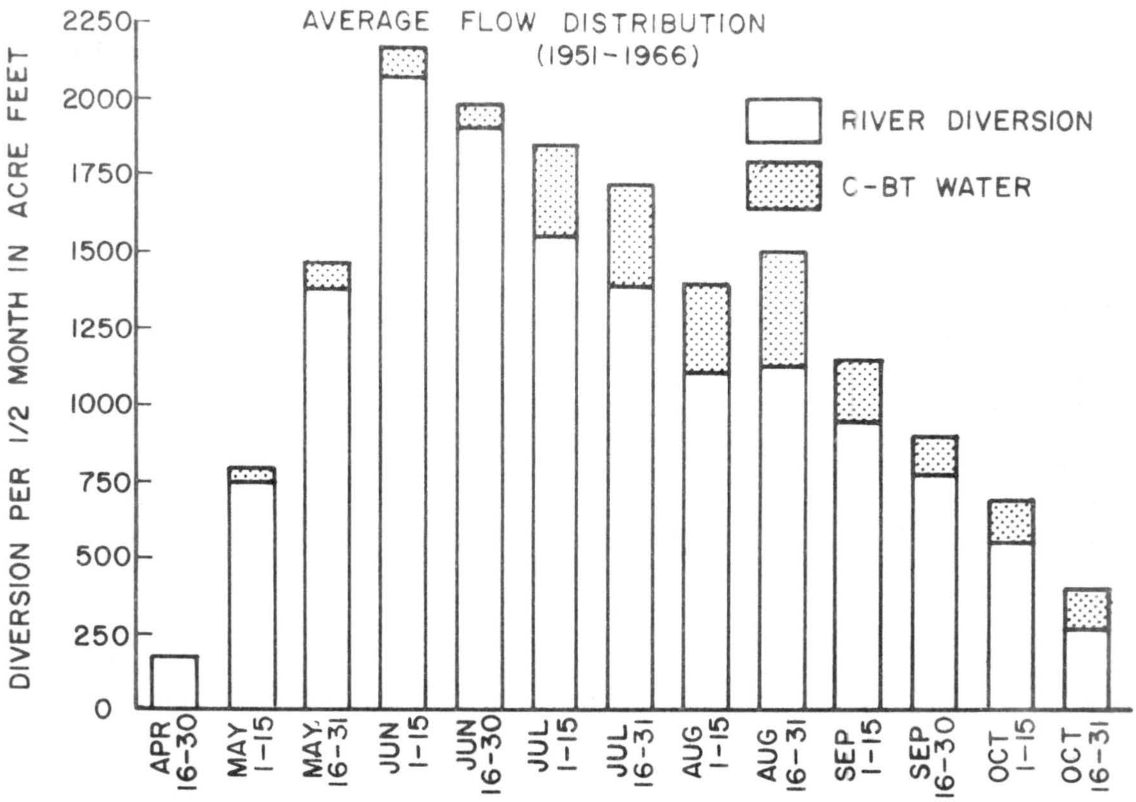
The lowest total diversion of water in the Highline Canal occurred in 1961. Figure 9-B shows the flow distribution for that year. Comparison with Figure 9-A indicates that runoff was significantly below average in 1961. The C-BT water helped to even out the flow during periods of high demand.

Colorado-Big Thompson Project

After 1900, when the canal and reservoir systems were essentially complete, the direct streamflow had been overappropriated. Irrigators then gave serious thought to tapping the headwaters of the Colorado River to obtain supplemental irrigation water. The largest of the visionary transmountain diversion projects was the Colorado-Big Thompson Project. The C-BT Project collects water from the Colorado River basin and diverts the water through the 13.1 mile long Alva B. Adams to the eastern slope of the Rocky Mountains. The water passes through five hydraulic turbines before being stored in large reservoirs for agricultural and municipal uses. The project was started in 1938 and completed in 1956 at a cost of 164 million dollars.[18]

The C-BT water virtually erased the prospect of widespread water shortages in the late summer months. Perhaps more important than

(Fig 9-A)



(Fig. 9-B)

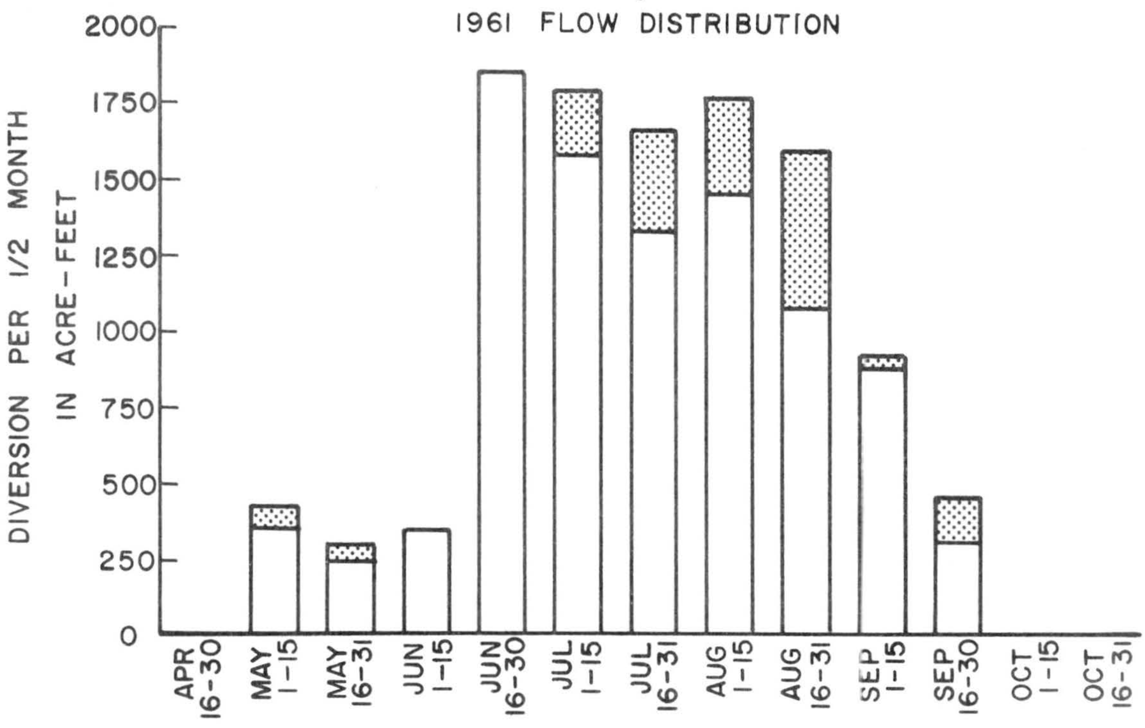


Fig. 9 - Temporal Flow Distribution - Highline Canal

the physical volume of water is the fact that the water can be used at the discretion of the irrigator. This added flexibility in planning gives the farmer a slight advantage over the vagaries of nature. In a great many cases, it would appear that the farmers use C-BT water as insurance against drought. If the water supply is average or above average, the individual farmer can usually rent the C-BT water to farmers who need supplemental water.

In an average year the C-BT Project conveys up to 260,000 acre-feet of water to the east slope drainage. The vast majority of this water is used for irrigation; however, in recent years municipal uses have increased considerably. In the study area, about 6,400 acre-feet of C-BT water are used annually for irrigation. This constitutes about 16% of the water which is diverted for irrigation.

The general effect of C-BT water on the productive capacity of northeastern Colorado is reported in "Introduction of Supplementary Irrigation Water."[3]

> "Generally, farms were enlarged somewhat and farmers brought more land under irrigation. More land was planted to intensive, high-water requirement, row crops and fewer acres to low-value short-season crops. Yield increases were reported on all crops grown, particularly row crops and alfalfa. Twice as many farmers were fertilizing after C-BT water was used than before and they were fertilizing more heavily. One can speculate that this is due partly to the complimentariness between water and fertilizer and partly to increasing knowledge of the value of fertilizer."

Canal System Consolidation

Existing irrigation distribution systems in the Cache la Poudre valley form an intricate system of closely paralleling canals and laterals. These canals were constructed during the periods of rapid growth with limited amounts of capital and machinery. Some canals are separated at the point of diversion by only a concrete wall. These systems stand out vividly in comparison with the well planned, comprehensive basin development which is used today.

The complete reconstruction of canal and lateral systems in most areas would be impractical and, probably, financially infeasible. However, in some areas, it might be possible to combine the systems by enlarging the highest ditch and either eliminating the lower ditches or using parts of them as lateral systems. The following problems will be found to exist in areas where there are duplicate or parallel systems:

(1) An excessive amount of land is required for the water conveyance system;

(2) Costly river diversion structures are required to serve each canal;

(3) The number of farm turnouts is greatly increased because some farms receive water from more than one canal system;

(4) The number of bridges and culverts is greatly increased;

(5) Seepage and evapotranspiration losses are greater than for a single canal;

(6) The costs of operation, maintenance and administration are higher than for a single canal system; and

(7) There is excessive hazard to life and property in residential areas.

In recent years, water demand for this region has again exceeded the available supply. This is partly due to the increased demand for municipal and industrial water and partly due to the increased acreages of water-intensive row crops. Reservoir sites on the Cache la Poudre River have been investigated, but the development of these sites is not economically justifiable at the present time. It appears that the best way to satisfy the increased demand is to seek a more efficient use of the existing water supply through the elimination of seepage and evaporation losses. The ramifications of this situation are illustrated by this statement by A. A. Bishop.

