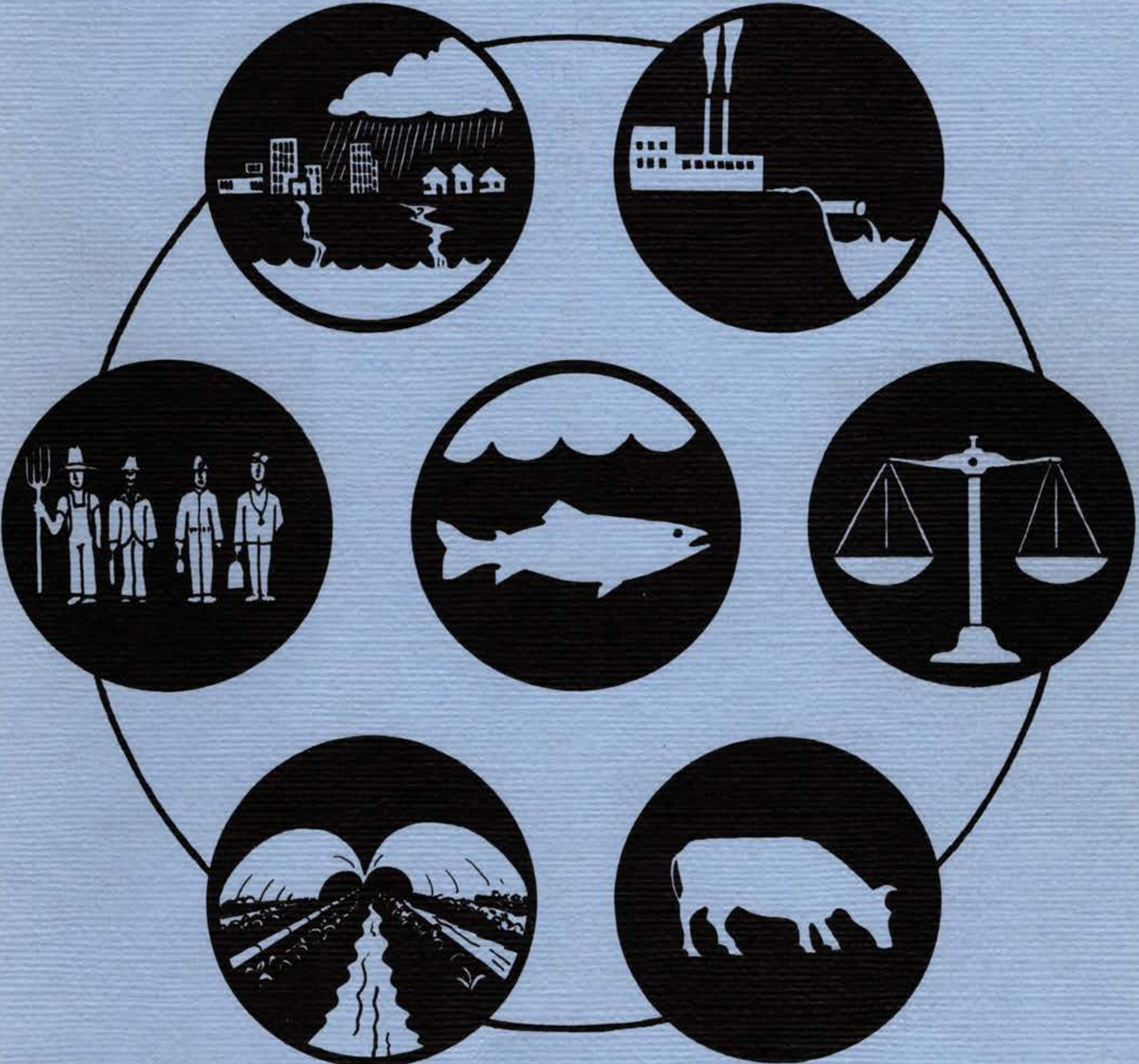
WATER QUALITY IMPACTS OF IRRIGATED AGRICULTURE



Water Quality Management Plan

22

LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS

PREPARED BY TOUPS CORPORATION   LOVELAND, COLORADO   APRIL, 1977

WATER QUALITY IMPACTS OF IRRIGATED AGRICULTURE IN THE LARIMER-WELD REGION

Prepared For

Larimer-Weld Regional
Council of Governments

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CONTENTS

APPENDICES:

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (Continued)

CHAPTER 1.0

SUMMARY AND CONCLUSIONS

1.1 ABSTRACT

The objective of this project was to identify the water quality impacts of irrigation return flows on streams in the Larimer-Weld region of northern Colorado. The 6,700 square mile region contains 500,000 acres of irrigated land. Existing data was collected on agricultural practices in the region including irrigation and drainage systems, fertilizer and pesticide use, and soils. A sampling program, including flow measurement provided data on the quality and quantity of both surface and subsurface returns. A hydrologic analysis identified diversions made from the rivers of the region as well as the return flows entering the rivers. Sampling data, hydrologic analysis, and analysis of agricultural practices resulted in definition of the impacts of irrigated agriculture upon water quality.

The streams of the region are dried up repeatedly at various points of diversion. Below these points many stream segments and downstream diversions are sustained entirely by irrigation return flow. Salinity is the most significant problem resulting from irrigated return flows in the region. The discharge of salts within return flows is associated with seepage from lakes, canals, and irrigated lands. In certain areas underground seepage waters flowing over saline shale formations dissolve salts which are subsequently discharged to streams. High nitrate levels were denoted in tile drainages from farms using heavy manure applications plus commercial fertilizers. Sediment discharges were restricted to a few areas with fine soils. There appears to be a potential for reducing the discharge of salinity by reducing seepage losses in canals and reduction of losses of applied irrigation water. Nitrate levels in streams might be reduced by better fertilizer management.

There is no information presently available to define the effectiveness of potential management practices in reducing the discharge of pollutants, the cost, or the financial feasibility of those practices. Development of this information is the objective of the Best Management Practices Project. This project is being implemented during the 1977 irrigation season. It involves detailed analysis of factors controlling pollutant loading at four individual sites in the region.

1.2 INTRODUCTION

The Larimer-Weld Regional Council of Governments is a designated Areawide Waste Treatment Management (208) Planning Agency. The investigation of water quality impacts of irrigated agriculture has a high priority in the development of the Areawide Waste Management Plan. The reasons for this are:

1. The 6,700 square mile region contains 500,000 acres of irrigated land.
2. Irrigation constitutes approximately 90 percent of the total water demand in the region.
3. The diversion and application of water for irrigation has significant impacts on the quantity and quality of streams in the region.
4. Irrigated agriculture is a major element of the economy in the Larimer-Weld region.
5. In the initial development of the approach to 208 planning in the region, great concern was expressed by representatives of the agricultural community concerning the applicability of water pollution control regulations to irrigated agriculture.

In response to these considerations, the Larimer-Weld Regional Council of Governments included an element in the 208 plan to define the water quality impacts of irrigated agriculture. This report presents the results of the initial efforts toward meeting that goal. A subsequent phase of the program will assess the technical, institutional, and financial feasibility of implementing best management practices to mitigate water quality impacts of irrigated agriculture.

A major impediment in analyzing the water quality impacts of irrigated agriculture was the lack of adequate water quality and hydrologic data for the four major drainages in the region--the Cache la Poudre River, Big Thompson River, St. Vrain River, and South Platte River. As a result, the 208 program necessarily included an extensive water quality sampling program and stream measurement program. Water quality samples of irrigation return flows were collected at numerous discharges in the region. In addition, return flows were measured at the same time water quality samples were taken. In-stream water quality samples and flow measurements were also taken throughout the region to identify impacts of return flows on water quality and quantity. More than 150 locations were sampled and measured throughout the region.

The sampling and measuring program was augmented with data collected from the State Engineer's Office concerning the amount of water diverted at approximately 100 diversion structures throughout the region. In addition, pertinent information on soil types that can affect water quality was collected. Collection and analysis of this data has resulted in the definition of the impacts of irrigated agriculture on the water quality and quantity in the Larimer-Weld region.

1.3 SUMMARY

Irrigated agriculture has been the cornerstone of the economy in the Larimer-Weld region since the 1870's. There are approximately 500,000 acres of irrigated land in the region which are distributed among four drainage basins--the South Platte River, Big Thompson River, Cache la Poudre River and the St. Vrain River. The latter three drainages are tributary to the South Platte. Irrigation has made the Larimer-Weld region one of the most productive agricultural regions in the United States. Value of all crops produced in the region was approximately $173 million in 1975.

Water for irrigation is supplied by natural runoff from snowmelt and is supplemented with trans-mountain diversions. Approximately 100 diversion structures have been built on the streams in the region to provide water to a complex storage and distribution system. During the irrigation season, these diversions dry up the river at several points. All rivers in the plains area of the region are totally managed to optimize the use of water throughout the year.

The supply system includes approximately 2500 miles of canals, with capacities ranging from 5 cubic feet per second (CFS) to 1000 cfs. In addition, there are 70 private reservoirs with a capacity of 400,000 acre-feet and major reservoirs associated with the Colorado-Big Thompson diversion project with a capacity of 270,000 acre-feet.

Common irrigation methods include furrow irrigation (56% of the irrigated land), flooding (34%), and sprinkler irrigation (10%). There are 2,700 farms in the region containing irrigated land.

It is estimated that about 10 percent of the irrigated land in the region is served by drainage. The SCS estimates that 410 miles of subsurface drainage and 97 miles of open surface drains are currently in use in the two-county region.

Nitrogen and phosphorous fertilizers are the major fertilizers used in the region. Potassium and zinc are used to a lesser extent. Manure is a highly significant fertilizer material in the region, especially in areas near concentrated animal feeding operations surrounding Greeley. Fully 75 percent of the irrigators applied insecticides at the recommended rate during 1976 to either corn or beets. Alfalfa, beans, and small grains were less likely to receive insecticide applications with only approximately 50 percent of the growers applying one or more insecticides at the recommended rates to these crops during 1976. Herbicides are used by approximately 80 percent of all irrigated crop growers in the region.

An extensive sampling program was conducted to identify the pollutional characteristics of irrigation return flows. Major constituents sampled included the common anions and cations, ammonia, biochemical oxygen demand, and nitrates. Salinity was found to be the most significant pollutant in the region. Salinity levels in tile drain discharges commonly ranged from 1000 to 3000 mg/l with the actual range being from 500 to 6000 mg/l. Over 50 percent of the tile drain samples exceeded 1500 mg/l. The occurrence of highly saline discharges in the region is closely related to irrigation over shallow shale deposits which are found in approximately 20 percent of the irrigated area. The principal loading mechanism is the flow of subsurface irrigation return flows and seepage from unlined canals horizontally across the shale layers. Horizontal flow over the shale provides an excellent opportunity for dissolution of salts and an increase in salinity in return flows. These conditions exist in each of the four major drainage basins.

Nitrate concentrations in irrigation return flows were most often in the range of 4 to 12 mg/l as nitrogen. Higher concentrations were found in areas where manure from feedlots has been applied continuously over many years and in conjunction with commercial fertilizers. Manure applications of 15 to 20 tons per acre are common in some areas of the region. Continued application at these high rates results in the presence of excess nitrates in the soil.

Sediment does not appear to be a major problem associated with irrigation discharges in the region. This partly results from the fact that there are few direct discharges of irrigation tailwater to streams. The rivers of the region tend to have flood plains serving as buffer zones prohibiting direct tailwater discharges. Some isolated occurrences of excessive sediment were found in the Little Thompson River drainage.

Phosphorus levels were quite low in samples taken in tile drains due to the fact that phosphorus rapidly becomes attached to soil particles and remains in the soil profile. Phosphorous levels in tailwater samples commonly ranged from 0.1 to 0.4 mg/l. No samples were taken of pesticides due to budgetary constraints.

Levels of biochemical oxygen demand, ammonia, and fecal coliform were consistently low in surface and subsurface drainage from irrigated lands. Biochemical oxygen demand averaged 2.5 mg/l; ammonia concentration averaged less than 0.1 mg/l as nitrogen; and fecal coliforms were found to be very low.

It is not possible to understand the water quality impacts of irrigation return flow in the region without understanding the regional hydrology. The hydrologic impact of irrigation diversions and return flows is significant. Diversion structures dry up all of the steams in the region at numerous points. Below these points irrigation return flow in the form of seepage, drainage, or tributary inflow constitutes practically all of the flow in the river. Many water rights on the downstream reaches of the streams are fulfilled entirely by losses from upstream areas, i.e., irrigation return flows. Data indicates that most rivers in the area gain from 1.5 to 3.0 cfs per mile.

On the Cache la Poudre River irrigation return flows are by far the largest discharge. Return flows are approximately 150 million gallons per day (mgd) over the length of the river compared to less than 25 mgd for point source discharges. Total dissolved solids concentrations on the Poudre River increased from approximately 50 mg/l at the point where the river leaves the mountains to over 1500 mg/l at the mouth of the river approximately 50 miles downstream. Nitrate levels increased fron near 0 to 6 mg/l in the lower reaches. Sediment levels in the Poudre River increased from 20 mg/l in upstream reaches to approximately 80 mg/l in the lower reaches.

On the Big Thompson River, irrigation return flow discharges are approximately 44 mgd as compared to the point sources of approximately 15 mgd. Total dissolved solids increase from very low levels to approximately 1200 to 1500 mg/l in the lower reaches of the river. The Little Thompson River enters the Big Thompson near Milliken and discharges a large salt load to the river. Nitrate levels in the Big Thompson increase from near 0 to 2 mg/l as nitrogen near the mouth of the river.

Irrigation return flows contribute approximately 26 mgd in the Little Thompson River. Other discharges are less than 5 mgd. The Little Thompson has the highest salinity levels of any rivers in the region. The river has concentrations of nearly 1500 mg/l upstream of Berthoud. Cencentrations continue to increase to over 2000 mg/l slightly east of Berthoud. Tributaries and drains entering the Little Thompson have consistently high dissolved solids levels resulting from irrigation over shallow underlying shale deposits. The

Little Thompson also has the most significant sediment problems in the region. In the lower reaches of the Little Thompson, sediment levels reach 150 to 200 mg/l. This can be partially attributed to irrigation of fine soils in the Little Thompson basin.

Irrigation discharge to the St. Vrain River is approximately 88 mgd. Other discharges in the area are less than 5 mgd. Salinity levels are approximately 1200 mg/l near the mouth of the St. Vrain. Several tile drains sampled in the St. Vrain region had extremely high total dissolved solids levels. Nitrate levels in the St. Vrain River generally range between 2 and 3 mg/l as nitrogen.

Irrigation return flows contribute approximately 188 mgd to the South Platte River as it flows through the region. Municipal and industrial discharges contribute approximately 1 mgd. Total dissolved solids levels are 600 to 700 mg/l where the river enters the region in south Weld County. As the stream leaves the region, total dissolved solids levels are generally 1200 to 1500 mg/l. Nitrate levels appear to be fairly constant in the Larimer-Weld region, ranging from 3 to 4 mg/l as nitrogen.

Water quality standards are defined by the State of Colorado. These standards include assignment of acceptable levels of chemical constituents in water which will enable attainment of fishable or recreational waters. Data collected as part of the 208 program indicate that agricultural discharges would not specifically interfere with attainment of these goals. In some instances in the Larimer-Weld region, discharge of sediment may exceed limits established under water quality regulations. A major impediment to achieving fisheries in the plains area of the region is the diversion of water under legally-decreed water rights which causes streams to dry up.

In addition to legally established standards, water pollutants may interfere with established beneficial uses of water. However, water quality does not appear to have impaired the use of water for irrigation or stock watering in the region. Regulations promulgated under the Federal Safe Drinking Water Act place limitations on inorganic chemicals, organic chemicals, turbidity, and microbiological contaminants in drinking water. Of the constituents limited, nitrate is the only constituent tested for in the analysis of irrigation return flow. Nitrate concentrations in drinking water are limited to 10 mg/l as nitrogen. Nitrate levels in streams have not been found to exceed the 10 mg/l limit. Nitrate levels in excess of 10 mg/l have been found in public drinking water supplies in some communities along the South Platte River which are dependent on groundwater for supply. It is highly probable that nitrate discharges to groundwater basins from application of commercial fertilizer and manure to irrigated lands contribute to excess nitrogen in the groundwater basins.

Existing data is not adequate to determine if there is a long-term trend towards increasing salinity, nitrates, or other pollutants in the groundwater basins of the region.

1.4 CONCLUSIONS

The analysis of water quality impacts of irrigation return flows has led to the development of conclusions in several categories as described below.

1.4.1 Wasteloads From Irrigated Agriculture

1. Factors affecting on-farm generation of agricultural waste loads include irrigation methods, drainage practices, physical characteristics of the soil, chemical characteristics of the soil, quality of water applied for irrigation, topography, on-farm irrigation efficiency, and subsoil conditions.

2. Factors affecting on-farm generation of agricultural waste loads are highly variable within the region, and will produce variable results in terms of quality and quantity of discharges.

3. The principal pollutants discharged by irrigated agriculture in the Larimer-Weld region are salinity, nitrates, and sediment.

4. Levels of biochemical oxygen demand, ammonia, and fecal coliforms were uniformly low in irrigation discharges.

5. Sediment problems were limited to a few streams in the area.

1.4.2 Water Quality Impacts of Irrigation Return Flows

1. Water quality impacts of irrigation return flows are directly dependent on the hydrology of streams in the region.

2. Through the many reaches of streams, irrigation return flow is the sole source of water supply.

3. Irrigation return flows increase levels of salinity from approximately 50 mg/l as the major tributaries leave the mountains to 1200 to 1500 mg/l at the confluence of the South Platte.

4. Salinity levels of the South Platte River increase from approximately 700 mg/l to 1200 mg/l as it flows through the Larimer-Weld region.

5. Irrigation discharges to streams are by far the largest discharge and are on the order of 500 mgd as compared to approximately 46 mgd from municipal and industrial discharges.

6. Diversion of water in the streams for municipal, industrial, and agricultural water supply is the controlling factor limiting the legally specified water quality goals, i.e., fishery and recreational.

7. Irrigation return flows have contributed to excess salinity and nitrates experienced in groundwater basins.

1.4.3 Potential for Pollutant Reduction

1. Due to the highly variable factors controlling discharge of pollutants from the 2,700 irrigated farms in the region, the application of control measures must be site specific in order to be effective in preventing, controlling, or abating pollution from irrigated agriculture.

2. The potential for pollutant reduction exists through best management practices developed and applied in specific areas of the region.

3. Discharge of salts could be reduced by reducing excessive seepage and subsurface return flows across shallow lying shale areas of the region.

4. Nitrate levels could be reduced through better fertilizer management.

5. No information is presently available on the cost-effectiveness of such measures.

6. Application of best management practices for reduction of pollutant discharge could have both long-term and short-term effects.

Many of the questions raised regarding cost-effectiveness of pollution control measures for irrigated agriculture will be answered in the best management practices analysis. This analysis is presently underway and will be completed in March 1978.

CHAPTER 2.0

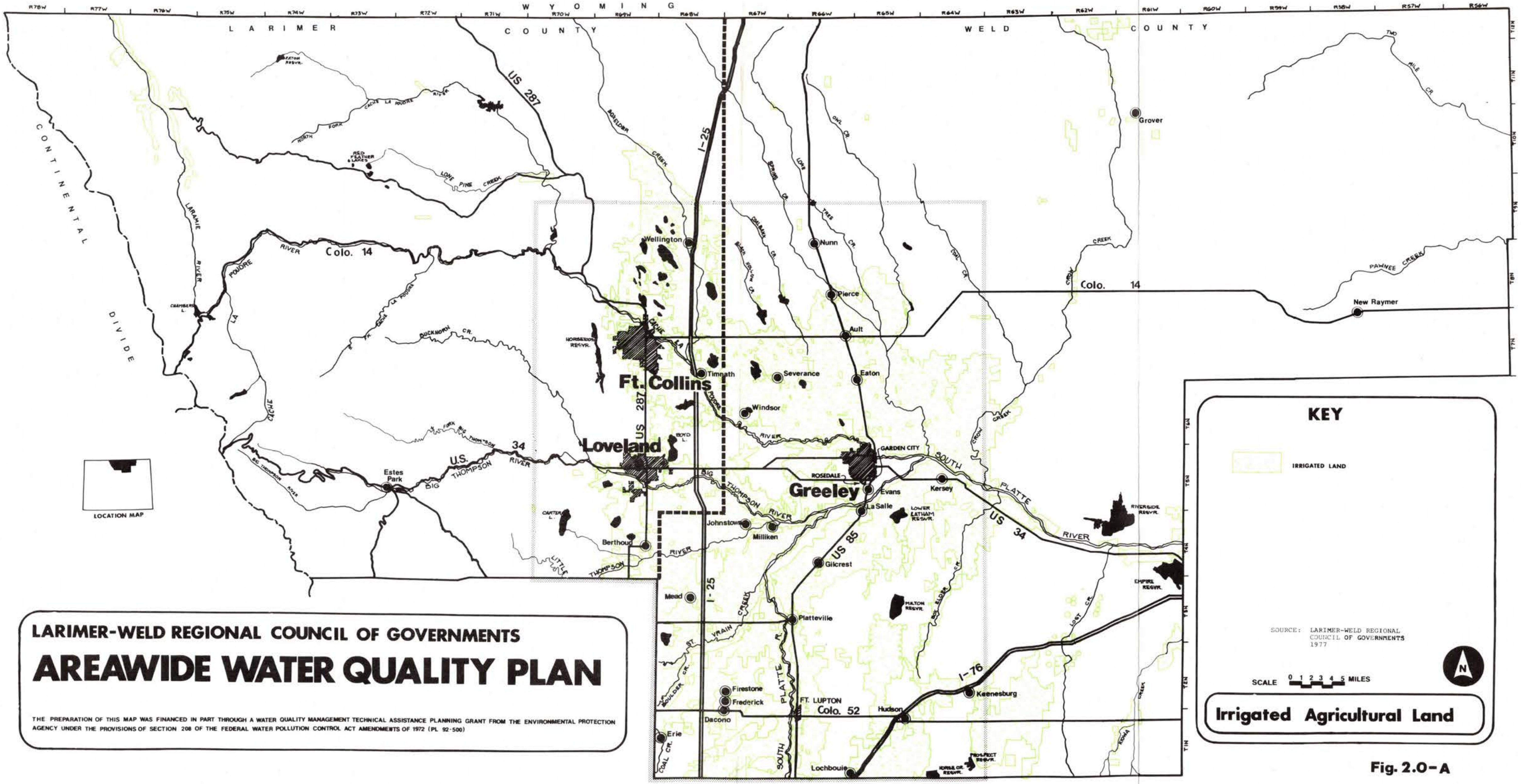
IRRIGATION IN THE LARIMER-WELD REGION

Irrigated agriculture has been the cornerstone of the economy in the Larimer-Weld region since the 1870's, and continues to be a major element in the regional and state economy. There are approximately one-half million acres of irrigated farmland in the Larimer-Weld region. Corn and sugar beets are the most economically important crops. A portion of the corn produced supplies the regional cattle feeding industry, which produces 800,000 to 900,000 head of fattened cattle each year. The extent of irrigated land in the region is shown in Figure 2.0-A.

2.1 DEVELOPMENT OF THE IRRIGATION SYSTEM

In 1858, the town of LaPorte was founded approximately ten miles northwest of the present site of the city of Fort Collins. The first attempt to raise crops under irrigation in the Cache la Poudre valley was at LaPorte in 1860. Vegetables, small fruits, hay and oats were raised. Ditches were small and irrigated only alluvial bottomland immediately adjacent to the river. Prior to 1870, only about 1000 acres were irrigated in the region.

The real boom began with the arrival of the Union Pacific Railroad and the coming of the Union Colony to the Greeley area in 1870. The Colony, under the leadership of Nathan C. Meeker and the patronage of Horace Greeley, was founded on the belief that higher lands above the river could be successfully adapted to cultivation with irrigation. The colonists are credited for putting the use of water for irrigation on a truly practical and cooperative basis. No other irrigated region in the world supplied the inspiration or example as did the colonists in systematizing the practice of irrigation, (Steinel, 1926).



LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS

AREAWIDE WATER QUALITY PLAN

THE PREPARATION OF THIS MAP WAS FINANCED IN PART THROUGH A WATER QUALITY MANAGEMENT TECHNICAL ASSISTANCE PLANNING GRANT FROM THE ENVIRONMENTAL PROTECTION AGENCY UNDER THE PROVISIONS OF SECTION 208 OF THE FEDERAL WATER POLLUTION CONTROL ACT AMENDMENTS OF 1972 (PL 92-500)

KEY

🟩 IRRIGATED LAND

SOURCE: LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS 1977

SCALE 0 1 2 3 4 5 MILES

N

Irrigated Agricultural Land

Fig. 2.0–A

They pooled their money to buy land and to construct irrigation canals (Greeley No. 2 and Greeley No. 3 Canals). Water rights were attached to a particular piece of land but could be rented out to other farms for one season. No charges were made for the use of water, only a fee of $.25 per acre was charged for ditch maintenance.

This method of supplying water to farms along the Greeley No. 2 and 3 was in direct contrast to other canals within the state during the 1870's and 1880's. Private companies including English companies owned canal systems and in turn placed a royalty of $10 to $30 an acre for the privilege of using the water carried by the canal. A State Supreme Court decision in 1888 was made in favor of farmers which settled the fact that ditch companies were common carriers and that they have no property interest in the waters of the state, hence can charge no royalty and can make only a reasonable charge for conveying water to consumers.

This decision (Wheeler vs. Northern Irrigation Company, commonly called the English Company), curbed inflation and speculation and allowed irrigated agriculture to proceed in a more stable line under state supervision. Although the Greeley colonists were among the first to irrigate vast land areas above river valleys, many canal systems within the two-county region were started during the 1860's. The Big Thompson Ditch was built in 1864 and irrigated 1500 acres. Other canals out of the Big Thompson River that followed in the late 1860's and 1870's included the Handy Canal, Louden Canal, Hillsborough Canal, and the Home Supply Canal.

Irrigation from the St. Vrain River began about 1871 when a considerable acreage just east of Longmont was irrigated through the Highland Canal. Lesser capacity ditches followed during the 1870's in diverting water from the St. Vrain.

By 1882, the Cache la Poudre Valley was declared to be one vast network of irrigating canals. The Greeley colonists, as mentioned earlier, were irrigating the lower area of the Poudre Valley while large irrigated acreages in the upper portions around Fort Collins got started about 1872 when the Lake Canal was projected for 15 miles in length. The Mercer Canal was rechartered in 1872 and extended to 13 miles in length. Other canals from the Poudre followed quickly. The Larimer-Weld Canal, second largest in the state at that time, was supplying water to 60,000 acres by 1881.

Canals from the Platte, Little Thompson, and lower portions of Boulder Creek were also quickly constructed during the 1870's and 1880's. By 1890, more miles of canals had been constructed in the region than there was water available. It became apparent that late season water would have to be provided if the region was to produce large acreages of corn, sugar beets, and alfalfa.

Reservoirs were the partial answer to this acute late season water problem. The first plains irrigation reservoir of any size was constructed in 1890. This reservoir still goes by the name of Terry Lake and is located just north of Fort Collins. It was built by farmers of the Larimer and Weld Canal to supply late irrigation water to approximately 60,000 acres.

Many reservoirs were established throughout the region from 1900 to 1925. Reservoirs filled from the Poudre alone totalled 150,000 acre-feet of capacity by 1922. Enlargements to original, smaller reservoirs took place for many years; however, no significant changes took place in the amount of the total irrigated acreage after the turn of the century (Evans, 1971).

The Colorado-Big Thompson Project, initiated in 1938, consisted of a series of projects completed between 1951 and 1956. These projects imported water from the Western Slope of Colorado and provided for the storage and delivery of this water nearly anywhere in that portion of the two-county region irrigated with surface water. In the system, water from five Western Slope lakes in the Colorado Basin can be carried through the Alva B. Adams Tunnel and delivered to several reservoirs in the Big Thompson Basin. Water delivered to the foothills area can be carried through the Charles Hansen Canal north into Horsetooth Reservoir and eventually into the Cache la Poudre. Water carried into the foothills area is put in Carter Lake to be carried south by the St. Vrain Supply Canal which can feed the Little Thompson, St. Vrain Creek, Left Hand Creek, and Boulder Creek. Water from the Big Thompson Project has not been used to irrigate more land. Rather, it is used to supply the late season water needed to grow corn, beets, and other crops in the existing irrigated areas where late season water had historically been lacking.

2.1.1 The Larimer-Weld Region

The Larimer-Weld region, located in northern Colorado, extends from the Continental Divide and North Platte River Basin boundaries on the west to well out onto the northeastern Colorado plains. Both counties are bounded by the Wyoming border on the north and the Weld County line extends southward to only around fifteen miles north of Denver. Snowmelt from the mountain region supplies water for the Cache la Poudre

River, Big Thompson River, Little Thompson River, and St. Vrain Creek, as well as a few of their tributaries. The South Platte flows into Weld County from the south. Its origin is in the mountains southwest of Denver and is another source of water to the region.

The Larimer-Weld region is semi-arid and supports only range land and some winter wheat under non-irrigated conditions. Mean annual precipitation for Greeley and Fort Collins is 12.05 and 14.58 inches per year, respectively. Table 2.1.1-A shows a yearly breakdown of these figures. Much of the precipitation comes during the months of April, May, and June, as seen in the monthly breakdown shown in Figure 2.1.1-A.

Temperature is one of the major limiting factors on the variety of crops grown in the Larimer-Weld region. (Figure 2.1.1-B) The average length of the growing season in the irrigated area is from 140 to 145 days. This is sufficient to raise corn, sugar beets, grains, potatoes, beans, alfalfa, and many vegetables. Crop types are largely the result of the climate of the Larimer-Weld region.

2.2 DISTRIBUTION OF IRRIGATED LAND

2.2.1 Land Use and Ownership in the Larimer-Weld Region

Land use for each county is shown in the pie charts in Figure 2.2.1-A. The largest contrast between the two counties is the percentage of land in Federal and State ownership Larimer County is 56 percent owned by Federal and State versus 9 percent for Weld County.

2.2.2 Distribution of Irrigated Land in the Larimer-Weld Region

Most of the irrigated land in Larimer and Weld Counties lies below the major canals supplying surface water. Many of the areas irrigated by wells rely upon recharge by seepage from adjacent irrigation canals and farms. While surface water is by far the most important source to the west of the Platte, groundwater is a significant source to some areas southeast and east of the Platte River.

The location of irrigated lands is a result of the proximity to the canal system or availability of groundwater. Figure 2.0-A shows the location of irrigated land in the Larimer-Weld region. Table 2.2.2-A gives a breakdown of irrigated acreage by subbasins.

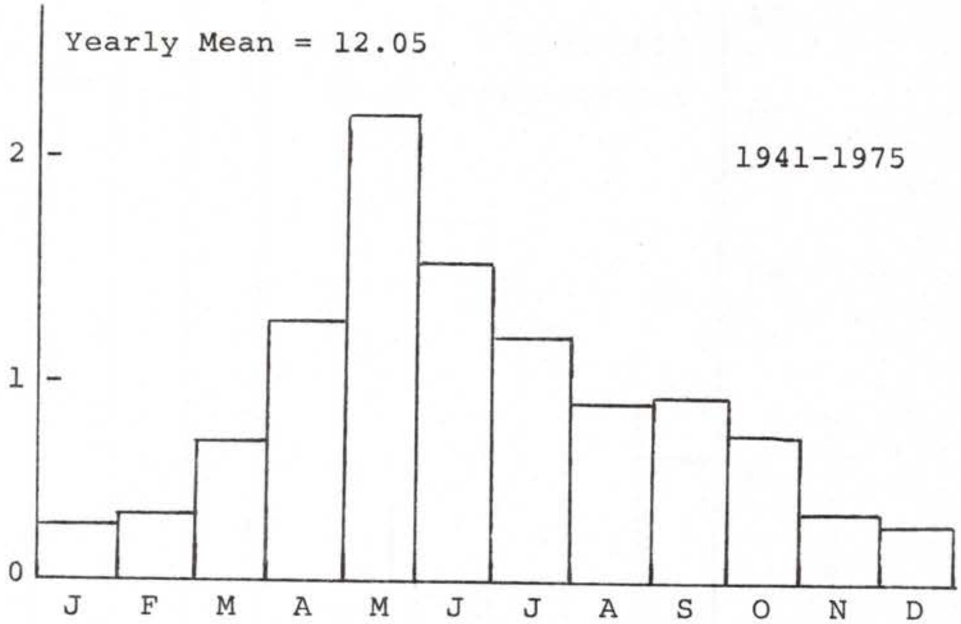
Irrigated acreage changes yearly in the two-county area. Urbanization takes land out of agricultural use while newly

TABLE 2.1.1-A

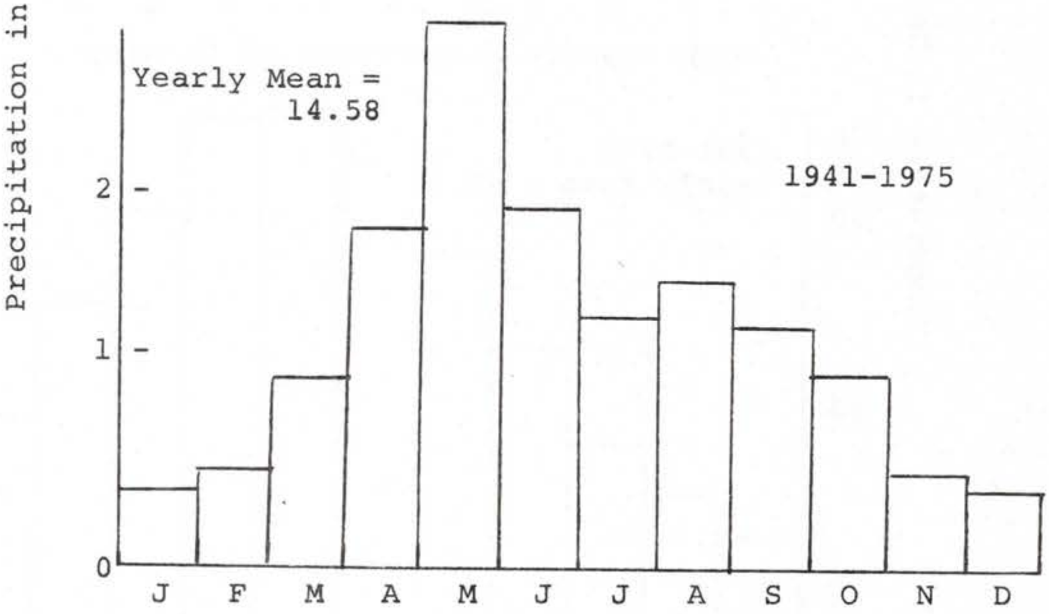
ANNUAL AND MEAN ANNUAL PRECIPITATION FOR GREELEY, FORT COLLINS *

YEAR	GREELEY	FORT COLLINS
1941	16.00	17.81
42	16.25	21.19
43	8.90	12.27
44	13.19	13.53
45	16.77	15.73
46	11.31	14.11
47	14.26	17.95
48	5.92	10.45
49	12.14	18.79
50	9.28	12.70
51	15.45	22.52
52	9.24	12.74
53	8.73	11.42
54	5.65	7.98
55	11.42	12.97
56	10.43	12.19
57	14.16	19.56
58	12.86	17.44
59	11.86	14.67
60	10.30	10.01
61	18.68	28.42
62	10.96	13.20
63	12.98	12.00
64	7.71	8.07
65	16.21	16.17
66	10.64	7.34
67	14.07	21.29
68	8.44	13.31
69	17.18	17.71
70	12.16	14.29
71	11.61	12.86
72	14.34	9.91
73	10.85	13.16
74	10.76	10.96
75	11.03	15.62
Mean	12.05	14.58

* Data collected from State Climatologist Office, Colorado State University, Fort Collins, Colorado.



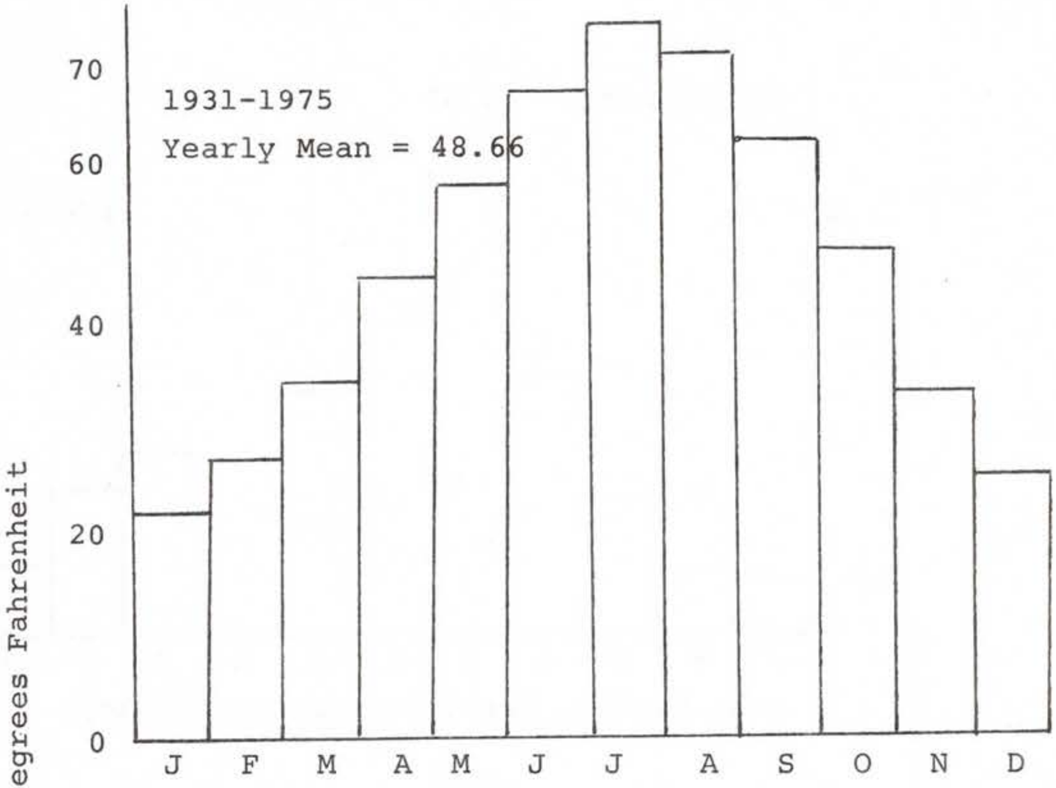
Mean Monthly Precipitation at Greeley



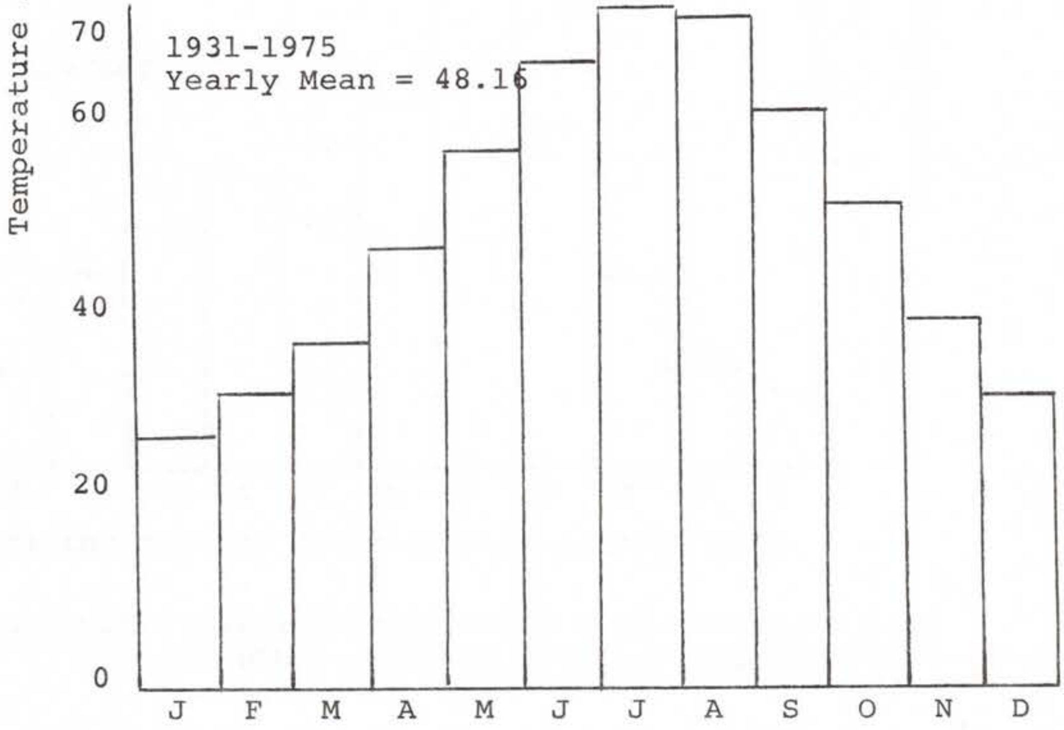
Mean Monthly Precipitation at Fort Collins

Data collected from State Climatologist Office, Colorado State University, Fort Collins, Colorado.

Figure 2.1.1-A Mean Monthly Precipitation at Greeley and Fort Collins



Mean Monthly Temperature at Greeley



Mean Monthly Temperature at Fort Collins

Data collected from State Climatologist Office, Colorado State University, Fort Collins, Colorado.

Figure 2.1.1-B Mean Monthly Temperature at Greeley and Fort Collins.

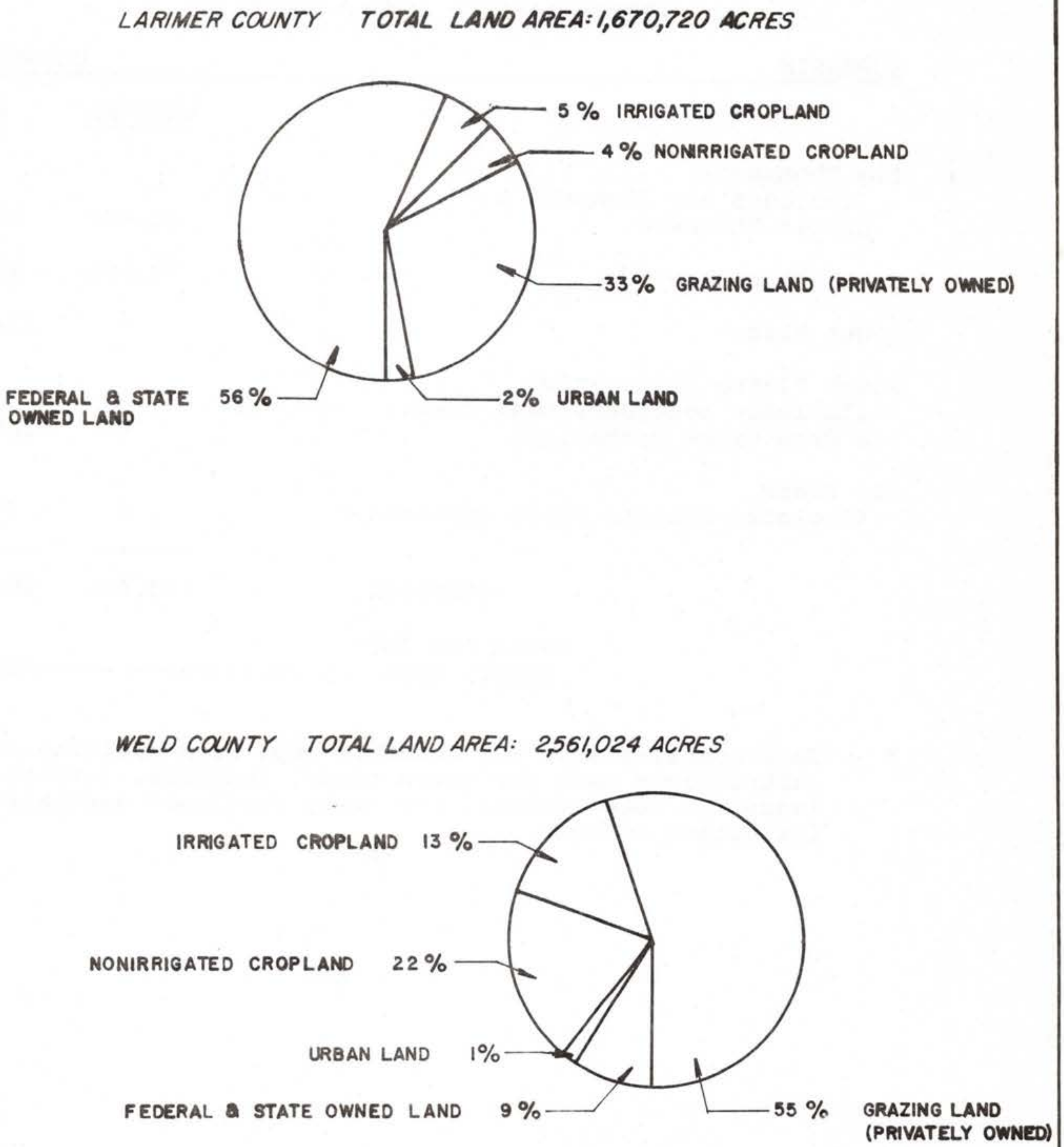


FIG. 2.2.1.A 1974 LAND USE IN THE LARIMER-WELD REGION [a]

[a] *1974 CENSUS OF AGRICULTURE (PRELIMINARY REPORT). U.S. DEPT. OF COMMERCE, ISSUED JULY & AUGUST 1976. AND TOUPS CORP.*

TABLE 2.2.2-A

IRRIGATED ACRES BY SUBBASIN

WITHIN LARIMER & WELD COUNTIES*

SUBBASIN	COUNTY	
	LARIMER	WELD
Big Thompson (Includes Big Thompson & Little Thompson	32,400	45,500
Cache la Poudre	70,600	83,300
South Platte	0	133,900
South Platte Tributaries (Includes Boxelder, Lost Creek, & Crow Creek subbasins)	0	109,600
St. Vrain (Includes Boulder Creek subbasin)	0	33,200
SUBTOTAL	103,000	405,500
TOTAL FOR TWO-COUNTY AREA		508,500

* Data compiled from SCS Land Use Maps with addition or subtractions made for known roads, feedlots, farmsteads, industry, subdivisions, and newly developed sprinkler irrigation systems.

developed irrigation wells add to the total of irrigated acreage. Total irrigated acreage in the two-county area varies according to the source of information. Table 2.2.2-B illustrates the variance.

2.3 ECONOMIC CONDITIONS IN THE LARIMER-WELD REGION

2.3.1 Crop Types and Values

The irrigated portion of Larimer and Weld Counties is one of the richest agriculture areas in the areas in the nation. Soil, water, and climate provide the ingredients for sustained high crop yields. Major crops grown include: corn for silage (48% of state total), sugar beets (38%), dry beans (28%), barley (24%), corn for grain (19%), oats (18%), hay (17%), potatoes (10%), and winter wheat (9%). Values of all crops produced in the region were nearly $78 million in 1971 and $173 million in 1975, (Colorado Department of Agriculture, 1976).

The production of livestock is similarly important to the regional and state economics. The two-county region had 47% of all cattle on feed in Colorado, 23% of cattle and calves on farms, and 40% of dairy cattle as of January 1, 1976.

Figure 2.3.1-A presents economic values for various crops in the two-county region. Sugar beets and corn for silage lead all other crops in the region in terms of total dollar value during 1974. It should be pointed out that sugar prices have fallen substantially since the 1974 census. The economic value of sugar beet production in the region during 1976 and 1977 would show a marked decrease from the 1974 values. Other crops that add substantial economic value within the region but are not presented on the table include onions, carrots, cabbage, broccoli, tomatoes, sweet corn, cucumbers, string beans and other lesser grown vegetable crops.

2.3.2 Farm Size Distribution and Values

Figure 2.3.2-A and 2.3.2-B shows the farm size distribution, total number of farms, and the number of farms by value of sales in Larimer and Weld Counties for 1969 and 1974. In this table we see that there has been a slight decrease in the total number of farms. Each size category of farms had similar decreases from 1969 to 1974. The average value per farm nearly doubled during the five year period. This value includes land and buildings. A total of 1,586 farms each showed gross sales of over $40,000 in 1974. This represented over 37 percent of the total number of farms within the two-county region.

TABLE 2.2.2-B

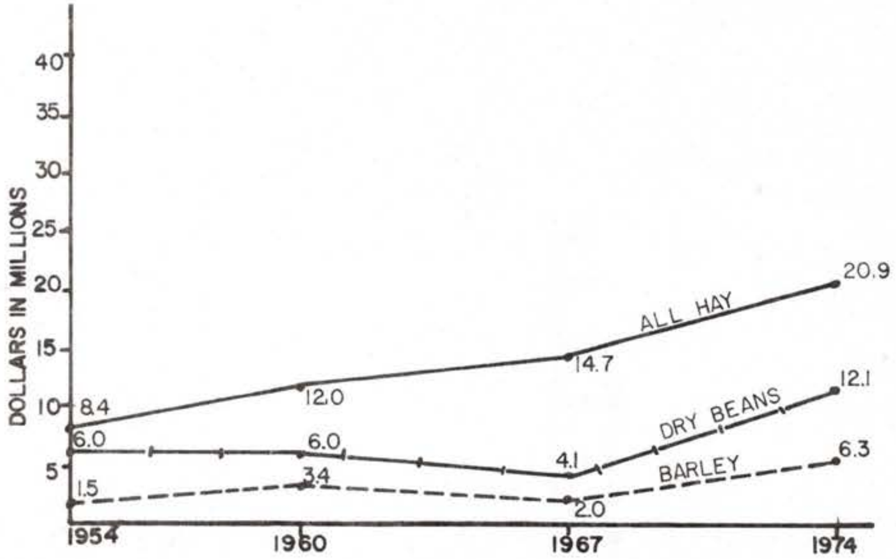
COMPARISON OF IRRIGATED ACREAGES

	SOURCE NUMBER			
COUNTY	A	B	C	D
Larimer	102,477	107,780	87,500	103,000
Weld	367,491	416,850	401,073	405,500
Total	469,968	524,630	488,573*	508,500**

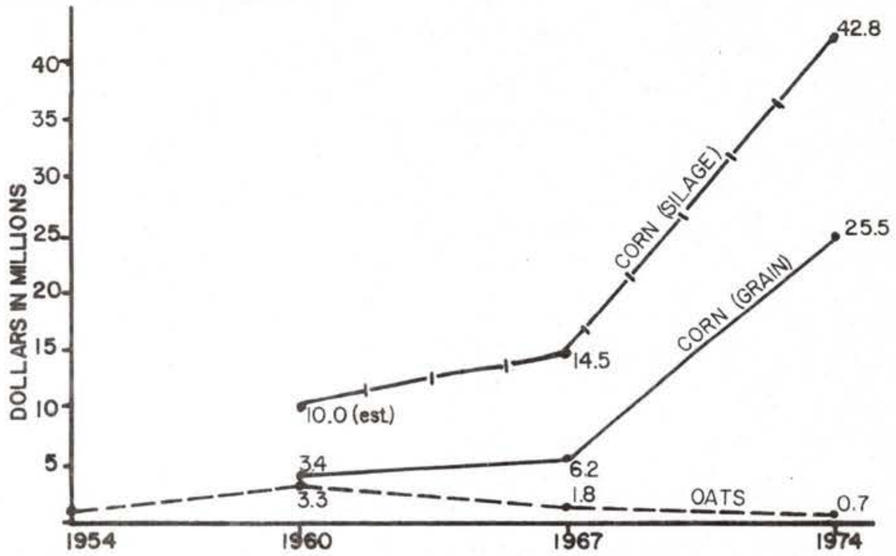
Source A: 1969 Agriculture Census, U.S. Department of Commerce
B: 1970 Agriculture Statistics, Colorado Department of Agriculture
C: 1974 Larimer & Weld Counties Abstract of Assessment as published by each County Assessor
D: Toups Corporation, Loveland, Colorado, October, 1976.

* Total does not include 50,628 acres in the two-county area that is titled "Meadow and Irrigated Pasture Land" by both County Assessors. Toups Corporation assumes that most of this acreage is low-lying bottomland that is subirrigated or lands subject to periodic overflows from adjacent streams.

** Toups Corporation final acreage resulted from comparing Sources A, B, and C. Figures were then adjusted slightly after discussions on urbanization and newly developed center-pivot irrigation systems with personnel located at SCS Field Offices in Brighton, Longmont, Greeley, and Fort Collins. David Geoglein, salesman employed by Raincat Irrigation Systems located at Greeley, also supplied information regarding newly developed center-pivot sprinkler systems within the two-county region. Toups' final acreage does not include sub-irrigated acreage or so called "meadow land".



LARIMER-WELD CROP PRODUCTION



LARIMER-WELD CROP PRODUCTION

FIG. 2.3.1-A ECONOMIC VALUE FOR VARIOUS CROPS WITHIN THE TWO COUNTY REGION

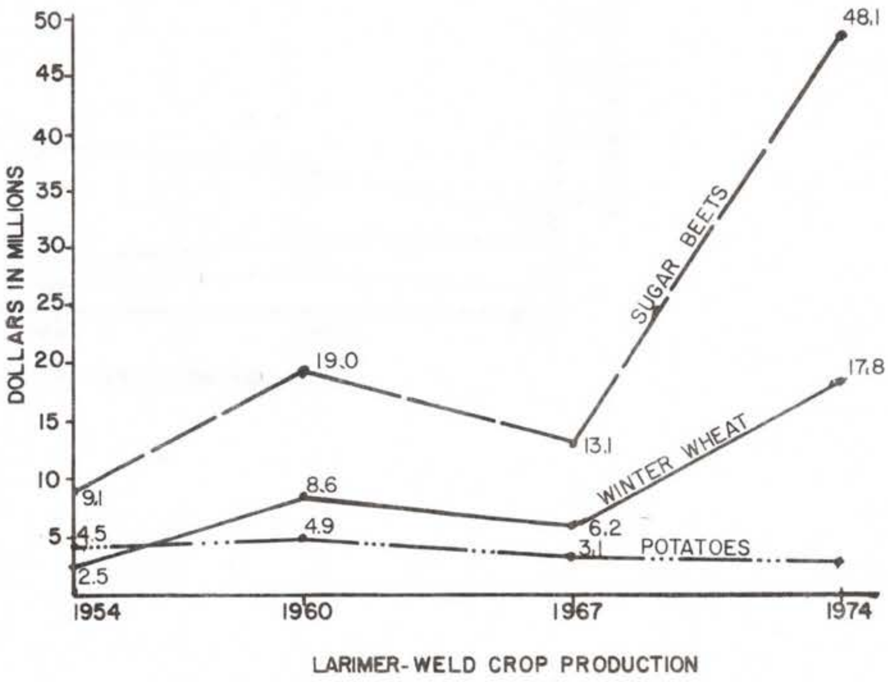


FIG. 2.3.1-A (CONT.) ECONOMIC VALUE FOR VARIOUS CROPS WITHIN THE TWO COUNTY REGION [a]

[a] *1969 & 1974 CENSUS OF AGRICULTURE (PRELIMINARY REPORT) U.S. DEPT. OF COMMERCE, AND 1954-1976 COLORADO AGRICULTURE STATISTICS, COLO. DEPT. OF AGRICULTURE.*

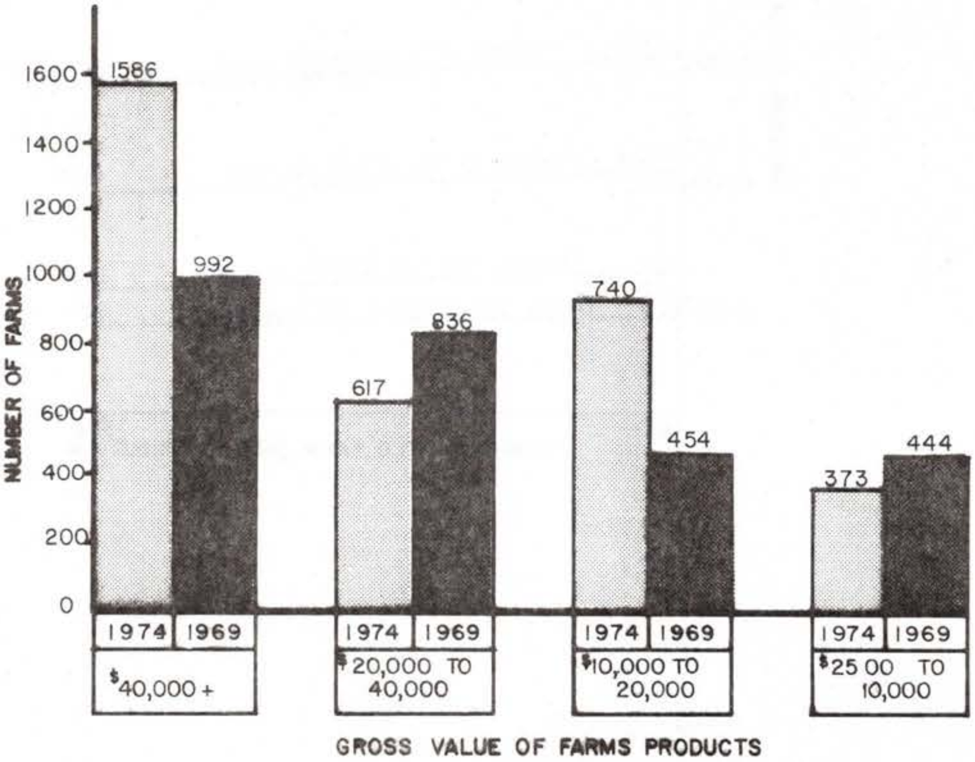
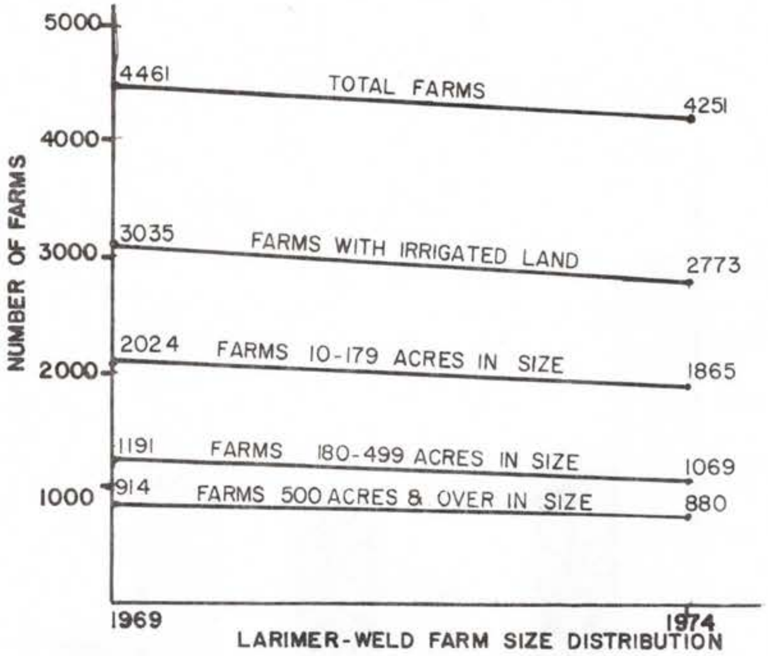


FIG. 2.3.2-A FARMS BY VALUE OF SALES, LARIMER & WELD COUNTIES [a]

[a] *1974 CENSUS OF AGRICULTURE (PRELIMINARY REPORT) U.S. DEPT. OF COMMERCE, ISSUED JULY 1976 FOR WELD COUNTY & AUGUST 1976 FOR LARIMER COUNTY.*



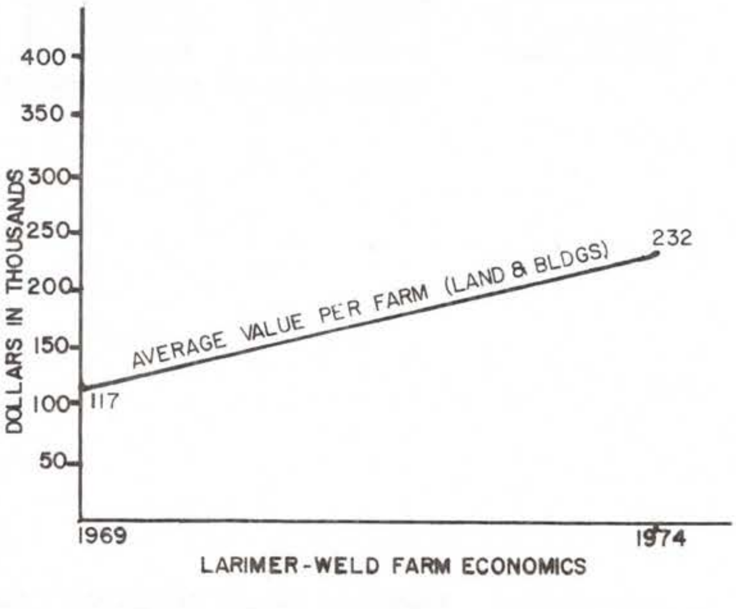


FIG. 2.3.2-B. **FARM SIZE DISTRIBUTION & FARM ECONOMICS IN LARIMER & WELD COUNTIES**

CHAPTER 3.0

IRRIGATION PRACTICES

3.1 DIVERSIONS

3.1.1 Points of Diversions

Irrigation diversions are made from all of the rivers in the basin. The Cache la Poudre has the most complicated system. There are 23 separate diversions from the mainstream of the Cache la Poudre. In addition, there are diversions from the North Poudre, Boxelder Creek, and other tributaries of the Cache la Poudre. Figure 3.1.1-A shows a schematic of the distribution system in the Poudre Basin. Water deliveries are made by a complicated system of exchange and replacement. The many lakes in the basin are utilized in the exchange system.

Diversion points for the Big and Little Thompson are shown on Figure 3.1.1-B. There are thirteen points of diversion from the Big Thompson and nine points of diversion from the Little Thompson. The exchange system is much less important in the Big Thompson than in the Poudre. Exchange is insignificant in the Little Thompson.

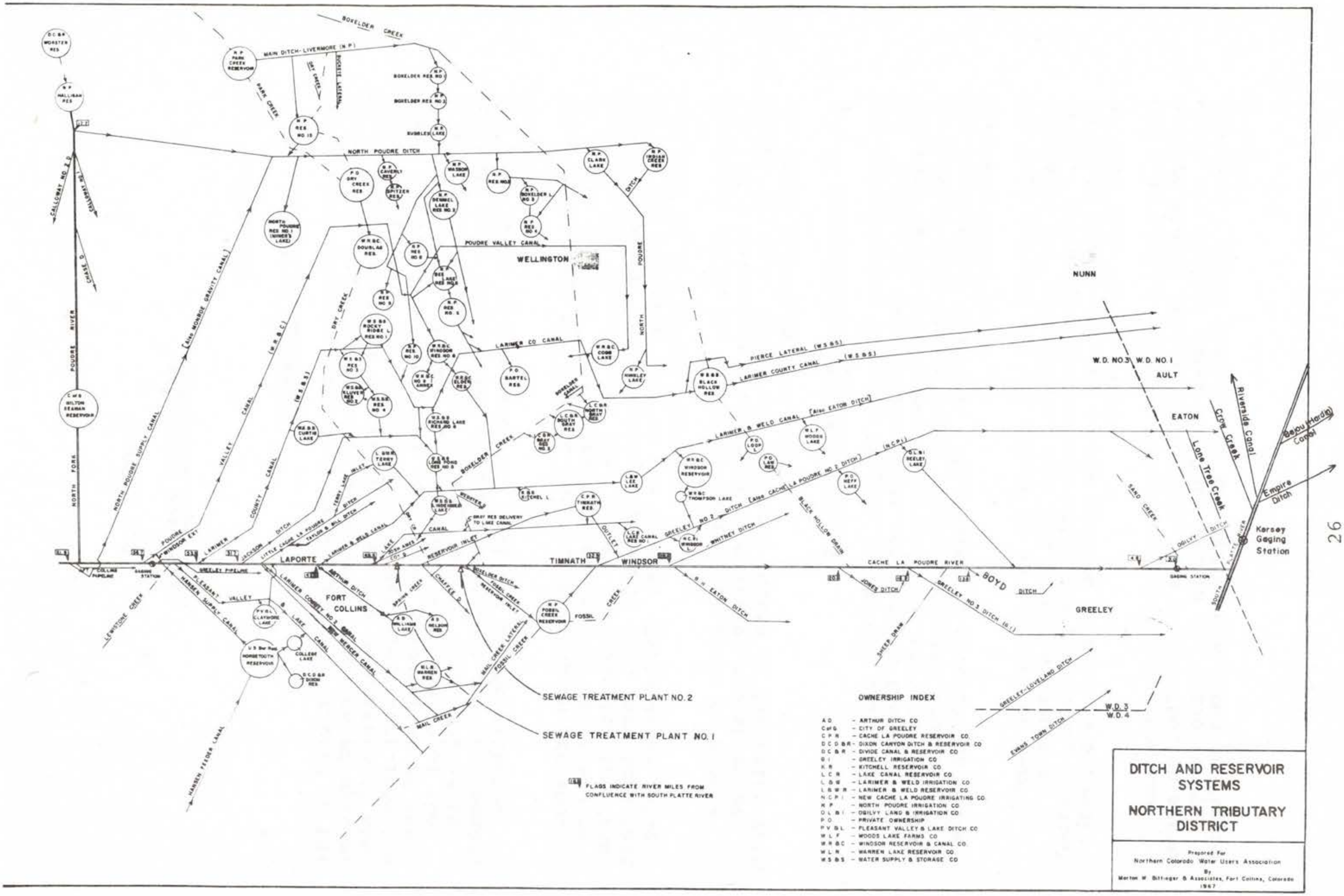
Diversion points on the South Platte are shown on Figure 3.1.1-C. Diversions downstream from Kersey are shown on Figure 3.1.1-A. There are fourteen points of diversion from the South Platte in Weld County.

3.1.2 Colorado-Big Thompson Project

The Colorado-Big Thompson Project (C-BT) was built by the U.S. Bureau of Reclamation under contract to the Northern Colorado Water Conservancy District. The project was built to provide late season water to the irrigated area within the Conservancy District. This water is diverted from the Colorado River Basin.

The C-BT project did not result in an increase of land available for agricultural use, but rather a change in crops. A considerable acreage which was previously planted in small grains and hay is now planted in corn as a result of this late season water.

The C-BT project includes diversion facilities from the western slope, several reservoirs, and a distribution system which can deliver water anywhere within the Conservancy District. Major features of the system are shown on Figure 3.1.2-A.



