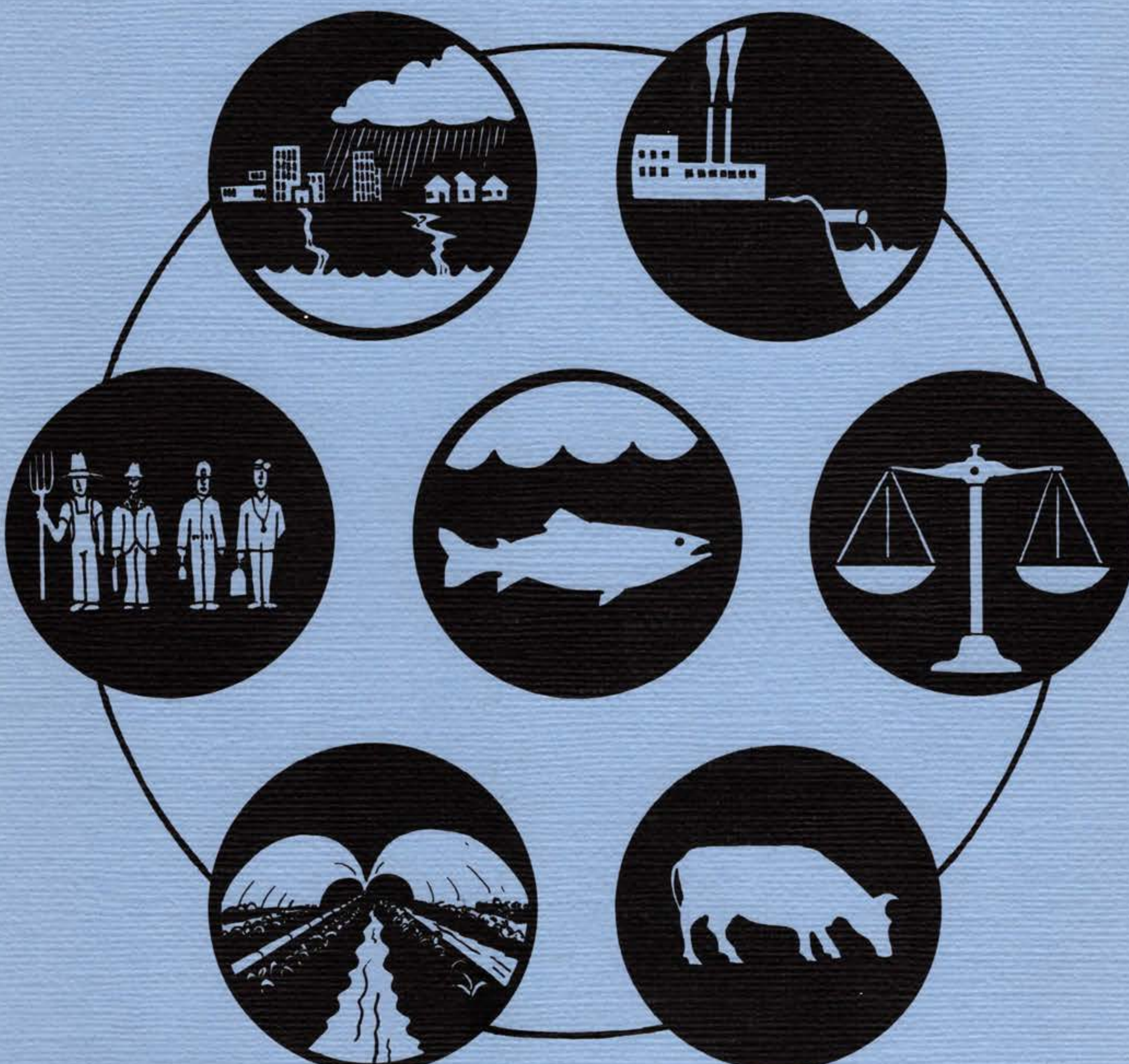
INTERIM REPORT — ENGINEERING

NON-POINT SOURCE CONTROL

ANALYSIS AND RECOMMENDATIONS



Water Quality Management Plan

LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS
LOVELAND, COLORADO

PREPARED BY
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Larimer-Weld Regional Council of Governments

208 AREAWIDE WATER QUALITY MANAGEMENT PLAN

NON-POINT SOURCE POLLUTION CONTROL

Prepared For

Larimer-Weld Regional
Council of Governments

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1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

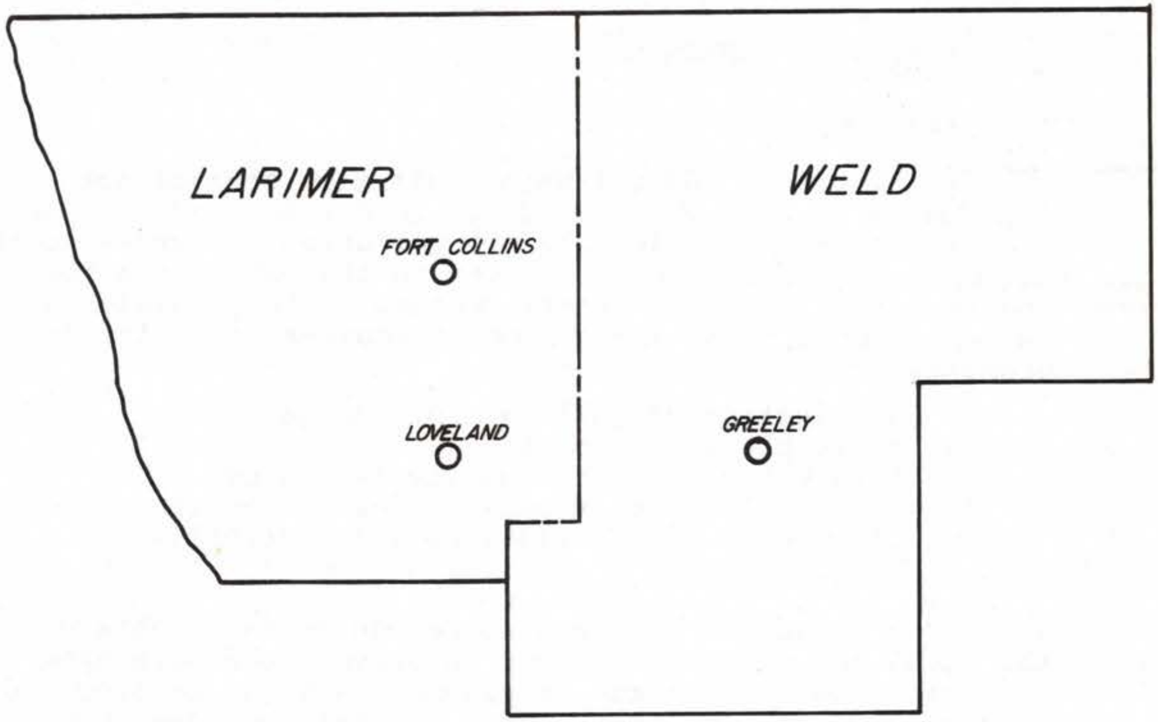
The intent of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) is to develop and implement a process by which essentially all pollutional sources to the nation's waters can be eliminated to the extent feasible and the integrity of these waters restored. The legislation addresses both point and non-point sources of pollution. Goals promulgated by the Act include:

- Elimination of pollutant discharge into navigable waters by 1985;
- Attainment of water quality levels by July 1, 1983, that provide for protection of aquatic life, wildlife, and recreational activities.

It is the policy of Congress to recognize the rights of the local and state government to prevent and eliminate pollution and to plan the development and use of land and water resources. Section 208 of the Act provides that funds may be made available to local agencies and promulgates guidelines for the development of areawide planning processes. Control of non-point pollutant discharges is an integral feature of water quality management.

This report has quantified the extent of non-point pollutional impacts to the waters of the Larimer-Weld region and delineated the best practices to be utilized by the region for non-point pollutant abatement. It is intended to be both an assessment and guidance document for local pollution control. Figure 1.1-A shows the location and areal extent of the Larimer-Weld region within Colorado.

The relative level of effort expended on the subjects of silviculture, construction, septic tanks and leachfields, sludges and solid waste management was less than that devoted to urban runoff. In general, and specifically for the towns of Estes Park, Fort Collins, Greeley, and Loveland, this reflects the relative emphasis these subjects were given in the COG 208 work plan in terms of funding allotments.



LARIMER-WELD COUNTIES

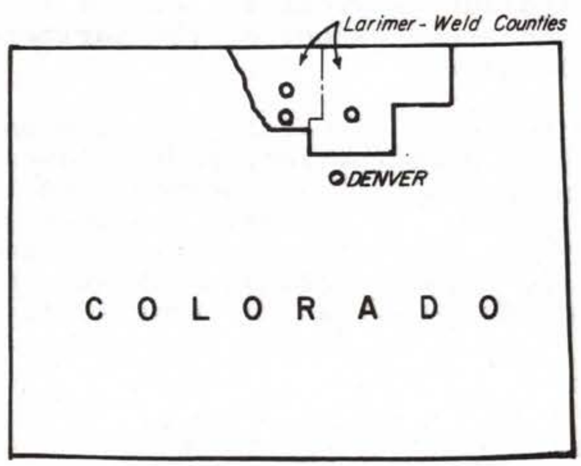


FIG. 1.1-A. LOCATION MAP - LARIMER - WELD REGION

1.2 APPROACH TO DEVELOPING NON-POINT SOURCE CONTROL IMPLEMENTATION PROGRAMS

For each of the non-point source categories examined in this study, strategies are recommended to meet fully the objectives of Section 208 (2) requiring the establishment of a"process to identify....and set forth procedures and methods to control....(non-point source pollution) to the extent feasible....". The proposed "implementation strategies" (used synonymously with "implementation process") recognizes four fundamental implementation responsibilities described in "Institutional and Financial Analysis and Recommendations, Volumes I and II, (Larimer-Weld COG, Nov. 1977). They are:

- Areawide planning
- Management
- Operations
- Regulations

Further the implementation strategies take into account the following factors:

1. The state of the art of analytical tools;
2. The availability or lack thereof of an adequate data base;
3. The scope and level of analyses conducted to date;
4. Ongoing related programs;
5. The severity of the pollution problem.

The recommended implementation plan will be defined in terms of a long-range (20-year) program designed to meet broadly-stated objectives. Additionally one-year Action Plans (AP) are described for each of the implementation functions described above. The Action Plans will serve to initiate the implementation process by defining specific tasks and assignments which implementing agencies must accomplish in a one-year period. Tasks include such requests as areawide planning and analysis; reporting; monitoring and evaluating; detailed facility planning; development of rules and regulations; and others. Following completion of the AP's, the long-range program objectives will be modified, if needed and subsequent one-year action plans developed.

The tasks defined herein are considered to be necessary components of a long range non-point source control strategy. The prioritization and implementation of the tasks will be dependent upon available local, state and federal resources and funding. The assignment of responsibilities, prioritization and financing of tasks will be included in the Larimer-Weld 208 Water Quality Management Plan.

1.3 SUMMARY AND CONCLUSIONS

Non-point sources of pollution are extremely difficult to quantify and manage because of their diffuse nature. Unlike point sources of pollution which are discharged at a specific location, non-point sources may be generated over a wide geographic area. Water quality impacts may be immediate or may be cumulative over a long period of time. Non-point sources of pollution need additional monitoring and analysis to provide officials of the region with specific information for sound water pollution control administration but measures can be taken now that relieve impacts. Guidelines and recommendations formulated herein as part of the Larimer-Weld Water Quality Management Plan will serve to guide local administrative decisions as they relate to non-point sources of pollution.

1.3.1 Urban Runoff

The extent of urban runoff pollution in the major urban areas including Greeley, Ft. Collins, Loveland and Estes Park was estimated. Wasteloads for suspended solids, biochemical oxygen demand and nitrogen were calculated for the years 1975 and 2000 using conventional methodologies and field data extrapolated from the Denver metropolitan area and from authoritative studies. In relationship to other point and non-point pollution generators, urban runoff is not believed to contribute significantly to nitrogen and BOD in surface and ground water bodies. However, sediment generated from urban activities may cause concern because of the wide variety of pollutants which are absorbed, adsorbed or otherwise adhere to sediment. Such pollutants include heavy metals, asbestos, petroleum compounds, pesticides and others. The fate of these pollutants on water quality are not known.

A determination of the short-and long-term in-stream effects is complicated by the lack of an adequate water quality data base and the complex system of agricultural ditches, canals and reservoirs which intercept much of urban stormwater discharges. As a consequence, an aggressive structural program for urban runoff pollution control alone is not recommended at this time.

However, the establishment of a region-wide combined stormwater management and water quality control program could be effective in reducing pollutant loads and preventing flood hazard and damage. With regards to the status of stormwater management, a number of findings were reached. They are:

- The regional agricultural water supply system of ditches and reservoirs is frequently used to contain and transport runoff generated within urban areas. Community growth in the two-county area is such that reliance on the agricultural system to satisfy urban drainage requirements may no longer be blindly assumed. Ditch systems may not possess channel capacities capable of conveying the volume of tributary inflow. Flooding associated with "breakouts" could have severe economic and human impact;

- The agricultural community is becoming increasingly aware of damage to ditches and reservoirs attributable to urban runoff. Channels may be physically impaired by excessive scouring; reservoir capacity may be reduced through sedimentation;

- Any future effort to remedy urban drainage problems in the region should incorporate water quality considerations as a basic component;

- Study should be conducted to identify areas of greatest pollutional concern. Mitigation strategies should be formulated which may include structural and/or non-structural options;

- The matter of urban stormwater discharge to components of the agricultural water supply system should be addressed. Additional drainage studies to assess total impact of urban runoff on the irrigation system as well as hydraulic analysis of ditches and reservoirs will be in order. Negotiations should be conducted with ditch companies for the purpose of drafting a formal agreement which explains rights, obligations, and liability of all parties involved. Legal questions of urban runoff disposal need to be resolved;

- Urban stormwater should be the subject of a comprehensive monitoring program. The program will determine whether the recommended controls implemented in the region are adequate to protect the aquatic environment;

- A lack of coordination exists in the region among entities responsible for drainage control. Fragmented policy results in less than optimum mitigation of pollution, increased hazard of flooding, and generally high costs to taxpayers for flood control related activity.

Current utilization of irrigation conveyance systems for management of stormwater runoff is encouraged because it provides water for agricultural interests and prevents the conveyance of potential water quality degrading materials into waters that may support high quality aquatic life. Evaluation of the complex impacts of these waters on agricultural lands is in order, plus due consideration for protection of public health, a necessary prerequisite to ditch discharge.

In light of these findings a program has been defined to:

1. Increase coordination among entities involved in stormwater management;
2. Identify sensitive areas;
3. Define detailed programs for designing, financing, and constructing stormwater management systems with pollution control features;
4. Evaluate the need for and implement, if appropriate, codes and ordinances for on-site attenuation of stormwater runoff;
5. Increase data base and exchange of relevant data and information;
6. Continue ongoing housecleaning-type activities, including street-sweeping and litter control which are currently adequate in the major urban centers;
7. Monitor and evaluate the progress of the urban runoff control program.

1.3.2 Silviculture

The extent of water quality impacts of silvicultural and recreational activities in the mountain areas of the region are not known. However, the extent of silviculture and recreation is such that water quality impacts, particularly sediment, could be expected. Data and analysis is needed before an aggressive control program is developed. The U. S. Forest Service has developed a plan of study to determine the extent of pollution in the mountain areas and control options. It is recommended that this study or a study of similar scope be undertaken.

It has been estimated that in 1975 the rate of utilization of National Forest areas of the region exceeded 1.8 million recreation visitor days with an estimated 2.6 million visitor days by 1980. Recreation includes snowmobiling, off-road vehicle use, camping, hiking and horseback riding. With the substantial increase in urban growth occuring along the front range, a corresponding increase in recreational use can be anticipated. Such uses can be disruptive to natural vegetation and cause increased sediment loads. Currently recreational use of the National Forest areas is largely unregulated. As an interim step in determining long range control programs if determined appropriate as a consequence of further analysis, a public education program should be implemented aimed towards modifying recreational practices to mitigate potential adverse water quality impacts.

1.3.3 Construction

Sediment generated by construction activities are known to have substantial local adverse impacts. As part of a comprehensive review and evaluation of non-point source control codes and regulations, construction related ordinances should be strengthened. Attempts should be made to identify critical areas where unregulated construction activities would potentially cause significant adverse ecological on water quality impacts.

The land use suitability maps and analyses contained in the report, "Larimer-Weld Region Land Use Alternatives, Analysis of 20 Year Growth Demands and Impacts," (Larimer-Weld COG, September 1977) should be used as a reference document.

1.3.4 Septic Tanks and Unlined Sewage Lagoons

Leachate from failing septic systems are known to degrade ground and surface water quality in the region. A complete inventory of impacted areas has not been developed. It is not known whether unlined sewage lagoons are causing water quality degredation or localized health problems. An implementation program for failing septic systems and unlined sewage lagoons would include the following components:

1. Strengthen the capabilities of management and regulatory agencies to regulate the design and location of new septic systems;
2. Assess the extent of groundwater pollution resulting from unlined sewage lagoons and develop a program to control the problem;

3. For areas where it is documented that potential health problems occur as a result of failing septic systems, develop a program and capability for amelioration including improved operation and maintenance, abandonment, and construction of small community or individual sewage systems.

1.3.5 Sludge, Solid Waste and Hazardous Substance Management

Evaluation of water quality impacts resulting from solid waste and hazardous substances management practices is beyond the scope of this study. Management of manure from concentrated animal feeding operations is believed to contribute to increases in groundwater nitrogen levels in certain areas of the region. Best Management Practices for manure management as a resource is the subject of a separate study. However, cursory review of major land disposal sites (dumps and sanitary land fills) reveal that better operational practices are warranted which could mitigate potential adverse water quality impacts. Basic components of the implementation program include:

1. Define through further study the extent, nature and location of significant existing or potential ground and surface water quality degradation resulting from solid waste management;
2. Establish policies, programs and appropriate regulatory measures to abate or prevent pollutant loadings from solid waste management;
3. To fully integrate water quality management and solid waste management planning;
4. To develop guidance and education for the handling, transport, disposal and spill prevention of hazardous substances.

2.0 URBAN RUNOFF

Areawide plans for stormwater control are oriented toward major urbanized areas of a region. Management strategies in the Larimer-Weld region will be developed herein for the cities of Fort Collins, Greeley, and Loveland.

2.1 GENERAL IMPACTS OF URBAN RUNOFF

Urban runoff in the Larimer-Weld region has become a concern within the last few years. In 1971 Fort Collins acquired assistance in preparing a drainage and runoff study. In 1973 the city of Greeley developed their Comprehensive Drainage Plan to provide information on design and construction of storm sewers. Also in 1973, a Larimer-Weld Regional Storm Drainage Study was completed. None of these recent documents discusses the effects of urban stormwater drainage upon water quality.

2.2 EFFECTS OF DEVELOPMENT ON RUNOFF

2.2.1 Runoff

Urban runoff is an important aspect of municipal water management. Development of residential, commercial and industrial facilities makes more land previously pervious to rainfall impervious. Such a relationship, expressed by the "rational method", is depicted in the following equation: $R = CiA$, where

R = Total runoff of water
C = Runoff coefficient
i = Rainfall in inches per hour
A = Area expressed in acres

The runoff coefficient in the above equation can vary from 0.10 in parks and grassed open areas up to 0.95 for roofs and asphalted areas. Table 2.2.1-A shows runoff coefficients for various surfaces. As the amount of development increases (i.e., from open spaces to houses and asphalt), the coefficient increases and hence the total amount of runoff water from a given area increases. A change of runoff coefficient from 0.10 to 0.50 as a drainage basin experiences development increases the runoff water from a given storm by five times. This means five times the amount of runoff can reach a receiving stream and five times the amount of water must be managed to protect the downstream facilities from flooding.

TABLE 2.2.1-A. RATIONAL METHOD RUNOFF COEFFICIENTS FOR COMPOSITE AREAS

CHARACTER OF SURFACE	RUNOFF COEFFICIENTS
Streets:	
Asphalt	0.70 to 0.95
Concrete	0.80 to 0.95
Gravel	0.15 to 0.30
Drives and Walks:	0.75 to 0.85
Roofs:	0.70 to 0.95
Lawns, Sandy Soil:	
Flat, 2%	0.05 to 0.10
Average, 2 to 7%	0.10 to 0.15
Steep, 7%	0.15 to 0.20
Lawns, Heavy Soil:	
Flat, 2%	0.15 to 0.20
Average, 2 to 7%	0.20 to 0.25
Steep, 7%	0.25 to 0.35

Figure 2.2.1-A shows runoff characteristics from a generalized area experiencing growth. Peak flows from storms in an undeveloped area are five times smaller than flows from a fully developed area. The danger of flooding is greatly increased when an area is developed. Figure 2.2.1-B illustrates how proper management can reduce flooding danger. Proper stormwater management involves the use of good design principles and current technology to allow slow release of stormwater volumes.