> "Agriculture, with its widespread irrigation, now consumes more water than all other uses combined and will probably continue to be the largest single consumptive user of water. Along with the use of water, irrigation is probably a major source of waste of the valuable water resources. This is due in large measure to the inefficiency of existing canal and distribution systems with their duplication and obsolescence."[10]

Water is a flow resource. The flow comes in a continuous stream which is independent of use. From a conservation standpoint, a flow resource is renewable. In an optimum state of conservation, the maximum practicable use of flow resources is the goal of the resource user. In this area, the supply of water is completely appropriated; therefore, each canal system must increase its efficiency in order to appreciably increase the effective supply of water. Seepage losses in an unlined canal vary from 25% to 40% of the water diverted. Using these estimated figures, the annual loss from the four canals included in this study is probably between 10,000 and 16,000 acre-feet.

Chapter III

LAND USE

General

The problems introduced into this study by the expansion of the city of Fort Collins and the growth of Colorado State University are reflected mainly in the changing land use pattern to the south and west of the city. The general tendency for growth is to the south; this fact is evidenced by the large number of subdivisions being constructed in this area. In this expanding process, land is taken out of agricultural production and an increased demand is placed on the water supplies. The amount of land which must remain under agricultural production is highly dependent on the crop yields. Decreasing yields due to past exploitive practices will lead to greater agricultural land requirements, while increasing yields will allow an expansion of the residential areas without the necessity of increasing agricultural land requirements.

The concept of land-use capacity refers to the ability of a given unit of land resource to produce a net return above the production costs associated with its use. Land resources are compared by the monetary or social value of their use-capacity. Comparisons involving use-capacity always refer to a given period of time. Use-capacity changes with changes in the resource base, changes in the state of technology and changes with man's desire for certain types of output. Changing opportunities and the shift of land to new uses can also have a marked effect upon the use-capacity of individual pieces of property.

Most lands are suited for a variety of uses. Since there is no definite system for determining priorities for land use, a wide variation of opinion exists regarding what lands should be made available for any given type of use. In general, it can be assumed that landowners will tend to use their land resources for the uses which will promise them the highest return on their investment. Land resources are at their highest use-capacity when they are used in such a manner that they provide an optimum return to their operators.

In our society, land resources can usually earn their highest return when used for commercial or industrial uses. These uses are often able to outbid other types of uses for almost any site. Residential uses ordinarily have the next priority followed by various types of cropland, pasture, grazing and forest uses. The concept of use-capacity is a desirable goal for the resource user. It should be noted, however, that the concept is relative to the existing conditions.

In an area such as Fort Collins, where the population growth is expected to be rapid and continual, there will have to be changes in land use in order to accommodate the population growth. As population increases, the intensity of land use generally increases. When studying the intensity of land use, two important concepts are of value. The intensive margin is defined as the point at which the last units of labor and capital used barely pay their cost (marginal cost equals marginal revenue). The extensive margin is usually considered to be the no rent margin at which the land under optimum conditions will yield just enough to cover the costs of production (average cost equals marginal cost). When the physical supply of land is the limiting factor, operators have a tendency to push their operations to the intensive margin. When a non-land resource is the limiting factor, it is most profitable for operators to proportion their input factors around the limiting resource. If the supply of the limiting resource is increased, it will have the effect of increasing both the intensive and extensive margins of land.

Through the consolidation of irrigation systems, an additional quantity of water would be made available to the farms. Since irrigation water is a limiting resource in this area, the effect of consolidation will remove some of the constraints on production. With increased yields, the amount of agricultural land could be held at the present level and support an increasing population.

By increasing the dependable supply of irrigation water, the use-capacity of agricultural lands surrounding Fort Collins would be increased. With higher efficiency and higher profits, the land would probably remain in agricultural use for a longer period of time, i.e., it would be more costly for residential and commercial uses to obtain additional land.

The City of Fort Collins

Over the past few decades, the growth of the city of Fort Collins has been steady and continuous. In part, much of this growth is due to the rapid expansion of Colorado State University. As the city has grown, land has been taken from agricultural production; residential areas now include much of the land adjacent to the canals. Subdivisions are being rapidly constructed in the areas to the south and east of Fort Collins.

With increased population there is increased demand for municipal water. The city of Fort Collins owns some stock in all four of the canals and 4,967 shares of Colorado Big-Thompson Project water. City water ownership of canal water is shown in Table III (based on average flows).

TABLE III. CITY WATER OWNERSHIP

Source	Shares	Aver. Annual Vol. of Water (Acre-Feet)
Arthur Canal	110.75	432
New Mercer Canal	8.62	286
Larimer Co. Canal #2	4.03	197
Highline Canal	38.76	2295
Total		3210

The stock owned by the city of Fort Collins entitles the city to over 10% of the river water diverted by the canals. At the present time, the city is not using all this water, but with increasing pressure due to population growth, the city will undoubtedly start using this water in the near future. At the present time, Fort Collins water users consume 254 gallons per capita per day.[5] Based on the present population of 38,000 people, water consumption is approximately 10,800 acre-feet per year. Table IV shows a record of population growth and gives estimates of future population.

TABLE IV. POPULATION GROWTH OF FORT COLLINS[6]

Year	Population	Year	Population
1920	8,755	1975	50,500
1930	11,489	1980	59,000
1940	12,251	1985	67,500
1950	14,937	1990	76,000
1960	25,027	1995	84,500
1964	31,800	2000	93,000
1965	33,500	2005	101,500
1970*	42,000	2010	110,000

*The estimated future Fort Collins population was based on a trend line from 1960 to 1965 extended to the year 2010.

From these figures it is obvious that the city must continually increase its water supply. The most attractive source for municipal water is from the C-BT Project. Municipalities throughout northeastern Colorado have been increasing their holdings of C-BT stock. During 1964, the city obtained an additional 1,355 acre-feet units of C-BT water.[3] The attractiveness of C-BT water is due primarily to the fact that it is storage water and may be used on demand.

Increasing urbanization also increases the potential flood hazard to urban areas. Considerably more precipitation runs off impervious surfaces such as roofs, sidewalks and streets than off bare land. Extensive high capacity drainage systems will be required to prevent major flood damage in the Fort Collins area. Precipitation in this region is characterized by short rainfalls with high intensity. This type of rainstorm has a short time of concentration, i.e., the runoff occurs quickly, and peak flows are high.

The major flood in this area was associated with the rainstorm of August 2-3, 1951, when 6.06 inches of rain fell in a 28-hour period. The flood damage to the Bellvue-Fort Collins area was estimated at two and one-half million dollars.*

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*Fort Collins Coloradoan, August 5, 1951.

At the present time, the city of Fort Collins is engaged in a storm water drainage study.[8] The possibility of co-ordinating the city's storm water drainage and the canal consolidation is being considered to determine whether a dual-purpose irrigation-flood control channel would be beneficial to both projects. Since the consolidation proposal calls for the abandonment of some of the canals as they pass through the town, the city would be interested in obtaining the vacated canal right-of-way to serve as a conveyance system to dispose of excess storm waters.

In the preliminary report by J. T. Banner and Associates, it is recommended that storm waters from the area south of La Porte Avenue and north of Horsetooth Road should be conveyed to the Spring Creek drainage channel. This channel would have to be improved throughout its entire length to accommodate the expected flood flows. In determining the magnitude of the flood flows, the "rational method" was used. In this method, the magnitude of the predicted flood is given by the formula $Q = C\,i\,A$,

where Q = discharge in cubic feet her second,
C = runoff coefficient,
i = rainfall intensity in inches per hours, and
A = the drainage area in acres.

This method has been used extensively for predicting storm flows and has proven to be satisfactory in most cases. The runoff coefficient, C is the fraction of runoff which can be expected. C varies with the slope of the area and the perviousness of the terrain. In this study, composite coefficients were computed for various types of surfaces, and an average value of $C = 0.50$ was found to be representative of this area under the expected conditions for future development. Figure 10 is included in this study to show the expected rainfall intensities and durations.

The expected flood flow which would have to be carried concurrently with the irrigation water in a consolidated canal is approximately 1500 cfs. This flow is for a rainstorm with a ten-year frequency under the conditions of ultimate development. Due to the magnitude of the storm flow, it would be desirable to have a joint facility from La Porte Avenue to the Spring Creek channel, which would be capable of carrying a total flow of 2000 cfs (combined irrigation and storm flows). If the canals were consolidated, the vacated right-of-way of the Larimer County Canal #2 could then be developed to provide additional flood protection by conveying storm flows to the Spring Creek channel.