FLAGS INDICATE RIVER MILES FROM CONFLUENCE WITH SOUTH PLATTE RIVER

OWNERSHIP INDEX

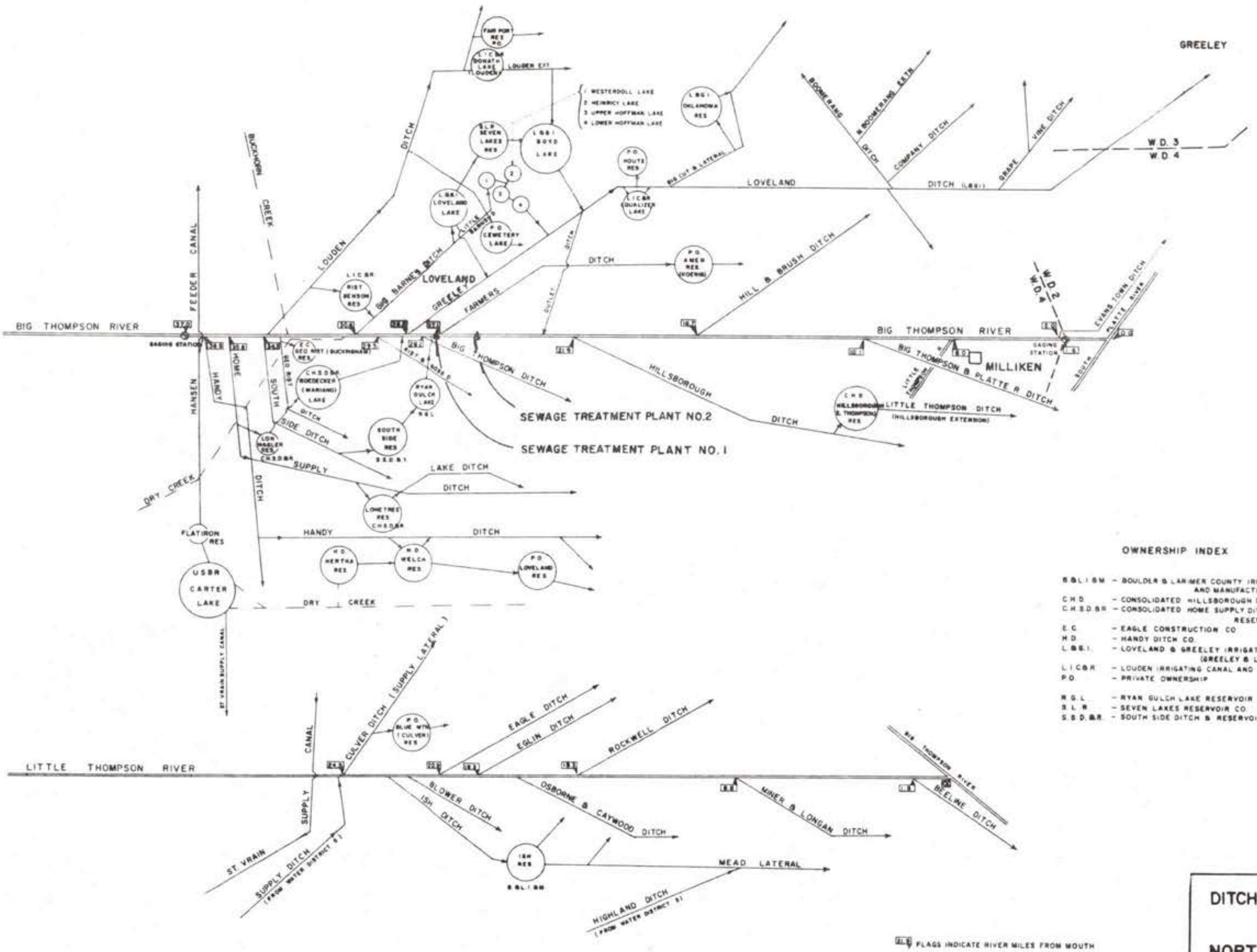
A.D.	ARTHUR DITCH CO
C of G	CITY OF GREELEY
C.P.R.	CACHE LA POUDRE RESERVOIR CO.
D.C.D.&R.	DIXON CANYON DITCH & RESERVOIR CO
D.C.&R.	DIVIDE CANAL & RESERVOIR CO
G.I.	GREELEY IRRIGATION CO
K.R.	KITCHELL RESERVOIR CO
L.C.R.	LAKE CANAL RESERVOIR CO
L.&W.	LARIMER & WELD IRRIGATION CO
L.&W.R.	LARIMER & WELD RESERVOIR CO
N.C.P.I.	NEW CACHE LA POUDRE IRRIGATING CO
N.P.	NORTH POUDRE IRRIGATION CO
O.L.&I.	OGILVY LAND & IRRIGATION CO
P.O.	PRIVATE OWNERSHIP
P.V.&L.	PLEASANT VALLEY & LAKE DITCH CO
W.L.F.	WOODS LAKE FARMS CO
W.R.&C.	WINDSOR RESERVOIR & CANAL CO
W.L.R.	WARREN LAKE RESERVOIR CO
W.S.&S.	WATER SUPPLY & STORAGE CO

DITCH AND RESERVOIR SYSTEMS

NORTHERN TRIBUTARY DISTRICT

Prepared For
Northern Colorado Water Users Association
By
Morton W. Bittinger & Associates, Fort Collins, Colorado
1967

FIG. 3.1.1-A



OWNERSHIP INDEX

B.&L.I.&M.	- BOULDER & LARIMER COUNTY IRRIGATING AND MANUFACTURING CO
C.H.D.	- CONSOLIDATED HILLSBOROUGH DITCH CO
C.H.S.D.&R.	- CONSOLIDATED HOME SUPPLY DITCH AND RESERVOIR CO
E.C.	- EAGLE CONSTRUCTION CO
H.D.	- HANDY DITCH CO.
L.&G.I.	- LOVELAND & GREELEY IRRIGATING CO (GREELEY & LOVELAND)
L.I.C.&R.	- LOUDEN IRRIGATING CANAL AND RESERVOIR CO
P.O.	- PRIVATE OWNERSHIP
R.G.L.	- RYAN GULCH LAKE RESERVOIR CO
S.L.R.	- SEVEN LAKES RESERVOIR CO
S.S.D.&R.	- SOUTH SIDE DITCH & RESERVOIR CO

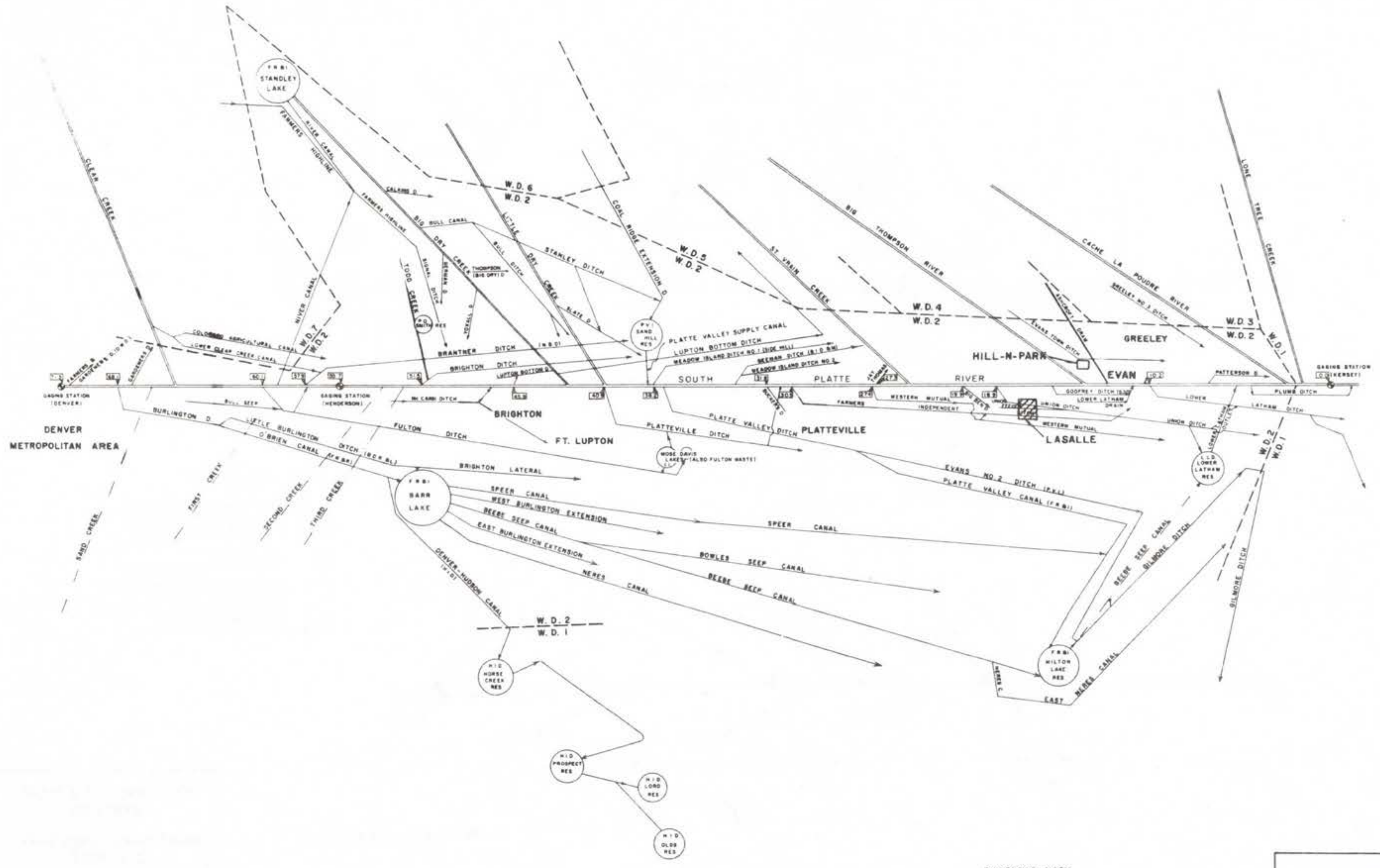
21.9 FLAGS INDICATE RIVER MILES FROM MOUTH

DITCH AND RESERVOIR SYSTEMS

NORTHERN TRIBUTARY DISTRICT

Prepared For
Northern Colorado Water Users Association
By
Morton W. Bittinger & Associates, Fort Collins, Colorado
1967

FIG. 3.1.1-B



FLAGS INDICATE RIVER MILES FROM DOWNSTREAM GAGING STATION

OWNERSHIP INDEX

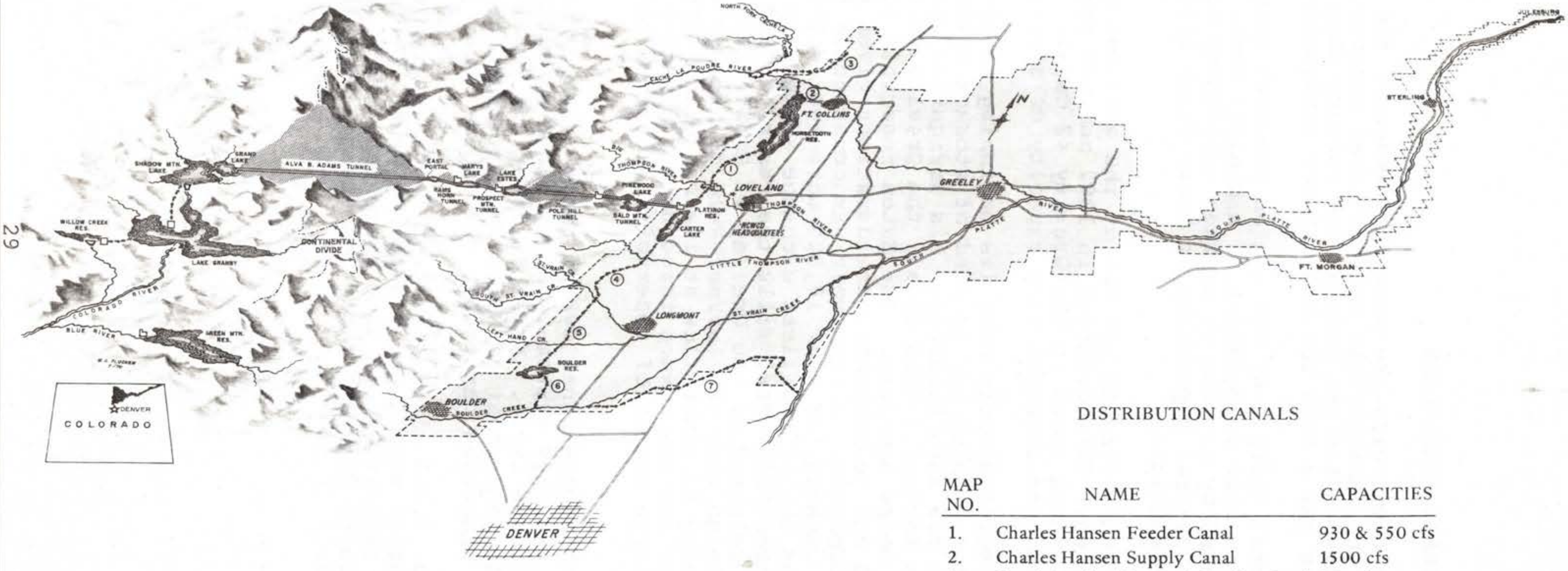
B.D.R.& L. - BURLINGTON DITCH, RESERVOIR & LAND CO.
B.I.D.& M. - BEEMAN IRRIGATING DITCH & MILLING CO.
D.W.D. - DENVER WATER DEPARTMENT
F.R.& I. - FARMERS RESERVOIR & IRRIGATION CO.
H.I.D. - HENRYLYN IRRIGATION DISTRICT
I.I. - IONE INVESTMENT CO.
L.L.D. - LOWER LATHAM DITCH CO.
N.B.D. - NEW BRANTNER DITCH CO.
P.I.& M. - PLATTEVILLE IRRIGATION & MILLING CO.
P.V.I. - PLATTE VALLEY IRRIGATION CO.
S.3.D. - SECTION 3 DITCH CO.

DITCH AND RESERVOIR
SYSTEMS
UPPER PLAINS DISTRICT

Prepared For
Northern Colorado Water Users Association
By
Morton W. Bittinger & Associates, Fort Collins, Colorado
1968

FIG.3.1.1-C

LOCATION OF COLORADO – BIG THOMPSON PROJECT FACILITIES AND DISTRICT SERVICE AREA



DISTRIBUTION CANALS

MAP NO.	NAME	CAPACITIES
1.	Charles Hansen Feeder Canal	930 & 550 cfs
2.	Charles Hansen Supply Canal	1500 cfs
3.	North Poudre (Munroe) Gravity Canal	250 cfs
4.	St. Vrain Supply Canal	625 & 575 cfs
5.	Boulder Feeder Canal	200 cfs
6.	Boulder Creek Supply Canal	200 & 175 cfs
7.	South Platte Supply Canal	230 to 115 cfs

FIG. 3.1.2-A Source: Northern Colorado Water Conservancy District.

3.2 STORAGE RESERVOIRS

Numerous reservoirs are located throughout the irrigated area of the Larimer-Weld region. Most reservoirs were constructed after the turn of the century when mutual canal companies saw a need for late summer irrigation water.

The natural terrain of the region provided excellent reservoir sites for water impoundment at a minimal cost. Reservoirs were formed by placing an earthen embankment at the lower end of a natural depression or basin which allowed for large storage capacities.

The Timnath Reservoir was one of the earliest reservoirs constructed. This occurred in 1892 and was completed by farmers owning stock in the Greeley #2 Canal. This reservoir has since been enlarged to a capacity of over 10,000 acre-feet.

The Windsor Reservoir owes its beginning to ex-Governor B.H. Eaton. Eaton was in need of storage water to help irrigate his farm holdings. His irrigation water was supplied from the Larimer & Weld Canal; the Greeley #2 Canal was located below his farm. The Eaton reservoir plan was greatly enlarged due to economic considerations given by these two canal companies. A reservoir was constructed to have a useable capacity of over 18,000 acre-feet. This reservoir served as one of the first exchange systems in the region. The Larimer-Weld Canal fills the reservoir and water can then be released to the Greeley #2 Canal. The actual exchange is completed when the Larimer-Weld diverts an equal part of the Greeley #2 river flow at its headgate. Irrigation water exchanges are now common throughout the region mainly because of the large number of reservoirs scattered throughout the area.

The North Poudre Canal System plays a larger role in the general exchange system than any other canal system in the region [Evans 1971]. Numerous lakes and reservoirs are under the management of North Poudre which carries out complex exchanges throughout the Poudre River Basin.

Table No. 3.2-A gives a list of major reservoirs presently in operation within the two-county area. Ownership and maximum capacities are also presented. Data was supplied by the Northern Colorado Water Conservancy District located at Loveland.

TABLE 3.2-A MAJOR RESERVOIRS & CAPACITIES IN LARIMER-WELD REGION

Name	Capacity (ac-ft)	Ownership
Cache la Poudre Basin		
Hallingan	6,428	North Poudre Ditch Co.
Indian Creek	1,906	North Poudre Ditch Co.
Clarks Lake	871	North Poudre Ditch Co.
N. Poudre #2	3,478	North Poudre Ditch Co.
N. Poudre #3	2,760	North Poudre Ditch Co.
N. Poudre #4	1,386	North Poudre Ditch Co.
N. Poudre #5	7,217	North Poudre Ditch Co.
N. Poudre #6	7,011	North Poudre Ditch Co.
N. Poudre #15	5,517	North Poudre Ditch Co.
Park Creek	7,320	North Poudre Ditch Co.
Fossil Creek	11,100	North Poudre Ditch Co.
Cobb	22,300	Windsor Res. & Canal Co.
Douglas	8,834	Windsor Res. & Canal Co.
#8	10,291	Windsor Res. & Canal Co.
#8 Annex	3,657	Windsor Res. & Canal Co.
Chambers	8,824	Water Supply & Stor. Co. (Larimer County Canal)
Long Draw	4,400	Water Supply & Stor. Co.
Black Hollow	7,486	Water Supply & Stor. Co.
Curtis	1,259	Water Supply & Stor. Co.
Kluver	1,231	Water Supply & Stor. Co.
Long Pond	3,847	Water Supply & Stor. Co.
Richards	919	Water Supply & Stor. Co.
Rocky Ridge	4,493	Water Supply & Stor. Co.
W.S. & St. #3	4,826	Water Supply & Stor. Co.
W.S. & St. #4	1,142	Water Supply & Stor. Co.
Larimer-Weld (Terry)	8,028	Larimer & Weld Res. Co.
Eaton (Worster)	3,750	Larimer & Weld Res. Co.
Cache la Poudre Res. Co. (Timnath)	10,070	Cache la Poudre Res. Co.
Windsor Lake	1,277	Cache la Poudre Res. Co.
Barnes Meadows	2,046	City of Greeley
Big Beaver	1,693	City of Greeley
Comanche	2,256	City of Greeley
Peterson	1,184	City of Greeley
Seaman	5,008	City of Greeley
Claymore	956	Pleasant Valley & Lake Canal
Warren Lake	2,264	Larimer County #2
Miscellaneous Reservoirs	11,364	
Subtotal	124,286	

TABLE 3.2-A (Continued)

St. Vrain Basin [a]		
1/2 Beaver Park	2,161	Supply Ditch Company
1/2 Beaver Park		Highland Ditch Company
McIntosh	2,459	Highland Ditch Company
Highland #1	1,033	Highland Ditch Company
Highland #2	3,712	Highland Ditch Company
Highland #3	1,696	Highland Ditch Company
Foothills	4,346	Highland Ditch Company
Foster	2,000 (Est.)	Highland Ditch Company
Mulligan	880 (Est.)	Highland Ditch Company
Platte Valley Reservoir	3,076	Rough & Ready Ditch Co.
Oligarchy Reservoir #1	1,737	Oligarchy Ditch Co.
Union Reservoir (Calkins)	12,715	Union Reservoir Co.
Subtotal	35,277	
South Platte Basin (Brighton to Greeley)		
Lower Latham Reservoir	5,740	Lower Latham Res. Co.
Milton	43,140	Farmers Res. & Irrigation Co.
Subtotal	48,880	
Total All Major Storage Reservoirs (Excluding CBT Project)	414,531	
Colorado Big Thompson Project Reservoirs, (Eastern Slope Reservoirs Only		
Carter Lake	112,200	USBR
Flatiron	760	USBR
Horsetooth	151,800	USBR
Lake Estes	2,700	USBR
Marys Lake	900	USBR
Pinewood	2,200	USBR
Total CBT Eastern Slope Storage	270,560	

[a] These reservoirs provide water to farms in both Boulder and Weld Counties and may be located in Boulder County as well as Weld County.

3.3 CONVEYANCE SYSTEMS

3.3.1 Water Rights and Priorities

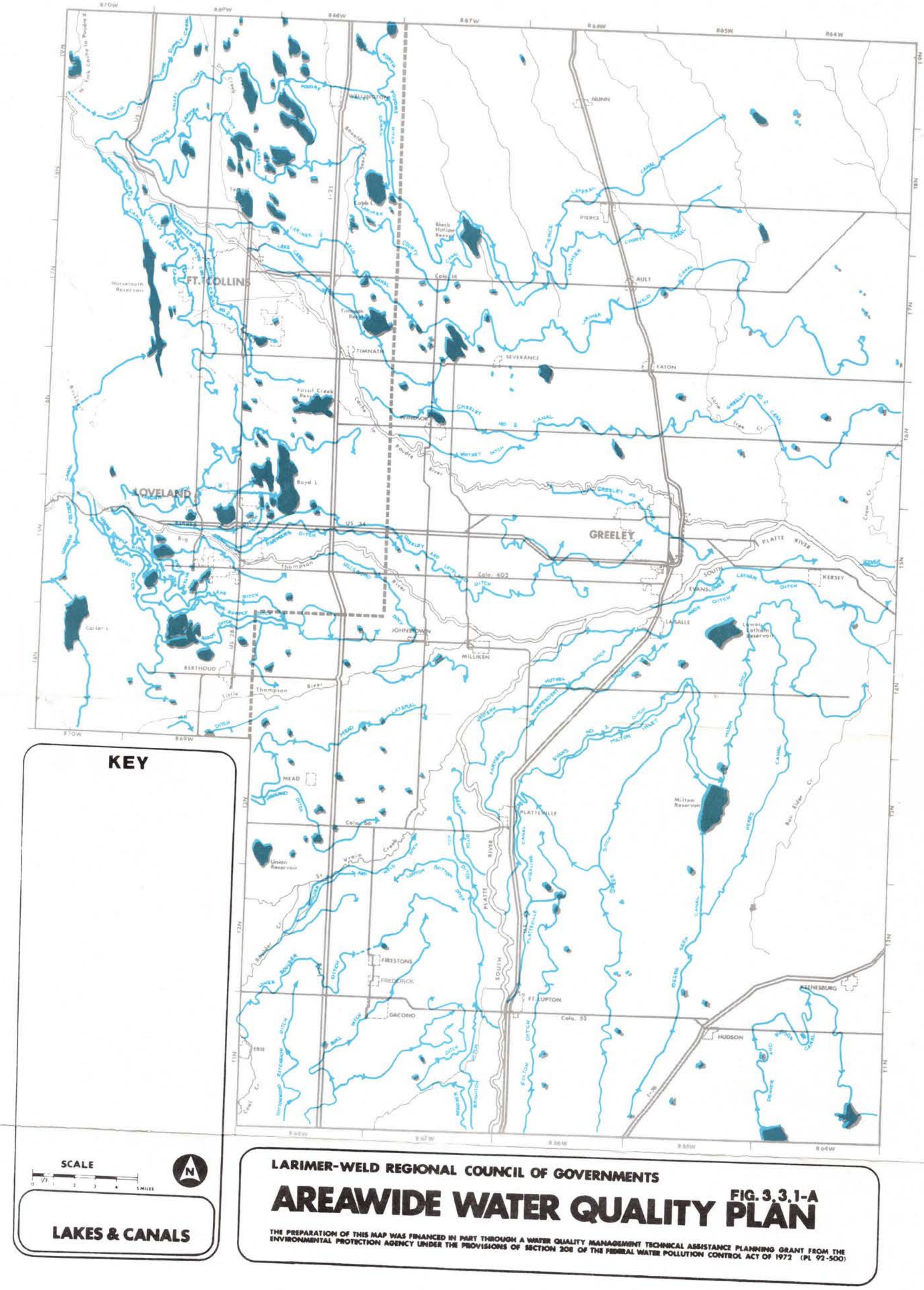
Colorado water rights are governed under the law of "Prior Appropriation." Many Western states, because of arid or semi-arid conditions, control the use of water just as Colorado does. Eastern states operate under riparian principles. The riparian owner has the right to make a reasonable use of the stream only if his land touches the stream. Other landowners do not have such rights.

In Colorado, a stream flowing by or through a farm does not mean that the farmer may use water from the stream for irrigation purposes. Prior appropriation gives the first user of water, obtained from natural sources, the continuing right to use said water regardless of the proximity of the land to the water source. Under this principle, the first or prior user of water for beneficial use has the best right. His right is specific as to time, place, and amount of water to be used. Water used from the same source by others is governed by the right of the prior user. In water short periods, the reduction of water to users is the reverse of the order in which they obtained their rights. A water right is said to be "senior" when the water right has a priority which predates other recorded water rights.

Pioneer farmers in the Larimer-Weld region started bonding together over one century ago by forming mutual stock companies. These companies saw the need to tap existing water supplies in order to irrigate portions of the semi-arid region. By the turn of the century, the irrigation stock companies had networked nearly one-half million acres of land with canals and their laterals. The total undertaking proved to be one of the largest privately financed irrigation systems in the world [NCWCD 1974/5]. Figure 3.3.1-A shows a map of the current canal system for the two-county region.

3.3.2 Early Canals

Canal No. 2, now known as Greeley No. 2 Canal, was the first large canal in the State of Colorado designed to irrigate terraces above the alluvial river bottoms [Evans 1971]. This canal was begun in 1870 by the leaders of the Union Colony which was located in the Greeley area. The point of diversion for the No. 2 Canal is on the north side of the Cache la Poudre River at a point approximately 2 miles southeast of Timnath. The canal continues eastward to Crow Creek near Barnsville.



LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS

AREAWIDE WATER QUALITY PLAN

FIG. 3.3.1-A

THE PREPARATION OF THIS MAP WAS FINANCED IN PART THROUGH A WATER QUALITY MANAGEMENT TECHNICAL ASSISTANCE PLANNING GRANT FROM THE ENVIRONMENTAL PROTECTION AGENCY UNDER THE PROVISIONS OF SECTION 208 OF THE FEDERAL WATER POLLUTION CONTROL ACT OF 1972 (PL 92-500)

TABLE 3.3.2-A OWNERSHIP OF COLORADO-BIG THOMPSON WATER

Class of Service	1975 Quota (ac-ft)	% of Total Quota	Deliveries (ac-ft)	% of Total
Irrigation	169,585	68.4	189,018	76.3
Municipal-Domestic	67,441	27.2	26,071	10.5
Multi-Purpose	10,974	4.4	3,950	1.6
Industrial	0	0.0	0	0.0
Subtotal	248,000	100.0	219,039	88.4
	Balance Cancelled		28,646	11.6
Total Certified for Delivery			247,686	100.0

Canal No. 3 was the first canal constructed by the Union Colony. This canal was relatively short and did not advance far from the Cache la Poudre River. This canal presently runs through the near center of Greeley and is only about 9 miles in length.

The Larimer & Weld Canal was the next large canal constructed which diverted water from the Cache la Poudre River. This canal was enlarged and lengthened during the period 1879-1881.

The Larimer County Canal and the North Poudre Canal followed with points of diversion placed farther up the Cache la Poudre. The North Poudre Canal maintains 214 miles of ditch system and has the distinct disadvantage of not receiving any return flows from other canal systems. It is the furthest north canal in the two-county region.

Irrigation canal companies were formed rapidly during early settlement of the two-county region. The period of time from the 1870's to the turn of the century was a time when the flows of the South Platte River, Big & Little Thompson Rivers, St. Vrain Creek, Boulder Creek and the Cache la Poudre River were heavily tapped by diversions.

3.3.3 Canal Lining

The total miles of all major canals within the two-county area and percentage of the total canal network that has been concrete lined were determined through personal interviews with ditch company personnel and SCS Field Office employees located in Greeley, Brighton, Longmont, and Fort Collins.

Major canals were defined as having an approximate capacity of 30 cubic feet per second and over. Numerous small ditches were identified with capacities from 5 to 30 cfs. The total miles of these smaller ditches may approach or exceed the total miles of the major canals.

SCS cumulative records show 782 miles of concrete ditch lining installed in the two-county region, as of 1977. This total is for all size ditches, including on-farm ditches.

The information collected in the interviews indicate that about 1,243 miles of major canals are operating within the two-county region. Only 3.1 percent of this total (40 miles) has been concrete lined. The balance of the concrete lining (742 miles) has been performed on the smaller ditches, laterals, and on-farm ditches.

SCS cumulative records also indicate that 561 miles of underground pipelines are being used to convey irrigation water in the two-county area. Less than one percent of this total has been installed by the major canals. Small lateral companies and individual farms have installed the balance of the pipelines now in operation.

Conclusions may be made based on the data collected in the interviews:

1. Individual farm owners (who usually are shareholders within the mutual canal stock company that provides water to their farm) would rather make capital improvements to their private lands than to the mutual ditch company because capital improvements are more tangible on their own farms.

2. Mutual ditch company governing boards take pride in holding annual assessment costs to a minimum for each shareholder. Most ditch companies assess for only bare operating and maintenance needs with little or any revenues set aside for planned or unplanned works of improvement.

3. Federal cost-sharing for conservation measures has been available in varying amounts through USDA agencies for a number of years. These cost-sharing monies have predominately been allocated to individual landowners to help pay the cost of conservation practices including pipelines and concrete ditch lining. This may be due, in part, to the lack of initiative taken by the major ditch companies. However, the overriding reason could be the philosophy that federal funds for cost-sharing practices should assist, directly, the greatest number of individuals possible thus placing canal companies in a low priority.

4. Cost-benefit data is generally lacking regarding canal lining. Typically, concrete lining for a canal with a 100 cfs capacity would require $75,000 per mile according to the SCS Area Engineer located at Greeley.

   The value of an acre foot of water varies from year to year because water is dependent upon the needs of the user. Natural precipitation amounts and time of season that this moisture is received will vary irrigation water needs considerably. The recent cost to purchase CBT water was about $600.00/AF (one unit). With an average delivery rate of 75 percent, the adjusted rate for CBT water, would be $800/AF. Colorado Big Thompson water values appear to be increasing rapidly primarily because of drought conditions throughout the region.

   A canal company could amoritize the $75,000 cost of lining over a 50-year period at a 7 percent interest rate. The yearly cost to the company would be $5,256. To purchase the right to use an acre foot of water yearly for 50-years at $800.00 could also be amoritized at 7 percent. This would show an annual value of $56.06 for each acre foot of water. The canal company would have to save nearly 94 acre feet of water yearly for each mile of lined canal to cover the costs.

3.3.4 Canal Seepage Losses

Scientific findings on establishing canal losses within the region are greatly lacking. The magnitude of the complexity of water accountability within the area is difficult to assess. Exchange water, exchange stock, irrigation return flows, storm flows, evaporation, and canal seepage all act to complicate water accounting. Seepage losses submitted by a few local canal companies through a questionnaire sent out by the Colorado Division of Water Resources in the Fall of 1976 are tabulated in Table 3.3.4-A. The losses are unofficial and have not been verified.

The 1974/75 Annual Report of the Northern Colorado Water Conservancy District (NCWCD) shows annual water losses as being less than 5 percent for their entire system. These losses occur through evaporation and seepage and through an over-delivery loss of 1 to 2 percent. Table 3.3.4-B shows comparisons for 1975 and averages for 1957-1974.

TABLE 3.3.4-A WATER LOSSES FROM SELECTED CANALS IN THE LARIMER-WELD REGION[a]

	Avg. Daily Diversion (cfs)	Loss (csf/mile)	Loss (acre-feet/ day/mile)	Approx. Miles of Canal	Loss cfs-Entire Canal	Canal[b] Efficiency(%)
Poudre Valley	350	5.6	11.2	30	168	52
Larimer County	500	4.04	8.08	42	170	66
Consolidated Hillsborough	63	0.5	1.0	18	9	86
Little Cache la Poudre	70	1.0	2.0	3.6	3.6	95
New Mercer	50	2.0	4.0	13	26	48
Larimer County #2	100	3.0	6.0	13.3	39.9	60
Lake	125	3.0	6.0	17	51	59
Boxelder	40	1.6	3.2	5.2	8.3	79
New Cache la Poudre (Greeley #2)	500	4.0	8.0	38	192	62
Greeley Canal #3	75	2.0	4.0	9	18	76
Whitney	62	2.5	5.0	7	17.5	72
Ogilvy	60	1.6	3.2	13	20.8	65
Larimer & Weld	700	3.85	7.7	50	192.5	72
B.H. Eaton	30	2.0	4.0	3.5	7	77
Arthur	35	1.6	3.2	6	9.6	73

[a] Canal efficiency is the amount of water available for farm delivery as a percentage of the total water diverted into the canal system. The remaining percentage is made up from losses due to seepage, phreatophyte and hydrophyte use, and operational losses. Operational losses include canal breakage, sluicing, and diversions in excess of demands.

[b] Qazi 1976].

TABLE 3.3.4-B WATER LOSSES FROM C-BT PROJECT FACILITIES

	1975 (ac-ft)	1957-74 Average (ac-ft)
Beginning East Slope Storage - Nov. 1	103,796	101,059
Adams Tunnel Imports	235,228	229,298
East Slope Stream Flow Stored	5,465	6,529
Total Available	344,489	336,886
District Deliveries Thru Oct. 31	211,116	217,590
Ending Storage - Oct. 31	116,787	104,465
Total Accounted for	327,903	322,055
System Loss	16,586	14,831
Percent Loss	4.8	4.4

The NCWCD has a substantial number of miles of canal lining and pipelines within their system which greatly reduces potential seepage. Water losses for private canal companies may be increased by conveyance systems which are open-ended. Most canals end by discharging into drainways or creeks out of necessity. Extra water, if available, is usually put into a canal system to make sure that the last farm receives water as needed. This results in losses to the canal company.

These "regulating" losses have run from 5 to 30 percent of the diversion amount [USDA, SCS-1970]. Carefully managed canals that are not excessively long can usually be expected to hold regulating losses below 10 percent of the diversion amount.

The Home Supply Canal with their point of diversion near the mouth of the Big Thompson Canyon west of Loveland has substantially cut their total water losses in recent years [Keirnes, 1976]. Losses have been as high as 25 to 30 percent prior to extensive rehabilitation to their total conveyance system starting in 1965. Losses now have been determined to be close to 15 percent.

The North Poudre Irrigation Company with over 200 miles of total ditch system estimates their total annual water loss at 20 percent [Dumler, North Poudre Irrigation Company 1976].

3.4 IRRIGATION SYSTEMS

3.4.1 Methods Of Irrigation

Four general methods of irrigating crops are used throughout the nation. They are: 1) furrow-ditch; 2) flood; 3) sprinkler; and 4) sub-irrigation. All of these four methods are used in the two-county region. Table 3.4.1-A indicates the extent of each method that is being used on farms in Larimer and Weld Counties. The corresponding Table 3.4.1-B gives a comparison for irrigated acreage within Colorado. Only applied water methods have been considered. Sub-irrigation does exist in the two-county region but this method is not considered relevant for the purpose of this report. The general methods are widely dispersed throughout the region with the exception of the sprinkler method which is used in certain areas as previously described.

TABLE 3.4.1-A.[a] LARIMER-WELD COUNTIES

Method of Irrigation	
Furrow-Ditch	289,000 Ac. or 56.9%
Flooding	170,500 Ac. or 33.6%
Sprinkler	49,000 or 9.6%

[a] No published figures could be found as to acreages associated with each irrigation method for the two-county area. Personal interviews by Kent Ververs, IPA Resource Conservationist assigned to the Larimer-Weld Regional COG, with SCS personnel located in the two-county region, Extension Service personnel, Soil Conservation Board of Supervisor members, and others with knowledge of the area were all used to arrive on final acreage figures.

TABLE 3.4.1-B[a] COLORADO

Method of Irrigation	
Furrow-Ditch	1,405,923 Ac. or 50%
Flooding	1,197,047 Ac. or 42.5%
Sprinkler	210,721 Ac. or 7.5%

[a] U.S. Department of Commerce 1973.

3.4.1.1 Furrow Ditch Method

The furrow-ditch method is used most extensively in the two-county area because of the large acreage of corn, beets, beans, and other row crops being grown; the initial cost of establishing this method is low compared to the sprinkler irrigation method.

Water is delivered to the furrows through a head ditch in the furrow-ditch method. Syphon tubes are normally used to syphon water out of the head ditch into the individual furrows which run down-slope. The furrows are made between planted rows of crop when the crop is planted or during the first cultivation process. Length of furrows is a direct function of farm geometry, soil texture, and crop type. An average length of furrows is 1/16 to 1/8 mile for sandy loam soils and 1/8 to 1/4 mile and greater for heavier textured soils.

The greatest irrigation efficiency in the furrow-ditch method can be made by using the largest practical stream in each furrow to force the water through the field. The stream should then be cut back to a size that will permit little tail water runoff for the balance of the irrrigation. Over-irrigation of the upper end of the field is reduced by farmers applying this management method.

The maximum stream size for each furrow which may be used will depend on size, shape, slope and length of the furrows. The type of crop and growth stage of the crop must also be considered. From an erosion standpoint, the maximum stream in gpm should not exceed the value of 10 divided by the slope in percent [USDA,SCS Field Manual]. A 2 percent gradient on a given field would then work out to be a rate of 5 gpm needed for each furrow.

A variation on the furrow-ditch method is called "corrugation irrigation." This method is used to irrigate close growing, noncultivated crops such as alfalfa, small grains and pasture grasses. Corrugations (small distribution ditches) are made prior to planting the crop. The corrugations allow for the distribution of irrigation water over the entire field.

3.4.1.2 Flooding

Perhaps the oldest type of irrigation is the flooding method. The Larimer-Weld region has over 33 percent of the irrigated land under this method of irrigation. Three types of flood irrigation are used within the region: basin or level borders, graded borders, and the contour grade ditch.

The latter is the type most used by irrigated farmers in the area using the flooding method. It is generally associated with fields that are too steep (over 3-4 percent) for other gravity methods of irrigation. Ditches are constructed nearly on the contour (0.1 - 0.2 of 1.0 percent grade) and are spaced at various intervals throughout the entire field. Irrigation water is turned out of the contour ditches at various points and allowed to run until the area between each contour ditch is fully irrigated. Close growing crops should always be grown where this type of irrigation is used so that erosion can be held to a minimum.

The basin or level border type is used very little in the region. The topography of the area is not conducive to extensive use of this type of flood irrigation. Occasional fields of pasture grasses and fields of alfalfa are irrigated by the basin type or irrigation.

The graded border type of flood irrigation is used throughout the area. This type is used almost as much as the contour grade ditch type. Land leveling by machine over the past 20 to 30 years has provided many additional acres to be irrigated by the graded border type of flood irrigation. SCS Field Office records indicate that 175,100 acres (some fields have been leveled more than once) have been machine leveled. This represents about one-third of the total irrigated land within the two-county region.

Machine leveled fields do not necessarily provide for a near perfect uniform grade. Many fields are machine worked just to "soften" the grade or are worked to fill a small depression where water would originally "pond" prior to the leveling job.

Graded borders call for the field to be divided into rectangular parallel strips separated by small earth dikes called border ridges. These ridges are usually broad and of low profile to allow for planting and harvesting with the rest of the field. Close growing crops nearly always are used with this type of flooding. A volume of water is introduced by syphon tubes or other means into the upper end of each border area and then allowed to flow the entire length of the area between the border dikes. The graded border type is a very efficient type of flood irrigation. This is especially true when a sufficient head of water is available and when a uniform slope is provided in a downfield direction with little or no cross slope.

A unique variation of the graded border type is used quite extensively throughout the irrigated region. This variation simply involves the use of an earthen farm ditch in place of a border ridge. The ditch embankments still act as a border ridge but the ditch itself is a conveyance means to speed up delivery of water to the lower end of each field strip. This variation method is considered more efficient than the regular graded border type because the entire portion of the water used for each strip does not have to flow as a sheet from the upper end to the lower end.

Water movement down through the soil profile is a function of opportunity time. The upper end of any surface irrigated field has more time to absorb water than the lower end of the same field. Consequently, many surface irrigated fields lose valuable irrigation water past the root zone at the upper end of the field prior to achieving a desirable water penetration depth at the lower portion of the field.

3.4.1.3 Sprinkler

The two-county area presently has less than 10 percent of its irrigated land under sprinkler irrigation. This method appears to have more potential for adoption in the future. The sprinkler method involves conveyance of water flows in a pressurized pipe and subsequent release above ground in the form of a spray through heads or nozzles. All major crops within the region can be grown using the sprinkler method. It is regarded as the most efficient method for applying irrigation water. The method provides for a very high degree of water control. To obtain the best efficiency possible, a farmer or operator using a sprinkler system must know several things with respect to his field conditions. These include:

- The soil type and depth;
- Net amount of water required for replacement;
- The peak consumptive use rate for the crop being grown;
- The maximum rate of water delivery through the system;
- Good knowledge of water application efficiency.

Soil type and depth is a function of infiltration rates and water holding capacity of the soil.

Net amount of water required for replacement is measured in acre-inches. It is the amount of water needed to refill the crop root zone to field capacity.

Peak consumptive use rate information is needed to show the evapo-transpiration loss by growing plants at a time during the season when plants require their maximum amount of soil moisture. The peak consumptive use is expressed in fractions of acre-inches needed daily.

Maximum capabilities of the sprinkler system are furnished by the manufacturing company. Pressure capacities in pounds per square inch and the delivery rate in gallons per minute are essential for the farmer's correct planning.

Water application efficiency is the percentage of applied irrigation water that is stored in the soil and available for consumptive use by the crop. Due to unavoidable losses, no field application of irrigation water can ever be 100 percent efficient. Application losses occur from evaporation, deep percolation past the root zone, and from surface runoff.

There are certain limitations in the use of sprinkler systems [Toups 1975]. Wind may cause an unequal distribution of water; excessive evaporation may take place on dry, hot days; water must be in constant supply; the water must be clean enough to pass through the sprinkler heads; and the water must not be high in dissolved solids to the extent that salt deposits accumulate on the leaves.

There are many types of sprinkler systems varying from labor intensive hand moved systems to fully automated center pivot units. Approximately 80 percent of the sprinkler irrigated acreage in the two counties is being irrigated by center pivot units. The four SCS Field Offices at Brighton, Greeley, Fort Collins, and Longmont reported in November, 1976 that close to 300 center pivot units are now operating in the two-county area. Each unit will irrigate an average of 130 acres.

The center pivot system is made up of a horizontal member which rotates about a center point. The horizontal radial arm is the support for the sprinkler heads. It is mounted on powered sets of wheels spaced uniformly along the arm. Operating pressures up to 100 psi are needed to make the system function properly. Consequently, this system is a high energy user.

Other types of sprinkler systems in use include hand-moved, side roll, portable solid-set, and solid set. None of these irrigation systems are used on any significant amount of acreage. Only about 10,000 acres are irrigated in the region using these less popular systems.

A most important factor influencing field application efficiency regardless of the irrigation method used is the skill of the operator and his interest in using that skill to achieve sound water management [USDA,SCS 1970]. All factors may be favorable for good water management but if the irrigator operates his farm without regard to a plan, a high application efficiency will not be achieved. The plan must involve the application of water commensurate with crop needs and with the soil intake rate.

3.4.2 Improvements to Irrigation System

A number of possible improvements to surface irrigation systems may increase water use efficiency and reduce labor requirements with proper management. Because of the increased irrigation efficiency, these on-farm structural improvements may provide benefits to water quality. Typical improvements made on farms are installation of irrigation structures for water control, concrete lining of laterals and on-farm ditches, subsurface irrigation pipelines for use at lateral canals and on-farm distribution, and land leveling. Drainage practices may also be considered to be on-farm improvements.

The extent to which these improvements in irrigation systems have been made in the Larimer-Weld region is delineated in Table 3.4.2-A. Irrigation structures are used for measuring water, controlling the flow of water, allowing water to run down a steep grade without erosion occurring and turning the water from one field to another. Ditch lining and pipelines increase efficiency in the distribution system by reducing seepage losses. This increased efficiency is especially beneficial to areas or fields at the end of the lining or pipeline. Land leveling improves efficiency improving the overland flow of water in surface irrigation systems.

TABLE 3.4.2-A MAJOR IRRIGATION PRACTICES & INSTALLATIONS PRESENTLY IN USE ON FARMS HAVING IRRIGATED LAND IN LARIMER & WELD COUNTIES

Practice	Amount		Unit	Total[a]
	Larimer	Weld		
Subsurface Drainage Lines	194	216	miles	410
Surface Drainage Ditches	23	74	miles	97
(Acreage benefited from Surface & Subsurface Drainage)	-	-	Ac.	50,029[b]
Irrigation Structures for Water Control	7,910	10,782	No.	18,692
Irrigation Ditch Lining (Concrete)	65	717	miles	782
Irrigation Pipeline (Subsurface)	180	381	miles	561
Land Leveling[c]	57,500	117,700	Ac.	175,200

Data Compiled from SCS Field Offices located at Greeley, Fort Collins, Brighton and Longmont.

[a] As of June 30, 1976.
[b] 1969 Census of Agriculture (U.S. Dept. of Commerce 1973)
[c] Some lands may have been leveled more than once.

3.5 DRAINAGE SYSTEMS IN THE IRRIGATED PORTIONS OF LARIMER AND WELD COUNTIES

3.5.1 History

Subsurface drainage by open ditch is not extensively used in the two-county region. During the early days of agriculture in the region, many open ditches were excavated for drainage purposes. Most of these drain ditches are still in use and are reasonably effective. However, few, if any, are now being constructed. They require extensive right-of-way, are unsightly, and maintenance is high.

Subsurface drainage by means other than open ditch (tile drains) has also been applied to agriculture lands since portions of the two-county area were placed under irrigation about a century ago. Most of the early subsurface drains were home-made wooden structures that had limited value. Many of these drains were too shallow or were improperly located to function effectively.

Since World War II, great strides have been made in the design and installation of subsurface drainage systems. The USDA's Soil Conservation Service has the primary responsibility in the nation for providing technical assistance to private land owners on drainage problems. One of the most significant advances in designing subsurface drains was the recommendation of a filter or gravel envelope for the entire length of the drain system. The gravel permits water to flow rapidly into the drain line and also screens out fine clay particles which can eventually plug or reduce the effectiveness of the drain line.

Manufactured clay tile replaced the wooden structures years ago. Clay and concrete tile were used almost exclusively from the mid-1940's until the early 1970's. Plastic, perforated, flexible tubing usually 6-inch and 8-inch diameter sizes has gained tremendous acceptance the past few years. The plastic tubing is now used in the large majority of subsurface drainage systems throughout the two-county region. The change to plastic has been made primarily for economic reasons. A new modern machine is capable of trenching, laying the plastic tubing, and gravel enveloping the tubing all in one operation. This affords a fast, efficient method of installation. The machine is also guided by a laser beam to maintain strict depth control which is vital for the most effective drain system.

3.5.2 Extent of Drainage Now in Use

The 1969 Agriculture Census shows that 50,029 acres of irrigated land was being drained by subsurface and surface methods in the two-county region, or about 10 percent of the total irrigated land. A total of 607 farms, or 21 percent, reported some portion or all of their farms as being drained. Local Soil Conservation Service Field Offices report that possibly another 9,000 acres have been drained by subsurface methods since 1969. SCS records for subsurface drainage are reported in lineal feet of drain line installed and not by acreage affected by such installations. SCS records show that 410 miles of subsurface tile drains and 97 miles of subsurface open drainage ditches are currently in use in the two-county region. This would indicate that 116 acres are benefited (water table lowered to at least 5-foot depth) for each mile of subsurface drains that are now in use (59,029 acres ÷ 507 miles).

It is reasonable to expect that 60 to 100 acres of land will benefit from each mile of subsurface drain installed (according to technicians at the Greeley SCS Field Office and the SCS Area Engineer also located at Greeley, who design about 20 farm drainage jobs each year). However, they conclude that the acreage which benefits from drains installed will vary considerably due to soil type, topography, distance to drain outlets, irrigation methods, and other factors.

The SCS Area Engineer also stated that about 80,000 acres in Larimer and Weld Counties are in need of subsurface drainage or approximately 18% of the remaining irrigated land that isn't presently being drained.

3.5.3 Factors Affecting the Need for Drainage

The Larimer-Weld County Region with its semi-arid climate has a very small need to dispose of excess runoff from precipitation. The general undulating topography of the region coupled with many natural drainages almost always allows for the natural removal of excess water even from the most intense storms. Many irrigated farms are isolated topographically by large irrigation canals. These canals normally can absorb runoff from light to moderate intensity storms.

The excessive use of irrigation water is the greatest single cause for drainage problems in the arid and semi-arid west according to the SCS [USDA - SCS Handbook]. Water tables rise dramatically when excessive amounts of water are applied. Water tables that rise to within the normal root zone of any crop will adversely affect the crop yield. Poor or improper irrigation methods contribute substantially to deep percolation losses of not only water but also applied fertilizers. The loss of fertilizers is an economic loss to the farmer and a contributor to the degradation of ground waters.

Subsurface drainage systems are required when water tables are impeding normal crop growth. The drainage systems not only lowers the water table to a safe level, but it provides for downward percolation of water in the soil profile. This permits leaching of soluble salts past the crop root zone. The salts accumulate by precipitation from the evaporation of water brought near the surface from a high water table.

A somewhat unique situation in the Larimer-Weld Region is that any soil type or series may develop a need for drainage. Geologic formations may restrict the downward percolation of ground waters with the end result being a high water table. Shale, sandstone, and limestone are the most common restrictive formations within the region.

Many high water tables occur below main irrigation canals and large laterals. Irrigation water storage reservoirs located throughout the two-county region are associated with high water tables which can be found near or immediately below these facilities. Very few of the reservoirs have any lining material for the prevention of seepage. Some have been constructed at sites where the natural soil material is somewhat impervious. Seepage is not a major problem at these sites.

Irrigation canals and their major laterals in the two-county irrigated area have a very low ratio of concrete ditch lining vs. the total miles of canal network. Lining canals where known seepage losses are high would eliminate some needs for drainage practices.

One major concrete lining job was completed in the late 1960's. This job involved the lining of nearly 3 miles of the Handy and Home Supply joint canal at a location some four miles southeast of Loveland. The joint canal has a capacity from 110 to 165 cfs. Home Supply completed another 2 miles of ditch lining in 1973 at the lower end of their system near Johnstown. This section of lining was designed for about 50 cfs capacity.

Other major canals have completed some concrete lining, but the largest portions of lining have been completed near the points of diversion at the river source or where the canals run through the city limits of Fort Collins, Loveland, and Greeley. Some short sections of lining have been completed at points where extreme seepage was known to have been occurring.

3.5.4 Internal Drainage Characteristics of Major Soils Groups Within the Two-County Region

Internal drainage characteristics of the soils in the irrigated portion of the two-county region are extremely variable. Soil textures vary from clays to sand and gravel profiles. Some soils may have clay topsoils with a gravel substrata while others may have sandy topsoils with shale or sandstone occurring within 40-inches of the surface. Many irrigated fields will have extreme soil variations within only a few hundred feet.

Figure 3.5.4-A displays a map identifying depth to impervious layers which may restrict internal drainage. It also shows alluvial formations which may have high water tables. The major soil groups according to internal drainage characteristics in the two-county area are listed as follows [Developed from SCS Soil Association maps for Larimer and Weld Counties]:

Group A: Soils that have restricting layers of shale, sandstone, or limestone generally occurring within 40 inches of the surface.

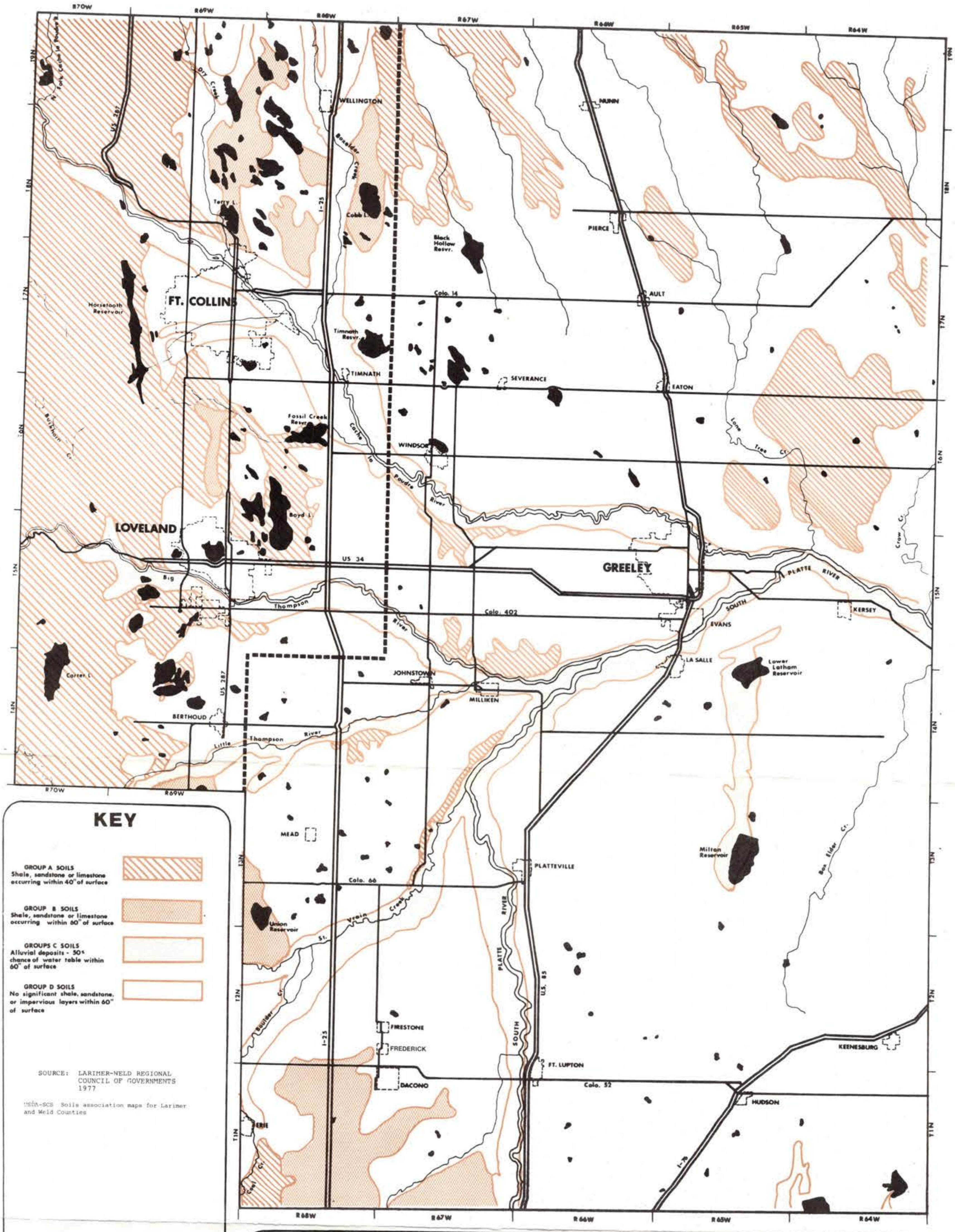
Group B: Soils where shale, sandstone, or limestone may have a 50 percent occurrance of being present within 60 inches of the surface.

Group C: Soils found within flood plains and in low terrace areas where the probability of water tables occurring within 60 inches of the surface is greater than 50 percent.

Group D: Soils that rarely have shale, sandstone, or limestone occurring within 60 inches of the surface.

As mentioned previously, any soil type may develop a need for subsurface drainage. The Group A soils listed above, however, are extremely subject to high water table because of the shallow depth to shale, sandstone, or limestone. The total acreage of this soil group under irrigation is only about 12 percent of the total land area being irrigated. It should be pointed out that the methods of irrigation on the Group A soils are predominately flood and furrow ditch. Sprinkler irrigation, if applied properly would greatly reduce the need for subsurface drainage within the Group A soils. Irrigation water efficiency is substantially higher using the sprinkler method than other methods.

Group B soils comprise only about 3 percent of the total irrigated acreage in the two-county region. These soils, similar to the Group A soils, are predominantly irrigated by



KEY

GROUP A SOILS Shale, sandstone or limestone occurring within 40" of surface	▨
GROUP B SOILS Shale, sandstone or limestone occurring within 60" of surface	▩
GROUPS C SOILS Alluvial deposits - 50% chance of water table within 60" of surface	☐
GROUP D SOILS No significant shale, sandstone, or impervious layers within 60" of surface	☐

SOURCE: LARIMER-WELD REGIONAL
COUNCIL OF GOVERNMENTS
1977

USDA-SCS Soils association maps for Larimer and Weld Counties

SCALE

0 1/2 1 2 3 4 5 MILES

N

SOILS
(Impervious Layers)

LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS

Fig. 3.5.4 -A

AREAWIDE WATER QUALITY PLAN

THE PREPARATION OF THIS MAP WAS FINANCED IN PART THROUGH A WATER QUALITY MANAGEMENT TECHNICAL ASSISTANCE PLANNING GRANT FROM THE ENVIRONMENTAL PROTECTION AGENCY UNDER THE PROVISIONS OF SECTION 208 OF THE FEDERAL WATER POLLUTION CONTROL ACT OF 1972 (PL 92-500)

flood and furrow-ditch methods. Because of restrictive layers found many times within the top 60 inches of these soil profiles, the Group B soils are subject to high water tables. Sprinkler irrigation would greatly reduce the possible need for subsurface drainage within this group of soils.

The Group D soils are highly productive. They make up nearly three-fourths of the total irrigated area. These soils will rarely develop a high water table where these soils are not subject to canal and reservoir seepage and are not irrigated excessively. Unfortunately, many of the soils within this group do get seepage from canals and reservoirs and many are over-irrigated to the point where subsurface drainage installations are needed to lower water table levels.

A subsurface drainage location map was developed from SCS Field Office records located at Greeley (Figure 3.5.4-B). This map shows the location outlets from 239 subsurface drain lines installed over approximately the past 25 years. Data is lacking for developing a similar map for the Fort Collins-Loveland area. It is interesting to note that subsurface drainage systems have been installed throughout the irrigated work area of the Greeley SCS Field Office. However, a direct correlation could be found between the soil group and location of subsurface drainage installations. The high occurrance of subsurface drain lines installed northeast of Greeley in the Gill-Galeton area where soils are very shallow to shale indicates that this area is extremely difficult to irrigate by gravity means without a high water table developing. The occurrance of subsurface drainage jobs in this shallow soil area is significantly greater than in any other area serviced by the Greeley Field Office.

Another correlation found was that many subsurface drain lines are installed in fields immediately below major canals and laterals, and also adjacent to surface drainways, indicating high seepage losses from these conveyance systems.

The Group C soils are found adjacent to all major rivers and streams in the two-county area. Approximately 50 percent of the area is irrigated by surface methods. These soils usually have sand or gravel located within 60 inches of the surface and the probability of a water table within this depth is greater than 50 percent. The water table level is associated with the river flow level and seepage from higher laying irrigated lands. Many acres of the Group C soils are not irrigated by surface means but are subirrigated. Native and introduced grasses that have a high pH tolerance are commonly grown on these soils.

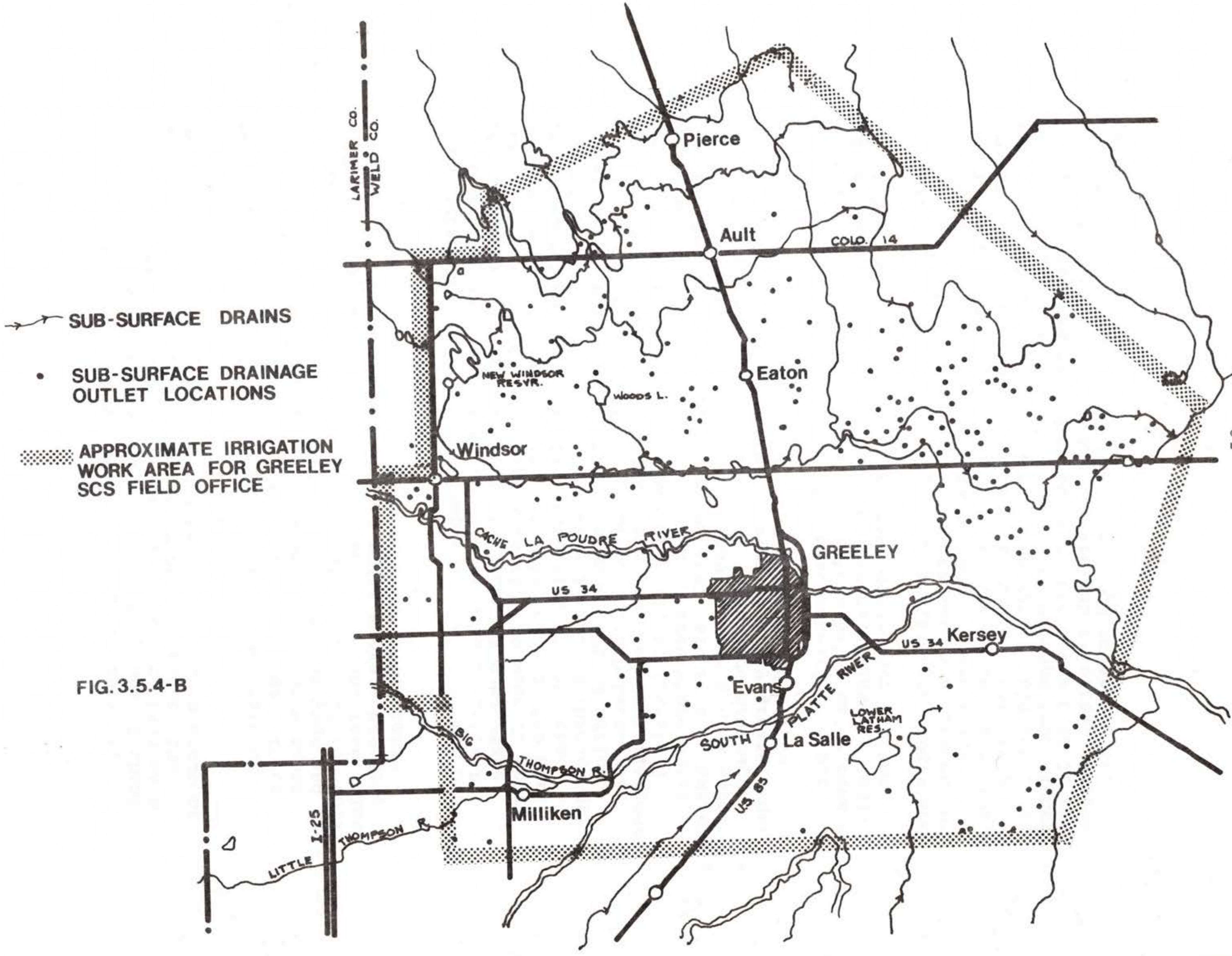

SUB-SURFACE DRAINS
SUB-SURFACE DRAINAGE OUTLET LOCATIONS
APPROXIMATE IRRIGATION WORK AREA FOR GREELEY SCS FIELD OFFICE
LARIMER CO.
WELD CO.
Pierce
Ault
COLO. 14
Eaton
NEW WINDSOR RESVR.
WOODS L.
Windsor
CACHE LA POUDRE RIVER
GREELEY
US 34
US 34
Kersey
Evans
SOUTH PLATTE RIVER
LOWER LATHAM RES.
La Salle
US 85
BIG THOMPSON R.
Milliken
I-25
LITTLE THOMPSON R.

FIG. 3.5.4-B

Subsurface drainage has not been installed in any substantial amount within this group of soils. The major problem of subsurface drainage installation in these soils lies with the difficulty in obtaining adequate relief or drop in the terrain. Many drains have to be run over excessive distances to adequately drain a given field. Costs associated with rights-of-way and extra lineal feet of drain line prohibit in many cases subsurface drainage within the Group C soils.

3.5.5 Costs Associated with Subsurface Drainage

One contractor [Ed Loloff] located in the Greeley area constructs about 90 percent of all subsurface drainage installation within the two-county area [Loloff 1977]. Six- and eight-inch perforated plastic pipe are the most common sizes used in draining irrigated farm land.

Recent price quotes from this contractor indicate that an average farm subsurface drainage job would cost about $4.50 per lineal foot. This would be for a complete and guaranteed installation. Engineering services by the SCS are free to Soil Conservation District cooperator farmers and are not reflected in the above costs. A conservative estimate of 10 to 15 percent for engineering services would normally be added if those services were not provided free of cost. The per acre cost for subsurface drainage using $4.50 per lineal foot and by using 60 to 100 acres benefited by each mile of drain line installed would then show a cost per acre of between $237.00 and nearly $400.00.

These costs can be compared to $1800 to $2000 per acre which is the approximate value of good irrigated farms within the region. The costs can also be considered against the initial costs associated with purchasing a sprinkler system. A center pivot sprinkler system will normally have an initial cost of about $300.00 per acre. The sprinkler irrigation method would eliminate the need for subsurface drainage systems on many farms within the two-county region.

3.6 FERTILIZER USE ON IRRIGATED LANDS WITHIN LARIMER AND WELD COUNTIES

3.6.1 Fertilizer Deficiencies in Colorado Soils

More than 10,000 soil samples were analyzed by the Colorado State University Soil Testing Laboratory during the years 1971 through 1975 [CSU 1976]. The results showed that there are only five nutrients sufficiently deficient to be of concern on field crops in Colorado. These nutrients are Nitrogen (N), Phosphorus (P), Potassium (K), Zinc (Zn) and Iron (Fe).

Nitrogen was found to be deficient in 50 percent of all fields tested (less than 10 ppm nitrate nitrogen (NO_3-N) in the surface plow layer) in Colorado. About 36 lbs/acre of NO_3-N in the top surface foot represents 10 ppm. Figure 3.6.1-A presents a bar graph on five nutrients in Colorado soils.

Available phosphorus was found to be very low (0-7 ppm) or low (8-14 ppm) in 48 percent of the fields tested. Only one percent of soils tested showed a deficiency (0-60 ppm) for available potassium. Available zinc was deficient (0-.50 ppm) in only 2 percent of the fields with another 17 percent being marginal (1.6-3.5 ppm).

3.6.2 Fertilizer Sales in Colorado

The Tennessee Valley Authority through their publication "Fertilizer Summary Data" [1974] lists statistics on fertilizer (commercial) use in Colorado. These statistics are displayed in Table 3.6.2-A.

3.6.3 Fertilizer Use in Larimer and Weld Counties

A commercial soils testing laboratory located in the two-county area (Triple S Lab, Loveland, Colorado) gave fertilizer recommendations in a private interview for major crops grown in the irrigated portions of the two-counties (Table 3.6.3-A). The recommendations are based upon recent soil tests and do not take into account unique situations such as heavy manure applications being applied. All figures are strictly averages.

When making fertilizer recommendations, the commercial laboratory uses an average value of 4 lbs. available N, 2 lbs. available P_2O_5, and 5 lbs. available K_2O for each ton of manure applied. A 15 ton/acre manure application would then have a value of 60 lbs., 30 lbs., and 75 lbs. of available NPK, respectively. These values would then be subtracted from what the actual test would indicate as being required for top yields.

Average figures from leading fertilizers dealers and prominent farmers interviewed within the two-county region indicated that the average irrigated crop grower was applying 175 lbs. available N/Ac to corn. The three major materials used to supply nitrogen are ammonium nitrate, anhydrous and liquid ammonia, and ammonium sulfate.

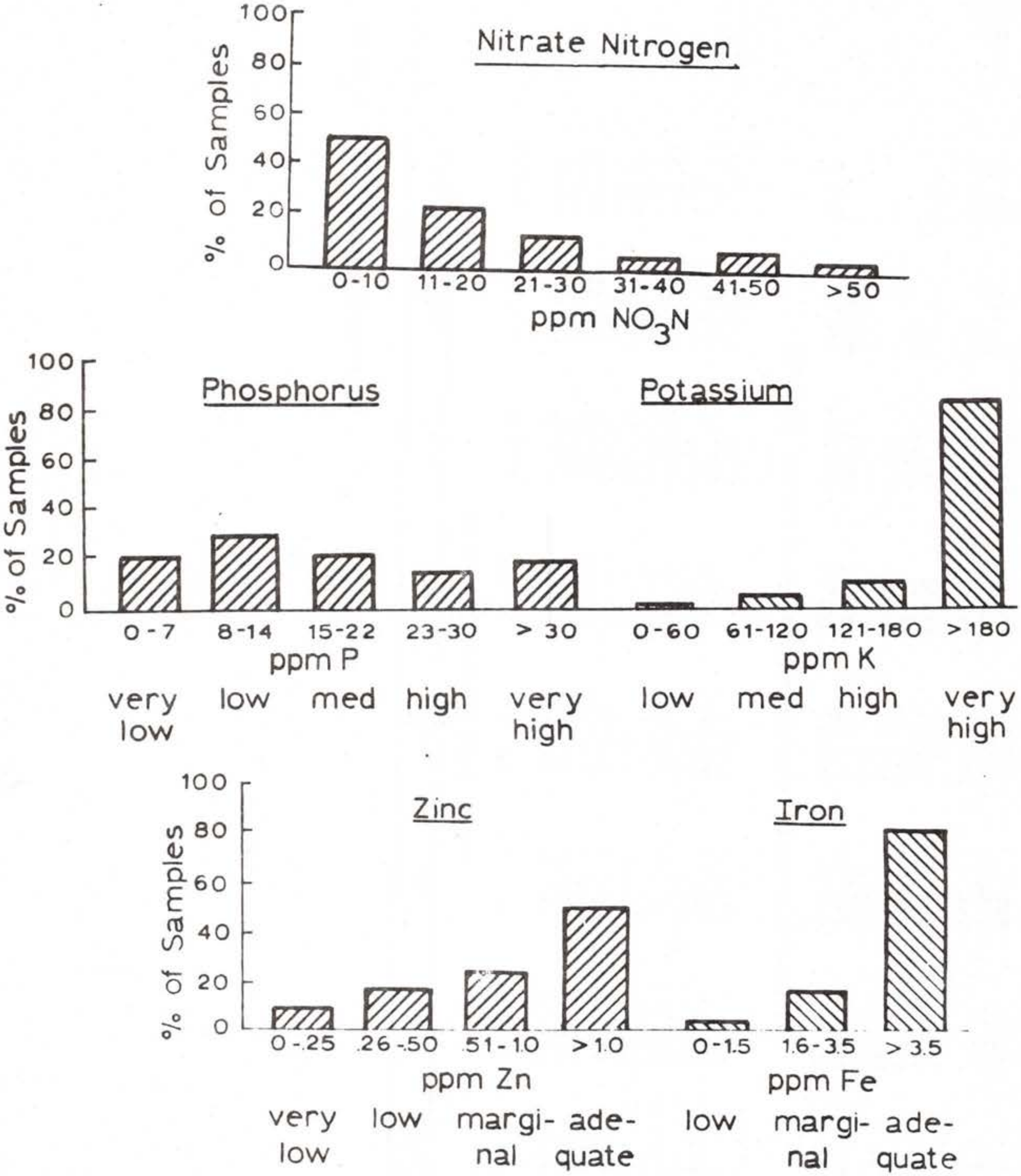


Figure 3.6.1-A Nutrient Deficiencies in Colorado Soils

TABLE 3.6.2-A COLORADO SUMMARY OF FERTILIZER STATISTICS

	1950	1955	1960	1965	1970	1972	1973	1974 (prelim.)
	COMMERCIAL FERTILIZERS (Tons)							
Total Fertilizer Material	39,143	48,732	96,260	187,981	268,467	309,551	320,056	362,591
Total N	3,416	7,468	23,510	39,097	80,143	90,981	97,170	118,554
N in mixtures	1,672	1,415	2,621	8,716	14,068	15,757	17,548	12,920
Total P_2O_5	9,048	11,144	17,477	32,267	41,843	45,508	48,037	44,475
P_2O_5 in mixtures	3,303	2,471	4,623	16,783	33,449	36,526	39,741	26,084
Total K_2O	1,282	899	1,596	3,102	7,247	8,832	7,802	10,214
K_2O in mixtures	1,021	680	1,197	1,472	1,107	1,069	1,789	1,869
Total plant nutrients	13,746	19,511	42,583	74,466	129,233	145,321	153,009	173,243
Average analysis	34.6	40.5	44.9	41.5	49.1	47.9	49.2	49.1
Total nutrients in mixtures	5,996	4,556	8,441	26,971	48,624	53,352	59,078	40,873
Average analysis of mixtures	34.1	33.9	44.6	50.5	54.7	55.3	56.1	50.3
	SELECTED DIRECT APPLICATIONS MATERIALS (Tons of Materials)							
Ammonium nitrate	2,192	7,032	23,767	40,871	43,180	32,309	54,306	62,851
Anhydrous ammonia	-	2,636	9,250	11,026	48,278	53,942	53,932	73,067
Aqua ammonia	-	-	-	-	505	3,085	3,283	558
Nitrogen solutions	-	-	3,816	5,364	18,599	26,618	28,294	37,734
Urea	-	556	2,159	5,017	1,383	3,721	3,416	2,646
Ammonium sulfate	3,804	2,812	5,021	9,343	13,054	33,033	16,001	16,003
Sodium nitrate	-	-	-	-	-	-	-	11
Ordinary superphosphate	1,475	720	2,870	106	1,026	940	-	8,286
Concentrated superphosphate	11,219	13,926	14,697	20,050	12,359	16,017	13,531	4,597
Ammoniated phosphates	-	-	8,670	7,202	6,812	5,486	7,738	29,429

TABLE 3.6.2-A (Continued)

	1950	1955	1960	1965	1971	1972	1973	1974 (prelim.)
	CONSUMPTION OF FERTILIZERS BY CLASS (Tons of Materials)							
Dry direct applications materials	-	26,706[a]	97,752[b]	115,499	106,100	129,358	129,139	-
Dry mixtures	-	14,665[a]	21,237[b]	53,119	68,900	79,093	88,617	-
Fluid direct application materials	-	6,378[a]	10,300[b]	18,057	68,500	83,800	85,600	-
Fluid mixtures	-	25[a]	252[b]	1,306	20,000	17,300	16,700	-
	SEASONAL FERTILIZER CONSUMPTION (%)							
Mixtures used in fall	14.6	27.0	20.4	36.0	24.3	23.4	19.8	-
Straight materials used in fall	32.7	27.9	28.0	28.0	26.2	29.4	28.8	-
All fertilizers used in fall	24.6	27.7	26.5	30.3	25.6	27.5	25.6	-

a. 1954 data
b. 1961 data

TABLE 3.6.2-A (Continued)

MIXED FERTILIZERS

1950		1960		1965		1972		1973	
Grade	Tons	Grade	Tons	Grade	Tons	Grade	Tons	Grade	Tons
10-16-8	3,731	18-46-0	1,572	18-46-0	17,682	18-46-0	60,548	18-46-0	61,657
12-24-0	3,680	16-48-0	987	16-48-0	6,061	10-34-0	10,449	16-48-0	7,546
10-10-10	1,567	8-25-0	764	12-5-7	4,898	16-48-0	3,400	10-34-0	7,187
6-24-6	1,423	10-30-10	622	10-34-0	3,689	20-10-5	2,920	16-20-6	2,745
7-21-7	1,326	6-10-4	531	29-14-0	1,592	6-10-4	1,438	20-10-5	2,218
10-20-0	1,149	16-6-8	277	6-10-4	948	11-37-0	1,218	11-37-0	1,992
10-12-8	979	20-20-0	204	30-10-0	717	30-10-0	733	30-10-0	1,279
6-30-0	597	10-20-0	164	25-25-0	510	12-24-12	655	11-55-0	258
5-10-5	394	20-10-0	124	22-22-0	195	9-30-0	26	16-16-16	110
10-10-5	249	13-13-13	109	16-16-8	161			12-12-0	50
Total 10 leading grades	15,095		5,354		36,453		81,387		85,042
Total all grades	17,594		18,933		54,425		96,393		105,317

TABLE 3.6.2-A (Continued)

FERTILIZER AND HARVESTED ACREAGE

	1967	1968	1969	1970	1971	1972	1973	1974
Harvested crop acreage (thousand acres)	4,952	4,655	5,533	5,711	5,607	5,442	5,789	-
Total plant nutrients (lbs/acre harvested)	41	51	43	45	49	53	53	-
Total wheat acreage (thousand acres)	1,961	1,933	2,145	2,420	2,541	2,400	2,370	2,540
Nitrogen applied (lbs/acre)	4	4	2	3	2	61	54	35.4
P_2O_5 applied (lbs/acre)	-	-	-	-	-	-	19	-
K_2O applied (lbs/acre)	-	-	-	-	-	-	10	-
Total corn acreage (thousand acres)	-	-	-	-	406	360	435	410
Nitrogen applied (lbs/acre)	-	-	-	-	151	166	167	157.8
P_2O_5 applied (lbs/acre)	-	-	-	-	55	80	81	56.0
K_2O applied (lbs/acre)	-	-	-	-	12	51	43	32.0

TABLE 3.6.3-A TYPICAL FERTILIZER USE IN LARIMER & WELD COUNTIES (Triple S Lab, Loveland, Colorado 1976)

						Soil Type	
CROP	NO_3-N	P_2O_5	K_2O	Zn	Fe	Sandy loam	Clay loam
Corn	200#	40#	20#	3#	-	X	
	160#	40#	20#	3#	-		X
Beets	120#	100#	-	1#	-	X	
	90#	120#	-	1#	-		X
Barley	80#	20#	-	-	-	X	
	50#	20#	-	-	-		X
Beans	-	25#	-	3#	-	X	
	-	25#	-	3#	-		X
Alfalfa	-	40#	-	-	-	X	
	-	40#	-	-	-		X
Onions	120#	100#	-	3#	-	X	
	90#	120#	-	3#	-		X
Potatoes	120#	100#	-	3#	-	X	
	90#	120#	-	3#	-		X

Phosphorus (P_2O_5) is being applied at the rate of 30 to 50 lbs/Ac. on corn. Beets receive about 100 lbs. N and 100 lbs. of P_2O_5 according to the interviews. The leguminous crops of beans and alfalfa receive amounts of P_2O_5 in the range of 30 to 45 lbs/Acre. Small grains, including wheat, barley and oats, receive about 25 lbs. N and 30 to 40 lbs. P_2O_5/Acre. Zinc is being applied at the rate of from 3 to 5 lbs./Acre, especially on corn and beet crops. Potash is rarely used according to those interviewed. Occasionally it is used as a mixed fertilizer such as a 20-10-5 (NPK) material.