The rational method is generally appropriate for determining runoff in hydrologic basins of less than one square mile in area. More sophisticated methodologies are required for large urban drainages.

2.2.2 Costs

A feature of urban runoff is that cost of facilities is often absorbed by people experiencing the problem and not the ones causing this problem. Generally, towns are situated

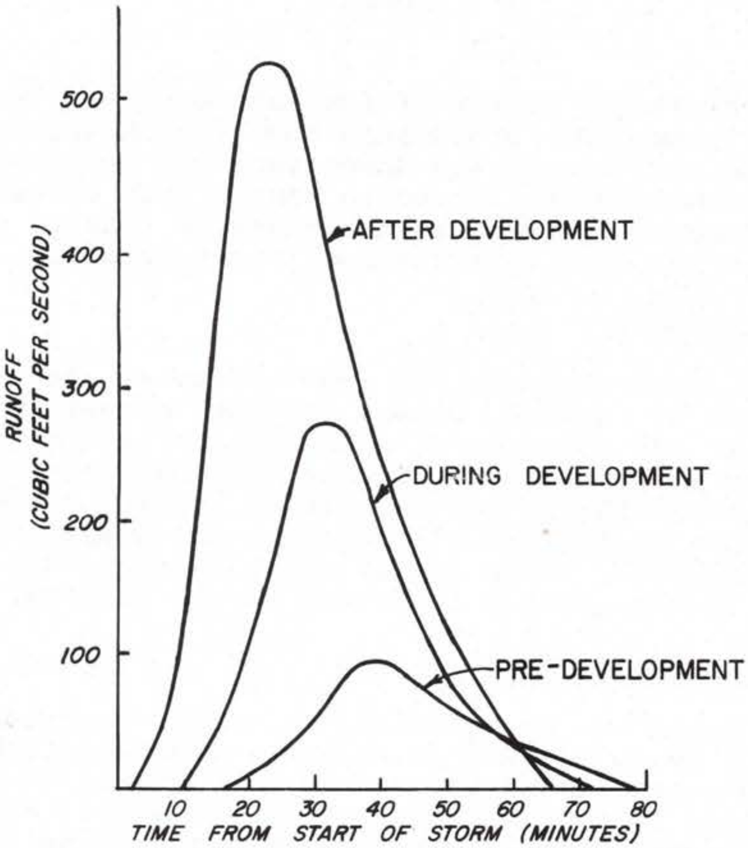


FIG. 2.2.1-A. HYDROGRAPHS OF DEVELOPING AREA SHOWING VARIOUS STAGES OF DEVELOPMENT

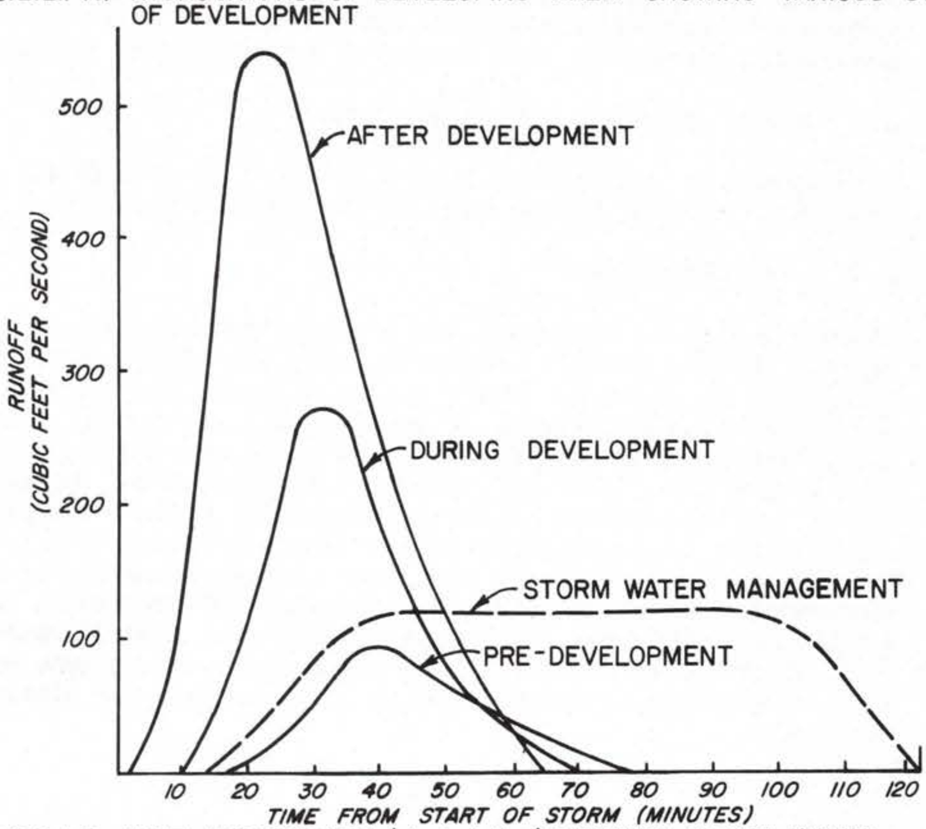


FIG. 2.2.1-B. UNIT HYDROGRAPH (dashed line) SHOWING STORM WATER MANAGEMENT APPLIED TO STUDY AREA

near rivers at the bottom of drainage basins. As the municipalities grow, stormwater runoff from upslope development is transported downstream and people located downslope are forced to manage this excess water. Generally established residences tend to pay for protection from upstream settlement runoff.

2.2.3 Groundwater

Increased imperviousness has other effects. Deep percolation of rainfall waters provides necessary groundwater for recharge of subterranean basins. By channeling stormwater runoff away from the underlying soils, a municipality can experience increased cost of water supply as supply wells must be dug deeper to reach the groundwater. These deeper wells increase the cost of water transportation into city supply systems.

2.2.4 Beneficial Uses

Rainfall water can be channeled to supply beneficial uses instead of being allowed to escape downstream from urban areas. One beneficial use served extensively in the Larimer-Weld region is irrigated agriculture. Many towns within the area convey runoff water directly to irrigation ditches that pass through the city. Detention ponds and storage reservoirs contain runoff water which can provide aesthetic benefits and recharge groundwater supplies.

2.3 WATER QUALITY OF URBAN RUNOFF

An important aspect of runoff water, highlighted in this chapter, is the water quality of urban drainage.

2.3.1 Pollutants

Figure 2.3.1-A compares the concentrations of biochemical oxygen demand (BOD), suspended solids (SS), and total coliform in sewage, storm water runoff and treated sewage. The high concentration of pollutants in urban runoff can contribute greatly to the water quality degradation of a river system. BOD can reduce the amount of oxygen in the river and therefore endanger aquatic life. Suspended solids can result in aesthetic deterioration, reduced light penetration, increased mud and sludge accumulations in waterways, and can carry nutrients and bacteria to waterways. Bacteria and virus in urban runoff can contribute to public health problems. Increased treatment costs are experienced when downstream users utilize this water for domestic purposes.

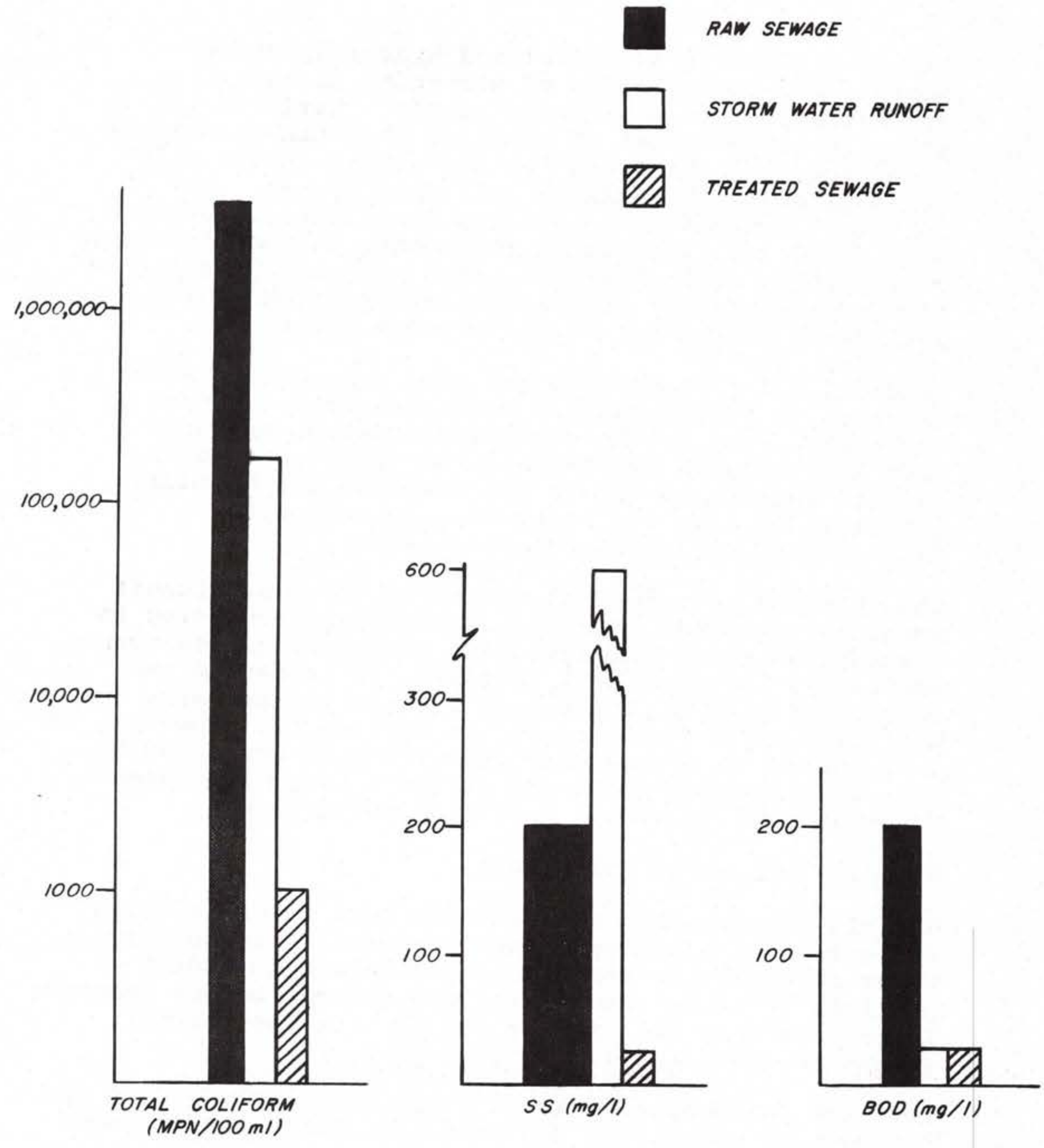


FIG. 2.3.1-A. CONCENTRATIONS OF BOD, SUSPENDED SOLIDS, AND TOTAL COLIFORM FOUND IN STORM WATER RUNOFF COMPARED TO RAW AND TREATED SEWAGE (a)

(a) Based on Field et al, 1976

Figure 2.3.1-B is a generalized hydrograph that depicts the relationship of suspended solids concentration and stormwater runoff. Early in the storm, a large amount of material that can contribute to pollution is "flushed" by the storm. After this first flushing of roadways and storm sewers, the pollutant concentration quickly diminishes. Although Figure 2.3.1-B illustrates the change in concentration of suspended solids through time, such an illustration also represents the general characteristics of all pollutants discharged during a storm event.

Figure 2.3.1-C represents the same generalized storm depicted in Figure 2.3.1-B with stormwater control measures. Many of the stormwater control measures such as retention basins which are discussed later in this chapter assist in distributing the hydraulic load through time and substantially reduce the first flush and runoff pollution load.

The chemical and physical nature of the urban runoff water is extremely variable. It differs according to season, frequency and intensity of precipitation events, and many other pertinent factors. It is beyond the capabilities of this planning program to determine the exact nature of urban runoff in the region. However, it is possible to review more detailed work performed by others in similar areas and obtain a rough assessment of pollutants in runoff waters in the region.

2.3.1.1 Origin of Pollutants

The old concept that rainwater is pure water is being put aside. A raindrop actually begins as a contaminant. Water particles in the atmosphere adhere to a dust particle or other atmospheric contaminant before becoming large enough to fall to the ground. On the descent, other air contaminants are collected.

Once the raindrop reaches an urban area, it may pick up a number of additional contaminants, which may include:

- Dust, from roofs and streets;
- Pesticides from lawns, gardens, and parks;
- Fertilizers from lawns, gardens, and parks;
- Fecal materials from dogs, cats, birds and rodents.

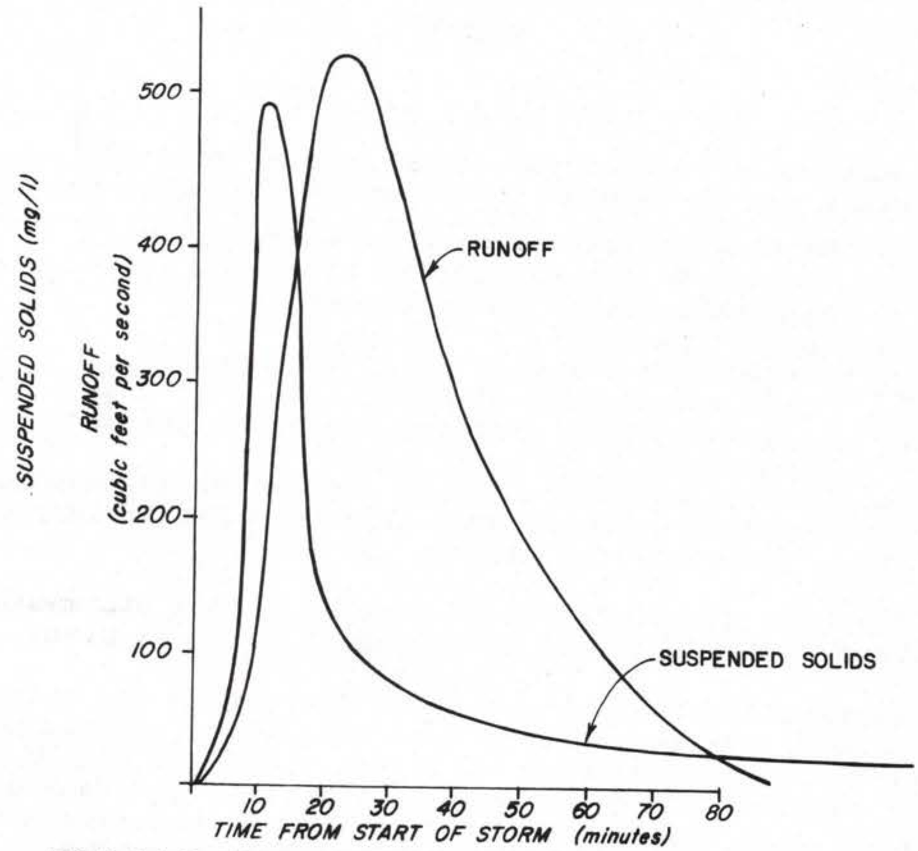


FIG. 2.3.1-B. GENERALIZED HYDROGRAPH SHOWING STORM WATER AND SUSPENDED SOLIDS DISCHARGE FROM AN URBAN AREA

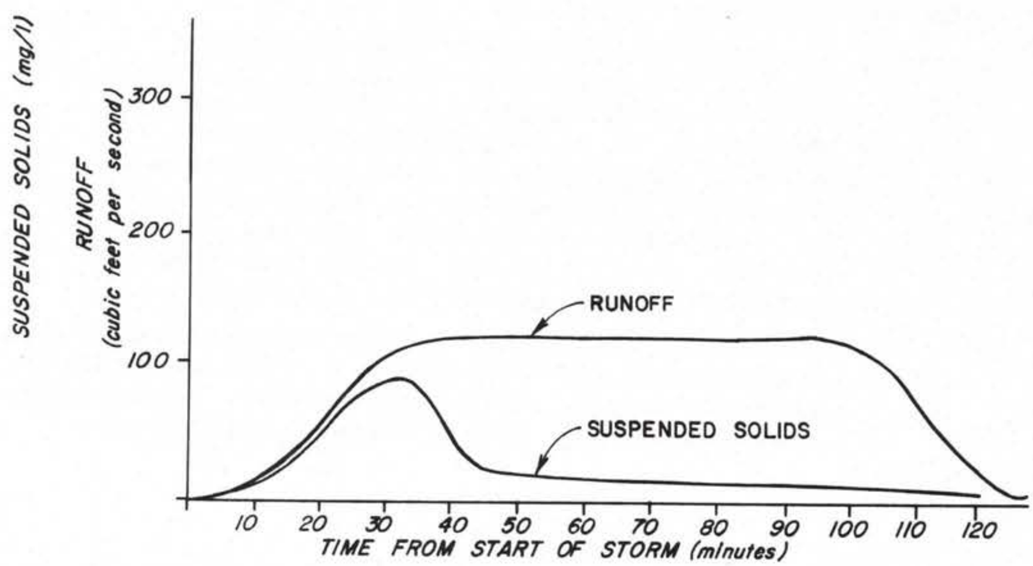


FIG. 2.3.1-C. GENERALIZED HYDROGRAPH SHOWING STORM WATER AND SUSPENDED SOLIDS DISCHARGE FROM URBAN AREA WITH STORM WATER CONTROL MEASURES

Once the water reaches the street, these and additional materials may be carried to the stormwater drain, such as:

- Detergents from automobile washing;
- Particles from automobile tires;
- Automobile emission particles;
- Asphalt particles;
- Garbage and other material intended for the solid waste stream;
- Oils and grease from improperly maintained vehicles;
- Leaves and other natural vegetative materials;
- Anything else that may have been indiscriminantly dumped on the street.

All of these materials may be carried into a stormwater drainage system and from there into a canal or river.

The observation that all of these pollutants may enter a stormwater system doesn't mean they will. Contaminants located close to the curb will have a greater chance of being carried into a stormwater drain. Particles away from the curb may settle out of the water before reaching the curb and particles near the curb have more water to push them into a stormwater conveyance system.

Factors which affect the quantity and nature of contaminants in any given city include the following [Sartor & Boyd, 1972]:

- Geographical locale. This parameter exerts a substantial influence on climatic conditions (seasonality of snow, rainfall, and wind) in a particular community. It also is important in that it reflects a community's proximity to fixed area sources of airborne particulates (plains, tilled fields, etc.) and the amount and type of vegetation and associated leaf-fall;

- Community activities. This generalized factor encompasses the presence of point sources of airborne matter from residential, commercial, industrial, and institutional activities;

- Public works practices and controls. Street cleaning operations, street maintenance practices, snow and ice control measures, and policies oriented toward refuse collection and litter abatement all influence accumulation rates of urban wastes;
- Community characteristics. Nature of a community can be described in terms of land area and use patterns, population magnitude, density and distribution, air quality, and public attitude toward community cleanliness and aesthetics.

2.3.1.2 Role of Suspended Solids

In addition to being the major constituent of urban stormwater runoff, suspended solids act as a transport vessel for a variety of other contaminants. Nitrogen, phosphorus, oils, grease, pesticides, and bacteria are often associated with suspended particles.

2.3.1.3 Distribution of Runoff Pollutants

The urban runoff contaminants are not distributed uniformly across a roadway. This non-uniform distribution has a direct bearing on the quantity of suspended solids and associated pollutants that become a part of the stormwater pollution load. These solids are typically distributed according to the pattern indicated in Table 2.3.1-B.

TABLE 2.3.1-B. DISTRIBUTION OF STREET SURFACE CONTAMINANTS [a]

STREET LOCATION (Distance from Curb)	SOLIDS LOADING INTENSITY (% of Total)
0 - 6 in.	78
6 - 12 in.	10
12 - 40 in.	9
40 - 96 in.	1
96 to center line	2

[a] Sartor & Boyd, 1972.

The bulk of pollutant material, particularly particulate solids, is concentrated toward the curb. This occurrance is associated with the tendency of traffic to blow material out of traffic lanes and to initiate transport by direct impact. Typical distribution of particulate pollutants across a street cross-section would show some accumulation in the center, little in the traffic lanes, and heavy concentration in the curb lane. The curb buildup is accelerated if car parking is allowed. This relates not so much to parked cars as a source of pollution, but rather because their presence arrests the movement and fosters the accumulation of material. Largest deposition of solids is in the gutter, since the curb obstructs the transverse movement of particulate matter. Median strips at grade are generally areas in which street surface contaminants accumulate. Raised medians are relatively clean. At points where breaks are provided, significant accumulation of particles is common.

Liquids such as oils and grease which spill or leak on the street surface exhibit a distribution that differs markedly from that of particulate solids. Liquid substances are found in greatest concentrations down the center of each traffic lane and along the middle of parking lanes.