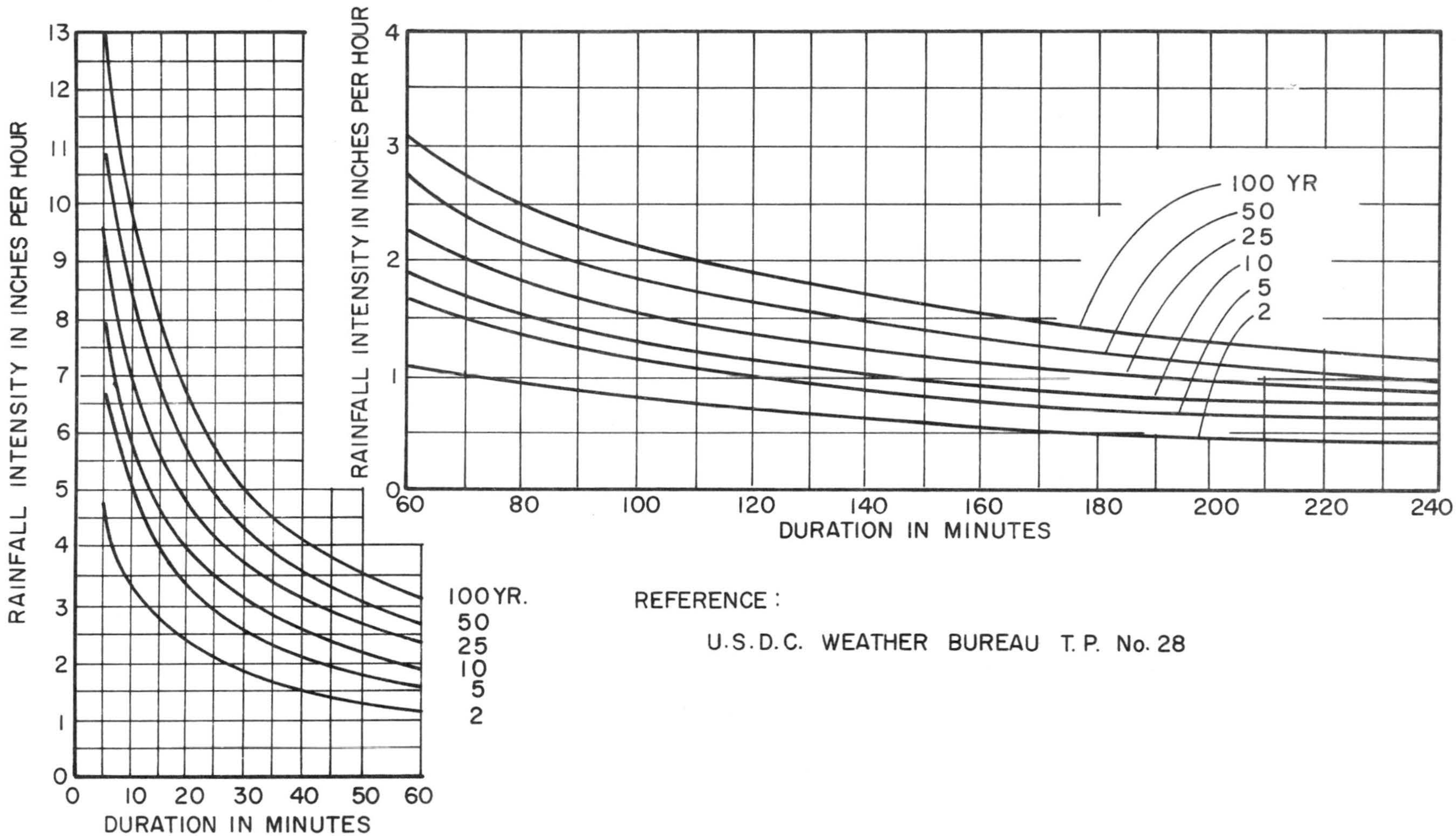

Fig. 10 - Fort Collins Rainfall Intensity Duration Curves

Chapter IV

CANAL SYSTEM CONSOLIDATION

Canal Linings

The main advantages of concrete canal linings are (1) a saving in water, (2) reduced damage to adjacent lands from seepage, (3) greater safety and (4) reduced operation and maintenance costs. The main disadvantage of concrete lined canals is the initial construction cost.

In instances where right-of-way requirements necessitate the acquisition of expensive agricultural land, the use of a lined canal will decrease the width of the required right-of-way; this is due to the fact that a lined canal has improved hydraulic conditions, hence, higher flow velocities and a smaller cross-sectional area.

The reduction of seepage losses is particularly important when a canal can only divert limited amounts of water. In years of drought, it is especially important to prevent the loss of excessive amounts of water. The main factors which must be determined in order to estimate the value of canal lining are (1) the amount of water which is lost from the system and (2) the value of the water which is lost. It is particularly difficult to place a monetary value on the water which is lost. If the water supply is normally abundant in quantity and coincides with optimum crop water requirements, the need for lining is not nearly as critical as if there is a water shortage. The major consideration for estimating the value of the water is the beneficial use which could have been made of the water had it remained in the system. Recent studies have indicated that the value of marginal irrigation water ranges from $12 an acre-foot in years of full supply to $78 an acre-foot in years of drought.[3] In this study, a value of $25 an acre-foot is used for evaluating the project over the fifty-year repayment period.

Additional benefits which can be obtained through system consolidation are a savings in right-of-way, a reduction in operation and maintenance costs, reclaiming of some seeped and waterlogged land, flood control benefits for the residents of Fort Collins and a reduction in the potential social hazard of having open canals pass through residential areas. <u>In computing the benefits which can be obtained from consolidation, only the agricultural value of the water is used in this study.</u>

The design flow for the consolidated system will be approximately 350 cubic feet per second. An unlined main canal would require a fifty-foot right-of-way, whereas a lined canal will require only a thirty-foot right-of-way. The lined canal is necessary for this consolidation to reduce water losses and to minimize right-of-way acquisition problems.

Consolidation Proposals

The existing canal system is shown in Fig. 11. Elevation decreases from west to east; therefore, it is possible to consolidate all four of the canals by using the basic right-of-way of the Highline Canal. Using modern equipment, it would be possible to straighten the canal in many areas. The average slope on the main canal would be approximately four feet per mile. Using the Manning formula for open channels,[11] the concrete canal cross section required for the 300 cfs design flow has an eight-foot bottom width, 1½:1 side slopes and a flow depth of about 4.3 feet. The flow velocity would be approximately 4.8 feet per second.

Figure 12 shows one possible way (Proposal #1) to consolidate all four canals. Due to the lack of storage reservoirs on this system, it would be desirable to construct dams as shown in Fig. 12 at Claymore Lake and College Lake. These lakes could serve as regulating reservoirs on the system. The additional elevation required to enter Claymore Lake would be obtained by eliminating a two and one-half mile reach of canal which follows Bingham Hill. This section of canal is reported to be a reach with high seepage losses. Construction of a high capacity lined canal around Bingham Hill would be very costly since the hill is composed of exposed rock. The construction of an 1,850 foot tunnel would be required to bypass this section of canal. The resultant increase in capacity of Claymore Lake would be about 600 acre-feet. The Highline Canal uses Claymore Lake primarily for storage of river water which is rented to various canal companies. Very little of the water in Claymore Lake can be used by the Highline Canal because there is only a small difference in elevation between the maximum lake surface and the canal bottom. A return canal has been constructed which carries water back to the Cache la Poudre River for use by other canals.

At the present time, College Lake serves as the reservoir for water used by the Colorado State University Hydraulics Laboratory. Water is released through an outlet in Soldier Canyon Dam, passes through the laboratory facilities and then enters College Lake. For the past two years, the Highline Canal has used the Soldier Canyon outlet to obtain its allotment of C-BT water. Under the proposed consolidation, the C-BT water for all four canals would be conveyed through this system. This would eliminate approximately twelve miles of conveyance of the C-BT water in open channels and make additional water available for the non-consumptive research purposes at the hydraulics laboratory. College Lake could be raised to provide an additional 500 acre-feet of storage.

The major channel for carrying water east to the areas served by the lower three canals would be via the Spring Creek channel. This channel would have to be greatly improved and could be lined if necessary. Several obstructions are present in the channel due to the encroachment of residential housing. At the point where Spring Creek intersects the present New Mercer Canal, water would be diverted to the south to serve lands under the Larimer County Canal #2 and the New Mercer Canal. A small pipeline could be constructed approximately one