The two-county region is one of the largest producers of slaughter cattle in the United States. Manure is available in large sums and is applied to irrigated fields, normally in late fall season, throughout the two-county area. Not all farmers, however, apply feedlot manure. The reasons vary because of the economics of hauling the manure: many farms do not have feedlots: and many farmers feel commercial fertilizers are adequate to obtain top yields.

Fertilizers are applied at various time of the year, although on-farm fertilizer application practices are tailored to individual requirements of crops and soils, a generalized pattern is evident in the Larimer-Weld Region.

Dry fertilizers are normally applied in late fall and again in the spring prior to planting time. Many crops are "side-dressed" with fertilizers after the crop has begun to grow. This is usually done in late May. Some mid-season applications of liquid fertilizers are made directly in the irrigation water that is to be turned into a given field.

3.7 CHEMICAL ERADICATOR APPLICATION

3.7.1 Agricultural Pesticides Used on Irrigated Crops Within Larimer and Weld Counties

Agricultural pesticides are extensively applied in the two-county region. Nearly all farmers with irrigated land use some type of pesticides each year.

The term "pesticide" (for this report) includes insecticides and herbicides. Fungicides and nematocides are other pesticides that have some use in this region but have not been elaborated on this report.

A large number of insecticides are available on the market for the elimination of nuisance organisms. Many are highly toxic to fish and wildlife, and extreme caution and care are needed when applying these chemicals.

Insecticides recommendation rates are expressed in pounds per acre of actual toxicant per acre or in percent of actual toxicant for ready-to-be applied liquid spray. Insecticides may be purchased according to application methods available to the grower. He may choose from wettable powders, soluble powders, dusts, emulsifiable concentrates, granules, or solutions.

The net effect to the environment by the use of insecticides is complex. Tremendous benefits have accrued to man and his surrounding by the use of most agriculture chemicals. The persistant insecticides (primarily chlorinated hydrocarbons) that are related with the phenomenom of biological magnification of residues within animal tissue are of great concern to Federal and State monitoring agencies [USDA 1968].

Great strides in the past few years have accounted for insecticides that degrade more rapidly in the environment and are not the threat to fish and wildlife as they were in years past. However, many highly toxic insecticides are still in use and should be substitued for alternate pesticides which have a low level toxicity in relationship with fish and wildlife habitat.

Table 3.7.1-A shows the acute toxicity of pesticides to mammals, birds and fish. The table gives the concentrations or dosages found to produce 50 percent mortality among test animals. Usually 1/10 to 1/100 of the values shown in the table would be considered a safe level for fish and wildlife [Croswell _et. al._].

TABLE 3.7.1-A TOXICITY OF PESTICIDES [a]

	Oral LD_{50} [1]		48-hr. or 96-hr. LC_{50} [4]
	Mammal [2] (mg/kg)	Bird [3] (mg/kg)	Fish (ppm)
Aldrin	35	6	.003
BHC	1,000	118	.79
BUX	87	10	.29
Captan	9,000	>2,000	.13
Chlordane	457	14	.010
Chlorobenzilate	729		.71
Ciodrin	125	790	.76
Ciovap	3,420		.73
Co-Ral	22	8	.18
Dasanit	22	< 1	
DDT	113	595	.002
Demeton (Systox)	4	5	.081
Diazinon (Sarolex)	125	4	.030
Dibrom	430	52	.078
Dichole (Phygon)	1,300	>2,000	.047
Dieldrin	46	79	.003
Dimethoate (Cygon, Defend)	215	9	9.6
Dioxathion (Delnav)	50	240	.014
Disyston	12	7	.040
Dithane M-45	>8,000	707	
Dyfonate	8	17	
Endrin	8	1	.0002
EPN	14	3	
Ethion	96	1,297	.23
Ethylene dibromide	117		8.0
Furadan	8	< 1	.21
Gardona	4,000	2,000	.53
Guthion	14	75	.010
Heptachlor	90	>2,000	.009
Imidan	216	237	

TABLE 3.7.1-A TOXICITY OF PESTICIDES (Continued)

	Oral LD_{50} [1]		48-hr. or 96-hr. LC_{50} [4]
	Mammal [2] (mg/kg)	Bird [3] (mg/kg)	Fish (ppm)
Kelthane	809	265	.10
Landrin	208	17	
Lannate	17	15	
Lead arsenate	10		>10.0
Lindane	88	900	.018
Malathion (Cythion)	1,375	167	.019
Meta-Systox R	65	42	4.0
Methoxychlor	6,000	>2,000	.007
Methyl parathion	9	8	1.9
Mocap	62	4	
Morestan	3,000		.096
Morocide	161		.040
Nicotine sulfate	50	587	
Omite	2,200		
OMPA	9	19	10.0
Parathion	3	2	.047
Perthane	8,170		.005
Phorate (Thimet)	2	< 1	.005
Phosdrin	6	1	.017
Phosphamidon	11	3	8.0
Phostex	2,500		
Pyrenone (pyrethrin)	1,500	>10,000	.054
Ronnel (Korlan, Trolene)	1,250	611	.64
Rotenone	132	>1,414	.022
Ruelene	460	265	1.9
Sevin (Carbaryl)	500	700	1.0
Supracide	25	24	
TDE (DDD)	3,400	386	.009
Tedion	1,470	>2,000	1.1
Temik	< 1		
TEPP	1	4	.39
Thiodan (Endosulfan)	110	31	.001
Toxaphene	69	24	.003
Trichlorfon (Dylox, Neguvon)	275	37	.16
Trithion (carbophenothion)	32	121	.23
Vapona (DDVP)	62	8	.70
VC-13	250		
Zinophos	12	2	
Zolone (Phosalone)	96		

TABLE 3.7.1 (Continued)

[1] Median lethal dose: the amount of the toxicant, expressed in milligrams per kilogram of body weight, that would kill 50% of the animals that receive it.

[2] Test mammal: white rat. Toxicant administered as a single dose (oral). Data mostly from Toxicology Section, Public Health Service.

[3] Test bird: Mallard duck, ring-necked pheasant, Bobwhite or California quail. Toxicant administered as a single oral dose. Data from Denver Wildlife Research Center, Bureau of Sport Fisheries & Wildlife.

[4] 48-hr. or 96-hr. median lethal concentration: the concentration of toxicant in water (milligrams per liter, or parts per million by weight) lethal to 50% of the fish exposed for 48 to 96 hours.

Test fish: mostly bluegills or rainbow trout, which are among the more sensitive species.

[a] Data mostly from the Department of Interior NTAC Report on Water

Quality and the Fish-Pesticide Research Laboratory, Bureau of Sport Fisheries and Wildlife, Columbia, Missouri.

3.7.2 Insecticides Used on Crops in Larimer & Weld Counties

Insecticides used for major crops in Larimer and Weld Counties for 1976 and their respective applications rates are shown in Table 3.7.2-A.

TABLE 3.7.2-A. COMMONLY USED INSECTICIDES IN LARIMER AND WELD COUNTIES [a]

Crop	Insecticide Most Commonly Used	Rates Per Acre
Corn	Dimethoate (Cygon-400)	1/3 - 1/2#
	Disyston	1#
	Parathion	1/2#
	Meta-Systox R	1/3 - 1/2#
	Sevin 4-oil	1#
	Dyfonate	2.5 fl.oz/ 1000 LF of row
	Furadon (flowable)	2.5 fl.oz/ 1000 LF of row
Beets (sugar)	Temic	1 - 2#
	Thimet	1#
	Dylox	1/2 - 1#
	Parathion	10 oz.
	Dyfonate	1 - 1/2#
	Diazinon	1 - 2#
Small Grain (Barley, wheat, oats)	Parathion	
	Disyston	1/2 - 3/4#
Alfalfa	Furidan	1/4#
	Cygon	1/2#
	Sevin	1 - 1-1/2#
	Malathion	1 - 1/4#
	Encapsulated Methyl Parathion (PENNCAP-M)	1 Quart
Beans	Sevin	1#
	Serimol	1#
	Parathion	1/2#

[a] Developed from private farmer interviews, commercial aerial applicators and local fertilizers and chemical companies and Insecticide Control Handbook for Colorado.

Private interviews with growers, commercial applicators, pesticide dealers and agency personnel have indicated that irrigated crop growers apply one or more of the insecticides listed above for each major crop grown in the two-county region.

TABLE 3.7.2-B INSECTICIDE USE ON VARIOUS CROPS IN THE LARIMER AND WELD REGION

Crop	% of Growers Applying one or more insecticides at the recommended rate for 1976
Corn	75%
Beets	75 - 80%
Small Grain	30 - 40%
Alfalfa	50 - 60%
Beans	50%

A study of the efficiency of the use of pesticides in agriculture completed in 1975 [EPA 1975] states that insecticides used on corn alone has increased substantially during the past 10 years. The study also shows that about 50 percent of the total corn acreage harvested for grain in the nation currently is treated with insecticides. It was estimated in the report that less than half the treated acreage actually requires insecticide treatment.

3.7.3 Herbicides

Herbicides for weed control are classified as selective or non-selective. The selective herbicides are designed to rid certain classes of weeds from certain crops. Non-selective herbicides are applied to kill a wide range of weeds and other undesireable vegetation.

Treatment methods may be made as a foliage application which is usually a spray, or as a soil application. Soil application of selective herbicides is known as preemergence or postemergence methods. Soil applications of non-selective herbicides are used as a fumigant or as a soil sterilant. Both are applied to remove all plant growth. The fumigants usually have a very short life while the soil sterilants are used to kill deep rooted perennials and may kill all plant growth from a few months to years, depending on the chemical used.

Foliage application of herbicides is termed as translocated or as contact. Translocated chemicals simply move within the plant and normally destroy the root system of perennial plants. The contact chemicals kill only those portions of the plant which the chemical has contacted. Thorough coverage of the entire plant is necessary for a complete one-application kill.

Table 3.7.3-A, Chemicals Used for Weed Control, is a list of chemicals available for weed and undesirable plant control [CSU 1976].

TABLE 3.7.3-A. CHEMICALS FOR WEED CONTROL

A. SELECTIVE HERBICIDES

1. Foliage Applications

   a. Translocated

      2, 4-D
      4 (2, 4-DB)
      2, 4, 5-T
      2, 4, 5-TP (silvex)
      MCPA
      barban (Carbyne)
      dalapon (Dowpon)
      dicamba (Banvel)
      Phenmedipham (Betanal)
      glyphosate (Roundup)

   b. Contact

      bromoxynil (Brominal-Buctril)
      paraquat (Paraquat)
      Dinoseb (Dow General, Premerge, Others)
      DSMA (Ansar, Trans-Vert)
      linuron (Lorox)
      MSMA (Ansar, Trans-Vert)
      Selective Weed Oils

TABLE 3.7.3-A (Continued)

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2. Selective Soil Applications

   a. Preplant, preemergence and postemergence[a]

      alachlor (Lasso)
      atrazine (AAtrex)
      benefin (Balan)
      bensulide (Betasan, Prefar)
      banzadox (Topcide)
      bifenox (Modown)
      butralin (Amex 820)
      butylate (Sutan +)
      chloramben (Amiben)
      chlorpropham (Chloro-IPC)
      cyanazine (Bladex)
      cycloate (Ro-Neet)
      cyprazine (Outfox)
      DCPA (Dacthal)
      desmedipham (Betanex)
      diallate (Avadex)
      dichlobenil (Casoran)
      difenzoquat (Avenge)
      dinitramine (Cobex)
      diphenamid (Dymid)
      diuron (Karmex)
      endothal (Endothal, Aquathal)
      EPTC (Eptam)
      ethofumesate (Nortron)
      isopropalin (Paarlan)
      methazole (Probe)
      metribuzin (Sencor/Lexone)
      naptalam (Alanap 3, Alanap 10G)
      nitrofen (TOK E-25, TOK WP-50)
      penoxalin (Prowl)
      phenmedipham (Betanal)
      procyazine (Cycle)
      profluralin (Tolban)
      pronamide (Kerb)
      propachlor (Ramrod)
      propazine (Milogard)
      propham (Chem-hoe)
      prynachlor (Basamaize)
      pryazone (Pyramin)

TABLE 3.7.3-A (Continued)

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siduron (Tupersan)
simazine (Princep)
solan (Solan)
terbacil (Sinbar)
terbutryn (Igran)
triallate (Avadex BW, Fargo)
trifluralin (Treflan)
vernolate (Vernam)

b. Non-Selective Herbicides

1. Foliage Applications

a. Translocated

AMS (Anmate-X)
amitrole (Weedazol, Amitrol, Amino-triazole)
amitrole-T (Amitrole-T, Cyrol)

b. Contact

endothal (Penco, Endothal, Aquathal)
Weed Oils and Aromatic Solvents

2. Soil Applications

a. Fumigants

Allyl Alcohol
Calcium cyanamide (Aero-Cyanamide)
A mixture of 1,3-dichloro-propene &
    1,2-dichloro-propene
Methyl bromide (Dow fume, MC-2, Bed fume)
DMTT (Mylone)
1,3-Dichloropropene (Telone)
metham (Vapam, VPM

b. Soil Sterilants

AMS (Anmate, Ammonium Sulfamate)
erbon (Baron and Erbon R)
Borates
Chlorates
  Atlacide and Atlacide 2,4-D
  Monobor-Chlorate
2,3,6-TBA (Trysben 200)
fenac (Fenac)

TABLE 3.7.3-A (Continued)

- dicamba (Banvel)
- TCA (Sodium TCA)
- picloram (Tordon)
- Triazine Compounds
  - simazine (Princep)
  - altrazine (AAtrex)
  - Atratol
  - propazine (Milogard)
  - prometone (Pramitol 25 E and Pramitol 5PS)
- Urox and Urab
- Substituted Urea and Uracil Compounds
  - monuron (Telvar)
  - diuron (Karmex)
  - linuron (Lorox)
  - bromacil (Hyvar-X, Hyvar X-1)
- Krovar I
- Ureabor

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[a] These herbicides were not separated as to preplant, preemergence or postemergence, because many of them can be used different ways. This is described in the "remarks" column for each herbicide.

Chemical weed control in field crops has increased significantly through the United States during the past two decades. The use of herbicides applied on corn alone during the 10-year period from 1959 through 1968 increased from 20,051,000 acres treated to 49,930,000 acres treated. Of all the corn harvested in 1959 for grain, only 25 percent was estimated to have had chemical weed control application but in 1968, the figure rose sharply to 76 percent [USDA 1972].

Many reports now conclude that chemical weed control in all the large corn growing states exceeds 90 percent of corn acreage planted. Von Rumker & Horay [1974] reported in 1974 that close to 100 percent of all corn growers in the leading corn growing states use herbicides and that close to 90 percent of the total corn acreage in the midwest is treated with herbicides.

3.7.3.1 Toxicity, Common Names and Uses of Selected Herbicides

Tables 3.7.3-B and 3.7.3-C display toxicity, common trade names and general uses of some herbicides.

TABLE 3.7.3-B RELATIVE TOXICITY OF SOME HERBICIDES TO RATS [a]

Common Name or Designation	Common Trade Names	Oral LD$_{50}$ Mg/Kg
Sodium Arsenite	Atlas A, Triox	10
DNBP	Premerge, Sinox, PE	40
Paraquat	Paraquat	150
2,4,5-T	Various Brands	300
Diquat	Diquat	400
Silvex	Kuron, Weedone-TP	500
2,4-D	Various Brands	500
MSMA	Ansar, Daconate	700
Cacodylic Acid	Phytar 560	830
Aspirin	(For Comparison)	1,240
Linuron	Lorox	1,500
TBA	Trysben 200	1,640
DSMA	Ansar, Sodar	1,800
Norea	Herban	2,500
Amitrole	Amintotriazole	2,500
Borate	Borax, Borascu	2,500
Dicamba	Banvel	2,900
Prometone	Pramitol	2,980
DCPA	Dacthal	3,000
Altrazine	AAtrex	3,080
TABLE SALT	(For Comparison)	3,320
Diuron	Karmex, Krovar 1	3,400
Monuron	Telvar	3,600
Chloroxuron	Tenoran	3,700
Prometryne	Caparol	3,750
AMS	Ammate	3,900
TCA	Various Brands	5,000
Siduron	Tupersan	5,000
Simazine	Princep	5,000
Sodium Chlorate	Sodium Chlorate	5,000
Propazine	Milogard	5,000
Bromacil	Hyvar X, X-L Krovar 1	5,200
Picloram	Tordon	8,200
Dalapon	Dowpon	9,300
Benefin	Balan	10,000

[a] Colorado Weed Control Handbook. Extension Service, Colorado State University (1976)

TABLE 3.7.3-C CLASSIFICATION OF HERBICIDES BY CHEMICAL FAMILIES [a]

Chemical Family	Common Name	Trade Name(s)	Toxicity Class [b]	Some General Uses
Amino Acids	glyphosate	Roundup	III	Foliar treatment, general vegetation control, non-cropland.
Benzoic acids	chloramben	Amiben, Vegiben	III	Preemergence in certain agronomic crops.
	dicamba	Banvel	II	Pre and postemergence in certain grass crops.
	2,3,6-TEA	Trysben, Benzac	III	Non-cropland weed control.
Benzonitriles	dichlobenil	Casoron	III	Preemergence weed control in fruit crops and ornamentals.
	bromoxynil	Brominil, Buctril	II	Early postemergence for certain small grains.
Carbamates	chlorpropham	Chloro-IPC, Furloe	III	Preemergence, certain hort. and agron. crops.
	barban	Carbyne	III	Wild oat control in wheat and barley.
Carbanilates	phenmedipham	Betanal	III	Postemergence sugarbeet herbicide.
Dinitroanilines	benefin	Balan	III	Preplant incorporated certain agron. & hort. crops.
	dinitramine	Cobex	III	Experimental preplant incorporated.
	fluchloralin	Basalin	III	Preplant incorporated certain agronomic crops.
	nitralin	Planavin	III	Preplant incorporated beans and hort. crops.
	profluralin	Tolban	III	Experimental preplant incorporated.
	trifluran	Treflan	III	Preplant incorporated agron. & hort. crops.
Dipyridyls	diquat	Ortho Diquat	II	Contact, non-crop, aquatic and desiccant.
	paraquat	Ortho Paraquat	I	Contact, non-crop, minimum tillage, directed post.
Halogenated Aliphatic acids	dalapon	Dowpon, Basfapon	II	Foliar treatment for control of annual and perennial grasses.
	TCA	Various	III	Selective and non-selective grasses.
Inorganic compounds	AMS	Ammate	III	Translocated foliar spray for woody plants.
	boron	Borax, Borascue	III	Non-selective vegetation control.
	copper sulfate	Bluestone, Cutrine	III	Algae control in aquatic situations.
	sodium chlorate	Atlacide, others	III	Short-term soil sterilant.
Organic Arsenicals	DSMA	Various	III	Postemergence crabgrass control in lawn & cotton.
	MAA	Various	II	Postemergence crabgrass control in lawn & cotton.
	MSMA	Various	II	Postemergence crabgrass control in lawn & cotton

TABLE 3.7.3-C (Continued)

Chemical Family	Common Name	Trade Name(s)	Toxicity Class[b]	Some General Uses
Phenols	dinoseb	Premerge, Sinox	I	Early post and directed sprays for certain crops.
Phenoxy compounds Acetic	2,4-D	Various	III	Broadleaf, in cereal crops, lawns, pastures, etc.
	MCPA	Methoxone, Weedar Weedone	III	Broadleaf, in cereal crops, lawns, pastures, etc.
	2,4,5-T	Various	II	Foliar spray for wood plants.
Butyric	2,4-DB	Butoxone, Butyrac	III	Postemergence, certain hort. and agron. crops.
	MCPB	Thistrol, Can-Trol	III	Postemergence weed control in legume crops.
Propionic	2(2,4-DP)	Weedone	III	Postemergence weed control in lawns and turf.
	2(MCPP)	Several	III	Postemergence weed control in lawns and turf.
	2,4,5-TP (silvex)	Kuron	II	Broadleaf control in lawns & aquatic weeds.
Phenyl ethers	nitrofen	TOK	III	Pre and postemergence, certain hort & agron crops.
	bifenox	Modown	III	Experimental preemergence for corn.
Phthalic acids	DCPA	Dacthal	III	Preemergence use in hort. and agron. crops.
	endothal	Aquathol, Hydrathol	II	Aquatic weed control.
	Naptalam	Alanap	III	Preemergence use in certain horticultural crops.
Pyridyls	picloram	Tordon	III	Non-cropland weed control.
Pyridazinones	Pyrazon	Pyramin	III	Pre and postemergence in sugarbeets.
Substituted Amides	alachlor	Lasso	II	Premergence in corn and other agron. crops.
	bensulide	Betasan, Prefar	III	Preemergence annual grass cont. in turf & cucurbits.
	benzadox	Topcide	III	Postemergence control of kochia in sugarbeets.
	diphenamid	Dymid, Enide	III	Preemergence weed control in agron & hort crops.
	pronamide	Kerb	III	Experimental preemergence, alfalfa.
	propachlor	Ramrod	II	Preemergence, certain agronomic crops.
	prynachlor	Basamaize	III	Experimental, preemergence, annual grasses, broadleaf, corn and beans.

TABLE 3.7.3-C (Continued)

Chemical Family	Common Name	Trade Name(s)	Toxicity Class[b]	Some General Uses
Thio-carbamates	butylate	Sutan	III	Preplant incorporated for weed control in corn.
	CDEC	Vegedex	III	Preemergence in certain vegetable & agron. crops.
	cycloate	Ro-Neet	III	Preplant weed control sugarbeets.
	diallate	Avadex	III	Preemergence control of wild oats.
	EPTC	Eptam	III	Preplant incorporated, several hort. & agron. crops.
	EPTC + antidote	Eradicane	III	Preplant incorporated use in corn.
	pebulate	Tillam	III	Preplant incorporated use in tomatoes.
	triallate	Fargo	III	Wild oat control in wheat and barley.
	vernolate	Vernam	III	Preplant incorporated use in hort. crops.
s-Triazines (symmetrical)	ametryne	Evik	III	Postemergence directed in corn.
	atrazine	AAtrex	III	Preemergence & early post in corn & sorghum.
	cyanazine	Bladex	II	Preemergence & early post in corn.
	cyprazine	Outfox	II	Early postemergence weed control in corn.
	prometone	Pramitol	III	Soil sterilant for non-cropland.
	propazine	Milogard	III	Preemergence use in sorghum.
	simazine	Princep	III	Long term soil sterilant.
	terbutryn	Igran	III	Preemergence in sorghum.
as-Triazines (symmetrical)	metribuzin	Sencor, Lexone	III	Preemergence and post weed control in potatoes.
Triazoles	amitrole	Weedazol, Amino-triazole	III	General weed control non-crop areas.
	methazole	Probe	II	Experimental preemergence use in onions & sorghum.
Uracils	bromacile	Hyvar	II	Non-crop soil sterilization.
	terbacil	Sinbar	IV	Preemergence weed control in certain fruit crops.
Ureas	chloroxuron	Tenoran, Norex	III	Early postemergence use in strawberries.
	diuron	Karmex	III	Pre in several agron. crops and soil sterilant.
	fenuron	Dybar	III	Soil treatment for woody plants.
	linuron	Lorox	III	Pre and post directed in several agron. crops.
	monuron	Telvar	III	Pre in several agron. crop and soil sterilant.
	siduron	Tupersan	III	Preemergence annual grass control in turf.

TABLE 3.7.3-C (Continued)

[a] Colorado Weed Control Handbook, Colorado State University Extension Service (1976).

TOXICITY CLASSES [b]

I = highly toxic LD_{50} rating 1-50 mg/kg = probable lethal dose to man a pinch or 1 teaspoon.

II = moderately toxic. LD_{50} rating 50-500 mg/kg = probable lethal dose to man 1 teaspoon to 2 T's full.

III = slightly toxic. LD_{50} rating 500-5000 mg/kg = probable lethal dose to man 1 oz. to 1 lb. (1 pt).

IV = almost non-toxic. LD_{50} rating above 5000 mg/kg = probable lethal dose to man 1 pt. to 1 qt. (2 lbs.).

3.7.4 Herbicide Use in the Larimer-Weld Region

Private interviews with growers producing irrigated crops in the Larimer-Weld region and discussions with fertilizer and chemical dealers located within the two-county region point out that herbicides are extensively used by close to 80 percent of all irrigated crop growers in the region.

Table 3.7.4-A shows major crops in the two-county region grown and the corresponding herbicides most commonly used along with application rates:

TABLE 3.7.4-A HERBICIDES COMMONLY USED IN THE LARIMER-WELD REGION [a]

Crop	Herbicide Most Commonly Used	Rates per Acre
Corn	AAtrex	1-1/2 to 2 lbs.
	2,4-D	1/2 to 3/4 lb.
	Banvel	1/8 to 1/4 lb.
	Lasso	3 lbs.
	Bladex	1-1/2 to 2 lbs.
	Many combinations of the above	
Beet (sugar)	Ro-Neet	3 to 4 lbs.
	Betanal	1 to 1-1/4 lbs.
	Dowpon Basfapon	1-1/2 to 3 lbs.
	Betanex	3/4 to 1-1/4 lbs.
Small Grain (Barley, wheat Oats)	2,4-D	1/2 to 1 lb.
	Banvel	1/8 to 1/4 lb.
	Ca-Byne	1/4 to 3/8 lb.
Beans	Treflan	1/2 to 3/4 lb.
	Eptam	3 lbs.
	Lasso	3 lbs.
Alfalfa	Princep	1-1/2 lbs.

[a] Developed from private farmer interviews, local fertilizer and chemical companies and from the Weed Control Handbook of Colorado published by CSU Extension Service.

CHAPTER 4.0

WASTE DISCHARGERS ASSOCIATED WITH IRRIGATED AGRICULTURE

4.1 SAMPLING PROGRAM

4.1.1 Selection of Sites

A sampling program was conducted to identify the relationship between irrigation and water quality in the Larimer-Weld region. Two general types of sampling sites were necessary in this analysis: 1) sampling sites which could be associated with specific fields and/or sub-basin drainages were necessary in order to define the quality of irrigation return flows, and 2) sampling of rivers and returns to rivers were necessary in order to identify the impact of return flows upon water quality in the major streams. A significant difference between the return flows leaving a small area and an actual impact upon the stream was expected since the complicated irrigation network facilitates considerable reuse of any wastewater.

A flexible sampling program was desirable since the study was directed towards a large region with little or no previous data. Areas of specific interest and specific problem areas had not been identified prior to the start of this program. In the flexible sampling program a commitment was made not to sample specific sites at regular intervals.

The flexible program allowed good coverage of a large area without committing resources to sampling sites which might later prove to be of little interest.

Samples of both surface and subsurface return flows were necessary to this program. Surface irrigation systems generally require that some water run off the end of the field in order to achieve a good distribution of water in the field. This tailwater may then seep into the ground, be reused, or return to the river through a natural or man-made channel. Most tailwater in the region is reintroduced to the distribution system.

Subsurface return flow may re-enter the river through artificial drainage or by ground water flow. Artificial tile drains discharge to a wet area, a natural or man-made channel, or to a major river. Ground water movement is the major source of return flows to the rivers. Ground waters recharge most streams in the irrigated region to an extent, and are a major source of water in streams and rivers throughout the irrigated region.

Sampling sites were located by checking maps for obvious surface return channels and field checking. A cooperative agreement between the Larimer-Weld Council of Governments and the Soil Conservation Service (SCS) was reached and their aid was enlisted in finding sampling sites. The SCS offers free design of sub-surface tile drainage facilities and for this reason is aware of the location of some of these facilities, although records have sometimes been destroyed a few years after installation. In addition, local personnel are well traveled in the area they serve and have a general knowledge of the function of the various ditches and streams. Of equal importance is the fact that SCS personnel are acquainted with many farm operators who allowed access to their land for sampling purposes.

The cooperation of many farm operators was a significant contribution to this study.

4.1.2 Pollutants Associated with Irrigated Agriculture

Pollutants associated with irrigated agriculture are salinity, nitrates, sediment, phosphorus, and pesticides. Samples were analyzed for each of these parameters, with the exception of pesticides.

The pollutants associated with irrigation returns occur in lower concentrations than those in municipal and industrial wastes. Biochemical oxygen demand (BOD), fecal coliform bacteria, and ammonia nitrogen are not usually associated with irrigated agriculture. Nitrate nitrogen and phosphorus (both nutrients for plants and algae) are associated with irrigated return flows as well as municipal and industrial wastes.

Salinity is a pollutant resulting from domestic and agricultural use, as well as natural background conditions. Saline water is that which contains significant concentrations of dissolved cations (calcium, magnesium, or sodium) and anions (chloride, carbonate, bicarbonate, sulfate, or nitrate). These salts become dissolved as the water contacts saline rocks or soils. Evaporation and transpiration from irrigated cropland remove pure water concentrating the salts in the remaining water.

Evaporation from lakes, canals, and wetlands as well as transpiration by phreatophytes (water loving plants) also concentrates these salts. Increases in salinity are associated with drainage and sub-surface returns. Tailwater rarely exhibits significantly increased salinity. Saline water is of less value to downstream irrigators since it may reduce yields, and requires the use of less valuable crops. It also requires improved irrigation and drainage practice and equipment. Saline waters are of less value for domestic and industrial use.

Nitrate concentrations of greater than 10 mg/l as N (45 mg/l NO_3) are considered unsuitable for domestic and dairy use since they have been linked to methemoglobinemia in infants (blue babies).

Nitrogen fertilizers have become an economic necessity in modern agriculture. While nitrogen may be in several forms when applied as fertilizer, commercial fertilizers are oxidized to the soluble nitrate form by soil bacteria.

Nitrates not used by plants may be leached from the root zone and therefore are associated with drainage and subsurface returns in agriculture. Nitrate concentrations in tailwater are not significantly higher than source water unless fertilizer is mixed into irrigation water.

Sediment is the result of erosion. It is a pollutant for domestic and recreational uses, but amounts incurred in the Larimer-Weld region do not deter the quality of water for irrigation. Soil loss in the irrigated portion of the Larimer-Weld region is mainly associated with furrow irrigation.

Phosphorus is a pollutant to water since it is a nutrient required by algae. Phosphorus has a high affinity for soil particles and for this reason phosphorus exported from agricultural land is associated with sediment. The phosphorus adsorbed by mineral soil particles and contained in organic soil particles is not used by algae until soluble forms are exhausted.

Pesticides are a pollutant for all uses of water, especially domestic use. The many types of pesticides and the minute concentrations encountered makes analysis difficult and expensive. For this reason samples were not analyzed for pesticides in this study; rather, data from the U.S. Geological Survey sampling sites at Kersey and Julesburg, Colorado were used.

Pesticides vary considerably in their characteristics. A joint USDA, ARS and EPA study [1975] indicates the following for 171 different pesticides.

Predominant Transport Mechanism	Percent of Sample
Associated with sediment	46
Associated with water	30
Associated with sediment and water	16
Unknown	8
	100

4.2 POLLUTANT LEVELS IN THE IRRIGATION RETURN FLOWS OF THE LARIMER-WELD REGION

This chapter presents data from the sampling program. The data indicates that there are some water quality problems in the Larimer-Weld region associated with irrigation return flows. Salinity is the most significant of these problems. Levels of nitrogen are fairly high at times, but these nitrate levels may not be significant to downstream users.

4.2.1 Salinity

4.2.1.1 Introduction

Salinity is a significant pollutant in the Larimer-Weld region, as in the remainder of the western United States. In the Larimer-Weld region, the pick up of salts results from the weathering of shale underlying upland soils. This yields high sulfate waters. The irrigation system of reservoirs, canals, and on-farm distribution increases contact with shale formations. Many irrigated upland soils along the front range have this shale as their parent material. Weathering of subsoils is an ongoing process. Levels of total dissolved solids in the major rivers are detrimentally affected by the return of underground water which has had contact with the shale formations. Opportunity for water contact with the shale increases when the shale is close to the surface.

4.2.1.2 Salinity and Water Quality

Salinity imparts an objectionable taste to water. It is also a detriment to water quality for agricultural and industrial use. Because of the objectionable taste of saline water, recommendations have been made by several agencies that levels of total dissolved solids (TDS) be no greater than 500 to 1000 mg/l. Water with concentrations above this level have a noticeably poor taste. Yet in many areas of the Great Plains, there are no water resources free from impairment by high TDS. Sulfate is an objectionable ion since it may cause distress in the lower intestinal tract of humans or animals not accustomed to it. Calcium and magnesium are ions responsible for "hard" water, a condition impairing the effectiveness of soap.

From an agricultural standpoint, salinity is the most serious pollutant. Above certain concentrations in the root zone, salinity impairs osmotic processes resulting in reduced crop yield. For this reason, salts must be leached from the root zone. Water quality determines, to a large extent, the type of crop to be grown.

4.2.1.3 Salinity in the Larimer-Weld Region

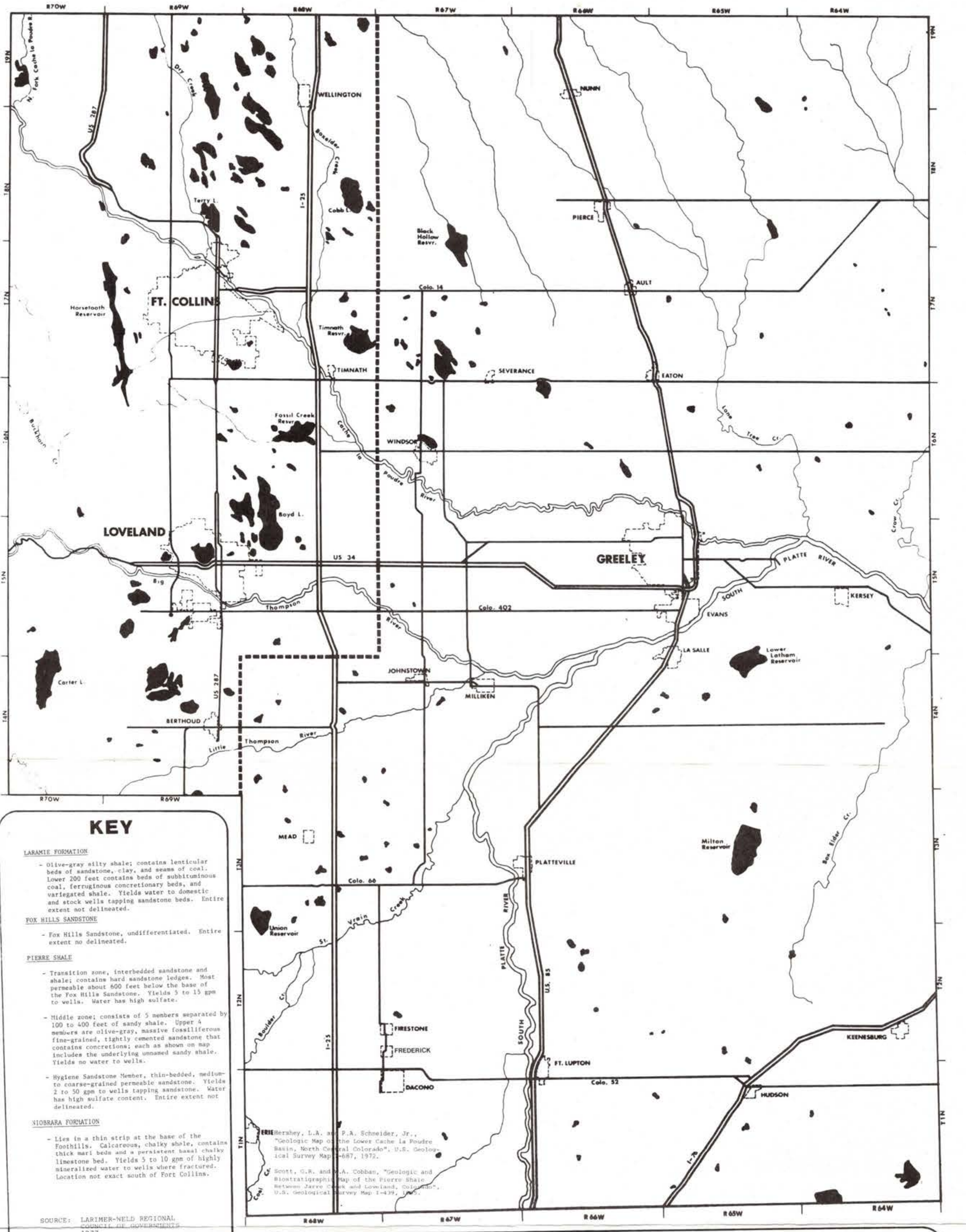
Salinity in the Larimer-Weld region is attributable to contact between water and the shale formations. The shale is close to the surface in several scattered places throughout the region. Figure 4.2.1-A shows the location of underlying formations which may be affecting water quality.

While the Pierre middle zone is nearly impermeable, water having contact may be affected. Water contacts the shale in several ways. In some places, the shale is a surface outcropping, while in other places the shale is overlain by soil weathered from the shale. Reservoirs, canals, and irrigated lands lie on top of the shale terrace. Water seeping from this land is continually weathering the shale below and dissolving salts.

The Pierre shale is impermeable with the exception of two layers within the shale group: the topmost transition zone and the lower hygiene sandstone member. These may yield from 5 to 15 and from 2 to 50 gpm to wells, respectively [Hershey, and Schnieder, 1972]. The Pierre transition layer has an adverse effect on water quality, yielding high sulfate waters. This transition layer may be overlain by a soil weathered from it or by a loess (wind deposited soil). In either case, water seeping from ditches, reservoirs, and over irrigation has the opportunity to weather the underlying shale and dissolve salts.

While not highly permeable, it is believed that the contact opportunity afforded by canals, reservoirs, and over-irrigation produces enough seepage to be of concern. Water produced by seepage through these layers is quite mineralized, with TDS levels from 4000 to 6000 mg/l.

A second way in which water contacts shale is by ground water movement through the loess perched on top of the shale terrace. Very high TDS concentrations were found in drains which removed water from these water tables on top of the shale. Drains PD5, SVD2, SVD3 are examples of drains producing 4000 to 6000 mg/l TDS water on top of the transition layer of the Pierre. Drains SPD3 and SPD4 produce 2000 to 4500 mg/l TDS water from on top of the Laramie formation. This



Hershey, L.A. and P.A. Schneider, Jr., "Geologic Map of the Lower Cache la Poudre Basin, North Central Colorado", U.S. Geological Survey Map I-687, 1972.

Scott, G.R. and W.A. Cobban, "Geologic and Biostratigraphic Map of the Pierre Shale Between Jarre Creek and Loveland, Colorado", U.S. Geological Survey Map I-439, 1965.

KEY

LARAMIE FORMATION

- Olive-gray silty shale; contains lenticular beds of sandstone, clay, and seams of coal. Lower 200 feet contains beds of subbituminous coal, ferruginous concretionary beds, and variegated shale. Yields water to domestic and stock wells tapping sandstone beds. Entire extent not delineated.

FOX HILLS SANDSTONE

- Fox Hills Sandstone, undifferentiated. Entire extent no delineated.

PIERRE SHALE

- Transition zone, interbedded sandstone and shale; contains hard sandstone ledges. Most permeable about 600 feet below the base of the Fox Hills Sandstone. Yields 5 to 15 gpm to wells. Water has high sulfate.
- Middle zone; consists of 5 members separated by 100 to 400 feet of sandy shale. Upper 4 members are olive-gray, massive fossiliferous fine-grained, tightly cemented sandstone that contains concretions; each as shown on map includes the underlying unnamed sandy shale. Yields no water to wells.
- Hygiene Sandstone Member, thin-bedded, medium- to coarse-grained permeable sandstone. Yields 2 to 50 gpm to wells tapping sandstone. Water has high sulfate content. Entire extent not delineated.

NIOBRARA FORMATION

- Lies in a thin strip at the base of the Foothills. Calcareous, chalky shale, contains thick marl beds and a persistent basal chalky limestone bed. Yields 5 to 10 gpm of highly mineralized water to wells where fractured. Location not exact south of Fort Collins.

SOURCE: LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS 1977

SCALE

0 1/2 1 2 3 4 5 MILES

N

Geologic Formations

LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS

FIG. 4.2.1-A

AREAWIDE WATER QUALITY PLAN

THE PREPARATION OF THIS MAP WAS FINANCED IN PART THROUGH A WATER QUALITY MANAGEMENT TECHNICAL ASSISTANCE PLANNING GRANT FROM THE ENVIRONMENTAL PROTECTION AGENCY UNDER THE PROVISIONS OF SECTION 208 OF THE FEDERAL WATER POLLUTION CONTROL ACT OF 1972 (PL 92-500)

data indicates that the break between certain shale layers and overlying loess is not distinct.

While salt pickup is possible from runoff over exposed shale and tailwater from irrigation, both of these mechanisms are very small in their contribution to total loading. Runoff from non-irrigated areas of exposed shale is small, and occurs very rarely while high TDS levels occur consistently throughout the year. While this runoff has a significant effect on streams and ponds in the non-irrigated area, most of these do not contribute to river flow. In addition, a runoff event probably lowers TDS levels in dry-land water bodies. In the sampling program, tailwater, supply water, and drain water samples were collected at two areas, one south of Severance, and one near Barnesville. In each of these locations, tailwater showed almost no TDS increase, while drain samples were highly mineralized.

Salts picked up from the shale are concentrated by evapotranspiration from the irrigated areas and wetlands extending downstream in the South Platte Basin.

4.2.1.3.1 Salinity Levels in the Larimer-Weld Region

Levels of total dissolved solids in the region are displayed on Figures 4.2.1-B through 4.2.1-M. Samples from the major rivers in the plains are generally in the 1000 mg/l range, with over 85 percent of samples below 2000 mg/l. Return flows from tile drains and tributaries fed by irrigation returns place a salinity load on the major rivers. Thirty-eight percent of tile drain samples contained over 2000 mg/l TDS. Tributary samples appear to be more diluted yet because of their greater flow probability placing a greater loading on the stream. Thirty-nine percent of tributary samples contain over 1500 mg/l TDS. Seepage of ground water into the river may well be the major source of salinity loading.

The data for each basin was displayed for the rivers and for the drainage and tributary samples combined. In the Cache la Poudre River, 44 percent of the samples were below 1000 mg/l and 46 percent were above (Figure 4.2.1-F). In the Big Thompson River, water quality in the river is very good with respect to TDS. Return flows place a pollutant load upon the river, (Figure 4.2.1-I), yet none of the returns are of extremely high concentrations. The quality of the Little Thompson, on the other hand, is distinctly impaired by salinity (Figure 4.2.1-J), and inflows to the river in the plains are of two distinct types depending upon location: (1) moderately saline (1000-1500 mg/l TDS); (2) highly saline (2500-3500 mg/l TDS) (Figure 4.2.1-K). St. Vrain Creek has a few very highly saline return flows (Figure 4.2.1-M) yet the volume of these returns is not sufficient

Salinity - All Basins

Fig. 4.2.1-B AB I. All Samples

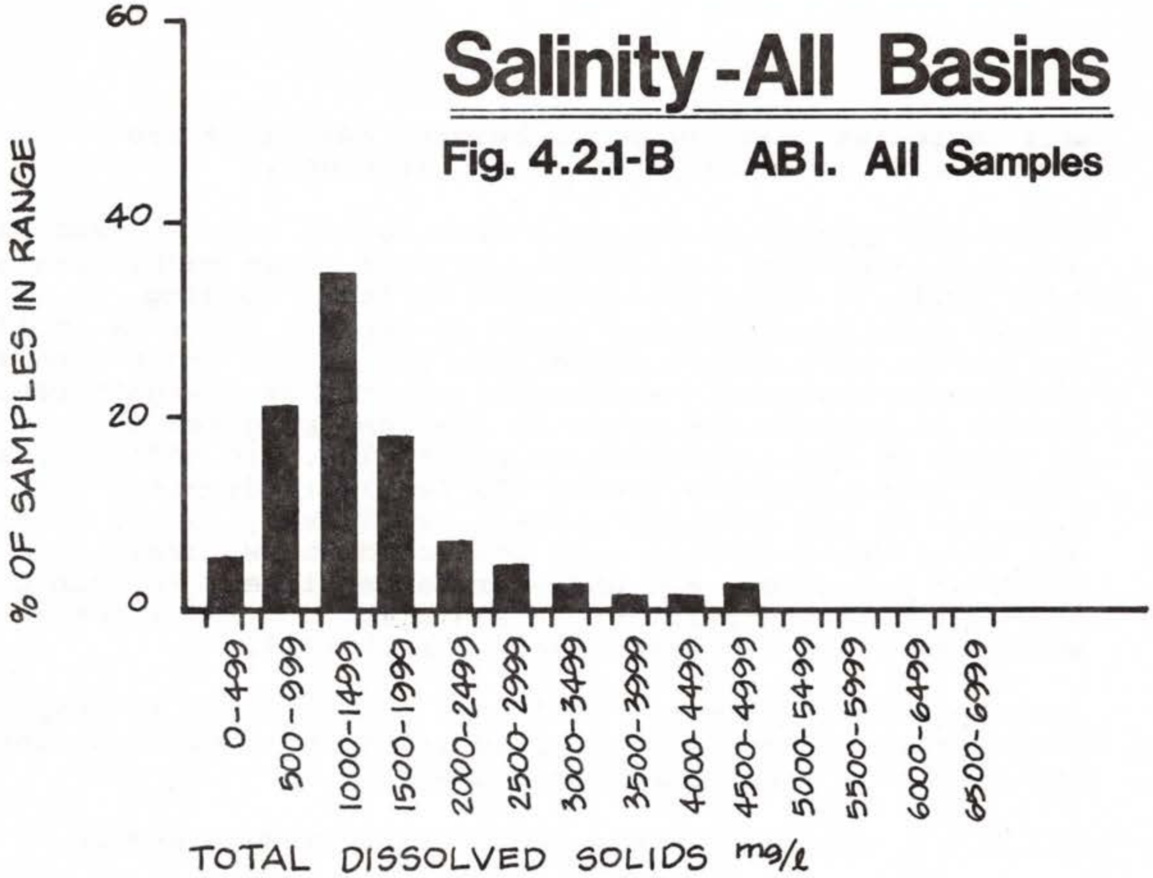
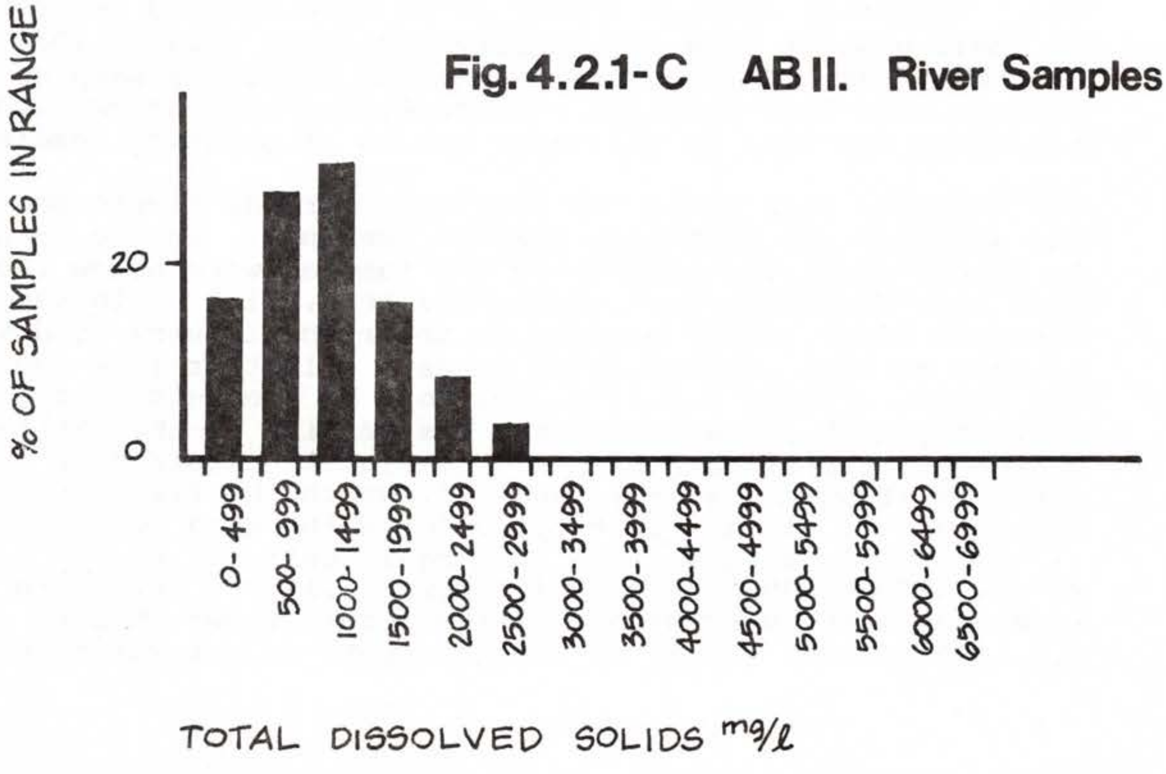


Fig. 4.2.1-C AB II. River Samples



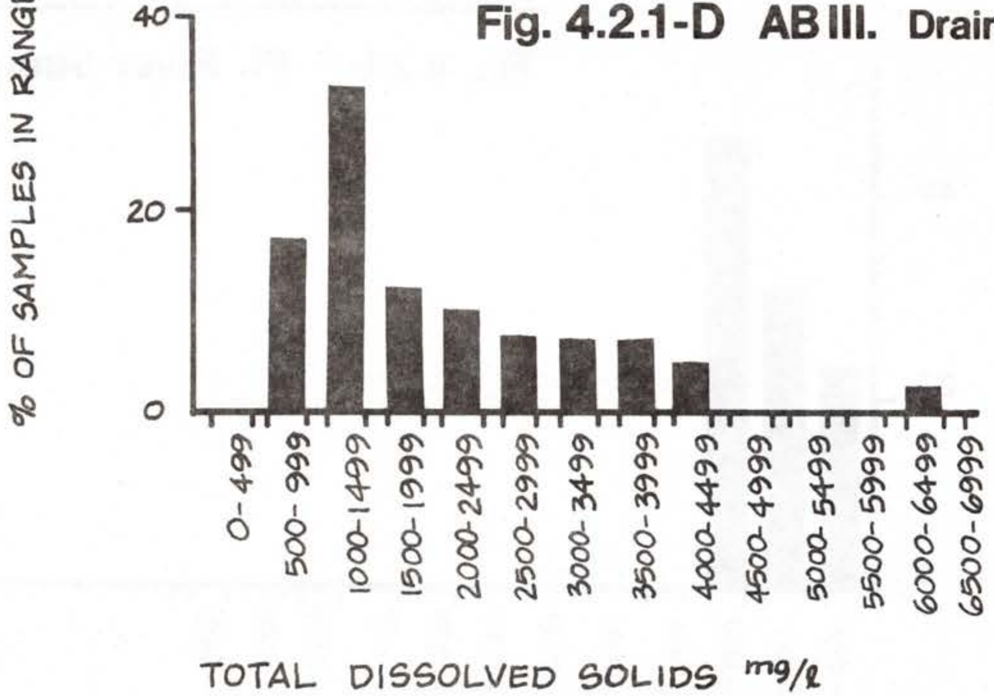


Fig. 4.2.1-D AB III. Drainage Samples

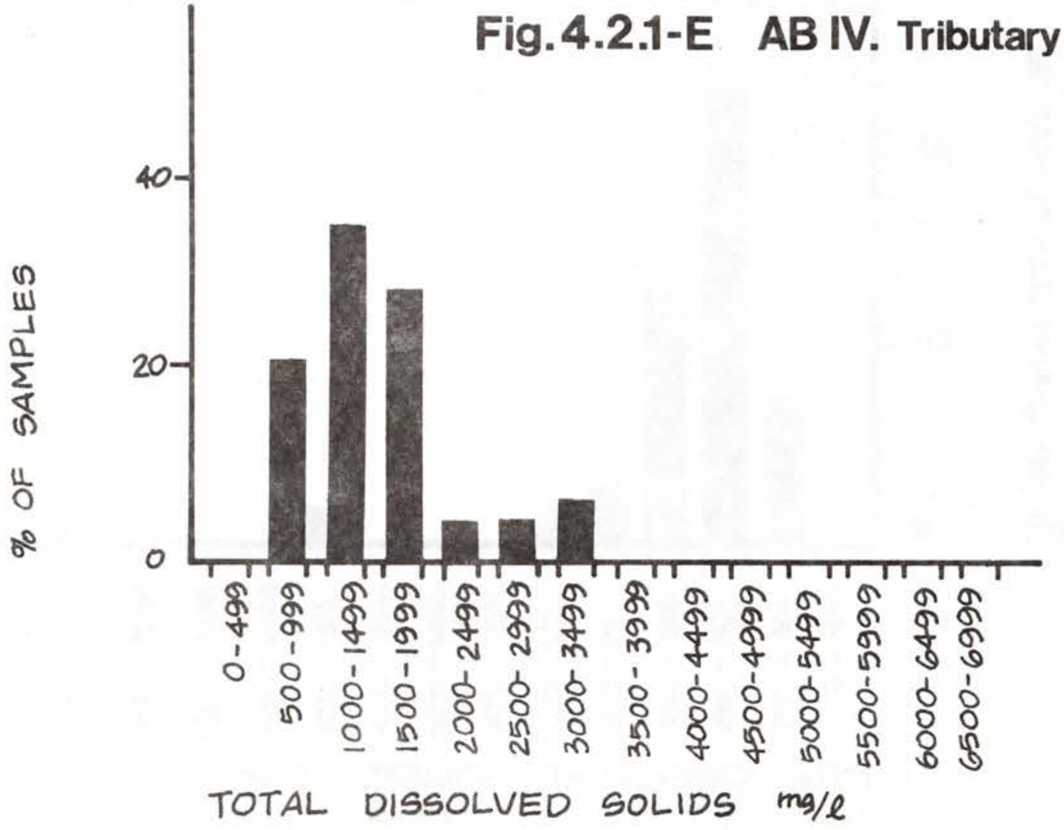


Fig. 4.2.1-E AB IV. Tributary Samples

Cache La Poudre

Fig. 4.2.1-F **Pl. River Samples**

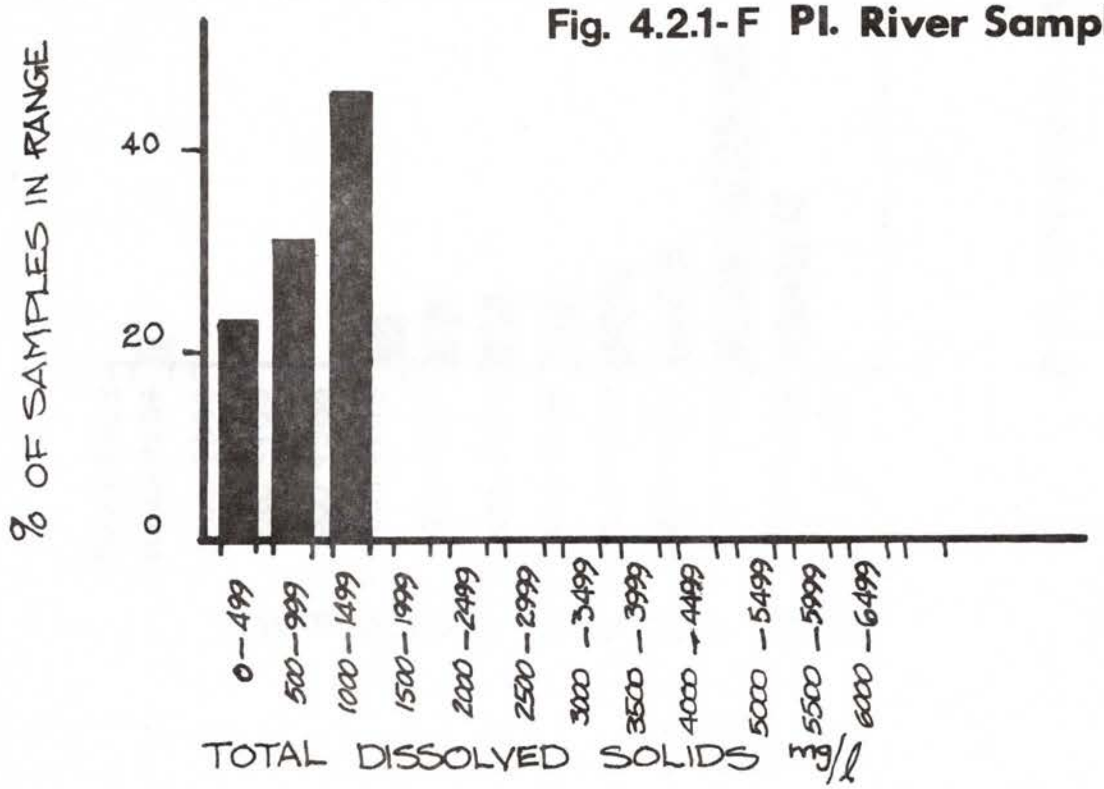
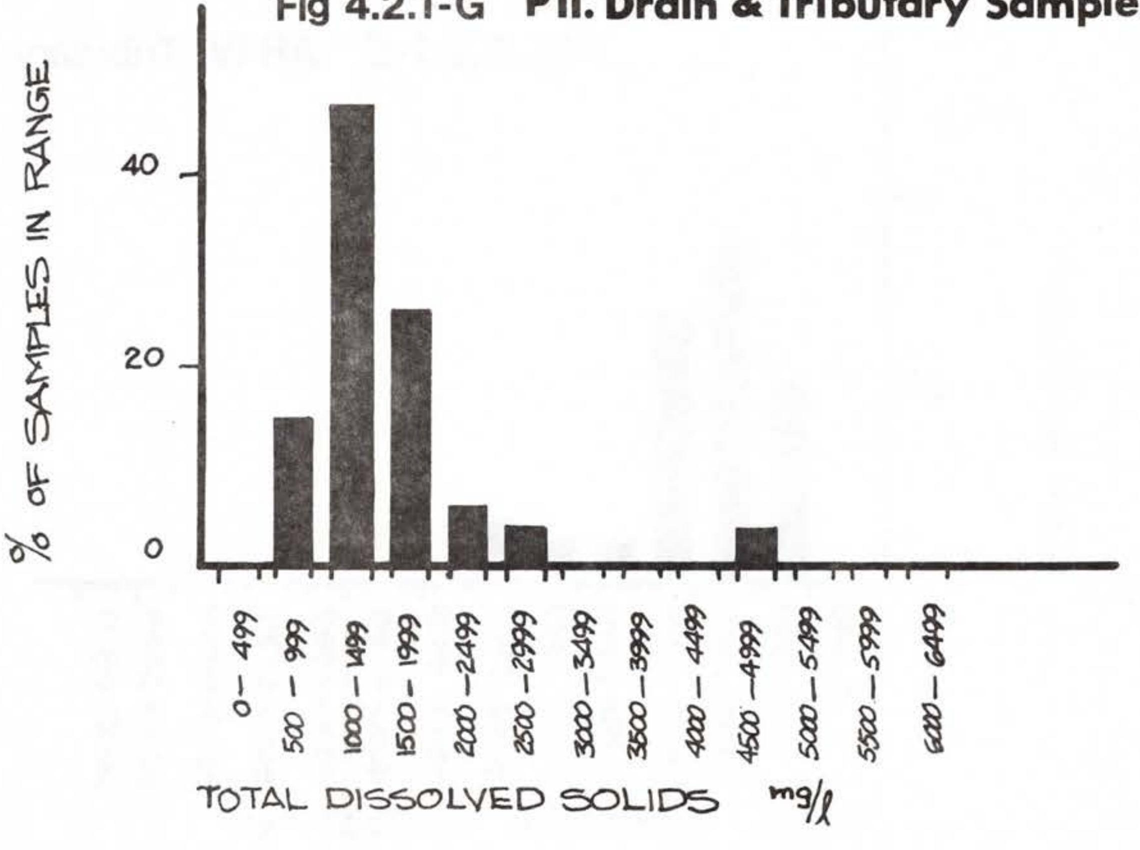


Fig 4.2.1-G **PII. Drain & Tributary Samples**



Big Thompson

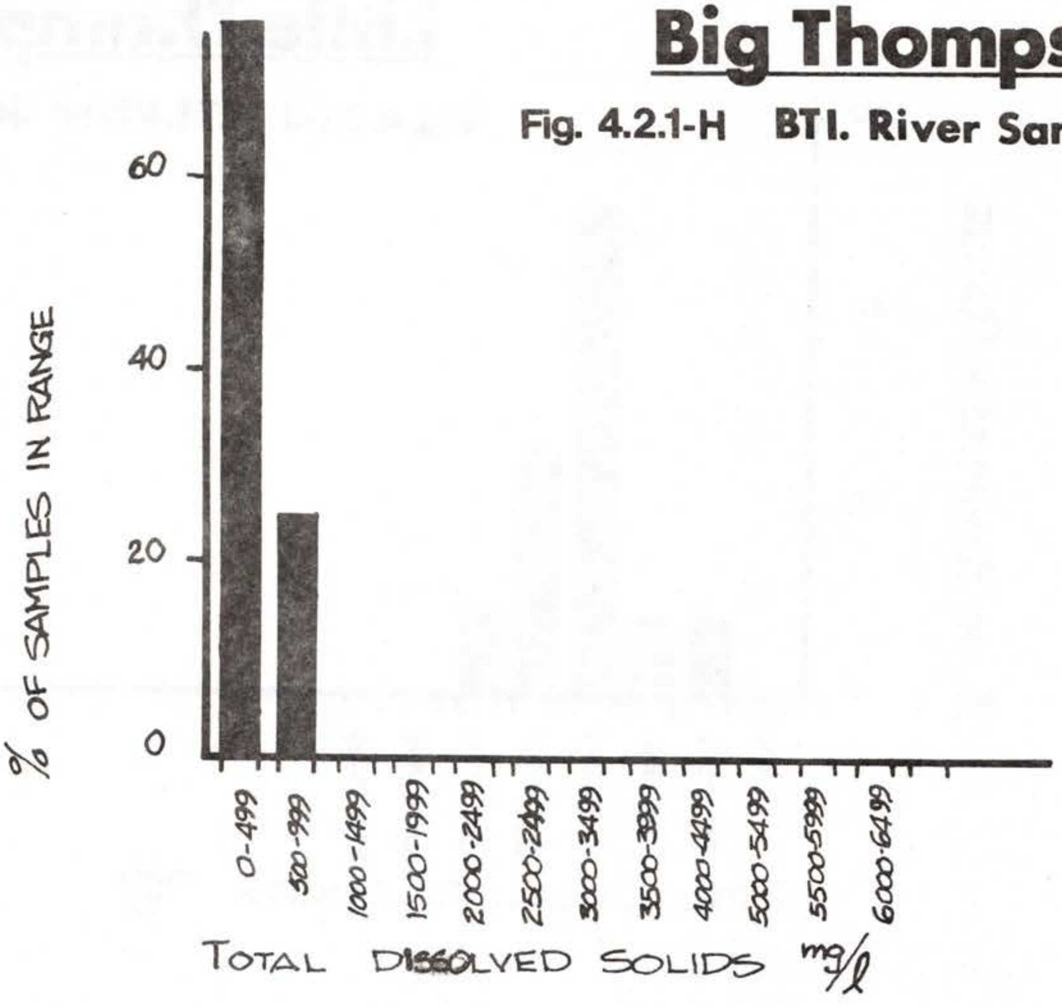


Fig. 4.2.1-H **BTI. River Samples**

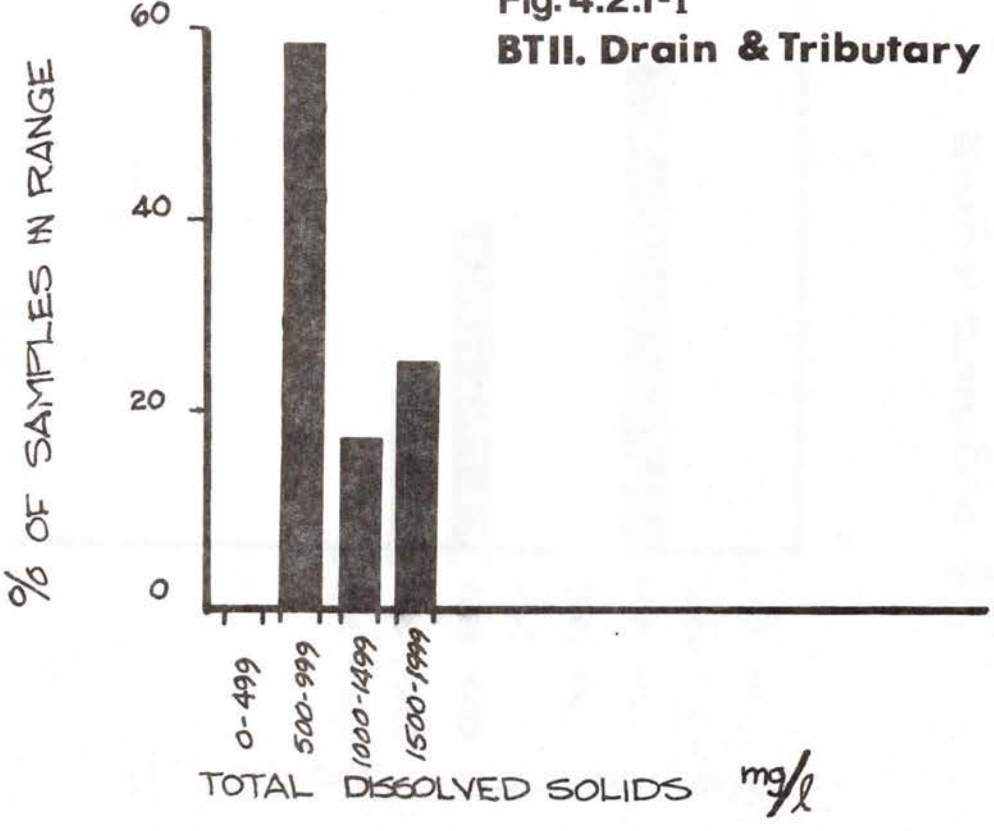


Fig. 4.2.1-I
BTII. Drain & Tributary Samples

Little Thompson

Fig. 4.2.1-J **LT I. River Samples**

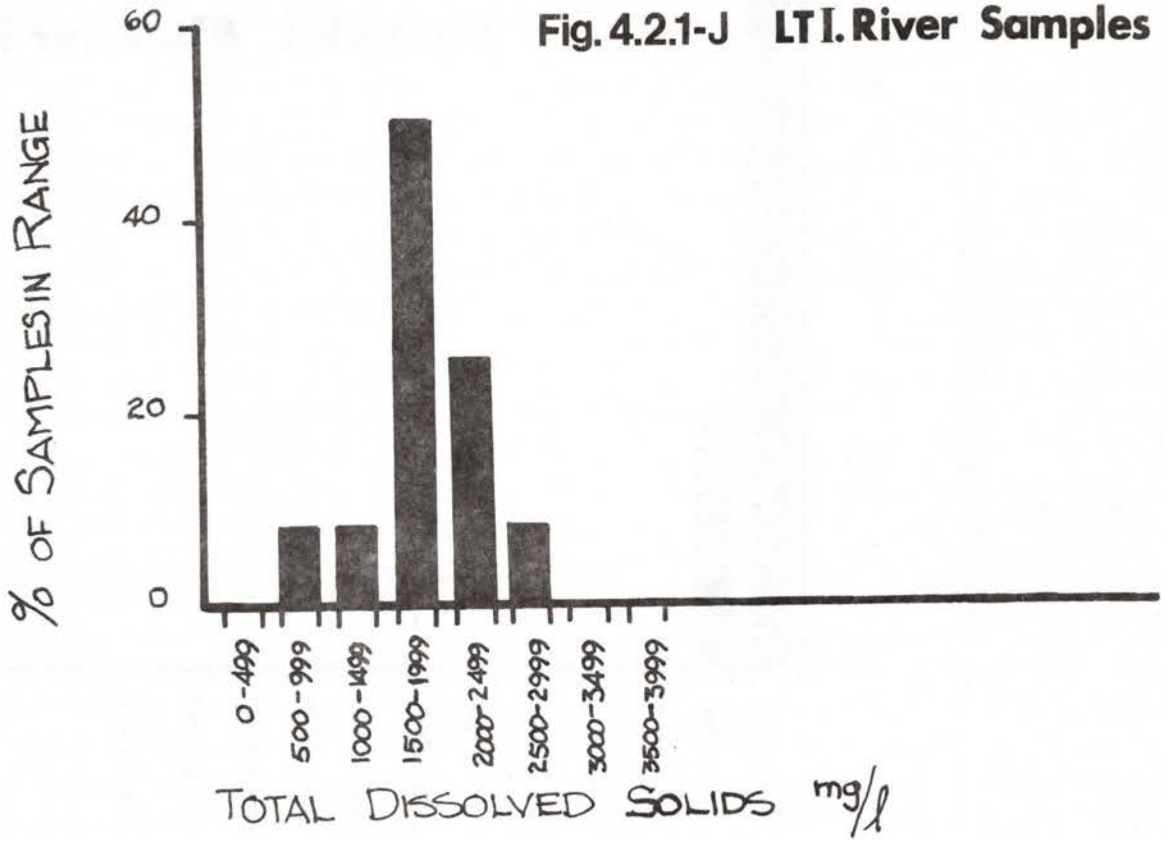
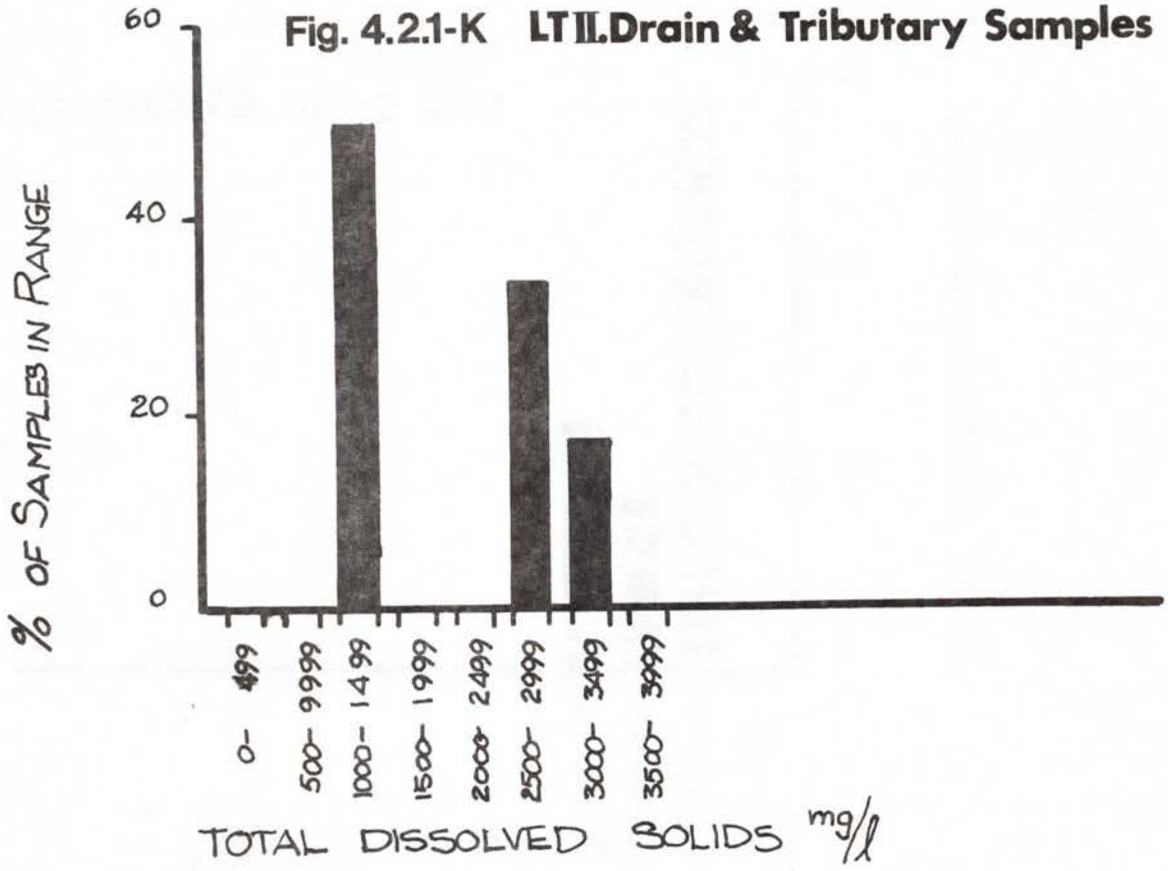


Fig. 4.2.1-K **LT II. Drain & Tributary Samples**



St. Vrain

Fig. 4.2.1-L SV-I. River Samples

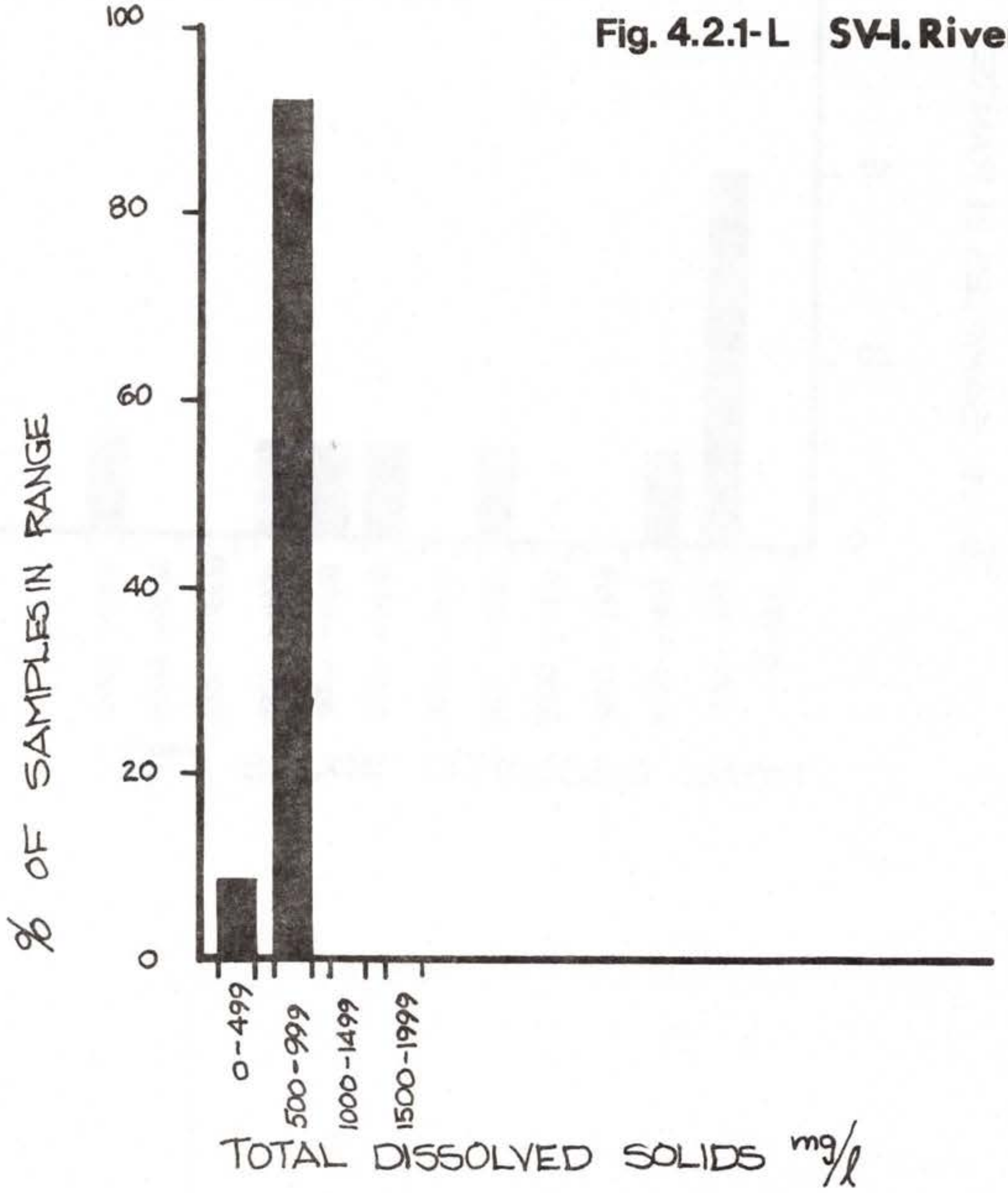
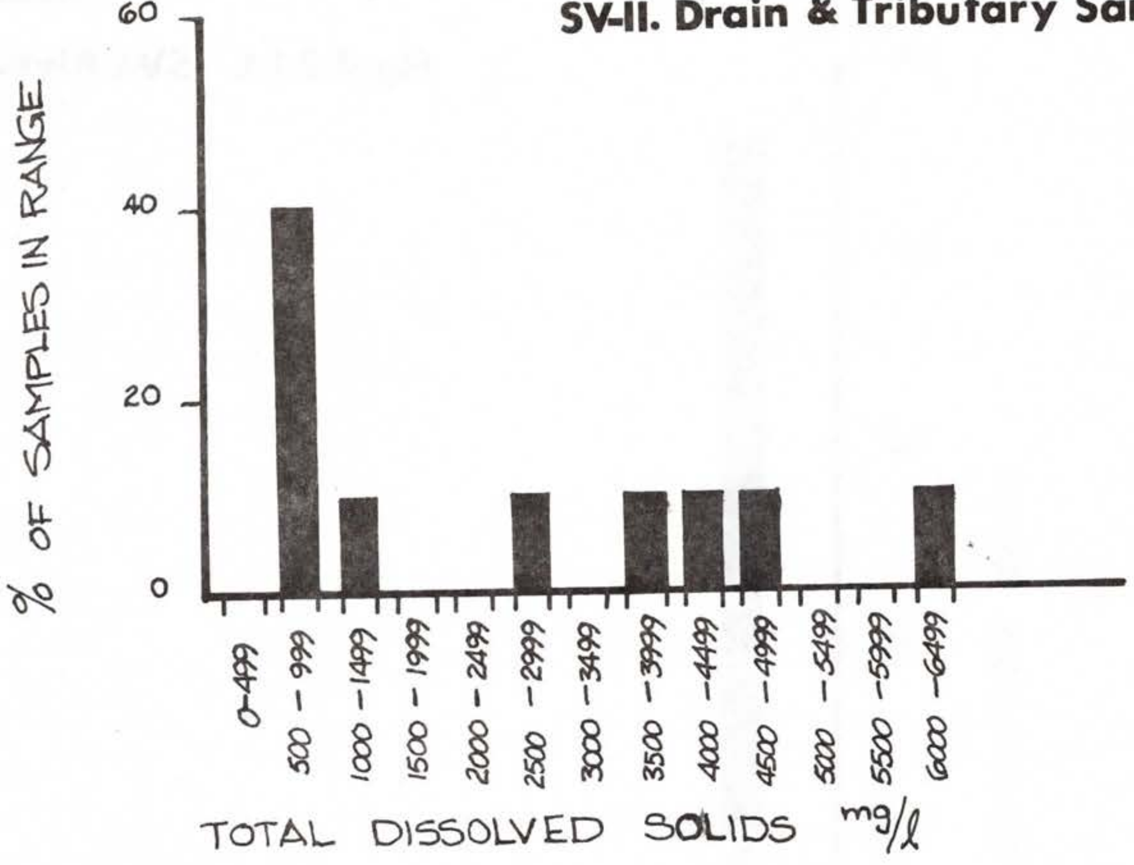


Fig.4.2.1-M
SV-II. Drain & Tributary Samples



to cause a large degradation to the water quality (Figure 4.2.1-L). The South Platte River ultimately receives all of these flows. The average annual TDS at Kersey is around 1200 mg/l (Figure 5.6.2-A).