2.3.1.4 Fines

A great portion of the overall pollutant load is represented in the fine solids fraction of street surface contaminants. From the standpoint of quantity, however, these fines account for only a minor portion of the total loading on street surfaces. As shown in Table 2.3.1-C, the very fine silt-like material (43 microns) comprises nearly one-fourth of the oxygen demanding material and about one-third to one-half of the algal nutrients. It also represents about one-half of the heavy metals and slightly less than three-fourths of the total pesticides [Sartor & Boyd, 1972]. This concentration of pollutants is contained in a very small amount of minute particles, accounting for only 5.9 percent of the total solids load. This implies that urban runoff pollution control must be directed at control of very small particles.

2.4 EFFECTS OF URBAN RUNOFF

Water quality impacts of urban runoff to the receiving water environment are extremely complex and difficult to define. Impacts may be immediate, cumulative, or long-term.

TABLE 2.3.1-C. PERCENT OF STREET POLLUTANTS IN VARIOUS PARTICLE SIZE RANGES [a]

Pollutant	Percent of Pollutant Associated with Each Particle Size Range					
	Particle Size (microns)					
	> 2,000	840 → 2,000	246 → 840	104 → 246	43 → 104	< 43
Total Solids	24.4	7.6	24.6	27.8	9.7	5.9
Volatile Solids	11.0	17.4	12.0	16.1	17.9	25.6
BOD_5	7.4	20.1	15.7	15.2	17.3	24.3
COD	2.4	4.5	13.0	12.4	45.0	22.7
Kjeldahl Nitrogen	9.9	11.6	20.0	20.2	19.6	18.7
Nitrates	8.6	6.5	7.9	16.7	28.4	31.9
Phosphates	0	0.9	6.9	6.4	29.6	56.2
Heavy Metals (All)		48.8			51.2	
Pesticides (All)		27.0			73.0	
Polychlorinated Biphenyls		66.0			34.0	

[a] Sartor & Boyd, 1972.

Sophistication of state-of-the-art urban runoff technology is not developed to a level that can definitely address the area of runoff-induced water quality impacts. Generalized assessment is possible, however.

At times in certain areas of the two-county area, stormwaters can generate a total pollution load greater than the discharge of treated municipal effluents. However, this load is unique in that it is generally sporadic. Unlike a municipal waste discharge which is continuous from day to day, urban runoff provides large amounts of pollutants flushed to the hydrologic regime within a short time period.

Salts carried in stormwater can be quite concentrated, especially during winter. Application of salts to highways and streets to prevent icing and provide safety to street travelers can cause large volumes of salts to be carried by urban runoff. Discharge of these salts to rivers and reservoirs can alter the aquatic life within them.

The potentially toxic constituents in urban runoff resulting from oils, gasoline, cleaning solvents, paints, tars and heavy metals from car exhaust can contribute to loss of aquatic life if present in sufficient quantities.

The nutrients in stormwater runoff from lawns, animal wastes and detergents used for car and house washing can foul the waters in which they are deposited.

2.5 URBAN STORMWATER DRAINAGE SYSTEMS

Four of the major urban drainage systems were analyzed within this report. The three large urban areas of Fort Collins, Greeley, and Loveland were reviewed and mapped. A review was also made of the facilities at Estes Park due to the uniqueness of the area's topography and soil. Other urban communities in the region may use the information presented to conceptually assist development or evaluation of their stormwater drainage strategy.

2.5.1 Estes Park Stormwater Drainage System

The Estes Park storm runoff system has evolved with development of the town. One underground drainage system serves the main thoroughfare (Highway 34) and outlets into the Big Thompson River above Lake Estes. The remaining system is a mixture of curb and gutter barrier systems and natural percolation.

The community of Estes Park is built upon loose sandy granite soils. These soils act as the major runoff system for the entire area. Their abundance and porosity make them capable of quickly adsorbing large amounts of water. Many roadside, parking lot and roof top drains simply drain out onto this open soil where water and water-carried pollutants percolate.

Due to the small area of Estes Park and the pervious soils around the developed area, this system can adequately handle most flood flows. Some damage was experienced by the flood of 1976 but even the best designed drainage systems cannot economically plan for a storm of this magnitude.

In some ways the runoff system at Estes Park is the most modern in terms of pollution control in the two-county region. The extensive use of percolation basins, holding ponds, vegetation strips and gravel inlets in the community allows considerable groundwater recharge and adequately prevents many pollutants from getting into a major waterway. However, all of these practices have not apparently resulted from conscientious planning but rather stem from use of existing soil and topography as it relates to the community's development.

Severe problems do exist in Estes Park. Development on steeper slopes is decreasing the land area available for water adsorption. Road access into these developed areas has developed potential channels for rain water. The increased runoff and associated velocities are presently causing erosion problems. Driveways are losing soil and major drains contribute to total sediment loads. Observed runoff management problems are:

- Rooftop and parking lot runoff directly distributed to Big Thompson River;
- Urban housing developments proceeding without any runoff control;
- Runoff culverts channeling flows directly into residential developments;
- Erosion extensive in private driveways;
- No street sweeping program.

Runoff pollution in the Estes Park community could contain many unique constituents in higher than normal concentrations. The higher altitude results in poorer quality auto emissions. These emission particles settle to roadways and parking lots.

2.5.2 Fort Collins Stormwater Drainage System

A large amount of the total runoff system in Fort Collins is curb collected and transported. Runoff water coming off streets and other impervious surfaces are collected by curbs and transported downhill to a catch basin or discharge location. Discharge points take curb water to deposit points in canals, lakes, holding ponds, or natural water courses. Figure 2.5.2-A shows the major outline of the drainage system and the discharge points.

Most of the major urban discharge pipes (greater than 30-inch diameter) of the Fort Collins stormwater system flow into natural channels. The two major channels receiving runoff water are the Cache la Poudre River and its tributary, Spring Creek. Three 48-inch pipes collect runoff from the central town area and discharge it to the Cache la Poudre River. Numerous other smaller pipes also convey stormwater flows directly to the river.

Spring Creek receives urban runoff through a reach of over five miles as it winds through much of the newer residential area of south Fort Collins. A total of five discharge pipes two feet in diameter or larger are located along the creek. Many smaller discharges are located along the route and oftentimes curb collected runoff is discharged to Spring Creek. A total of 35 discharge pipes carry rainfall runoff to natural streambeds in Fort Collins.

Irrigation supply ditches and adjoining reservoirs collect much of the remaining stormwater runoff of Fort Collins and distribute it to agriculture lands. Some of the aspects of this type of management are discussed further in the implementation section of this chapter.

A small amount of wastewater is distributed to ponds and fields where the water is allowed to percolate into the soil. This water may move laterally to a flowing stream or percolate to recharge the groundwater. Some problems have been noted with the use of such retention basins. These problems stem from a poor design that fails to allow for low levels of oxygen at times.

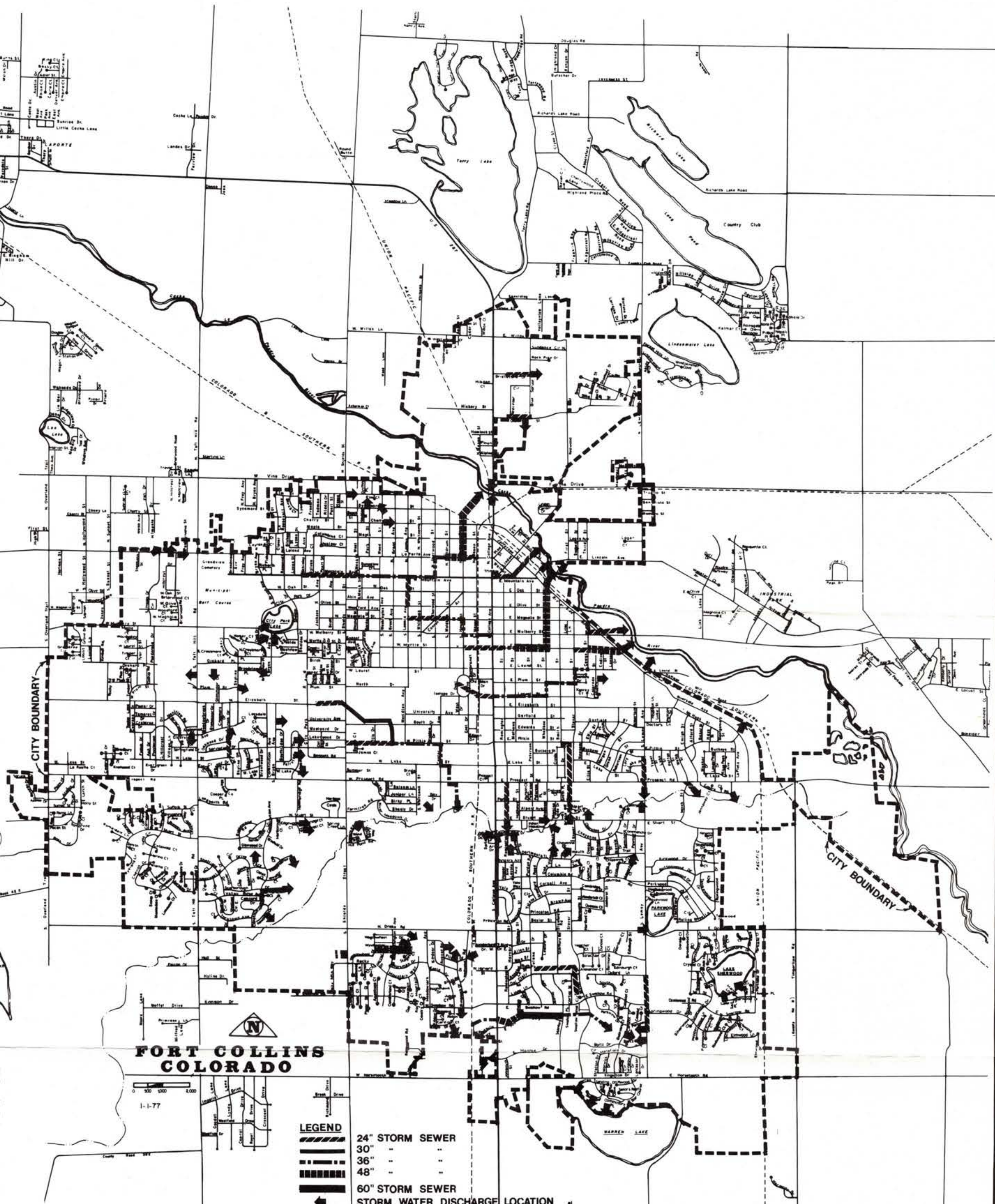


FIG. 2.5.2-A. MAJOR COMPONENTS OF THE FORT COLLINS STORM SEWER SYSTEM

A 1971 report gives recommended improvements for the city of Fort Collins runoff system [Black & Veach]. The recommended improvements involve increasing the total number of major discharge pipes to the Cache la Poudre River and construction of more and larger runoff lines discharging into Spring Creek. Three detention basins were recommended for construction along Spring Creek to reduce the quantity and velocities of flow along this channel. Since 1971, development south of Fort Collins has grown to such an extent that construction of these basins at the recommended sites is now impossible. The report was directed toward water runoff management and did not address possible water quality impacts.

2.5.3 Greeley Stormwater Drainage System

Stormwater management in the city of Greeley extends over six drainage basins. Excepting the city core area on the east end of town, the city uses curb and gutter extensively for stormwater conveyance. Large areas within the central part of the urban residential districts and areas in the south end of the city convey stormwater only by a curb and gutter system. The highly commercial city core has an extensive but old stormwater drainage system.

Figure 2.5.3-A shows the location of stormwater drainage pipes of the city of Greeley. Most of the older city stormwater discharge pipes flow directly into the Cache la Poudre River. As Greeley has developed southwest, the Greeley No. 3 Ditch received much of the stormwater runoff. Runoff flows have at times caused the ditch to overflow. Other discharge pipes empty into the Greeley-Loveland Ditch and onto undeveloped land.

Two four-foot diameter pipes discharge runoff water into the Cache la Poudre River. The remaining discharge points are mostly twenty-inch wood pipes serving high density commercial development from the central city. Due to the flat topography of the downtown area and the inability of these older stormwater sewers to convey stormwater flow, this area experiences minor flooding conditions from time to time. Major storms could cause flood damage.

A Comprehensive Drainage Plan for the City of Greeley, Colorado, prepared in 1974, provides the city with hydrologic and design information necessary to provide adequate stormwater safety. Within that plan is outlined the necessary steps to prevent flooding and provide safety for the residents of Greeley. Although the report contains

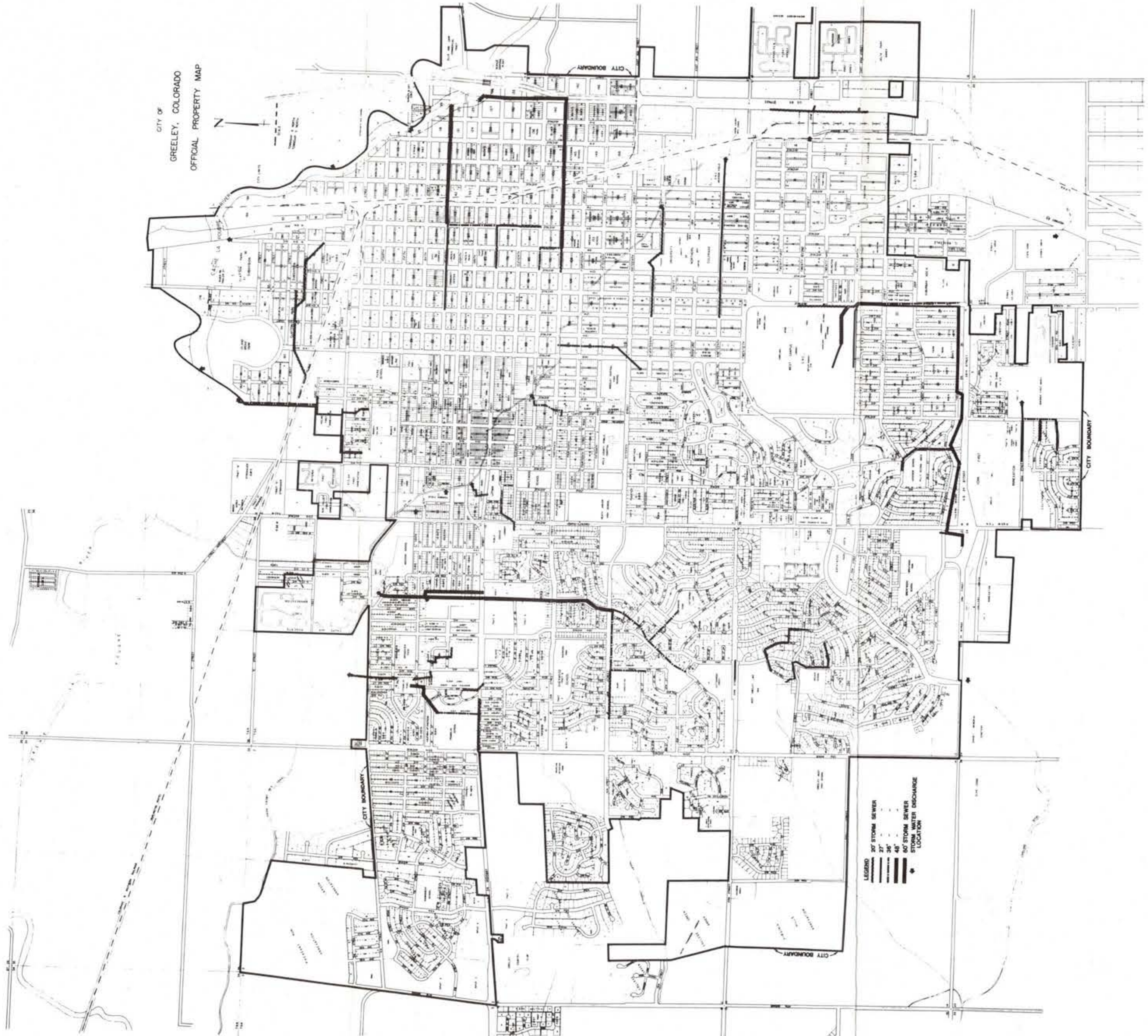


FIG. 2.5.3-A. MAJOR COMPONENTS OF THE GREELEY STORM SEWER SYSTEM

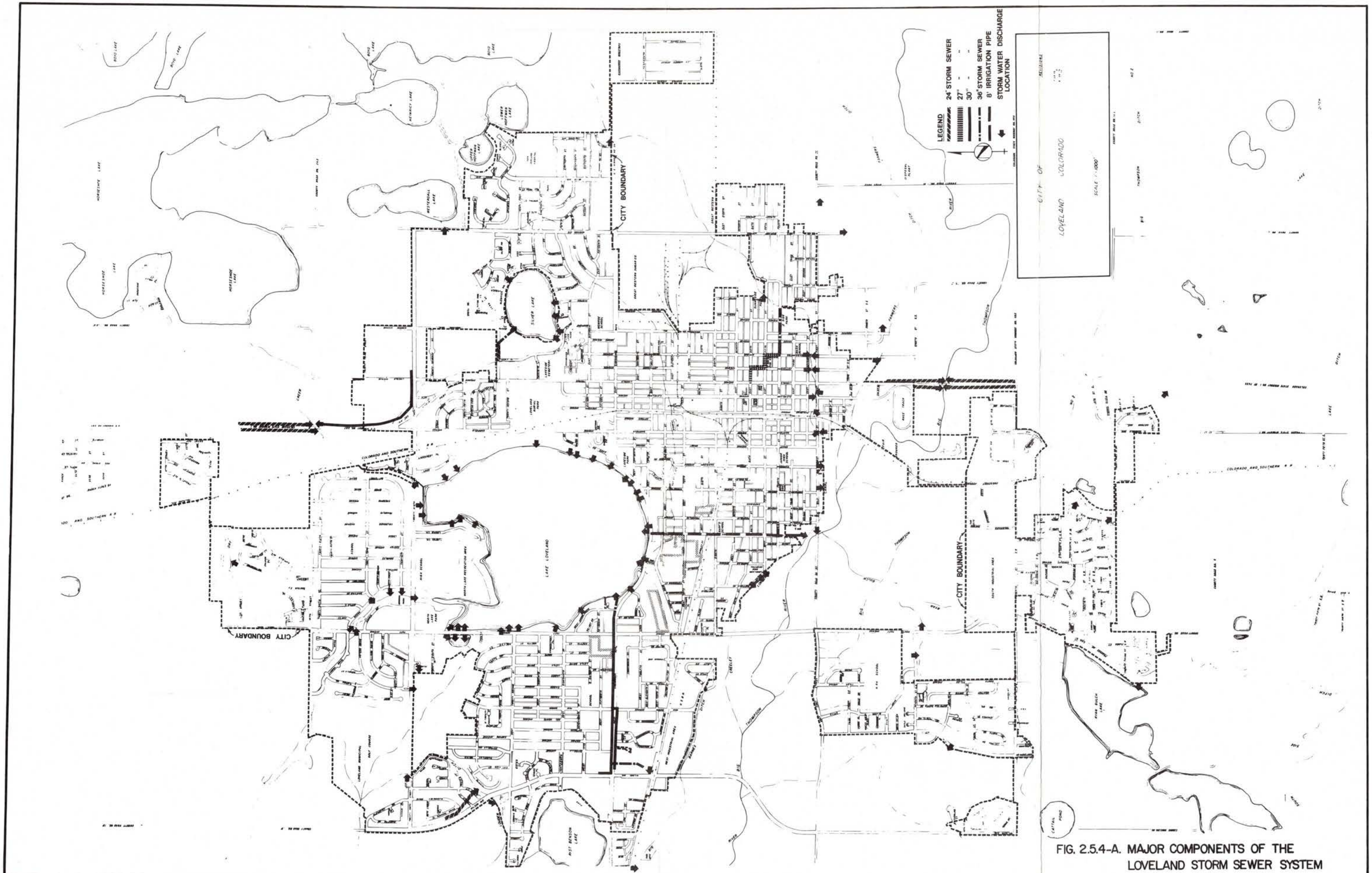


FIG. 2.5.4-A. MAJOR COMPONENTS OF THE LOVELAND STORM SEWER SYSTEM

recommendations for some detention ponds for safety measures which would also reduce sediment loads, the report does not mention any measures that may specifically lower the level of non-point urban runoff pollutional impacts. The City of Greeley appears to be making positive steps for hydrologic control of runoff but is not addressing water quality considerations.

2.5.4 Loveland Stormwater Drainage System

The city of Loveland has a unique stormwater drainage system. Where most municipalities collect stormwater runoff and deliver the water to a natural stream or basin, the city of Loveland uses a different approach. Extensive development of irrigated lands in the Larimer-Weld region has necessitated a concurrent development of ditches and reservoirs to serve these interests. Of the near ninety urban runoff discharge pipes in Loveland, over eighty percent discharge into an irrigation system. The remainder discharge into holding ponds, pastures, or similar perculation areas, and natural waterways. Upon examination of the system, less than one-half square mile, or five percent, of the city drains directly into a natural stream or waterway. Figure 2.5.4-A shows the general characteristics of the Loveland drainage system.