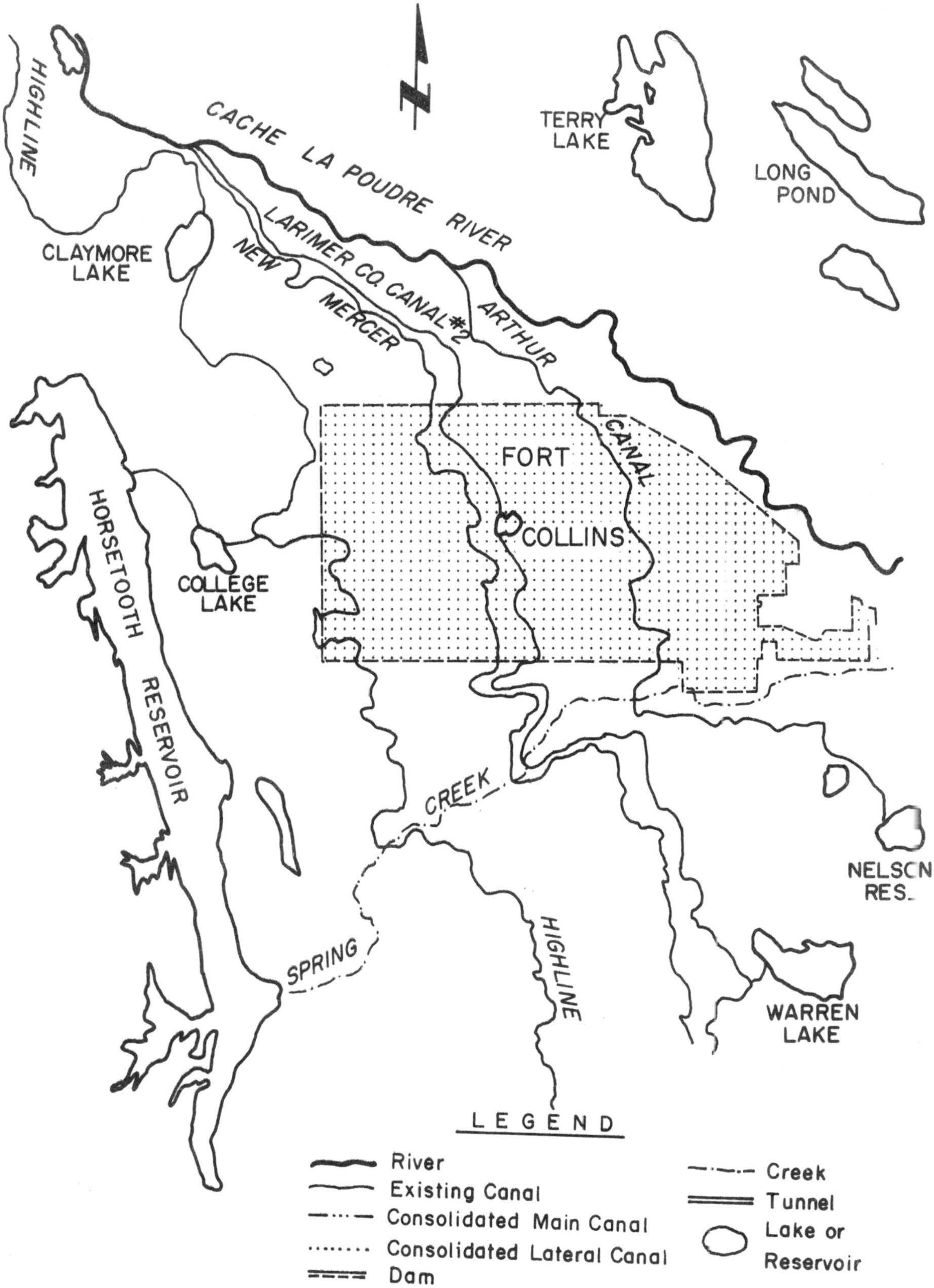

Fig. 11 - Existing Canal System

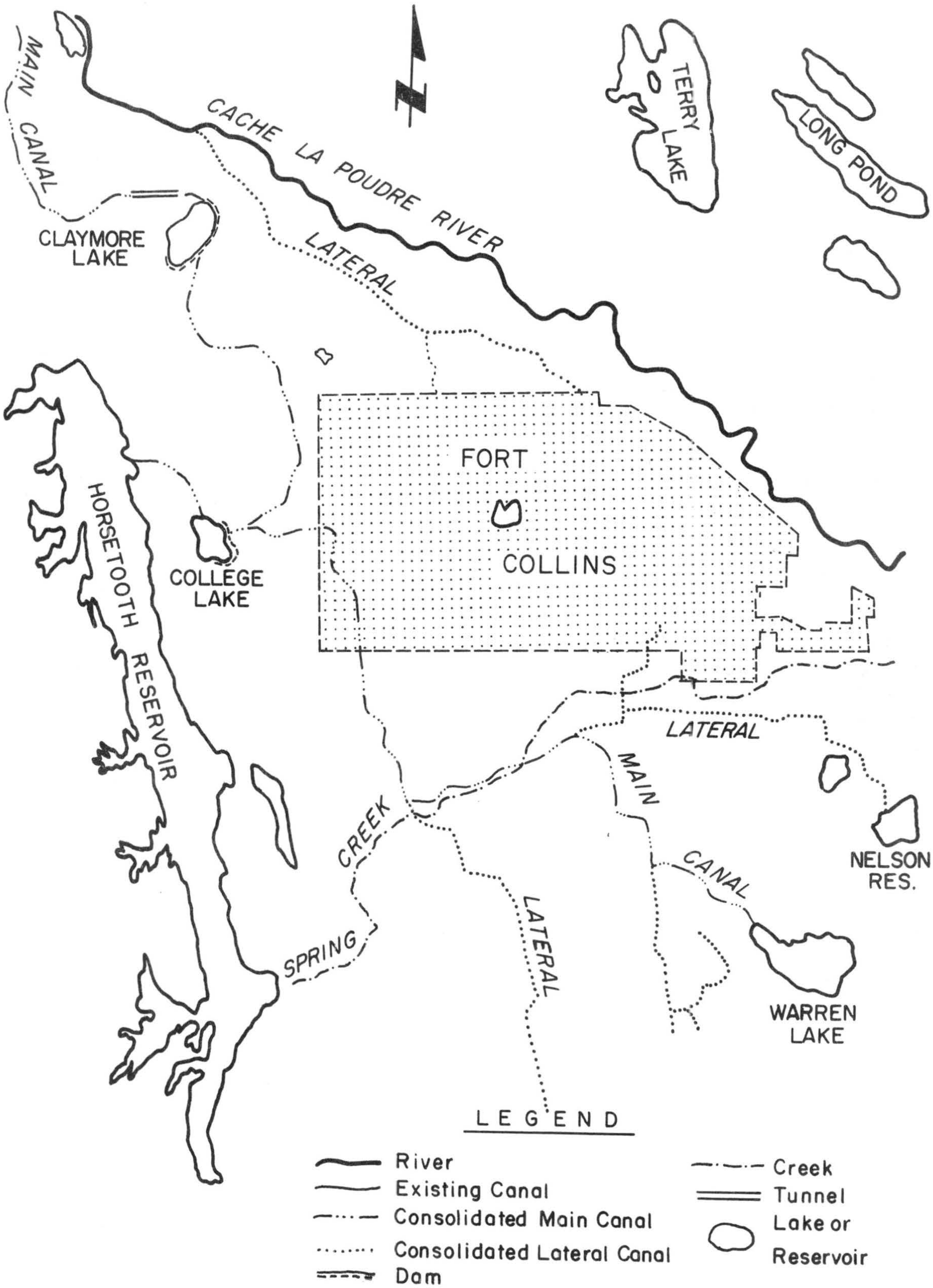

Fig. 12 - Consolidation of Four Canals

mile from this intersection to carry water down to the lands served by the Arthur Canal. A small lateral would have to be constructed north of the city in order to serve all areas which are presently served.

Approximately 6,000 acre-feet of water with a value of $150,000 would be saved annually with this consolidation. This is under the assumption that 25% of the water is presently lost through seepage and that after consolidation this loss would be reduced to 10%. The benefit-cost ratio of this proposal is 1.46. Table V summarizes the construction requirements and costs. The interest rate for this proposal is 3¼%. The total estimated construction cost is $2,533,000.

As was noted previously, the Board of Directors of the Arthur Canal has not expressed an interest in consolidation. A second means of consolidation would be to merge the upper three canals as in the previous proposal without including the Arthur Canal. Proposal #2 has a total construction cost of $2,140,000 and a benefit cost ratio of 1.42. The average annual volume of water which would be saved is estimated at 4,976 acre-feet with a value of $124,400. Figure 13 shows the proposed route for this consolidation.

The third possible consolidation would be to combine the New Mercer Canal and the Larimer County Canal #2. This consolidation would involve the construction of approximately 8.2 miles of main canal, 2.7 miles of lateral canal and 3 major siphons. The total canal mileage would be reduced from the present 26.1 miles to 11.3 miles. The canal could be straightened in many places but would have to remain within its present right-of-way as it passes through Fort Collins' residential areas.

The annual average water savings from this consolidation would be approximately 2,531 acre-feet valued at $63,275. This project has a benefit cost ratio of 1.55. The main disadvantage of this proposal is that no increase in storage capacity is provided. Since these canals have decrees which specify high flows, the canal cross section would have to handle the combined flow of their decrees. This consolidation proposal is shown on the map in Fig. 14.

Financing

A review of federal programs for financing small irrigation projects indicated that the most favorable method of financing this proposed consolidation would be obtained through the United States Bureau of Reclamation "Small Projects Act of 1956."[19]

Projects financed under this Act may be either new irrigation projects or the rehabilitation and betterment of existing systems. The total construction cost must not exceed $10,000,000 for either type project. The financial assistance which is available may be a loan, grant or a combination of these, not to exceed $6,500,000. Grants may be given for flood control, fish and wildlife protection or recreation

TABLE V. SUMMARY OF BENEFITS AND COSTS

Item	Proposal 1	Proposal 2	Proposal 3
1. Diversion Dam and Headworks on the Cache la Poudre River	$ 52,000	$ 52,000	$ 10,000
2. Tunnel Through Bingham Hill ~ 1850 ft	378,000	348,000	---
3. 8 Foot Bottom Width Canal	1,023,000	903,000	451,000
4. 3 Foot Bottom Width Canal	464,000	330,000	96,000
5. 42" Diameter Pipeline	43,000	---	---
6. Sag Pipe Structures	26,000	26,000	68,000
7. Miscellaneous Canal Structures, Flumes, Turnouts and Check Structures	89,000	74,000	38,000
8. Improvements at Claymore & College Lakes	96,000	96,000	---
Subtotal	$2,171,000	$1,829,000	$663,000
Engineering Cost @ 7%	145,000	128,000	46,000
Contingencies @ 10%	217,000	183,000	66,000
Total Estimated Cost	$2,533,000	$2,140,000	$775,000
Estimated Water Savings in Acre-Feet	6002	4976	2531
Estimated Value of Water Savings at $25/A-Ft	$150,050/Yr	$124,400/Yr	$63,275/Yr
B/C Ratio at 3¼% Interest	1.46	1.42	1.55