A detailed discussion of salinity loading and sources will be presented for each river basin.

4.2.2 Nitrates

Nitrate pollution of the ground water in Larimer and Weld Counties is wide-spread. Many of the farms and small town wells yield water which contains more than the 10 mg/l of nitrate-nitrogen set as a limit in the National Interim Primary Drinking Water Regulations (Federal Register 1975).

Nitrate is also a nitrogen form available to algae. It is for this reason that nitrates are considered a pollutant in surface water. Nitrates in major streams in the region are consistently below the 10 mg/l NO_3-N set as a safe limit for water supply.

4.2.2.1 Nitrogen as a Pollutant

Nitrate is a pollutant which has been linked to the occurrence of methemoglobinemia (blue babies) in infants. Nitrate is also an essential nutrient for algae. In normal concentrations, nitrate is not directly detrimental to fish.

Nitrate poisoning may occur in infants and in cattle. The infant need not have direct exposure as milk can carry high nitrates from the source water to the infant. The level of nitrates for safe water has been set at 10 mg/l as N.

As an algal nutrient, nitrate is readily available. However, algae growth is limited by a lack of either nitrates or phosphates. It is doubtful that nitrogen is the limiting nutrient in the plains area since high nitrate levels and low phosphate levels are found in most waters.

Nitrate is beneficial in irrigation waters since it is a plant nutrient.

Nitrate nitrogen is a key element in the nitrogen cycle. Nitrogen comprises 78 percent of the earth's atmosphere and is present in all organic matter. It is the nutrient required in the greatest amount by plants, including algae. The nitrogen cycle (Figure 4.2.2-A) is fairly complex, yet the pathways of the major nitrogen sources can be described with it.

Domestic sewage treatment plants release nitrogen in the forms of ammonia (NH_3), nitrite (NO_2), and nitrate (NO_3). All of these forms are eventually oxidized to nitrate. The nitrate form is highly soluble. The nitrite form is unstable and generally occurs in insignificant amounts.

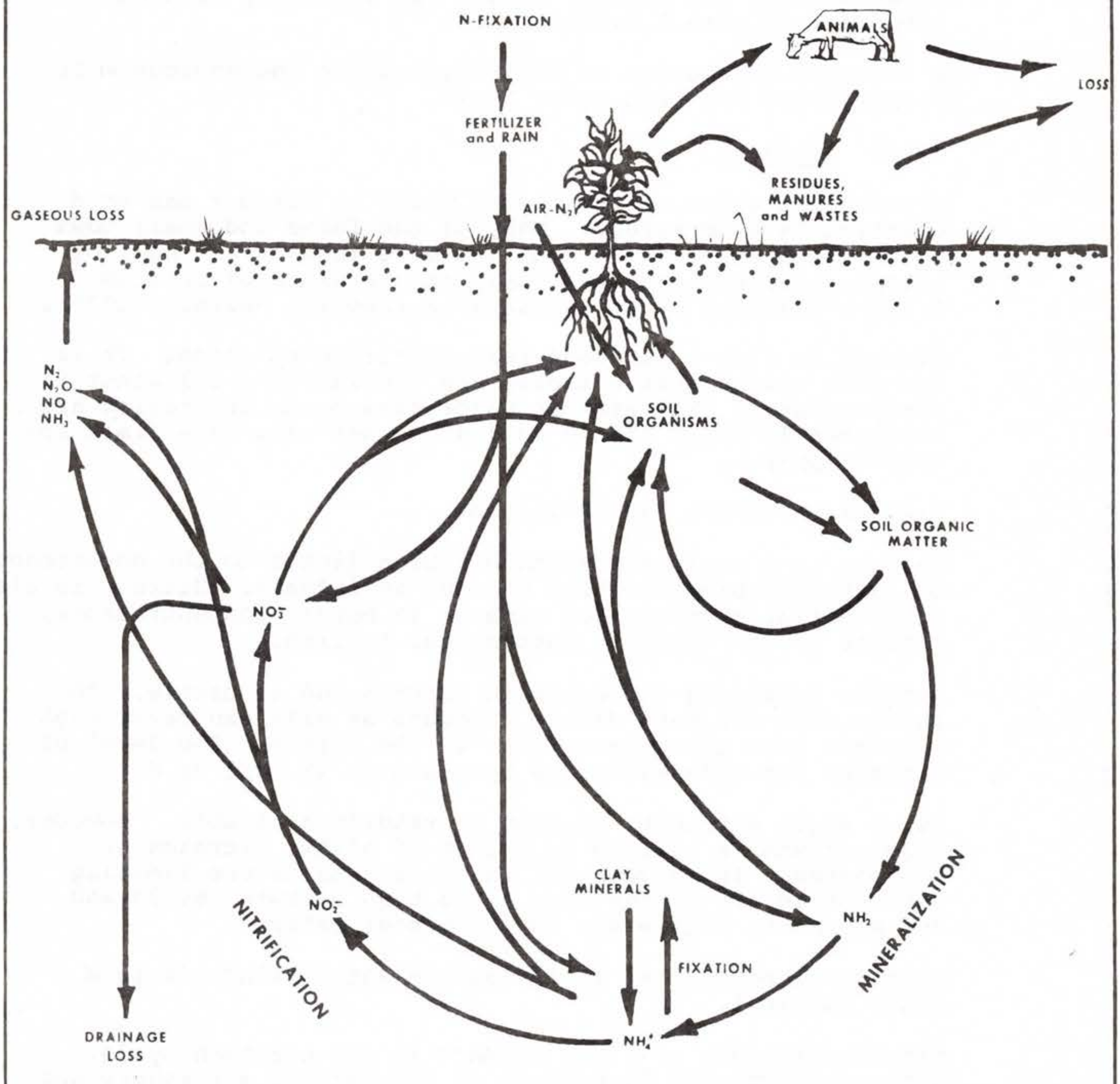


FIG. 4.2.2-A. THE NITROGEN CYCLE

toups corporation
loveland, co.

Only two naturally-occurring processes remove nitrate from water: denitrification and plant uptake. Denitrification is the anaerobic conversion of NO_3 to N_2 gas by bacteria. This conversion requires a carbon source. Denitrification does not occur in streams unless the streams become anaerobic, a highly undesirable and unusual condition in the region. Plant uptake occurs when nitrogen is adsorbed by algae and higher plants. Algal uptake is insignificant in removing nitrogen since algae can release nitrogen upon death.

Feedlots are another nitrogen source. In feedlots, the possible number of pathways to be taken by the nitrogen is much greater and highly dependent upon management and climate. Only a small percentage of the total nitrogen in manure is in the nitrate form.

4.2.2.2 Irrigation Return Flows as a Nitrate Pollution Source

In irrigation, nitrate pickup is associated with water leached from the root zone. Nitrate pickup in surface runoff is usually insignificant except where ammonia is bubbled into the irrigation water.

There are two schools of thought regarding the role irrigated agriculture plays in the pollution of ground water. The first claims that nitrate levels under dry land areas tend to be quite high and that high nitrate levels are not the fault of irrigation. This point of view contends that fertilizer use efficiency can be high and that seepage from canals and reservoirs tends to dilute high nitrate levels in the ground water.

The other school of thought points to the fact that while nitrate levels under dry land areas are high, levels under irrigated areas are also high. Since the volume of leachate under irrigated areas is many times greater than under dry land areas, the water quality under irrigated land can only be blamed on the leachate from irrigation. The efficiency of fertilizer use is usually quite poor as is the efficiency of water use. Further, levels of nitrates under cropped dry land areas cannot be equated with natural range conditions.

Both schools of thought present valid points. Existing data can be used in both arguments and scientific articles are published supporting both arguments. It is apparent, however, that nitrate levels in ground water are affected by the agricultural practice of irrigation. Industry and domestic sewage treatment facilities have little effect on underground nitrate levels.

An intense study of nitrates under field and corrals in northeastern Colorado was conducted in 1967 [Stewart, Viets, et al, 1967]. In this study, deep soil samples and ground water samples were classified by agricultural use of the land above. Land use classifications were irrigated fields in alfalfa, irrigated fields in other crops, non-irrigated fields in native grass, non-irrigated cropland, and corrals.

Average NO_3-N concentrations in water samples were as follows:

Irrigated Alfalfa	9.5 mg/l
Irrigated Fields (Other than Alfalfa)	11.2 mg/l
Corrals	13.3 mg/l
Non-irrigated Sod	11.5 mg/l
Non-irrigated Fields	7.2 mg/l

Soil samples were also analyzed in this study and average NO_3-N to a depth of 20 feet related to land use as follows:

	kg/ha	lbs/acre
Irrigated Alfalfa	70	79
Native Grassland	81	90
Cultivated Dryland	233	261
Irrigated Fields (excluding alfalfa)	452	506
Feedlots	1282	1436

Thus, concentrations of nitrates are high in the soil under irrigated lands. These concentrations were not proportionately high in the water samples, however. This can be attributed to dilution.

4.2.2.3 Fertilizer Use, Irrigation Management, Crop Production and Economic Return

While existing studies do not contain evidence showing irrigated agriculture to be at fault for nitrate pollution of the ground water, a potential for improvement exists. Under irrigated conditions, volumes of water entering the ground water are 3 to 5 times greater than under dry land conditions. This means that nitrates leached from the root zone are diluted by a large volume of leachate.

Fertilizer use is responsible for the high productivity of the Larimer-Weld region. Commercial fertilizers allow the year after year growing of corn and sugar beets, crops which remove a considerable amount of nitrogen. But fertilizer use in the area may well be in excess of that required for maximum yield or maximum economic return.

Ludwick, et al (1973), conducted a study of soil nitrates in eastern Colorado fields to be planted in sugar beets. Sugar beet production can be directly related to soil nitrate levels. In this study, 320 samples were taken of 1-, 2-, and 3-foot depths. All Great Western factory district samples averaged 100 lbs. NO_3-N/A. The Greeley District averaged 290 lbs. NO_3-N/A, a level already excessive for sugar beet production without the application of additional fertilizer. The study assumed that the high availability of manure in the Greeley area might have had some effect on this. While manure is one of the more environmentally desirable fertilizers due to its slow release, the fertilizer value of manure is often underestimated, resulting in more commercial fertilizer being applied than can be used by the crop or is in the farmer's best economic interest. All this indicates that soil tests by reputable independent laboratory's are environmentally important and can result in the best return to farmers.

Water use is also important in effective use of nitrogen fertilizer. Nitrates are highly soluble and leachate can export much of the nitrogen from the root zone. Several authors have found total nitrate loading to be directly related to leaching loss. While some leaching loss is necessary to maintain salt balance, excessive amounts may occur as a result of poor water distribution in irrigation.

4.2.2.4 Nitrates in Surface Waters as a Result of Irrigation Return Flows

While high nitrates are associated with leachate, a considerable amount of leachate finds its way to surface waters through tile drains and ground water movement. Most plains tributaries are fed by this seepage.

The configurations of samples from tile drains are shown on Figure 4.2.2-B. Eleven percent of the samples contain more than 10 mg/l. It should be noted that these samples were taken primarily in August. Fertilizers are generally applied in the spring and concentrations could be expected to be higher at that time.

Levels of nitrates in plains tributaries fed primarily by irrigation returns are shown on Figure 4.2.2-C. These streams may also contain high nitrate levels.

Levels of nitrates in rivers are shown on Figure 4.2.2-D. Nitrate levels in rivers will be discussed in more detail when each river is dealt with separately.

Nitrates

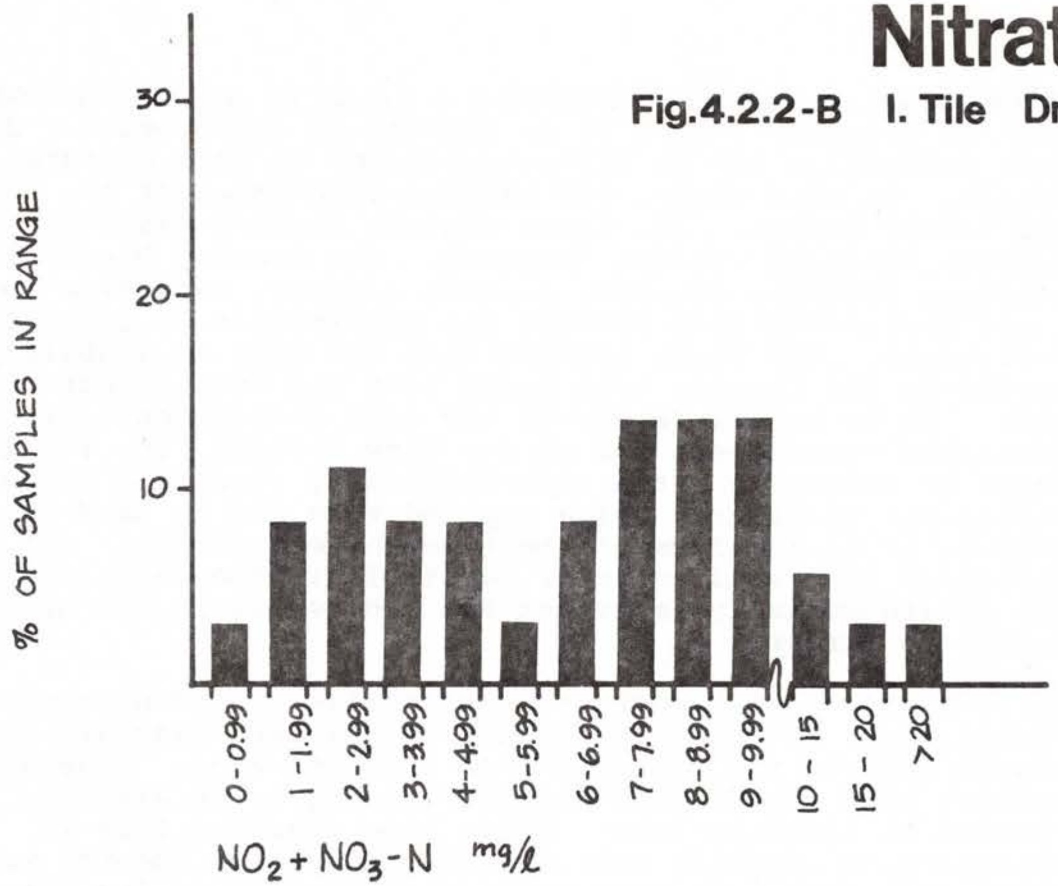


Fig.4.2.2-B I. Tile Drains

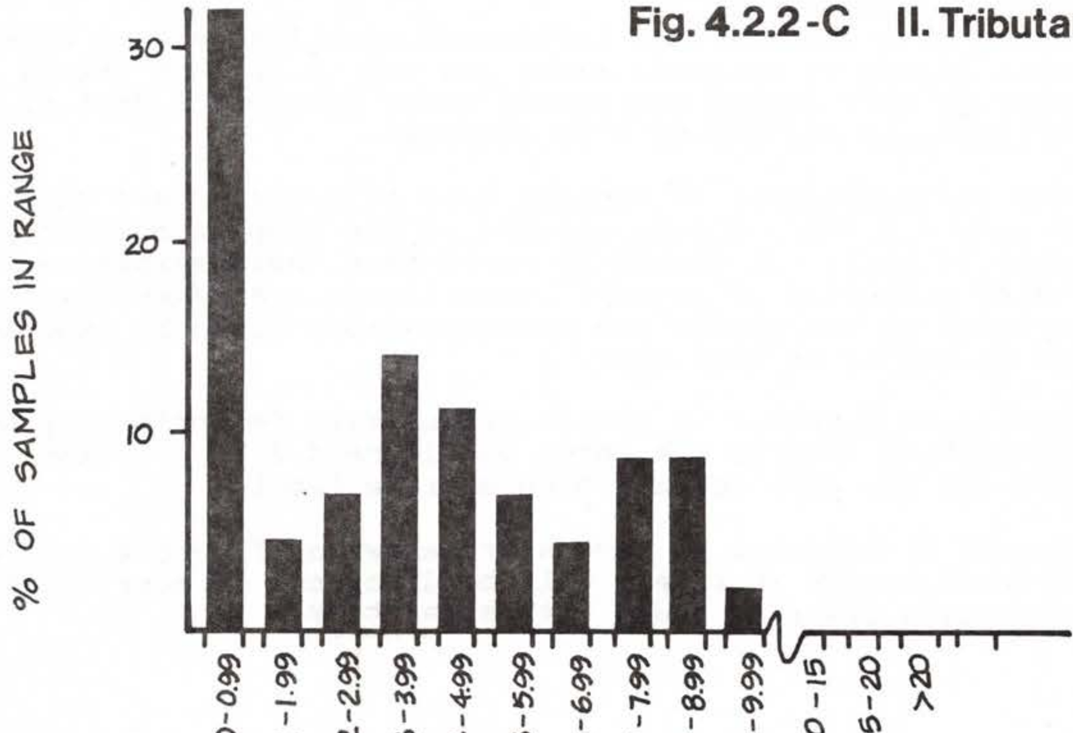
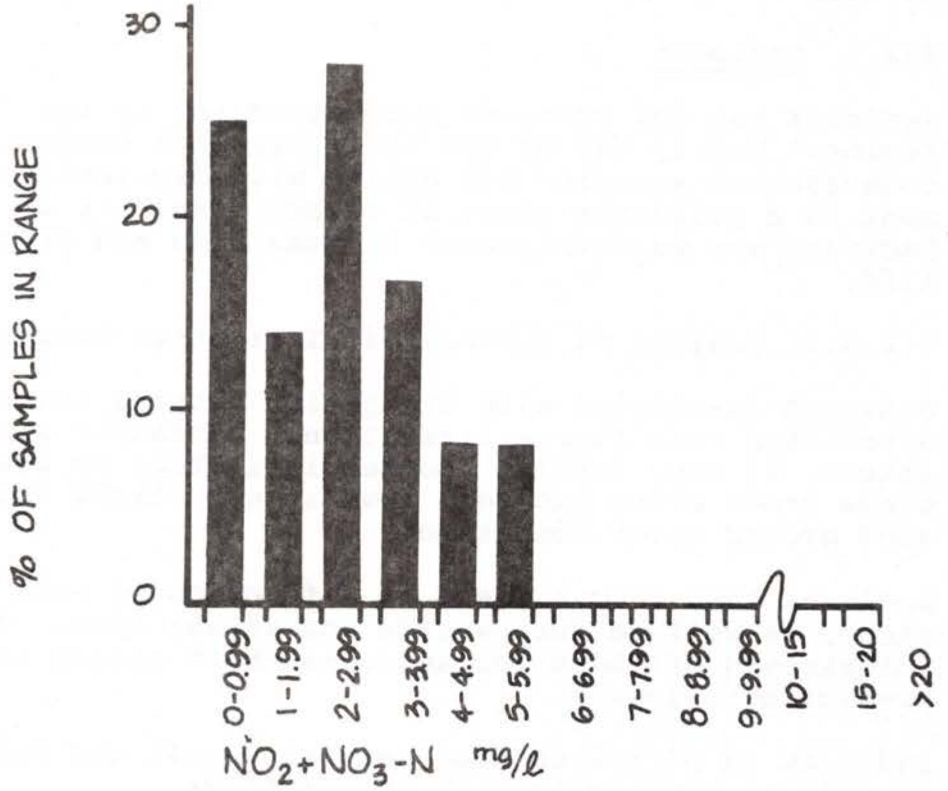


Fig. 4.2.2-C II. Tributaries

Fig. 4.2.2-D Ill. River Samples



4.2.2.5 Historical Nitrate Levels

Historical data of nitrate levels in rivers are shown along with fertilizer use on Figure 4.2.2-E. While there is some increase in nitrate levels in rivers, the increase is small compared to the increase in fertilizer use. Increased urban development also contributes to the increased nitrate levels.

4.2.3 Sediment

Sediment has not received much attention in the Larimer-Weld region. Nearly all of the soil loss work conducted by soil conservation agencies has dealt with dry-land areas. Sediment is a pollutant since it causes turbidity in the water. Sediment may be detrimental to some fish and other aquatic life.

4.2.3.1 Sources of Sediment in Irrigation Return Flows

Sediment associated with irrigation returns is nearly always associated with furrow irrigation. Sprinkler irrigation has little, if any, runoff. Border irrigation is used with close grown crops and soil loss is very small under these good ground cover conditions.

Sediment loss from a field is a function of soil type, slope, as well as furrow size and stream size. The complex interaction of these variables makes it nearly impossible to predict soil loss.

Sediment is picked up from natural runoff and bank erosion as well as from irrigation return flows.

4.2.3.2 Transfer Methods

Of all the soil displaced by irrigation practices, very little ends up in the river. In most of the region the flood plain exists as a non-irrigated buffer zone. In order to reach the river, tailwater must flow in a natural or artificial stream.

Much of the tailwater stands at the end of the field for a length of time. While standing, sediment can settle out. This is the major reasons for the wide scattering of suspended solids in tailwater samples (Figure 4.2.3-A).

The fraction of sediment reaching a tributary has an opportunity to reach a major river. Some sediment may settle out in a tributary, but more likely the tributary is dammed, diverted, or intercepted by an irrigation canal.

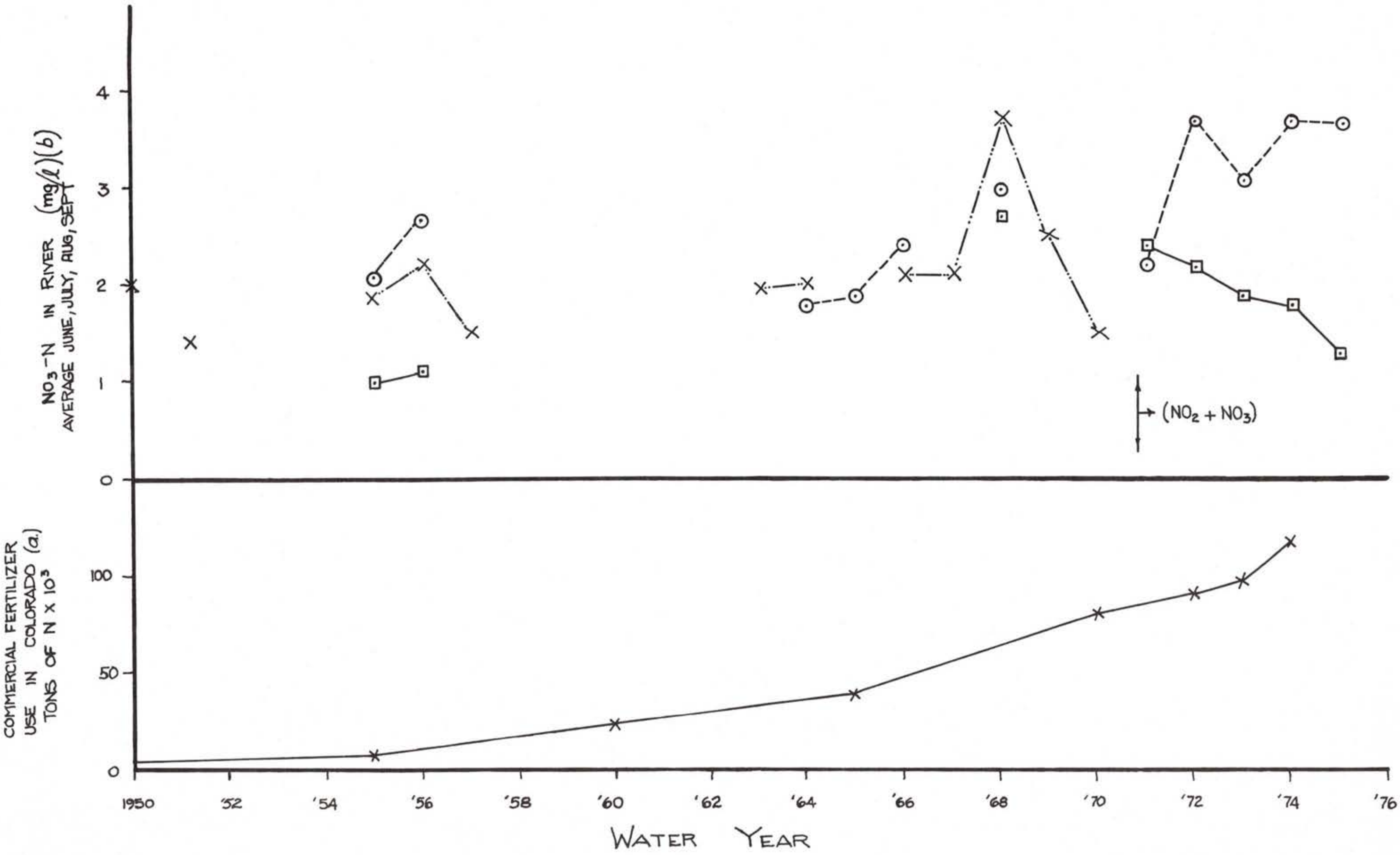


Fig. 4.2 2-E Average Summer Nitrate Levels & Fertilizer Use

(a) TVA National Fertilizer Research Center

(b) USGS

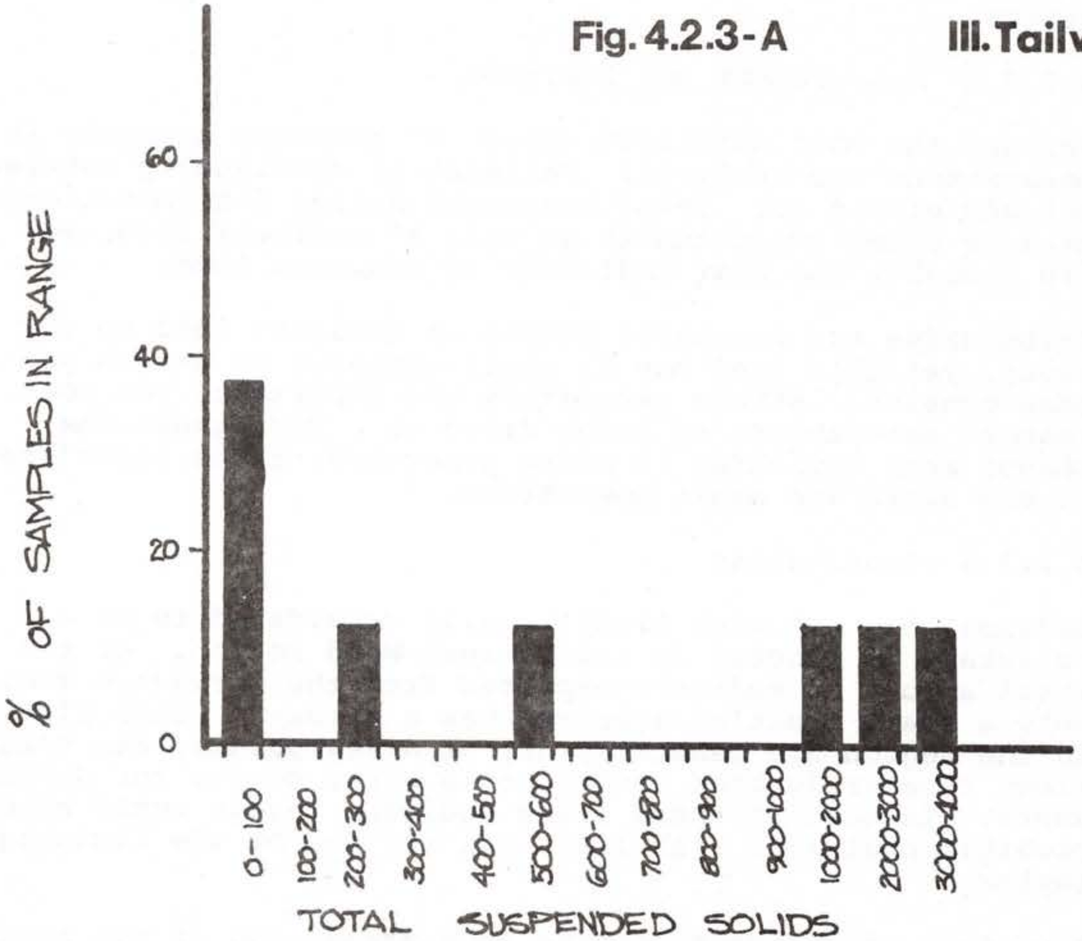


Fig. 4.2.3-A **III. Tailwater**

Tributaries draining the irrigated region tend to contain slightly higher concentrations of suspended solids than rivers they enter. Suspended solids concentrations in the tributaries and rivers of irrigated areas of the region are displayed on Figures 4.2.3-B and 4.2.3-C. Tributaries carrying return flow from irrigation do not have greatly higher concentrations of suspended solids than do receiving waters.

4.2.3.3 Measurement and Analysis

Perhaps the most difficult aspect of sediment analysis is measurement and analysis. Sediment is continually settled out and picked up. Total suspended solids determinations measure other constituents as well as sediment load, yet are probably the best indicator of sediment load.

Tributaries are the major source of sediment load to the river, yet this load may be small compared to stream and bank erosion. Stream velocities are important, yet most reaches are subject to being dried up. Throughout the season when tailwater is being generated, these flows are reused again and again downstream.

4.2.3.4 Conclusions

Sediment has not been traditionally considered to be a pollutant of concern in the Larimer-Weld region. Of the total amount of sediment exported from the irrigated fields, only a small fraction ever reaches a stream. Since rivers in the region are generally dry at a few points, the return flows from irrigation are the sole water source for downstream users. In some of these areas sediment levels would appear to prohibit desirable fish life, yet may not be the limiting factor.

Any study of sediment loading to a stream and of the load carried by the stream must also consider the changing soils of banks and bed as the stream leaves the mountains and flows out on the plains.

Velocities are also much changed on the plains, and such velocities favor the transport of the more visible smaller particles. Stream beds in the plains are composed of the rocks, gravel, and sands deposited as velocities slow down, yet banks are often composed of fine soil particles.

Sediment loads must be considered in light of the characteristics of the stream through the plains region. Plains tributaries discharge a water generally higher in total suspended solids than the receiving river. These higher suspended solids levels in the plains tributaries are partially due to tailwaters entering the tributary. Yet, the characteristics of these plains tributaries are such that suspended solids levels are naturally high.

Sediment

Fig.4.2.3-B **I. River Samples**

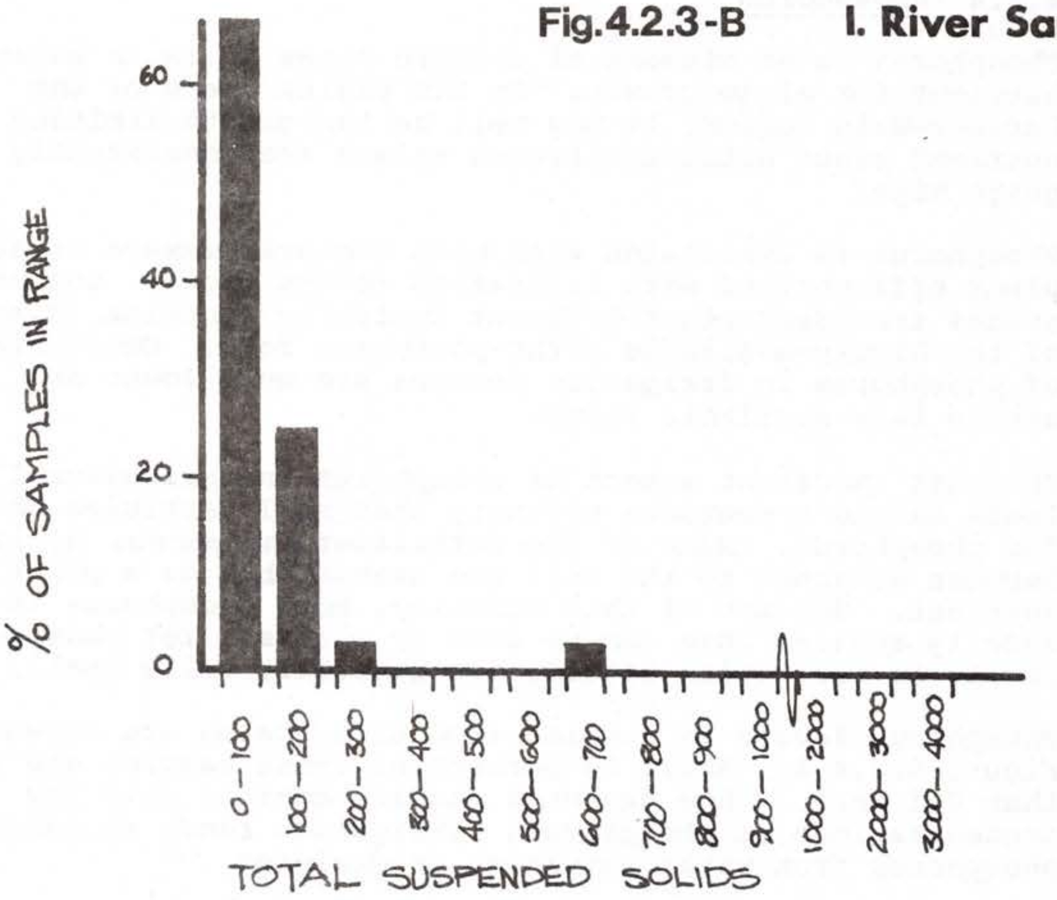
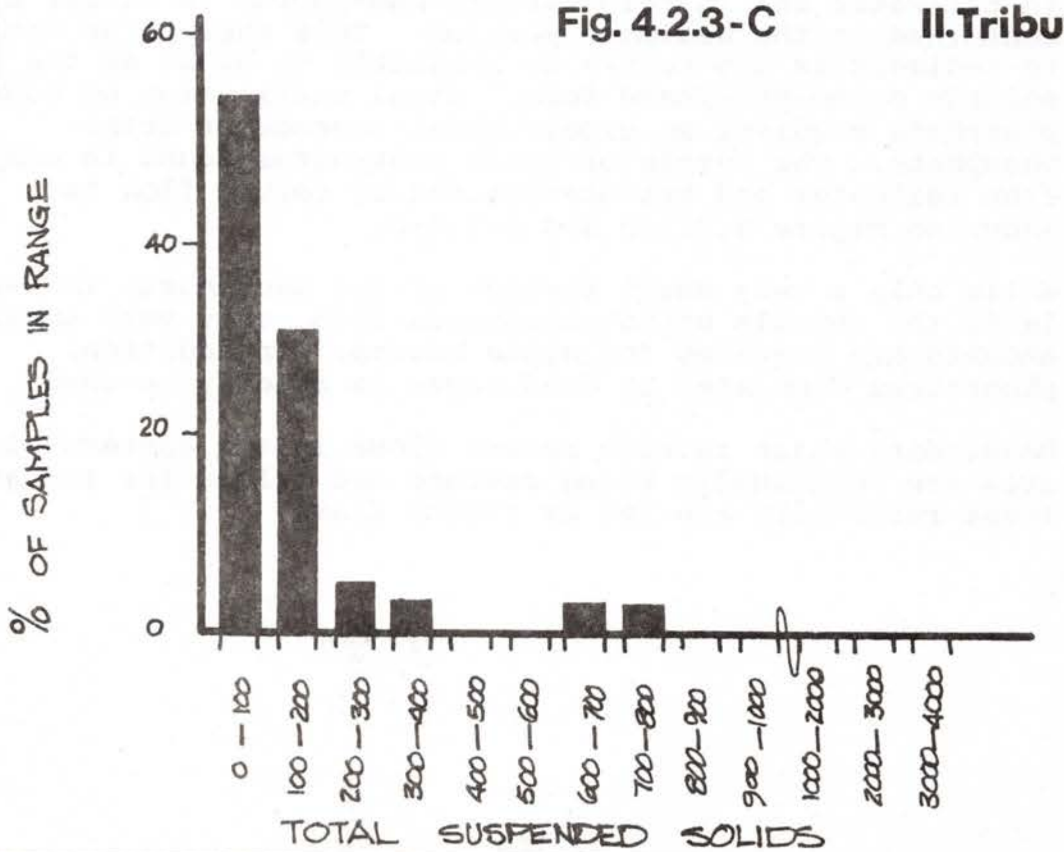


Fig. 4.2.3-C **II.Tributaries**



4.2.4 Phosphorus

Phosphorus is an element of concern since it is an essential nutrient for algae growth. In the plains areas of the Larimer-Weld region, it may well be the growth limiting nutrient since nitrate-nitrogen values are consistently quite high.

Phosphorus is associated with both domestic sewage treatment plant effluent and with irrigation return flows. Domestic sewage treatment plant effluent typically contains 10 mg/l of the highly-available ortho-phosphate form. Concentrations of phosphorus in irrigation returns are much lower and are in less available forms.

The most important aspect of phosphorus in agricultural lands is the tremendous affinity that soil particles have for phosphorus. Much of the fertilizer phosphorus applied becomes attached to the soil and unavailable as a plant nutrient. Because of this affinity, more phosphorus is usually applied than can be used by plants. Yet phosphorus levels in irrigation returns are generally quite small.

Phosphorus levels in samples from tile drains are shown on Figure 4.2.4-A. About 68 percent of these samples are less than 0.1 mg/l. Thus drainage samples contain very low concentrations of phosphorus. Irrigation tends to remove phosphorus from water returning as drainage.

Phosphorus levels in tailwater are higher than in drains. In tailwater and in tributaries, phosphorus is nearly all contained in the sediment portion. This phosphorus attached to sediment is not nearly so available to algae as the soluble ortho-phosphate form. Algal utilization of bound phosphate requires an almost total absence of ortho-phosphate. The levels of total phosphorus found in samples from tailwater and tributaries fed by return flow is shown on Figure 4.2.4-B and 4.2.4-C.

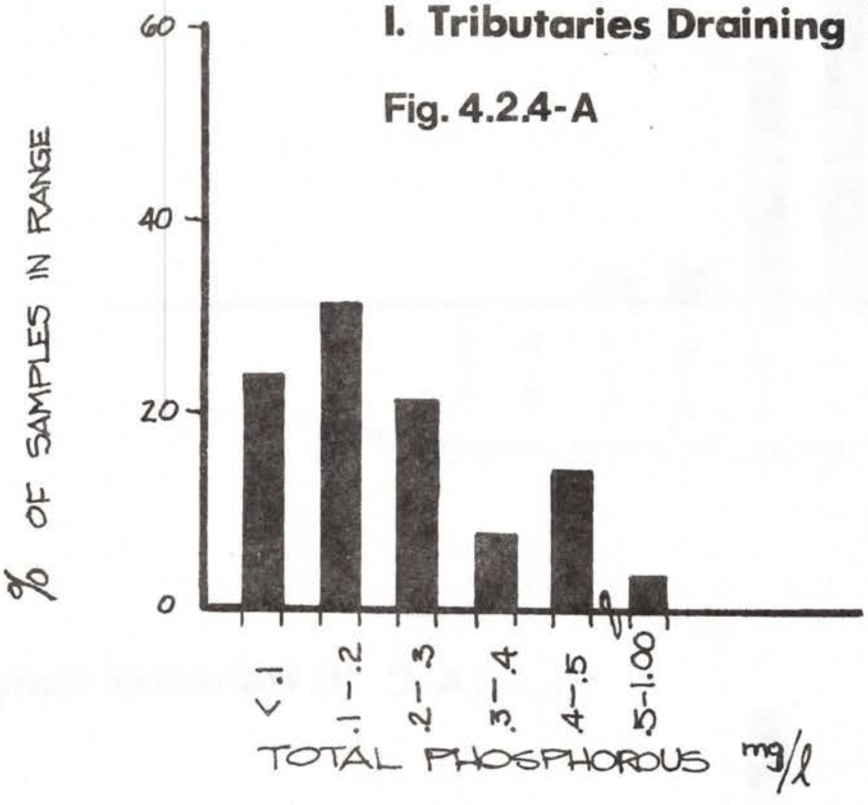
While only a very small portion of the phosphorus in returns is in the soluble ortho-phosphorus form, only very small amounts are required for algae blooms. In addition, phosphorus liberated by dead algae is readily re-used.

Reservoirs which receive return flows in the eastern plains area are continually being drained and filled for irrigation. These reservoirs are fed by return flows.

Phosphorous

I. Tributaries Draining Irrigated Areas

Fig. 4.2.4-A



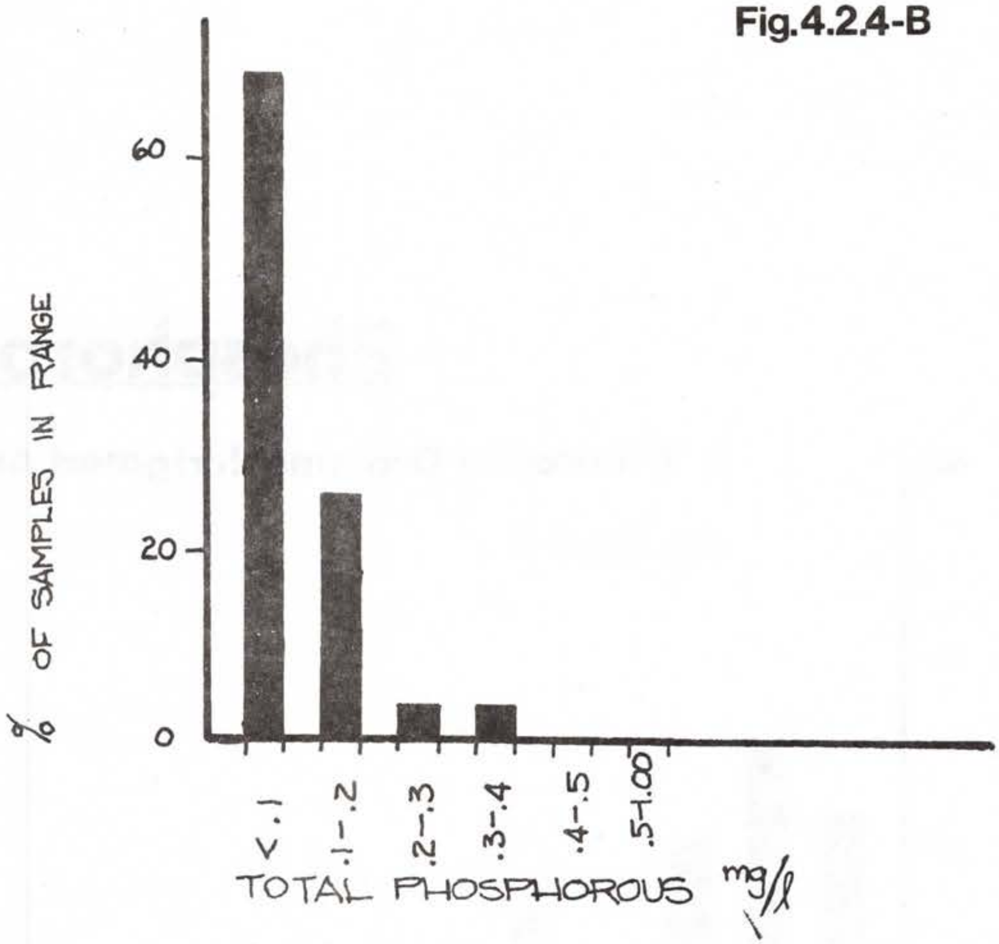


Fig.4.2.4-B III. Drains

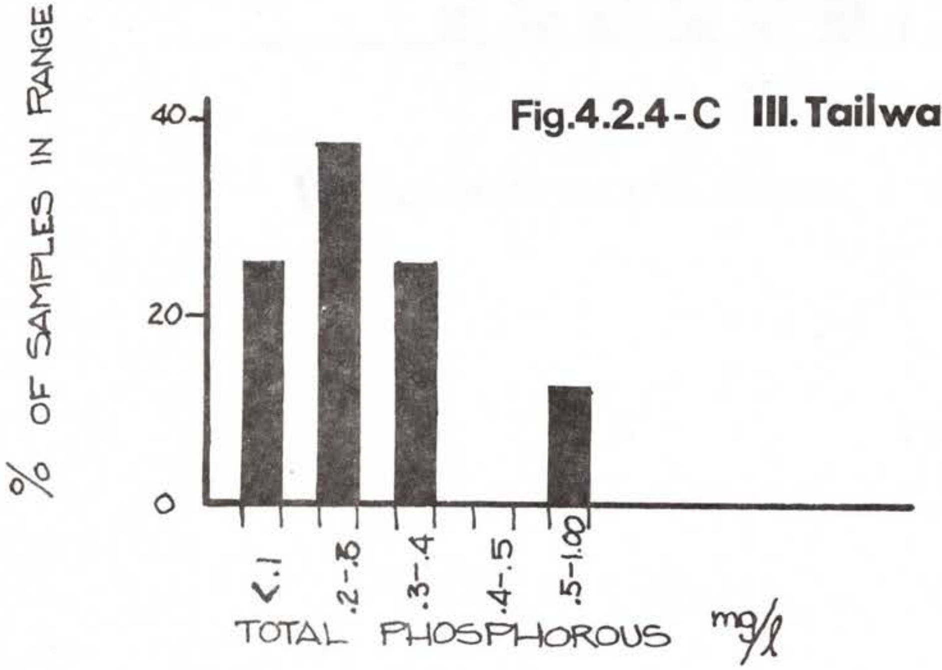


Fig.4.2.4-C III. Tailwater Samples

4.2.5 Pesticides

The agricultural practices of today tend to make pesticide use a necessity. Continued high yields of the same crop year after year would be impossible without insect and weed control. Pesticide use practices in the Larimer-Weld region are discussed in Section 3.7 of this report.

Pesticide levels have been monitored at the U.S. Geological Survey Water Quality Stations at Julesburg and Kersey on the South Platte River, and at Greeley on the Cache la Poudre River. This data is presented in Tables 4.2.5-A, 4.2.5-B, and 4.2.5-C. This data is summarized in Table 4.2.5-D. Here the number of samples showing measurable concentrations of pesticides is shown in relation to the total number of samples taken. The characteristics of the pesticides found in the various water samples of the region are summarized in Table 4.2.5-E and 4.2.5-F. Several pesticides have been denied registration by the EPA. They are: DDT, Aldrin, Deldrin, Heptachlor, and Chlordane. These are not described in the table. Several other pesticides are being reviewed and may not be re-registered.

Pesticides may travel with either soil or water. Those traveling by either method have the greatest propensity for being removed from agricultural land; those traveling by water are next; and those associated with the soil are least likely to be transported.

TABLE 4.2.5-A. PESTICIDE LEVELS - CACHE LA POUDRE RIVER NEAR GREELEY, COLORADO WATER YEAR 1972[a] (μg/l unless otherwise noted)

Date	Discharge (cfs)	Aldrin	Chlordane	DDD	DDE	DDT	Diazinon	Dieldrin
May 23	15	.00	.0	.00	.00	.00	.02	.01

Date	Endrin	Heptachlor	Heptachlor epoxide	Lindane	Malathion	Methyl Parathion	Parathion
May 23	.00	.00	.00	.00	.00	.00	.00

TABLE 4.2.5-B. PESTICIDE LEVELS, SOUTH PLATTE NEAR KERSEY, COLORADO
WATER YEAR 1973 [USGS DATA]

(μg/l unless otherwise noted)

Pesticide	Date			
	12/17/72	3/7/73	6/26/73	9/11/73
Temperature (°C)	1.0	5.0	24.0	--
Aldrin in Filt. Frac.	.00	.00	.00	.00
Aldrin in Susp. Frac.	.00	.00	.00	.00
Aldrin	.00	.00	.00	.00
Aldrin in Bottom Deposits	--	.0	--	--
Chlordane in Filt. Frac.	.0	.0	.0	.0
Chlordane in Susp. Frac.	.0	.0	.0	.0
Chlordane	.0	.0	.0	.0
Chlordane in Bottom Deposits [a]	--	0	--	--
DDD in Filt. Frac.	.00	.00	.00	.00
DDD in Susp. Frac.	.00	.00	.00	.00
DDD	.00	.00	.00	.00
DDD in Bottom Deposits [a]	--	.0	--	--
DDE in Filt. Fract.	.00	.00	.00	.00
DDE in Susp. Frac.	.00	.01	.02	.02
DDE	.00	.01	.02	.02
DDE in Bottom Deposits [a]	--	.0	--	--
DDT in Filt Frac.	.00	.00	.00	.00
DDT in Susp. Frac.	.00	.00	.02	.00
DDT	.00	.00	.02	.00
DDT in Bottom Deposits [a]	--	.0	--	--
Diazinon in Filt. Frac.	.03	.03	.03	.03
Diazinon in Susp. Frac.	.00	.00	.00	.01
Diazinon	.03	.03	.03	.03
Dieldrin in Filt. Frac.	.00	.00	.01	.01
Dieldrin in Susp. Frac.	.00	.00	.02	.03
Dieldrin	.00	.00	.03	.04
Dieldrin in Bottom Deposits [a]	--	.0	--	--
Endrin in Filt. Frac.	.00	.00	.00	.00
Endrin in Susp. Frac.	.00	.00	.00	.00
Endrin	.00	.00	.00	.00
Endrin in Bottom Deposits [a]	--	.0	--	--

TABLE 4.2.5-B. (continued)

Pesticide	Date 12/17/72	 3/7/73	 6/26/73	 9/11/73
Heptachlor in Filt. Frac.	.00	.00	.00	.00
Heptachlor in Susp. Frac.	.00	.00	.00	.00
Heptachlor	.00	.00	.00	.00
Heptachlor in Bottom Deposits [a]	--	.0	--	--
Heptachlor Epoxide in Filt. Frac.		.00	.00	.00
Heptachlor Epoxide in Susp. Frac.		.00	.00	.00
Heptachlor Epoxide	.00	.00	.00	.00
Heptachlor Epoxide in Bottom Deposits [a]	--	.0	--	--
Lindane in Filt. Frac.	.00	.00	.00	.00
Lindane in Susp. Frac.	.00	--	.00	--
Lindane	.00	--	.00	--
Lindane in Bottom Deposits [a]	--	.0	--	--
Malathion in Filt. Frac.	.00	.00	.00	.01
Malathion in Susp. Frac.	.00	.00	.00	.00
Malathion	.00	.00	.00	.01
Methyl Parathion in Filt. Frac.	.00	.00	.00	.00
Methyl Parathion in Susp. Frac.	.00	.00	.00	.00
Methyl Parathion	.00	.00	.00	.00
Parathion in Filt. Frac.	.00	.00	.00	.01
Parathion in Susp. Frac.	.00	.00	.00	.00
Parathion	.00	.00	.00	.01
PCB in Filt. Frac.	.0	.0	.0	.0
PCB in Susp. Frac.	.0	.0	.0	
PCB	.0	.0	.0	.0
PCB in Bottom Deposits [a]	--	0	--	--
2,4-D in Filt. Frac.	.00	.05	.10	.39
2,4-D in Susp. Frac.	.00	.00	.00	.00
2,4-D	.00	.05	.10	.39
2,4,5-T in Filt. Frac.	.00	.01	.01	.02
2,4,5-T in Susp. Frac.	.00	.00	.00	.00
2,4,5-T	.00	.01	.01	.02
Silvex in Filt. Frac.	.00	.00	.05	.03
Silvex	.00	.00	.05	.03

[a] µg/kg.

TABLE 4.2.5-C. PESTICIDE LEVELS, SOUTH PLATTE RIVER NEAR JULESBURG, COLORADO
PESTICIDE ANALYSIS OCTOBER 1971 TO SEPTEMBER 1974
(µg/l unless otherwise noted) (a)

Pesticide	Date						
	8/31/72	10/31/72	4/27/73	6/29/73	11/28/73	3/29/74	4/17/74
Discharge (cfs)	288						
Aldrin in Filt. Frac.					.00	.00	.00
Aldrin in Susp. Frac.					.00	.00	.00
Aldrin	.00	.00	.00	.00	.00	.00	.00
Chlordane in Filt. Frac.					.0	.0	.0
Chlordane in Susp. Frac.					.0	.0	.0
Chlordane	.0	.0	.0	.0	.0	.0	.0
DDD in Filt. Frac.					.00	.00	.00
DDD in Susp. Frac.					.00	.00	.00
DDD	.00	.00	.00	.00	.00	.00	.00
DDE in Filt. Frac.					.00	.00	.00
DDE	.01	.00	.00	.00	.00	.00	.01
DDT in Filt. Frac.					.00	.00	.00
DDT in Suxp. Frac.					.00	.00	.01
DDT	.00	.00	.00	.00	.00	.00	.01
Diazinon in Filt. Frac.					.01	.01	.00
Diazinon in Susp. Frac.					.00	.00	.00
Diazinon	.00	.00	.00	.01	.01	.01	.00
Dieldrin in Filt. Frac.					.00	.00	.00
Dieldrin in Susp. Frac.					.00	.00	.01
Dieldrin	.02	.00	.00	.00	.00	.00	.01
Endrin in Filt. Frac.					.00	.00	.00
Endrin in Susp. Frac.					.00	.00	.00
Endrin	.00	.00	.00	.00	.00	.00	.00

TABLE 4.2.5-C. (continued)

Pesticide	Date						
	8/31/72	10/31/72	4/27/73	6/29/73	11/28/73	3/29/74	4/17/74
Heptachlor in Filt. Frac.					.00	.00	.00
Heptachlor in Susp. Frac.					.00	.00	.00
Heptachlor	.00	.00	.00	.00	.00	.00	.00
Heptachlor Epoxide in Filt. Frac.					.00	.00	.00
Heptachlor Epoxide in Susp. Frac.					.00	.00	.00
Heptachlor Epoxide	.00	.00	.00	.00	.00	.00	.00
Lindane in Filt. Frac.					.00	.00	.00
Lindane in Susp. Frac.					.00	.00	.00
Lindane	.00	.00	.00	.00	.00	.00	.00
Malathion in Filt. Frac.					.00	.00	.00
Malathion in Susp. Frac.					.00	.00	.00
Malathion	.00	.00	.00	.00	.00	.00	.00
Methyl Parathion in Filt. Frac.					.00	.00	.00
Methyl Parathion in Susp. Frac.					.00	.00	.00
Methyl Parathion	.00	.00	.00	.00	.00	.00	.00
Parathion in Filt. Frac.					.00	.00	.00
Parathion in Susp. Frac.					.00	.00	.00
Parathion	.00	.00	.00	.00	.00	.00	.00
PCB in Filt. Frac.					.0	.0	.0
PCB in Susp. Frac.					.0	.0	.0
PCB	.0	.0	.0	.0	.0	.0	.0
2,4-D in Filt Frac.					.00	.03	.04
2,4-D in Susp. Frac.					.00	.00	.00
2,4-D	.0	.00	.00	.00	.00	.03	.04

TABLE 4.2.5-C. (continued)

Pesticide	Date						
	8/31/72	10/31/72	4/27/73	6/29/73	11/28/73	3/29/74	4/17/74
2,4,5-T in Filt. Frac.					.00	.00	.00
2,4,5-T in Susp. Frac.					.00	.00	.00
2,4,5-T	.00	.00	.00	.00	.00	.00	.00
Silvex in Filt. Frac.					.00	.01	.00
Silvex in Susp. Frac.					.00	.00	.00
Silvex	.00	.00	.00	.00	.00	.01	.00

(a) U.S.G.S. data.

TABLE 4.2.5-D. POSITIVE PESTICIDE SAMPLES [a] [b] [c]
Samples with measurable levels/total samples taken

	STATION				
		South Platte at Julesburg		South Platte at Kersey	Poudre at Greeley
Element	WY 72	WY 73	WY 74	WY 73	WY 72
Aldrin					
Chlordane					
DDD					
DDE	1/1		1/4	3/4	
DDT			1/4	1/4	
Diazinon		1/3	2/4	4/4	1/1
Dieldrin	1/1		1/4	2/4	1/1
Endrin					
Heptachlor					
Heptachlorepoxide					
Lindane					
Malathion				1/4	
Methyl Parathion					
Parathion				1/4	
PCB					
2,4-D	1/1		2/4	3/4	
Silvex			1/4	2/4	

[a] Samples with no measurable level of a particular pesticide not displayed,

[b] includes only presently registered pesticides

[c] from U.S. Geological Survey Data

TABLE 4.2.5-E. AGRICULTURAL HERBICIDES FOUND IN WATERS IN LARIMER-WELD REGION: TYPES, TRANSPORT MODES, TOXICITIES AND PERSISTENCE IN SOIL [f]

Common Name	Chemical Class [a]	Predominant Transport Mode [b]	Toxicity [c]		
			a	b	c
2,4-D Acid	PO	W	370	>50	10-30
2,4-D Amine	PO	W	370	>15	10-30
2,4-D Ester	PO	S	500-875	4.5[e]	10-30
2,4, 5-T	PO	W	300	0.5-[e] 16.7	
Silvex	PO	SW	375	0.36	

[a] PO = phenoxy compounds

[b] Predominate transport modes:
S = Soil
W = Water
SW = Soil and Water

[c] Expressed as the lethal dose, or lethal concentration, to 50 percent of the test animals (LD_{50} or LC_{50}, respectively.

(a) Rate, Acute oral LD_{50} mg/kg

(b) Fish, LC_{50} mg/l (Rainbow trout except as noted)

[c] Approximate persistance in soil, days.

[d] For Spot.

[e] For Killfish.

[f] USDA, ARS and EPA, 1975

TABLE 4.2.5-F. AGRICULTURAL INSECTICIDES AND MITICIDES FOUND IN WATERS OF LARIMER-WELD REGION: TYPES, TRANSPORT MODES, AND TOXICITY [e]

			Toxicity[c]	
Common Name	Chemical Class[a]	Predominant Transport Mode[b]	Rat, Acute Oral LD$_{50}$ mg/kg	Fish LC$_{50}$ mg/l[d]
DDE	OCL	S	3360	.009
DDT	OCL	S	113	.002
Diazinon	OP	SW	76	.030
Malathion	OP	W	48	.019
Parathion	OP	S	4	.047

[a] OCL - Organochlorines.
OP - Organophosphorous compounds.

[b] S - Soil.
W - Water.
SW - Soil and Water.

[c] Expressed as lethal dose or lethal concentration to 50 percent of the test animals (LD$_{50}$ or LC$_{50}$, respectively).

[d] 48- to 96-hour for rainbow trout.

[e] USDA, ARS and EPA, 1975

CHAPTER 5.0

ANALYSIS OF WATER QUALITY IMPACTS OF IRRIGATION RETURN FLOWS IN THE LARIMER-WELD REGION

5.1 INTRODUCTION

Irrigation in the Larimer-Weld region impacts water quality in several ways. The hydrologic impact of irrigation diversions and return flows is the most significant. Return flows enter the river as the result of surface returns and ground water returns caused by the seepage of water from canals and irrigated land. Much of this seepage is intercepted by lower canals, especially in the Poudre basin. Seepage back to the river from the water table which has been built up by irrigation is the major source of return flow. Tailwater returns to the river are much smaller in volume and generally occur as discharges into the smaller tributaries of the major rivers. For most of the rivers in the Larimer-Weld region, there is a flood plain serving as a buffer zone and making it impractical for tailwaters to be discharged directly to the river.

Irrigation return flows are important primarily because they discharge into a river which may be nearly dry due to irrigation diversion. A hydrologic analysis is provided for all of the basins in the Larimer-Weld region. It is apparent that downstream flows are made up entirely of irrigation return flows. These streams may actually be dried up several times along their length in the irrigated region. Throughout the summer months, water is carried in the canals paralleling the river. Downstream canals divert the water that has seeped out of upstream irrigated areas and back into the river.

The irrigation season continues from May to September and flows in the river vary significantly during this time. Flows in the river during other months are subject to diversion for storage.

The seepage of ground water back into the river continues well past the irrigation season. River flows in the winter are due to this ground water inflows since freezing conditions minimize surface runoff. A large volume of ground water returns is found in all river basins of the region. Estimates range from 1.5 cfs/river mile to 3.0 cfs/river mile in the Little Thompson and Poudre basins, respectively. Return of ground water seepage makes up most of the water required for downstream diversions. These seepage returns carry salts and nitrates and may possibly carry some pesticides. The pollutants, total dissolved solids (salinity), nitrates, and sediment received primary consideration in the analysis. Phosphorus concentrations in return flows were found to be quite small, generally less than 0.1 mg/l. Phosphorus levels of 0.2 mg/l are generally required to produce algal blooms in lakes.

Salinity would appear to be the most serious pollutant to the region. Salinity pickup is entirely attributable to subsurface seepage returns. Tailwater (surface runoff) from irrigation does not pick up significant dissolved solids. Dissolved solids are concentrated through evaporation and plant transpiration from irrigated areas, water bodies, and wetlands. Most important is the pickup of dissolved solids from saline rock formations. High ground water flows horizontally towards the river on top of the relatively impermeable shale formations.

Salinity in the river must be considered in light of the hydrologic situation. These seepage return flows have a very significant effect on water quality when they make up nearly all of the flow in a river.

Nitrates are a pollutant of lesser concern. In surface waters they serve as fertilizer for algae or for agricultural crops when diverted. This fertilizer value for algae may not be significant as lakes down-stream which are filled by irrigation return flow are generally dry during the late summer when algal blooms would be noticed. While nitrate levels in the rivers have been studied in this program, the importance of these levels in downstream waters has not been defined. Some improvement could be made in ground water nitrate levels.

5.1.2 Sources of Irrigation Return Flows

Irrigation return flows occur as ground water seepage, tile drain flow and tailwater flow. Return flow from these sources also may enter natural drain ways which subseuqently discharge to the main stem of the Cache la Poudre. In this report, this is referred to as tributary inflow.

Tailwater is usually allowed to flow into a collector ditch. From the ditch the tailwater may enter an irrigation canal serving lower lands, may seep into the ground, may enter a natural tributary, or may enter a tailwater reuse pond. In some areas, tailwater enters the river directly; however, this only happens when the irrigated land is directly appurtant to the river. The flood plain area of the Cache la Poudre River is generally used as non-irrigated grazing land which is naturally sub-irrigated by the high water table. This area serves as a buffer zone and very little tailwater enters the stream directly.

Tile drains provide drainage for approximately 50,000 acres of irrigated land in the region to relieve high water tables. High water tables are associated with the presence of impermeable layers underlying the soil and with areas below ditches. Many of these tile drains discharge to irrigation canals. Some tile drains discharge directly back into the river. It was impossible to locate all drains discharging to the river, and from a pollutant loading standpoint, tile drainage was considered to be in the same category as seepage. Stream flow measurements indicated that discharge from tile drainage systems is a relatively small portion of the total return flow reaching rivers.

Ground water seepage into streams represents the major source of irrigation return flows to the river. The sources of seepage include canals and seepage loss of applied irrigation waters. Seepage from canals occurs from the highest canal down to the lowest. The highest canal (furthest canal from the river) will only lose water to seepage while a lower canal (parallel to highest canal and river but lying between them) will intercept seepage water as well as lose water. The river finally intercepts this seep water. Over application of irrigation water represents another source to the ground water.

The following analyses of the water quality impacts of the irrigation return flows present an analysis of the sources of several pollutants in each river basin and the concentrations found in irrigation return flows. All studies of the impact of irrigation return flow should be examined in light of the hydrologic situation.

5.2 CACHE LA POUDRE RIVER

5.2.1 Hydrologic Analysis

The hydrology of the Cache la Poudre River is the result of irrigation development since 1860. By 1880 most of the major ditches and diversion structures had been constructed. In the 1950's additional water supplies were secured through the Colorado-Big Thompson Project, which imports water from the Western Slope.

Water requirements of the many diversions are met by a system of management and exchange. Water is released to the river from several reservoirs, including Horsetooth Reservoir which typically releases 700 to 800 cfs in the summer. This water is diverted for irrigation downstream. Fossil Creek Reservoir serves as an equilizer on the system, storing water not needed downstream or releasing water to meet downstream needs. The river is dried up below the Fossil Creek Reservoir inlet if Horsetooth water is not needed by the Greeley No. 2 ditch. Diversions nearly always dry up the river upstream of Windsor. All flow in the river below the point where it is dried up is from irrigation return flows.

A schematic of the ditch system is shown on Figures 3.1.1 A, B, and C. Flow profiles showing the effect of diversions and return flow are shown on Figures 5.2.1-A and B.

Irrigation return flow provides the necessary water for downstream diverters. During the irrigation season, all of the water below the B.H. Eaton Ditch (where the river is dried up) is return flow. This water is recycled in the irrigation system by the Greeley No. 3 Ditch and the Ogilvy Ditch, both of which dry up the river throughout the summer. The Cache la Poudre River is entirely made up of irrigation returns below the point where it is dried up.