Reservoirs within Loveland receive most of the stormwater runoff. Lake Loveland itself accepts 33 stormwater drains. Many of these are small direct drains from Highway 34 and Taft Avenue bordering the lake. Two major drains discharge into the lake. A 36-inch drain collects stormwater tributary to Highway 34 and commercial areas on the west end of town and delivers it to the lake. Another large pipe (30-inches) discharges from an area of about 160 acres of new residential development. This pipe drains much of the area between 14th Street and 22nd Street and west to Wilson Avenue.

Most of the storage water from Lake Loveland is delivered for irrigation. Some of the water in storage (hence urban drainage) is delivered to the Greeley water treatment facility. A 36-inch pipe also delivers stormwaters to Silver Lake. This system drains much of the area east of the railroad and south of 29th Street to 20th Street. Lake Loveland and Silver Lake accept flows from another fifteen discharge pipes indirectly because of stormwater discharges into canals that supply these lakes.

The city of Loveland is presently evaluating the adequacy of their drainage and flood control system. It is suggested that they continue in such vein using whatever regional assistance that is available to coordinate their efforts with county officials.

2.5.5 Other Systems

It was not within the scope of this program to analyze all the regional urban areas for storm drainage and urban runoff pollutional problems. Some of the smaller communities of the region have experienced flooding as a result of large storms as well as associated pollution. The rapidly growing communities such as Windsor, Dacono, Evans, Firestone, Fort Lupton and Frederick (as outlined in the Larimer-Weld regional population and land use component of this areawide water quality plan) will need to address this problem. They should begin now to provide means of acquiring the necessary funds and legal leverage to prevent development of drainage hazards.

2.6 EXISTING ORDINANCES AND POLICIES

The legal and political measures presently existing within the Larimer-Weld region to control urban drainage are quite variable. Control ranges from specific enunciation of what may and may not be done by an urban developer to a lack of a policy addressing problems of urban drainage.

2.6.1 Larimer County

In 1973 the Larimer-Weld Regional Planning Commission prepared a drainage plan oriented toward implementing sound drainage practices within the region. The following policy statements were formulated in the report:

1. A master plan for drainage shall be maintained.
2. Drainageways shall be used for storm runoff and shall not be destroyed or built over.
3. Runoff can be stored in retention ponds which reduce the drainage capacity, land areas, facilities and expenditures required downstream due to slower delivery. These areas can parallel the need for recreation areas and open space.
4. It will be the policy of the Larimer-Weld Regional Planning Commission to encourage consideration of drainage information presented in this report in design of new subdivisions. Plans should be required to contain provisions for flows at least as large as those in this study unless the developer can prove otherwise.
5. Individual counties will be encouraged to include consideration of storm drainage in comprehensive planning for the two counties.

6. In those subdivisions having no drainage area within their boundaries but from which a substantial increase in runoff is anticipated, the possibility of dedication of alternate sites of contribution or funding for alternate locations should be investigated.
7. It will be the policy of the Larimer-Weld Regional Planning Commission to include this drainage study in open space planning.
8. In future updates of the Larimer-Weld Regional Planning Commission's Comprehensive Plan, it will be the policy of the Commission to include results of the Drainage Study as it relates to comprehensive planning.

None of these policy statements have been initiated into a county ordinance. However, the County Engineer does not approve for development any plattings that fail to address drainage problems. The county requires that drainage facilities within a development be capable of handling a fifty-year storm. Generally the county is concerned about possible flooding hazards but is not concerned with the pollutional aspects involved. Development platting is approved if a drainage study submitted to the County Engineer shows that the natural drainage characteristics are maintained and property is protected.

This type of piecemeal approval can fail to provide adequate future protection from upslope development. An overall plan that establishes and coordinates drainage studies and land use policies can avoid such problems and control associated pollution.

2.6.2 Weld County

Weld County is also beginning to implement the drainage practices developed by the Larimer-Weld Regional Planning Commission in 1973 (see Section 2.6.1). Again, these policies are not county ordinances. However, the County Engineer may require compliance before platting approval. Coordination with upslope Larimer County on drainage requirements and goals is a viable means of controlling the associated pollutional loads and impacts.

2.6.3 City of Fort Collins

The city of Fort Collins does not presently have an ordinance that outlines runoff control requirements for developers within the city. Fort Collins does have a runoff policy that is enforced by the City Engineer. The policy requires that the developer develop a drainage plan that will provide protection from a fifty-year storm and release runoff from the storm at the two-year storm runoff rate.

The city is able to enforce this policy through the engineer's office by not approving platting of developments until drainage requirements are met. The engineer reviews the development to see if natural drainage patterns have been preserved and that adequate protection is provided to prevent flooding and reduce property damage. Generally, detention ponds are used to gain the engineer's approval. The policy does not specifically address any of the pollutional aspects of urban runoff. Because most of the urban runoff pollution is suspended particles, and detention ponds do reduce the quantity of suspended materials, some measure of water quality control is maintained.

A 1971 engineering survey for the city of Fort Collins made a number of suggestions for improvements of the urban runoff system [Black &Veatch, 1971]. Among the suggested improvements were four large detention basins. The city has since analyzed all of these sites in terms of cost effectiveness and determined that two recommended basins required a large amount of fill and were too costly. A third basin was located on State property of Colorado State University, and the State refuses to sell or provide easements on that land for such purposes. [Parsons, 1977]. Development around the fourth recommended basin has not proceeded to a level that warrants pond construction.

2.6.4 City of Greeley

Article IV of Section 17 of the Greeley City Code deals with storm sewers and drainage. That code outlines guides for connecting to storm sewers, roof water, sizes of connections, inspections and fees.

The Code requires that all connections to storm sewers be preceeded by a permit. Applications for permits are processed by the City Engineer and must include cost of connection. Roof water drains are now allowed to drain to sidewalks but must convey the water to the curb.

The Code also delineates the sizes on service connections required before areas are paved. All installations must be under the direction of the City Engineer. To provide funds for construction and enlargement of the storm sewer system, the City of Greeley requires a drainage fee be assessed for all property served by city water supply. Minimum fee is one hundred and fifty dollars ($150.00). The city also reserves the right to assess an additional fee if drainage from an area contributes "an extraordinary load." The owner is responsible for construction of proper drainage components in addition to the drainage fee. The city assumes the cost of increasing the capacity of downstream facilities.

The Greeley Code helps to cover cost of drainage facilities and demonstrates the responsibility of the developer in providing drainage facilities. The Code does not outline which specific storm event must be accommodated; however, since the City Engineer provides final review of all systems, approval is not given unless the design is adequate. The city code also fails to address any factors of urban runoff that affect water quality.

2.6.5 City of Loveland

The City of Loveland does not have an ordinance that provides specific guidelines for developers and engineers in the design of stormwater runoff systems. It does provide some general outline for safety from rainfall events. Section 16.28.060 of the Municipal Code states:

> "subdividers must dedicate a right-of-way for storm drainage purposes," conforming with the channel and dedicating "sufficient easements or construction, or both, to care for such surface and stormwater and disposal thereof." Listed in City Code 1/15/76.

Section 16.28.061 goes on to say that adequate drainage should be provided so as to reduce exposure to flood hazards. Section 15.04.035 also states that developments must be "reasonably safe from flooding."

Another section of the Loveland Municipal Code is remotely related to urban runoff. Section 12.36.030 states that "it is unlawful for any person to dump, discard, throw, or in any manner place trash, refuse, or any objects whatsoever into a ditch or canal within the city limits." By preventing debris from accumulating within the canals, danger from flooding due to storm events or other high ditch flows is reduced.

There is no existing city policy which defines the requirements that must be met by a developer for rainfall drainage [Becker, 1977]. Presently the City Engineering Department reviews platting of developments on a case-by-case basis. Each case is analyzed to see if natural flow of water drainage (lay of the land) has been maintained.

Loveland has recently obtained the services of a drainage consultant and drafted a proposed stormwater control ordinance. Although not presently adopted by the City Council, the ordinance will provide the city with the funds and power to:

- Define extent and character of present drainage basins;
- Establish design criteria for drainage structures;
- Develop a cost per acre charge for each drainage basin and charge said for maintaining flood control.

This draft ordinance does not address the problem of pollution control of urban runoff. Rather, it is oriented exclusively toward the drainage aspect of urban runoff.

The city of Loveland recognizes that development of a city drainage ordinance that is not integrated into a county or regional drainage policy will be ineffective in providing for future drainage needs. Use of the Larimer-Weld Regional Council of Governments in helping to draft ordinances to be used regionally can alleviate some of these problems. Such coordination would address aspects of water quality degradation as well as flooding hazards.

2.7 NATURE OF AREAS CONTRIBUTING URBAN RUNOFF

Fort Collins, Greeley, and Loveland were analyzed for general demographic characteristics to provide basic information needed to develop wasteload quantities presented in Section 2.8 and to provide an overview of the urban areas. Demographic and physical characteristics of the major urban areas of the region are summarized in Table 2.7-A for 1975 and the year 2000.

TABLE 2.7-A. DEMOGRAPHIC AND PHYSICAL CHARACTERISTICS MAJOR URBAN AREAS [a]

CHARACTERISTIC	CITY					
	FORT COLLINS		GREELEY		LOVELAND	
	1975	2000	1975	2000	1975	2000
Population Density (persons/acre)	4.8	5.6	4.4	6.8	4.2	5.6
Mean Annual Precipitation (inches)	14.58		12.05		14.58 (Est.)	
Developed Acreage	11,700	26,600	13,134	19,000	6,000	10,900

[a] Larimer-Weld Regional Population and Land Use Component, Areawide Water Quality Plan.

The Larimer-Weld Regional Population and Land Use component of the Areawide Water Quality Plan has projected land use demands into the year 2000. Table 2.7-B is drawn from this report and is the basis for projecting the wasteloads and estimating the general nature of the major urban areas to the year 2000.

TABLE 2.7-B. SUMMARY LAND USE DEMAND FORECAST: 1975-2000 [a]

Land Use	1975 Estimated Acreage	Additional Acreage	Year 2000 Total Acreage
Residential	33,040	30,370	63,410
Commercial	1,665	329	1,995
Industrial	2,570	2,440	5,010
Institutional	2,100	2,740	4,840
Local Recreation	--	1,360	1,360 [b]
Total	39,375	37,239	76,615 [b]

[a] Toups Corporation, Quinton-Redgate, 1977.
[b] Does not include existing recreational acreages.

From these tables it can be seen that the extent of urban areas of Larimer and Weld Counties are much the same. Residential acreage will remain at about 82 percent with industrial nearly equal to institutional acreage, each comprising about 7 percent of the urban land acreage. As more data and better models become available, these projections may change. However, they are the basis for the runoff and wasteload evaluation presented in this report.

2.8 WASTELOAD MASS EMISSION RATES

The chemical and physical nature of the urban runoff waters is highly variable. It is a function of storm event, season and a great number of other factors. Detailed reports developed by experts in the field of urban runoff were reviewed to assess the pollutant contribution of this source in the Larimer-Weld region.

2.8.1 Urban Runoff Quality Data

The five-county metropolitan area of Denver began in 1975 to develop a Denver regional non-point source pollution analysis. This segment of a total $1.29 million program for water pollution control was funded by the U.S. Environmental Protection Agency and managed by the Denver Regional Council of Governments (DRCOG). This analysis has provided DRCOG with an idea of the quality of water coming from urban areas in Denver. Some of these areas are similar to areas in the Larimer-Weld region in land use, climate, topography, and drainage system.

2.8.2 DRCOG Data

One location used to sample urban runoff water quality was Littleton. Littleton is a residential area of about 600 acres composed of new or relatively new single family units much like many of the newer urban developments in the Larimer-Weld region. Data collected from this area would be similar to many areas in Fort Collins, Greeley, and Loveland with relative flat slopes in residential areas. This data was used to assess the relative impact of urban runoff on water quality in the region.

For water year 1975, most of the parameters analyzed were relatively low except for coliforms. The high coliform concentrations are most likely to be from deposition of fecal material by house pets. Temperature is mostly a function of the season. In August the high discharge temperature would reduce the amount of oxygen available in the discharge waters. Low oxygen levels in streams can cause loss of aquatic life.

Data collected in 1976 is more thorough and shows that spring rains in early March caused very high concentrations of many pollutants to be discharged. Nitrogen concentrations were much higher but diminished to acceptable levels very quickly. Data collected at Littleton for the March 1976 storm is typical of most stormwater runoff events with high initial concentrations. Following this "first flush," constituent levels subside. It appears that this data would closely correlate with data collected in urban areas of the Larimer-Weld region.

An area about five times the size of the Littleton sample site was also sampled by DRCOG. This area in Lakewood near the Federal Center is about half residential and half developed light industry with a great deal of impervious surface due to the Federal Center. Again, coliform counts were very high for possibly the same reason as at Littleton. This sample area would be like many light industrial-residential areas in the Larimer-Weld region. This data shows that urban runoff water is not of high quality and cannot be used industrially, agriculturally, or for culinary purposes without some improvement.

2.8.3 Wasteloads

Determining how much of the constituent wasteload actually gets into the waters of Larimer and Weld Counties is a difficult and costly task. However, by utilizing data developed from other sources and by using appropriate methodologies, an approximation of wasteloads within the two-county region can be developed [Heaney, Huber & Nix, 1976]. Results of this wasteload analysis for residential land use are shown in Table 2.8.3-A for the three major municipalities within the region. Present and year 2000 wasteloads were calculated.

TABLE 2.8.3-A. AVERAGE ANNUAL URBAN RUNOFF WASTELOADS FOR FORT COLLINS, GREELEY, AND LOVELAND - 1976/2000

	MUNICIPALITY					
	FORT COLLINS		GREELEY		LOVELAND	
YEAR	1976	2000	1976	2000	1976	2000
Acreage	11,700	26,600	13,134	19,000	6,000	10,900
Population Density (people/acre)	4.8	5.6	4.4	6.8	4.2	5.6
Annual Stormwater Runoff (acre-ft/year)[a]	3,900	10,100	1,800	3,560	2,075	4,140
Suspended Solids (lbs/acre-year)[b]	155	165	123	148	146	165
(tons/year)[c]	1,013	2,410	913	1,510	498	990
BOD_5 (lbs/acre-year)[b]	7.6	8.1	6.0	7.3	7.1	8.1
(tons/year)[c]	57	136	51	85	28	56
Nitrogen (lbs/acre-year)[b]	1.2	1.3	1.0	1.2	1.2	1.3
(tons/year)[c]	8.7	21	8	13	4.6	8.5

[a] Based on average rainfall developed from 25 years of record.
[b] Residential land use only.
[c] All land uses.

The demographic and physical data necessary to develop wasteload quantities for Fort Collins, Greeley, and Loveland are presented in Table 2.7-A. These factors of population density and annual precipitation are used with the equations presented in Appendix A to develop wasteload projections.

It has been calculated (see Section 6.2) that wasteloads from water treatment facilities may deposit over three tons of solids per day into the waterways of Larimer and Weld Counties. Based upon calculations of loads caused by urban stormwater drainage, this source may contribute six and one-half tons per day on an average annual basis from the three major cities in the Larimer-Weld region. By the year 2000, the urban runoff contribution may be as much as thirteen tons of suspended solids per day! Of course, mass emissions are not physically added to the surface water regime on an average daily basis. Rather, loading is in the form of a slug discharge which occurs during a storm event. These urban runoff or stormwater loads, however, do not all deposit into waterways of the region. Approximately eighty percent of this runoff flow is diverted into ditches, canals and reservoirs managed by water users associations and ditch companies within the area.

Data developed by Wells, et. al., [1973] in Lubbock, Texas, would indicate that the estimates presented in Table 2.8.3-A may be lower than actual annual wasteloads. This data has been developed for a year of average rainfall. Years of lower than average rainfall would produce less wasteloads and years of above average rainfall could significantly increase these amounts.

Table 2.8.3-A shows that for an average rainfall year at the 1976 development level, nitrogen carried by stormwaters may exceed 21 tons per year for the three urban areas. Because much of the urban runoff of the area enters irrigation systems, this nitrogen provides some available nutrients for crops and can lead to eutrophication of reservoirs.

Total available phosphorus loads caused by urban runoff within the three cities is calculated at about 6.4 tons per year. In a manner comparable to nitrogen loading, increased phosphorus supply to reservoirs can aid plant growth and lead to reservoir water quality degradation.

Presently, almost 170 tons of BOD may be added to waters within the Larimer-Weld region by runoff from urban watersheds. This means that 170 tons of oxygen must be made available to microorganisms within the water annually to sufficiently degrade this material for maintenance of water quality and normal water usage. Additional oxygen must be available to support aquatic life already present within the water. After providing for aquatic life needs, there is about 5.4 pounds of oxygen available for every acre-foot of water and therefore this stormwater must be distributed through approximately 63,000 acre-feet of water annually to adequately satisfy the oxygen requirements. As large as these numbers may appear, there is adequate assimilation capacity within the irrigation and river system to handle this oxygen demand without adverse effects. However, it does illustrate that urban runoff wasteloads are large enough to impact waters of the Larimer-Weld region and consideration of their impact is important. When large pollution loads are not sufficiently distributed, aquatic life may be harmed.

2.9 WATERS IMPACTED BY URBAN RUNOFF

2.9.1 Natural Waterways Receiving Urban Runoff

The Cache la Poudre and Big Thompson Rivers receive almost all of the urban runoff in the Larimer-Weld region. Figure 2.9.1-A shows the location of major urban runoff discharges into these two waterways. Figure 2.9.1-A also illustrates that impact of urban runoff would be most significant along the Cache la Poudre River as it accepts much larger flow volumes than the Big Thompson River.

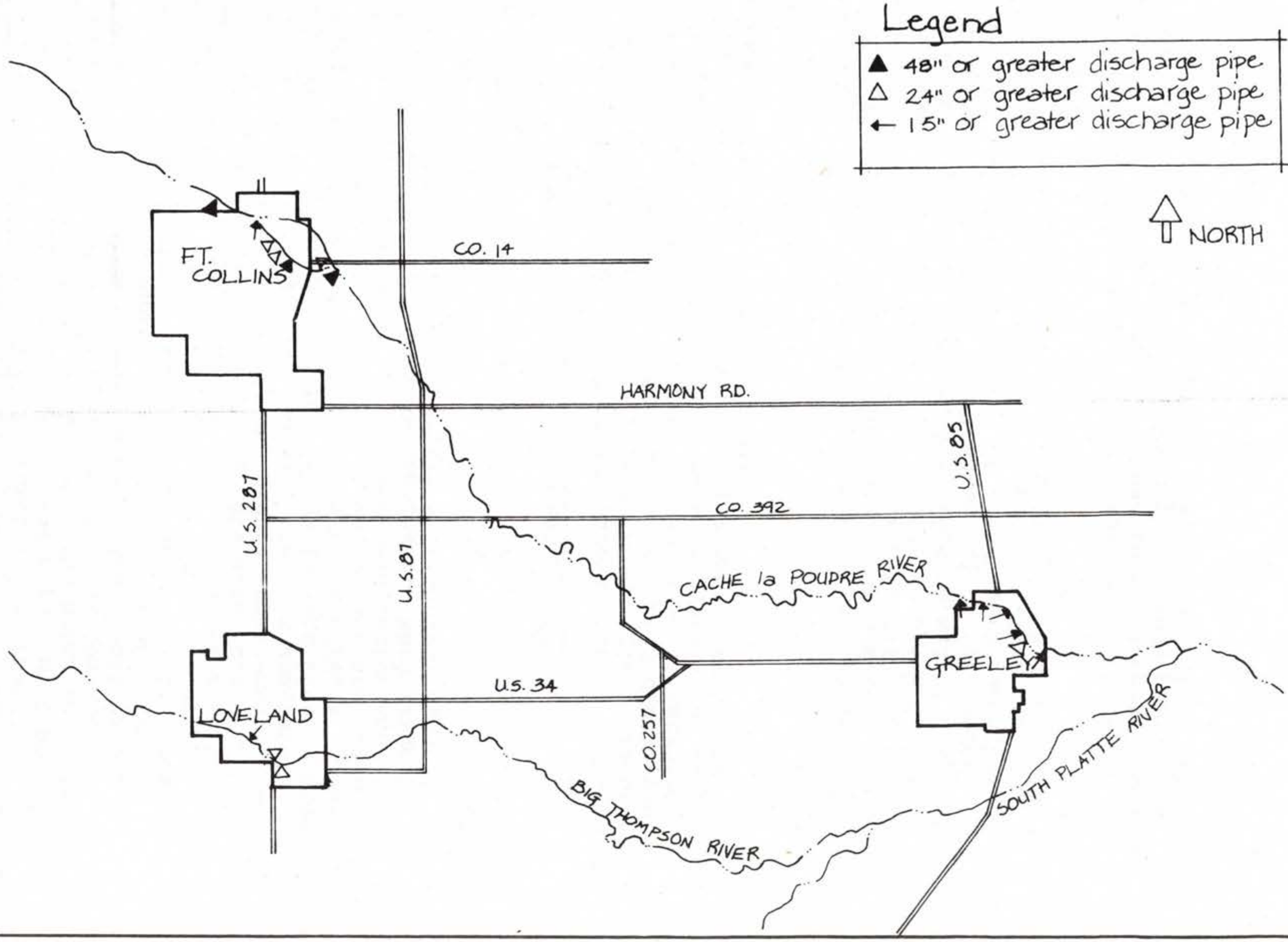
2.9.2 Ditch Companies

Distribution canals and reservoirs receive the majority of this urban runoff water. These agriculture water conveyance systems are owned and operated by ditch companies. In the past, this runoff water was gladly accepted by the ditch operators. Now, problems with this method of disposal are beginning to develop. Overloading and corresponding flooding caused by large volumes of urban storm runoff is the major concern of these ditch companies. They are especially concerned about their liability when ditches overflow.