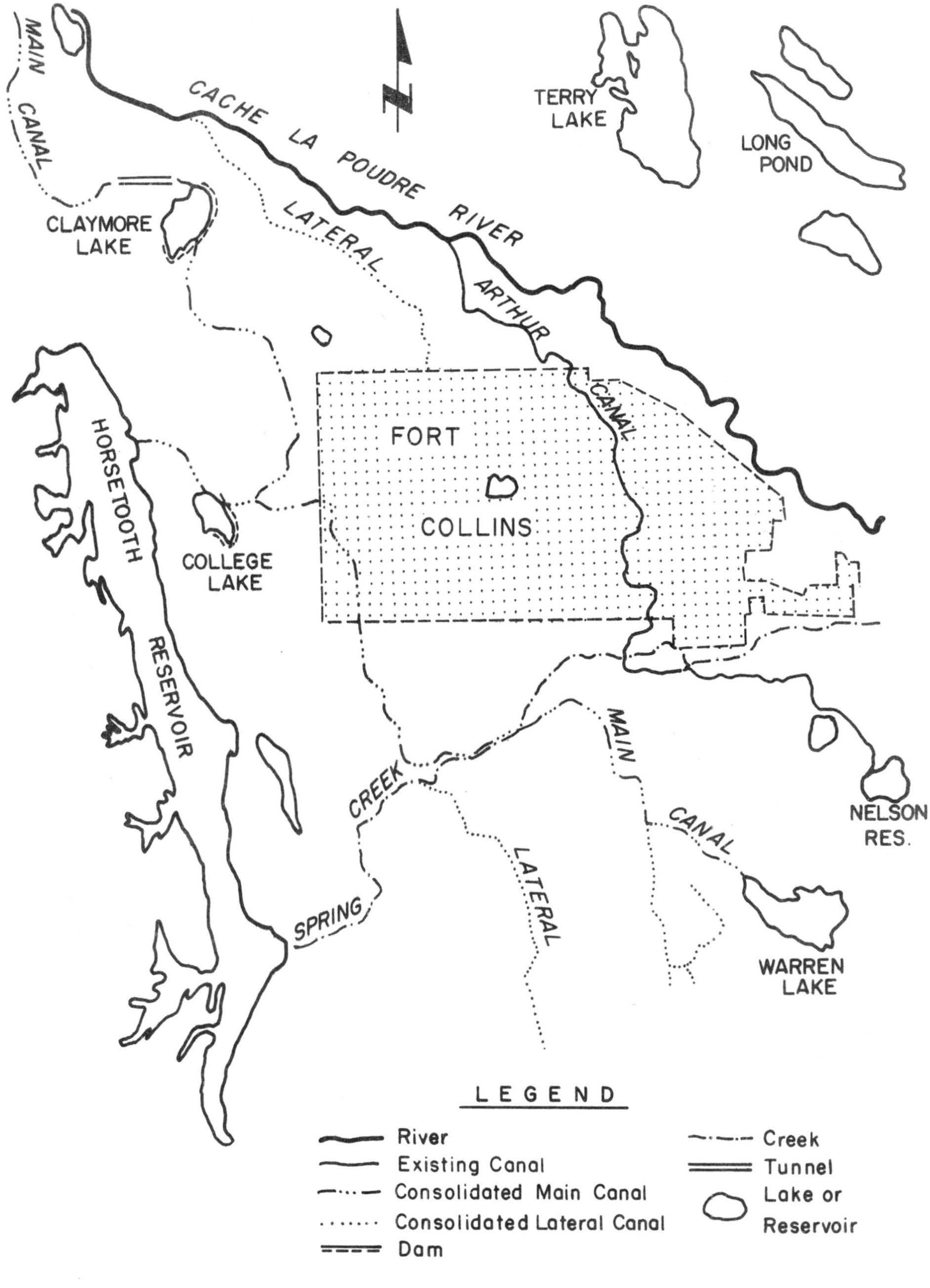

Fig. 13 - Consolidation of Three Canals

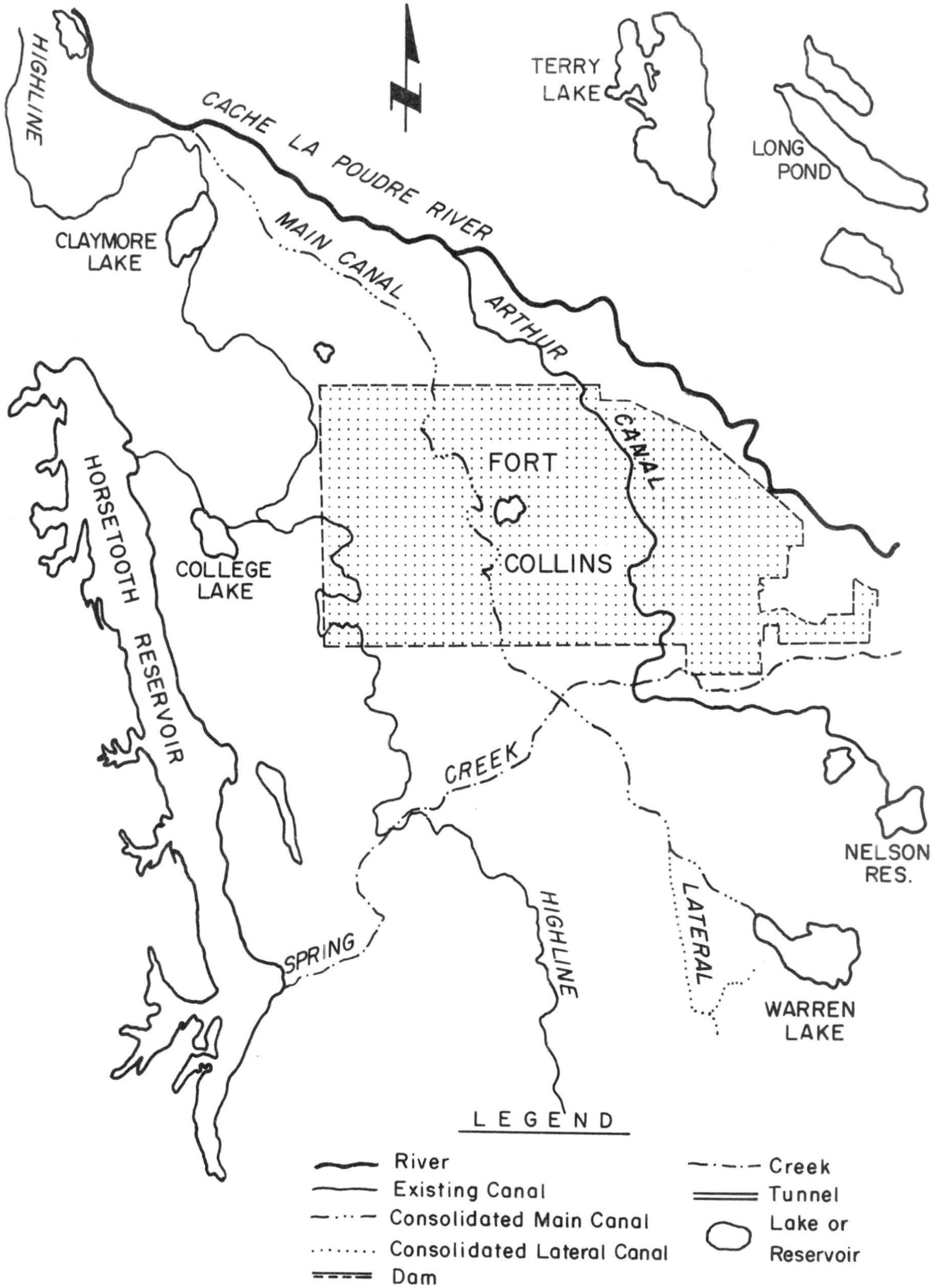

Fig. 14 - Consolidation of Two Canals

purposes where the general public benefits, but the project must be primarily for irrigation. The maximum amount of the grant is 50% of the construction cost.

An individual or an unorganized group of individuals cannot obtain a loan or a grant. It is necessary to form an organization such as a conservancy district, irrigation district or a water users association which has the capability to contract with the United States government under the conditions imposed by the Reclamation laws.

Loans on irrigation projects are interest free for lands not in excess of 160 acres in a single ownership (320 acres for husband and wife). Interest is charged on the reimbursable portions of the project for lands in excess of 160 acre single ownership, municipal and industrial water, and commercial power. The interest rate on such portions of the loan is based on long term obligations of the United States. At the present time, this rate is 3¼%.[19]

Loans are to be repaid in the minimum period of time which is consistent with project benefits. The maximum period is fifty years. In some cases, no payments are required until the full magnitude of the project benefits become available.

Under this Act, the applying organization is responsible for the planning, construction, operation and maintenance of the system. Construction plans are reviewed by the Bureau of Reclamation prior to the beginning of construction. The applying organization must have preliminary plans of the project before applying for a loan, and, hence, engineering costs may not be included in the loan.

Chapter V

SUMMARY AND CONCLUSIONS

General

Many of the facets of irrigation system consolidation have been presented in this thesis. The major assumption for determining whether consolidation would be beneficial was that seepage losses could be reduced from their present level of about 25% to 10% through the construction of a lined canal. The economic feasibility of these proposals was judged only on the monetary value of the water savings. The indirect benefits to the city of Fort Collins and the canal companies were not included in the economic analysis. The consolidation of irrigation canals passing through the city would provide the following benefits to the city and to the canal companies.

(1) Benefits to the city of Fort Collins

- (a) a reduction in the hazard to life and property in residential areas;
- (b) a reduction in the number of bridges and culverts required in the city; this would reduce bridge maintenance and construction costs;
- (c) the vacated canal right-of-way could be used to provide flood control channels for the benefit of the city;
- (d) additional land available for residential development; and
- (e) the elimination of many insect breeding places.