Water finally entering the South Platte has been used a number of times. The Cache la Poudre is generally dried up at four places -- Fossil Creek Reservoir inlet, B. H. Eaton, Greeley #3, and Ogilvy Ditch. Table 5.2.1-A displays data from the stream gage maintained near the Kodak plant at Windsor, a relatively low-flow portion of the river below the B. H. Eaton ditch.

5.2.1.1 Seepage Losses to the Cache la Poudre

Seepage into the river represents the major source of return flows in the Cache la Poudre basin. In the study program for the Larimer-Weld Regional Council of Governments, the volume of these seepage returns was estimated in three ways. First, a water budget was conducted on the river using the river commissioners' data. Several points of known flow and known zero flow were available, providing control points on the system. Diversion and lake release records were also used in making the budget. This budget was conducted for August 31, 1976, as well as for days in May and August, 1972. The August 31, 1976, data was chosen for its coincidence with the sampling program. In the August 31, 1976, budget, it was necessary to add 184 cfs of return flow over a stretch of slightly over 50 river miles. Another budget for August 12, 1972, required 159 cfs. These analyses indicated that seepage returns were approximately 3.0 cfs per river mile in the stretch from LaPorte to the mouth. Secondly, flow measurements were taken in several sections of the river in order to qualify seepage. These measurements were taken in early November 1976, after the irrigation season was concluded. At that time, seepage entering the river was the only source of flow. Some of the results are displayed

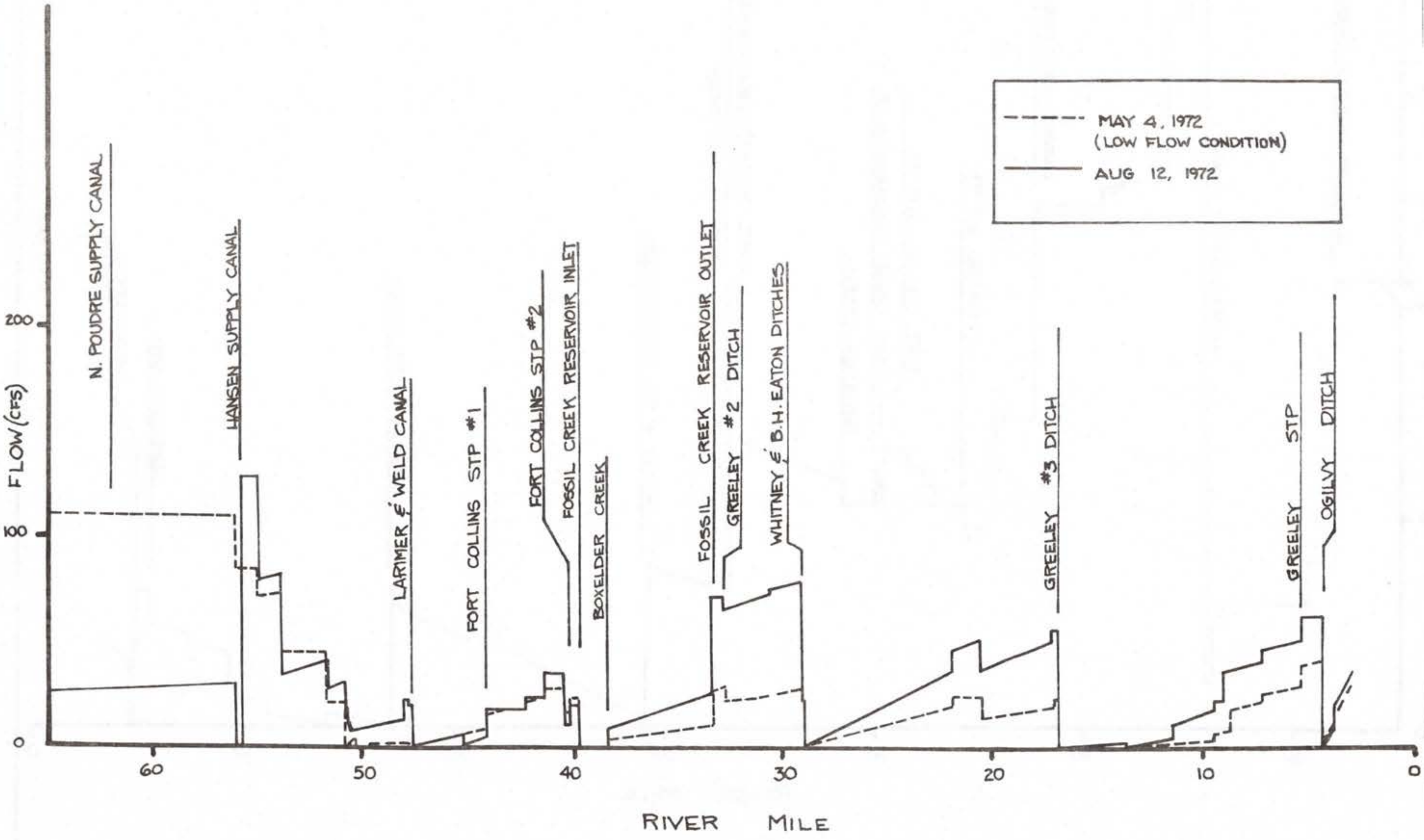


Fig. 5.21-A **Stream Flow Cache La Poudre**

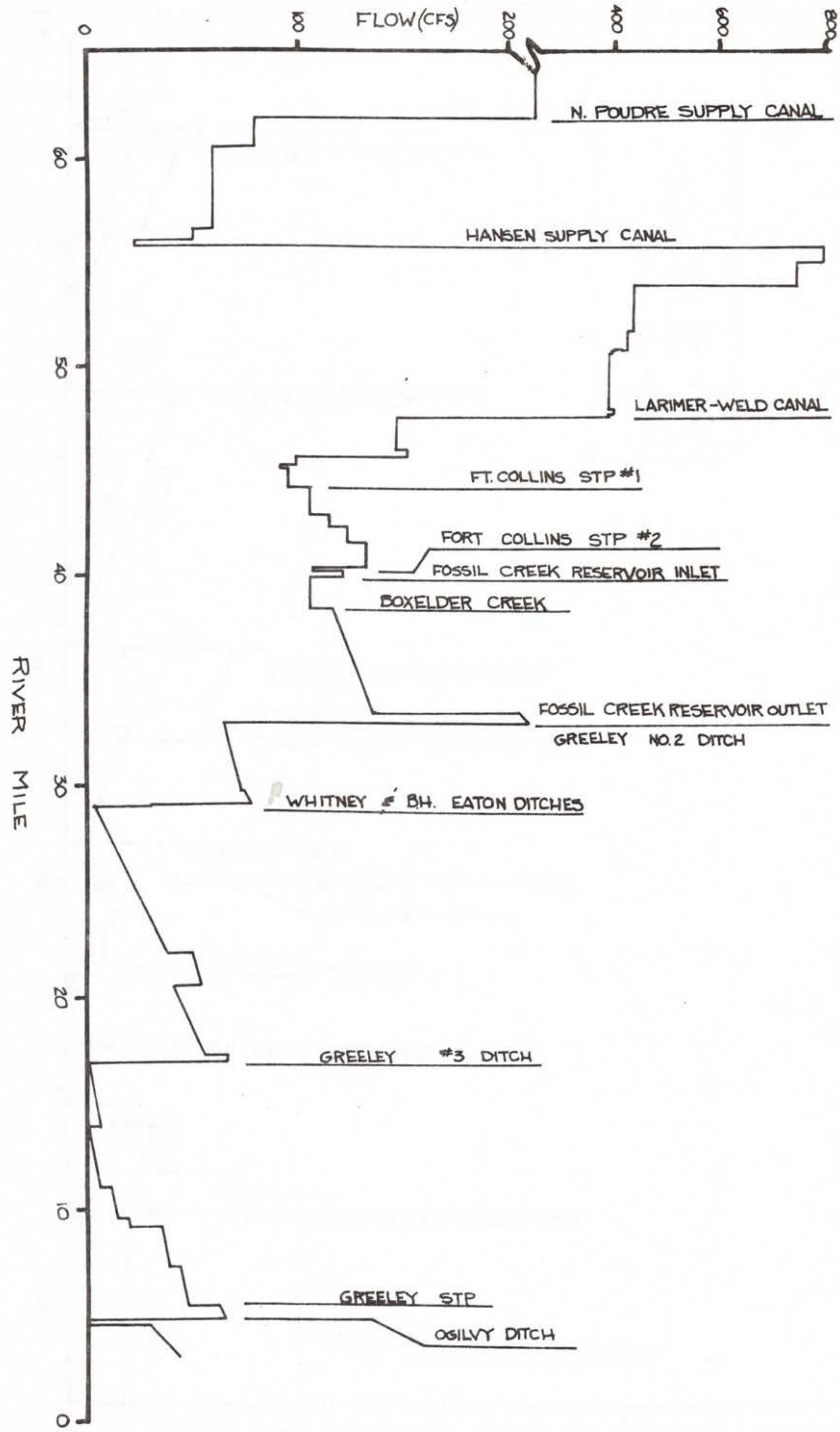


Fig. 5.2.1 - B

Stream Flow Cache La Poudre AUG. 31, 1976

TABLE 5.2.1-A CACHE LA POUDRE RIVER KODAK GAGE

Water Year	Mean Daily Flow In cfs								Mean Daily Flow For Specified Period							
	O	N	D	J	F	M	A	M	June		July		August		Sept.	
									Low 7-Day	Month	L-7 Day	Month	L-7 Day	Month	L-7 Day	Month
1971								953		693		208	70.5	79	30.4	54.9
1972																
1973																
1974	104	153	87	75	113	75.6	67.7	137		534		69.5	33.2	37	26.2	30
1975	63.3	68.3	71	61	67.8	39.4	72.9						38.8	45		58
1976	48.8	31.8								40.1		40.6	24.2	112	28.1	38.2

TABLE 5.2.1-B MEASURED SEEPAGE INTO SELECTED STRETCHES OF THE CACHE LA POUDRE RIVER, NOV. 3, 1976

RIVER SEGMENT	RIVER MILE	SEEPAGE
Fossil Creek Reservoir Inlet (0-flow) to Boxelder Creek	39.8-38.3	4.6 cfs/mile
Boxelder Creek to I-25 Rest Stop	38.3-36.4	3.2 cfs/mile
County Road South of Timnath to Greeley No. 2 Diversion	35.2-32.9	2.1 cfs/mile

Finally, Jack Neutze, River Commissioner for the Cache la Poudre, has indicated that return flows are approximately 3 cfs per river mile based on his experience in managing the river over many years.

These three sources of information indicate that the average seepage in the Cache la Poudre is approximately 3 cfs/mile. While this seepage includes both seepage loss from ditches and irrigated lands, it is considered to be irrigation return flow. The actual amount of seepage return in specific sections may vary considerably from the 3 cfs/mile, but over the length of the river it represents a good average.

5.2.1.2 Tributary Inflow to the Cache la Poudre

Tributary inflow represents another major source of return flow to the river. Tributaries in the plains are supplied by water diverted for irrigation. This water may enter the tributary as seepage, tailwater, or through tile drains. Most of the major tributaries carrying return flow to the Cache la Poudre River were sampled and measured. The major tributaries and typical flows in these tributaries are displayed in Table 5.2.1-C.

TABLE 5.2.1-C TRIBUTARY INFLOWS TO THE POUDRE
AUGUST 31, 1976

Dry Creek	9 cfs
Spring Creek	10 cfs
Boxelder Creek	10 cfs
Fossil Creek	2 cfs
Consolidated Law Ditch	10 cfs
Sheeps Draw	5 cfs
Graham Seep	5 cfs
Eaton Draw	5 cfs
TOTAL	56 cfs

Flows in these major tributaries are fairly stable in the summer and early fall. This stable condition indicates that seepage contributes a high percentage of the total flow, as tailwater discharges range with the timing of irrigation.

5.2.1.3 Relationships to Other Dischargers

Irrigation return flows are by far the largest discharge to the river on a volume basis. With 170 cfs flowing into the river as seepage and 56 cfs flowing in at the major tributaries, at least 226 cfs (about 150 mgd) of return flows into the river continuously during the irrigation season and on into the fall. These discharges are compared with municipal and industrial dischargers as shown in Table 5.2.1-D.

TABLE 5.2.1-D AGRICULTURAL AND OTHER WASTE DISCHARGES TO THE CACHE LA POUDRE

Irrigation Return Flows	150 mgd [c]
Ft. Collins Wastewater (both plants)	16 mgd (summer)
Greeley Wastewater	6 mgd
Kodak Industrial Discharge	1.5 mgd
Windsor Discharge	.5 mgd
Greeley Water Treatment - Bellvue[a]	0.6 mgd
Ft. Collins Water Treatment[a]	2.0 mgd
Poudre Pre-Mix[a]	.004 mgd
Ft. Collins Light & Power[a]	.035 mgd
Lone Star Steel (cooling water)[a]	.029 mgd
Mountain Aggregates, Greeley[a]	.86 mgd
Greeley Industrial (Monfort)[a]	.58 mgd
GW Sugar, Greeley[a] [b]	5.0 mgd
GW Sugar, Eaton[a] [b]	5.1 mgd

[a] 1973 flow from South Platte River Basin Plan

[b] Seasonal

[c] Million gallons per day. 1 mgd = 1.55 cubic feet per second (cfs)

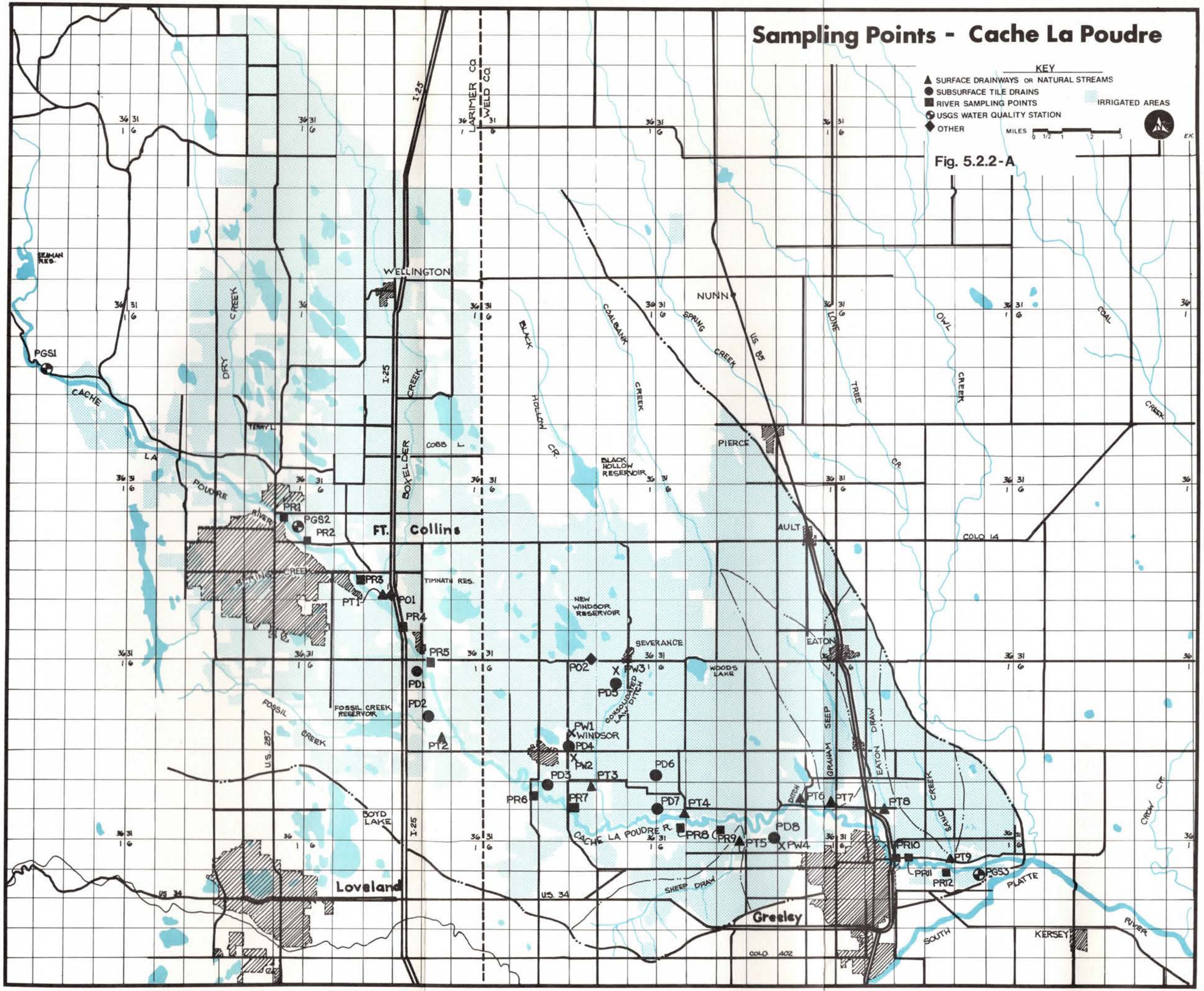
The volume of the discharge is not indicative of the quality. Each type of discharge has individual quality problems. The quality of irrigation discharges is reviewed elsewhere in this report. Municipal discharges must be considered detrimental even with good treatment. Several of the industrial discharges are quite detrimental as well.

5.2.1.4 Impact on Stream Hydrology

Hydrology in the Cache la Poudre basin is totally dominated by the system of irrigation supply, diversion, and return flow. The river is dried up several points along its course and irrigation returns comprise the entire flow in the lower reaches.

Flows below the Hansen Canal (which delivers Western Slope water via Horsetooth Reservoir) are often 700 to 800 cfs. These flows are diverted and lower stretches often have very small flows. The river is dried up at the Fossil Creek Reservoir inlet most of the year.

On the Cache la Poudre River, the entire flow below Windsor is made up of irrigation returns during summer and fall. Seepage into the river is approximately 170 cfs including the fraction of seepage carried by tile drains.



Sampling Points - Cache La Poudre

Fig. 5.2.2-A

Tributaries contribute approximately 56 cfs over the length of the river. Direct tailwater inflow to the river is very small, since most of the area directly adjacent to the river is not irrigated. Tributaries may carry some tailwater to the river, however.

5.2.2 Water Quality Analysis - Poudre River

Sampling sites in the Poudre basin are shown on Figure 5.2.2-A The river (suffix R), tributaries (suffix T), and tile drains (suffix D) were sampled.

5.2.2.1 Salinity

Soluble salts are added to the Poudre River by irrigation return flows and to a lesser extent by municipal and industrial discharges.

Salinity levels in the river are shown on Figure 5.2.2-B. The Cache la Poudre River increases from about 50 mg/l total dissolved solids (TDS) at the mouth of the canyon to 1500 mgd/l TDS at its mouth. Levels of TDS in the river increase significantly between Fort Collins and Interstate 25. This increase is the result of less saline water being diverted into Fossil Creek Reservoir and return flows of higher salinity entering the river below the Fossil Creek Reservoir inlet. Boxelder Creek is a major source of return flow below the Fossil Creek diversion, and typically discharges 10 cfs of 2000 mg/l TDS water. Ground water seepage into the river is also considerable in this segment of the river. TDS levels increase gradually from Timnath to the mouth. This increase is the result of water being recycled for irrigation. Many downstream diversions are satisfied by return flows. Irrigation increases salinity by evaporation and by contact with underlying shale formations.

1. Sources of Saline Discharges to the Cache la Poudre - Hydrologic analysis of the Poudre indicated that for much of the year, irrigation returns are the sole source of water for the lower reaches of the river. During the irrigation season, water is diverted for direct supply. During winter months, water is diverted for storage. Ground water seepage into the river is a major source of return flow year around. The quality of downstream reaches does not vary appreciably through the year as a result.

   Saline waters flow into the Poudre through tributary and ground water inflow. The Pierre Shale Formation adversely affects water quality along the front range yielding high sulfate water. While the river does not directly contact the formation, water diverted into canals and reservoirs does. Water applied to fields overlying this formation also has a significant opportunity to contact it. Nearly all of the Plains reservoirs are located over this shale formation, since it is the only area providing suitable topography. Fossil Creek (Figure 5.2.2-B) shows the effect of contact with the shale formation. Fossil Creek, flowing through the slightly permeable transition zones, supplied by seepage from the Fossil Creek Reservoir contains a high concentration of TDS.

One of the most significant areas of reservoir development is the shale area directly north of Fort Collins. Boxelder Creek serves as a return channel for the irrigated area to the north of Fort Collins and is perhaps the only channel carrying significant return flows back to the river in the vicinity of Fort Collins. It typically carries 10 cfs of 1800 mg/l TDS water. It cannot be considered to be the wasteway for the entire irrigated region north of Fort Collins. Much of the return flow is intercepted by one of the downhill parallel canals. These canals carry returns off to the east. While several of these canals eventually leave the hydrologic boundary of the Cache la Poudre, most of the water is used for irrigation in the Poudre basin. Seepage returns as well as tributary inflow returns carry the water back to the river in downstream reaches.

The shale formation north of Fort Collins would appear to affect water quality. This effect is emphasized by the fact that very little water remains in the stream for dilution because the river is generally diverted into Fossil Creek Reservoir. Return flow of seepage water and Boxelder Creek water comprise most of the flow directly below river mile (RM) 40. Wells in the shale formation north of Fort Collins yield water of 3000-4000 $\frac{\mu\text{mho's}}{\text{cm}}$ electrical conductivity. However, seepage out of the formation is small, due to the nearly impermeable nature of the shale.

The shale area extending north from Timnath and Windsor Reservoirs is also an area where water entering the ground water table is likely to become highly saline. Drain PD5 (see Figure 5.2.2-B) intercepts seepage from this area. While there is a definite increase in salinity as the river proceeds past Windsor, it is not an extreme one. The highly saline water from the shale area is a very small portion of the total return flow due to the very low permeability of the shale.

The Pierre shale areas north of Fort Collins and east of Fort Collins around Timnath Reservoir and Windsor Reservoir are areas of salt pick up. The impact of these areas is seen in samples PT1 and PD5 (Figure 5.2.2-B). Most of the shale area to the south of Fort Collins is not irrigated and there is little water contact with it, with the exception of Fossil Creek Reservoir.

2. Relationship to Other Dischargers - Municipal and industrial discharges are much less significant than irrigation return flows in regard to salinity loading. Municipal discharges from Fort Collins and Greeley are approximately 600 mg/l. In the Fort Collins area, these impact the water quality. Discharges from Greeley have lower TDS concentrations than receiving waters.

   Discharges from Windsor and Kodak have slightly higher concentrations of dissolved solids than receiving waters. These concentrations are no higher than irrigation returns in the area, and as the hydrologic analysis indicated, of much less volume.

3. Relationship of Current Levels to Historic Water Quality - No trend has been shown in total dissolved solids levels at the mouth of the Cache la Poudre. Annual average TDS levels are displayed on Figure 5.2.2-C. While levels since 1971 are numerically lower, this change can be attributed to the change in methods from residue at 180 degrees C to sum of constituents not destroyed at the 180°C temperature [Standard Methods].

4. Impact of Return Flows Upon Salinity in the Poudre River - Irrigation increases salinity because water removed from the basin as a result of transpiration by plants and evaporation from soil surface and water bodies concentrates salts in remaining water. In order to maintain a lasting agricultural economy, these salts must be carried away. This concept is valid on a regional basis as well as on the individual field basis.

   While salts are concentrated by evapotranspiration, this concentrating effect is not the only reason for increased TDS levels. The increase in salinity due to water contact with the Pierre shale transition layer and other upper Cretaceous formations contributes a significant salt burden to the Cache la Poudre River.

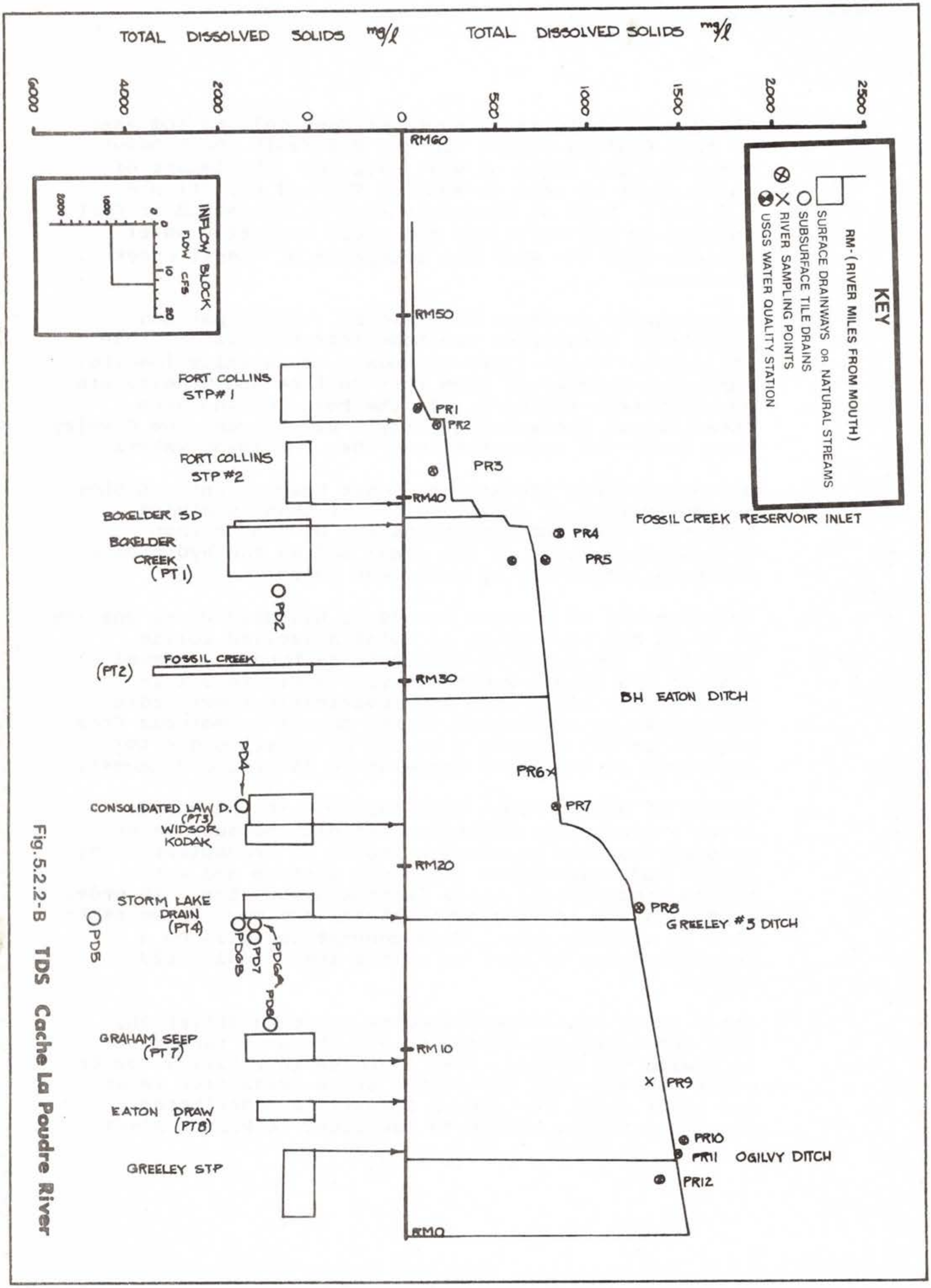


Fig. 5.2.2-B **TDS Cache La Poudre River**

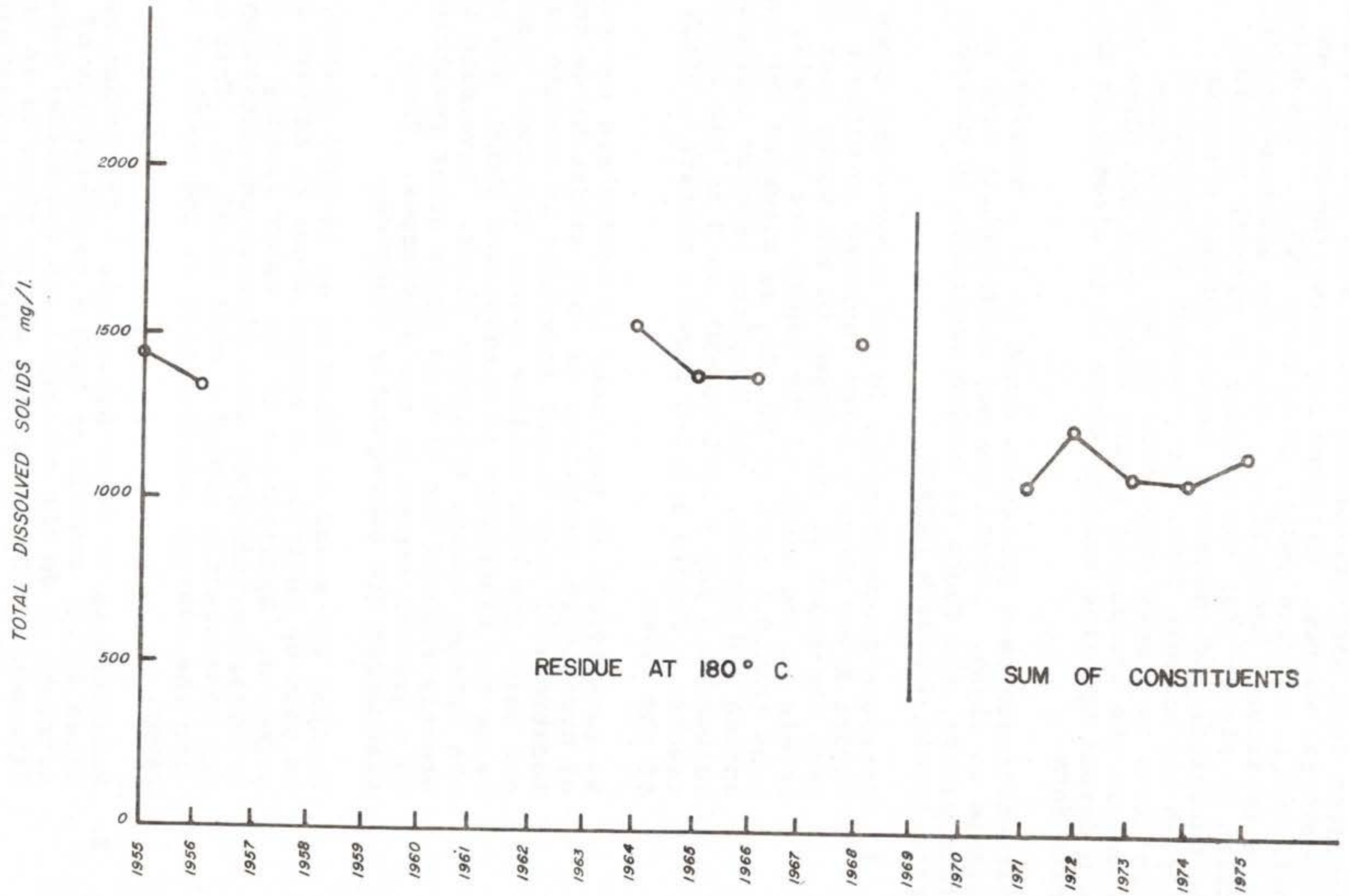


Figure 5.2.2-C Cache La Poudre Near Greeley — Mean Annual Total Dissolved Solids (From USGS Data)

5.2.2.2 Nitrates

The Cache la Poudre has the highest nitrate level of all rivers in the Larimer-Weld Region. It receives heavy loadings of nitrates from both irrigation return flow and municipal and industrial wastes. Nitrogen may enter the stream as ammonia (NH_3), nitrite (NO_2), or nitrate (NO_3). The nitrite form is relatively short lived, since the ammonia-nitrite reaction is slower than the nitrite to nitrate reaction. While municipal and industrial wastes contain nitrogen mainly in the ammonia form, the nitrogen in irrigation return flows is almost completely in the nitrate form. The nitrogen in the irrigation return flows does not place an oxygen demand upon the stream, since it is already in the nitrate form.

Nitrate-nitrogen is a pollutant since it is a nutrient available to algae. Levels are not sufficiently high in surface waters, the Cache la Poudre included, to consider nitrate levels a health hazard.

1. Nitrogen Concentrations in the River - The Cache la Poudre River shows a large increase in nitrate levels from the mouth of the canyon to the mouth near Greeley. Levels at the mouth of the canyon are generally less than 0.1 mg/l of NO_2+NO_3 as nitorgen (N) during spring and summer. The sampling program indicates values of 5 and 6 mg/l NO_2+NO_3 as N in the lower reaches. Figure 5.2.2-D shows a nitrate profile of the river.

   Nitrate levels in the Cache la Poudre are the result of hydrologic conditions as well as discharge conditions. Locations of significant increases in nitrate levels are below the Fort Collins sewage treatment plants, below the discharges of Windsor and Kodak, and below the Greeley sewage treatment plant. Diversion has greatly reduced the flow in these areas resulting in a greater impact by the discharges. These discharges are subsequently diverted.

   Because the river is dried up at several points, flow is made up entirely of return flows in several river segments. Examination of the water flowing in from tributaries indicates that nitrate concentrations are consistently around 5 mg/l of NO_3-N. This is also the average concentration at the mouth of the river.

2. Relationship to Other Discharges - Irrigation return flows do not contain as high a concentration of total nitrogen as do the municipal and industrial wastes. Nitrogen in the irrigation return flows is in the nitrate form. Much of the nitrogen in municipal and industrial wastes is in the ammonia form. This form

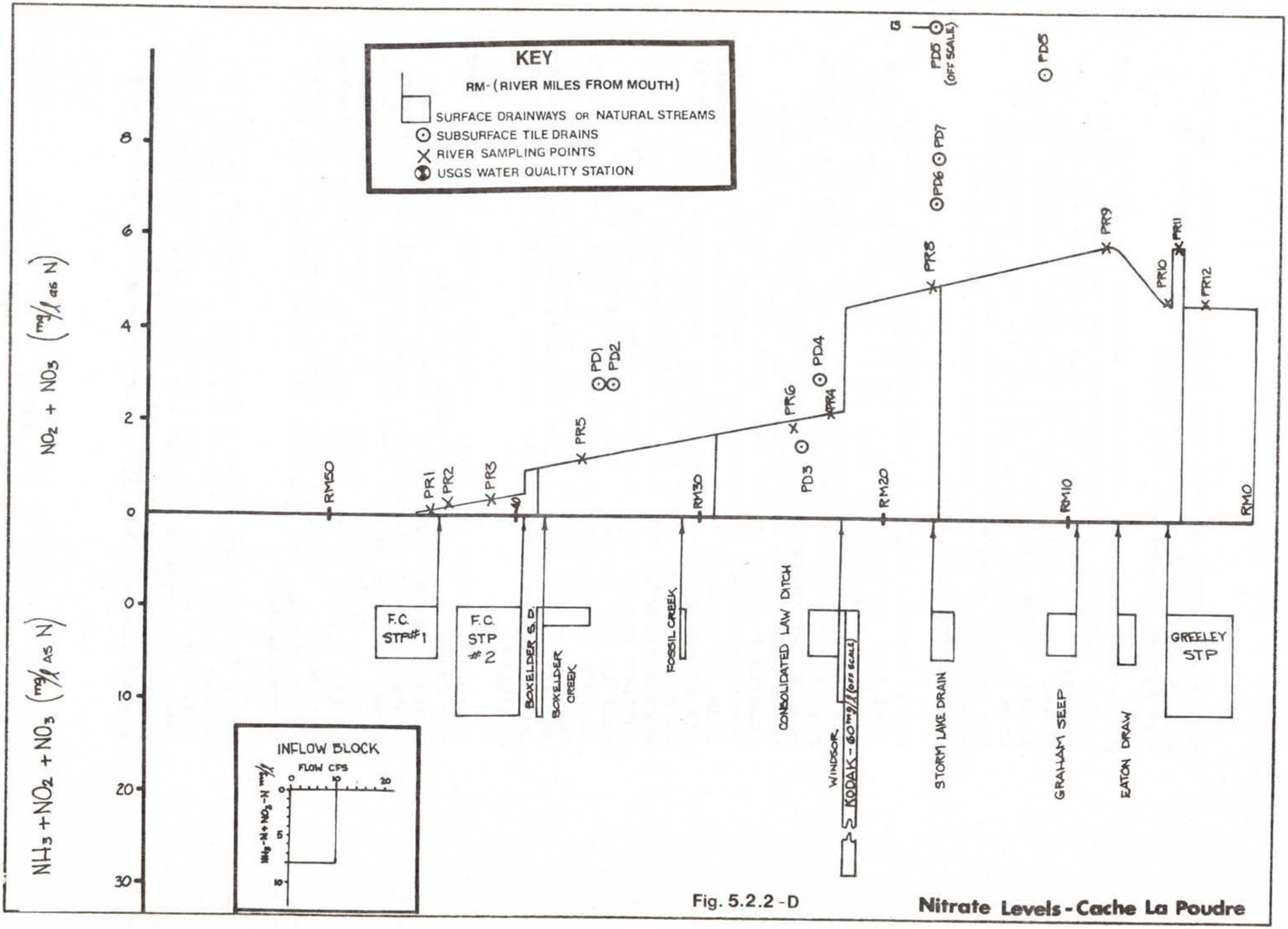


Fig. 5.2.2-D

Nitrate Levels - Cache La Poudre

places an oxygen demand upon receiving waters, and may be toxic to much aquatic life if concentrations in the stream exceed 1.5 mg/l NH_3-N.

While municipal and industrial discharges contain higher nitrogen concentrations, the volume of these discharges is much less than the volume of return flows. At several points on the stream, diversions dry up the stream and remove all upstream discharge water from the stream. Water quality is then determined by the quality of the return flows. In lower reaches, water quality is the same as return flow quality, emphasizing this fact.

While figures could be estimated for total nitrogen load from various sources, it is felt that such figures would be misleading. Each small segment of the river has individual characteristics. A few segments receive significant impact from municipal and industrial wastes. Downstream segments are hydrologically isolated from these discharges during most of the year. A second important point is the fact that the purely nitrate form discharged in agricultural return flow is different from the ammonia form, which constitutes a high percentage of municipal and industrial wastewater. The nitrate form is neither toxic to fish nor does it exert an oxygen demand. The nitrate concentrations found in surface waters have not been shown to deter water quality for any use. The only pollution aspect of nitrate for these concentrations is that it is an algae nutrient. The impact of algae on downstream users is unquantified, and the cost and effectiveness of management practices which could reduce loading has not been evaluated.

3. Historical Water Quality - Nitrate levels are shown for the Cache la Poudre in Figure 4.2.2-D. These are average summer conditions (June, July, August, and September) and represent a trend in quality of return flows over the years. The station (PGS3) is operated by the U.S. Geological Survey. It is located downstream of the Ogilvy Ditch, which dries up the river throughout the summer. Flows at this point are entirely irrigation return flows, and are also the flows which enter the South Platte.

   Water quality has shown a distinct increase in nitrate levels since 1971 (Figure 4.2.2-D). It is likely that these levels are the result of increased fertilizer use. Increased municipal and industrial loads on the river have increased nitrogen levels in some segments significantly. Yet diversions remove this water, and increased levels at Greeley are due primarily to irrigation return flows.

4. Impacts of Return Flows on Nitrogen Concentrations - Irrigation return flows cause a nitrate loading on the river. Total nitrogen concentrations in the irrigation returns are nearly always less than those in municipal and industrial wastes. However, the volume of irrigation returns are considerably larger than the volume of municipal and industrial returns.

Several interesting observations can be made from Figure 5.2.2-D. The first of these observations is that nitrate levels in tributaries draining agricultural land are fairly consistent. These tributaries have lower concentrations of nitrates than municipal and industrial discharges. Most of the lower tributaries have concentrations of approximately 5 mg/l NO_3-N. The river, composed entirely of return flow, has similar concentrations.

Another interesting aspect is the nitrate levels in tile drains. Tile drains give the best picture of the quality of seepage returns to the river. Drain PD1, PD2, PD3, and PD4 discharge water less than 3 mg/l NO_3-N while PD5, PD6, PD7, and PD8 discharge water of higher concentrations (Figure 5.2.2-D). Normally, a geographic distribution of nitrate levels would not be anticipated. Land use and fertilizer practice are noticeably different in the areas served by these drains, however. Lands served by drains PD1 and PD2 are pasture land not located near feedlots. Land served by PD5, PD6, and PD8 are intensively cultivated. On fields above these drains, heavy manure applications combined with chemical fertilizer applications were made. Assuming 50 percent first year availability of manure nitrogen, these fields received 250, 203, and 165 pounds/acre of fertilizer nitrogen, respectively. These farms receive heavy manure applications each year, and a considerable amount of nitrogen is probably carried over from these previous applications. The Greeley area has many feedlots providing much manure for fertilizer. Ludwick [1973] found that fields in the Greeley area had very high NO_3-N levels, generally enough to produce a maximum yield of sugar beets without additional fertilization. The data suggests that the high nitrogen levels in fields and in tile drains can be attributed to the under-estimation of the value of manure as fertilizer.

Whether the nitrate enrichment of surface waters is a problem or not is a matter open to question. For much of the year, these waters are rediverted for irrigation and for this use, nitrates are beneficial. Whether algae growth is a matter of concern in downstream irrigation reservoirs is a question which will affect the cost effectiveness of applying best management practices for control of nitrates.

5.2.2.3. Sediment

Sediment consists of both the mineral and organic soil particles removed by erosion and carried by the stream. The suspended particles carried under normal stream velocities were the only ones measured. These particles may settle out if velocity decreases. The most difficult problem in analyzing sediment loads is in defining the sources of that loading. Sediment is carried by the stream as a result of erosion in furrow irrigation, erosion from dryland, and erosion from bed and banks of both tributaries and major streams. Soil loss from sprinkler and border irrigated areas is insignificant. Sediment load has been measured as total suspended solids (TSS), which is the residue at 103°C. Both mineral (fixed) and organic (volatile) fractions are measured by this method. Organic portions may be added by municipal and industrial (M&I) wastes as well as by irrigation return flows. Figure 5.2.2-E shows suspended solids levels in the Cache la Poudre and many tributaries during the August, 1976 sampling program.

1. Suspended Solids Levels in the River - Suspended solids levels in the Cache la Poudre are relatively unaffected by return flows and municipal and industrial wastes above Fort Collins. While these levels are impacted by an artificial hydrology as well as by the changing nature of the stream as it flows from the mountains on to the Plains, they are not impacted by any significant irrigation return flows. Samples PR2 (river mile (RM) 44.9) and PR3 (RM 41.4) are representative of this high quality water in the Fort Collins area (Figure 5.2.2-E). These samples have total suspended solids in the range of 20 to 25 mg/l. Most of the loading of these solids is sand carried by the stream from the mountains.

   Below Fort Collins, flow is often diverted into the Fossil Creek Reservoir inlet. This usually causes a zero flow condition below this inlet with all downstream flows being made up of return flows. During the late summer, 1976 sampling season, however, river flows were allowed to go past this diversion in order to fulfill diversion requirements at Greeley No. 2 Ditch and also because downstream reservoirs were emptied early in the irrigation season. This has some impact on the results.

Suspended solids discharged by the Fort Collins No. 2 sewage treatment plant are sometimes discharged to the river. This is the first significant loading of suspended solids to the river. Permit requirements for domestic sewage treatment plants specify that they should have less than 30 mg/l of suspended solids. These suspended solids from domestic sewage treatment plants are organic in nature and are not the same as the soil particles lost through erosion, although they do have similar effects on the clarity of the water. Below this point, Boxelder Creek discharges to the Poudre. This creek typically discharges 10 cfs and total suspended solids levels were measured at 78 mg/l. It is expected that this is a fairly consistent discharge to the river throughout the irrigation season.

Impacts of these and other discharges are indicated by sample PR5 (RM 36.6) (Figure 5.2.2-E), which shows that the level of suspended solids in the river is approximately 55 mg/l. It should be noted that the tributaries discharging to the river have quite different beds and banks than does the river itself. Through this segment, the Cache la Poudre river has a bottom of relatively large stones while tributaries have beds and banks consisting of fine soil particles, and in some cases may even be gullies eroded from clay. The river at PR5 (RM 36.5) at station PR6 (RM 25.3) near Windsor was observed to have a low turbidity. All of the larger particles carried from the mountains have settled out and suspended solids in the river are generally the finer clays and silts picked up in the area. While sample PR6 shows a lower concentration than PR5, this does not give the entire picture. The smaller particles at PR6 are indicative of the changing nature of the river as indicated by its velocities and bed and bank conditions. These smaller particles make the stream appear more turbid.

Tributary inflows in the Windsor area carrying return flows with suspended solids are characterized by the Consolidated Law Ditch. This ditch returns water with around 65 or 70 mg/l of total suspended solids. This level is hardly any higher than that in the receiving waters. At PR8 (RM 17.7) we see that total suspended solids levels are slightly higher yet.

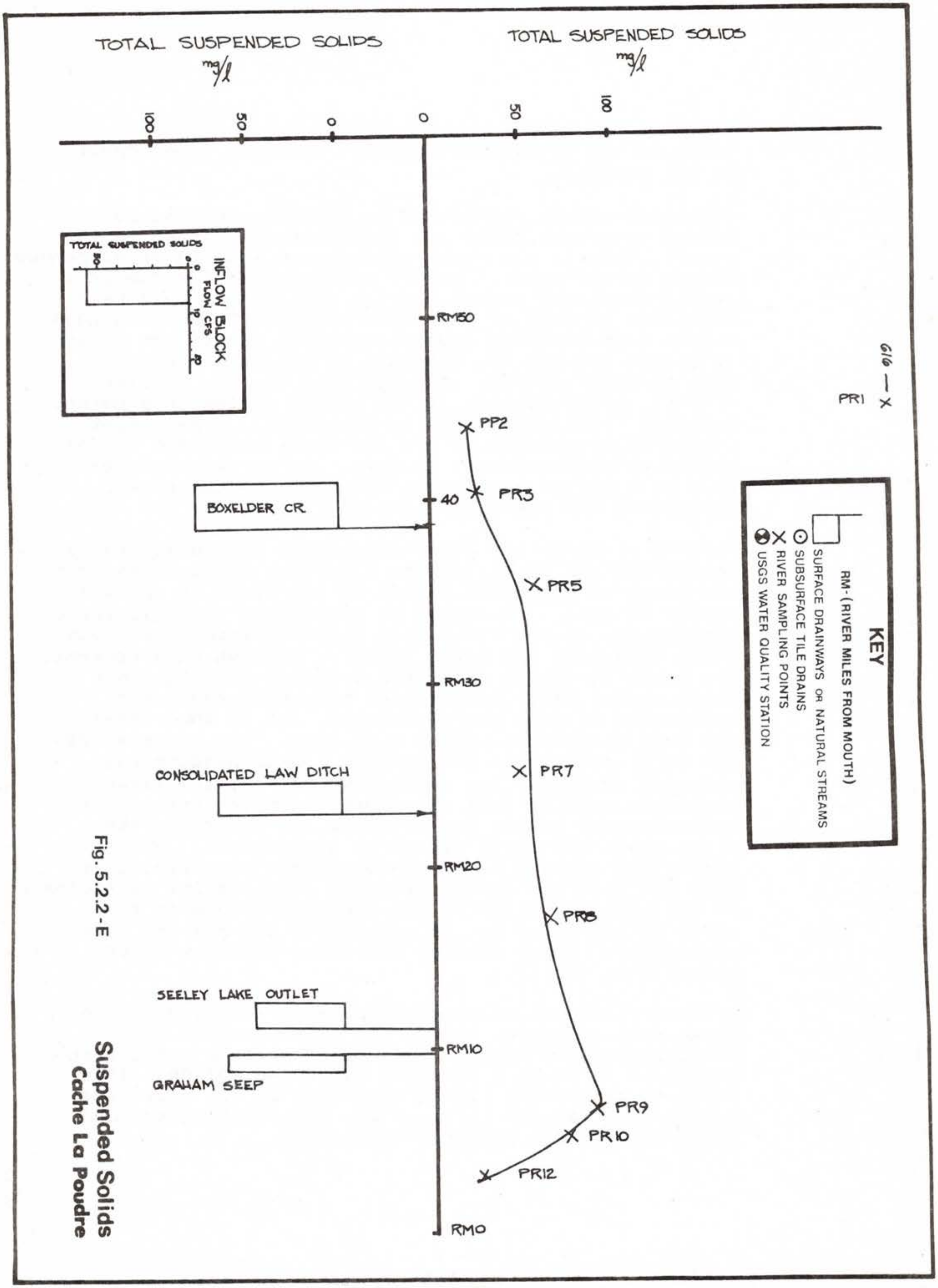


Fig. 5.2.2-E

Suspended Solids
Cache La Poudre

It is significant that below sample PR5, all flows are cut off and diverted and samples PR6 and PR8 are of entirely different water than sample PR5. The river at point PR6 is made up entirely of return flows while at PR8 there have been some municipal and industrial wastes added although irrigation return flows and perhaps, more importantly, bed and bank erosion are the causes of the suspended solids levels at these points. Further downstream, there is a significant increase in total suspended solids levels with samples PR9 (RM 8.3) and PR10 (RM 5.1). Levels of total suspended solids exhibited by samples PR9 and PR10 are partially due to bed and bank conditions, since these levels are higher than those seen in any of the irrigation return flows, particularly those in the area directly above the samples. That is, Graham Seep and Sealy Lake outlet both contribute much of the water to the river at point PR9 and PR10 and both have less total suspended solids levels than the river.

Near the mouth (PR12), total suspended solids levels are quite low again. The river has been diverted into the Ogilvy Ditch just above this point and irrigation return flows make up the entire flow of the river at point PR12. Most of these return flows come in as seepage. These are no large tributaries entering the river below the Ogilvy Ditch and above PR12. These return flows have resulted in a fairly low total suspended solids loading.

While loadings in the downstream reaches are often not much higher than in the upstream reaches, changing characteristics of stream bed and bank as well as stream velocities have caused a large difference in the particle size carried by the stream. The larger sandy particles carried in upstream reaches do not impact the visual clarity of the stream. In lower reaches, the smaller clay particles make the stream appear turbid.

2. Relationship to Other Discharges - The relationship of irrigation return flow to municipal and industrial discharges of suspended solids is quite variable. The relationship varies with individual river segments, and with the hydrologic conditions imposed on the river by demand for irrigation water.

   Downstream the discharges from Windsor and Kodak have an input on total suspended solids levels. While Kodak does not have high suspended solids levels, the Windsor sewage treatment plant is a lagoon and as such does have a significant level of suspended solids. These discharges have an impact on the stream since flows in this segment tend to be small.

The Greeley sewage treatment plant discharge as well as other discharges in the Greeley area are diverted into Ogilvy Ditch just downstream from Greeley. These discharges impact the river for only a small distance. The Greeley sewage treatment plant is required to produce a maximum of 30 mg/l of suspended solids (monthly average). The Cache la Poudre River at the point of discharge generally contains considerably higher concentrations than 30 mg/l. This does not imply that the volatile (organic) suspended solids discharged by the sewage treatment plants and other industrial wastes are of the same nature as the soil particles carried by the stream and measured as total suspended solids.

3. Historical Water Quality - There is essentially no historical data on sediment loading in the Cache la Poudre River. The Cache la Poudre has not been an area of concern as far as sediment loading goes. Sediment surveys of lakes conducted by the Soil Conservation Service have been restricted to those draining dryland areas in the region. After a hundred years of irrigation in the Poudre River Valley, sediment loads have probably stabilized.

4. Impact of Return Flows on Water Quality - The hydrologic changes imposed by man as well as the changes in bed and bank conditions along the length of the river caused by changing soil conditions are more important in sediment characteristics of the river than the irrigation return flows.

   The Cache la Poudre River below Fort Collins is made up entirely of return flows. Flows carried in by the various tributaries range from 50 to 75 mg/l TSS. The flows in these tributaries are the result of both tailwater discharges and seepage into the tributary. However, seepage into the tributary is probably in the neighborhood of 75 percent of the total flow of tributaries, especially in the late part of the season when this sampling program was conducted. The levels of suspended solids in these tributaries is the result in many cases of the soils which make up the bed and banks of these tributaries. These conditions are also seen in the river where seepage has been shown to make up most of the return flows.

   While not the case in point, the changing soil conditions and their effect upon sediment, or perhaps better phrased, turbidity in the water is best seen at Horsetooth Reservoir. Here crystal clear waters diverted from the mountains enter the lake and even under these quiescent lake conditions produce a fairly turbid water. The reason is easily seen when the lake is low and the fine, silty clay soils are observed.

Return flows discharging to the Cache la Poudre and the several tributaries sampled are not of significantly higher concentrations than the river itself. Only at Boxelder Creek does the return flow carrying tributary have a much larger concentration than the river itself. This condition existed only when approximately 100 cfs of river flow was allowed past the Fossil Creek Reservoir inlet. During low flow conditions when zero flow gets past Fossil Creek Reservoir inlet, water directly upstream of Boxelder Creek is probably not significantly better in quality than is Boxelder Creek.

5.3 BIG THOMPSON RIVER

5.3.1 Hydrologic Analysis

The Big Thompson leaves a narrow canyon to flow out on the Plains. Contact with the shale formations is small in the Big Thompson Basin, with the only significant area being directly southwest of Loveland. The Big Thompson is the central basin in the Colorado-Big Thompson Project.

Water supply to the Big Thompson is a result of natural flows as well as amendments from the Colorado-Big Thompson (C-BT) Project. Flows are altered by several reservoirs. A tunnel bypasses the natural stream to supply water for power generation. The stream gage at the mouth has little to do with actual flows available for irrigation since much of the water bypasses the gage. Generally, native water fulfills irrigation needs in the spring and early summer while Western Slope (Porject) water is required to meet late summer demands.

The Handy (river mile (RM) 36.8), Home Supply (RM 35.8), Louden (RM 34.3), and South Side (RM 34.3) ditches divert water prior to the confluence with Buckhorn Creek (RM 33.2). The Big Barnes Ditch just west of Loveland (RM 30.6) is owned by the Greeley-Loveland Irrigation Company and is used to fill Lake Loveland, Boyd Lake, and Seven Lakes. From the end of the irrigation season well into the winter, Big Barnes Ditch diverts all of the water from the river for storage. This is also the preferred point of diversion for the Greeley-Loveland Canal.

While the Greeley-Loveland Ditch is a large ditch and diverts most of the water from the river, the Hillsborough Ditch (RM 21.9) has excellent water rights and is nearly always supplied with river water. This canal has a capacity of 150 cfs. The Hillsborough Ditch may occasionally dry up the river approximately one mile west of Interstate 25.

Downstream ditches are Hill and Brush (RM 16.7) and the Big Thompson and South Platte Ditch (RM 10.1). The Little Thompson enters at River Mile 8.0. The Evans Town Ditch is at RM 2.0. Water needs for this ditch can be fulfilled by return flow and Little Thompson flow.

During the storage season, the Big Thompson is dried up by the Big Barnes Ditch west of Loveland for storage. Flows downstream of this diversion are made up entirely of groundwater inflow and waste discharges.

5.3.1.1 Sources

Water budgets were conducted for May 2, 1972; July 10, 1972; and August 31, 1976 (Figures 5.3.1-A and 5.3.1-B). These budgets required that 68 and 66 cfs be added in as return flow. A fairly intense sampling of tributaries indicated that 22 cfs entered the river in the small tributaries draining irrigated land. This does not include Buckhorn Creek and the Little Thompson. The magnitude of irrigation return flows for summer and early fall is as follows:

Tributary Inflows (not including Buckhorn Creek or Little Thompson)	22 cfs
Seepage Inflow	46 cfs

The 46 cfs of seepage inflow occurs over approximately 35 river miles. This represents approximately 1.3 cfs per river mile.

Much of the return flow occurs as tributary flow in the tiny streams in the eastern portion of the basin. These tributary returns are individually delineated in the sampling program data. Seepage inflows occur throughout the basin.

Irrigation return flows play a significant part in the hydrologic characteristics of the basin. Diversions lower the flow considerably so that at the mouth, little water is left. Flow at the mouth of the Big Thompson is all irrigation return, much of it from Little Thompson.

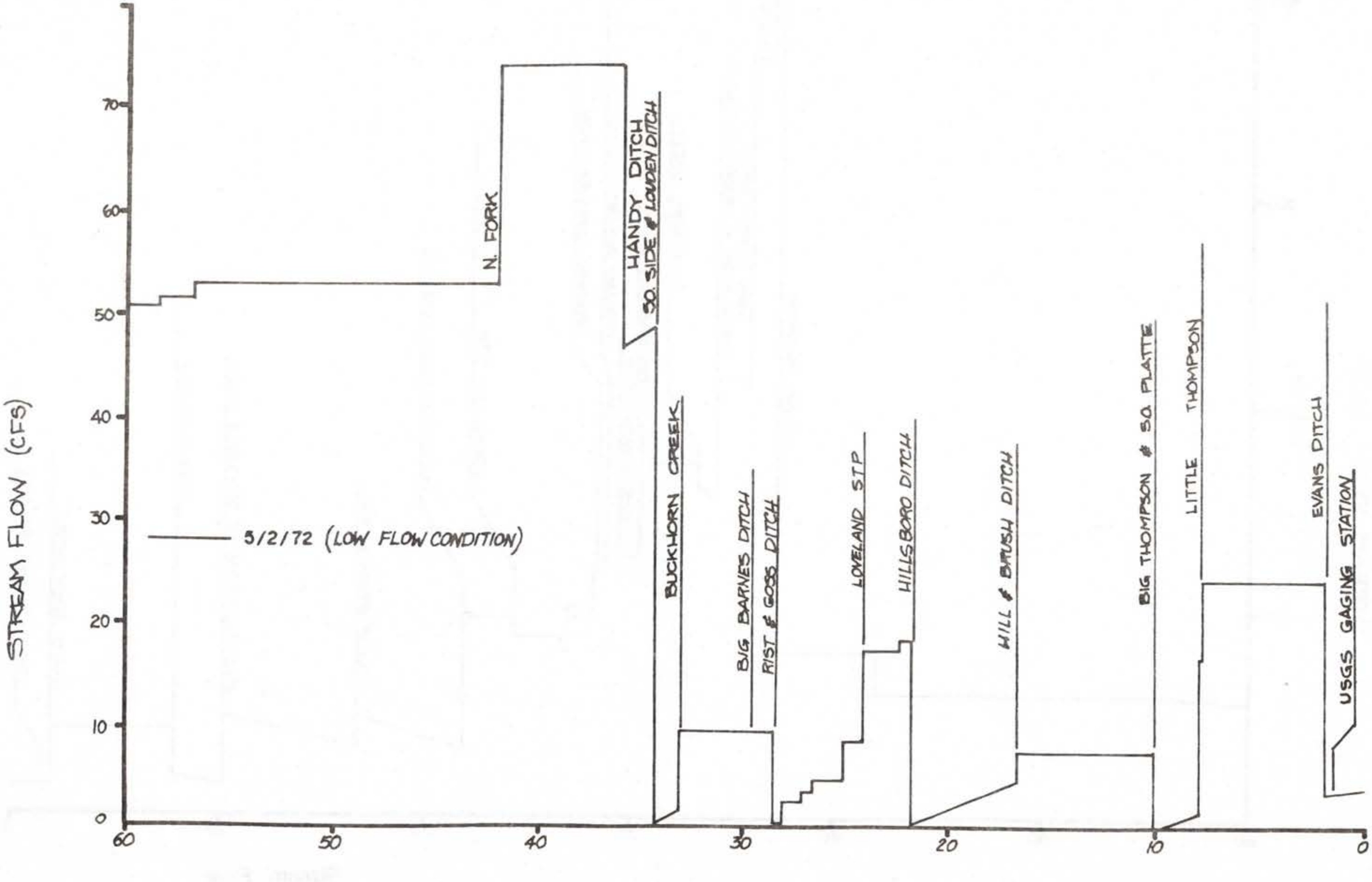


FIG. 5.3.1-A Stream Flow
BIG THOMPSON RIVER

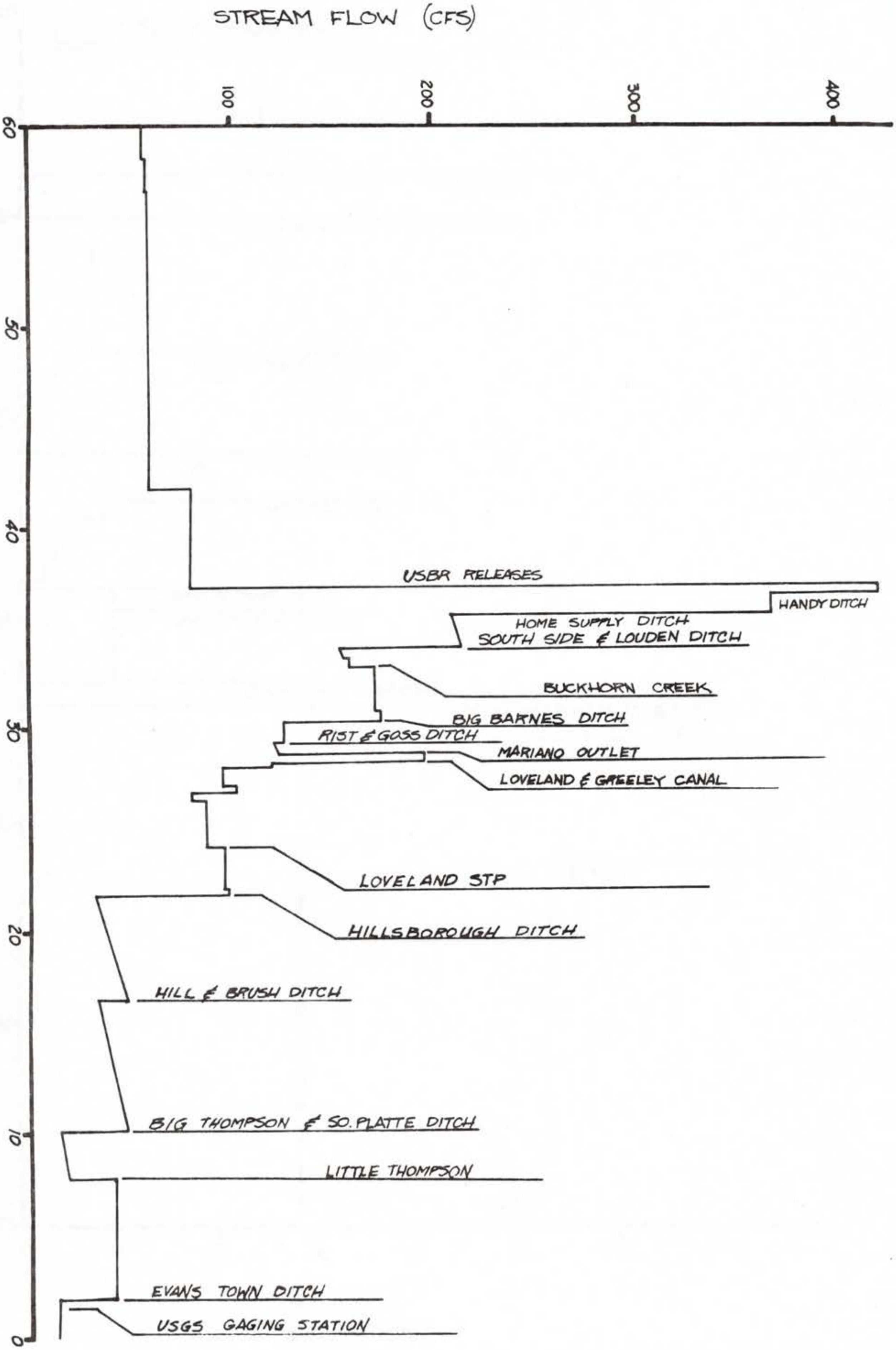


FIG.5.3I-B Stream Flow
BIG THOMPSON RIVER 7/10/72

5.3.1.2 Relationships to Other Discharges

The Big Thompson River receives municipal and industrial discharges as well as agricultural return flows. During the irrigation season, all of these discharges are eventually diverted for irrigation. Irrigation returns are the largest return to the river, representing approximately 68 cfs (44 mgd).

The magnitude of these returns is:

Irrigation Return Flow	44 mgd
Estes Park S.D.	[a]
Upper Thompson S.D.	[a]
Loveland Sewage Plant	6 mgd
Loveland Water Treatment	(Batch)
Great Western Sugar, Loveland	12 [a] mgd
Milliken Sewage Treatment	0.1 mgd

[a] Seasonal.

5.3.1.3 Impact on Stream Hydrology

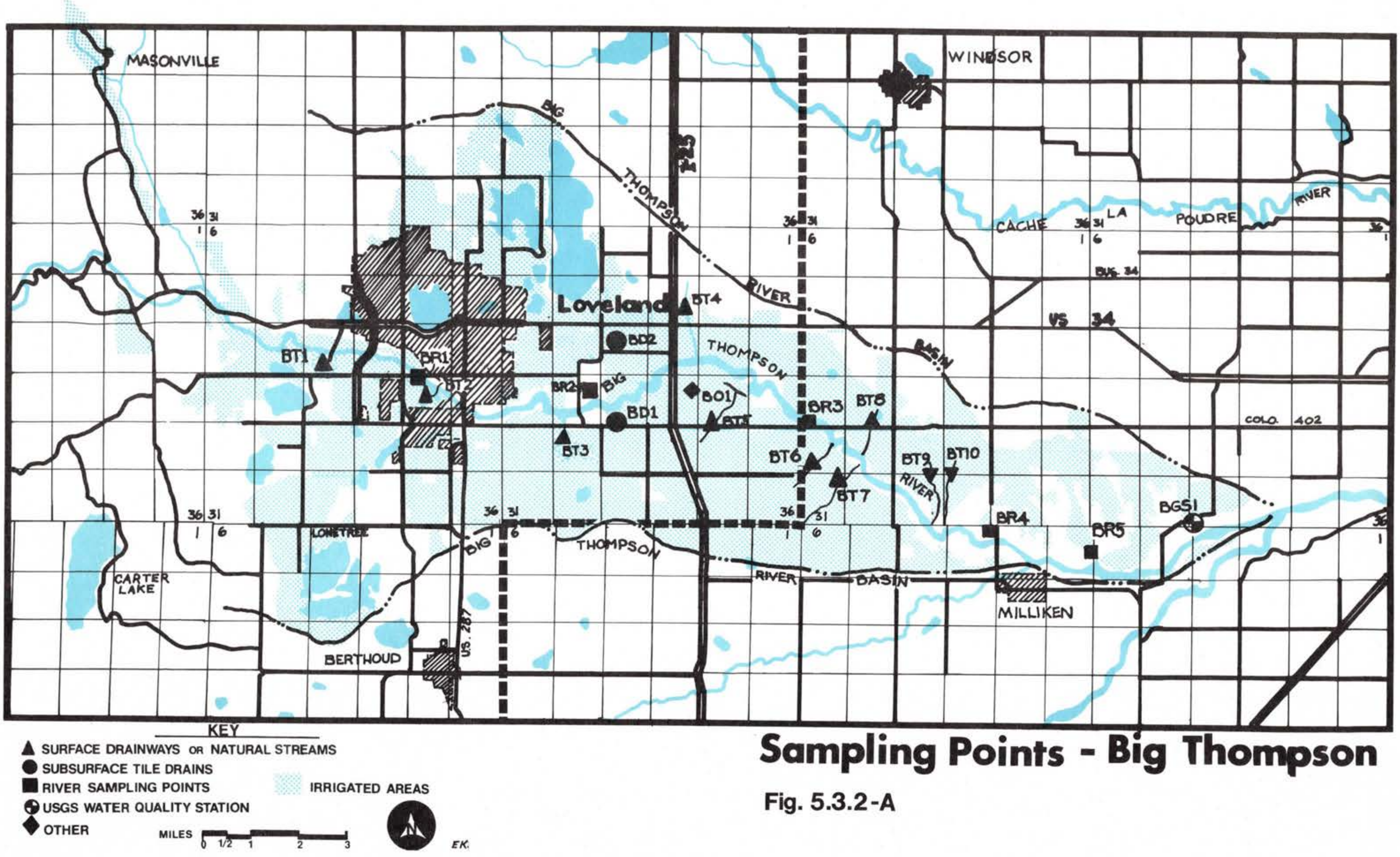
Irrigation return flows have less of a hydrologic impact upon the Big Thompson than upon other streams in the basin. Seepage inflows of about 1.3 cfs/mile are smaller than other rivers in the region. This can be largely attributed to the relatively narrow basin in which there is essentially only one tier of irrigation. This compares to the Poudre with four parallel canals north of the river.

To the east, topography is rolling in the area north of Johnstown, and as a result, more surface drainage is provided. This is seen in the many small tributaries draining into the river in this area.

Flow profiles are shown in Figures 5.3.1-A and 5.3.1-B for July 10, 1972, and May 2, 1972. Irrigation return flows present an increasing portion of the total flow as one progresses downstream from Loveland. The impact of return flows on the Big Thompson is much less than on other rivers in the area, since river water is generally required by downstream divertors. Below the Big Thompson and South Platte Ditch, however, river water is entirely return flow.

5.3.2 WATER QUALITY ANALYSIS

Sampling sites in the Big Thompson basin are shown in Figure 5.3.2-A. The river (suffix R), tributaries (suffix T) and tile drains (Suffix D) were sampled.



Sampling Points - Big Thompson

Fig. 5.3.2-A

5.3.2.1 Salinity

Levels of total dissolved solids (TDS) in the Big Thompson River are affected by flow conditions. Flow conditions in the Big Thompson were unusual throughout the sampling program since the July 1976 flood prevented full diversions at several structures. For this reason, flows were much higher than usual along the length of the river. The Hillsborough Ditch at river mile 21.9 is the last ditch which carries more than 50 cfs. Flows below this ditch can be quite small down to the confluence with the Little Thompson.

Understanding these facts about the hydrologic situation, the effects of return flows upon the river as it was in August 1976, will be shown and the impact that these return flows would have under more typical flow conditions discussed.

1. Levels in the River - Total dissolved solids levels in the Big Thompson River as it comes out of the mountains are very low and are unaffected by irrigation return flows. Total dissolved solids levels upstream from Buckhorn Creek are less than 100 mg/l. Shale areas in the Big Thompson River basin are located between the confluence of Buckhorn Creek and Loveland. Most of this area is not irrigated; however a small part southwest of Loveland is used for storage and for some irrigated land. Return flows in this stretch between Buckhorn Creek and Loveland would be expected to be of fairly high TDS levels. This condition is exemplified by sample BT2 (Figure 5.3.2-B). The Loveland Home Supply, South Side and Louden Ditch diversions can dry up the river at approximately River Mile 34. Flows below this would then consist only of return flows and the Buckhorn Creek flow. While sample BRI (RM 27.5) tested at about 200 mg/l TDS during the sampling program, it is conceivable that a low flow condition drying up the river above this point could result in much higher TDS levels.