Of increasing concern to the ditch companies is the biological, physical, and chemical nature of these runoff waters. Effects of lawn pesticides, grease, oils and other urban pollutants on crops is a developing concern of farmers and ditch companies.

FIG. 2.9.1-A

MAJOR URBAN RUNOFF DISCHARGES INTO WATERWAYS OF THE LARIMER-WELD REGION



The hydraulic demand placed upon these canals during large storms can cause ditch scour, eroding away the ditch structures and the ditch itself. This increases operational costs. The slower velocity of the ditches causes the suspended materials to settle, a phenomenon which reduces the carrying capacity of the ditch and increases supply and maintenance costs.

In conjunction with the ditch companies the City of Fort Collins has recently developed the necessary policies and criteria for use of irrigation ditches by the municipality [Wright-McLaughlin, 1977]. Adherence to the policies outlined in that document will take cities and ditch companies a long way toward reaching a workable agreement.

2.10 STRUCTURAL AND NON-STRUCTURAL MANAGEMENT OPTIONS

A mismanagement or a lack of management of stormwater runoff can cause flooding hazards and provide increased pollutant conveyance to the region's waters. A wide variety of control methods are presently developed ranging from enforcement of littering ordinances to design and construction of urban runoff water treatment facilities. These options for control vary considerably in terms of cost, ease of implementation, and practicality in the Larimer-Weld region. Many urban runoff management options yield benefit in pollution control and flood control. These alternatives must be carefully screened to optimize the type of control desired.

In response to the need of the 208 planning effort to screen alternatives available for urban runoff pollutant control, EPA has sponsored development of a relatively simplified analythical methodology [Heaney & Nix, 1977]. The procedure is graphical in nature and permits the analyst to examine a wide variety of control options operating in series with one another or in parallel. As an end product of the evaluation, a control cost function is developed for a community which represents the optimal (least costly) way of achieving any desired level of pollutant control. For a specified control level, the appropriate application of each available control option can be determined.

The assessment of urban runoff pollutant control technologies utilized herein is based on several theories of economics that have application to stormwater management. These include production theory and marginal analysis.

- Production theory.
  A production process attempts to increase the utility of a commodity [Heaney & Nix, 1977]. That is, for a given level of effort, an associated result will be realized. Technological relationships restrict options on input (effort) and output (result) levels. Production functions are governed by the law of diminishing returns. This rule states that as an input to a production process is increased, with all other inputs held constant, a point will be reached beyond which any additional input will yield diminishing marginal output.

- Marginal analysis.
  In economics, marginal analysis is defined as the incremental cost associated with an additional unit of a given commodity. Marginal analysis guides economic decision making in determining whether an action results in sufficient additional benefit to justify the extra cost. The concept of marginal analysis is governed by two basic rules [Baumol, 1965]:

  > The scale of an activity should, if possible, be expanded so long as its marginal net yield (taking into account both benefits and costs) is a positive value; and the activity should therefore be carried to a point where this marginal net yield is zero.
  >
  > For optimal results, activities should, whenever possible, be carried to levels where they all yield the same marginal returns per unit of effort (cost).

  Consider dollars spent for various urban runoff pollution control options. Assume that for a given level of pollutant removal, $2.00 is invested on Option A. By use of Option B, however, the same level of removal can be achieved for $1.00. The investor is missing the opportunity to gain $1.00 by not transferring the money spent on Option A to Option B. Therefore, to assure maximum return, both control strategies should be implemented at levels of equivalent marginal return or yield.

Options for stormwater pollution control may operate in parallel, series, or a combination of both. A parallel operation is one in which the untreated portion of any one option is not tributary to any other parallel option. In a serial operation, options are sequential with the untreated portion from one option serving as the influent to the next.

2.10.1 Non-Structural Options

2.10.1.1 Street Sweeping

Street sweeping is a long-established practice in American cities. This activity has primarily been directed toward removing unsightly debris. It has been determined, however, that a conscientious program of sweeping is effective in removing a portion of the potential pollution that otherwise would be available for transport in urban runoff [Sartor and Boyd, 1972; APWA, 1969]. Street surface contaminants are not distributed uniformly across a roadway. Solids loading intensity typically corresponds to the generalized distribution as previously shown in Table 2.3.1-B.

This tabulation shows that 88 percent of street solids are located within a 12-inch distance from the curb. Approximately 97 percent are situated within 40-inches. Cleaning efforts focused in the vicinity of curbs could be highly effective. A considerable reduction in pollution control efficiency is experienced when the sweeping operation is encumbered by curb-parked cars.

Characteristics of street surfaces influence the associated accretion of contaminants. Asphalt streets exhibit loadings about 80 percent greater than roadways of concrete. Streets composed partially of asphalt and partially of concrete accumulate pollutant loads about 65 percent heavier than streets constructed totally of concrete. Another important influence on street surface waste loading is road condition. Loading on streets in good-to-excellent condition is 2.5 times less than loading on streets in fair-to-poor condition [Sartor & Boyd, 1972].

Not all pollutants accessible to urban stormwater are available for removal by sweeping. Many impervious surfaces of a community are not subject to sweeping by municipal units. These include parking lots, driveways, and other such areas.

Relationships have been developed which describe the sweeping availability factor (portion of pollutant load which is sweepable) [Heaney & Nix, 1977]. It is computed as a function of imperviousness due to streets exclusively compared to total imperviousness of an area. The methodology utilized herein evaluates the sweeping availability factor in terms of developed population density.

Advantages and disadvantages of sweepers as a pollution control option are highlighted as follows [Heaney & Nix, 1977]:

- Advantages:
  - Control of pollutants at the source;
  - Sweeping provides both pollution control as well as aesthetic enhancement;
  - Budget usually already exists.
- Disadvantages:
  - Relatively low efficiency as a pollution control technique;
  - Sweeper operation presents a hazard to traffic;
  - Only the pollutional load near the gutter is affected;
  - Vehicular parking along streets reduces overall debris removal efficiency.

Inventories of street sweeping equipment serving major urbanized areas in the Larimer-Weld region are summarized in Table 2.10.1-A. Existing sweeping schedules are also identified.

TABLE 2.10.1-A. INVENTORY OF STREET SWEEPING EQUIPMENT AND AVERAGE FREQUENCY OF SWEEPING

	FORT COLLINS	GREELEY	LOVELAND
Broom Sweepers	3 [a]	3 [c]	2 [e]
Street Flushers	2 [a]	-	1 [e]
Frequency of Sweeping	1/Wk [b] (commercial) 1/Mo [b] (residential)	1/4 to 6 Wks. [d]	1/2 Mo. [f]

[a] McClure, 1977.
[b] Fisch, 1977.
[c] Calkins, 1977.
[d] Schaffer, 1977.
[e] Sitterle, 1977.
[f] Lebsack, 1977.

The characteristics of street surface pollution are of importance when street sweeping is considered as a non-structural control option. Conventional broom-type street sweepers are rather inefficient in removing fine material. Effectiveness of sweepers in cleaning various sized particles from road surfaces is depicted in Table 2.10.1-B. Sweepers generally leave behind 85 percent of solids finer than 43 microns, and 52 percent of material finer than 246 microns. Overall solids removal efficiency of broom sweepers is on the order of about 50 percent. Gutter brooms as presently designed tend to redistribute the dust and dirt fraction of street pollution (>2000 microns) over the roadway surface. They are not particularly efficient in moving the dust and dirt fraction out of the gutter [Sartor & Boyd, 1972].

Street flushers incorporate a vacuum pickup mechanism in contrast to the mechanical collection feature of broom sweepers. Hence, effectiveness of these units as pollution control devices is greatly increased. Vacuum-type sweepers have reportedly achieved efficiencies of greater than 95 percent [APWA, 1969]. Cost of such units is substantially greater than for brush types.

TABLE 2.10.1-B. BRUSH-TYPE SWEEPER EFFICIENCY FOR VARIOUS PARTICLE SIZE RANGES

PARTICLE SIZE (microns)	SWEEPER EFFICIENCY (%)
2000	79
840 - 2000	66
246 - 840	60
104 - 246	48
43 - 104	20
< 43	15
Overall	50

Increased removal efficiencies can be achieved by operating sweepers at a slower speed than the typical operating speed of about 6 mph. Conducting multiple passes will also result in greater contaminant uptake. An overall effectiveness of 70 percent can be realized with two cleaning cycles. The existing state-of-the-art of sweeper technology probably will not permit effectiveness values greater than 90 percent to be obtained [Sartor & Boyd, 1972]. Table 2.10.1-C summarizes the street sweeping efforts, in terms of equipment minutes per 1000 square feet of area swept, required to achieve greater removal effectiveness of the dust and dirt fraction of street surface contaminants. The effort is several times the effort normally expended in typical sweeping operations.

TABLE 2.10.1-C. EFFECTIVENESS OF INCREASED STREET SWEEPING EFFORT [a]

EFFECTIVENESS (%)	EFFORT (EQUIPMENT MINUTES/ 1000 SQ. FT.)	INCREASE OVER NORMAL EFFORT
95	1.5	6.3
90	0.85	3.6
70	0.50	2.1
Normal	0.237	-

[a] Sartor and Boyd, 1972.

The analysis developed herein of street sweeping as a non-structural stormwater pollutant control option is oriented toward management of biochemical oxygen demanding substances (BOD). Similar evaluation of other constituents could also be developed; however, repetitive analyses are time consuming and rigorous in nature.

Table 2.10.1-D depicts the effectiveness of broom sweepers in removing BOD associated with street surface particulate matter.

TABLE 2.10.1-D. BOD REMOVAL EFFICIENCY - SWEEPING

PARTICLE SIZE	SWEEPER EFFICIENCY	BOD ASSOCIATED WITH PARTICLE SIZE RANGE %	% REMOVED
43	15	24.3	3.6
43 - 104	20	17.3	3.5
104 - 246	48	15.2	7.3
246 - 840	60	15.7	9.4
840 - 2000	66	20.1	13.3
2000	79	7.4	5.8
			42.9

Assuming sweeping is limited to the area in the 0-40 inch distance from roadway curbs, 97 percent of street solids would be within this control option's sphere of influence. If solids of various particle sizes are uniformly distributed across the roadway surface, BOD actually removed by sweeping would be represented by 42.9 percent removal efficiency times 97 percent, or 42 percent.

A detailed evaluation of street sweeping as a non-structural pollutant control strategy is presented in Appendix B. Analyses were prepared for the three major urban areas of the region--Fort Collins, Greeley, and Loveland. Effectiveness of the street sweeping option are depicted graphically in terms of annual capital expenditure required to achieve various levels of BOD control. It is evident from Table 2.10.1-D and the figures in Appendix B that sweeping effort oriented toward controlling 30 to 40 percent of urban runoff pollution is technically achieveable. However, associated cost of a control program of the required intensity is quite high compared to other pollution control alternatives. Receiving water quality benefits to be realized primarily relate to the category of reduced suspended solids impact.

The three major urban centers in the Larimer-Weld region were contacted to establish the level of funding budgeted for street sweeping activity. Present expenditure is on the order of $360,000 annually, including equipment amortization. Fort Collins is responsible for nearly 60 percent of this expenditure. Street sweeping expenses incurred by Fort Collins, Greeley, and Loveland correspond, respectively, to approximately $18, $7, and $9 per urban acre. It is estimated that the level of total urban non-point BOD control achieved by present municipal street sweeping activity is equivalent to about 16 percent in Fort Collins, 12 percent in Greeley, and 14 percent in Loveland. These rates were derived from Appendix B, Figures B.1-M, B.1-N, and B.1-O. BOD removed from the urban environment each year by street sweeping is believed to be approximately 48,000 pounds. Fort Collins is responsible for controlling about one-half of this total.

2.10.1.2 Catch Basins

Catch basins are included in the assessment of "non-structural" control measures because such facilities are normally included as integral components of a runoff collection and disposal system.

Performance of catch basins as a stormwater pollutant control alternative was investigated recently in a national study [Metcalf & Eddy, 1976]. The report defines a catch basin as "a chamber or well, usually built at the curb line of a street, for the admission of surface water to a sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow."

The intended function of catch basins is to act as grit chambers designed to prevent sewer line clogging. Although BOD and suspended solids is not a primary function, the catch basin does serve much like a sedimentation/septic tank capable of removing a portion of the tributary BOD. During runoff events, however, the remaining BOD load may be flushed back into the storm drain system. Because of their relatively small capacity in relation to contributing drainage, catch basins were determined to be relatively ineffective as a wet-weather pollution control device.

2.10.1.3 Domestic Animal Control

No local or regional studies have been conducted to determine the amount of pollution contributed by pets within an urban area and therefore no idea of cost and effectiveness of methods is available. For years the expression "curb your dog" was used to imply that the proper place for these animals to deposit their wastes was adjacent to the street. The extent of the pet population and the more concentrated urban populations has made this type of strategy inappropriate. Animal waste should be deposited in grassed areas and frequently removed to the solid waste stream or incorporated into the soil. It is doubtful that a concerted domestic animal control effort would effectively control BOD and bacteria from urban runoff waters. The money involved may not result in a cost-effective level of pollution control.

2.10.1.4 Zoning and Land Use Control

Land use control and effective zoning does not substantially reduce the magnitude of urban non-point pollution loading, but does simplify the ease of non-point source management. Regulation of residential densities, commercial growth and location of parking areas can make street sweeping and other pollution control alternatives easier to implement and result in a higher level of control. Zoning and land use control is currently being used in the area but pollution control is not an objective of the present program.

2.10.1.5 Improved Garbage Collection

Scattered garbage and litter can be carried to the storm sewer with each storm event. Torn garbage bags, damaged containers, spilled wastes and ill-fitting or absent covers all contribute to additional pollution. Control can be achieved with a high level of performance by both the homeowner and the collector. Homeowner performance can be improved by increasing pride in the neighborhood and locally enforced ordinances that require a high quality solid waste containment level. A developed pride in workmanship by the collector can alleviate some of the problems. There is no data available that indicates the cost or the relative level of pollution control obtained by such efforts.

2.10.2 <u>Structural Options</u>

Structural options available for stormwater pollutant control include both storage and treatment technologies [Heaney & Nix, 1977]. These structural technologies are categorized either as primary or secondary control options. Primary devices utilize physical processes such as screening, settling, and flotation to derive the BOD_5 removal efficiencies presented in Appendix B. These limits were assumed 40 percent efficient.

Secondary treatment technologies utilize biological processes and/or physical/chemical applications. The performance of these units is usually rated at 85 percent. To facilitate assessment of control alternatives, no duplication of function was considered in developing costs as presented in Appendix B.

2.10.2.1 Storage

Storage alternatives consist of:

- In-line storage;
- Tanks;
- Lagoons;
- Tunnels;
- Porous pavements;
- Rooftop detention.

In-line storage, tanks and tunnels are generally a very costly control option. They require considerable modification of the existing stormwater system. These options become viable alternatives in densely populated areas where many of the other storage options are no longer available. The City of Chicago is currently using these techniques to update its stormwater drainage system. These do not appear to presently be viable options in the Larimer-Weld region.

There are two separate ways of designing lagoons for stormwater control. Retention ponds are designed to contain all of the water and associated pollutants from a specific storm event. Because retention ponds are not designed to release accumulated stormwaters, they provide a great deal of pollution control and help to recharge the groundwater.

Use of retention ponds can cause two problems in this region. First, retention ponds require considerable land area that must be totally allocated for the purpose of stormwater management. In view of the expected population increase in the region and the associated demand for open space, such use of land may not optimize its value. When retention ponds are constructed on tight, clay-like soils, another problem may develop. Such soils contain runoff waters for long periods, often causing septic conditions that result from biological decomposition of runoff carried materials. The resultant odor problems and aesthetic blight have given retention ponds a bad reputation within the region.

Detention ponds have most of the benefits of retention ponds without the problems. Detention ponds are runoff storage ponds that capture the stormwaters and release them at a later time using a more manageable release rate. Proper operation and maintenance of detention ponds avoids the problems of land use and septic conditions associated with retention ponds. These ponds can be developed in parks and other open space areas resulting in only a temporary (usually less than 7 days) curtailment of use. The benefits of detention basin usage are some groundwater recharge, partial in-pond BOD_5 treatment and physical settling of solids. A high level of operation and maintenance is required for detention ponds when multiple use of the land is encouraged.

A good measure of flood and pollution control can be provided by rooftop detention designs and use of porous pavement in large parking areas and main thoroughfares. These measures, however, are not immediately available in the region. Rooftop detention can be implemented with all new construction that provides for flat roofs, but cost on existing buildings would be high. Installation of porous pavements can be a quite successful means of controlling sediment loads and flooding. Practicality of these porous surfaces has not been adequately demonstrated for cold weather climates.

2.10.2.2 Treatment

Although many of the storage control options discussed above also provide some degree of treatment, they are kept separate for ease of assessment. Treatment strategies encompass:

- Sedimentation;
- Swirl concentrators;
- Microstrainers;
- Dissolved air flotation units;
- Contact-stabilization basins;
- Physical-chemical treatment systems.

All of the above treatment strategies utilize some degree of storage. The amount of storage needed depends largely upon the expected stormwater flow and the size of equipment to be utilized. Because of the small amount of rainfall in the Larimer-Weld region, use of expensive mechanical equipment is not encouraged at this time.

2.10.2.3 Increase Stormwater Sewer Capacity

The cost of redesigning storm sewers and reconstruction are quite prohibitive and such efforts do not result in any pollution load abatement. Because of the high cost and the lack of pollution control received by such a strategy, local officials are encouraged not to consider replacement of the storm sewers without first thoroughly investigating the other options that may prevent flooding.

2.11 RECOMMENDED IMPLEMENTATION STRATEGY FOR URBAN RUNOFF CONTROL

The implementation strategy defined herein attempts to meet fully the objectives of Section 208 (2) of Public Law 92-500 by establishing a "process to identify.... and set forth procedures and methods to control.... (non-point source pollution) to the extent feasible...." The implementation strategy or process recognizes the four fundamental implementation responsibilities described in Institutional and Financial Analysis and Recommendations, Volumes I and II (Larimer-Weld COG, November, 1977). They are:

- Areawide planning
- Management
- Operations
- Regulations

Further, the strategy takes into account the following factors:

1. The state of the art of analytical tools;
2. The scope and level of analysis conducted to date;
3. The availability or lack thereof of an adequate water quality data base;
4. Ongoing related programs;
5. The severity of the pollution problem.

The recommended implementation plan will be defined in terms of a long-range (20 year) program designed to meet stated objectives. Additionally, a one-year Action Plan (AP) will be described for each of the implementation functions described above. The Action Plan will serve to initiate the implementation process by defining specific tasks and assignments which implementing agencies must accomplish in a one-year period. Following accomplishment of the tasks, the long-range program will be modified, if needed, and subsequent one-year Action Plans developed.

2.11.1 Long-Range Urban Runoff Pollution Control Strategy

Objective:

The objectives of a long-range urban runoff control strategy are as follows:

- To establish policies, programs, and appropriate regulatory measures to prevent non-point pollutional loadings to irrigation systems, ground and surface waters resulting from urban growth;

- To abate existing pollutant loadings to the extent attainable through the use of "house-cleaning" -type operations;

- To integrate water quality considerations in the management of urban stormwater and flood control.

Discussion:

Sufficient analysis has been conducted to conclude that urban runoff poses a potentially significant contribution to ground and surface water quality degradation in certain areas of the Larimer-Weld region. This is due to the variety of pollutants which are present in urban stormwater discharges, the slug loading effect on stormwater conveyance systems and surface waters, and the increase in imperviousness resulting from projected urban growth. However, insufficient evidence has been documented to justify an aggressive and potentially costly structural urban stormwater quality control program at this time. Nonetheless, actions can be taken which could lead to a cost effective urban runoff quality control program. Basic elements of the program include improved litter control and street sweeping operations in the major urbanized areas (Fort Collins, Loveland, Greeley, Estes Park) and stormwater management.