(2) Benefits to the canal companies

- (a) a reduction in the water seepage losses;
- (b) an increase in the storage capacity of the canal systems;
- (c) an approximate 30-40% reduction in operation, maintenance and administration costs due to the decreased length of the canal;
- (d) a reduction in the number of required farm turnouts; and
- (e) a decrease in the total right-of-way requirements.

From the data presented in this thesis, it appears that system consolidation is economically justifiable.

The major influence which might tend to discourage consolidation is the growth of the city of Fort Collins. This growth could take large agricultural areas out of production and leave the remaining areas with the burden of repayment of the construction costs. However, it is likely that the city will acquire most or all of the water shares or rights on any new lands annexed to the city. It is assumed that the long term repayment obligations would stay with those holding the water shares (farmers, city, etc.).

Another difficulty which will be encountered in system consolidation is to determine the equitable portion of costs which must be carried by each canal company and the city of Fort Collins. In this respect, it should be noted that the formation of a new company and a new issue of stock might solve many problems. Administrative action will be necessary to ensure that each area of land has a better water supply after consolidation. Financing could also be accomplished on a combination acreage basis or on the basis of the total river diversion for the canal.

Suggestions for Further Study

Future studies of this type should be conducted in rural areas which are not adjacent to a rapidly expanding city. This would allow an assessment of consolidation solely on the benefits which would be incurred by the agricultural community. This would also reduce the number of organizations which would be directly involved in consolidation negotiations. The major problem imposed by a city is the rate at which land might be removed from production.

Additional storage of water is required to make the irrigation water available when it is most needed. The major inflexibility in the present system is this lack of storage. The C-BT water has greatly alleviated this problem, but considerable advantages could be gained through increased storage.

The most logical storage reservoir sites are in the mountain canyons where high capacity reservoirs can be constructed. These reservoirs would be deep and have small surface areas. Evaporation losses from such reservoirs would be appreciably less than for plains storage reservoirs of equal capacity.

One of the major problems which would be created by the construction of a dam on the river is that natural flows would be impounded, and this might tend to injure some of the junior appropriators on the stream. Several legal questions would have to be answered before construction of such a project could be undertaken. Each canal would have to be assigned a certain amount of the available river flow based on the average volumes of diversion in previous years.

A third area for additional study would involve a determination of the water requirements of several large farms in the sample area. Such a study might indicate that the farm distribution system can be improved to provide greater efficiency. Improving the efficiency of the individual farms might be preferable to consolidating canals, since it would apply to only limited areas and would ensure that those areas remained under agricultural production. Most farms in the sample area have unlined distribution canals and probably have high losses in some areas. An individual farmer could line suspected areas of high seepage and, thereby, greatly increase the beneficial use of his water.

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APPENDIX

TABLE VI. LIST OF HIGH FLOWS - OVER 350 CFS

Date	Arthur Canal	Larimer Co. #2 Canal	New Mercer Canal	Highline Canal	Total Flow
1951					
5/20	54	150	90	80	374
5/24	54	150	68	80	352
5/31	56	97	115	100	368
6/1	56	97	115	100	368
1952					
6/5	70	135	70	90	365
6/6	70	150	70	90	380
6/7	80	150	90	105	425
6/8	80	150	100	115	445
6/9	80	150	90	125	445
6/10	60	150	85	115	410
6/11	50	150	70	115	385
1953					
5/29	70	178	100	80	428
6/10	38	179	125	100	442
6/11	38	178	125	120	462
6/12	38	179	125	15	357
6/13	38	178	125	100	441
6/14	38	178	125	120	461
6/15	38	90	125	120	373
1954					
5/21	75	178	59	57	369
5/22	70	178	59	57	364
1955					
6/19	20	178	75	120	393
6/20	20	178	75	120	393
6/21	22	188	75	90	375
1956					
5/20	83	135	73	76	367
5/21	85	160	90	105	440
5/22	80	170	98	112	460
5/23	83	172	102	108	465
5/24	87	169	94	108	458
5/25	83	162	86	106	437
6/6	47	134	83	107	371
6/7	49	150	90	107	396
6/8	48	150	81	108	387
6/9	48	150	75	108	381
6/10	39	151	75	106	371
6/11	42	145	75	108	370
6/12	44	149	75	110	378

TABLE VI. LIST OF HIGH FLOWS - OVER 350 CFS - Continued

Date	Arthur Canal	Larimer Co. #2 Canal	New Mercer Canal	Highline Canal	Total Flow
1957					
6/13	44	150	80	90	364
6/14	75	150	100	86	411
6/15	75	150	60	92	377
7/1	60	110	90	96	356
7/2	63	110	100	103	376
7/3	61	110	100	100	371
7/4	60	110	100	102	372
7/5	57	110	100	98	365
7/6	62	110	100	101	373
7/7	57	115	100	100	372
7/8	55	115	100	100	370
1958					
6/9	64	141	76	104	385
6/10	65	144	79	113	401
6/11	71	142	90	116	419
1959					
6/8	67	144	92	97	400
6/9	62	155	96	105	418
6/10	87	155	89	74	405
6/11	87	161	81	112	441
6/12	42	173	90	110	415
6/13	30	118	95	108	351
6/20	54	120	75	109	358
6/21	46	126	76	109	357
6/22	52	140	69	100	361
6/26	70	139	34	108	351
1960					
5/21	60	159	40	99	358
1961					
6/25	54	149	51	101	355
1962					
5/12	76	142	60	115	393
5/13	74	137	61	115	387
5/14	72	136	59	114	381
1963	No days when total exceeded 350 cfs				
1964					
5/22	83	176	48	58	365
5/23	78	175	45	68	366

TABLE VI. LIST OF HIGH FLOWS - OVER 350 CFS - Continued

Date	Arthur Canal	Larimer Co. #2 Canal	New Mercer Canal	Highline Canal	Total Flow
1964					
5/24	87	173	36	69	365
5/25	85	177	43	67	372
5/26	70	177	51	56	354
5/27	58	177	64	86	385
5/28	64	176	42	70	352
1965	No days when total exceeded 350 cfs				
1966	No days when total exceeded 350 cfs				

TABLE VII. WATER SUPPLY DATA FOR THE ARTHUR CANAL

A - Annual Diversions in Acre-Feet 1951-1966

Date	River Diversion	C-BT** Water	Storage or Exchange	Total Diversion
1951	5,064	--	306	5,370
1952	6,904	--	438	7,342
1953	6,102	--	950	7,052
1954	5,165	874	89	6,128
1955	6,699	1,350	14	8,063
1956	6,111	1,029	28	7,168
1957	6,198	454	42	6,694
1958	5,028	1,458	30	6,516
1959	5,566	1,104	84	6,754
1960	6,966	1,378	36	8,380
1961	5,254	500	66	5,820
1962	6,640	854	44	7,538
1963	5,512	964	42	6,518
1964	5,570	1,048	0	6,618
1965	5,064	404	42	5,509
1966	4,606	1,226	32	5,864
Average	5,778	970.4**	140	6,902.4**
Percent	83.7%	14.3%	2.0%	100.0%

**C-BT Water averaged over 1954-1966 period

B - Statistical Determination of Variance

m	River Diversion	$(X-\overline{X})$	$(X-\overline{X})^2$
1	6,966	1,188	1,411,344
2	6,904	1,126	1,267,876
3	6,699	921	848,241
4	6,640	862	743,044
5	6,198	420	176,400
6	6,111	333	110,889
7	6,102	324	104,976
8	5,570	-208	43,264
9	5,566	-212	44,944
10	5,512	-266	70,756
11	5,254	-524	274,576
12	5,165	-613	375,769
13	5,064	-714	509,796
14	5,064	-714	509,796
15	5,028	-750	562,500
16	4,606	-1,172	1,373,584
Summation			8,427,755

$$s = \sqrt{\frac{\Sigma(X-\overline{X})^2}{n-1}} = \sqrt{561,850} = 750$$

TABLE VIII. WATER SUPPLY DATA FOR THE NEW MERCER CANAL

A - Annual Diversions in Acre-Feet 1951-1966

Date	River Diversion	C-BT** Water	Storage or Exchange	Total Diversion
1951	7,615	--	322	7,937
1952	4,499	--	1,494	5,993
1953	5,511	--	1,603	7,114
1954	2,293	2,212	28	4,533
1955	4,792	2,012	56	6,860
1956	5,527	1,443	0	6,970
1957	8,116	556	0	8,672
1958	2,780	2,280	104	5,164
1959	5,038	1,788	28	6,854
1960	4,016	2,298	46	6,360
1961	3,088	1,070	12	4,170
1962	5,906	1,448	48	7,402
1963	4,154	3,024	46	7,224
1964	4,474	2,884	0	7,358
1965	4,566	1,160	10	5,736
1966	3,100	3,622	26	6,748
Average	4,717	1,984**	239	6,940**
Percent	67.7%	28.8%	3.5%	100.0%