   The river shows a gradual increase in samples BR2, BR3, and BR4. It is thought that this gradual increase is the result of the hydrologic conditions during the August 1976, sampling program. Return flows between Loveland (station BR1) and the confluence with the Little Thompson are generally of fairly low TDS concentrations. This fact is due to the large amounts of water diverted as well as soils conditions east of Loveland. While salt pickup is high west and especially southwest of Loveland, to the east of Loveland salt pickup is negligible. Many samples have TDS levels from 500 to 800 mg/l, barely higher than the receiving waters at that point, even under these high flow conditions. The Little Thompson River impacts the Big

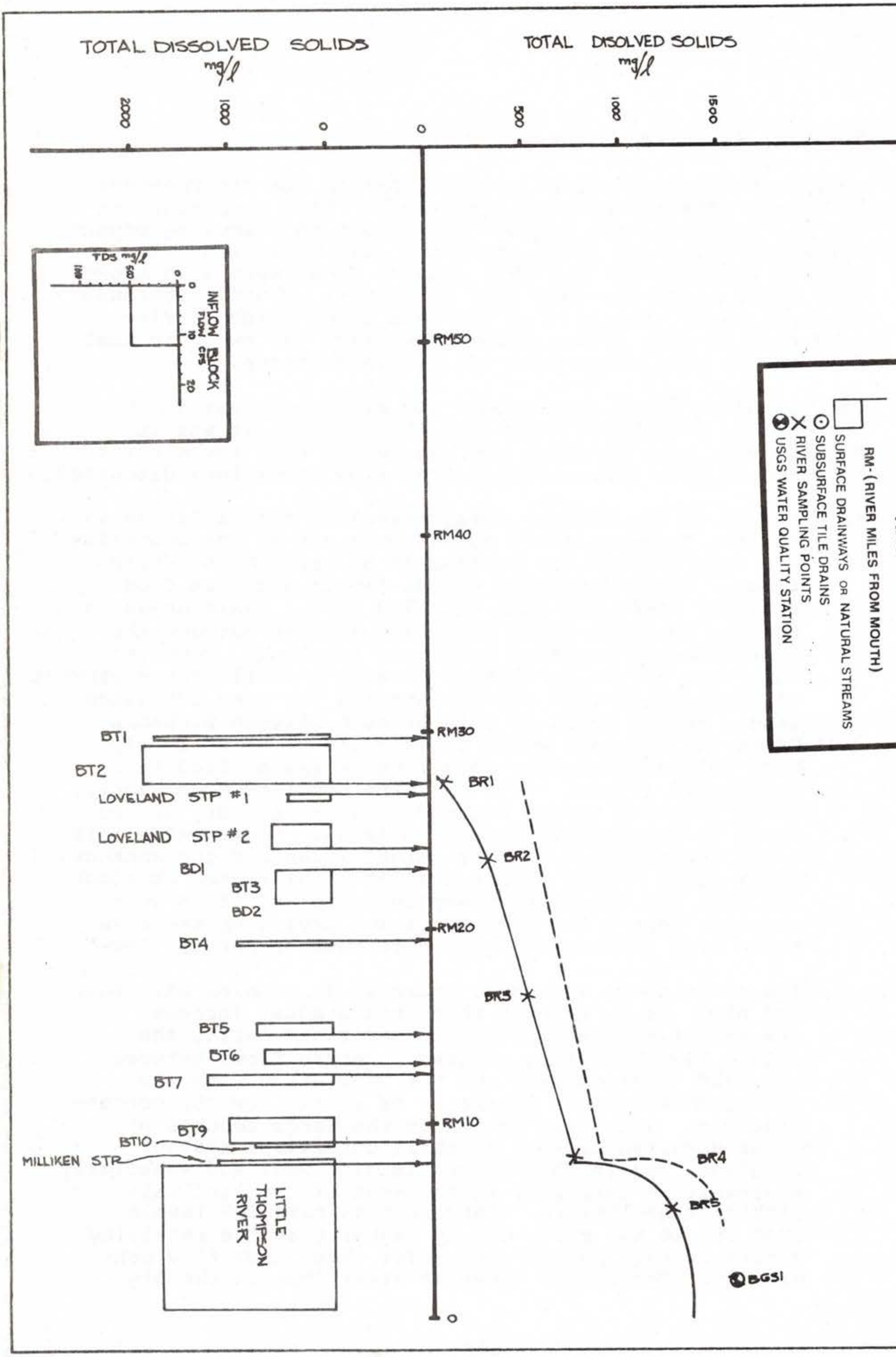


Fig. 5.3.2-B **TDS - Big Thompson**

Thompson considerably with fairly high TDS levels below the confluence. TDS level for the period of record at the U.S.G.S. station near the mouth is 1575 mg/l. This level was used to estimate the levels along the river under a more typical summertime hydrologic conditions as shown in the Figure 5.3.2-B on the dashed lines.

2. Relationship to Other Dischargers - Compared to return flows from seepage and tributaries, municipal and industrial dischargers place an insignificant salt burden upon the river. Levels at the sewage treatment plants are small with about 600 mg/l TDS leaving the Loveland No. 2 sewage treatment plant.

3. Historical Water Quality - There has been no significant change in TDS levels in the Big Thompson for the period of record. While levels prior to 1968 may seem higher, some of this difference may be attributed to a change in methods from residue at 180°C to the sum of the constituents. Levels are shown in Table 5.3.2-A.

TABLE 5.3.2-A HISTORIC LEVELS IN THE BIG THOMPSON RIVER AT THE MOUTH NEAR LASALLE (from USGS Data)

Year	Total Dissolved Solids (mg/l) Annual Average
1955	2094 [a]
1956	1623 [a]
1968	1547 [a]
1971	1412 [a]
1972	1818 [b]
1973	1397 [b]
1974	1385 [b]
1975	1330 [b]

[a] Residue at 180°C
[b] Sum of Constituents

4. Impact of Return Flows on Water Quality - Return flows west of Loveland have the most serious impact upon the TDS levels in the Big Thompson River. TDS levels in this area west of Loveland are often nearly 2000 mg/l. Flows into the river of this high TDS water are estimated at 25 to 30 cfs as a result of hydrologic balances made upon the river.

   Below Loveland return flows are fairly low in TDS with many samples in the 500 to 800 mg/l range. Return flows of this TDS concentration do not seriously impact the river and in some places the river may be of higher TDS concentration than the return flow due to the river being made up of stronger return flows from upstream areas.

   The Little Thompson has a salinity problem. Flows in the Little Thompson discharging to the Big Thompson are typically 30 to 35 cfs. This water generally imposes a significant salt load upon the Big Thompson River.

   Irrigation return flows seriously impact the TDS level in the Big Thompson River. However, diversions to irrigation cause greatly reduced flows in the river. Seepage from canals, reservoirs and irrigated fields enter the river at increased TDS levels. These levels may vary considerably due to soils and geologic conditions. Under adverse conditions with no flow in the river left for dilution, high TDS levels result.

5.3.2.2 Nitrates

1. Levels in the River - Nitrate levels in the Big Thompson River for September 1976, as well as irrigation return flows and some municipal and industrial return flows to the river are shown in Figure 5.3.2-C.

   Levels of nitrates in the river as shown in Figure 5.3.2-C are probably lower than typical levels since the July 1976, flood on the Big Thompson destroyed some diversion structures and as a result, flows in the river were much larger than usual.

   Levels in the river at the time of sampling results below 1 mg/l NO_3-N until river mile 10. The inflow

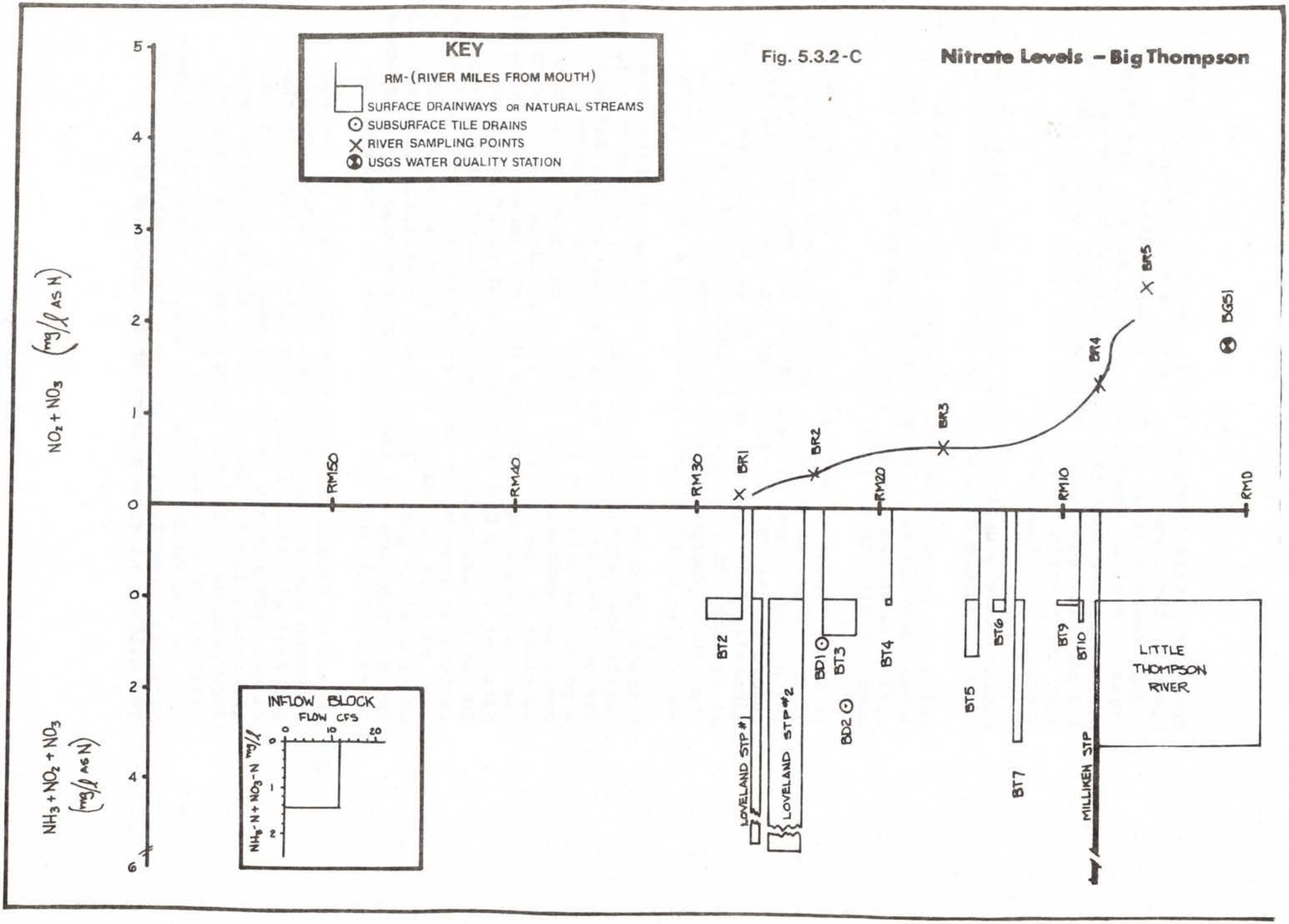


Fig. 5.3.2-C

Nitrate Levels – Big Thompson

from the Little Thompson River, as well as other return flows in the lower region, caused a significantly higher concentration in these lower reaches of the stream. Average summer (June, July, August, and September) Nitrate-N concentrations at the mouth have been 1.8 mg/l for the period of record (USGS data). The past three years, (1973, 1974, and 1975) have all averaged less than 2.0 mg/l.

Nitrate levels upstream from Loveland are quite low as shown by sample BR1, which is approximately 0.15 mg/l.

Below the Loveland sewage treatment plant, nitrate levels are higher. Levels are found to be up to 0.7 mg/l as N at BR3. These levels could be higher yet under conditions of lower flow.

It would appear that nitrate levels in the lower reaches of the river, as shown by samples BR4 and BR5 and by the average summer nitrate levels for the period of record at the USGS station near the mouth (BRGS1) are generally less than 2.0 mg/l. It is likely that levels at station BR5 are highly influenced by inflows from the Little Thompson and that irrigation return flows below this point dilute the water to a certain extent.

Nitrate nitrogen levels in the Big Thompson River are fairly low (generally less than 3 mg/l) and at this level are only detrimental to water quality in that nitrate is a potential nutrient for algae. During the summer, continual rediversion of flows in the river applies this nutrient to the fields. In winter, algae growth potential is much lower. Perhaps the only reason for controlling nitrates in the Big Thompson is control of algae in downstream irrigation reservoirs. Protection of these irrigation reservoirs which are privately owned and drained each year for irrigation has not been established as a water quality goal. There are no downstream reservoirs on the Big Thompson and the Big Thompson usually has a lower nitrate level than the Platte which it discharges to.

2. Impact of Return Flows on Water Quality - In the Big Thompson basin, the irrigation return flows have a surprisingly small impact upon nitrate levels in the river. Low nitrate levels are seen in almost all of the return flows. Nearly all of the irrigation return flow samples in the Big Thompson basin had nitrate-nitrogen concentrations less than 2.0 mg/l. Compare this to the Poudre where most return flows had nitrate-nitrogen concentrations in the neighborhood of 5.0 mg/l. The highest nitrate concentration observed in

drains were 3.0 mg/l, while levels in the river are generally low. The Loveland municipal discharges were found to be of much higher nitrogen levels than agricultural discharges in the basin.

3. Relationship to Other Dischargers - Nitrogen released by the Loveland sewage treatment facilities is of much greater concern than the nitrates released from irrigation in the Big Thompson basin. Nitrogen released from sewage treatment plants is mostly in the ammonia form. This form can be toxic to fish in the stream and exerts an oxygen demand upon the stream. For this reason, nitrogen from sewage treatment plants is of more concern than that from irrigation return flows which is in the nitrate form. The concentrations of NH3-N plus NO3-N observed in the sewage treatment plants at Loveland and Milliken is considerably larger than any irrigation return flows sampled in the Big Thompson.

4. Historical Water Quality - Nitrate levels for the Big Thompson River are shown in Figure 4.2.2-D. Levels in 1955 and 1956 were around 1.0 mg/l as N. In recent years, 1971 to 1975, levels are seen to have a lowering trend, although levels are still somewhat higher than the 1955 and 1956 samples. Data is insufficient to make any concrete observation.

5.3.2.3 Sediment

1. Levels in the River - Suspended solids levels for the Big Thompson River are shown in Figure 5.3.2-D. The July 1976 flood has an effect on sediment levels all the way to the South Platte. Along the entire length of the Big Thompson River large quantities of sediment were deposited in the stream bed.

   In the irrigated area, along the major length of the river, samples were about 60 to 80 mg/l. These levels are between the levels in the Cache la Poudre which are generally around 50 mg/l and the Little Thompson which has significantly higher concentrations of total suspended solids. The enormous amount of sediment carried down by the flood, must have increased sediment load in the Big Thompson River. The Big Thompson would be expected to have a comparable sediment load to the Cache la Poudre under normal conditions.

2. Relationship to Other Dischargers - Municipal and industrial dischargers generally discharge organic suspended solids. Permits specify that these dischargers

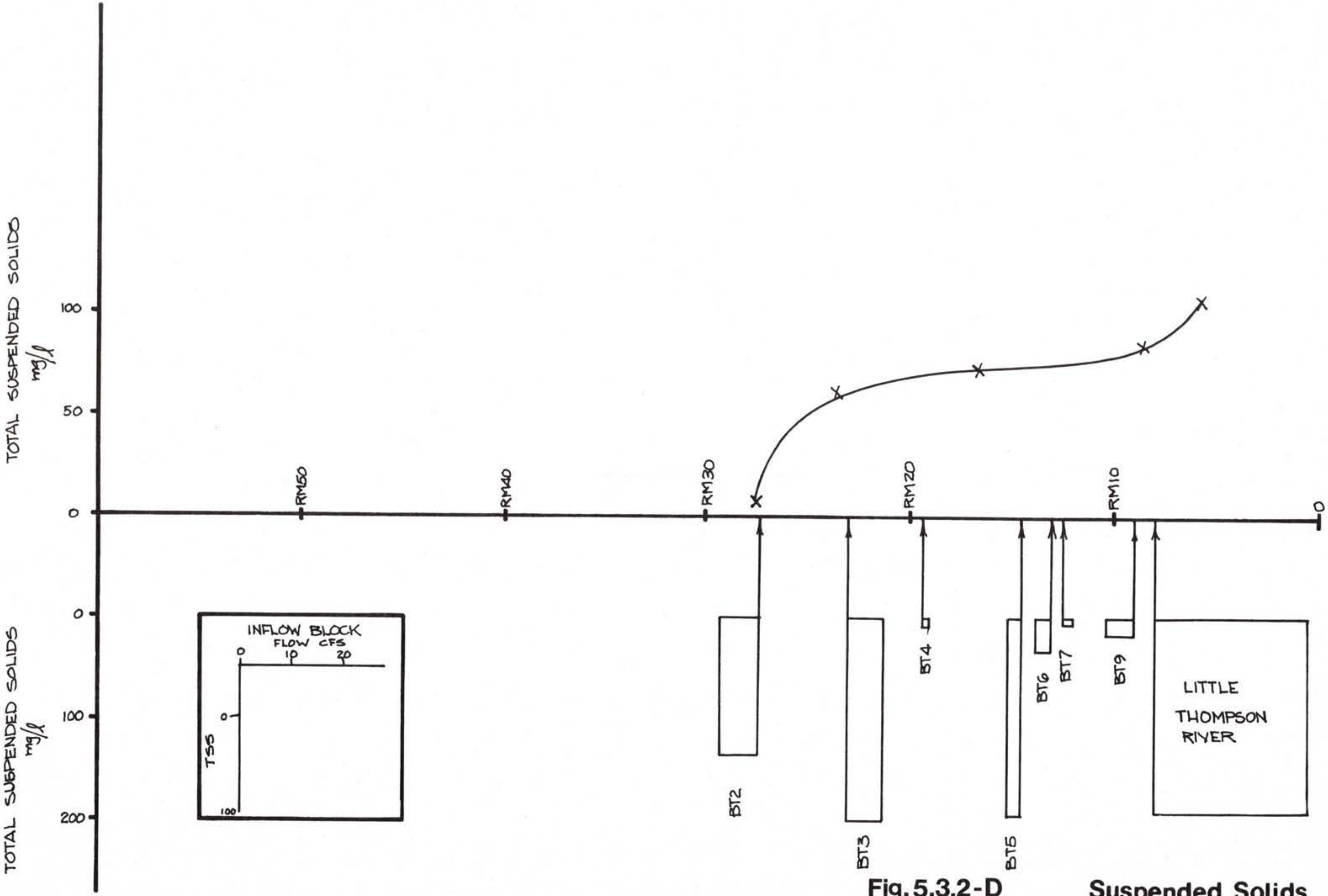


Fig. 5.3.2-D

Suspended Solids
Big Thompson

may not discharge more than 30 mg/l as a monthly average. Comparison of suspended solids loads between irrigation return flows and domestic sewage treatment plants is not really fair since the solids are of such different nature. The silt and clay particles in irrigation return flow are generally much less offensive than the bacterial organisms discharged from a sewage treatment plant.

3. Historical Water Quality - Sediment has not been a pollutant of concern in the northern Colorado area and for this reason, no data has been recorded as to previous suspended solids loadings in the return flows. Soil conservation agencies have not conducted any lake capacity loss investigations except in dryland areas. Generally, soil loss in dryland areas has been more of concern than soil loss from the irrigated areas. The July 1976 flood probably has more effect on suspended solids levels for the next few years than the past 100 years of irrigation. The flood completely changed the characteristics of the bed and bank of the river. Sediment is not conserved in the water and may be settled out or picked up depending upon its flow characteristics. Very low levels of total suspended solids are found in samples BT4, BT6, BT7 and BT9, all of which are return flow channels similar to BT2, BT3, and BT5. The tributaries with high levels of suspended solids are this way because of the slope of the stream bed and because of the soils associated with them.

   Of the total tailwater generated, only a very small fraction ever reaches the river. The changing characteristics of the stream as it changes from a clear mountain stream to a slow moving stream in the plains are perhaps the most important aspect of suspended solids loading. While this study has been unable to quantify the loading due to return flows, the changing nature of the stream in the plains may be more important than the surface tributary inflows. Most of the water coming into a stream in the irrigated areas was found to return as seepage into the river. Seepage returns carry no sediment and would appear to pick up a considerable amount as they travel downstream.

4. Impact of Return Flows on Water Quality in the Big Thompson basin - A fairly intensive sampling of tribtaries draining into the Big Thompson was conducted. Most of the major tributaries were sampled. Total suspended solids levels in these tributaries can be classified into two types: high or low. These types are associated with slope conditions in the area they drain.

The area south of the Big Thompson River from Loveland to just east of I-25 is characterized by relatively steep slopes. Samples BT3, BT4 and BT5 were taken from tributaries draining this region. These tributaries are seen to contain fairly high levels of total suspended solids with BT3 and BT5 being nearly 200 mg/l. These tributaries have a significant impact on total suspended solids levels in the river. A significant pickup of fine soil particles from the bed and banks may also play an important role in the increase in suspended solids levels.

Other areas in the Big Thompson basin display return flows of quite low total suspended solids levels. These areas are exemplified by samples BT4, BT6, BT7 and BT9. These tributaries have total suspended solids levels generally less than 30 mg/l and carry less of a total suspended solids load than the river to which they discharge.

The Little Thompson River basin is characterized by relatively steep slopes and some areas of fine soils. It can be seen that the Little Thompson River places a significant sediment load upon the Big Thompson River, with the Little Thompson River being nearly 200 mg/l of total suspended solids at the mouth.

5.4 LITTLE THOMPSON

5.4.1 Hydrologic Analysis

The major irrigation development in the Little Thompson Basin occurred in the period from 1860 to 1880. The Little Thompson is a small river. Natural flows at the mouth of the canyon are generaly around 4 cfs during the summer (Table 5.4.1-A) These native flows are augmented by flows from the Colorado-Big Thompson Project which delivers water via the St. Vrain Supply Canal. This canal supplied approximately 1550 acre-feet during August, 1976. The Supply Ditch (different from the St. Vrain Supply Canal) supplies native virgin water from St. Vrain Creek to the Little Thompson in the spring, with an average flow of 60 cfs before July 1. This canal is not generally used after July 1.

It should be noted that several canals originating in other basins supply water to fields which are in the Little Thompson watershed. The Handy Ditch and Home Supply Ditch originate at the Big Thompson. A portion of the water in these ditches is used in the Little Thompson Basin. The Highland Ditch brings in water from the St. Vrain. These waters contribute to return flows, and flows at the mouth of the Little Thompson are effected by these ditches.

TABLE 5.4.1-A LITTLE THOMPSON AT MOUTH OF CANYON
Water Year 1972, MEASURED FLOWS[a]

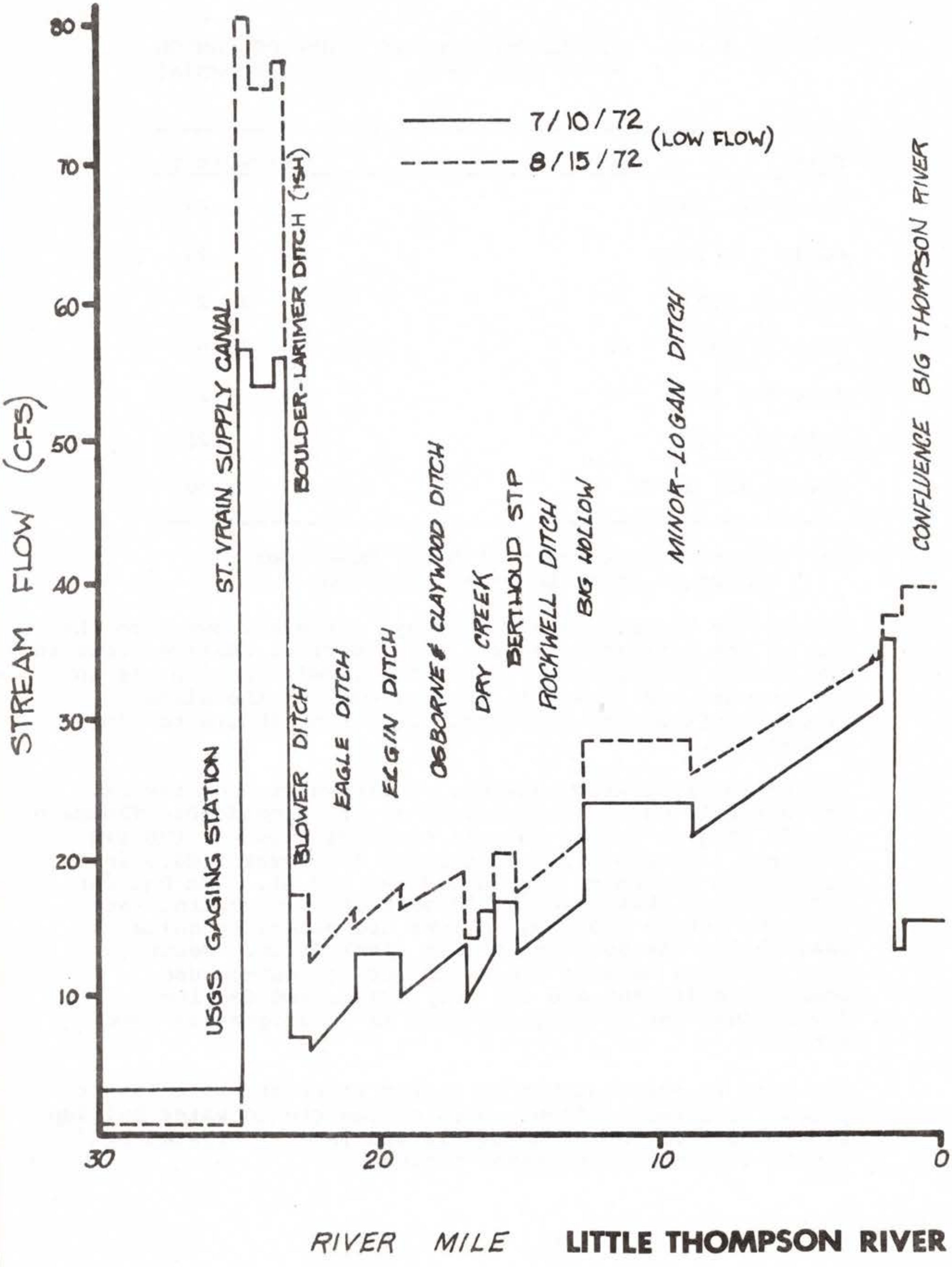
Date	Flow (cfs)
March 16, 1972	3.42
April 13, 1972	2.24
May 15, 1972	21.2
June 3, 1972	14.0
June 29, 1972	4.27
July 11, 1972	3.20
August 15, 1972	0.50

[a] Colorado Department of Water Resources
Office of State Engineer, Division I.

The Little Thompson River displays minimum flows from the end of the irrigation season until spring. Native flows in the Little Thompson are quite small, only about 5 cfs in late August and less yet (about 1 cfs) in the winter. Seepage inflow from irrigated areas contributes to flow downstream.

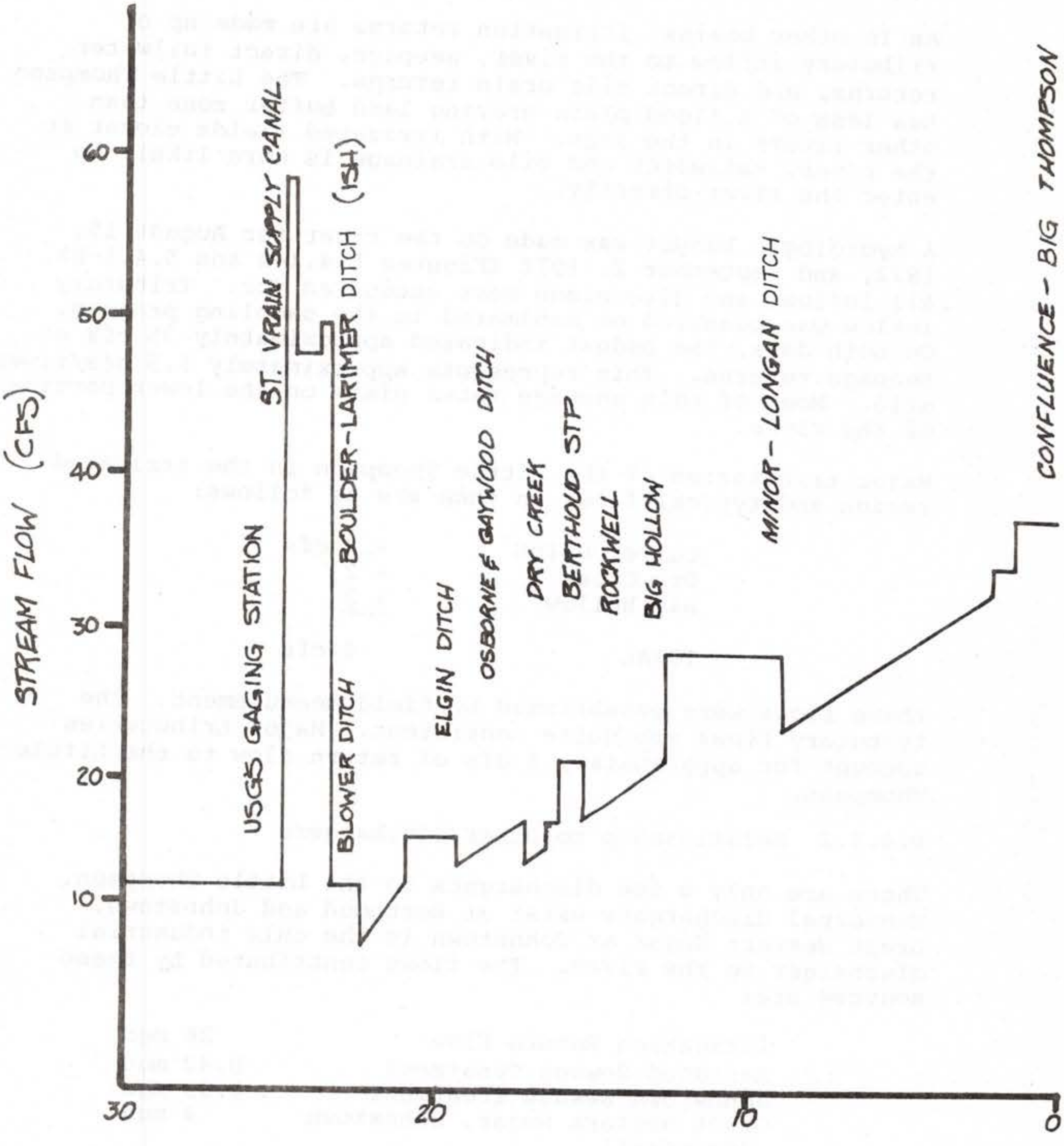
During the irrigation season, supply water from the St. Vrain Supply Canal (before July 1) or Colorado-Big Thompson (C-BT) Project (after July 1) provides flow for the Big Thompson. Flow profiles are shown for several days in the irrigation season on Figure 5.4.1-A and B). The Boulder-Larimer (Ish) Ditch is the largest ditch diverting water from the Little Thompson. Flows are generally quite small below the Boulder-Larimer (Ish) Ditch. Return flow supplies much of the water for downstream use. Downstream ditches are all very small, and despite diversions, the river gains flow as it progresses down stream.

The gain is attributable to ground water and to a lesser extent tributary inflow. Much of the ground water buildup is a result of loss from canals and lands irrigated by canals originating in other basins.



LITTLE THOMPSON RIVER

Fig. 5.4.1-A



LITTLE THOMPSON RIVER
9-2-76

FIG. 5.4.1-B

5.4.1.1 Sources of Irrigation Return Flows

As in other basins, irrigation returns are made up of tributary inflow to the river, seepage, direct tailwater returns, and direct tile drain returns. The Little Thompson has less of a flood plain grazing land buffer zone than other rivers in the area. With irrigated fields closer to the river, tailwater and tile drainage is more likely to enter the river directly.

A hydrologic budget was made on the river for August 15, 1972, and September 2, 1976 (Figures 5.4.1-A and 5.4.1-B). All inflows and diversions were accounted for. Tributary inflow was measured or estimated in the sampling program. On both days, the budget indicated approximately 35 cfs of seepage returns. This represents approximately 1.5 cfs/river mile. Most of this seepage takes place on the lower portion of the river.

Major tributaries of the Little Thompson in the irrigated region and typical flows in them are as follows:

Culver Gulch	+ 2 cfs
Dry Creek	+ 2
Big Hollow	+ 2
TOTAL	6 cfs

These flows were established by field measurement. The tributary flows are quite consistent. Major tributaries account for appoximately 6 cfs of return flow to the Little Thompson.

5.4.1.2 Relationship to Other Dischargers

There are only a few dischargers to the Little Thompson. Municipal dischargers exist at Berthoud and Johnstown. Great Western Sugar at Johnstown is the only industrial discharger to the river. The flows contributed by these sources are:

Irrigation Return Flow	26 mgd
Berthoud Sewage Treatment	0.42 mgd
Johnstown Sewage Treatment	0.33 mgd
Great Western Sugar, Johnstown (seasonal)	4 mgd

Thus irrigation return flow is the major discharge to the river. Other discharges are often diverted for irrigation once entering the river.

5.4.1.3 Impact on Stream Hydrology

Irrigation return flows are the sole source of water to lower reaches of the Little Thompson during the summer and fall. Typical native summer flow is around 4 cfs at the mouth of the canyon.

The Little Thompson River has a typical summer flow of 20 or 40 cfs at the mouth. At times, flow in the river may be zero or quite small below a diversion, although the river is not always dried up as is the Poudre. Nevertheless, irrigation returns account for nearly all the flow at the mouth of the Little Thompson. These returns amount to about 40 cfs over the length of the river.

5.4.2 Water Quality Analysis

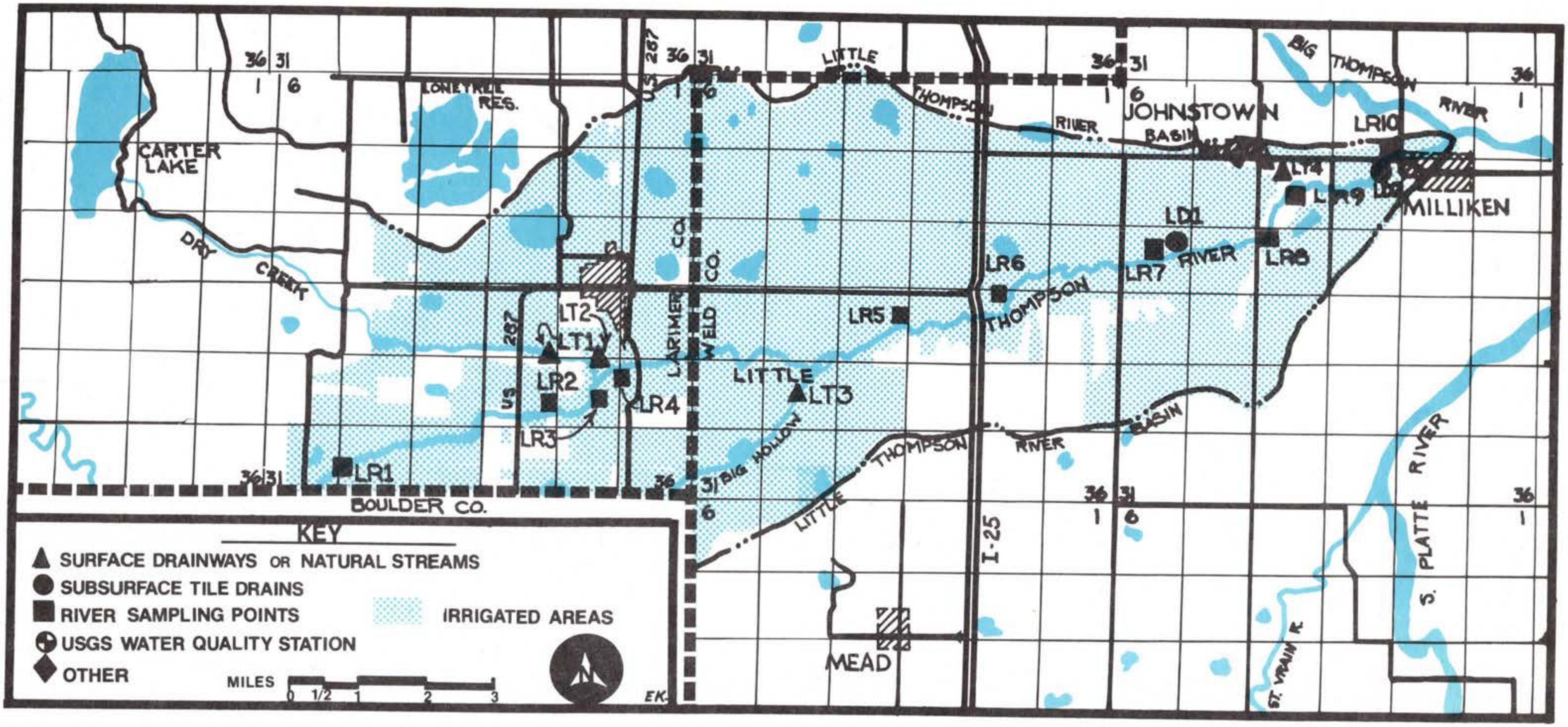
Figure 5.4.2.-A shows sampling points in the Little Thompson basin. The river (suffix R), tributaries (suffix T), and tile drains (suffix D) were sampled.

5.4.2.1 Salinity Levels in the Little Thompson

Seepage returns into the Little Thompson River seriously impair the water quality in terms of total dissolved solids. The water quality is fairly good leaving the mountains. Irrigation in the rolling country overlying shale formations in the west end of the Little Thompson basin seriously impairs water quality. As seen on Figure 5.4.2-B, total dissolved solids levels increase from about 700 mg/l at the Boulder-Larimer county line to nearly 2500 mg/l at Interstate 25. East of Interstate 25, return flows are of much better quality and dilute the river.

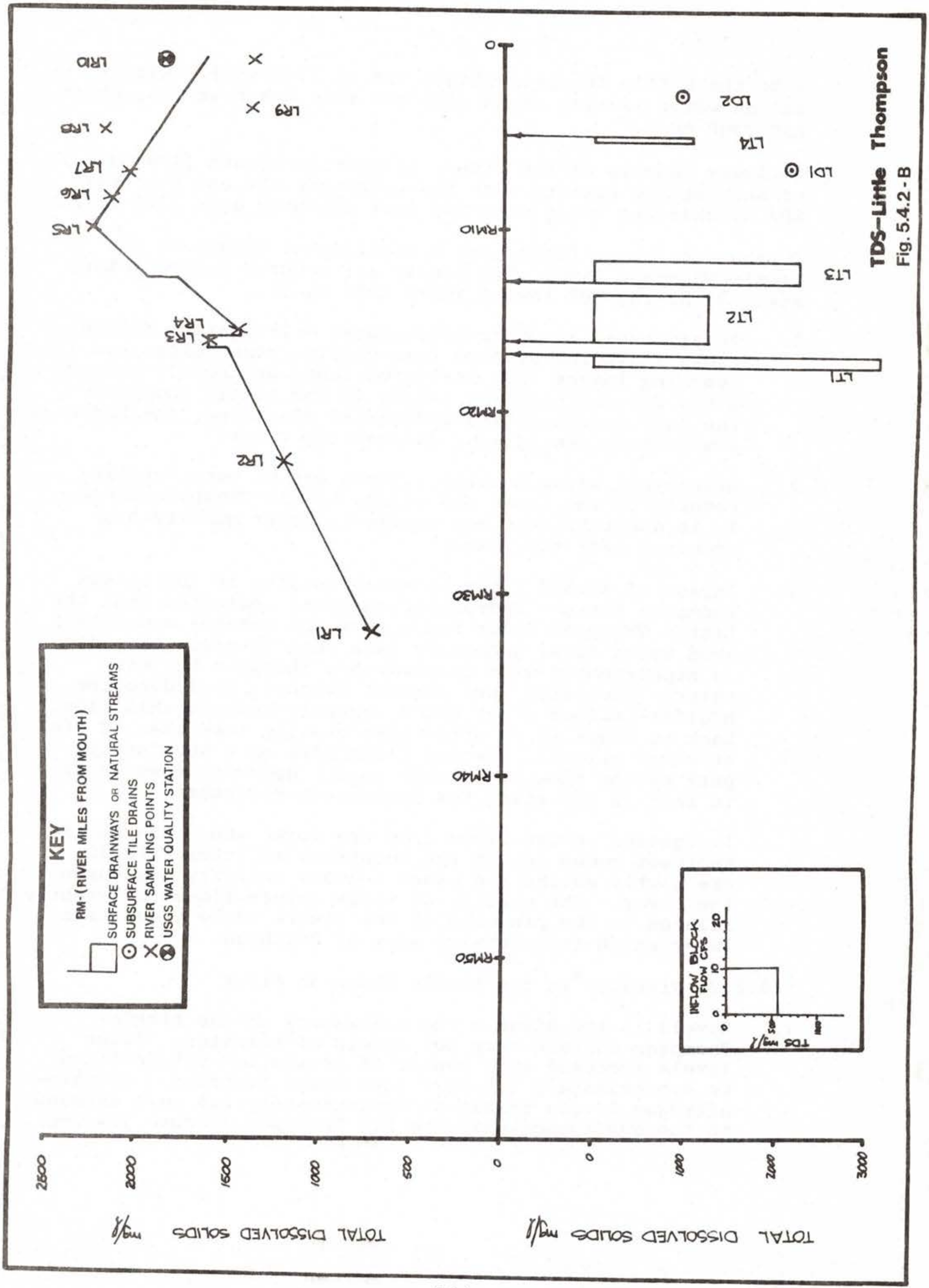
Seepage into the river upstream from river mile 16.5 raises the level from 700 to nearly 1700 mg/l TDS. Dry Creek, the first major tributary to flow into the Little Thompson, has typical TDS values over 3000 mg/l. Dry Creek is fed by seepage from irrigated lands as well as irrigation canals. It is possible that seepage out of Carter Lake and into a shale area is a significant contributor to the flow of highly saline water in Dry Creek.

In Berthoud, discharges from the sewage treatment plant as well as some local runoff discharge a water quality of approximately 1200 mg/l TDS, improving the stream water. Below Berthoud, Big Hollow discharges highly saline water



Sampling Points - Little Thompson

Fig. 5.4.2-A



TDS—Little Thompson

Fig. 5.4.2-B

into the Little Thompson with a TDS of 2700 mg/l. Highly saline water is also shown with the tile drain at LD1, which had 2500 mg/l.

In lower reaches of the river, irrigation return flows are of much better quality with the tributary LT4 and the drain LD2 discharging water with TDS just slightly over 1200 mg/l.

Irrigation return flows have a significant impact on the Little Thompson River with nearly all returns before Interstate 25 having TDS levels above 2500 mg/l.

1. Relationship to Other Dischargers - Irrigation return flows including seepage from canals, reservoirs, and leaching losses from irrigated lands are solely responsible for the high TDS levels in the Little Thompson. The only municipal and industrial discharge, the Berthoud sewage treatment plant, dilutes the river.

2. Historical Water Quality - There are no water quality records on the lower end of the Little Thompson River. It is doubtful that any change in water quality has occurred over the years.

3. Impact of Return Flows on Water Quality in the Little Thompson Basin - Hydrologic analysis indicated that the Little Thompson River had a very low natural summertime head water flow, generally less than 10 cfs. This flow is supplemented with Colorado-Big Thompson Project water. Diversion into several ditches, including the Boulder-Larimer (Ish) Ditch, greatly reduces this flow back to where it is oftentimes usually less than 10 cfs at river mile 23. Return flows make up a substantial part of the flow below this point; however, some water is left in the river for downstream diverters.

   Irrigation return flows from the point where the Little Thompson comes out of the mountains to Interstate 25 are highly saline and place a heavy salinity load upon the river. The quality of these return flows is directly related to the presence of the Pierre shale transition layer which is extensive west of Berthoud.

5.4.2.2 Nitrates in the Little Thompson River

1. Levels in the River - The headwaters of the Little Thompson contain very low levels of nitrates. These levels increase as a result of irrigation return flows to approximately 2.5 mg/l just above Berthoud. Nitrate-nitrogen levels remain at approximately 2.5 mg/l through to the confluence with the Big Thompson (Figure 5.4.2-C).

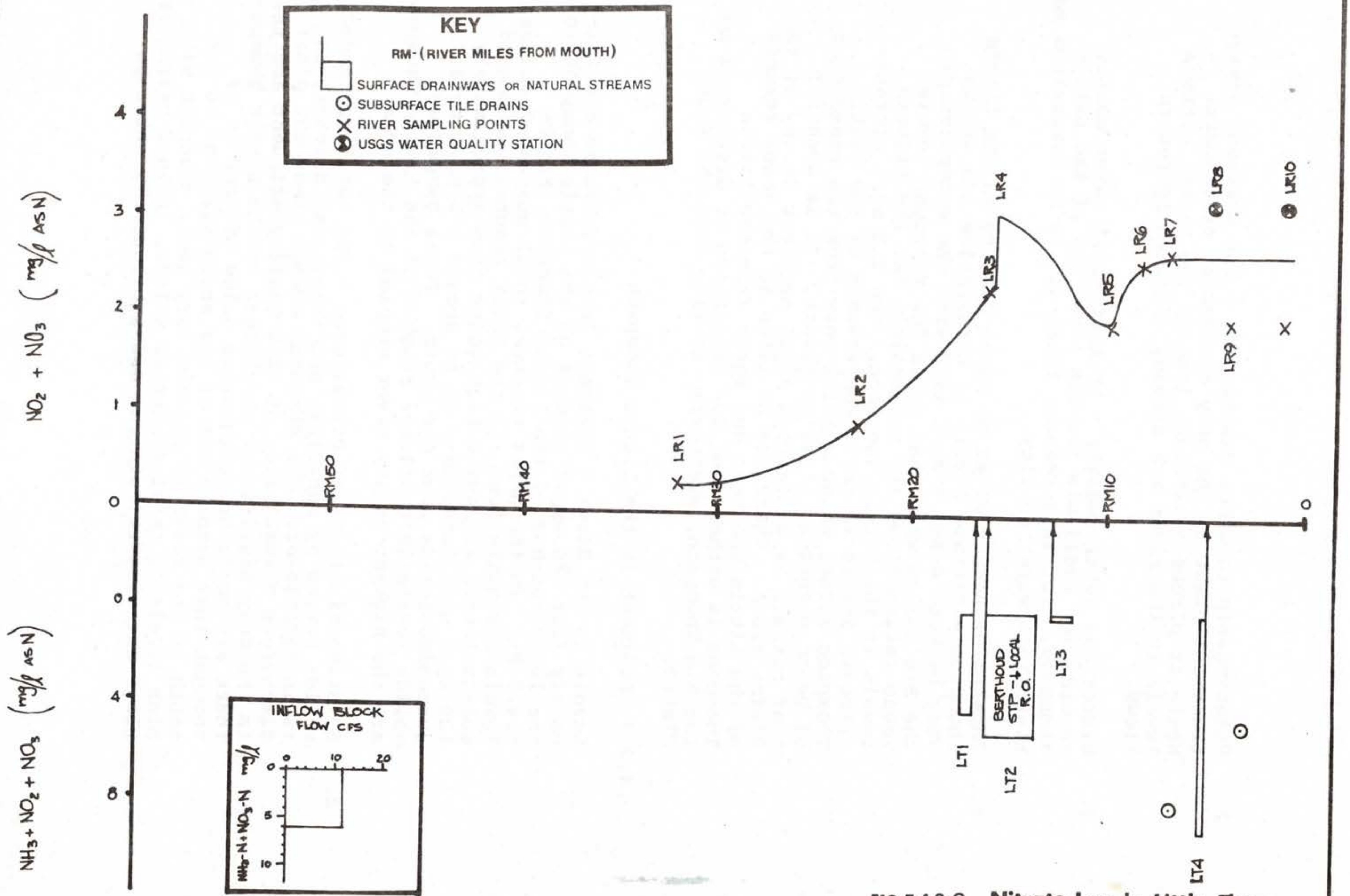


FIG.5.4.2-C **Nitrate Levels - Little Thompson**

2. Relationship to Other Dischargers - The Berthoud sewage treatment plant is the only discharger of concern. While it places a nitrogen load on the river, nitrate levels in the river are already affected by return flows.

3. Historical Water Quality - No historical water quality records are available for the lower end of the Little Thompson. For this reason, there can be no comparison made to historical water quality.

4. Impacts of Return Flows on Water Quality in the Little Thompson - Nitrate levels in tributaries and drains vary between 4 and 8 mg/l as N with the exception of the Big Hollow which had quite low nitrogen levels. These return flows are responsible for the nitrate levels in the Little Thompson. The 2.5 mg/l nitrate-nitrogen levels in the lower reaches of the Little Thompson affect water quality only from the standpoint of being potential algal nutrients. It is doubtful that nitrate is a limiting algal nutrient in any of the Plains areas. There are no lakes in the lower reaches of the Little Thompson and water from the Little Thompson is either used for irrigation or discharged to the Big Thompson, eventually to flow into the South Platte.

5.4.2.3 Sediment in the Little Thompson

1. Levels in the River - Sediment levels increase significantly from the upper reaches of the Little Thompson to the lower reaches of the Little Thompson (Figure 5.4.2-D). In the upper reaches, total suspended solids levels are quite low. In the lower reaches, suspended solids levels are quite high going from approximately 120 mg/l near Interstate 25 to around 175 mg/l total suspended solids near the mouth. Total suspended solids levels in the lower reaches of the Little Thompson are the highest of any river sampled in the area.

2. Relationship to Other Dischargers - The total suspended solids burden by municipal and industrial dischargers is insignificant. The Berthoud sewage treatment plant discharges a small flow of high quality effluent and this is the only significant discharger to the Little Thompson. There are no large tributaries below LT3, and it is thought that seepage out of the steep hillside to the south of the river is causing very small channels with high levels of total suspended solids. Actual tailwater flows entering tributaries and subsequently entering

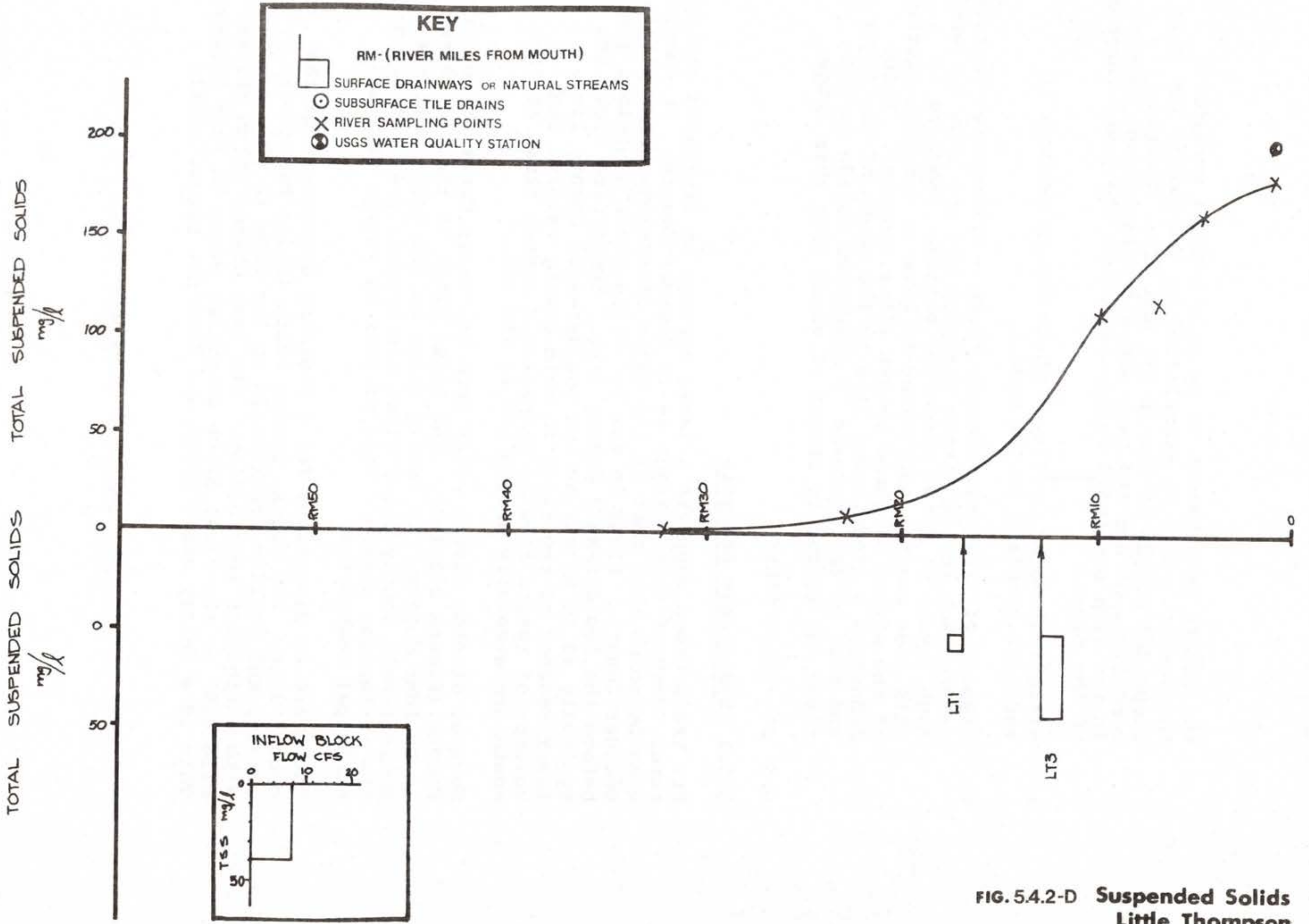


FIG. 5.4.2-D **Suspended Solids Little Thompson**

the rivers are thought to be only a small portion of the burden. This is exemplified by the fairly low flow suspended solids levels in LT1 and LT3. Changing conditions of bed and bank are also significant factors in the high suspended solids levels in the lower reaches of the river.

3. Historical Water Quality - There are no records of sediment sampling in the past.

4. Impacts of Irrigation Return Flows - Tributaries carrying return back to the Little Thompson did not show extremely high levels of total suspended solids. Sampling of this area was not sufficient to give an accurate picture of the effect of these return flows, however. Below Johnstown a steep ledge lies to the south of the river and much of the increase in suspended solids in the river may be due to runoff of water from this ledge.

5.5 ST. VRAIN CREEK

5.5.1 Hydrologic Analysis

St. Vrain Creek supports a large acreage of irrigated agriculture. Much of this acreage is in Boulder County. It should also be noted that most of the major diversions occur within Boulder County. Flows in the St. Vrain reach a minimum just before the Boulder-Weld County line. Summertime flows are typically 40 to 50 cfs at the Boulder-Weld County line. Lower reaches of the river in Weld County receive high volumes of return flow as seepage and summer flows at the mouth are generally around 150 to 180 cfs.

Several ditches divert water from St. Vrain Creek in Boulder County (Figure 5.5.1-A). The Bonus Ditch is the last ditch in Boulder County. It nearly dries up the Creek. At the Boulder-Weld County line, flows are typically 40 cfs during the irrigation season. Most of this is return flow and municipal wastewater.

There are no diversions for a distance downstream of the county line. Dry Creek, Spring Gulch (Union Reservoir outlet) and Boulder Creek build up the flow in this area with irrigation return flow. The Last Chance Ditch (river mile 6.8) is the first ditch diverting water in Weld County. This is a fairly small ditch and does not significantly

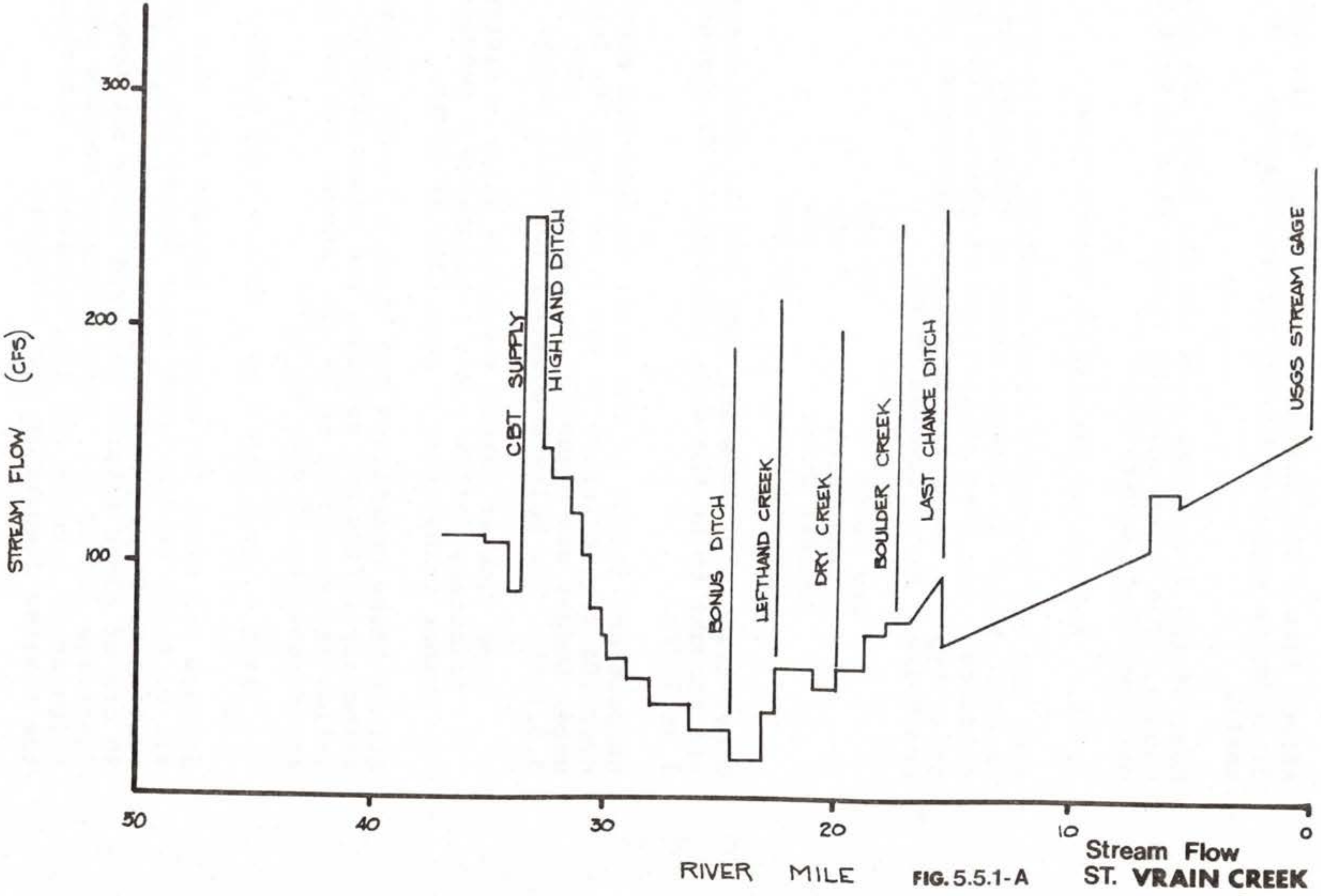


FIG. 5.5.1-A Stream Flow
ST. **VRAIN CREEK**
8-31-76

affect flow. The only other diversion is the Goose Quill Ditch which supplies Public Service Company. It is relatively small.

Most of the diversions from the St. Vrain are made in Boulder County. The creek collects return flow in Weld County, with only two small diversions.

5.5.1.1 Sources of Irrigation Return Flows

Over 100 cfs of return flows enter St. Vrain Creek over its length. While an intense study of tributary inflows was not conducted, the most significant of these tributaries and their typical flows are as follows: [Personal communication, Don Palmer, River Commissioner]

Dry Creek	10 cfs
Spring Gulch	4 cfs
Boulder Creek	5 cfs
Lefthand Creek	20 cfs

Other tributary flows are much smaller than these, and these are thought to be the only tributaries discharging more than 1 or 2 cfs.

Seepage and inflow of the small tributaries accounts for over 100 cfs of inflow to the river over its length. A water budget was conducted for August 31, 1976 (Figure 5.5.1-A). The balance equation for this budget is:

> Gage flow at canyon + Project water - diversions + tributary inflow + M & I discharge + seepage and minor tributaries = gage flow at mouth.

All of these quantities are known with the exception of tributary inflow and seepage, and minor returns. If tributary inflow is assumed to be 39 cfs (above) and M&I discharges are assumed as 15 cfs, we have:

$$87.5 + 160 - 240 + 39 + 15 + S + MT = 158$$

Seepage and minor tributaries account for 96.5 cfs. Nearly all of these return flows occur downstream of Longmont. A routing of these flows (Figure 5.3.1-A) indicated that about 90 cfs of these returns occurred below the Longmont municipal discharge (RM 22.5). This indicates seepage and minor tributaries account for approximately 4 cfs/river mile in the reaches downstream from Longmont.

The U.S. Geological Survey conducted a gain-loss study of St. Vrain Creek on October 22, 1976. This study indicated only very small gains and losses upstream of Longmont. No data was collected in the Weld County area where most of the inflow is suspected [USGS Advance Data].

5.5.1.2 Relationship to Other Dischargers

Irrigation returns by far exceed other discharges in magnitude. Municipal and industrial returns are small in the Larimer-Weld region; however, significant waste discharges are made to the St. Vrain in Boulder County. In Boulder County, the Longmont sewage treatment plant and Great Western Longmont both contribute large flows. In Weld County, dischargers are:

Irrigation Return Flows	135.5 cfs = 88 mgd
Erie S.D.	0.12 mgd
Tri-Area S.D.	.31 mgd
Public Service, Ft. St. Vrain	3.0 mgd

Irrigation return flow is by far the largest return of water to the creek.

5.5.1.3 Impact on Stream Hydrology

Irrigation return flows account for nearly all of the flow at the mouth of St. Vrain Creek. Flows at the Larimer-Weld County line are generally around 40 to 50 cfs in the summer; of this, approximately 20 cfs is discharge from the Longmont sewage treatment plant. Most of the remaining 20 cfs is irrigation return.

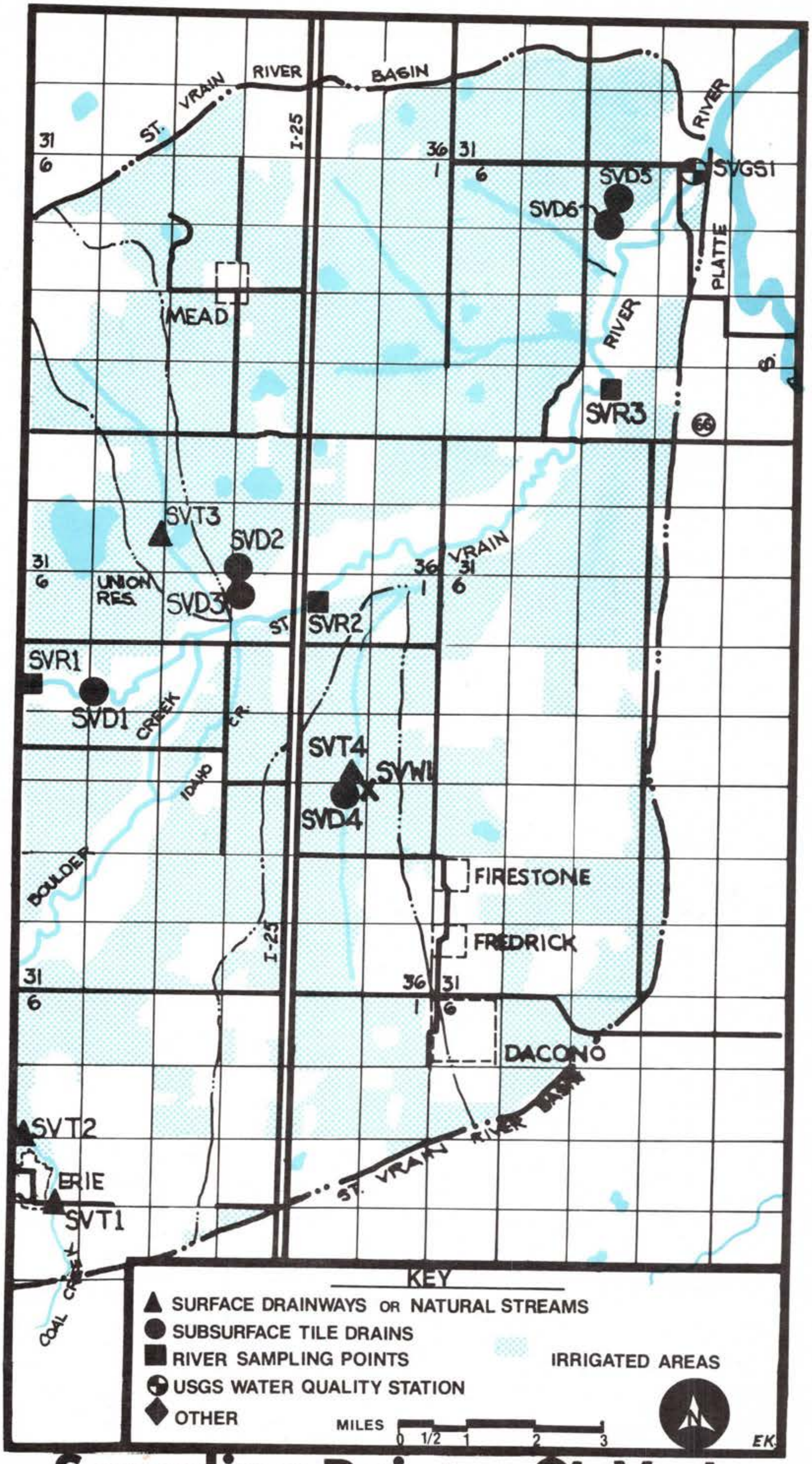
Flows at the mouth of the St. Vrain are typically 150 to 180 cfs in summer. Seepage and tributaries fed by irrigation returns account for nearly all of this flow.

5.5.2 Water Quality Analysis - St. Vrain Creek

Figure 5.5.2-A shows sampling points in the St. Vrain basin. The Creek (suffix R), tributaries (suffix T) and tile drains (suffix D) were sampled.

5.5.2.1 Salinity

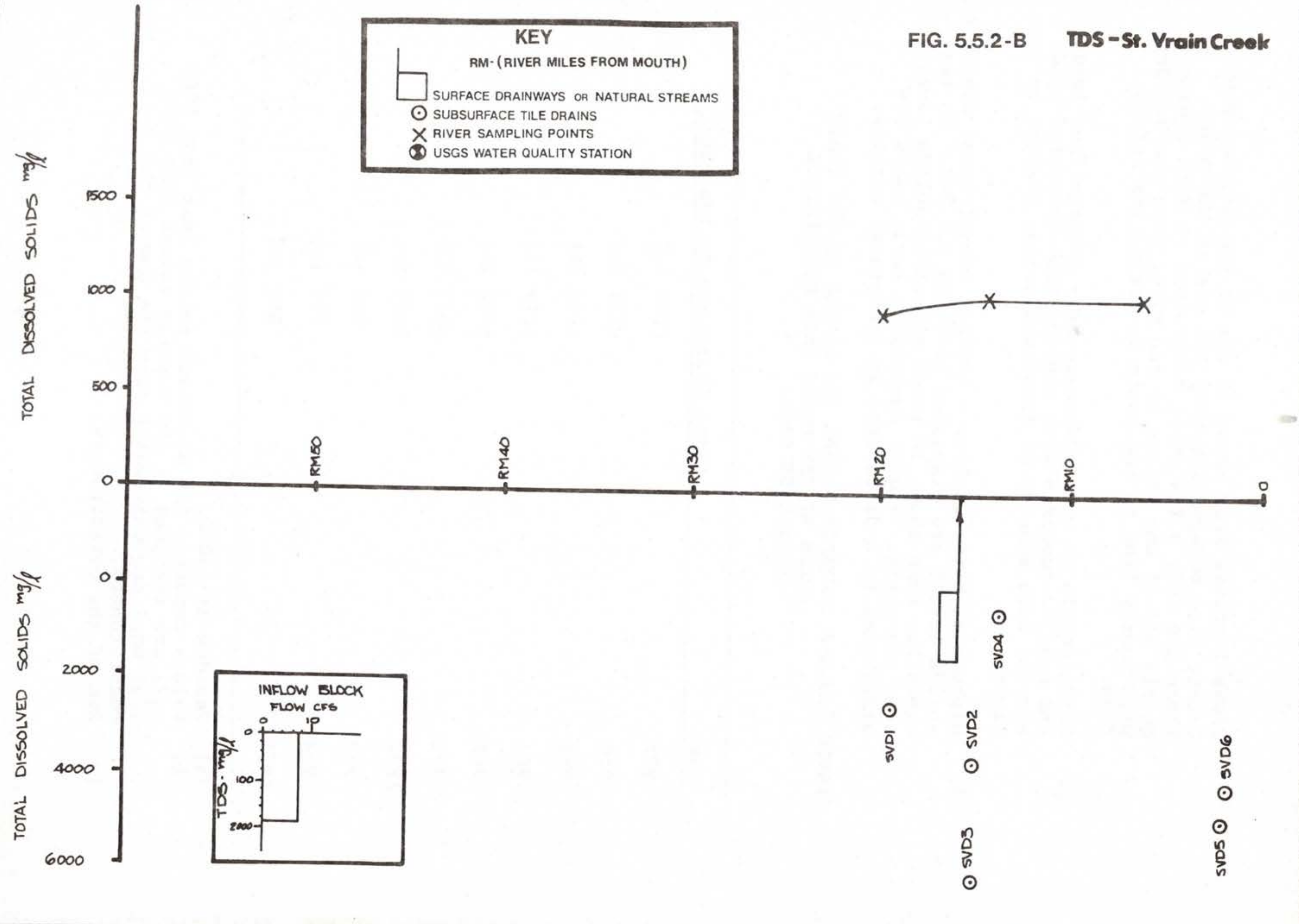
1. Levels in the River - Levels of total dissolved solids in the river increase from approximately 40 mg/l in the mountains to an average of 1058 mg/l at the USGS station at the mouth (Table 5.5.2-A). Most of the increase in salinity comes in Boulder County. TDS levels in the river are already at 950 mg/l as St. Vrain Creek enters Weld County (Figure 5.5.2-B). Levels increase slightly from the county line to the mouth. This level is fairly constant throughout the year.



Sampling Points -St. Vrain

Fig. 5.5.2-A

FIG. 5.5.2-B **TDS - St. Vrain Creek**



Flows increase from about 50 cfs at the Boulder-Weld County line to approximately 180 cfs at the mouth. There are only a few small diversions in Weld County. Nearly all of the inflow to the river from the Boulder-Weld County line to the mouth is irrigation return flow.

2. Relationship to Other Dischargers - Seepage from lakes and canals, combined with seepage from irrigated land are the sole sources of dissolved solids loading to the river.

3. Historical Water Quality - Average annual total dissolved solids levels are displayed in Table 5.5.2-A. No real trend has been shown in total dissolved solids levels over the years. Higher numbers in early years are attributed to a difference in analytical methods.

TABLE 5.5.2-A AVERAGE ANNUAL TDS LEVELS IN ST. VRAIN CREEK AT THE MOUTH NEAR PLATTEVILLE (From USGS Data)

Year	Total Dissolved Solids (mg/l
1955	1283 [a]
1956	1232 [a]
1966	1146 [b]
1967	1179 [b]
1968	1103 [a]
1971	821 [c]
1972	1002 [c]
1973	956 [c]
1974	973 [c]
1975	885 [c]

[a] Residue at 180°C.

[b] Values reported for dissolved solids less than 1000 mg/l are residues at 180°C while values more than 1000 mg/l are calculated from the sum of the constituents.

[c] Sum of the constituents.

4. Impact of Return Flows on Water Quality - While several of the drains sampled in the program exhibited extremely high total dissolved solids levels, the volume of water coming from highly saline soils is apparently not large compared to the total volume of inflow. Drainage in the St. Vrain area is concentrated in areas close to the stream on shale terraces. Very highly saline waters are noted in the drainage from the shale ledge located along the north side of the river. The shale ledge is significant from the Boulder-Weld County line all the way to the confluence with the South Platte.

5.5.2.2 Nitrates

1. Levels in the River - Nitrate levels in the lower reaches of the St. Vrain River vary from 2 to 3 mg/l. Levels in the upper reaches of the river are very low (Figure 5.5.2-C).

2. Relationship to Other Dischargers - Municipal and industrial dischargers in Boulder County place a load on the river. No significant municipal and industrial dischargers are in Weld County.

3. Historical Water Quality - Water quality records indicate that there has been a small increase in nitrates over the years. Average annual nitrate concentrations are displayed in Table 5.5.2-B.

4. Impact of Irrigation Return Flows on Water Quality - Irrigation return flows have a significant impact on water quality; however, most of the changes in water quality occur through Boulder County. Several tile drains have fairly high nitrate levels (Figure 5.5.2-C). The fact that the river does not really rise in nitrate levels from the Boulder County line to the mouth indicates that while there are some tile drains of very high nitrate concentrations, these are largely diluted by other inflows.