The urban areas of the region have been fortunate in the sense that community drainage requirements are largely accommodated by the existing system of natural drainages and man-made irrigation ditches and reservoirs. Although agricultural conveyance and storage structures were not originally designed to purvey or impound urban runoff, developing urban drainage patterns have evolved to include such facilities as an integral component. The drainage capability exhibited by the agricultural water supply system has historically functioned so well as to largely preclude the formulation of alternative local or regional runoff management strategies. Presently, however, the extent and rate of community growth in Larimer and Weld Counties is such that reliance on the agricultural system to satisfy urban drainage requirements may no longer be blindly assumed. Ditch systems may not possess channel capacities capable of conveying the volume of tributary urban inflow. In such cases, the occurance of a "breakout" is possible. The intense development of the urban environment in the region often is adjacent to ditch right-of-ways. Hence, flooding associated with breakouts could have severe economic and human impact.

The need for a comprehensive program for urban drainage management in the region has become apparent in recent years. Recurring incidences of flooding serve to keep the drainage issue in the public eye. A program of flood control is readily amenable to incorporation of features oriented toward preservation and enhancement of water quality. Communities of the region have the opportunity to protect receiving water quality in an integrated system of runoff control. The fact that local and regional attention is focused on urban drainage requirements is an extremely timely and propitious occurrence. This relates to the fact that it is extremely cost-effective to address water quality considerations in the initial formulation of a water quantity management program.

The character of the urban runoff collection and disposal systems in the region is ideally suited to incorporation of specific types of pollution control measures. These strategies will be highlighted.

Runoff detention or attenuation involves controlling drainage for the purpose of reducing peak flood crest by extending the duration of flow. Attenuation basins can serve to temporarily store tributary urban runoff. Inflow can be discharged to a conveyance facility such as a natural drainage or irrigation ditch through regulated releases when the major impact of a storm has subsided.

Attenuation basins are a preferred runoff control strategy because temporary storage can be provided to ensure that the conveyance capacity of existing structures is not exceeded. Hence, use of natural drainages and the agricultural water supply system is maximized in an engineered program of runoff management.

Sedimentation associated with relatively quiescent conditions produced in attenuation basins has significant merit as a form of urban runoff pollution control. Basins can be sized to allow a major portion of the suspended runoff load to settle out. Use of attenuation basins as a treatment for biochemical oxygen demanding substances (BOD) is viable primarily for those associated with settleable suspended material. Detention times provided bv attenuation facilities are not generally long enough to result in significant treatment of dissolved or fine BOD.

Continued street-sweeping at existing or slightly intensified levels of effort is a valuable means of achieving control of a portion of urban non-point pollution. Sweeping in conjunction with housekeeping and anti-litter programs has an appropriate role in mitigating pollutional impacts of urban runoff.

A practical approach to urban runoff control in the region would involve applying available control options at approximately the following specified levels of intensity:

Non-structural (street-sweeping)	:	15% of total BOD loading
Structural (storage/treatment)	:	40% of total tributary BOD loading

The total degree of BOD control attained would be on the order of 50 percent.

Annual expenditure of funds to achieve a 50 percent level of control would be roughly as follows (millions of dollars):

OPTION	FORT COLLINS	GREELEY	LOVELAND	TOTAL
Non-structural (street-sweeping)	0.18	0.14	0.06	0.38
Structural (storage/treatment)	0.22	0.16	0.09	0.47
	0.40	0.30	0.15	0.85

2.11.2 One-Year Action Plan - Areawide Planning

Areawide planning responsibilities include the following tasks:

Task 1: Provide technical assistance to management and operations agencies in the carrying out of their respective tasks as defined below.

Task 2: Refine and implement a water quality sampling and monitoring program for urban runoff pollution as an integral part of a comprehensive sampling and monitoring program. Federal, state, and local agencies and NPDES permit holders will be contacted to ascertain the availability of resources and programs which could be coordinated to improve the water quality data base. The feasibility of establishing a central data bank will be determined.

Task 3: Investigate the need for and develop, if appropriate, the substance of local subdivision codes and ordinances which lead to on-site attenuation of urban stormwater runoff. Such codes or ordinances would be oriented both for stormwater drainage/flood control and water quality control. Criteria will be developed based on sound economic and engineering principals.

Task 4: As a companion to or in lieu of Task 3, as appropriate, develop a manual for integrated stormwater management and quality control. The principal reference for developing a manual will be Urban Storm Drainage Criteria Manual (Wright-McLaughlin Engineers, March, 1969). The manual will provide guidance for management agencies to establish a cost-effective pollution control program as an integral part of overall stormwater management.

Task 5: Conduct technical studies to further define water quality impacts of urban runoff and control measures. Such studies would involve defining the capacity of existing drainage systems including irrigation canals, reservoirs, and structures, urban storm drainage systems and neighborhood stormwater catch ponds. Water quality sampling and flow measuring would be required. Operation of existing drainage systems would be assessed and recommendations made to improve operations for water quality purposes. The technical analysis would be conducted for the following urban areas: Fort Collins, Greeley, Loveland and Estes Park. Appendix C of this report is a detailed work plan for Task 5.

Task 6: Evaluate the performance of management agencies, assign new tasks and completion dates where warranted.

Management

Task 1: Define boundaries of urban stormwater management area for Fort Collins, Loveland, Greeley and Estes Park. Assess areas of rural development and determine areas of critical stormwater management problems for which control plans can be developed.

Task 2: For the urban areas of Fort Collins, Loveland, Greeley and Estes Park, define a long-range program (process) for integrating water quality control considerations into stormwater management programs. The program description will include, as a minimum, the following elements:

1. A definition of the urban stormwater management area (map);
2. An inventory (with map) of areas experiencing stormwater flooding problems, excessive sedimentation, structural problems, excessive public nuisances such as algae in ponds, grease slicks, floating debris, etc.;
3. Existing or planned annual budget expenditures for stormwater management including:
   - Administration costs
   - Engineering/legal fees
   - Estimated construction cost
   - Operations and maintenance costs (labor and materials).
4. A statement of additional technical assistance needs including estimated costs;
5. A list of organizations within the designated area who will participate in the development and implementation of a long-range stormwater management plan;
6. A list of practices or activities which the management agency feels have water quality significance and for which they will incorporate into their stormwater management program to the extent feasible;
7. A statement of affirmative action to implement the long-range plan to the extent feasible signed by the elected officials of the management agency.

The program will be submitted in report form to the areawide planning agency in time for incorporation into the annual 208 Plan Amendment Process. Guidance in preparation of the report will be provided by the Planning Agency. The report should be as brief and concise as possible.

Task 3: Develop and consumate agreements (contracts) with operations agencies defining relative roles and responsibilities.

Task 4: Monitor and evaluate operations agencies, as applicable, and certify compliance with respective implementation requirements to areawide planning agency.

Operations

Task 1: Continue ongoing housecleaning responsibilities, i.e., litter control and street-sweeping.

Task 2: Enter into intergovernmental agreements (contracts with management agency as defined in Management Task 3 above.

Regulatory

No new regulatory responsibilities are recommended at this time. Planning Task 3 may result in regulatory measures to be incorporated into the 208 Plan.

3.0 SILVICULTURAL ACTIVITIES AND THEIR WATER QUALITY IMPACT

The evaluation of silvicultural activities provides a general overview of water quality impacts attributable to pollutional sources in forested areas of the two-county region. The analysis is included to provide background information to local and regional officials on which they can base judgments concerning forestry activities. This investigation places silviculture in a proper perspective with other regional non-point sources of pollution.

3.1 FOREST OPERATIONS

A large number of activities within the forested areas can contribute to degradation of water quality. Many activities loosen soil and contribute to erosion and sediment in the streams. Additional human encroachment can impact water quality by increasing nutrient levels. Figure 3.1-A shows the location of the major silvicultural operations in Larimer County that may impair water quality. These operations include logging, construction, grazing, and recreational uses of the forest.

Three ranger districts are located in Larimer County. The Estes Park Ranger District manages the national forest land south of Storm Mountain in Larimer County. Within this area, a considerable amount of the forest land is under private ownership and management. North of the Estes Park Ranger District and Rocky Mountain National Park is the Poudre District. The Cache la Poudre River borders the District to the west and north. The area within Larimer County north of the Cache la Poudre River to Wyoming and west of Highway 287 managed by the U.S. Forest Service is within the Red Feather Lakes District. Much of this area is also privately owned and managed. The forested area in the region is about 25 percent of the total area and nearly 1,500 square miles of land is federally owned.

3.2 GENERAL FOREST WATER QUALITY

It is important that the present water quality of the forested areas are adequately assessed so that future or present practices that may alter the water quality may be identified. Water quality data for the forest waters has been collected by the United States Geological Survey for only a short time. Data is available for water years 1971 to present at most sites and for larger periods of record on the plains. Temperature, specific conductance, pH, dissolved solids, chlorine, nitrogen, hardness and dissolved oxygen are all analyzed with monthly samples. Occasional heavy metal and pesticide samples have also been analyzed.

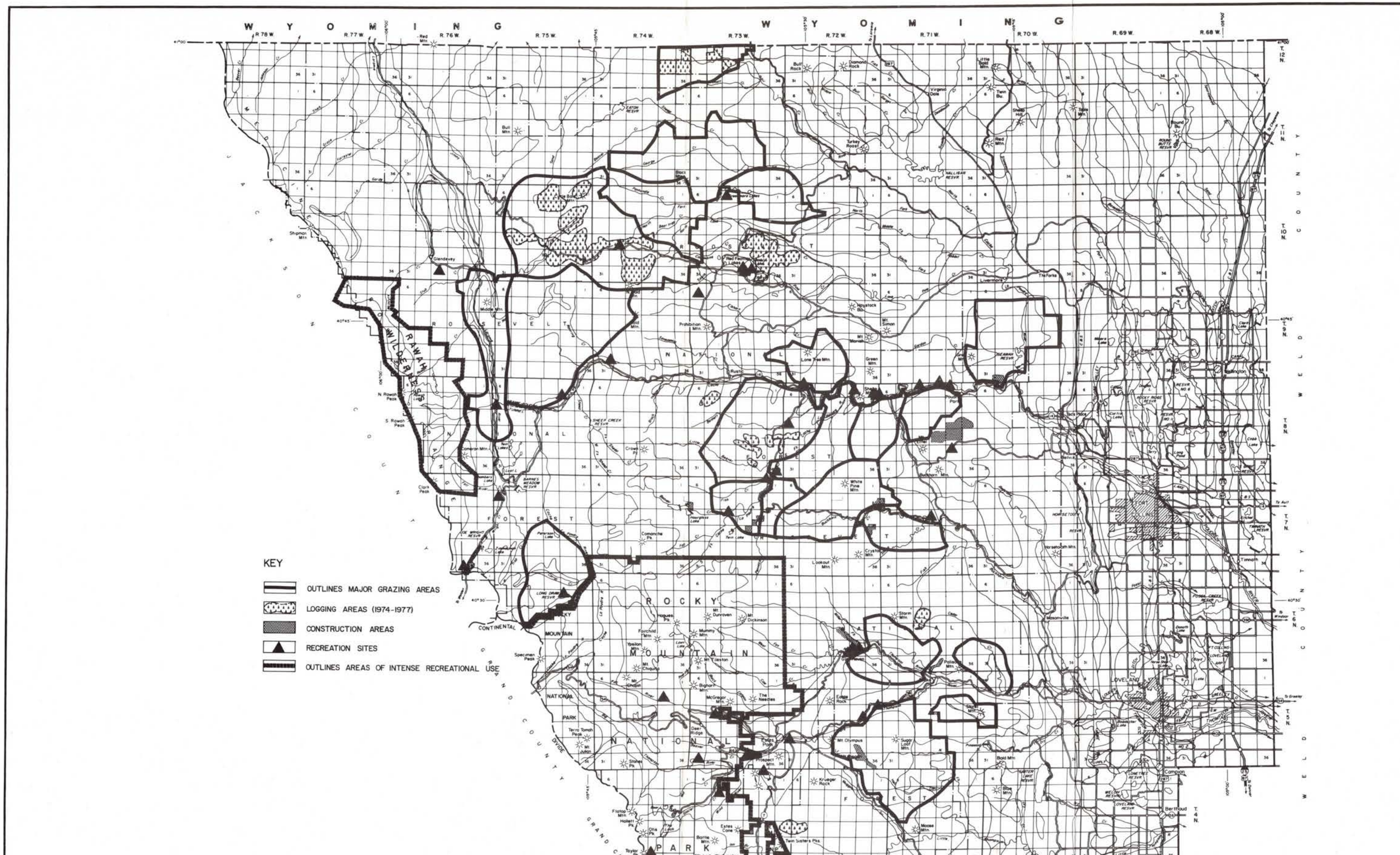


FIG. 3.1-A. MAJOR FOREST ACTIVITIES AFFECTING WATER QUALITY

Long term records for the Big Thompson River and the Cache la Poudre River are not available in the mountainous areas.

3.2.1 Big Thompson River

Water quality data from the Big Thompson River has been collected only sparsely. Data collected in November of 1973 indicates that water quality above Lake Estes is very good from the standpoint of maintaining a high quality fishery.

The Public Health Service has collected some water quality data on the Big Thompson River in May and July, 1976. This data indicates that the general water in the forested areas is low in suspended material, biochemical oxygen demand (BOD) and coliforms, but does accumulate constituents along the river's course. Suspended solids nearly double between the Estes Park area and the Narrows. Coliform counts also increase along the river's course. It is difficult to determine how much of this increase is due to normal forest activity and how much is due to human encroachment and activity along Highway 34 and the Big Thompson River.

One difficulty associated with determining the base water quality level of the Big Thompson River is that the flood of 1976 had and will continue to have a significant effect on these waters. High sediment loading will continue to be characteristic of the river for many years. Other pollutants including BOD, metals and color will continue to be found in these waters as a result of the flood. Implementation of management practices that prevent additional material from getting into the Big Thompson River will assist this river in returning to a scenic waterway capable of supporting a fishery. Presently both the U.S. Forest Service and the Soil Conservation Service are involved in a program to rechannelize the river. The program will eventually do much to control channel sediment. When completed, this effort will cost over $1.0 million.

3.2.2 Cache la Poudre River

Water quality data in the Cache la Poudre River drainage is more extensive than that for the Big Thompson. Water samples have been collected near Rustic and at the mouth of the Poudre Canyon near Fort Collins since October 1971 by the USGS. Generally the water quality is good. Constituents of dissolved solids, specific conductance and coliforms in the water increase in concentration as the river approaches Fort Collins.

Continual monitoring on a routine basis of the major streams should be implemented. Once a monitoring program is established, it will be possible to fully evaluate the impacts of the various silvicultural activities on water quality.

3.3 LOGGING

The most severe water quality impairments in forested regions is generally associated with logging operations. Most noticeable is the increased sediment caused by construction, tree falling, skidding, road use, dust and off-road use by equipment. The above activities all contribute to soil disturbances which provide loosened material for easy transport by water. Logging work can also impact water quality by increasing water temperature through the removal of vegetative cover, reducing dissolved oxygen through introduction of organic materials, and allowing more exotic pollutants such as solvents, solid wastes, and chemicals associated with heavy equipment use to reach the streams.

Logging within the Estes Park District is limited to small operations. Most of the logging is used to increase snowpack and provide firewood [Condon, 1977]. By thinning high mountain areas more snow can be packed at the ground level; this provides a slower release of moisture than would be observed if the snow was caught in branches. It also reduces evaporation losses during snowmelt. Logging operations in the Poudre and Red Feather Lakes Districts are on a larger scale. Figure 3.1-A shows the location of major cutting operations that were recently completed or that are soon to be initiated by the Forest Service. The major timber sale areas are located east and west of Red Feather Lakes.

The more exotic techniques such as helicopter and balloon logging are not economically feasible in this area. These techniques are feasible only in areas exhibiting difficult access and high yields. The U.S. Forest Service has for many years stressed the importance of adequate planning and maintenance as part of all logging operations. Because of the planning and control measures promulgated by the Forest Service, discharge of sediment and other pollutants to the streams of the region is kept to a low level.

In communications with Colorado Forest Service officials it was determined that 50 percent of the total timber sales in Larimer County are private sales. The difficulty of field checking on private timber sales prevents their presentation in Figure 3.1-A.

Private logging contracts do not always contain contract requirements for sediment and erosion control measures. The private logging contracts are usually smaller than Forest Service contracts and hence provide less economic incentive for the contractor to control the pollutional aspects of his operation. Further, the private timber grower usually lacks the background needed to provide water resource protection within a sales contract. The State Forest Service does provide technical assistance to the private grower. There is no charge for this resource management advice. This service is not often utilized because of the inconvenience to the grower and the lower price received for timber due to increased sediment and erosion control costs.

This high level of timber harvest by private landowners indicates that superior water quality management by the Forest Service alone will not guarantee high quality mountain water. Local regulatory programs can help to alleviate the water quality problems that stem from inadequate control of private timber management.

3.4 CONSTRUCTION

Most of the construction activities pursued by the Forest Service in the region are related to logging activities. Most logging in the district is near existing roads, and not much new access or rebuilding construction is required. Logging road construction can cause severe water quality deterioration unless proper control is exercised. The design engineer must have a knowledge of local conditions. This knowledge prevents the construction of roads on loose soils, unstable slopes, near streams, in wet or boggy areas, and at inappropriate times of the year. By careful pre-construction planning, many problems that relate to water quality can be avoided. Once construction begins, adequate temporary drainage measures must be utilized and followed by permanent facilities as soon as possible to assure protection throughout the life of the project. Proper timing can assist revegetation efforts and avoid unnecessary soil exposure during wet periods. All of the techniques outlined in the following chapter on construction can and should be used within the forest area.

Because retired logging roads often become recreation roads following the project, it is necessary to insure proper maintenance. Ditches, culverts, and catch basins must be adequately cleaned. Vegetative efforts must be inspected and accelerated where measures appear to be inadequate. Access must be prevented in areas where further road use may impair water quality or when weather conditions prohibit stream protection.

Recreational road construction, public facility construction, private home development and accompanying access also contribute to construction in forested areas. Figure 3.1-A shows the location of construction activities in the forested areas. Water quality management measures applicable to logging road construction are also available for implementation with these other construction activities.

3.5 GRAZING

The most noticeable water quality impact in the forested areas may be caused by grazing. Figure 3.1-A shows the areal extent of the major grazing allotments. Most of the private lands in the Laramie River basin are also grazed but are not included in Figure 3.1-A because of their scattered nature. The Estes Park District has four active grazing allotments in Larimer County. One is located in the North Fork of the Big Thompson drainage west of Drake. A second area of about 30 square miles is located south of the Big Thompson River between Drake and Estes Park. Another grazing allotment is around Stone Mountain, and a final allotment is located around Alexander Mountain. Seven grazing allotments are presently active in the Poudre District. These grazing areas are located on the eastern end of the District and cover over a third of the District's land area.

Grazing within the Red Feather Lakes District is extensive. Only the Rawah Wilderness and the general area south of Red Feather Lakes are not presently under active grazing allotments.

It is difficult to assess the water quality impairment caused by cattle and other stock grazing. Grazing allotments are based upon range studies that incorporate the forage type, forage conditions, animal type and possible resource damage. Continual monitoring of grazing areas reduces the possibility of resource damage.

Cattle spend much time in close proximity to streams. Watering and grazing near flowing water can cause stream bank deterioration and can greatly increase the sediment load. Nutrient loading can also be experienced. Water quality can be maintained by controlling salting and watering of stock to areas where environmental deterioration will be minimized.

3.6 RECREATION

There are three picnic grounds located on the North Fork of the Big Thompson River and a fourth facility located east of Estes Park near Mount Pisgah. Located along the Cache la Poudre River are four campgrounds and three picnic areas. Adding to this use are four rest areas and a trailhead which receives automobile and foot traffic. Another picnic ground and one more campground are located in the Poudre District. Five campgrounds are within the Red Feather Lakes District. These locations have sealed vault facilities and are insignificant pollution sources. Due to the high intensity road and foot traffic at these areas, considerable sediment can be carried to nearby streams. Solid wastes also enter the waters near these facilities when users are careless. Figure 3.1-A shows the location of the recreation facilities within the National Forest.

3.6.1 Diffuse Sources of Pollution in Intense Recreation Use Areas

Aesthetic qualities of forested areas attract large numbers of people every year. Waters in forested areas are used for fishing, bathing, utensil cleaning, fecal waste removal, liquid waste removal, and consumption by people and animals. All of these activities can result in some level of pollution and are generally termed diffuse sources of pollution. Other recreational activities that can affect forested water quality are intense trail use resulting in soil and sediment movement and increased use of pack animals on trails. Grazing by this pack stock can also lead to erosion, increased sediment deposition, and nutrient loading.