**C-BT Water averaged over 1954-1966 period

B - Statistical Determination of Variance

m	River Diversion	$(X-\bar{X})$	$(X-\bar{X})^2$
1	8,116	3,399	11,553,201
2	7,615	2,898	8,398,404
3	5,906	1,189	1,413,721
4	5,527	810	656,100
5	5,511	794	630,436
6	5,038	321	103,041
7	4,792	75	5,625
8	4,566	-151	22,801
9	4,499	-218	47,524
10	4,474	-243	59,049
11	4,154	-563	316,969
12	4,016	-701	491,401
13	3,100	-1,617	2,614,689
14	3,088	-1,629	2,653,641
15	2,780	-1,937	3,751,969
16	2,293	-2,424	5,875,776
Summation			38,594,347

$$s = \sqrt{\frac{\Sigma(X-\bar{X})^2}{n-1}} = \sqrt{2,572,956} = 1,604$$

TABLE IX. WATER SUPPLY DATA FOR LARIMER CO. #2 CANAL

A - Annual Diversions in Acre-Feet 1951-1966

Date	River Diversion	C-BT** Water	Storage or Exchange	Total Diversion
1951	11,657	--	354	12,011
1952	8,076	--	1,005	9,081
1953	8,420	--	2,607	11,027
1954	2,029	3,980	62	6,071
1955	7,335	2,492	56	9,883
1956	8,813	1,582	28	10,423
1957	8,596	650	254	9,500
1958	5,254	2,468	22	7,744
1959	7,564	2,210	496	10,270
1960	7,576	1,852	1,192	10,620
1961	4,890	1,606	682	7,178
1962	10,718	2,218	670	13,606
1963	2,102	3,108	1,306	6,516
1964	8,622	2,246	0	10,868
1965	8,394	1,314	1,604	11,312
1966	3,592	4,188	18	7,798
Average	7,102	2,301**	648	10,051
Percent	70.4%	23.1%	6.5%	100.0%

**C-BT Water averaged over 1954-1966 period

B - Statistical Determination of Variance

m	River Diversion	$(X-\bar{X})$	$(X-\bar{X})^2$
1	11,657	4,555	20,748,025
2	10,718	3,616	13,075,456
3	8,813	1,711	2,927,521
4	8,622	1,520	2,310,400
5	8,596	1,494	2,232,036
6	8,420	1,318	1,737,124
7	8,394	1,292	1,669,264
8	8,076	974	948,676
9	7,576	474	224,676
10	7,564	462	213,444
11	7,335	233	54,289
12	5,254	-1,848	3,415,104
13	4,890	-2,212	4,892,944
14	3,592	-3,510	12,320,100
15	2,102	-5,000	25,000,000
16	2,029	-5,068	25,684,624
Summation			117,453,683

$$s = \sqrt{\frac{\Sigma(X-\bar{X})^2}{n-1}} = \sqrt{7,830,245} = 2,798$$

TABLE X. WATER SUPPLY DATA FOR HIGHLINE CANAL

A - Annual Diversions in Acre-Feet 1951-1966

Date	River Diversion	C-BT** Water	Storage or Exchange	Total Diversion
1951	12,710	--	238	12,948
1952	14,172	--	793	14,965
1953	14,373	--	1,339	15,711
1954	13,065	2,648	839	16,552
1955	15,205	1,568	819	17,592
1956	15,872	838	736	17,446
1957	14,607	112	310	15,029
1958	13,754	1,094	742	15,590
1959	12,942	1,110	1,318	15,370
1960	15,852	1,278	1,862	18,992
1961	9,492	414	1,078	10,984
1962	17,524	928	636	19,088
1963	14,326	1,392	2,040	17,758
1964	16,178	1,250	950	18,378
1965	14,134	1,200*	1,072	16,406
1966	11,706	1,200*	622	13,528
Average	14,119	1,156**	962	16,299**
Percent	87.0%	7.2%	5.8%	100.0%

*Estimate **C-BT Water averaged over 1954-1966 period

B - Statistical Determination of Variance

m	River Diversion	$(X-\bar{X})$	$(X-\bar{X})^2$
1	17,524	3,405	11,594,025
2	16,178	2,059	4,239,481
3	15,872	1,753	3,073,009
4	15,852	1,733	3,003,289
5	15,205	1,086	1,179,396
6	14,607	488	238,144
7	14,373	254	64,516
8	14,326	207	42,849
9	14,172	53	2,809
10	14,134	15	225
11	13,754	-365	133,225
12	13,065	-1,054	1,110,916
13	12,942	-1,177	1,385,329
14	12,710	-1,409	1,985,281
15	11,706	-2,413	5,822,569
16	9,492	-4,627	21,409,129
Summation			55,284,192

$$s = \sqrt{\frac{\Sigma(X-\bar{X})^2}{n-1}} = \sqrt{3,685,613} = 1,920$$

TABLE XI. COMBINED WATER SUPPLY DATA FOR THE FOUR CANAL SYSTEMS

A - Annual Diversions in Acre-Feet 1951-1966

Date	River Diversion	C-BT** Water	Storage or Exchange	Total Diversion
1951	37,046	--	1,220	38,266
1952	33,651	--	3,730	37,381
1953	34,406	--	6,499	40,905
1954	22,552	9,714	1,018	33,284
1955	34,031	7,422	945	42,398
1956	36,323	4,892	792	42,007
1957	37,517	1,772	606	39,895
1958	26,816	7,300	898	35,014
1959	31,110	6,212	1,926	39,248
1960	34,410	6,806	3,136	44,352
1961	22,724	3,590	1,838	28,152
1962	40,788	5,448	1,398	47,634
1963	26,094	8,488	3,434	38,016
1964	34,844	7,428	950	43,222
1965	32,158	4,078	2,728	38,964
1966	23,004	10,236	698	33,938
Average	31,717	6,414**	1,988	40,119**
Percent	79.0%	16.1%	4.9%	100.0%

**C-BT Water averaged over 1954-1966 period

B - Statistical Determination of Variance

m	River Diversion	$(X-\overline{X})$	$(X-\overline{X})^2$
1	40,788	9,071	82,283,041
2	37,517	5,800	33,640,000
3	37,046	5,329	28,398,241
4	36,323	4,606	21,215,236
5	34,844	3,127	9,778,129
6	34,410	2,693	7,252,249
7	34,406	2,689	7,230,721
8	34,031	2,314	5,354,596
9	33,651	1,934	3,740,356
10	32,158	441	194,481
11	31,110	-607	368,449
12	26,816	-4,901	24,019,801
13	26,094	-5,623	31,618,129
14	23,004	-8,713	75,916,369
15	22,724	-8,993	80,874,049
16	22,552	9,165	83,997,225
Summation			495,881,072

$$s = \sqrt{\frac{\Sigma(X-\overline{X})^2}{n-1}} = \sqrt{33,058,738} = 5,750$$

TABLE XII. TEMPORAL FLOW DISTRIBUTION FOR HIGHLINE CANAL

River Diversion in Acre-Feet

Year	Apr 16-30	May 1-15	May 16-31	June 1-15	June 16-31	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Oct 16-31
1951	--	--	2087	1866	1918	1924	1692	159	724	1269	873	198	--
1952	--	516	992	2926	1781	1529	1269	1169	1277	926	1043	744	--
1953	--	397	1551	2158	1976	1210	1311	1188	1267	1083	986	897	349
1954	948	1190	1603	1196	1301	1244	1226	904	405	399	635	1252	762
1955	377	1210	1488	1613	2114	1236	1263	1182	1291	1065	670	994	702
1956	274	1422	2458	2751	1654	1218	1323	1089	1303	722	591	641	426
1957	--	--	73	1958	2715	2805	1872	1188	1283	1055	647	904	107
1958	--	--	60	2450	1950	1218	1316	1200	1256	1186	1190	1234	694
1959	--	34	764	2470	2722	1482	1258	1200	1274	774	892	72	--
1960	348	1360	1844	2788	2232	1440	1294	1202	1300	772	678	410	184
1961	--	360	254	360	1860	1582	1326	1464	1080	892	314	--	--
1962	--	1930	2226	2386	2536	1978	1660	1044	1286	1184	1294	--	--
1963	614	1280	1698	1614	1470	1206	1274	1206	1280	1210	858	450	166
1964	--	934	1950	2550	2034	1362	1260	1198	1244	570	1006	1128	942
1965	--	700	1648	2548	960	2202	1506	1204	1284	1204	878	--	--
1966	158	1026	1658	1592	1662	1200	1282	1192	654	1122	160	--	--
Aver.	170	772	1397	2077	1930	1552	1383	1112	1138	965	795	558	271

TABLE XIII. TEMPORAL FLOW DISTRIBUTION FOR HIGHLINE CANAL

C-BT Project Water in Acre-Feet

Year	Apr 16-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Oct 16-31
1954	--	--	145	369	198	389	280	246	537	198	250	36	--
1955	--	--	69	--	20	169	194	103	357	296	103	188	69
1956	--	--	--	--	42	73	60	61	18	139	113	165	167
1957	--	--	--	--	--	--	44	40	28	--	--	--	--
1958	--	--	--	--	--	184	118	166	324	180	106	16	--
1959	--	--	--	--	--	234	118	204	292	188	74	--	--
1960	--	--	--	--	--	198	194	300	268	154	110	54	--
1961	--	--	--	--	--	160	94	52	82	26	--	--	--
1962	--	--	--	--	--	--	--	48	542	258	80	--	--
1963	--	30	208	106	24	214	146	220	376	58	10	--	--
1964	--	6	96	--	--	124	270	190	302	182	64	16	--
1965	C-BT Water Diverted Through College Lake												
1966	" " " " " "												
Aver.	--	3	47	43	26	159	138	148	284	153	83	43	21