5.6 SOUTH PLATTE RIVER

5.6.1 Hydrologic Analysis - South Platte River

Flows in the South Platte River are a result of diversions and return flows during the May through September irrigation season. Several diversions dry up the river at points throughout Weld County. Return flows are the sole source of water in downstream reaches of the stream. Figure 5.6.1-A shows a low flow condition on the South Platte River during the summer irrigation season. Typically, flows experienced

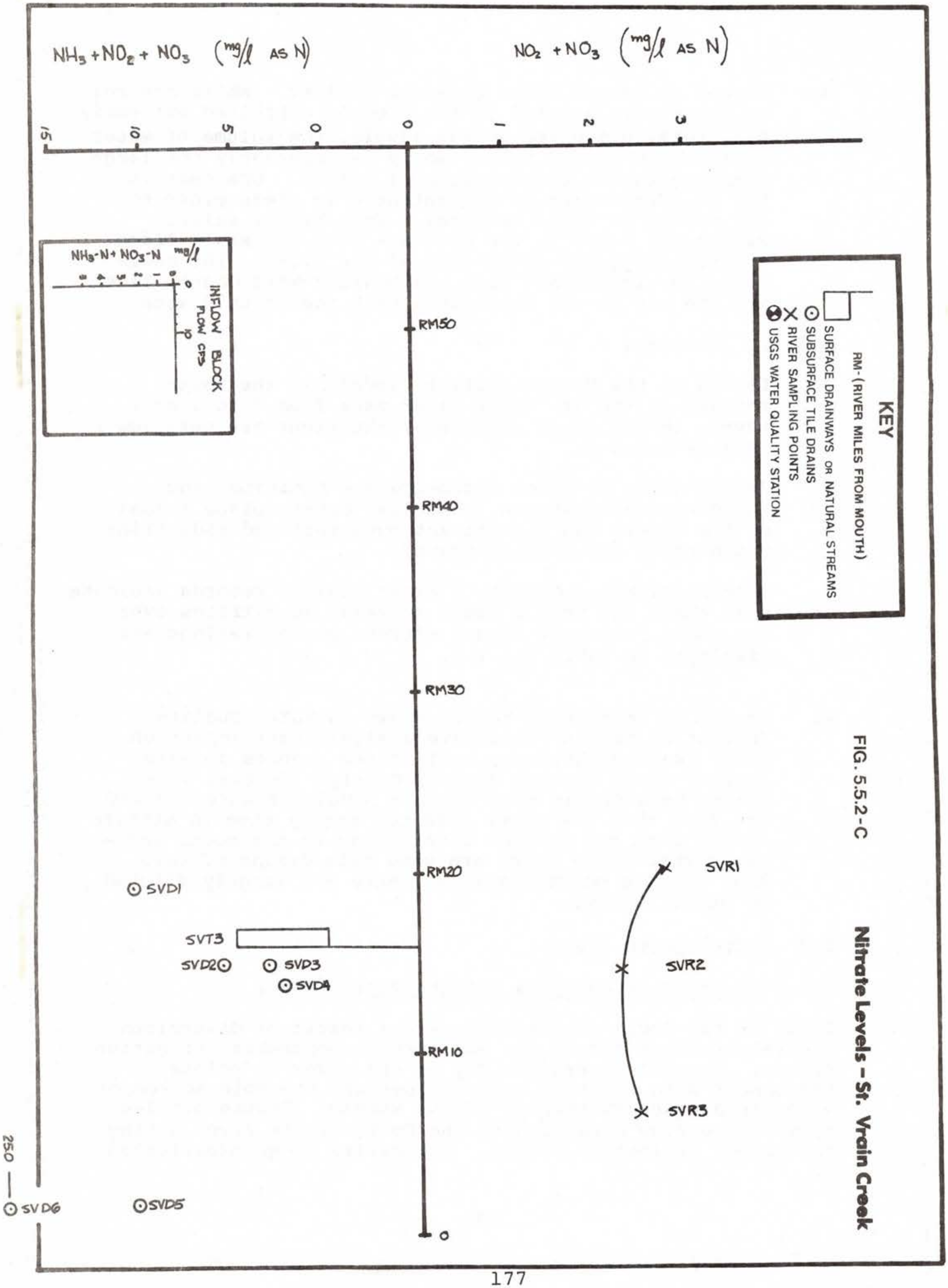


FIG. 5.5.2-C

Nitrate Levels – St. Vrain Creek

in summer would be higher than the low flow condition, as displayed in Figure 5.6.1-A. In the reach between the Weld County line and Fort Lupton, the Lupton Bottom Ditch diverts some South Platte River water. Flows through Fort Lupton are generally considerable, in the range of 60 to over 100 cfs. The Platteville Ditch is a rather large diversion which depletes water from the river but does not dry it up. Downstream at the Platte Valley Supply Canal, water from Sand Creek Reservoir (supplied by the Colorado-Big Thompson Project) is put into the South Platte River. The Evans No. 2 Ditch, located slightly downstream, diverts much of this water. Several small ditches divert water below the Evans No. 2 Ditch and some may even dry up the river at times. A live stream is normally maintained in the South Platte up to Jay Thomas Ditch. Water is managed so that the Jay Thomas Ditch typically dries up the river. Tributary inflow and return flow provide the water necessary to fulfill downstream diversion requirements.

TABLE 5.5.2-B AVERAGE ANNUAL NITRATE CONCENTRATIONS ST. VRAIN CREEK AT MOUTH NEAR PLATTEVILLE, COLORADO (USGS Data)

Year	NO_3-N (mg/l)
1955	1.7 [a]
1956	1.4 [a]
1966	2.0 [a]
1967	1.8 [a]
1968	3.5 [a]
1971	2.4 [b]
1972	2.7 [b]
1973	2.1 [b]
1974	2.9 [b]
1975	2.2 [b]

[a] NO_3-N

[b] NO_2-N + NO_3-N

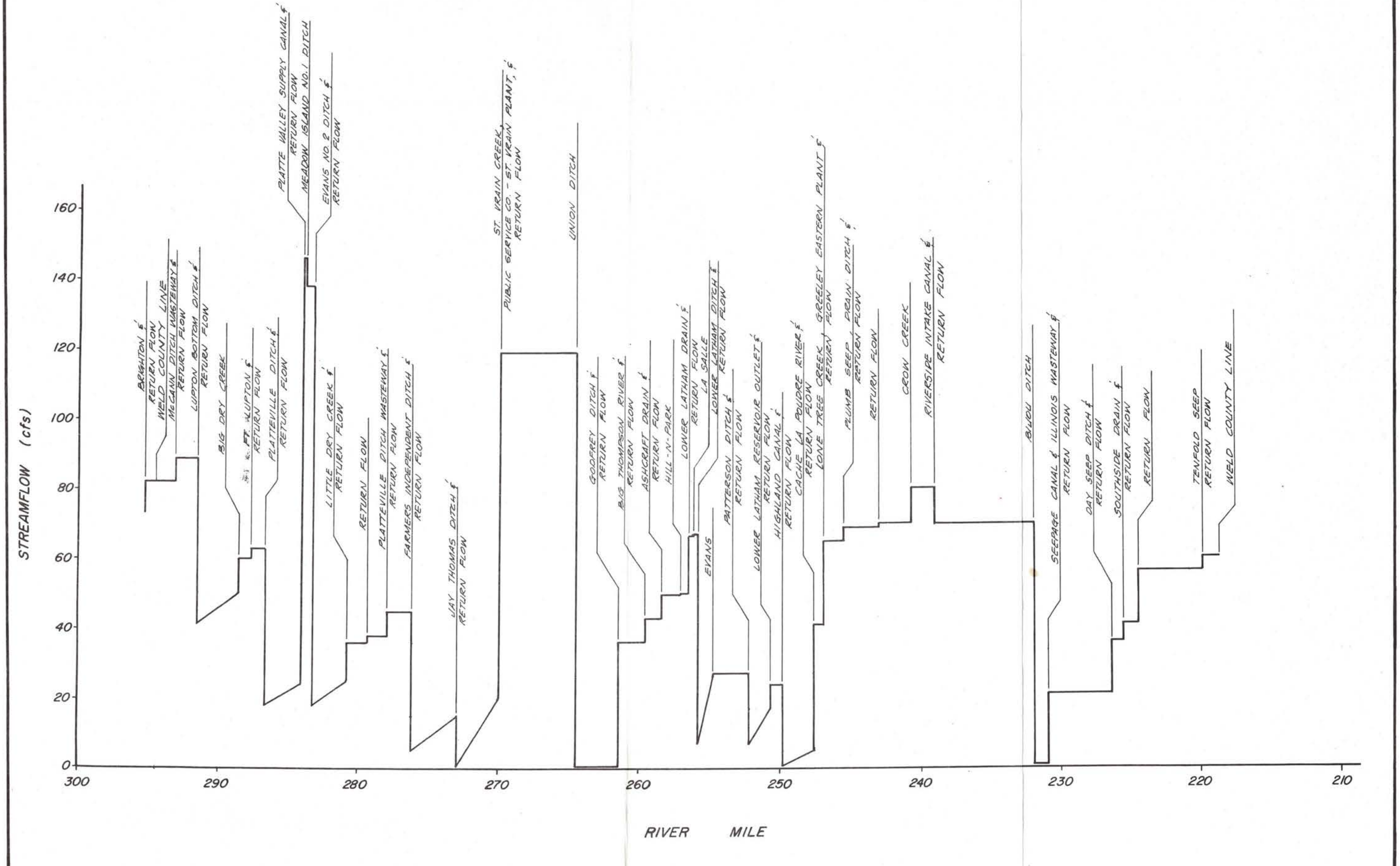


FIG. 5.6.1-A LOW FLOW CONDITIONS - SOUTH PLATTE RIVER

St. Vrain Creek is a significant return flow to the South Platte. The St. Vrain typically discharges from 150 to 180 cfs to the South Platte. This water is almost entirely return flow from irrigation in the St. Vrain basin. Union Ditch is located downstream at approximately river mile 264. The Union Ditch almost always dried up the South Platte during late summer. Inflows below the Union Ditch consist mostly of agricultural return flow and provide water for downstream users. The Godfrey Ditch, Big Thompson River, Ashcroft Draw, and the Lower Latham Drain are significant return flow channels in the region upstream from Greeley.

The Lower Latham Ditch is a significant diversion. Just below this ditch lies the Highland Canal. These two ditches may exhaust the river upstream from the Cache la Poudre. In the Greeley area, inflow from the Cache la Poudre and Lone Tree Creek again build up the flow in the South Platte. Minor return flows below this are from Plumb Seep and Drain as well as Crow Creek and many other minor tributaries. Just below Crow Creek near Kuner are the Empire and Riverside Reservoir intakes. These two intakes divert water from the South Platte for storage and subsequent irrigation use. The Bijou Ditch generally dries up the river below these diversions. Most of the water diverted by the Bijou Ditch is used in Morgan County. Downstream from river mile 232, the Bijou diversion, several seepage canals return water to the river. Among these seepage canals are included the Seepage Canal, Illinois Wasteway, Day Seep (Schultz) Ditch, Southside Drain, Tenfold Seep, and Putnam Seep. Other minor return flows are also contributers to the flow in the South Platte as it leaves Weld County.

5.6.1.1 Sources of Return Flow

Extensive study of seepage and returns tributary to the main stem South Platte has been performed by USGS and local water commissioners. Results of several detailed seepage runs are summarized in USGS Colorado Water Resources Circular 28 "Hydrology of the South Platte River Valley, Northeastern Colorado." For purposes of presentation, data in the report were averaged in terms of seepage and surface inflow per mile for various reaches of the South Platte. Primary backup data for this report as well as other seepage runs is contained in the files of USGS and District Water Commissioners.

Flow in the South Platte River below Platteville is primarily irrigation return flow during the May through September irrigation period. The water table recharges the river to a large extent. Development of wells over the years has somewhat lessened the amount of ground water seepage back into the South Platte, especially in upstream areas of tributary basins.

The irrigation return flow to the South Platte can be classified into two basic sources--tributary inflow and direct seepage from ground water. Tailwater discharges directly to the river are minimal since most of the river bottom land is flood plain which is not irrigated. Tile drainage discharges are considered to be a part of the seepage inflow for this analysis since identification of all tile drains as point sources is essentially impossible.

A hydrologic budget was conducted for the South Platte for an extreme low flow condition. In this budget, inflows from major streams were obtained from gaging stations records, while minor stream flows were estimated from information received from the District Water Commissioners. Seepage inflows were used to balance the budget at points of known flow. Stream inflows were as follows:

	(cfs)
Big Dry Creek	10
Little Dry Creek	8
St. Vrain Creek	66
Big Thompson River	30
Ashcroft Draw	2
Lower Latham Drain	16
Cache la Poudre	35
Lone Tree Creek	20
Plumb Seep	3
Crow Creek	10
Seepage Canal & Illinois Wasteway	11
Day Seep Ditch	10
Southside Drain	2
Tenfold Seep	1
Total Flow	224 cfs

Inflow from some of these streams is fairly consistent during average and low flow conditions. Low flow in St. Vrain Creek would be considered to be considerably less than flow normally experienced during the irrigation season. This creek often contributes flows of 150 to 180 cfs to the South Platte. The Cache la Poudre and Big Thompson also generate a somewhat larger flow during normal conditions. Flows for the minor tributaries are considered to be fairly typical.

In the portion of the South Platte River in Weld County it was necessary to add in 196 cfs of seepage inflows in order to make the flows in the river balance at the points of known flow. This represents approximately 2.5 cfs per river mile.

The major streams entering the South Platte (St. Vrain, Big Thompson, and Cache la Poudre Rivers) are fed by storage releases and irrigation return flows from lands irrigated with water which has come down from the mountains in these basins. The minor streams are fed by irrigation return flows from lands irrigated with water diverted from major streams fed by mountain runoff.

5.6.1.2 Relationship to Other Dischargers

Other dischargers to the South Platte in the two-county area are relatively negligible. The towns of Fort Lupton, LaSalle, and Evans contribute municipal waste discharge; however, this is quite small in relation to the total flow of the South Platte. Industrial discharges are small in the Larimer-Weld Region also.

5.6.1.3 Impact on Stream Hydrology

Irrigation return flows generally make up all of the flow in the South Platte River downstream from Evans No. 2 during the irrigation season. These return flows are present into the fall as ground water continues to seep into the river. The South Platte is dried up in several places during the summer irrigation season. These places are typically below the Jay Thomas Ditch, below the Union Ditch, and below the Highline Canal and the Bijou Ditch. Irrigation returns and tributary inflows make up all of the flow below these ditches and fulfill requirements for downstream diversion.

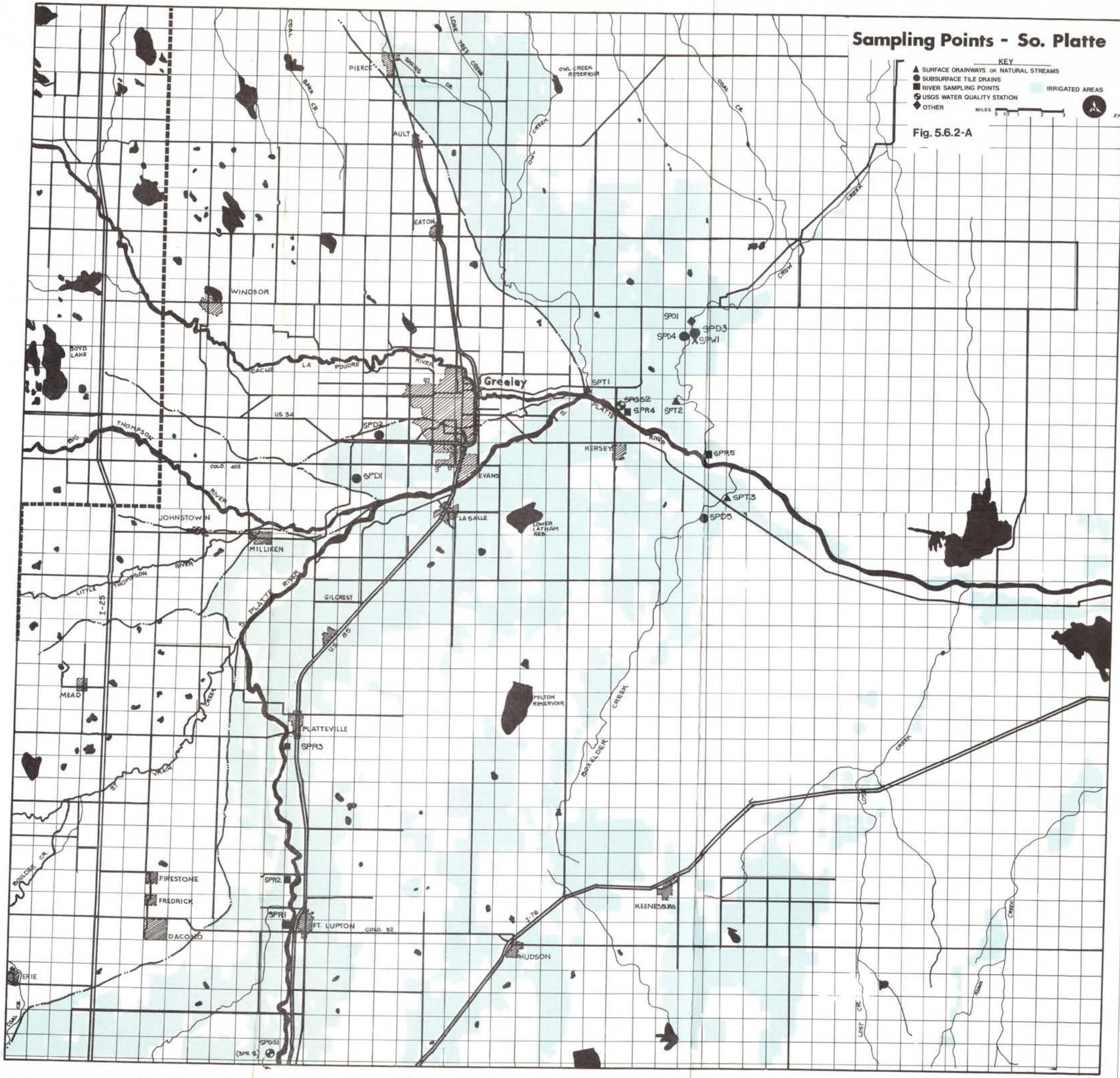
5.6.2 Water Quality Analysis - South Platte River

Figure 5.6.2-A shows sampling points in the South Platte basin. The river (suffix R), tributaries (suffix T), and tile drains (suffix D) were sampled.

5.6.2.1 Salinity

1. Levels in the River - The South Platte River shows an increase in salinity through the Larimer-Weld region. This is seen on Figures 5.6.2-B and 5.6.2-C. Figure 5.6.2-C shows average high, average low, and annual average levels of total dissolved solids as indicated by the Colorado West Wide Study Team (Toups, ECI, 1974). The annual average of total dissolved solids levels increased from 500 to 950 mg/l in the stretch from Henderson to Kersey. The average high total dissolved solids level increases from 900 at Henderson to 1350 at Kersey.

   In the sampling program conducted for the Larimer-Weld Regional Council of Governments, total dissolved solids



Sampling Points - So. Platte

Fig. 5.6.2-A

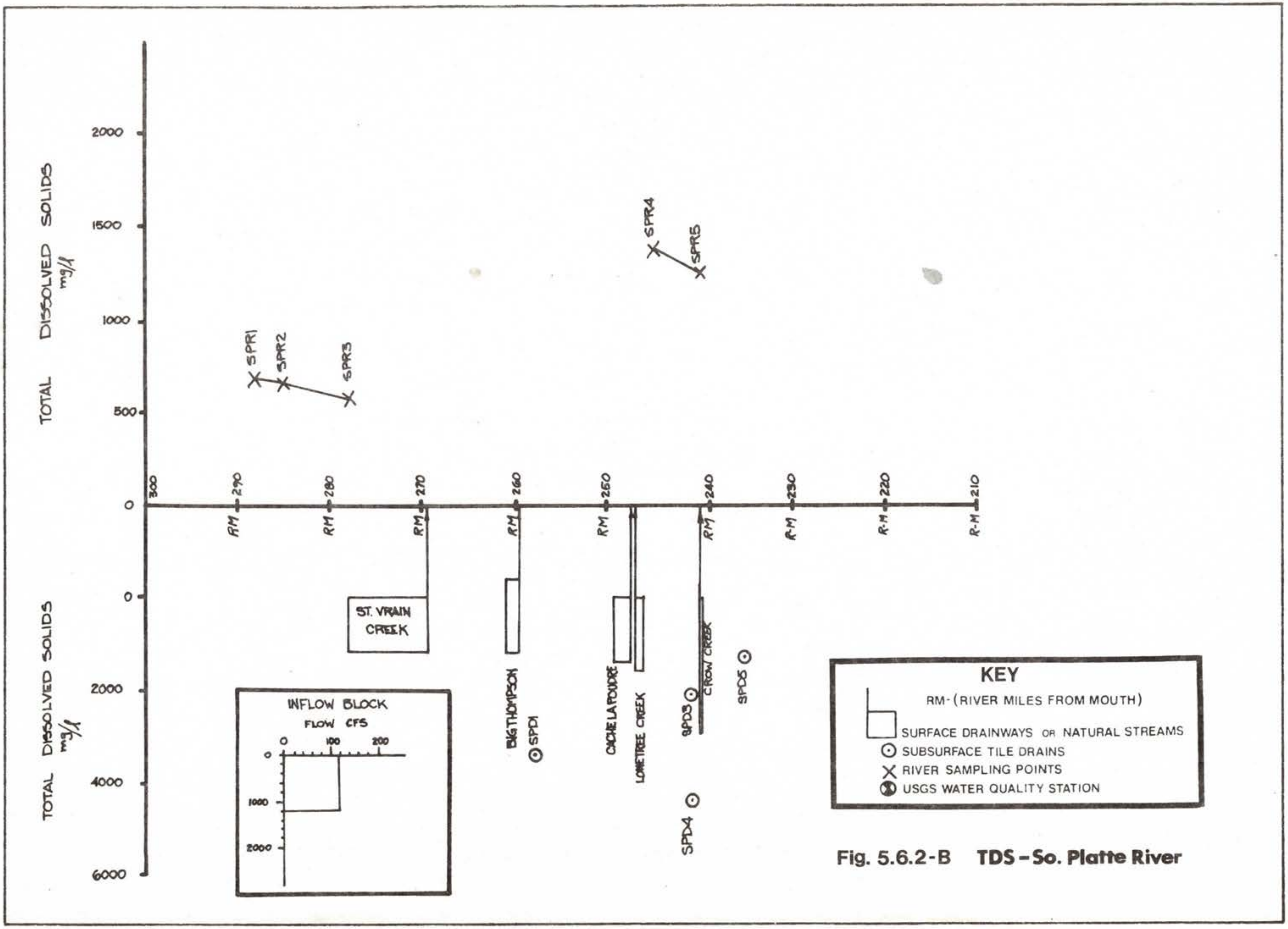


Fig. 5.6.2-B **TDS – So. Platte River**

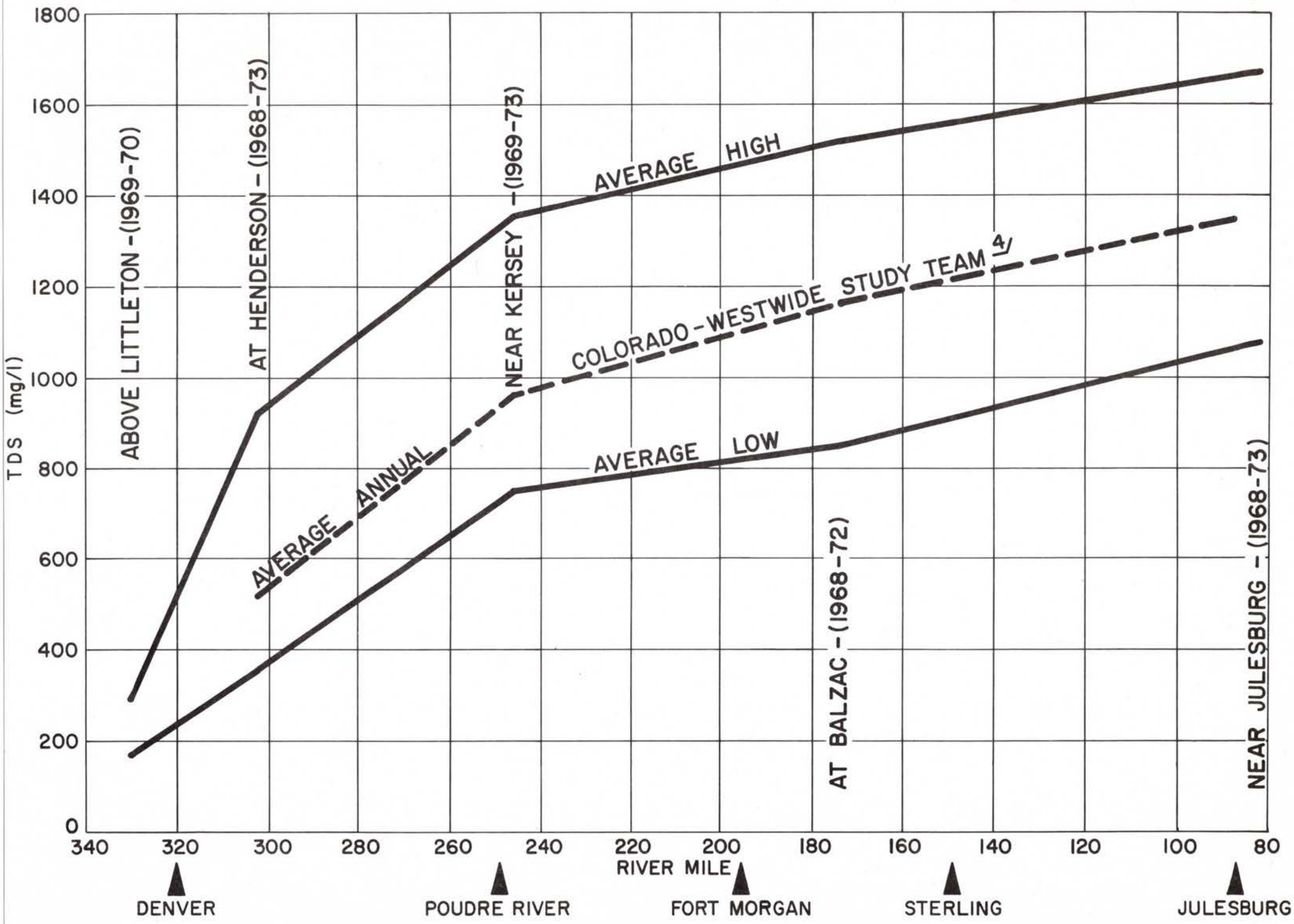


Fig. 5.6.2-C **TOTAL DISSOLVED SOLIDS (TDS) PROFILE - SOUTH PLATTE RIVER**

levels were found to decrease from Ft. Lupton to Platteville in samples SPR1, SPR2, and SPR3. The average of these three samples was 627 mg/l. Downstream samples, SPR4, and SPR5, average 1305 mg/l. This data shows that total dissolved solids levels increase significantly in the South Platte through the Larimer-Weld region.

2. Relationship to Other Dischargers - The municipal discharges of small towns along the South Platte do not affect the salt load.

3. Historical Water Quality Trends - Figure 5.6.2-B shows historical average annual TDS levels of the South Platte at several locations. No real trend is shown in these figures, although there may be a slight raise.

4. Impact of Irrigation Return Flows on Water Quality -The South Platte is highly influenced by irrigation return flows coming into the river through the Larimer-Weld region. All of the major rivers and streams flowing into the South Platte raise the total dissolved solids level. Additional flows of saline water, some of which are much more saline than these tributaries occur through seepage. The St. Vrain Creek discharges a large flow of water, typically about 1200 mg/l TDS. Below the St. Vrain Creek at river mile 265, however, most of the flow in the river is dried up or diverted by the Union Ditch. This ditch dries up the river much of the time and flow below this point is all return flow.

   Return flow comes into the river in the Big Thompson which discharges water of about 1200 mg/l TDS; the Cache la Poudre discharges approximately 1600 mg/l TDS water, Lone Tree Creek discharges 1700 mg/l TDS water, Crow Creek discharges a very small flow of high TDS water. Seepage into the river through this area represents a significant contribution to the flow as well and the quality of these seepage flows is highly dependent on the quality of water diverted. Most fall between 1000 and 4000 mg/l TDS.

   TDS levels in the South Platte are increased significantly throughout the Larimer-Weld region. Lower reaches of the river are composed of flow coming in from the Cache la Poudre and the Big Thompson as well as some smaller streams and a good deal of seepage. These flows determine the quality of the lower reaches of the Cache la Poudre.

5.6.2.2 Nitrates

1. Levels in the River - The sampling program found nitrate levels in the river to be fairly consistent throughout the region and no increase in levels was seen from the Ft. Lupton area to beyond Greeley (Figure 5.6.2-D). The level of nitrates remains about 3 mg/l as N throughout the Larimer-Weld region, despite the fact that some return flows have quite high nitrate levels.

2. Relationship to Other Dischargers - Most of the municipal discharges in Weld County are small and do not significantly effect the South Platte.

3. Historical Water Quality - Average summer nitrate levels are shown over the years in Figure 4.2.2-D. No real trend is noted, although there were a few high years, notably 1968.

4. Impacts of Return Flow on Water Quality - Irrigation return flow makes up all flow in the South Platte during the summer. Nitrate levels in the river do not rise in Weld County.

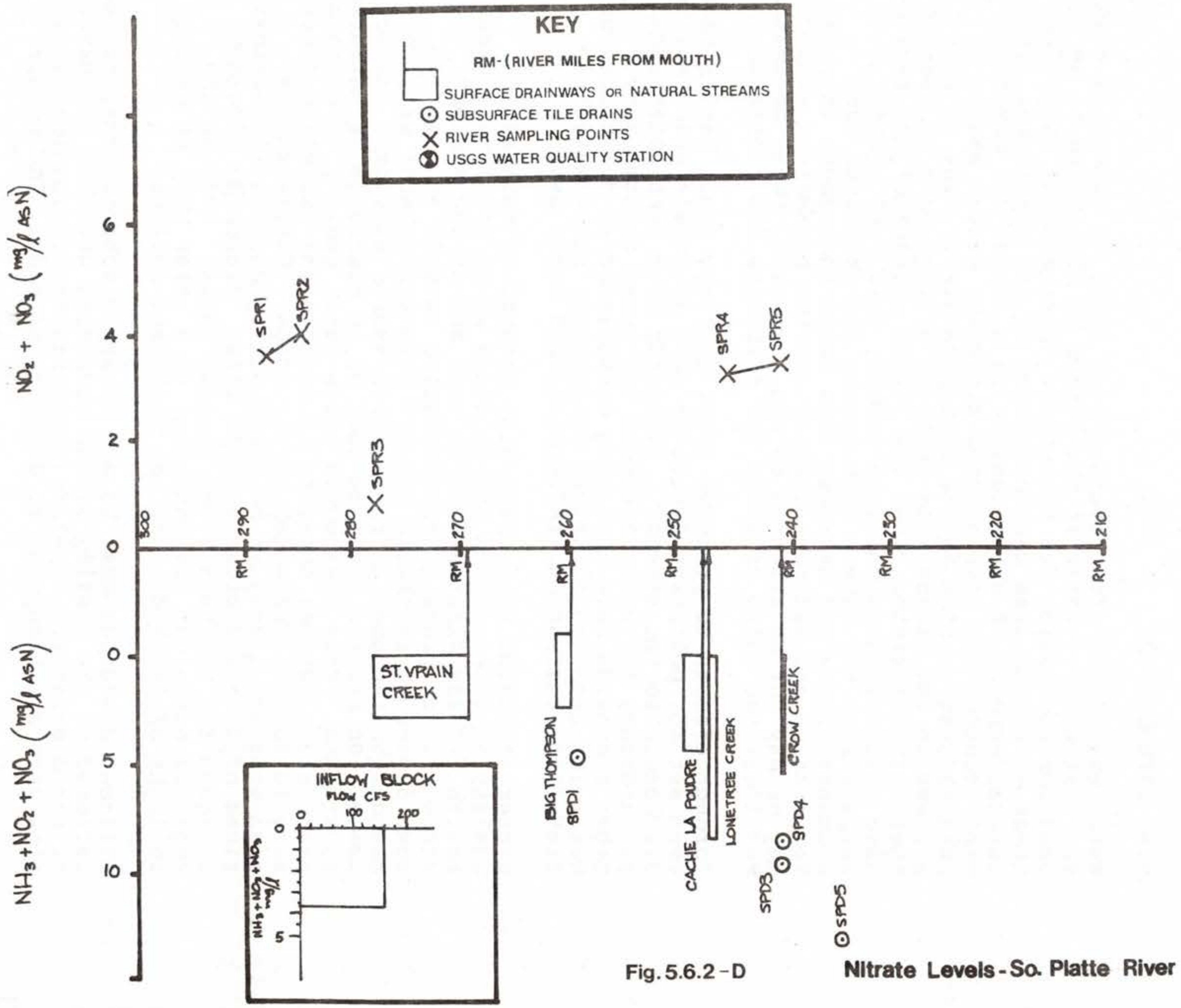


Fig. 5.6.2 - D Nitrate Levels - So. Platte River

CHAPTER 6.0

WATER QUALITY STANDARDS AND IRRIGATION RETURN FLOW

6.1 INTRODUCTION

Water quality is often evaluated in terms of potential uses for that water. Water in the stream is considered to be used for recreation and fisheries. The value of water for these in-stream uses can be defined by its qualities. Yet several aspects of water quality in a stream are beyond man's control and have existed since the stream was in a natural state. Flow is one such parameter. Many of the streams in the plains area would be dry for much of year in their natural state. Even the larger streams of the region have small flows in the late summer, fall, and winter. Seepage into the rivers from canals and irrigated land augments rivers and balances flow rates throughout the year. Temperature and sediment loading are two parameters which may or may not be affected by man. However, these parameters may limit the value of water for fisheries and recreation.

Through efforts to preserve water quality, legal limits have been set for pollutant levels as well as levels which may be discharged to the streams. Standards have been established as mandatory for water intended for human consumption. Other standards have also been established as desirable for water for human consumption, irrigation, stock watering, fisheries, recreation, industrial, and other uses.

Stream standards were originally created to maintain a quality of water in the stream which would not impair human health. These first standards were set as the minimum acceptable to pressure public health as well as maintain some degree of aesthetic value. Future standards will be based upon the goal of fishable, swimable streams. Public Law 92-500 has the ultimate goal of no discharge of pollutants to streams. This goal would allow water quality to be in a near natural state; however, it ignores the depletion necessary to fulfill our water supply needs. Future stream standards are likely to be goals set by biological considerations of fish and other aquatic life. Standards should be designed for regional water quality goals. Only in the regional basis can the potential of a water body be defined in light of its hydrology and pollutant sources.

Effluent standards must be met by any discharge; they may be tailored to the quality of the receiving water or the nature of the discharger. Quality standards for irrigation return flow have not been made to date in Colorado. The permit program would appear to provide the legal basis for the setting of return flow standards.

Water quality for beneficial use refers to the quality in relation to its potential use. Such potential uses might be domestic, irrigation, stock watering, fisheries, and recreation. Efforts should be directed toward improving the quality of water for beneficial uses under this concept.

6.2 STREAM STANDARDS

Water Quality Standards for Colorado [Colorado Department of Health, Water Quality Control Commission, 1974] sets limits for several parameters according to various stream classifications. These water quality standards are summarized in Table 6.2-A. Classification for plains area streams in the Larimer-Weld region is given in Table 6.2-B. Mountain segments of the Cache la Poudre, Big and Little Thompson, and St. Vrain Rivers have higher classifications which have not been displayed since they are unaffected by irrigation return flows.

Water quality standards were established to meet the goal of fishable and swimmable waters. These standards were made with municipal and industrial dischargers as the pollutors of major concern. Because the standards are not readily applicable to streams fed by irrigation return flow, some comment on the various parameters is in order.

Settleable Solids: Stream standards specify that all state waters shall be "free from substances attributable to municipal, industrial, or other discharges or agricultural practices, which will settle to form objectionable sludge deposits."

This qualification could be interpreted two ways: 1) settleable solids shall be zero (no sediment should be carried by the stream), or 2) only volatile settleable solids need be zero. Volatile settleable solids are mostly organic solids which would be associated with municipal and industrial wastes, and possibly with feedlot runoff. Whatever the case, this requirement does not specify clearly what settleable solids are, or how they are to be measured.

Floating Solids: Floating plant materials may be carried by irrigation return flows.

Taste, Color, Odor: Color and odor are associated with irrigation return flows; taste is altered by dissolved solids. Color may be affected by sediment pickup.

TABLE 6.2-A. WATER QUALITY STANDARDS SUMMARY

Standard	Class			
	A_1	A_2	B_1	B_2
Settleable Solids	Free From	Free From	Free From	Free From
Floating Solids	Free From	Free From	Free From	Free From
Taste, Odor, Color	Free From	Free From	Free From	Free From
Toxic Materials	Free From	Free From	Free From	Free From
Oil and Grease	Cause a film or other discoloration	Cause a film or other discoloration	Cause a film or other discoloration	Cause a film or other discoloration
Radioactive Material	Drinking Water Standards	Drinking Water Standards	Drinking Water Standards	Drinking Water Standards
Fecal Coliform Bacteria	Geometric Mean of <200/100ml from five samples in 30-day per.	Geometric Mean of <200/100ml from five samples in 30-day per.	Geometric Mean of <1000/100ml from five samples in 30-day per.	Geometric Mean of <1000/100ml from five samples in 30-day per.
Turbidity	No increase of more than 10 J.T.U.	No increase of more than 10 J.T.U.	No increase of more than 10 J.T.U.	No increase of more than 10 J.T.U.
Dissolved Oxygen	6 mg/1 minimum	5 mg/1 minimum	6 mg/1 minimum	5 mg/1 minimum
pH	6.5 - 8.5	6.5 - 8.5	6.0 - 9.0	6.0 - 9.0
Temperature	Maximum 68°F Maximum Change 2°F	Maximum 90°F Maximum Change: Streams - 5°F Lakes - 3°F.	Maximum 68°F Maximum Change 2°F	Maximum 90°F(32°C) Maximum Change: Streams - 5°F. Lakes - 3°F.
Fecal Streptococcus	Monthly average of <21/100ml from five samples in 30-day per.	Monthly average of <20/100ml from five samples in 30-day per.	---	---

TABLE 6.2-B. SOUTH PLATTE RIVER BASIN - CLASSIFICATION (CDH, WQCC 1974)

Area No.	Area	From	To	Quality Class
2	Main Stem of South Platte	Exposition Avenue Denver	Colorado-Nebraska State Line	B_2
14	Main Stem of Boulder Creek	Intersection with State Highway #119 at mouth of Boulder Canyon	Mouth	B_2
20	Main Stem of Big Thompson	Town of Loveland's water treatment plant	Confluence with South Platte River	B_2
22	Little Thompson River	Point of diversion for Culver Ditch	Confluence with Big Thompson	B_2
23	Buckhorn Creek	Source	Mouth	B_1
26	Main Stem of Cache la Poudre	Point of diversion for City of Greeley water treatment plant	Confluence with South Platte	B_2

Toxic Materials: Pesticides may be toxic at unusually high concentrations.

Oil and Grease: Not associated with irrigation return flows.

Radioactive Materials: Not associated with irrigation return flows.

Fecal Coliform Bacteria: The sampling program has indicated that these bacteria which are indicative of fecal contamination by warm-blooded animals are insignificant in irrigation return flow. Bacteria transfer through the soil is insignificant. Incorporation of manure in the soil minimizes runoff potential.

Turbidity: Turbidity is a measure of the clarity of water. The presence of clay particles, algae, and suspended solids increases turbidity. Tailwater entering a stream can increase turbidity. Turbidity also changes as a result of changing stream bed conditions, and as a result of discharge of algae, as from a lagoon and several other reasons. Turbidity increases due to "natural" sources are exempted from the regulations.

Dissolved Oxygen (DO): Irrigation return flows exhibit almost no Biochemical Oxygen Demand (BOD). DO of ground water returns may be low, but loading is smaller than reaerated rate pH. Alkaline soils in the area tend to raise pH; however, this increase is generally not enough to be of concern.

Temperature: Irrigation return flows have a higher temperature than water which has never been removed from the river. Where a surface return tributary enters a river of almost no flows, the return could possibly cause more than 2°F. (1°C) temperature rise.

Total Dissolved Solids: The Commission did not adopt salinity standards, but indicated that study was necessary.

6.2.1 Streams in the Larimer-Weld Region and Stream Standards

Streams in the Larimer-Weld region currently meet most of the standards. The major streams in the plains area are all classified B-2. Table 6.2.1-A displays B-2 standards as well as the range of values found in the various streams.

TABLE 6.2.1-A POLLUTANT LEVELS AND STREAM STANDARDS

	B_2 Stream Standards	South Platte (Weld Co.)	Big Thompson below Water Treatment Plant	Little Thompson below Culver Ditch	Poudre below Greeley WTP (Bellevue)
Stream Classification		B_2	B_2	B_2	B_2
Settleable Solids	Free from				
Floating Solids	Free from				
Taste, Odor, Color	Free from				
Toxic Materials	Free from				
Oil and Grease	Cause a film or other discoloration				
Radioactive Material	Drinking Water Standards				
Fecal Coliform Bacteria	Geometric Mean of 1000/100 m/l from 5 samples in 30-day period	100-410 (range of grab samples)	34-520 (range of grab samples)	520-1200	100-5500
Turbidity	No increase of more than 10 J.T.U.				
Dissolved Oxygen	5 mg/l minimum	6.2-7.3	6.6-8.1	7.4-8.8	6.3-8.2
pH	6.0 - 9.0	7.0-7.4	6.5-7.6	6.9-8.1	7.0-8.3
Temperature	Maximum 90°F. (32°C) Streams - 5°F. Lakes - 3°F.	17.5-20 °C	14-22 °C	16.5-17 °C	16.5-22 °C
Fecal streptococcus	-------				

6.3 EFFLUENT LIMITATIONS AND IRRIGATION RETURN FLOW

Current effluent limitations do not apply to irrigation return flow. (Colorado Department of Health, Water Quality Control Commission, 1975.) Irrigation return flow is considered a non-point source under current federal law. As such, it is required to meet best management practices in the future.

6.4 WATER QUALITY IMPACTS AND BENEFICIAL USES

The quality of surface waters in the Larimer-Weld Region has been dealt with in previous sections of this report. This section will discuss the quality required for various beneficial uses.

6.4.1 Irrigation

6.4.1.1 Water Quality Requirements for Irrigation

Dissolved solids are the pollutants of major concern in irrigation waters. The various cations and anions increase osmotic pressure. In the soil solution, water may contain five to ten times the salinity of irrigation water. High osmotic pressure of the soil solution can result in reduced yields or the requirement to grow tolerant crops.

In addition to the overall impairment of osmotic processes caused by saline water, specific elements are of more concern than others. Sodium may harm soil structure and pH, in addition to being hard to leach. Chlorides are more toxic than sulfates. Bicarbonates increase the potential of a sodium hazard, Boron is a toxic element to plants, but there is a wide tolerance range among plants.

6.4.1.2 Water Quality for Irrigation in the Larimer-Weld Region

A wide range of water quality is observed in the irrigation waters of the Larimer-Weld region. Salinity tends to increase downstream. Sodium is not a problem, as sodium adsorption ratios may increase to 2.8, still a fairly low figure. Because of the low sodium content, biocarbonate is not an anion of concern. Boron is not an element of concern in the region either.

The quality of waters for irrigation in the Larimer-Weld region is limited only by total salinity. Generally, those who get their water from a ditch delivering virgin river water have excellent water. Those on the eastern fringe who receive water which has been leached through the ground several times have a much lower quality water.

Figure 6.4.1-A shows a diagram for the classification of irrigation waters. River water in the region, below the point where most of the water is return flow, is generally of class C3-S1. This high salinity-low sodium water may be used on salt tolerant plants with good drainage. Virgin river water in all of the basins is of very low TDS levels. Contact with saline formations as well as use for irrigation increases TDS levels until they are of lowered quality for irrigation purposes downstream.

6.4.2 Stock Watering

Of the pollutants studied in this program, livestock would appear to be sensitive to salinity and nitrates. Sediment and phosphorus are not a significant detriment in quantities normally found.

Salinity impairs osmotic functions in animals as well as in plants. Various levels of tolerance and suitability have been established, but these levels cover such a wide range as to be nearly meaningless. Water quality effects weight gain in fattening animals, and it is generally felt that over a certain limit weight gain will be lowered. The State of Colorado indicates that a TDS level of 2500 mg/l is suitable for livestock use (McKee and Wolf, 1963).

6.4.3 Domestic Use

Several physical (aesthetic), chemical, and bacteriological standards are placed on water for domestic supply, Irrigation return flows and receiving waters may not meet these standards because of diminished physical and chemical quality. Table 6.4.3-A displays recommended and mandatory limits for many constituents.

Physical parameters impairing water quality are turbidity and odor. These properties are generally treated in conventional water treatment. Surface irrigation systems which return tailwater to the river can increase turbidity in the river. While turbidity is increased by irrigation returns in the Larimer-Weld region, surface waters are not used for domestic supply downstream.

Chemical characteristics of drinking water must meet many criteria in order to be considered good. Needless to say, many water supplies do not meet recommended limits. Various cations and anions associated with irrigation return flows, as well as total dissolved solids levels, have either recommended limits or mandatory limits.

WATER QUALITY CRITERIA

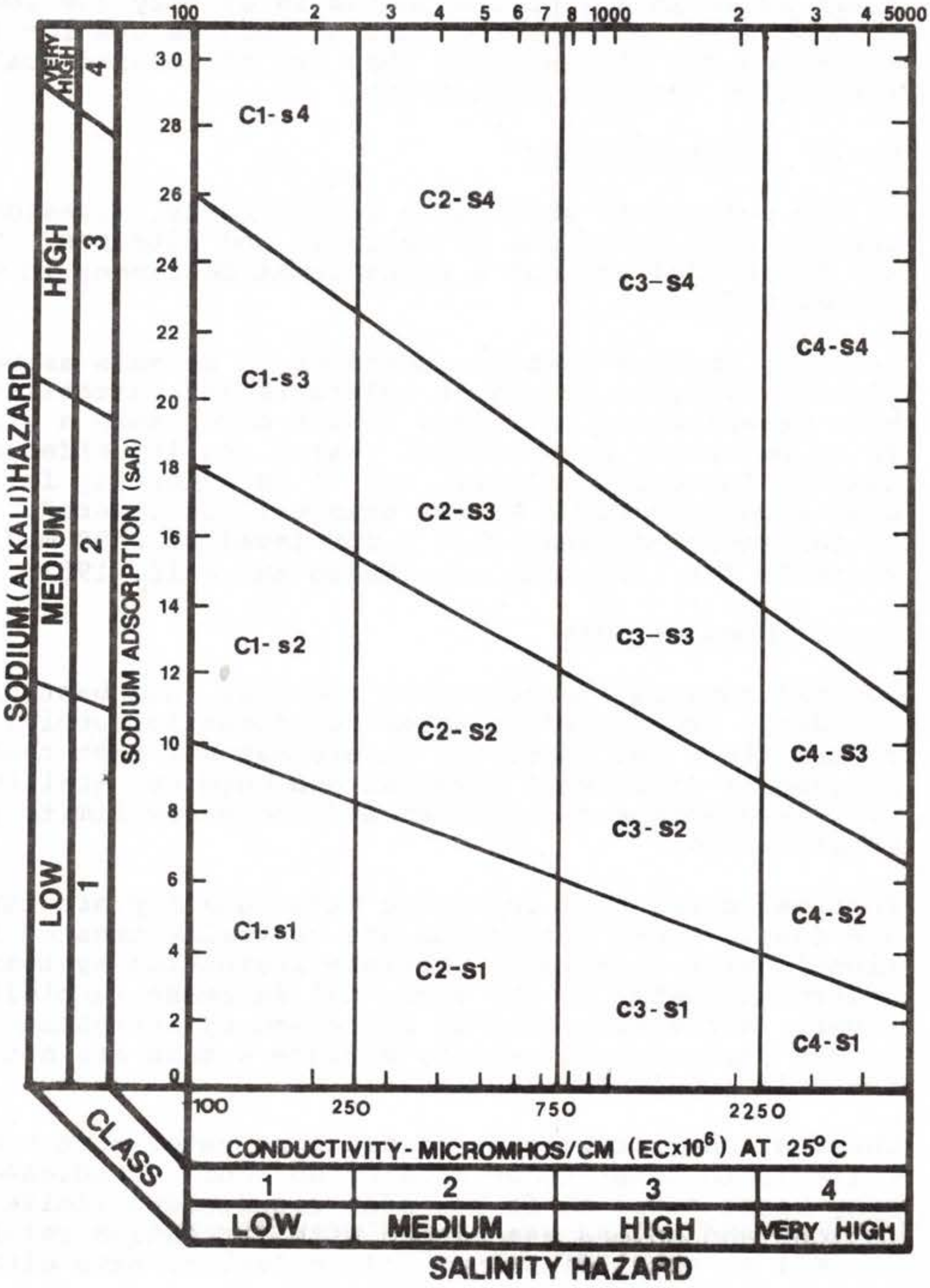


FIG.6.4.1 A DIAGRAM FOR THE CLASSIFICATION OF IRRIGATION WATERS

TABLE 6.4.3-A DRINKING WATER STANDARDS [a]

Constituent	USPHS Drinking Water Standards [b]		California Department of Health Standards		EPA Interim Primary Water Standards mg/1
	Recommended limits mg/1	Mandatory limits mg/1	Upper limit mg/1	Short-term limit mg/1	
Physical Characteristics:					
Turbidity	5	--	0.5	--	
Color, units	15	--	15	--	
Odor, threshold odor number	3	--	3	--	
Nonfilterable residue	--	--	--	--	
Taste	--	--	--	--	
Chemical Characteristics:					
Alkyl benzene sulfonate (ABS)	0.5	--	--	--	
Aluminum (Al)	--	--	--	--	
Arsenic (As)	0.01	0.05	0.1	--	0.05
Barium (Ba)	--	1.0	1.0	--	1.0
Cadmium (Cd)	--	0.01	0.01	--	0.01
Carbon-chloroform extract (CCE)	0.2	--	0.7	--	
Chloride (Cl)	250	--	500 [d]	600	
Chromium (Cr, hexavalent)	--	0.05	0.05	--	0.05
Copper (Cu)	1.0	--	1.0	--	1.0
Cyanide (CN)	0.01	0.2	0.2	--	0.2
Fluoride (F) [c]	0.8-1.0	1.3	0.8-1.0	1.3	[e]
Hardness (as $CaCO_3$)	--	--	--	--	
Iron (Fe)	0.3	--	0.3	--	
Lead (Pb)	--	0.05	0.05	--	0.05
Magnesium (Mg)	--	--	--	--	
Manganese (Mn)	0.05	--	0.05	--	
Mercury (Hg)	--	--	0.005	--	0.002
Nitrate (NO_3)	45	--	--	--	
Nitrate-N+ Nitrite-N	10	--	10	--	10
Phenols	0.001	--	--	--	
Selenium (Se)	--	0.01	0.01	--	0.01
Silver (Ag)	--	0.05	--	--	0.05
Sulfate (SO_4)	250	--	500 [d]	600	
Total dissolved solids (TDS)	500	--	1,000 [f,g]	1,500 [h]	
Zinc (Zn)	5	--	5	--	

---

[a] Units per milligrams per liter, unless otherwise stated.

[b] United States Public Health Service Drinking Water Standards of 1962.

[c] Fluoride concentrations in public water supplies in California are regulated by the State Board of Public Health. For mean annual temperature of 60°F, fluoride concentration cannot exceed 1.0 mg/l.

[d] Recommended: 250 mg/l.

[e] For mean annual temperature of 60°F, fluoride concentration cannot exceed 2.0 mg/l.

[f] Recommended: 500 mg/l (specific conductance: 800 microhomos).

[g] Upper limit: 1,000 mg/l (specific conductance: 1,600 microhomos).

[h] Short-term limit: 1,500 mg/l (specific conductance: 2,400 microhomos).

Total dissolved solids levels increase as a result of irrigation. There are no mandatory limits for total dissolved solids, as no detriment to the health has been shown as a result of consuming high TDS water. Within reasonable limits, dissolved solids are an impairment only to taste. Water with TDS concentrations high enough to be harmful is so unpalatable that it is rarely used for water supply purposes.

Nitrate and nitrite is limited to 10 mg/l as N in the EPA Interim Primary Water Standards. This has been established as a safe amount.

Irrigation leachate can be of significantly higher nitrate concentration than applied water. Although returns of seepage water rarely cause surface water to contain more than 10 mg/l NO_3-N+NO_2-N, ground water may contain this much or more. The exact reason for these high levels in ground water is not easy to find. Irrigation may or may not be the cause.

The anions chloride and sulfate have also had recommended levels. Sulfate can cause distress in the lower digestive tract of humans and animals. Chlorides impair the taste of water when levels reach approximately 400 mg/l.

Dissolved solids and possibly nitrate levels place a definite impairment on water quality for downstream uses. Nearly all of the municipalities downstream rely upon wells in the South Platte Alluvium.

6.4.4 Fisheries

Water quality and stream hydrology limit the types of fish which can live in a stream. Stretches of a river which are periodically dried up cannot support significant fish life. The water quality necessary to support a suitable fish species diversity has the following proposed limits: (McKee and Wolf, 1963).

1. Dissolved oxygen not less than 5 mg/l;

2. pH approximately 6.7 to 8.6 with an extreme range of 6.3 to 9.0;

3. Specific conductance at 25°C, 150 to 500 µmho with a maximum of 1000 to 2000 µmho permissible for streams in western alkaline areas (Note: total dissolved solids (mg/l) generally equals about 0.7 x specific conductance);

4. Free carbon dioxide not over 3 cc per liter;
5. Ammonia not over 1.5 mg/l;
6. Suspended solids such that the millionth intensity level for light penetration will not be less than 5 mg/l.

These should not be interpreted as maximum sublethal levels. Rather, they are conditions favorable to a good mixed warm water fish population.

The Cache la Poudre, Big Thompson, Little Thompson, and St. Vrain are all dried up by irrigation diversions after they exit from the mountains. These streams must be considered to be warm water fisheries below the diversion points. Irrigation return flows are generally only a very small portion of the total flow above these points. Flow depletion and natural temperature change are the restrictions upon fish life in stretches above the first point of zero flow.

Below that point, only warm water fish can be found. Trout and other desirable cold water fish cannot generally be supported in these downstream reaches. Late August temperatures are generally below 18°C as the rivers exit from the mountains. After the river is diverted, temperatures may range from 20 to 22°C. Suspended solids may be around 50 mg/l, and reaches of the rivers below the first zero flow points are often impacted by municipal and industrial returns.

The most severe restriction on fish life is the hydrologic situation in these downstream areas. Any reach of the stream is subject to no flow conditions. Water may stand or pool in these stretches and may be heated substantially. As a result of temperature increase, DO may be lowered. Fish able to exist in these reaches must be able to survive this changing environment.

During the sampling program, abundant fish life was observed in most of the lower reaches of the Cache la Poudre. The fish life was restricted to warm water fish, primarily carp. Warm water fisheries have limited recreational value in the region due to the proximity of the better cold water fisheries. Habits of the carp generally prohibit coexistance with more desirable fish.

6.4.4.1 Water Quality of Irrigation Return Flows and Fish Requirements

Fish production in reaches of the rivers below the point of zero flow is restricted primarily by the hydrologic situation.

This includes most of the plains area of these streams. These areas are subject to drying up or at least zero flow (standing water). Zero flow produces warm water, and as a result the fish living in areas where river water is 100 percent irrigation return flow are those species best adapted to the hydrologic and temperature condition.

Pesticide levels and fish tolerance are presented in Section 3.7. Data is insufficient at this time to make conclusions, however, pesticide levels have nearly always been below fish tolerance limits.

6.4.5 Recreation

Recreational water use includes swimming, boating, and aesthetic enjoyment. Water quality requirements of swimmable waters are: (a) they must be aesthetically enjoyable, i.e., free from obnoxious floating or suspended substances, objectionable color, and foul odors; (b) they must contain no substances that are toxic upon ingestion or irritating to the skin of human beings; and (c) they must be reasonably free from pathogenic organisms. (McKeen and Wolf 1973). Requirements for boating are mostly aesthetic.

Irrigation return flows are generally acceptable waters for swimming and boating from a quality standpoint. Some degradation is noted from sediment which may increase turbidity. Surface returns are a small portion of total return flow in the region, and sediment levels are not highly objectionable. Irrigation returns generally have low bacteria levels. Even where manure is used as fertilizer, it is generally plowed in well enough that bacteria is not a problem.

The major problems with swimming and boating in areas affected by irrigation return flow are the hydrologic situation and access. Although segments of the streams impacted by municipal and industrial discharges might be objectionable, water quality of irrigation return flow is good for these purposes. The major problem is quantity. Rivers in the region have an unswimmable and unboatable depth after the first point of zero flow. Reaches upstream are quite acceptable for recreational use when access is available. In addition, downstream reaches of the St. Vrain and some parts of the South Platte have sufficient flows to have value for floating. Use of these waters is restricted by access problems across private property.

6.4.6 Return Flow Detriment to Beneficial Use

Table 6.4.6-A shows a summary of the beneficial uses of water and compares the possible uses of water to the quality of irrigation return flows. Salinity is the most serious pollutant restricting downstream use of the irrigation return flow.

TABLE 6.4.6-A SUMMARY OF BENEFICIAL USE ASPECTS OF RETURN FLOW

	Irrigation	Stock Water	Domestic	Fish	Recreation
Salinity	X	O	X		
Nitrates		O	X		O
Sediment		O	O	O	O
Phosphorus					O

X - Definite detriment.
O - Possible detriment. Concentrations observed in the Larimer-Weld region are rarely high enough to cause a serious quality impairment.

Salinity in return flows from the region is high enough to be detrimental to downstream irrigation and domestic uses Levels may on occasion be so high as to cause less than optimum weight gain in stock.

Nitrate levels are occasionally high enough to be detrimental for domestic use and may sometimes be high enough to be detrimental for dairy use. Generaly, nitrate levels in the river and alluvial aquifer from which downstream municipalities get their water are not so high as to cause any problem although in some locations high nitrates are common. This is more the case where wells draw from ground water returns rather than depleting the river. Nitrates serve as an algal nutrient and for this reason may possibly be detrimental to recreation use. The extent of the downstream algae problem has not been studied, however.

Sediment could possibly affect stock water, domestic fish and recreational uses of water. Levels observed in rivers in the Larimer-Weld region are generally low enough that sediment does not affect any of these uses. Phosphorus, as an algal nutrient, could possibly be detrimental to recreation. This is not generally the case in the region, however, since return flows are continually reused and high phosphorus levels in irrigation water may be removed through plant uptake.

CHAPTER 7.0

POTENTIAL FOR BEST MANAGEMENT PRACTICES

One of the goals of Public Law 92-500 is to implement best management practices for nonpoint pollution sources. "The term best management practices (BMP) means a practice or combination of practices that is determined by the state (designated areawide planning agency) after problem assessment, examination of alternative practices, and appropriate public participation to be the most effective, practicable (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality roles."

This report has presented an assessment of the water quality impact of irrigation return flow in the Larimer-Weld region. This assessment has led to several conclusions regarding the water quality problem in the region and can hopefully serve as a foundation for evaluation of prospective management practices, eventually leading to the definition and implementation of best management practices.

This problem assessment has dealt with a large area with particular conditions in each of the five rivers studied. This study has identified the major reasons for water quality being as it is in the region. One of the major water quality problems is the hydrologic situation in which most of the rivers are subject to zero flow conditions shortly after they exit the mountains. Salinity is the major water quality problem resulting from irrigation return flow. Improved fertilizer management techniques may lower nitrate levels. Levels of sediment and phosphorus resulting from return of tailwater flows to the stream do not appear to be the major limitation on water quality in the region.

Practices which are used to abate pollution from irrigation return flows are often beneficial to crop production and pollution control. Such practices might include canal lining, improvement or change in application system, artificial drainage, improvement in management of irrigation, tailwater recovery, and treatment of return flow. Economic considerations generally make prevention more effective than treatment.

7.1 SALINITY PROBLEM IN LARIMER-WELD REGION

7.1.1 Salt Pickup

Salts are associated with the groundwater return flows to the river. Surface returns generally have only slightly increased salinity as a result of flowing over the field. There is an enormous amount of ground water flow in the region and seepage into the river runs as high as 3 cfs per river mile in the Cache la Poudre Basin. Much of the ground water flow is intercepted by lower canals and tile drains and does not get back to the river directly. Ground water which is perched on top of underlying shale layers shows a very high salinity level as does that ground water which has seeped through the permeable transition shales. The total dissolved solids levels in the return flows from tile drains appears to be directly related to the depth to the impermeable shale layers. The depth to shale (impervious layers) as well as the identification of types of shales and water bearing characteristics of these types are shown in Figures 3.5.4-A and 4.2.1-A, respectively. These maps indicate possible problem areas which can be verified by examining sample locations and data.

The lake areas north of Fort Collins lie in the Pierre Shale which is shallow to the surface. While much of this area is irrigated, this particular element of the Pierre shale is considered to be nearly impermeable. This layer is overlain by soil with depth to shale of approximately 60 inches, 50 percent of the time. There is little seepage out of these lakes. Yet, canals flowing through the soil and irrigation of lands on top of the shale create a perched water table with excellent contact opportunity with the shale. Wells in this area typically yield 3000 to 5000 mg/l TDS water. Boxelder Creek, which receives drainage from this area, has a fairly constant total dissolved solids level of approximately 2000 mg/l.

In the Fossil Creek and Boyd Lake area between Loveland and Fort Collins, a very high TDS level was found in the stream which intercepted seepage from Fossil Creek Reservoir. This transition layer of the Pierre shale is more permeable than those shales north of Fort Collins. Indications are that the amount of seepage from the reservoir is relatively small although highly concentrated.

In the area near Severance high total dissolved solids levels were observed in return flows from a tile drain overlying the Fox Hills Sandstone formation. It would appear that this could be another area of salt pickup.

West of Berthoud, Dry Creek has a high salinity level. Possible sources of this high TDS level (slightly over 3000 mg/l) are seepage from Carter Lake and irrigation of the rolling grazing land overlying the shale hills in the area.

High TDS levels were also shown near several tile drains on the north side of St. Vrain Creek between Highway 66 and the confluence with the South Platte. In these areas the transition layer of the Pierre shale is also relatively close to the surface and horizontal flow across the shale from areas above the actual drain location. The Gill-Galeton area north of Greeley represents another area where high TDS levels are noted in tile drains overlying a shallow shale layer.

While other areas of salt pickup probably exist, these areas have been found through the sampling program to contribute fairly high dissolved solids loadings. Water supplies to the fields above these drains were of high quality. The concentrations found in these drains represent a pickup of salts. Drains from areas in the alluvium as well as from areas where the shale was very deep below the drain do not exhibit this high concentration.

The quality of water found in drains overlying the shallow shale layers is not reflective of practices on that particular farm. These drains usually intercept water which is flowing horizontally from uphill areas and causing problems on a particular farm as the soils sloped down towards the river on the relatively level shale shelf. Total loading of dissolved solids from an area has been shown to be inversely proportional to water use and for this reason the drain which intercepts leachate would show a higher concentration of dissolved solids for better practices. Loading of dissolved solids to the river is dependent upon the geology of an area and irrigation techniques practiced on individual farms. The role of the canal system in this problem as well as the high consistency of irrigation techniques in the region would appear to make a regional approach valid.

7.1.2 Management Practices Applicable to Salinity Control

Management practices applicable to salinity control are based upon minimizing water contact with underlying shales. These techniques are then aimed at reducing the flow of water into the ground water basin or removing it before it contacts the more saline soils below.

Canal lining is one possible alternative. Canals north of Fort Collins typically lose 3 cfs per mile to the next canal below and gain 3 cfs per mile from the canal above. Cost is the main drawback to canal lining.

Improved irrigation management is another alternative. Computerized irrigation scheduling services are now operated in some parts of the country. These services rely upon computer accounting of weather data, and personnel trained in irrigation and soil moisture measurement to optimize on-farm irrigation. Average farm irrigation efficiency across the nation now averages about 40 percent. Such a scheduling system could easily add a 10 percent improvement [Jensen 1975]. In addition, irrigation scheduling has shown consistently improved crop yields.

Modification of application systems represents another possibility for decreasing losses of water from over-irrigation. Sprinkler irrigation offers good uniformity and the improved characteristics of slow leaching. The improved controls generally result in much less water being leached from the root zone. Drawbacks include energy consumption and cost.

Modification of current surface systems represents a promising alternative. One of the major reasons surface irrigation efficiency is not higher is labor requirements. Currently systems are managed to meet minimum labor costs rather than maximum efficiency. The gated pipe now in use represents only a fraction of the possibilities available for improvement and eventual remote control of surface irrigation distribution systems.

Another possible alternative is increased drainage. Drainage is most effective in reducing salinity in return flows when it intercepts the seep water before it mixes with the highly saline water perched directly on top of the shale.

A best management practice for the area will identify cost-effective combinations of solutions applicable to small areas or the area as a whole, which can best reduce the salinity levels in rivers of this region and downstream.

7.1.2.1 Nitrates and Possible Management

High nitrate levels may be found in streams and ground water in the area. These levels may cause algal blooms in surface waters. Above certain levels, nitrates pose possible health hazards. Many high nitrate levels were found in the drains of farms around Greeley. These farms receive large manure applications each year due to their proximity to feedlots. They receive commercial fertilizer in addition to these manure applications. Indications are that more soil testing is needed. Research on the fertilizer value of manures produced in the region and the release of nitrogen from spring-applied manures would be of great benefit.

7.1.2.2 Sediment and Phosphorus

Discharges of sediment and phosphorus to the rivers of the region are generally reduced by the existence of a non-irrigated flood plain. This pasture land serves as a buffer strip, reducing direct tailwater discharges and allowing sediment to settle out before receiving waters.

Some sediment problems are noted in the region, however. The Little Thompson generally lacks this buffer strip and is surrounded by significant slopes. As a result, it has a higher sediment load. In addition, tributaries may carry sediment to the larger rivers.

Potential management practices for sediment control include buffer strips, tailwater ponds, and pumpback systems.

Sediment does not appear to be a major pollutant in the region, and acceptable levels of sediment control can probably be met through better management.

APPENDIX A

PART I.

This appendix contains a description of each of the sampling sites in the program. Data from each of these sampling sites is presented in Appendix B. Maps showing the sampling sites are provided in Figures 5.2.2-A, 5.3.2-A, 5.4.2-A, 5.5.2-A and 5.6.2-A. The prefixes used in enumeration denote the river basin: Cache la Poudre (P); Big Thompson (BT); Little Thompson (LT); St. Vrain (SV); and South Platte (SP). The suffixes denote the type of sample: river (R); tributary (T); tile drain (D); tailwater (W); and other (O).

DESCRIPTION OF SAMPLING SITES:

I. POUDRE BASIN

A. Sites on River

PGS1. Cache la Poudre at mouth of canyon near Fort Collins, Colorado. State PGS1 is a water quality station operated by the U.S. Geological Survey. The sampling site is at the gaging station. The station is located in the NW 1/4 of Section 15, T8N, R70W.

The station is downstream of the North Poudre Supply Canal and the Poudre Valley Canal which divert considerable flows from the river. The station is upstream of the Hansen Supply Canal which augments the river with Colorado Big Thompson water.

There are no municipal waste treatment facilities upstream of this site. The few residences in the canyon are served by septic tanks.

Irrigation return flows do not affect the water quality at this point. There is no irrigated land in the Cache la Poudre Canyon above the station. The station is below the confluence with the North Fork Cache la Poudre River. While the North Fork of the Cache la Poudre contains some return flow, most of these flows are retained by Seaman Reservoir which releases them only when discharging over the spillway.

PR1. Cache la Poudre River at the Linden Street Bridge in Fort Collins, Colorado. Flows at this point are greatly reduced by several diversions including the Larimer County Canal, Pleasant Valley Canal, Jackson Ditch, Larimer County #2 Canal, New Mercer Canal, Larimer and Weld Canal, and several smaller canals.

Small quantities of irrigation return flows may enter the river in the area between PGS1 and this station. The area irrigated in this stretch of river is significant, but there are no major tributaries or seep canals affecting the river in this stretch. Roadside ditches, subsurface drains, and seepage may carry some minor returns. The Hansen Supply Canal typically discharges from 400 to 900 cfs to the river above this point. The canals mentioned above divert most of this water, with typical flows at site PR1 being around 100 cfs. Thus any return flow entering the river above this point is diluted and diverted before reaching the Linden Street Bridge in Fort Collins.

PGS2. Cache la Poudre at Fort Collins, Colorado. This U.S. Geological Survey station is at the Lincoln Street Bridge and only a few hundred feet away from PR1.

PR2. Cache la Poudre River at Highway 14 Bridge, Fort Collins, Colorado. This sampling site is only a short distance downstream from the previous sampling site and lies directly below the outfall of the Fort Collins #1 sewage treatment plant. At the time of testing, the sewage plant was discharging 13 cfs. This discharge contained 650 mg/l total dissolved solids (TDS).

There are no direct agricultural dischargers between point PR1 and PR2. Land to the southwest of the river is urban. Some of this land to the northeast of the river is farmed, but most has gone to gravel pits and similar operations. There is probably a significant amount of seepage through the alluvial formations into the river through the Fort Collins area, however.

PR3. Cache la Poudre River at Prospect Street Bridge. This station does not receive significant quantities of agricultural discharge. Land along the river between stations PR2 and PR3 has largely been sold out for gravel mining. Again, significant seepage into the river is suspected.

PR4. Cache la Poudre at Interstate 25 rest stop is downstream of Boxelder Creek, which is a major conveyance of irrigation return flow from a large irrigated area to the north. Flows in Boxelder Creek are typically around 10 cfs. Two ditches, Fossil Creek Inlet and Boxelder, divert water between stations PR3 and PR4. Station PR4 is downstream of the Fort Collins Sewage Treatment Plant #2 which was discharging 14 cfs of 500 mg/l TDS water at the time of sampling.

PR5. Cache la Poudre River at Harmony Road. This site is located about one-half mile south of Timnath. The river receives both municipal and agricultural discharges between station PR3 and this station.

PR6. Cache la Poudre River at County road 1-1/4 miles south of Windsor High School. Flows at this point southeast of Windsor are greatly reduced by diversions to the B.H. Eaton Ditch, Greeley No. 2 Ditch, and Whitney Ditch. There are no municipal or industrial discharges between PR5 and PR6.

There are several sources of agricultural return flows between stations PR5 and PR6. Small streams carrying agricultural returns as well as tile drains both enter the river. The river is generally dry below the B.H. Eaton Ditch in August, and return flows generally comprise 100 percent of the August flow at this point. Most of the flood plain land is non-irrigated pasture in this area.

PR7. Cache la Poudre River at Highway 257 Bridge south of Windsor. This sampling site is very near the previous one. There are only minor localized return flows entering between stations PR6 and PR7.

PR8. Cache la Poudre River south of Bracewell. This sampling point is downstream of the discharges of Eastman Kodak and the town of Windsor. The small Jones Ditch diverts some flow above this point. There are a few sources of irrigation returns in this stretch, mostly seepages.

PR9. Cache la Poudre River one mile south and 1-1/2 miles east of Bracewell. Just below the last sampling point. The stretch between PR8 and PR9 has the diversion for the Greeley #3 Canal. A few minor seepages of return flow occur in this stretch.

PR10. Cache la Poudre River at 8th Street, Greeley. Between station PR9 and PR10, three major tributaries which are primarily fed by return flow enter the river. There are no major diversions in this stretch. Sheeps Draw and Graham Seep are entirely fed by irrigation returns and each drain large areas. Eaton Draw receives domestic water as well as irrigation returns.

PR11. Cache la Poudre River below Greeley Sewage Treatment Plant. This sampling point is just a short distance downstream of PR10 and is just below the Greeley Sewage Treatment Plant outfall. No agricultural returns are released between PR10 and PR11.

PR12. Cache la Poudre River at County Road 45 east of Greeley. This point is downstream of the Ogilvy Ditch diversion. The point is not far downstream from PR 11, and there are no major tributaries containing return flow in this stretch, although there is seepage.

PGS3. Cache la Poudre River near Greeley, Colorado. This USGS station is located in NW 1/4 Section 11, T5N, R65W, three miles upstream of the mouth. This station is in essentially the same place as station PR12.