3.6.1.1 Control

Heavy use areas such as the Rawah Wilderness area and Rocky Mountain National Park are most likely to notice water quality impacts from these diffuse sources. Since 1962 use of Rocky Mountain National Park has increased by 60 percent. By the year 2000 the number of visitors is expected to exceed 3.5 million per year. The National Park is presently employing a number of methods to control the impacts of heavy recreational use. Sewage and solid wastes are being hauled out of the park where they may be properly treated. Overnight use in the park is controlled by a permit system, a means which provides a limit to gross possible impacts. Areas of very heavy use such as the Longs Peak Trail have privy deposits removed by helicopter.

3.6.1.2 Pollution Loads Evaluation

The major problem with evaluating the possible impacts on water quality due to intense recreational use is determining the total wasteload generated by these uses. Methods for distinguishing between human wastes and ungulate contamination have not been fully developed and therefore it is difficult to evaluate the potential pollutional load contributed by human use. However, the impact must be large. From January 1, 1977, to August 23, 1977, a total of 49,000 camper nights had been experienced within Rocky Mountain National Park. This level of use corresponds to over 3.5 tons of BOD potentially deposited as human feces in the park alone. Currently the National Park Service is establishing a monitoring program in two locations. One location is a wild area lacking trails and with prohibited overnight use. The other monitoring area, near the Longs Peak Trail, is known to have a large volume of human use. It is suggested that this monitoring system be provided sufficient funds and staff to yield the quality of information needed to fully evaluate the impacts and wasteloads from diffuse sources in areas of intense recreational use. Any level of effort below this may fail to provide the needed information to guarantee water quality in such alpine areas.

The information that has been gathered in overnight recreational impacted areas demonstrates the occurrence of relatively insignificant impact from excrement. However, the small amount of data developed that specifically deals with this aspect of pollution does not provide sufficient information to adequately address this complex problem. Impacts of trail use have been repeatedly documented.

3.7 FIRE

Uncontrolled fires have long been recognized as a phenomenon that can contribute to adverse effects upon water quality. Such fires can initiate a sequence of erosion such as:

- Destruction of plant cover, litter, humus and the upper structure of the soil;
- Exposed soil tends to puddle and reduce infiltration of rainwater;
- Surface runoff is increased;
- Soil particles no longer protected by vegetation or litter are easily carried by runoff to streams below.

The extent of the fire damage, soil type and slope all govern the degree of these effects.

Fire damage to vegetation, litter, humus, and soils is a function of the heat of the fire and hence the fuel availability and weather. High intensity fires (from 20,000 to 100,000 BTU/sec/ft of fire front) occur only where accumulations of fuels, brush and timber are thick.

3.8 FOREST SERVICE PROPOSAL

In 1975 the United States Forest Service submitted a proposal which was directed at acquiring the necessary data for evaluating silvicultural impacts to water quality. The proposal outlines the following objectives:

- Identify sources of non-point water quality pollution;
- Identify in quantitative terms the relationship between non-point pollution sources and land use activities;
- Develop, through basic land and stream characterizations, prediction of water quality changes in response to various land use activities;
- Recommend management prescriptions to improve or maintain existing water quality--identification of "Best" management practices;
- Initiation of "baseline" water quality monitoring for assessment of effectiveness of "Best" management practices (long term). Assessment of water quality changes beyond existing conditions over time.

Land uses associated with grazing, wilderness, timber, private development, recreation and off-road vehicle use are specifically addressed within the scope of study and assessment of impacts associated with each use will be possible if such a study were initiated.

The proposal delineates a work plan that is both complex and broad. The work begins with a water quality sampling network aimed primarily at identifying "sensitive" landforms. The data collected will be analyzed in conjunction with seasonal and streamflow characteristics. Infrared flight observations will also be used because of their value for land use and type differentiation. The resultant land and water quality characterization will make land use impact determination an easier task.

The study is a two-year research program that involves three levels of study. Level I develops broad land use and water quality data for background information on Levels II and III. The data collected for Level I is also used for model development. Study Level II involves more intense data collection within a narrower spectrum of land uses than used in Level I. This level of study will help identify land types and potential or existing water quality hazards. The selected sampling locations and large number of samples will allow development of prediction techniques for a quantitative assessment of various non-point source water pollution impacts. The final study level is directed at acquiring a qualitative assessment of silviculture activity and water quality. The entire study would cost approximately $350,000.

3.9 SUMMARY

Development of recommendations for initiation of Best Management Practices (BMP's) in the Larimer-Weld region concerning silvicultural activities must be oriented toward the region's water quality goals. Commercial, agricultural, industrial, recreational, and residential uses of these mountainous waters all imply different water quality criteria. Development of a BMP for silviculture must incorporate all of these possible in-forest and downstream beneficial uses into a technological and economic water pollution control guideline.

Analysis of the relative water quality impacts of the various silvicultural activities cannot proceed from a poor data base. Because most constituents involved in silviculture non-point pollution also occur naturally, it is a difficult problem to separate natural and man-induced levels of water quality degradation. In addition, natural streams tend to have large seasonal fluctuations in suspended solids, BOD and turbidity. Therefore, it is difficult to determine the origin of the various changes in water quality. Means have been developed that allow separation of natural sediment from activity induced sediment. These techniques utilize statistical analysis to arrive at flow and sediment load relationships. Means should be found to implement a water quality sampling program that will provide water quality planners and forest managers with the necessary information to make decisions that minimize water quality impacts.

3.9.1 Logging and Construction

Logging roads generate a large amount of non-point waste constituents within the forested areas. Careful pre-construction planning and on-site management during construction can prevent many problem situations from occurring. The U.S. Forest Service utilizes many pollution prevention techniques. Implementation of these techniques by all people involved in forest construction should be encouraged as a measure to mitigate impacts on this non-point source activity.

The first measure to guarantee retention of high water quality within the mountainous areas of Larimer County is law. Such measures as the Idaho Stream Protection Act and Stream Standards established in Washington and Oregon are helping to preserve water quality in those areas. Such law should not be a set of hard and fast rules delineating specific requirements. For example, a BMP may prohibit construction on slopes of greater than forty percent. However, construction of a route three to five times longer than the original road distance to avoid a forty percent slope area cannot be seen as a worthwhile trade in terms of cost or pollution control. A concept that allows evaluation of trade-offs between alternative practices will be the best approach.

3.9.2 Grazing

Careful resource evaluations made by state and federal officials on their lands prevent severe water quality problems due to grazing from developing on these lands. Private landowners who lack this type of range management expertise often fail to prevent range damage and protect water quality.

A means of helping private landowners assess grazing capabilities of their land may be utilization of a permit system for a non-point source generator.

3.9.3 Recreation

Studies conducted on the impact of intense recreational use of forested areas have not been able to show that present levels of recreational use are creating a pollution hazard. These studies need a higher level of effort to reach such a conclusion. Monitoring of streams and lakes in impacted areas should be increased to address this question. A thorough program should be established that can assess the pollution loading to alpine lakes and streams.

3.9.4 Fire

Each fire can result in benefits and losses to forest water quality. Local fires appear to not severely alter water quality.

3.9.5 Control

Non-point source control in forested areas should be directed toward a high level of performance in all areas of forest management. A high level of performance means utilization of applicable sediment control measures, specific site evaluations for climatic and hydrological factors, adequate training of forest management personnel and operators, and proper maintenance of facilities. Existing federal and state forest agencies can provide the direction and assistance needed to guarantee a high level of performance by all parties involved in forest use.

3.10 RECOMMENDED IMPLEMENTATION STRATEGY

The implementation strategy defined below is a process which will lead to the abatement and prevention, to the extent feasible, of pollution from silvicultural activities. The process recognizes the following factors:

1. The availability of adequate data base;
2. The state of the art of analytical tools;
3. The level of analysis conducted to date;
4. Ongoing related programs;
5. The severity of the pollution problem.

3.10.1 Long-Range Program

Objective:

The objectives of a long-range program for the control of pollution from silvicultural activities is as follows:

- Through water quality sampling, monitoring, and analysis, define the extent of existing or potential water quality degradation resulting from silvicultural activities (including recreation), the aereal extent of pollution generating activities including the identification of sensitive areas, and cause and effect relationships;
- To establish policies, programs, and appropriate regulatory measures to abate and prevent pollutant loadings from silvicultural activities on surface water systems;
- To establish public educational programs which could result in activities and practices that reduce or mitigate man's impact on water quality in the mountain areas of the region due to recreational activities.

Discussion:

The three components of this implementation program can provide the region with a high level of control of mountain water quality.

The first component of implementation is development of necessary data to arrive at an understanding of how silviculture activities affect water quality. The levels of effort described by the United States Forest Service in their proposal to the Larimer-Weld Regional Council of Governments will do an excellent job of collecting the necessary local data, and it is recommended that study or a study of similar scope be implemented.

The conclusions and recommendations that are developed by the study outlined in Section 3.8 will be able to outline specific requirements of silviculture non-point source pollution control. These control requirements could then be implemented as county ordinances or other regulatory requirements as the second component of silviculture control.

4.0 EROSION AND SEDIMENT CONTROL DURING CONSTRUCTION ACTIVITIES

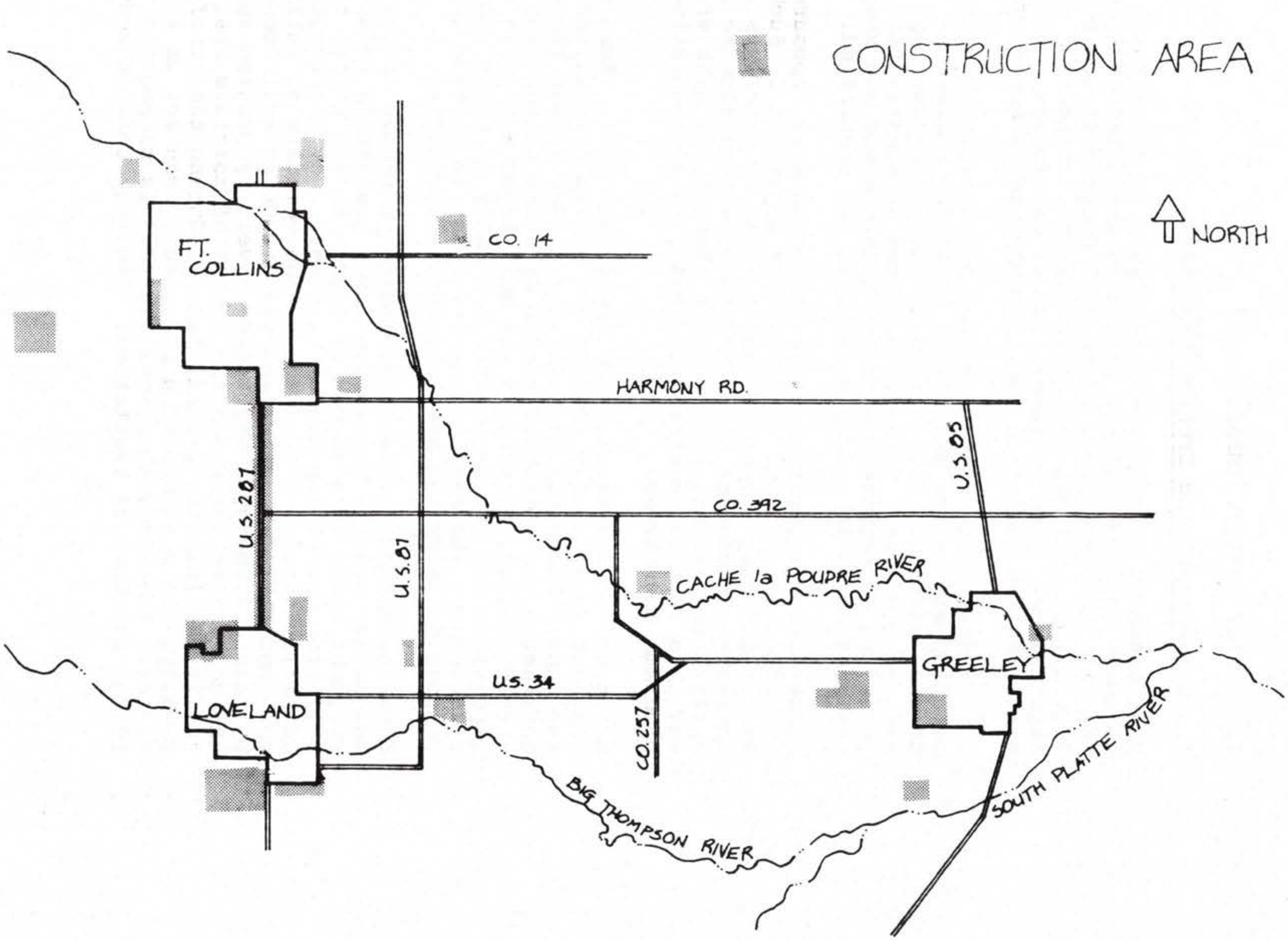
4.1 CONSTRUCTION

Construction can include a broad array of activity. Construction activities extend from patio building to stadium construction, street and gutter work to power line fitting. All these activities can contribute to regional water quality degradation and erosion problems. Pollutional impacts of construction activities are very much a real problem. Removing vegetation from a construction site and thereby exposing the soil to wind and water can cause extensive water quality impacts. Construction can result in 2,000 times more sediment than equivalent forest areas. Additional impacts can be caused by use of pesticides, mismanagement of solid wastes, construction chemicals, leaking machinery, paints and solvents. Proper management can reduce all problems associated with construction to an acceptable level.

4.2 CONSTRUCTION LEVELS IN LARIMER AND WELD COUNTIES

Most of the construction in the Larimer-Weld region is associated with urban housing development. Other construction activities include power line construction, new structures, street and gutter, ditch work, agriculture improvements, highways, commercial buildings, and recreational development. Figure 4.2-A shows major development areas in the urban area of Larimer and Weld Counties. It is important to emphasize that the expected high rate of growth within the region will mean that construction levels will increase over the next 20 years. According to the population and land use report aspect of the 208 Water Quality Plan, the population of Fort Collins is expected to increase by about 2.6 times. Loveland will grow about 2.4 times and Greeley will more that double. The town of Windsor may quadruple! The construction levels to accomodate such growth will also more than double. Maps showing the suitability of much of the two-county area for development from the standpoint of slope, soils, hydrology, and vegetation can be found in the report entitled, "Larimer-Weld Region Land Use Alternatives-Analysis of 20 Year Growth and Impacts," (August, 1977).

FIGURE 4.2-A MAJOR AREAS OF CONSTRUCTION IN THE LARIMER-WELD REGION



4.3 WATER QUALITY IMPACTS

4.3.1 Sediment and Erosion Problems

Most types of construction can result in significant sediment loads. Sediment particles are detached from the soil by some force. Such soil detachment can be a result of tillage, machinery working, compaction or rain energy. Each of these factors can loosen soil particles and assist in their conveyance to waterways.

Fine sands, silt, clays and organic particles carried in solution with water are called suspended sediment. Coarser particles not carried in suspension make up bedload sediment. Soil disturbances in construction areas can contribute greatly to both bedload and suspended sediment loads in nearby streams if not controlled.

Construction activities cause increased soil exposure and offer more direct runoff access to streams. Such direct and easy access of runoff water to waterways can increase the content and velocity of waters flowing into a receiving stream, can increase channel and bank erosion which in turn can contribute greatly to sedimentation problems downstream.

All types of construction do impact the soil. Even the smallest jobs usually require use of vehicles driven across the land. Such soil disturbances either loosen the soil increasing the potential amount of sediment that may impact stream quality, or compact the soil layer making it more impervious and increasing the intensity of water runoff. Disturbances increase sediment loading to streams while compaction increases soil erosion in streams.

Construction activities also damage or remove natural vegetative cover. Vegetative cover assists in reducing sediment loads in a number of ways. It can shield the soil from direct impacts of raindrops. By intercepting rainfall, natural cover reduces the velocity of falling rain and therefore decreases the amount of soil loosened by rainfall energy. Vegetative cover, by pushing apart the soil, also increases the amount of moisture that can infiltrate into the ground, hence reducing the runoff amount. Finally, the presence of a plant cover can act as a runoff filter. Water moving across the soil is slowed and filtered by the presence of vegetation. Sediment load is reduced.

Many types of construction alter the existing land contour. Some types level the area and hence may actually reduce total possible sediment load coming from the construction area. Other types of construction such as highways or mountainous road construction may greatly alter natural slopes and also increase sediment loading during storm events. By careful planning of all construction activities, these impacts upon water quality may be lessened.

4.3.2 Water Quality Changes Caused by Construction

Erosion and sediment are not the only water quality impacts caused by construction. Other impacts to water can be caused by use of pesticides, construction chemicals, cement, lime, fertilizers, oils, paints and solvents. Additional environmental impacts can result from the presence of solid wastes, litter, petroleum products, garbage and sanitary facilities. Many of the sediment control measures available to the construction manager are also effective in controlling these other constituents. Control is enhanced when pesticides, fertilizers, and other chemicals are used only when needed and applied only as suggested by the manufacturer. Proper maintenance of machinery and use of care in fueling machinery can provide nearly all of the control necessary to regulate water quality impacts of petroleum products. Education of personnel, good site selection and maintenance can effectively handle problems of paints and solvents, garbage, solid wastes, and sanitary waste.

4.3.3 Highway Construction Impacts

Many roads in Colorado, particularly in mountainous areas, are constructed adjacent to streams. This creates a short-term construction impact and a long-term impact from the disturbed soil.

Moving soil during cut and fill operations creates highly erodable conditions. Operating heavy equipment in the stream during construction generates large quantities of sediment in the stream, increasing turbidity and suspended solids.

Long-term problems are created by the long stretches of disturbed soil along the banks of the streams. Stabilizing vegetation returns to these areas extremely slowly because of the difficulty of establishing root systems in the loose granite soil and the soils' inability to hold moisture within a young plant's root zone.

4.4 METHODS OF CONTROL

A great number of control measures are available to reduce sediment load impacts caused by construction activities. There is presently very little legal control of construction in the region that protects water quality. The County Engineer's Office, by reviewing major developments for platting and drainage, is in a position to make sure that proper procedures are utilized that will protect water quality but presently does not usually review these plans with such objective in mind. Present land use guidelines can also aid in controlling construction impacts on the region's waters. Control measures herein are separated into two categories: non-structural and structural.

4.4.1 Structural Methods

Structural measures for construction runoff control are much the same as used in urban runoff control. Gravel inlets to drainage systems can provide excellent sediment control by slowing the velocity of the approaching water. Sediment settles out or is filtered by the gravel. Straw or sandbags can also act as sediment traps before runoff water is allowed to enter a runoff collection chamber. Bales of straw and sandbags act as miniature detention ponds with some filtering capability.

Sediment basins are another method of controlling sediment loads and slowing erosion causing carrier velocities that often result from construction activities. Such basins can be part of an existing ponding system or prepared before a project is initiated. Wet sedimentation basins are usually a part of an existing pond system. Dry basins are usually made on-site and allowed to dry after storm events.

Diversions, when used to control impacts of construction activity, are usually used to detain water for a period of time to reduce peak flow amounts and extend the time of flow. Dikes, ditches, and terraces are structural means of reducing velocities and changing peak flow timing to reduce the impact of construction runoff.

Two additional structural alternatives are available to diminish water quality impacts caused by construction. The first, channel relocation, involves increasing the stream capacity to handle increased discharges and reduce sediment loading and erosion. The cost of channel alteration prohibits its use for all but major construction operations. A final structural possibility is water treatment. Although on-site water treatment has been used at some construction sites, it is an expensive alternative that is not feasible for the vast majority of practices.

4.4.2 Non-Structural Methods

Non-structural methods of sediment control can be divided into two types, natural and management controls. Natural controls used to reduce sediment and erosion problems include retention of natural vegetation wherever possible, or reincorporation of sod or overstory vegetation as soon as possible. Natural ponding of water at the construction site can also reduce the total sediment load to a stream.

A great amount of sediment control and water quality impact control can come from a total management scheme and planned runoff management. Analyzing the construction sites for possible water management problems before actual construction begins can provide a total integrated approach that can be utilized for water pollution control. Such a management scheme should include:

1. A detailed plan to be utilized for the protection of the construction site and possible impacted areas. Such plan should provide protection for vulnerable areas on-site and downstream.
2. A measure of control, structural or non-structural, should be delineated to provide control of the speed and volumes of runoff from the area.
3. Methods to trap sediment should be included.
4. Soil stabilization methods should be outlined and a schedule should be made for grading, seeding and/or mulching. Management practices should include a method of adhering to stabilization schedules.
5. Each construction site should have a potential pollution analysis survey performed as an aspect of construction management.
6. Pollution abatement measures should be in the construction contract. Fluids, oils, fuels, wastewater, aggregate wash, salts, fertilizer and pesticide management should be included.
7. Finally, pollution control cannot be thorough unless maintenance of all facilities is a continuing process.