TABLE XIV. TEMPORAL FLOW DISTRIBUTION FOR HIGHLINE CANAL

Storage or Exchange Water in Acre-Feet

Year	Apr 16-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Oct 16-31
1951	--	--	--	--	--	--	--	--	--	139	--	99	--
1952	--	--	--	--	--	75	317	294	107	--	--	--	--
1953	--	--	--	--	20	345	307	165	141	79	179	103	--
1954	--	--	75	393	284	79	8	--	--	--	--	--	--
1955	--	--	125	--	40	274	309	71	--	--	--	--	--
1956	--	--	--	--	--	284	288	95	69	--	--	--	--
1957	--	--	--	--	--	--	24	38	105	143	--	--	--
1958	--	--	--	--	--	300	220	74	148	--	--	--	--
1959	--	--	112	--	--	130	320	274	34	--	--	144	304
1960	--	170	--	--	--	130	322	252	4	--	--	--	984
1961	--	80	40	--	--	60	250	248	240	2	158	--	--
1962	--	--	--	--	--	--	--	114	330	192	--	--	--
1963	--	--	--	76	140	300	180	--	--	--	--	1048	296
1964	--	--	--	--	--	202	320	142	--	--	--	--	286
1965	--	--	--	108	--	--	168	300	192	--	304	--	--
1966	--	--	--	--	154	258	210	--	--	--	--	--	--
Aver.	--	16	22	36	40	152	203	129	86	35	40	87	117

TABLE XV. TEMPORAL FLOW DISTRIBUTION FOR NEW MERCER CANAL

River Diversion in Acre-Feet

Year	Apr 16-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Oct 16-31
1951	--	--	1807	1339	1777	1170	914	83	321	204	--	--	--
1952	--	331	--	1985	934	607	266	292	--	58	--	26	--
1953	--	119	748	2095	1006	579	353	280	248	--	--	--	83
1954	--	236	835	391	313	228	115	60	--	--	--	115	--
1955	--	262	716	889	1398	486	311	311	419	--	--	--	--
1956	--	492	1579	1646	861	359	155	282	153	--	--	--	--
1957	--	--	--	813	2285	2590	1079	409	329	208	282	121	--
1958	--	--	--	1016	974	342	344	28	76	--	--	--	--
1959	--	--	78	1896	1580	734	308	296	62	--	84	--	--
1960	--	114	646	1342	976	492	276	170	--	--	--	--	--
1961	--	--	--	8	1066	886	352	298	252	182	44	--	--
1962	--	648	1030	510	1148	1018	1086	390	76	--	--	--	--
1963	22	344	916	822	626	328	148	232	352	286	78	--	--
1964	--	--	1094	840	804	520	952	214	--	--	50	--	--
1965	--	198	886	1202	226	1002	496	292	264	--	--	--	--
1966	--	328	726	858	718	228	146	60	--	36	--	--	--
Aver.	1	192	691	1103	1043	723	456	231	160	61	34	16	5

TABLE XVI. TEMPORAL FLOW DISTRIBUTION FOR NEW MERCER CANAL

C-BT Project Water in Acre-Feet

Year	Apr 16-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Oct 16-31
1954	--	--	276	319	222	411	444	133	282	127	--	--	--
1955	--	--	69	22	--	292	194	83	778	393	125	56	--
1956	--	--	--	--	--	97	476	155	242	294	179	--	--
1957	--	--	--	--	--	--	--	--	--	246	272	38	--
1958	--	--	--	--	--	394	224	494	518	446	204	--	--
1959	--	--	--	--	--	40	306	392	484	302	264	--	--
1960	--	--	--	--	--	176	342	614	758	312	96	--	--
1961	--	--	--	--	4	40	280	270	274	90	112	--	--
1962	--	--	--	--	--	--	154	332	568	226	168	--	--
1963	2	274	272	252	14	544	718	608	184	64	92	--	--
1964	--	--	174	--	54	588	732	434	580	250	72	--	--
1965	--	--	104	--	--	46	224	326	460	--	--	--	--
1966	--	--	574	388	262	728	602	466	440	140	22	--	--
Aver.	--	21	113	75	43	258	362	331	428	223	123	6	--

TABLE XVII - TEMPORAL FLOW DISTRIBUTION FOR THE LARIMER CO. #2 CANAL

River Diversion in Acre-Feet

Year	Apr 16-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Oct 16-31
1951	--	--	3138	2747	1595	3201	678	50	103	113	32	--	--
1952	--	--	837	3263	3221	260	139	169	58	54	75	--	--
1953	--	--	1833	5127	936	115	113	131	--	--	165	--	--
1954	--	97	1367	103	101	111	111	36	12	--	--	83	8
1955	--	75	348	2172	4328	115	97	101	99	--	--	--	--
1956	--	452	3023	3087	1829	113	109	103	97	--	--	--	--
1957	--	--	--	2325	1890	2535	1505	103	109	59	42	28	--
1958	--	--	--	2946	1722	98	116	110	110	70	82	--	--
1959	--	--	24	3300	3336	520	112	108	108	--	56	--	--
1960	512	332	2154	2202	2810	104	110	104	52	28	--	--	--
1961	--	512	586	116	3244	512	112	138	110	240	2	--	--
1962	260	2050	1976	1126	3328	2200	112	102	110	96	28	--	--
1963	--	94	96	488	2228	100	104	94	108	78	18	--	--
1964	--	66	3946	2200	1812	310	106	106	64	12	--	--	--
1965	--	62	3088	2704	696	2678	106	102	86	94	382	--	--
1966	--	102	238	1704	1194	104	122	64	--	64	--	--	--
Aver.	48	240	1416	2257	2142	817	235	101	77	57	55	7	--

TABLE XVIII. TEMPORAL FLOW DISTRIBUTION FOR THE LARIMER CO. #2 CANAL

C-BT Project Water in Acre-Feet

Year	Apr 16-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Oct 16-31
1954	--	--	492	988	532	458	391	208	496	363	52	--	--
1955	--	--	--	--	--	362	625	334	506	629	36	--	--
1956	--	--	--	--	--	236	334	236	222	220	334	--	--
1957	--	--	--	--	--	--	--	38	73	476	--	63	--
1958	--	--	--	--	--	242	418	650	242	708	208	--	--
1959	--	--	--	--	--	254	378	576	438	468	96	--	--
1960	--	--	--	--	--	122	262	652	508	308	--	--	--
1961	--	--	--	--	--	--	156	234	384	832	--	--	--
1962	--	--	--	--	--	--	520	368	678	278	374	--	--
1963	--	--	378	214	12	268	634	540	338	430	294	--	--
1964	--	--	--	--	--	366	228	678	526	448	--	--	--
1965	--	--	--	--	--	--	--	372	482	460	--	--	--
1966	--	--	--	432	218	920	786	846	964	22	--	--	--
Aver.	--	--	67	126	59	248	364	441	451	434	107	5	--

TABLE XIX. TEMPORAL FLOW DISTRIBUTION FOR THE ARTHUR CANAL

River Diversion in Acre-Feet

Year	Apr 16-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Oct 16-31
1951	--	--	955	1094	325	1236	849	139	212	182	54	18	--
1952	--	256	863	1730	1261	855	986	389	151	81	40	133	159
1953	--	36	1157	1601	881	855	480	516	175	44	36	65	256
1954	--	411	1494	1180	1042	182	101	54	48	20	93	306	234
1955	232	454	1518	1489	542	641	536	450	139	83	129	308	178
1956	--	563	1661	1187	1134	625	196	508	115	38	22	16	46
1957	--	--	--	285	1314	1671	1372	691	369	105	169	222	--
1958	--	--	32	1378	1076	1048	232	116	116	56	96	374	504
1959	--	--	266	1562	1486	962	602	402	98	34	154	--	--
1960	324	526	1272	780	1450	1194	424	120	32	32	248	498	66
1961	--	64	118	594	1670	880	1052	418	188	228	42	--	--
1962	136	1388	798	326	1432	934	926	320	116	90	174	--	--
1963	42	752	1588	1434	448	218	122	402	270	206	30	--	--
1964	--	202	1744	410	1328	1084	532	162	74	26	8	--	--
1965	--	200	1378	383	256	1368	476	490	362	134	16	--	--
1966	500	452	1370	1338	456	168	116	86	32	84	4	--	--
Aver.	77	338	1017	1067	1006	870	550	328	156	90	82	121	90

TABLE XX. TEMPORAL FLOW DISTRIBUTION FOR THE ARTHUR CANAL

C-BT PROJECT WATER IN ACRE-FEET

Year	Apr 16-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug 1-15	Aug 16-31	Sept 1-15	Sept 16-30	Oct 1-15	Oct 16-31
1954	--	--	24	56	--	95	113	153	222	159	52	--	--
1955	--	69	14	--	--	42	208	139	240	399	69	170	--
1956	--	--	--	--	--	14	278	151	141	153	292	--	--
1957	--	--	--	--	--	--	--	--	208	175	71	--	--
1958	--	--	--	--	--	104	276	266	300	346	166	--	--
1959	--	--	--	--	--	--	58	188	348	338	172	--	--
1960	--	--	--	--	--	--	150	356	358	406	108	--	--
1961	--	--	--	--	--	--	--	194	174	94	38	--	--
1962	--	--	--	--	--	--	104	174	312	182	82	--	--
1963	--	--	--	--	--	100	326	312	80	96	50	--	--
1964	--	--	--	--	--	--	14	410	278	180	166	--	--
1965	--	--	--	--	--	--	--	84	212	72	36	--	--
1966	--	--	--	--	6	246	366	302	200	106	--	--	--
Aver.	--	5	3	4	0.4	46	146	209	236	208	100	13	--