B. Cache la Poudre Tributaries

PT-1. Boxelder Creek has a total drainage area of 160,640 acres, of which 30,521 acres are irrigated. Irrigation returns make up almost the entire flow of the creek. The Wellington Sewage Treatment Plant makes an insignificant contribution to the flow. Several diversions along the creek reintroduce return flows to the distribution system. The sampling point was near the mouth, just above the Boxelder Sanitation District Sewage Treatment Plant.

PT-2. Fossil Creek is the natural channel on which Fossil Creek Reservoir is built. Releases from the reservoir are put into another channel. Seepage from Fossil Creek Reservoir supplies most of the water for Fossil Creek. Fossil Creek Reservoir is in a shale formation.

PT-3. This sampling point is referred to either as the Consolidated Law Ditch or the Black Hollow Drain. The ditch was sampled one mile south of Highway 392 and about 3/4 mile west of Highway 257. The ditch runs about another mile before entering the Poudre River. The Eastman Kodak Company has irrigation rights on this ditch. This creek typically discharges 5 to 10 cfs to the Cache la Poudre River.

PT4. This creek is known as Storm Lake Drain. A sample of this creek was taken about 1/2 mile south and 1/2 mile west of Bracewell. Combined drainage and tailwater return flows supply water to this drain.

PT-5. Sheeps Draw is a major tributary carrying return flows. Irrigation returns are the only dry weather source of flow in Sheeps Draw. Approximately 5,030 of the 8,960 acres in the Sheeps Draw drainage basin are irrigated. Flows in Sheeps Draw are typically 10 to 15 cfs.

PT-6. Seely Lake Outlet. This releases water for irrigation when flow is high and serves as a tailwater return when flow is low.

PT-7. Graham Seep. This stream drains aroung 10,400 acres, almost all of which is irrigated. Irrigation returns subsurface and surface are the sole source of dry weather flow in this stream. The stream was sampled at the County Road 1 mile southeast of Seely Lake.

PT-8. Eaton Draw receives domestic sewage from the Town of Eaton and sugar processing waste as well as from irrigation return flow. This draw typically contributes around 5 cfs to the river, of which about 0.5 cfs is Eaton effluent. The sugar processing plant was not in operation at the time of sampling. Eaton Draw has a drainage basin of around 7,040 acres, about 90 percent of which is irrigated.

PT-9. Sand Creek drains almost 5,900 acres, but these flows are not returned to the river as Sand Creek is intercepted by Ogilvy Ditch. The sampling point was above the interception.

C. Subsurface Drains - Poudre Basin

PD1. This drain has its outlet about one mile south of Timnath. The drain serves to relieve high water table problems below Boxelder Ditch. Drains of this type are generally interceptors running parallel to and just downhill from the ditch in question.

PD2. This drain has its outlet 1-3/4 mile south of Harmony Road and 1/2 mile east of Interstate 25. PD2 drains land below Boxelder Ditch. PD2 discharges to a small creek.

PD3. This drain discharges to the Cache la Poudre River on the County road southwest of Windsor near PR6. This drain relieves the high water table from the alluvial land below the Whitney Ditch.

PD4. This tile drain was sampled from a junction box located about 1/4 mile north of the Windsor Cemetary. The drain affects about 65 acres of sugar beets. Figure A-1 shows the layout of the drain. From this figure, it is apparent that most of the flow in the pipe is seepage from Windsor Lake and the Greeley #2 Canal. The water from the junction box continues down to another junction box located just south of Highway 392. Much of the water from this box is pumped for irrigation. Left over water eventually reaches the river.

PD5. This sampling point is a tile drain junction box located 1/2 mile southwest of Severance. The location of the tiles is shown on Figure A-2. Seepage from Gress Reservoir would appear to contribute to the need for drainage, although some must be seepage loss of irrigation water. Corn is the crop grown on the drained area. The area was fertilized as follows:

	Pounds of Active Ingredients Per Acre				
	N	P_2O_5	ZN	Cu	Boron
100 Ac. Corn, Fall 1975	50	0	8	2	1
June 1976	50				

This ground was also fertilized with 25 tons/acre manure which would be expected to contain a maximum of:

	N	P_2O_5	K_2O
Fall 1975	300	75	225

One-third to one-half of the nutrients in the manure would be available the first year. This drain was sampled at the junction box located on the map.

PD6. This drain relieves the high water table from a corn field below Greeley #2 Canal. About 40 acres of land are affected by the drain.

Figure A3 shows the location of this drain. The drain empties into a junction box which collects water from several drains.

Corn is grown in the major portion of the area served by this drain with some alfalfa grown in the lower area near the outlet. Fertilizer application over the area is as follows:

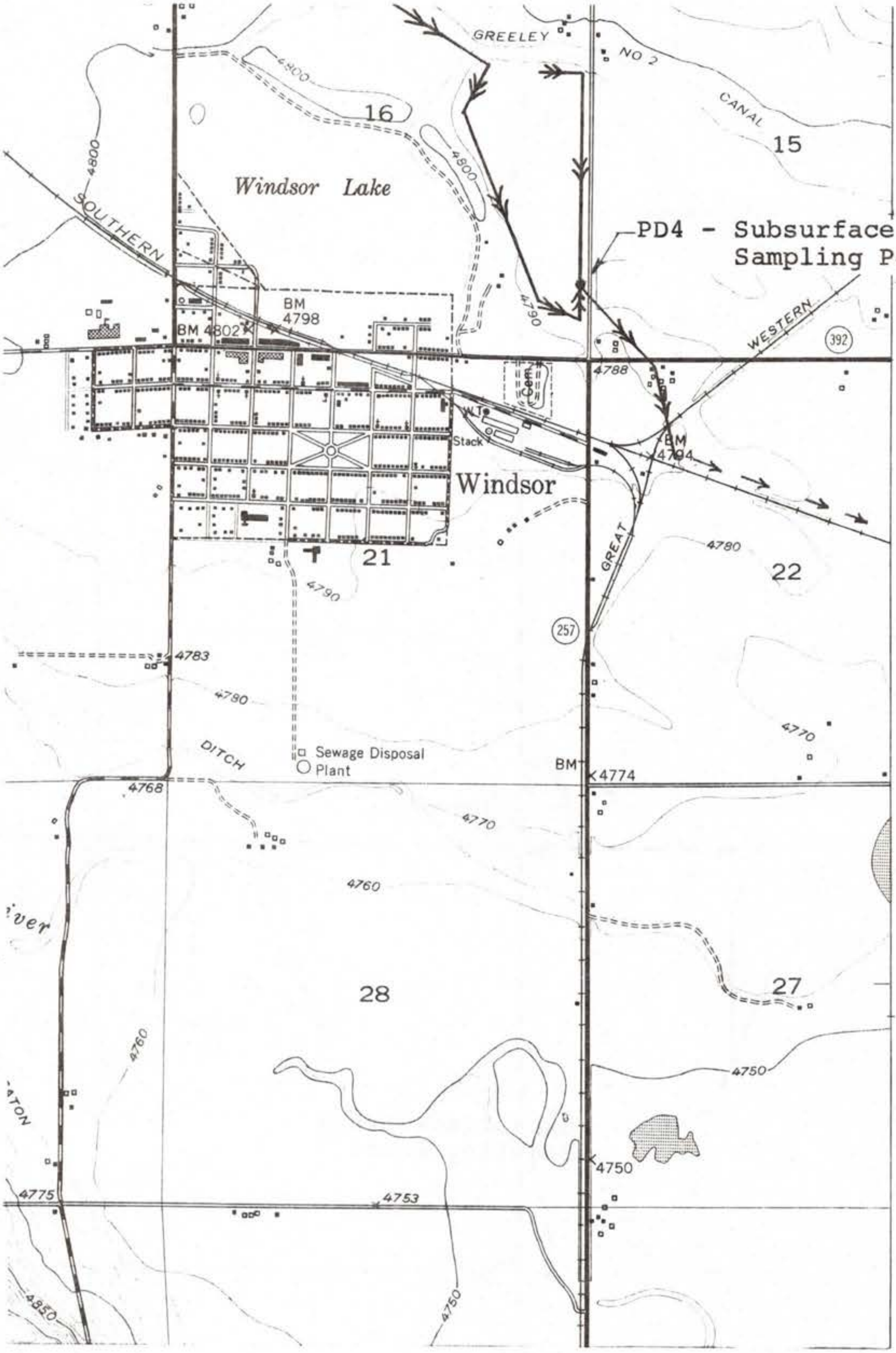
Entire Area:

Fall, 1975 - 15 tons/ac. manure. This manure would be expected to contain the following levels of constituents as a maximum:

N[a]	P_2O_5[a]	K_2O [a]
180	45	135

[a] Pounds/Acre.

One-third to one-half of these constituents would be expected to become available in the first year.



PD4 - Subsurface Drain Sampling Point

Figure A-1. Subsurface Drain PD4

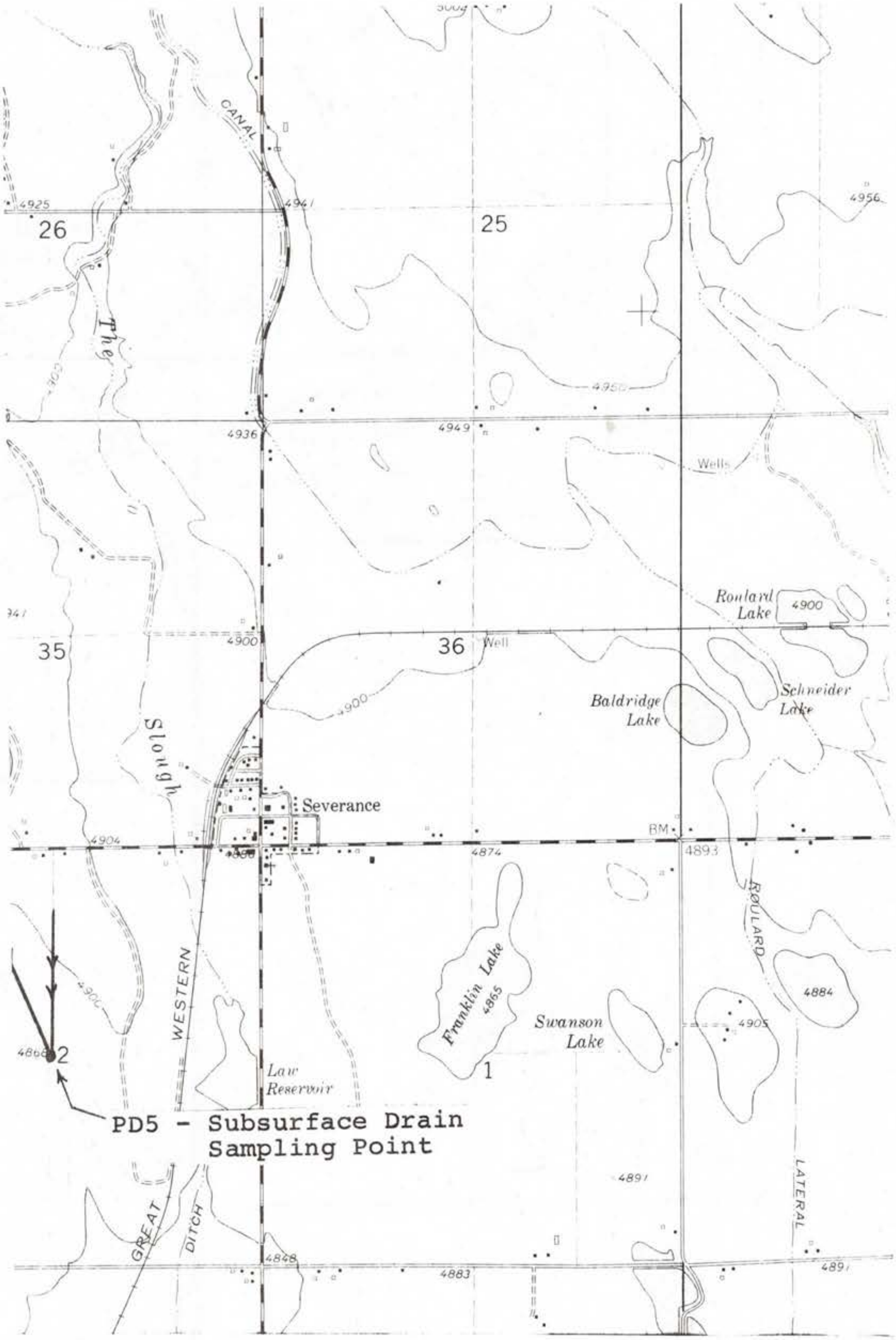


Figure A- 2 Subsurface Drain PD5

Corn: In addition to the manure, the corn received both Anhydrous Ammonia bubbled on with irrigation water and solid chemical fertilizer. The following levels of constituents were added:

	Pounds/Acre		
	N	P_2O_5	K_2O
Spring and Summer, 1976			
Anhydrous Ammonia	65		
Other Dry Fertilizer	48	30	0

Alfalfa: In addition to the manure, the alfalfa received some dry fertilizer analyzed as follows:

	Pounds/Acre		
	N	P_2O_5	K_2O
Spring, 1976		18.5	

Some samples were also taken from the junction box at this location which serves a much larger area. The junction box is quite old and it is not known what area is served by it.

PD7. This drain relieves the high water table from an unknown amount of pasture land below the Whitney Ditch. Most of the water is expected to be seepage directly out the ditch through alluvial soils.

PD8. This drain just northwest of Greeley relieves the high water table from about 20 acres of corn. Seepage from the Greeley #3 Ditch is the source of water. The location of this drain is indicated on Figure A-4.

The area drained by this drain received about 15 tons of manure per acre which contains the following nutrients:

	Pounds/Acre		
	N	P_2O_5	K_2O
Fall, 1975	180	45	135

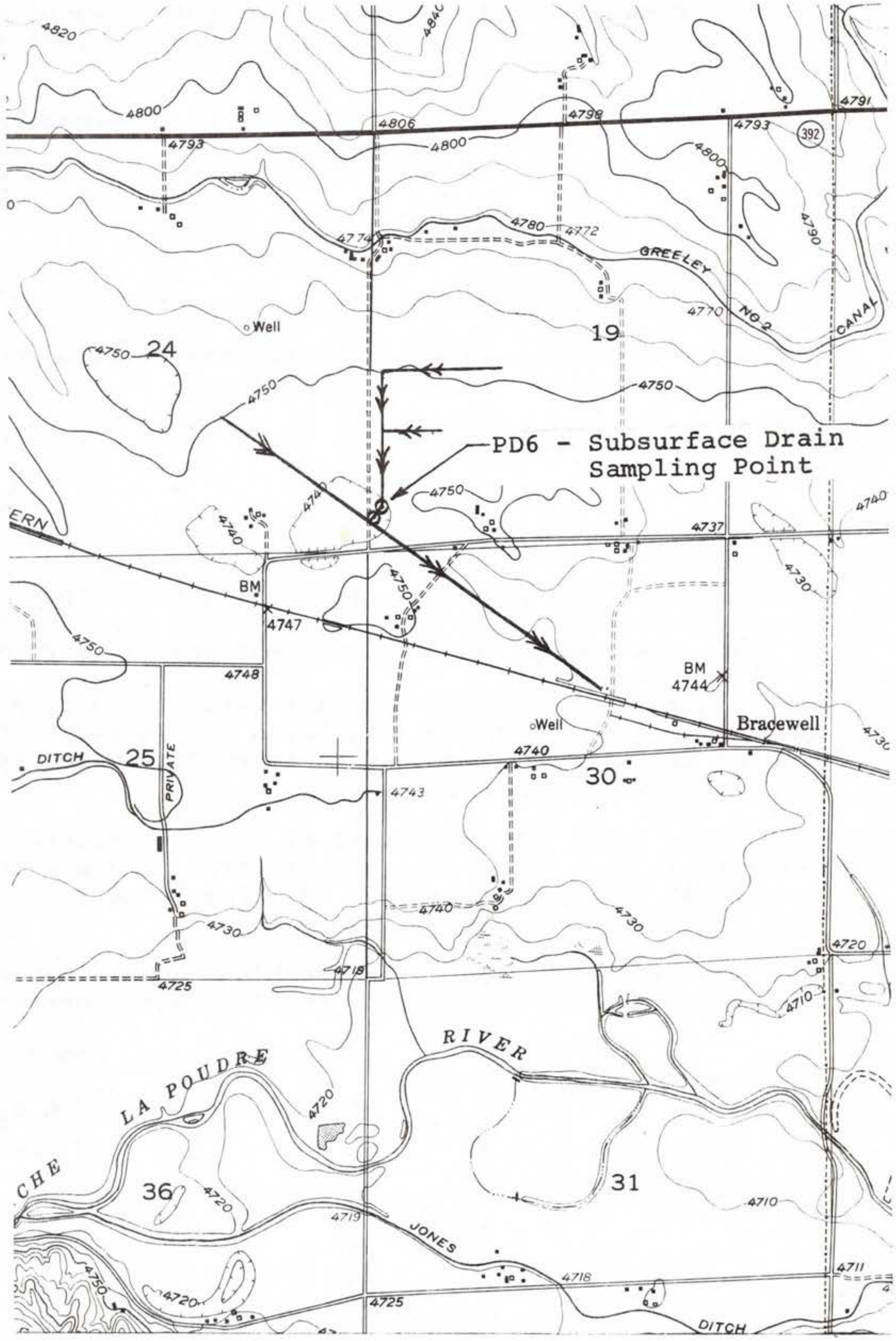

PD6 - Subsurface Drain Sampling Point

Figure A- 3 Subsurface Drain PD6

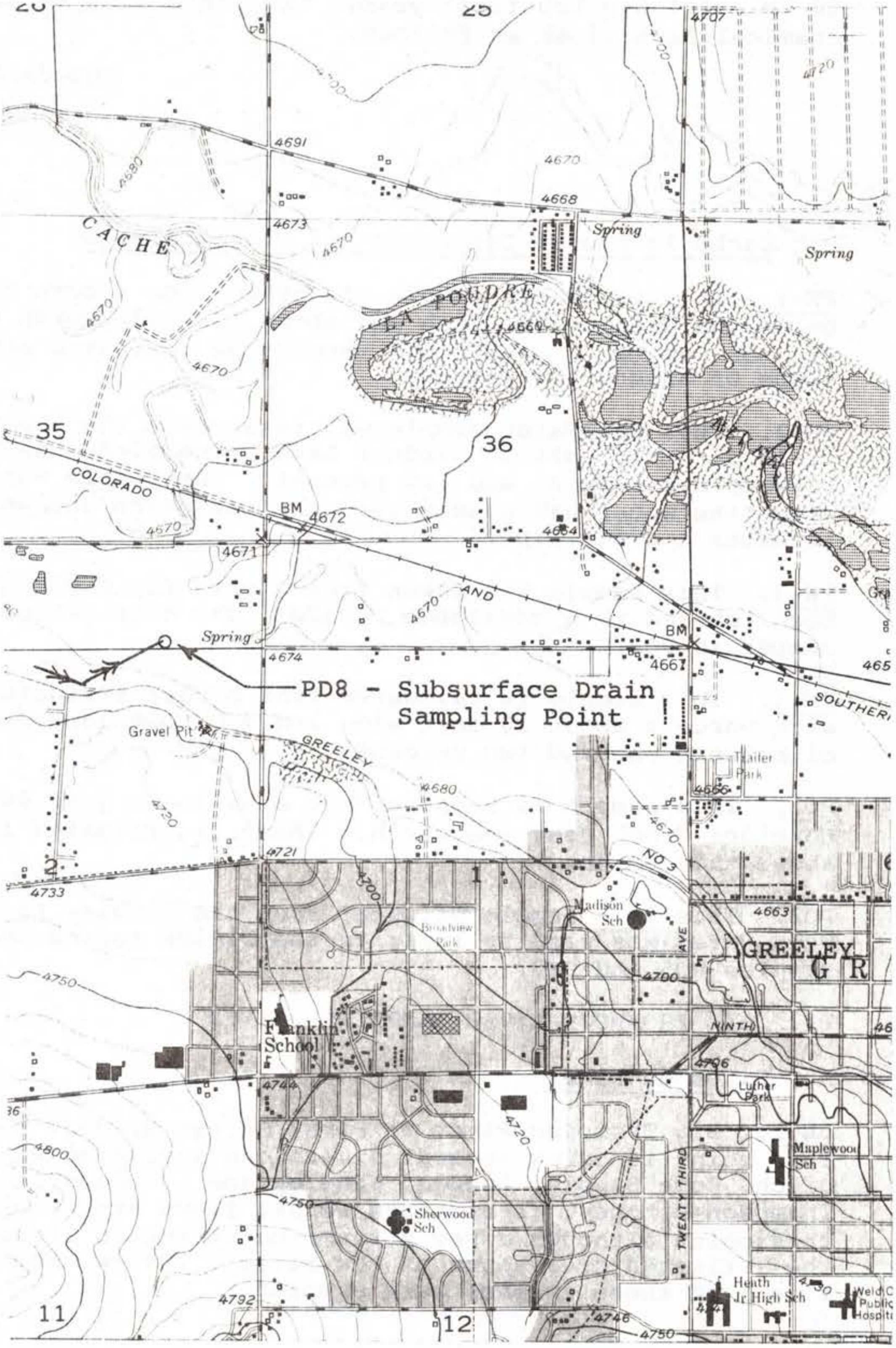


Figure A-4 Subsurface Drain PD8

One-third to one-half of these nutrients would be expected to be available the first year. The field also received chemical fertilizer as follows:

Pounds/Acre	
N	P_2O_5
75	50

D. Cache la Poudre Tailwater and Other Samples

PW-1. This tailwater sample was taken from a corn field below the Greeley #2 Ditch and about 1/2 mile north of the Windsor Cemetary. The field was furrow irrigated and had a slope of around 0.4 percent.

PW-2. This tailwater sample was taken from the sugar beet field directly east of Windsor Lake. The field has a slope between 0.8 percent and 1.0 percent. The sample was taken after the water had passed into the bar ditch and was about to enter a drain pipe.

PW-3. This sample was taken from a corn field which had been leveled to a desirable grade. The ditch water sample number is PO2.

PW-4. This sample is tailwater from border irrigated alfalfa with borders about 30 feet wide and 400 feet long on a slope of between one and two percent.

PO1. This sample is seepage from a hillside just east of Boxelder Creek near the mouth. There is irrigated land above this point.

PO2. This is a sample of water from the Findley Lateral. This water was used to irrigate the fields represented by samples PO5 and PW3.

II. BIG THOMPSON RIVER SAMPLING POINTS

A. Sites on River

BR-1. Big Thompson River at First Street Bridge, Loveland. This point is below several diversions including Handy Ditch, Home Supply, Louden, Greeley and Loveland, and Big Thompson Ditches. Irrigation return flows are minor above this point although a few streams carry return flows from the irrigated area south of the river. The two most significant of these streams were sampled.

BR-2. Big Thompson River at Larimer County Road 9 Bridge. This sampling point is 2 miles east of Loveland (Highway 287) and is downstream from both Loveland sewage treatment plants. Additional diversions have been made to Farmers Ditch. Irrigation return flows are minimal through this section, with only a few very small streams carrying the return flows. Most return flows are intercepted by canals running parallel to and just uphill from the river. These returns are then mixed with the high quality canal water which then seeps back to the river.

BR-3. Big Thompson at Larimer-Weld County Line. This sampling point is below the Hillsborough Ditch and the small Hill and Brush Ditch. Irrigation return flows enter the river as a result of groundwater seepage and a few small tributaries.

BR-4. Big Thompson at Highway 257 north of Milliken. This station is below the Big Thompson and Platte River Ditch. In the section between stations BR-3 and BR-4, a few small streams have carried return flows back to the river.

BR-5. Big Thompson River at County Road two miles east of Highway 257. This point is below the confluence with the Little Thompson. Some small tributaries also enter the river in this stretch.

BGS-1. Big Thompson at mouth near LaSalle. This U.S. Geological Survey gage is near the mouth below the Evans Town Ditch diversion.

B. Big Thompson Tributaries

BT-1. Unnamed ditch one-half mile east of Wilson on First Street in Loveland.

BT-2. Ryan Gulch at First Street, Loveland. This gulch carries releases and seepage from the Ryan Gulch Lake as well as seepage from nearby ditches and irrigated land.

BT-3. Stream about 2 miles east of Highway 287 on Highway 402. This stream carries seepage from uphill irrigated lands back to the river.

BT-4. Creek just east of Interstate 25 on Highway 34. This creek drains tailwater and seepage from the irrigated area to the northeast of the intersection.

BT-5. This creek was sampled 3/4 mile east of Interstate 25 on Highway 402. This creek is tributary to the Hillsborough Ditch and does not discharge directly to the Big Thompson River.

BT-6. This small creek was sampled 3/4 mile east of the Larimer-Weld County Line and 2-1/4 miles north of Highway 60. This creek is fed by seepage from the upland irrigated area.

BT-7. This small creek was sampled 1-1/4 mile east of the Larimer-Weld County Line road and 1-3/4 miles north of Highway 60. This slough drains about 2,100 acres of land, nearly all irrigated.

BT-8. This small creek was sampled at a point three miles north and 1/2 mile west of Johnstown. It serves as a seepage drain as well as receiving some tailwater from the irrigated region below the Loveland-Greeley Canal. There are 800 irrigated acres in the 1,500 acres drained by this creek.

BT-9. This small creek was sampled 2 miles north and 1 mile east of Johnstown. Its flow is generated primarily by seepage from groundwater seepage in the irrigated region.

BT-10. This small creek was sampled 2 miles north and 1-1/2 miles east of Johnstown. Flow is primarily the result of inflow and groundwater.

C. Big Thompson River Subsurface Drains

BD-1. Tile drain with outlet 1/8 mile east of County Road 9 (Larimer County) on Highway 402 southeast of Loveland. This drain drains an unknown amount of land below a lateral of the Home Supply Ditch.

BD-2. Tile drain 1-1/4 mile west of Interstate 25 and 1/2 mile south of Highway 34. This drain serves an area below Farmers Ditch and below Boyd Lake. The drain appeared to be the sole source of flow to the stream returning to the river.

D. Other Sampling Sites

BO-1. Hillsborough Ditch at Interstate 25. Much of the return flow is intercepted by this and other ditches.

III. LITTLE THOMPSON RIVER

A. Sites on River

LR1. Little Thompson River near Boulder-Larimer County Line. The river at this station is relatively unaffected by municipal or irrigation return flows. There is a small amount of irrigation above this point and most of the river flow is supported by natural flows from the mountains. This point is below several major diversions including Culver Ditch and Ish Ditch.

LR2. Little Thompson River at the County Road 1/2 mile east of Highway 287. In the section between this station and BR1, there is a significant amount of irrigated land. There are no municipal returns in this reach. Irrigation return flows occur through direct seepage, small influent streams, as well as other routes.

LR3. This station is below the confluence of Little Thompson River and Dry Creek but before discharge from the Berthoud Sewage Treatment Plant. Again at this station there is a significant amount of irrigation above the point and return flows occur in several manners.

LR4. This station is directly below LR3 and directly below the inflow of the Berthoud Sewage Treatment Plant. It has the combined flow of these two sources.

LR5. Little Thompson River one mile west of Interstate 25. At this point there is a considerable amount of irrigated land drained by the river. Most of the land to the south of here is dry land. The Rockwell Ditch diverts water above this.

LR6. Little Thompson River one-half mile east of Interstate 25 on Highway 56.

LR7. This station is located one mile west and 1-1/2 mile south of Johnstown. The Little Thompson River has drained yet more land.

LR8. Little Thompson River at Road 17 south of Johnstown.

LR9. Little Thompson River one-half mile south and one-quarter mile east of Johnstown.

LR10. Little Thompson River on Highway 257 north of Milliken.

B. Tributaries to Little Thompson

LT1. Dry Creek at County Road 1/2 mile east of Highway 287. Dry Creek drains about 3,800 irrigated acres and a larger area of dry land and mountain land. Perhaps the most significant source of flow is seepage from Carter Lake.

LT2. LT2 is the combined Berthoud Sewage Plant effluent mixed with local runoff from Berthoud.

LT3. This station is Big Hollow Creek 2-1/2 miles east and 1-1/2 mile south of Berthoud at Road 40-1/2. This creek drains both irrigated and wheat land, although irrigated land predominates. It is primarily served by the Ish Ditch and New Ish Ditch. The sampling point is below the confluence of the Holmes Draw.

LT4. LT4 is a ditch which flows into the Little Thompson near the Great Western Railway south of Johnstown. The nature of the discharge is unknown.

C. Subsurface Drains in the Little Thompson Basin

LD1. Tail drain with outlet one mile west of Johnstown and 1-1/2 mile south. This drain relieves the high water table from land below the Hillsborough Ditch.

LD2. This drain is combined agricultural tile drain and Johnstown sewage lagoon effluent. It is located near the intersection of Highway 60 and 257.

IV. ST. VRAIN CREEK

A. Sites on the Creek

SVR1. St. Vrain Creek at Boulder-Weld County Line. By the time the creek reaches the county line, there have already been significant diversions made for irrigation. The creek also receives the effluent from the Longmont Municipal Sewage Treatment facility as well as industrial discharges from agricultural processing industries.

SVR2. St. Vrain Creek at Interstate 25. This station is below all of the major diversions from St. Vrain Creek. A few return flows are noted for this point. Most of the major tributaries carrying return flow are intercepted by lower ditches, however. Ground water seepage may account for most of the return flow.

SVR3. St. Vrain River near Gowanda. Seepage into the river is significant up to this point. Most of the flood plain area is used for grazing land only. This, together with the salt tolerant plants which abound, indicates that there is a significant flow of groundwater into the river.

SVGS1. St. Vrain Creek at mouth near Platteville, Colorado. This geological survey station is located near the mouth of St. Vrain Creek. There should be no significant change in quality between here and the South Platte River.

B. Tributaries on the St. Vrain Creek

SVT1 and SVT2. These two sites on Coal Creek are significant because they are in an area where coal is directly under the surface of the soil. SVT2 varies from SVT1 in that it is downstream of the Erie Sanitation Lagoon.

SVT3. This unnamed creek was sampled two miles north of Highway 254 and 2-1/2 miles east of the Boulder-Weld County Line road northwest of Longmont. This creek is a typical tributary carrying return flows to the river. Most of the return flows in this creek are due to seepage into the creek and subsurface drainage, and tailwater.

SVT4. This small creek runs parallel to Interstate 25 and about one-half mile east of Interstate 25. It was sampled at a point 2 miles south of Highway 119 east of Longmont. This creek is not discharging to the St. Vrain -- rather it is intercepted by the Rural Ditch.

C. Subsurface Drains in the St. Vrain Creek Area

SVD1. This drain is located on a truck farm east of Longmont. Most of the water problem is apparently seepage from upland irrigated regions. Figure A-5 shows a map of the drain and groundwater flow direction. It is expected that large quantities of fertilizer and water are applied to this land, as this is the practice on most truck farms.

SVD2. This drain removes water table problems from about 80 acres. Most of this is in corn. This land received a manure application plus about 45 pounds nitrogen applied as chemical fertilizer to the corn plus 115 pounds per acre P_2O_5 applied to the corn. The grain occupied about 20 acres and received approximately 22 pounds nitrogen and 57 pounds P_2O_5 applied as chemical fertilizer. It had been a long time since the field had been irrigated when the sample was taken and most of the water flowing in the drains is expected to be groundwater flowing in a horizontal direction. Shale formations are not very deep below the surface.

SVD3. This is a lower drain on the same farm as the SVD2 drain. This drain is located right on top of the shale. It should be noted that both of these drains drain into ponds for reuse.

SVD4. This tile drain drains about 40 acres of corn, just about all of which have been irrigated in the last few days. This land received about 74 pounds N per acre and about 70 pounds of P_2O_5 per acre applied as commerical fertilizer in the spring. This drain also has an inlet which will allow tailwater inflow; however, this is not flowing at the current time. (Figure A-6)

SVD5. The location of this drain and drain SVD6 are portrayed on Figure A-7. These drains relieve the water table problem on the side of a hill sloping off of a shale plateau which is irrigated.

SVD6. Near SVD5. Turkey manure used as fertilizer. (Figure A-7)

D. Tailwaters and Other Samples in the St. Vrain Area

SVW-1. This tailwater sample was taken off the field drained by drain SVD4.

V. SOUTH PLATTE RIVER SAMPLING POINTS

A. Points on the River

SPGS-1. South Platte River at Henderson, Colorado. This USGS station located a few miles south of the Weld County Line; however there are no significant discharges into the river between the gaging station and the Weld County Line. The flow in the river that morning were made up of Denver Metro sewage returns, industrial returns from the Denver area, Clear Creek flows, as well as irrigation return flows.

SPR-1. South Platte River at Fort Lupton, Colorado. This sample taken at the Highway 52 bridge has received a few returns primarily from seepage into the river. The valley to this point is largely non-irrigated pasture alluvial soils which will conduct large quantities of seepage. A few return flows exist through this stretch.

SPR-2. This station is the South Platte River at Road 14 north of Fort Lupton. This station is about 2 miles north of Fort Lupton and is the primary discharge stream to Fort Lupton in the Fort Lupton lagoon effluent. There are probably not many significant agricultural return flows through this stretch.

SPR-3. South Platte River at Road 28 south of Platteville. This station is just south of Platteville and several diversions are made in the stretch between this station and SPR-2. Return flows probably impact the stream through this stretch mostly due to seepage.

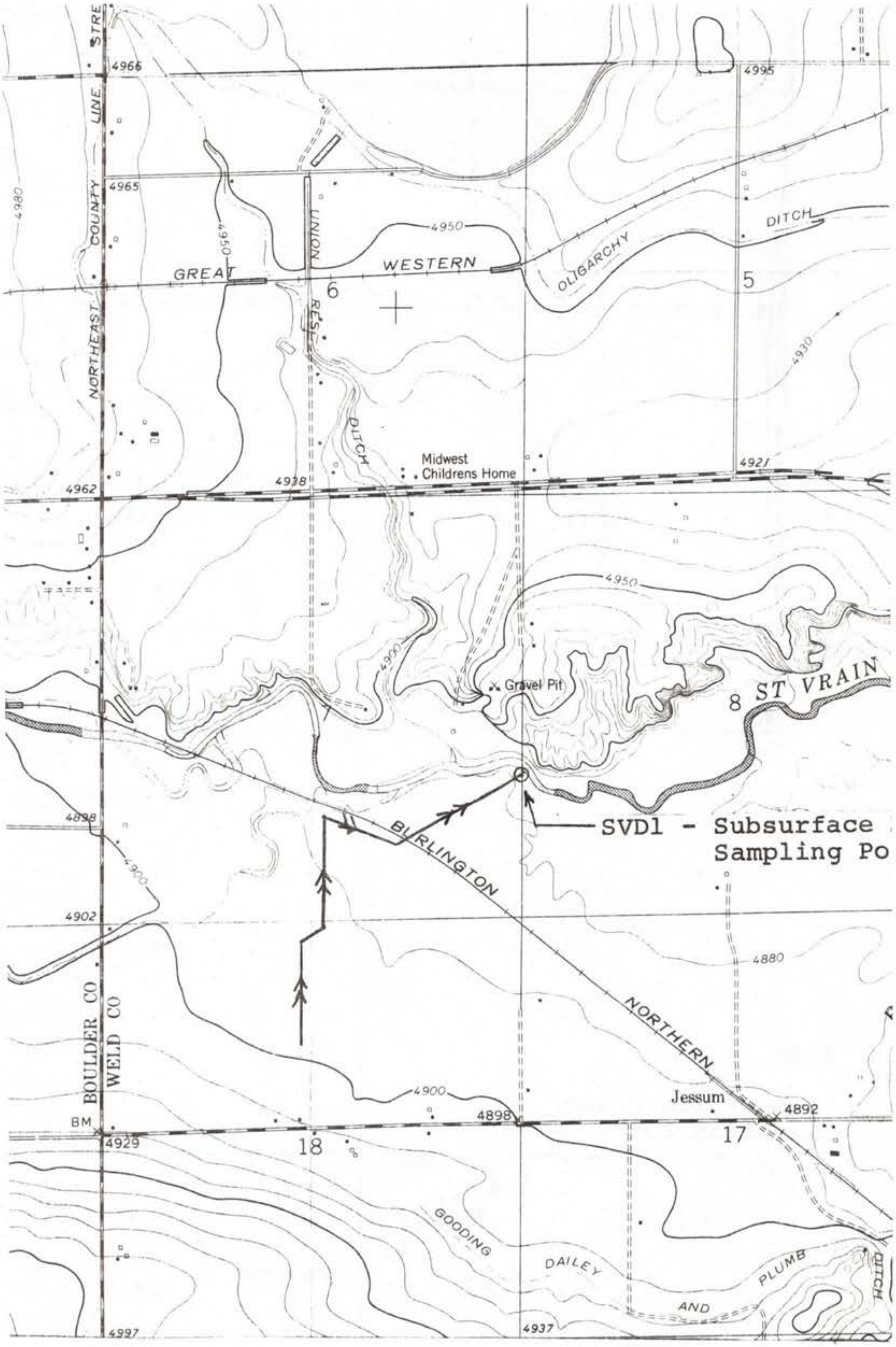
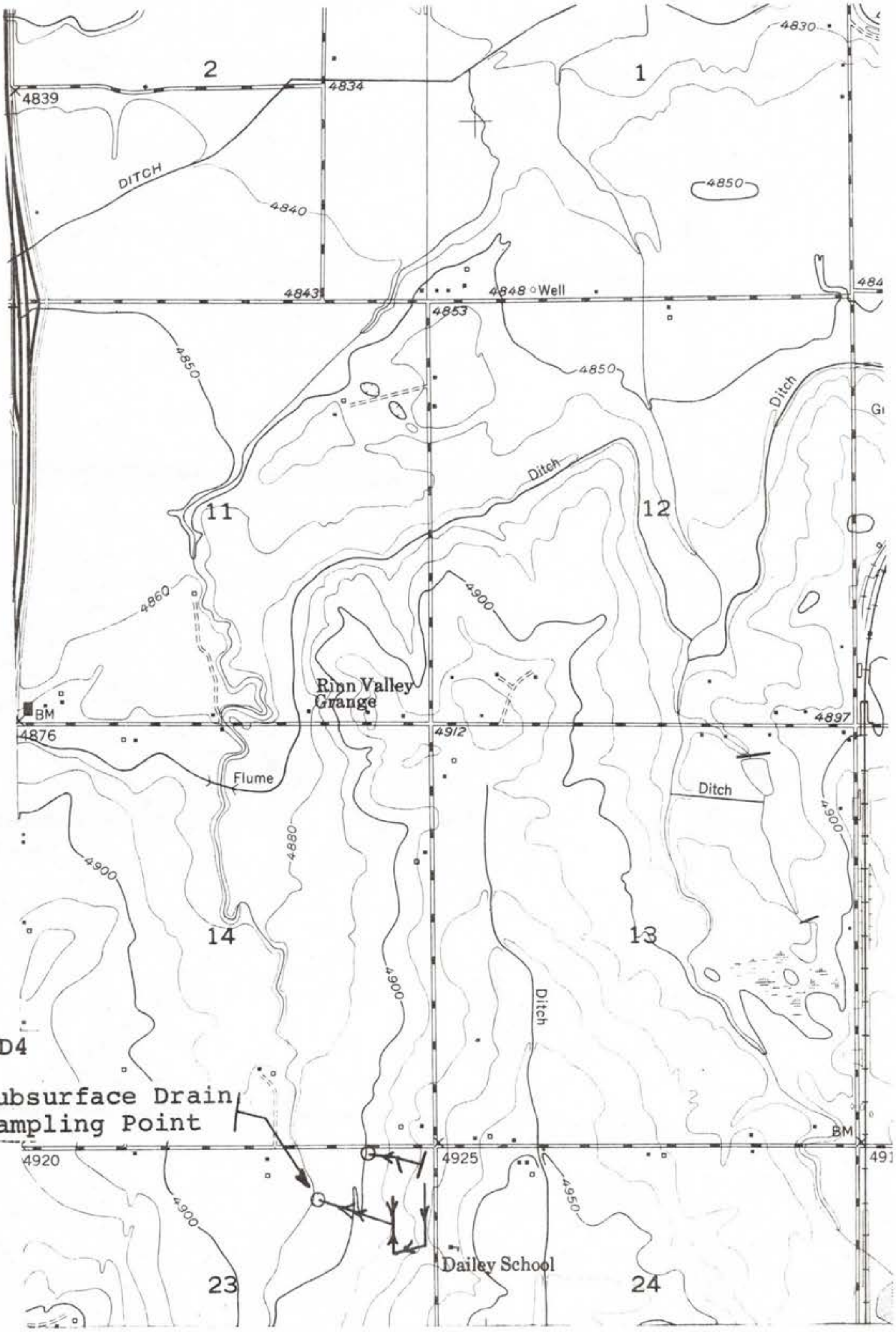


Figure A- 5 Subsurface Drain SVD1



SVD4

Subsurface Drain
Sampling Point

Figure A- 6 Subsurface Drain SVD4

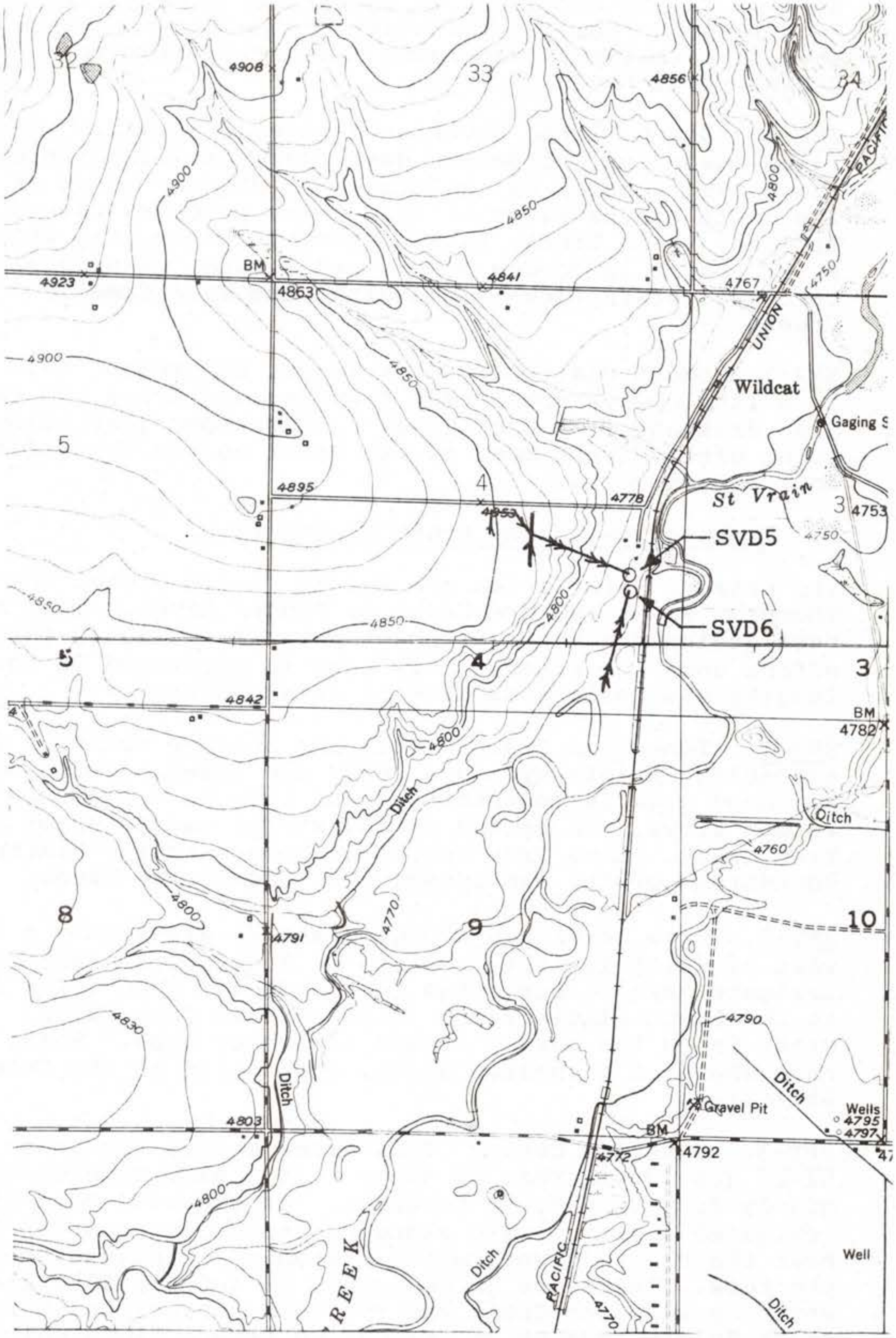


Figure A- 7 Subsurface Drain SVD5 and SVD6

SPGS-2. South Platte River at Kersey, Colorado. This station is not currently in operation; however, records were kept in prior years. The station receives flow from the several tributaries returning irrigation flow from the Larimer-Weld region.

SPR-4. South Platte River at Kersey, Colorado. This sample taken essentially from the same place as SPGS-2 which is at the gaging station on the bridge on Highway north of Kersey. The South Platte River at this point receives return flows from St. Vrain Creek, Little Thompson River, Big Thompson River, Cache la Poudre River, and several other streams carrying return flows--including Lone Tree Creek and Crow Creek.

SPR-5. South Platte River at Kuner, Colorado. This station is a little ways downstream from station SPR-4 and receives also drainage from Crow Creek. Diversions just below this point often divert most of the water to the Riverside and Empire Reservoirs.

B. Tributaries to the South Platte River

The primary tributaries are the St. Vrain Creek, the Big Thompson River and the Cache la Poudre River. They have not been assigned numbers although data is available for their effect upon the river. This data is portrayed in the more lengthy discussions of each of these rivers.

SPT-1. Lone Tree Creek. This has a large drainage area extending up into Wyoming. Only the lower portion of this drainage area is contributing and this is due to the irrigation return flows. No sewage or industrial wastes enter Lone Tree Creek. Lone Tree Creek discharges to the Platte just downstream of the confluence with the Poudre River.

SPT-2. Crow Creek has a huge drainage area, only a small part of which is irrigated and it is expected that only the irrigated area contributes to the flow. Crow Creek discharges to the South Platte River just upstream from Kuner. The creek is on the border of the irrigated area. Soils often have shale at a shallow depth, especially in the Galeton and Gill area.

SPT-3. Boxelder Creek. This creek enters the South Platte River just downstream of Kuner. It drains an area extending nearly down to Hudson, Colorado. In general, most of the irrigated area is right along the creek, except for the area near the Platte River, which probably contributes most of the flow. There are no municipal or industrial wastes entering Boxelder Creek and the flow can be considered to exist solely because of irrigation return flows which primarily return to this creek by seepage.

C. Other Tributaries to the South Platte Basin

Other tributaries such as the Beebe Seep and a few others never actually return to the river. They therefore do not impact the water quality in the river.

D. Drains to the South Platte Basin

SPD-1. The drain portrayed on Figure A-8 relieves the high water table from about 50 acres of corn. This water is primarily the result of a horizontal flow towards the South Platte River which is primarily produced from leaching from the irrigated area above the drain. A shale lens exists underneath this land, impeding downward movement of the water table. The effluent from this drain, which usually has only a small flow, arrives at Rehmer Lake. The water from this lake is eventually used for irrigation, as it discharges into the Evans Town Ditch.

SPD-2. This drain removes the high water table from about 100 acres of corn below the Greeley-Loveland Canal. Flow is a result directly from seepage out of the Greeley-Loveland Canal. A feedlot once existed on the upstream part of this area. This feedlot was abandoned in 1971, although it is expected that high nitrates still exist in the soil. The stream discharges to an open ditch tributary to the Ashcroft Draw. This drain is shown on Figure A-8.

SPD-3. This drain is located about halfway between Barnesville and Gill. The drain affects about 80 acres of corn. The field is underlayed by a shale formation which is generally in the neighborhood of three to seven feet below the surface. Water flow comes from seepage from the irrigated area below the Greeley No. 2 Ditch as well as from the ditch itself. Drain SPD-3 discharges into Crow Creek which is sampled later. There are several diversions on Crow Creek which prevent this flow from every returning to the South Platte. Of the 80 acres affected by this drain, about 40 acres are in corn and 40 acres are in alfalfa. Fertilizer usage was as follows:

	Pounds/Acre		
	N	P_2O_5	K_2O
Corn (40 acres			
Spring, 1976	80	50	5
Summer, 1976	40# as anhydrous ammonia		

(Figure A-9)

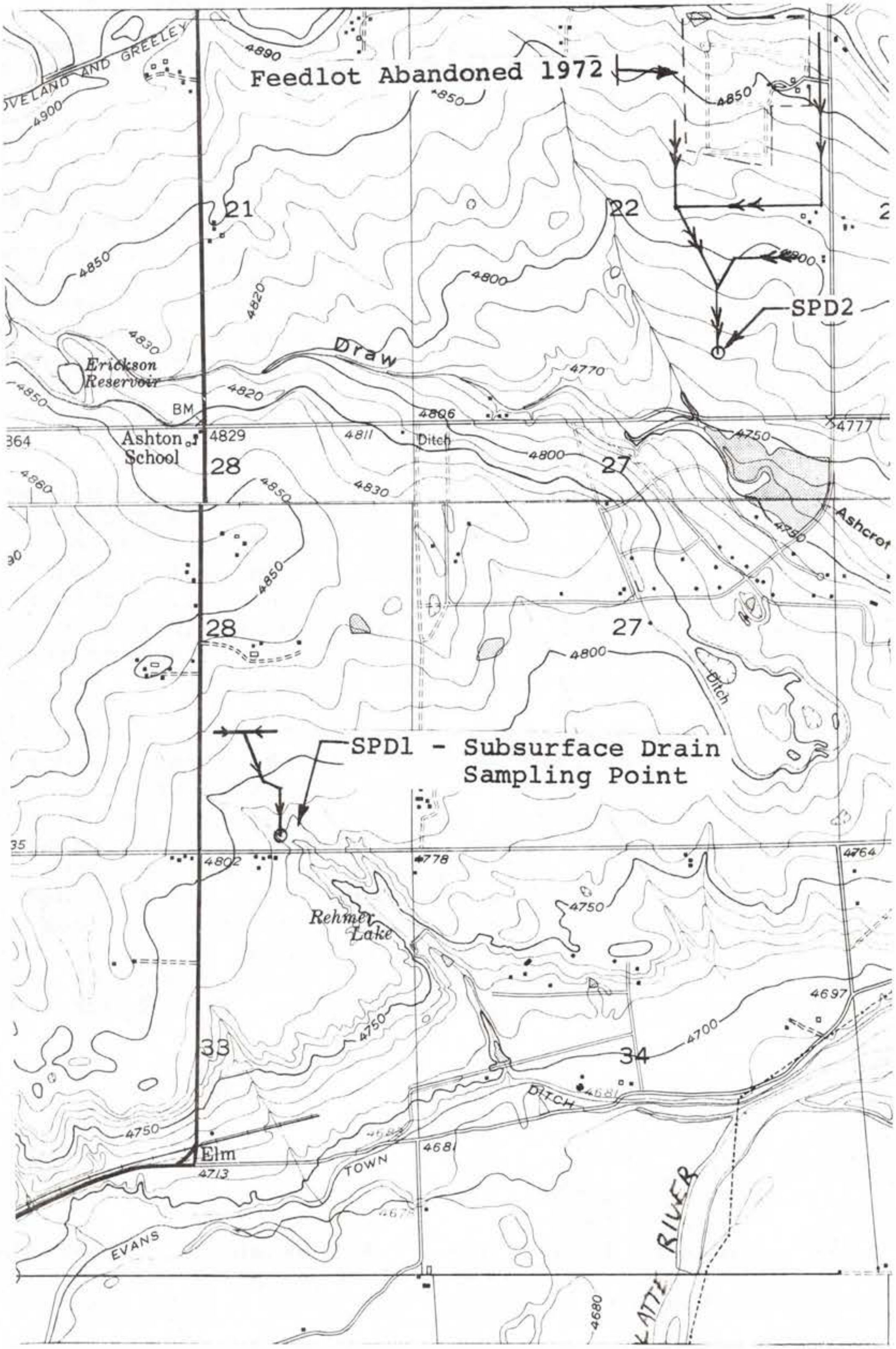


Figure A- 8 Subsurface Drain SPD1 and SPD2

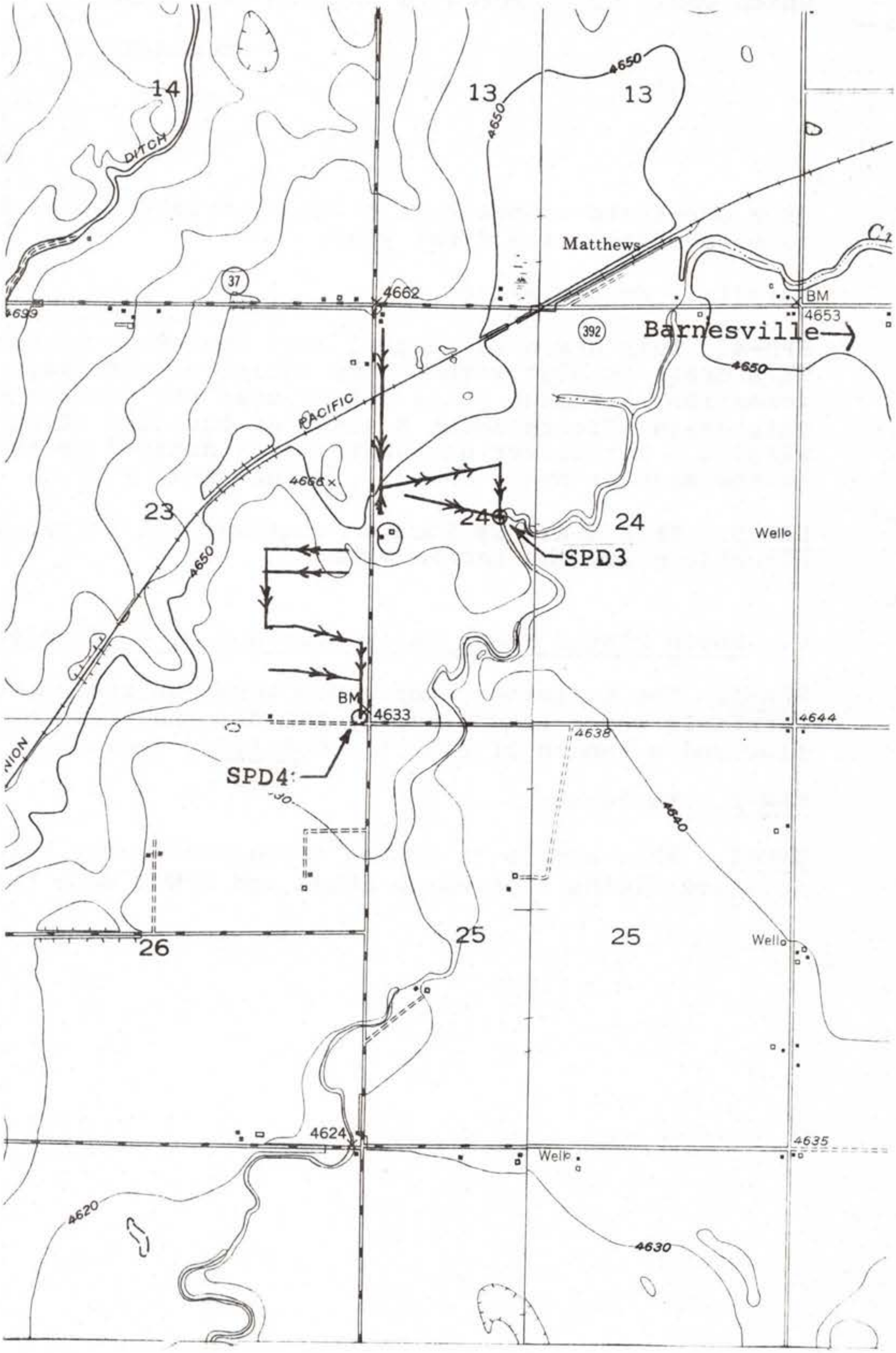


Figure A- 9 Subsurface Drain SPD3 and SPD4

In addition to this, the corn received 25 tons of manure which would be expected to analyze as follows:

Pounds/Acre		
N	P_2O_5	K_2O
300	75	225

From one-third to one-half of the nutrients would be expected to be available the first year.

Alfalfa: No fertilizer.

SPD-4. This drain is located just southwest of drain SPD-3. This drain is also with a pump outlet and overlays a shale formation, although it is not as near the surface as SPD-3. This drain affects about 8 acres of corn and 20 acres of alfalfa. Fertilizer use on the area drained by this drain is the same as drain SPD-3. (Figure A-9)

SPD-5. This drain is located southeast of Kersey and is directly below the Latham Ditch.

D. South Platte Basin Tailwaters and Other Samples

SPW-1. The tailwater sample was taken at the end of the cornfield which is drained by SPD-3. The field has light flow and a length of run of about 1,300 feet.

SPW-2. Tailwater.

SPO-1. This sample is of the irrigation water being used to irrigate fields from which SPD-3 and SPW-1 were taken.

APPENDIX B

Part 1: Data From The Sampling Program

This appendix contains data from the sampling program conducted for the Larimer-Weld Regional Council of Governments during the late summer of 1976. Also presented is data obtained by averaging historic water quality records maintained by the U.S. Geological Survey. This data is presented in Tables B-1 through B-5 for the Poudre (B-1), Big Thompson (B-2), Little Thompson (B-3), St. Vrain (B-4) and South Platte (B-5). Sampling sites on the rivers themselves are denoted by suffixes R and GS (Geological Survey) and are numbered from upstream to downstream.

Sampling site locations are shown in Figures 5.2.2-A, 5.3.2-A, 5.4.2-A and 5.6.2-A located in the main text. A detailed description of each sampling site is presented in Appendix A. Letters used in the naming of sampling sites refer to river basin and type of sampling site as explained in Appendix A, Section A-1.

TABLE B-1

Larimer-Weld Irrigation Return Flow Analysis
Data From Sampling Sites In The Poudre Basin

LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	mg/l except as noted										
				SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
PGS1	Mean Annual WY72-WY75				.01	.1	68							
	Monthly Mean WY72-WY75													
	Oct.						65							
	Nov.						61							
	Dec.						81							
	Jan.						61							
	Feb.						94							
	Mar.						82							
	Apr.						73							
	May						77							
	June						33							
	July						32							
	Aug.						60							
	Sept.						44							

TABLE B-1

LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	mg/l except as noted										
				SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
PR1	8/31/76	130		616		0.11	92							
PGS2														
PR2	8/31/76	97		21		0.22	188							
PR3	8/31/76	136		25		0.31	164							
PR4	9/15/76	120					844							
PR5	8/31/76	118		56		1.3	596							
	9/15/76	125				1.5	767							
PR6	9/15/76	15				1.9	815							
PR7	9/ 1/76	20		48		2.1	804							
PR8	9/ 1/76	46		64		5.0	1272							
PR9	9/15/76	15				5.9	1316							
PR10	9/ 1/76	68		89		4.0	1500							
PR11	9/ 1/76	54		72		6.0	1484							
PR12	9/ 1/76	19		24		4.7	1356							

TABLE B-1

LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	mg/l except as noted										
				SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
PGS3	Mean Annual WY71-WY75				.76	3.7	1118							
	Monthly Mean WY71-WY75													
	Oct.				.78	5.0	1352							
	Nov.				.83	4.6	1072							
	Dec.				.70	3.8	1078							
	Jan.				.91	3.8	1114							
	Feb.				1.2	2.8	1129							
	Mar.				.96	4.3	1202							
	Apr.				1.2	3.1	1390							
	May				.47	3.1	850							
	June				.31	2.1	517							
	July				.61	4.2	1105							
	Aug.				.50	4.1	1270							
	Sept.				.60	4.1	1338							

TABLE B-1

				mg/l except as noted									
LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
PT1	8/31/76	10		78	0.18	3.5	2032							
	9/15/76	8.8				3.3	1489							
PT2	9/15/76	1				5.6	3415							
PT3	8/ 3/76	8.2	5.3	14	0.2	4.5	1430	180	70	105	< 0.1	285	33	81
	8/10/76	6.9	7.4	135	< 0.1	7.4	1420	130	83	85	< 0.1	230	24	50
	8/18/76	6	11.0	56	0.2	3.4	1360							
PT4	9/15/76	5					1345							
PT5	9/15/76	15		112		6.6	900							
PT6	8/ 3/76	1	3.3	13	0.2	0.79	1580	90	135	115	< 0.1	185	38	100
	8/10/76	0.44	82	190	0.3	0.22	1170	90	93	87	< 0.1	185	26	55
	8/18/76	7	1.1	15	0.1	< 0.1	1910							
	8/24/76	6	12	32	< 0.1		1820	120	155	240	< 0.1	150	36	

TABLE B-1

LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	mg/l except as noted										
				SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
PT7	9/15/76	2.8		140		5.2	1465							
PT8	9/15/76	4				6.5	1248							
PT9	9/15/76	2				0.70	863							
PD1	9/15/76	0.22				2.8								
PD2	9/15/76	1				2.7	728							
PD3	9/15/76	0.22				1.5								
PD4	8/ 3/76	0.44			0.1	3.2	1500	84	150	105	< 0.1	335	33	850
	8/10/76	0.22	12	125	< 0.1	1.5	1400	120	66	85	< 0.1	270	24	500
	8/24/76	0.13			< 0.1	3.4	1340	165	85	110	< 0.1	305	28	780
	9/15/76						1267							

TABLE B-1

LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	mg/l except as noted										
				SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
PD5	8/10/76				<0.1	10.4	4760	410	375	360	<0.1	425	48	2800
	9/ 9/76	Near 0				13.0								
PD6A	8/ 3/76	.15			<0.1	7	1270	155	84	105	<0.1	370	31	670
	8/10/76	.22			<0.1	7	1330	120	100	105	<0.1	378	26	450
	8/18/76	.22			<0.1	7	1320	125	105	120	<0.1	370	24	710
	8/24/76				<0.1	8.8	1250	140	95	125	<0.1	365	24	600
PD6B	8/ 3/76	.22			<0.1	6.5	1770	195	99	135	<0.1	365	45	960
	8/10/76				0.2	5.9	2020	145	98	115	<0.1	340	36	650
	8/18/76		10	19	0.1	6.1	1630	200	62	135	<0.1	340	26	870
PD7	9/15/76	.44				8.0	1267							

TABLE B-1

				mg/l except as noted										
LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
PD8	8/ 3/76	0.8			0.1	9.9	970	160	46	68	<0.1	355	24	455
	8/10/76	0.44			<0.1	9.9	950	125	52	66	<0.1	355	20	340
	8/18/76	0.33			0.1	9.3	950	120	45	74	<0.1	355	20	365
PW1	8/10/76	0.1	0.3	18	0.1	9.0	1380	115	87	83	18	270	27	400
PW2	8/18/76	0.44	40	130	0.2	3.8	1360							
PW3	8/10/76	1.8	1190	2440	0.1	0.56	395	75	36	18	<0.1	195	9.9	115
PW4	8/18/76	0.22	2.9	6.1	0.8	3.8	1200							
PO1	9/15/76					9.7	748							
PO2	8/10/76		23	125	<0.1	<0.1	295	41	19	20	<0.1	79	20	115

TABLE B-2

Larimer-Weld Irrigation Return Flow Analysis
Data From Sampling Sites in The Big Thompson Basin

				mg/l except as noted										
LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
BR1	9/ 2/76			8		0.12	88							
BR2	9/ 2/76			62		0.35	300							
BR3	9/ 2/76			72		0.69	492							
BR4	9/ 2/76			84		1.4	728							
BR5	9/ 2/76			106		2.4	1248							
BGS1	Mean Annual WY 72- WY 75				.19	2.2	1438							

TABLE B-2

LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	mg/l except as noted										
				SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
BGS1	Monthly Mean WY 72-WY 75													
	Oct.				.22	3.5	1656							
	Nov.				.20	2.4	1546							
	Dec.				.15	3.0	1574							
	Jan.				.14	2.2	1666							
	Feb.				.31	2.1	1826							
	Mar.				.27	2.4	1776							
	Apr.				.37	2.0	1668							
	May				.11	1.1	811							
	June				.05	1.1	518							
	July				.10	2.2	1416							
	Aug.				.11	2.2	1394							
	Sept.				.19	2.1	1404							

TABLE B-2

				mg/l except as noted										
LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
BT1	9/ 8/76	Still	1.6	105	0.6	1.1	1850							
BT2	9/ 8/76	7.9	16	135	<0.1	.45	1910							
BT3	9/ 8/76	7.3	24	200	0.2	0.8	585							
BT4	9/ 8/76	0.3	2.3	9.6	0.2	0.11	970							
BT5	9/ 8/76	2.7	63	195	0.1	2.4	760							
BT6	9/ 8/76	2.7	9.9	33	0.2	1.3	705							
BT7	9/ 8/76	1.5	1.4	4.2	0.1	3.2	1270							
BT8	9/ 8/76	3	4.4	37	0.1	0.22	1780							
BT9	9/ 8/76	5	2.4	19	0.1	0.13	1070							
BT10	9/ 8/76	0.1	355		0.1	0.49	800	85	9.6	61	<0.1	580	5.7	270

TABLE B-2

LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	mg/l except as noted										
				SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
BD1	9/ 8/76	0.02			< 0.1	0.88	935	120	34	140	<0.1	550	7.1	285
BD2	9/ 8/76	0.09	1.6	1.1	< 0.1	2.4	505							

TABLE B-3

Larimer-Weld Irrigation Return Flow Analysis

Data From Sampling Sites in The Little Thompson Basin

				mg/l except as noted										
LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
LR1	9/ 8/76	3.3	1.6	2.3	0.1	0.32	705	165	41	48	<0.1	230	9.9	420
LR2	9/14/76	6.9		8		0.90	1200							
LR3	9/14/76	10				2.3	1633							
LR4	9/14/76	20				3.1	1460							
LR5	9/14/76	27		113		1.9	2259							
LR6	9/14/76	30				2.6	2163							
LR7	9/14/76	30		119		2.7	2067							
LR8	9/ 2/76			164		3.2	2180							
LR9	9/14/76	30		162		2.0	1392							
LR10	9/ 2/76			200		3.2	1872							
	9/14/76	32		184		2.0	1392							

LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	mg/l except as noted										
				SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
LT1	9/14/76	2.3		15		4.1	3126							
LT2	9/14/76	10				4.9	1250							
LT3	9/14/76	4.4		44		0.22	2452							
LT4	9/14/76	0.7				8.7	1007							
LD1	9/14/76	0.7				8.0	2259							
LD2	9/14/76	1				4.5	911							

B14

TABLE B-4

Larimer-Weld Irrigation Return Flow Analysis
Data From Sampling Sites In The St. Vrain Creek Basin

LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	mg/l except as noted										
				SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
SVR1	8/25/76	25	1.6	46	0.1	2.7	950	93	51	105	<0.1	225	14	740
SVR2	9/14/76	35				2.2	1007							
SVR3	9/14/76	40				2.4	1007							
SVGS1	Mean Annual WY 72-WY 75				.32	2.4	908							
	Monthly Mean WY 72-WY 75													
	Oct.				.39	3.3	769							
	Nov.				.39	2.5	941							
	Dec.				.35	3.4	912							
	Jan.				.37	1.9	874							
	Feb.				.53	2.7	890							

TABLE B-4

LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	mg/l except as noted										
				SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
SVGS1	Cont. Monthly Mean WY 72-WY 75													
	Mar.				.50	1.8	1098							
	Apr.				.35	2.0	1087							
	May				.19	1.8	697							
	June				.14	1.6	541							
	July				.22	2.5	948							
	Aug.				.15	2.8	1144							
	Sept.				.23	2.3	996							
SVT1	9/ 3/76			7		0.43	600							
SVT2	9/ 3/76			22		0.45	884							
SVT3	8/25/76	3-5	5.1	110	<0.1	2.0	1460	61	135	130	<0.1	280	21	810

LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	mg/l except as noted											
				SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
SVT4	8/25/76	3-5	170	890	0.1	2.5	830	67	39	130	<0.1	230	36	480
SVD1	8/25/76	0.6			<0.1	11.3	2520	225	135	210	<0.1	420	28	1320
SVD2	8/25/76	0.2			<0.1	3.4	3610	360	245	300	<0.1	335	36	2120
SVD3	8/25/76	0.2			<0.1	6.8	6070	380	460	610	<0.1	415	78	3600
SVD4	8/25/76	0.3	60	420	0.1	2.5	520	52	29	54	<0.1	160	21	170
SVD5	8/25/76	.04			<0.1	26.0	4860	270	365	540	<0.1	405	64	3120
SVD6	8/25/76	.12			0.1	11.3	4160	280	290	440	0.1	560	71	2160
SVW1	8/25/76		450	1280	0.1	2.0	515	44	38	68	<0.1	150	21	195

TABLE B-5

Larimer-Weld Irrigation Flow Analysis
Data From Sampling Sites In The South Platte Basin

LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	mg/l except as noted										
				SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
SPGS1	Mean Annual 1955 - 1973						611							
SPR1	9/ 3/76			6.0		3.5	660							
SPR2	9/ 3/76			63		4.0	636							
SPR3	9/ 3/76			10		0.78	584							
SPGS2	Mean Annual						1151							
SPR4	8/18/76	75	6.2	78	0.2	3.2	1370	130	60	120	< 0.1	250	36	555
SPR5	8/18/76	100	19	125	0.2	3.4	1240	130	60	125	< 0.1	255	41	580

TABLE B-5

				mg/l except as noted											
LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	SS	TOTAL P	$NO_2 + NO_3$ as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
SPT1	8/ 3/76	8	14	34	1.2	9.0	1790	96	98	250	<0.1	325	170	830
	8/10/76	10	5.8	45	0.4	8.6	1710	270	22	200	<0.1	335	100	650
	8/18/76	5	2.5	24	0.4	7.2	1600	250	15	205	<0.1	310	97	810
	8/24/76	7	10	125	0.4	8.3	1600	220	41	180	<0.1	300	44	790
SPT2	8/10/76	0.7	30	110	0.1	7.9	3170	220	84	410	<0.1	390	84	1550
	8/18/76	2	11	57	0.1	3.4	2130	170	87	330	<0.1	305	50	1070
	8/24/76	1-2	79	96	0.3	5.4	3210	185	85	480	<0.1	405	17	1940
SPT3	8/10/76	5	70	270	0.5	4.1	1400	150	58	200	<0.1	305	68	560
	8/18/76	5	17	185	0.4	.09	1420	125	59	210	<0.1	300	130	600
	8/24/76	15	130	370	<0.1	3.2	1220	125	59	140	<0.1	275	88	570
SPD1	8/ 3/76	.01			0.4	4.7	2960	84	250	240	<0.1	535	150	1820
	8/18-76	.002			0.1	5.0	3660	430	160	330	<0.1	480	43	2100

TABLE B-5

				mg/l except as noted											
LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
SPD2	8/ 3/76	0.32			< 0.1	15.6	1220	105	100	87	< 0.1	480	125	445
	8/18/76	0.18			< 0.1	1.9	1250	175	48	105	0.1	475	64	390
SPD3	8/ 3/76	0.53			0.1	9.7	2060	94	165	270	< 0.1	370	70	1240
	8/10/76	0.44			< 0.1	9.0	2170	215	98	270	< 0.1	384	60	950
	8/18/76	0.55			0.1	8.6	2430	250	80	330	< 0.1	370	72	1520
	8/24/76	0.44			< 0.1	8.3	1840	205	94	160	< 0.1	370	61	1260
SPD4	8/ 3/76	0.27			0.1	8.6	4660	225	150	740	< 0.1	550	285	3000
	8/10/76	0.22			< 0.1	6.8	4310	250	190	680	< 0.1	555	125	2150
SPD5	8/10/76	0.55			0.1	13.3	1260	140	58	135	< 0.1	275	67	480
SPW1	8/18/76	0.04	21	270	0.2	0.45	1020	84	88	77	< 0.1	150	17	520
	8/24/76	0.02	175	510	< 0.1	1.02	1140	87	94	105	< 0.1	200	17	660

TABLE B-5

LOCATION	DATE	FLOW (cfs)	TURBIDITY (Units)	mg/l except as noted										
				SS	TOTAL P	NO_2 + NO_3 as N	TDS	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
SP01	8/18/76	6	48	264	0.1	0.34	1000	78	66	77	<0.1	24	14	530

APPENDIX C

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