A number of principles and tools are available to the construction site planners that can be used to control pollution. To aid site evaluation, checklists are available. Stereoscopic aerial photos provide a means of assessing the possible hydrologic and hydraulic nature of runoff. Contour maps can help to plan the pollution control measures necessary at a construction site. Use of scientific professionals to assess vegetation type, cover, and nature of soils may sometimes be necessary on sites that are unique. All analysis should be directed toward assessment of possible water quality conflict.

4.5 RECOMMENDED IMPLEMENTATION STRATEGY

4.5.1 Long-range Program

Objective:

The objective of a long-range strategy for the control of pollution from construction activities is as follows:

- To establish defensible criteria, based on sound economic and engineering principals, to control erosion and sedimentation from construction activities;
- If applicable, establish local codes and ordinances to implement the above stated objective;
- Establish/implement a long-range education program.

Discussion:

Impacts of construction upon the water quality of the Larimer-Weld region is very insignificant when compared to other non-point sources of pollution. However, erosion impacts can be significant on a site-specific basis. Urban runoff and agricultural impacts, because of their close proximity to existing waterways, have greater possibility of impairing water quality. Because construction practices do not greatly alter stream quality does not mean that sound pollution control measures should not be implemented or that improvements are not important. The case for development of specific construction control ordinances becomes stronger in view of the very high level of construction activity currently pursued in the region. This high level will continue to increase and thereby increase the pollutional impact of construction.

Current ordinances on construction do not specifically address sediment control. Local ordinances or policies that require the development of a pollution control plan and the maintenance of a high level of performance by construction management and enforcement officials should adequately control water quality problems caused by construction. More careful analysis of control measures should be made where construction activity is close to waterways. The local 208 agency can assist the counties in developing more meaningful codes in relation to water quality preservation. Cities and counties can also develop construction ordinances that tie closely with the ordinances and controls suggested for urban runoff pollution control.

Special attention and study needs to be directed toward mountainous areas where construction is being pursued. Each road or other major construction activity should have a local design review that analyzes the total project. Such review should allow construction initiation only after all reasonable pollution control measures are agreed to be included in the construction plan. Local legal measures can be made available to insure compliance and regional study can define the level of control needed for specific areas and types of projects.

Ordinances should also be developed for housing construction, especially in sensitive areas, that prevent lengthy exposure of soils and require mitigation or control measures where necessary.

4.5.2 One-Year Action Plan - Areawide Planning

Task 1: Establish direct liaison with public and private agencies and organizations involved with construction activities.

Task 2: Evaluate need for establishing codes and ordinances.

Task 3: Establish substance if applicable, of codes and ordinances.

Task 4: Define the substance of a long-range educational program, administration, funding requirements.

Management - Operations - Regulation

No additional programs for control of pollution from construction activities are recommended at this time.

5.0 LEACHFIELDS AND UNLINED SEWAGE LAGOONS

Septic tank disposal of wastewater and percolation from unlined sewage lagoons represents a source of recharge to local groundwater. However, the benefit to the regional hydrologic regime may sometimes be negated by adverse water quality impacts. In certain localized areas in the region, surface and subsurface waters are contaminated by wastewater from septic tank leachfields and unlined sewage lagoons.

5.1 DESCRIPTION OF THE PROBLEM

Leachfields and lagoon systems are used by many individuals and communities in the region for wastewater disposal. Many of these systems are excellent, and cause absolutely no problems. Some cause local groundwater or surface water contamination.

5.1.1 Leachfields

Properly constructed and maintained septic tank/leachfield systems can provide adequate treatment for rural areas where central collection and treatment is not practical. Most problems with septic tank/leachfield systems arise from four basic causes:

1. Poor design or undersizing;
2. Improper maintenance;
3. Overloading due to heavy use;
4. Unfavorable leaching conditions due to shallow or low permeability soils or high groundwater.

In all these cases, there is a potential pollution hazard to local surface and groundwaters. The surface water pollution potential increases when the leachfields are very close to surface waters, especially in mountainous areas where fractures in the rock can provide a direct conduit from the leachfield to surface waters. The population and land use component of the 208 study has mapped the soil suitability of the triangle area of the region for septic tank and leachfield suitability.

These systems can also be health hazards, especially in high density areas where people rely on water wells for potable water. Another hazard exists when leachfields fail and sewage surfaces.

Problem constituents in domestic leachfield effluent are fecal coliforms, strepticocci, and nitrates. These constituents often appear in the surface or groundwaters in areas relying extensively on leachfields.

5.1.2 Seepage from Sewage Lagoons

Many communities in the region are served by either aerated or non-aerated stabilization ponds or lagoons. Very few of these are lined to prevent seepage. Many of the lagoons lose considerable quantities of water by seepage. This is evidenced by the fact that many lagoons have either little or no observed discharge, even where evaporation is less than inflow. The pollutants in this water percolate downward to the groundwater and can reappear in nearby water wells or surface waters. Pollutants typical of this source are BOD_5, TDS, nitrate and bacteria characterized by fecal coliforms. The bacteria normally die before they can travel very far in soil, so are generally only a problem if potable water wells are very close.

An analysis of available data indicates that for the lagoon systems which have no surface discharge, nearly 80 percent of the wastewater is eliminated through seepage while only 20 percent is evaporated. It is estimated that over 1 mgd of wastewater is lost to groundwater in Larimer and Weld Counties from lagoon systems. While this is insignificant when compared to such sources as irrigated agriculture, local effects can be detrimental.

The Colorado Department of Health has become increasingly aware of and concerned with this problem. Recent regulations have been proposed which require communities with unlined lagoons to obtain an NPDES permit. It is obviously difficult to monitor seepage to groundwater, so the only effective requirement would be to require lining.

It is probable that these regulations are needed and will be beneficial. However, little or no data on potential problems exist. Information normally exists only where a problem has actually developed. Throughout the state there are many non-point sources of groundwater contamination. The Department of Health should try to identify potential problem areas so remedial action can be taken before severe problems develop. Employment of a groundwater hydrologist by the Water Quality Control Division would be a positive step toward achieving control of these problems.

5.2 MAGNITUDE OF THE PROBLEM

Many people in the region are dependent on groundwater for their water supplies. This includes many people on community water supplies and those with individual water wells. This groundwater should be high quality water, free of toxic quantities of chemicals, tastes and odors, and organic contamination. Community water supplies must meet the stringent requirements of the Safe Drinking Water Act.

In some areas groundwater has become degraded to the point where county and state health officials are concerned. Figure 5.2-A shows the areas which are currently having surface or subsurface water quality problems.

Some communities along the South Platte River have noticed increasing levels of nitrates and dissolved solids. LaSalle has been officially notified that nitrate in its water supply exceeds Federal Drinking Water standards. The water wells at Red Feather may be polluted with bacterial contamination from septic tanks.

Several years ago an irrigation ditch was constructed near Severance which caused the groundwater level to rise. It is now high enough that many leachfields are lying in groundwater. Most residents solved the immediate problem of polluted wells by joining the North Weld Water Conservancy District and relying on this regional source of water supply. However, a few residents still use their wells for a potable water supply. Most residents irrigate their yards from water wells. Severance has recently received an 80 percent federal grant for design and construction of a wastewater conveyance and treatment facility. When these facilities are installed, the problem will no longer exist.

There are other, less critical problems in the region. Along the Big Thompson River before the flood, significantly increased levels of nitrogen and fecal coliforms in the river were measured. The same is true in the North Fork of the Big Thompson near the Forest Service picnic grounds. The septic tank/leachfield system serving Namaqua Hills near Loveland is overloaded. Lochbuie has had problems with leachfields of insufficient capacity. The Carma Carr Subdivision near Erie has had leachfield problems due to the presence of high groundwater.

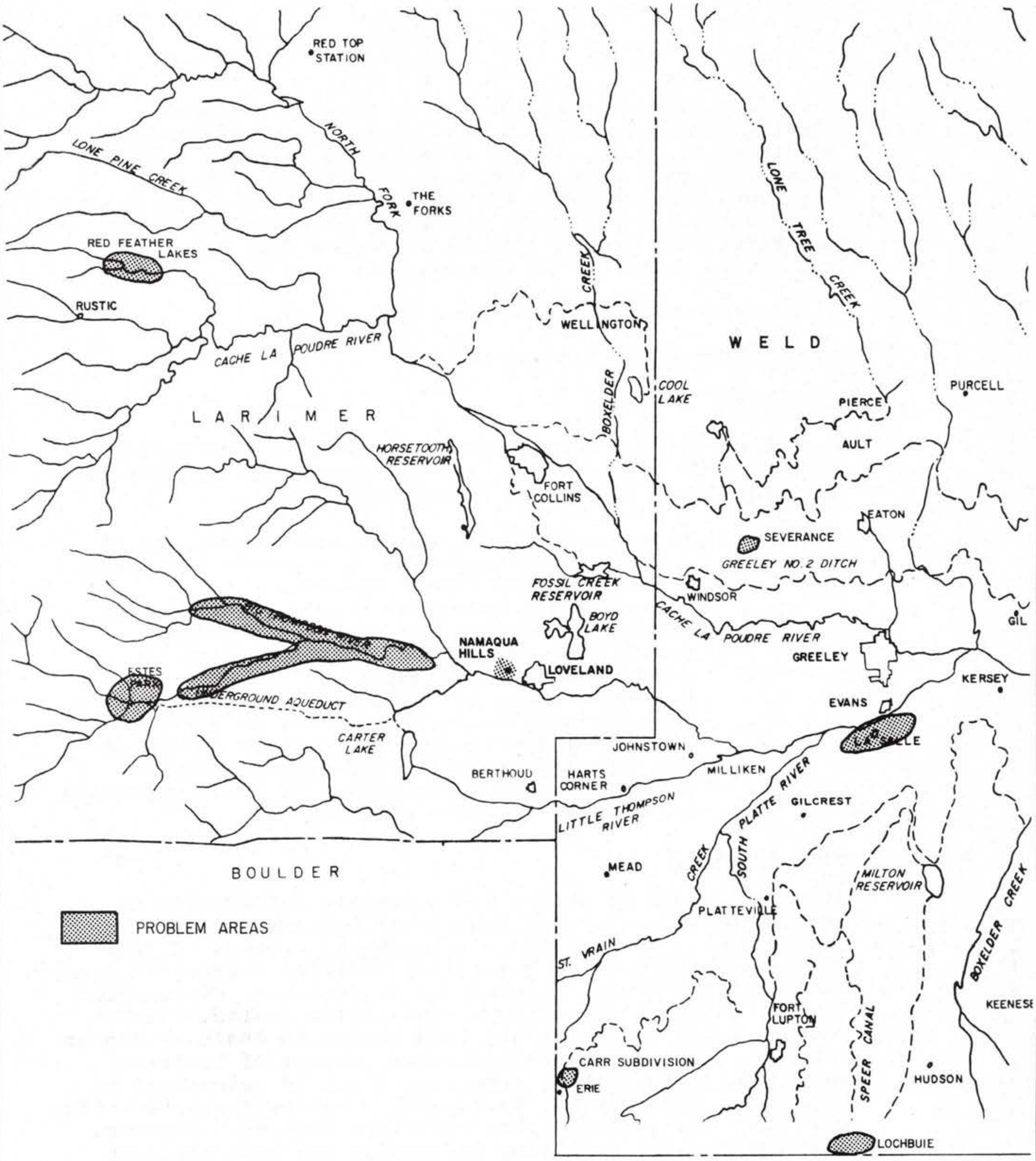


FIG. 5.2-A. AREAS CURRENTLY EXPERIENCING SURFACE OR SUBSURFACE WATER QUALITY PROBLEMS

There are groundwater problems in some of the more heavily populated areas around Estes Park that utilize septic tank and leachfield disposal of domestic wastewater. However, Upper Thompson Sanitation District has begun to serve many of these areas, a practice which is reducing the problem. Remaining unsewered areas in the Estes Park region will be served as soon as collection lines can be constructed.

5.3 RECOMMENDED IMPLEMENTATION STRATEGY

5.3.1 Long-Range Program

Objective:

The objectives of a long-range program for controlling pollution of ground water from failing septic systems and unlined sewage lagoons is as follows:

- To strengthen the capabilities of management and regulatory agencies to regulate the design and location of septic systems;
- To assess the extent of ground water contamination resulting from seepage of unlined sewage lagoons and develop a mechanism or program to regulate them;
- For areas where it has been documented that potential health problems occur as a result of failing septic systems, develop a program for improved operation and maintenance, or abandonment and construction of small community or individual sewage systems.

Discussion:

Study is needed to obtain the necessary information to assess the origin of and impacts of various groundwater contaminants. With respect to lagoons, a study of four to six pond sites that quantified effluent characteristics, extent of treatment, groundwater evaluations, evaporation losses, sludge accumulations, and inflow characteristics would provide the necessary information to evaluate lagoon impacts. Effluent characteristics, extent of treatment, and sludge accumulation rates could all be calculated by biological and chemical techniques. Inflow characteristics should be available in plan operation records. However, most communities utilizing lagoons do not have effluent records for inflow evaluation and therefore chemical and biological techniques may also be utilized for analysis of inflow characteristics. On-site evaporation losses could be calculated using pan evaporation techniques and extrapolating this data to the appropriate size of the lagoon. Groundwater evaluations would necessitate use of local wells as well as additional wells that may need to be drilled so that groundwater movement and groundwater pollutants could be evaluated in the vicinity of the lagoon. Such a detailed study will provide the region with knowledge of the amount of pollutants lagoons are contributing to the area's waters and the health impacts of these pollutants. The knowledge gained from this study can be used as a basis for development of specific regional controls needed in this area. A similar or concurrent groundwater study is also needed to control possible groundwater pollution originating from solid waste disposal sites.

Historically, the County Health Departments have regulated the design and location of individual septic systems. There is some concern that many systems have failed, some of which have been reviewed by the Health Departments. Further, there are no apparent standard and requirement for adequate maintenance of such systems. A strengthening of local health organizations would lead to a more effective regulatory program. Adequate data should be collected, recorded, and analyzed. Criteria should be established based on good epidemiological and water quality principles with which to assess and determine areas of major public health concern. Such a capability will be of major significance to communities who seek federal funding assistance for construction of waste treatment facilities. The Colorado Water Quality Control Commission considers the severity of the health problem in determining priorities for statewide funding.

5.3.2 One-Year Action Plan - Areawide Planning

Task 1: Define the location and extent to which unlined sewage lagoons cause significant water quality degradation. Conduct test field studies to ascertain the extent and mechanism by which ground water is degraded.

Task 2: Conduct critical review of present individual wastewater disposal systems in the area; evaluate their potential health and water quality impacts and recommend alternative treatment and disposal systems; establish eligibility and priorities for state and federal funding; recommend responsible agency.

Such a review will analyze the present regulations to determine their effectiveness in preventing water quality problems. The review would involve:

- Soil characteristics of areas where septic tanks are a commonly used wastewater treatment facility or a representative study area;
- Extent of surface or groundwater contamination presently caused by leachfields in the study area;
- Operation and maintenance levels for septic tanks;
- Effectiveness of present county regulations in protecting public health and recommendations for improvement;
- Feasibility of using other wastewater treatment techniques near housing clusters and where geologic constraints prevent the use of septic tanks.

County Health Departments should play a major role in the accomplishment of Task 2.

Management and Operations

No additional requirements are justified at this time.

Regulation: (County Health Departments)

Task 1: Participate in areawide planning Task 2. The County Health Departments will be required to furnish the following information:

- Inventory of areas for which failing septic tank systems are documented to cause ground/ surface water contamination which could result in public health problems;
- Inventory of areas for which failing septic tank systems are suspected to cause significant ground or surface water contamination;
- Data and information to support above inventories including:
  a. Location map;
  b. Frequency of maintenance;
  c. Number of septic systems;
  d. Estimated age of septic systems;
  e. Type of system (i.e., engineered or standard);
  f. Water quality and/or epidemiological data;
  g. Number and frequency of complaints;

- Number of septic tank approvals processed each year for the past five years;
- Statement of adequacy of resources (budget, staff, equipment) to review septic system requests.

6.0 LAND DISPOSAL OF SLUDGE

Sewage sludge is composed of solid material and water. The solid material in sludge is removed by mechanical wastewater treatment plants. The sludge handling processes constitute a significant percentage of the cost of treating municipal sewage.

Another type of sludge being disposed of in the area is drilling fluid from petroleum drilling operations. There are now nine known drilling fluid disposal sites in Weld County.

Sewage sludges and drilling fluid are disposed of on land. Sewage sludge may be either dried and applied as a soil conditioner or hauled in liquid form for land disposal. If applied in liquid form, the sludge is normally injected under the ground surface or is plowed into the soil after being applied. Drilling fluid can be disposed of in the same manner as liquid sewage sludge. Often, however, it is dumped into a lagoon or mud pit.

6.1 SLUDGE CHARACTERISTICS

The constituents contained in these sludges are a serious pollution concern. The parameters commonly found in municipal sludges are quite different from those found in drilling fluid. Consequently, they will be discussed separately.

6.1.1 Sewage Sludge Characteristics

Since the main treatment mechanism in most treatment plants is sedimentation, the majority of the impurities in the influent wastewater end up in sludge. A typical digested sludge contains about 5 percent solids and 95 percent water.

Pathogenic organisms may be present. Conditions in sludge digesters are unfavorable for reproduction but are not lethal. Nearly all of the metal ions which are contained in the influent sewage are transferred to the sludge. Nitrogen and phosphorus are also present, although most remain in the liquid effluent. If phosphates are removed by chemical precipitation, the mass of the sludge and phosphate content will be large.

Table 6.1.1-A shows the amount of some of the beneficial minerals in sewage sludge. Table 6.1.1-B shows the average concentrations from the literature of some of the detrimental metals in sludge. The reader should be cautioned that the concentrations of these metals varies greatly from one community to another. The presence or absence of industrial waste can have a significant effect on these concentrations. Metal plating operations in particular can increase metal concentrations in the sludge.

TABLE 6.1.1-A MINERAL NUTRIENT CONTENT OF MUNICIPAL SLUDGE [1]
(Percent of Dry Solids or mg/l, as Indicated)

COMPONENT	RANGE	MEDIAN	MEAN
Organic C %	6.5-48	30.4	31.0
Total P %	0.1-14.3	2.3	2.5
Total N %	0.1-17.6	3.3	3.9
NH_4-N mg/l	5-67,600	920	6,540
NO_3-N mg/l	2- 4,900	140	490

TABLE 6.1.1-B METAL CONCENTRATIONS OF MUNICIPAL SLUDGE [1]
(mg/kg)

COMPONENT	SYMBOL	RANGE	MEDIAN	MEAN
Cadmium	Cd	3- 3,410	16	110
Chromium	Cr	10-99,000	890	2,620
Copper	Cu	84-10,400	850	1,210
Mercury	Hg	0.5-10,600	5	733
Nickel	Ni	2- 3,520	82	320
Lead	Pb	13-19,700	500	1,360
Zinc	Zn	101-27,800	1,740	2,790

[1] Paper prepared for National Conference on 208 Planning and Implementation, U.S. Environmental Protection Agency, "Municipal Wastewater Sludge Management Alternatives", Culp/Wesner/Culp.

Due to the nature and large quantities of sewage sludge disposed of in Larimer and Weld Counties, a potential surface and subsurface water pollution problem exists. However, to date no serious health or pollution problems emenating from this source have been identified. It is recommended that this topic be analyzed further in a coordinated program with state and county health departments.

Communities in the region have found that dried sludge is easier and less expensive to dispose of than is wet sludge. Greeley, Estes Park, Berthoud, Loveland, and Fort Collins have wet sludge trucked to farm land. Trucking costs are high, and disposal is impossible when fields are wet. Fort Collins has sufficient sludge drying capability to dry all the anaerobic sludge produced. Home gardeners haul all of the sludge away at no cost to Fort Collins.

6.1.2 Drilling Fluid Characteristics

Drilling fluid serves several purposes for a drilling well. It is pumped down through the center of the drill pipe and comes back up between the outside of the drill pipe and the hole being drilled. The two main functions of drilling fluid is to carry the cuttings out of the hole and to keep a well from blowing out, should a high pressure formation be encountered.

To accomplish these functions, chemicals are added to water to make the "mud". The basic chemical used is bentonite, which is a type of commercial clay. Another commonly used chemical is barite which is produced from barium. The EPA recommended drinking water standard for barium is 1.0 mg/l. Other chemicals used to make the mud heavier or more viscuous (thicker) are added to drilling fluid.

As previously stated, most drilling fluid is disposed of in "mud pits". One problem with disposing this material in pits or lagoons is that it takes years before this material dries, creating a quicksand type of situation. Figure 6.1.2-A shows the known disposal sites, all of which are in Weld County. If applied thinly on a field and plowed in the same manner as sewage sludge, the material will dry rapidly. No surface or subsurface water quality problems from this source have been documented in this region.

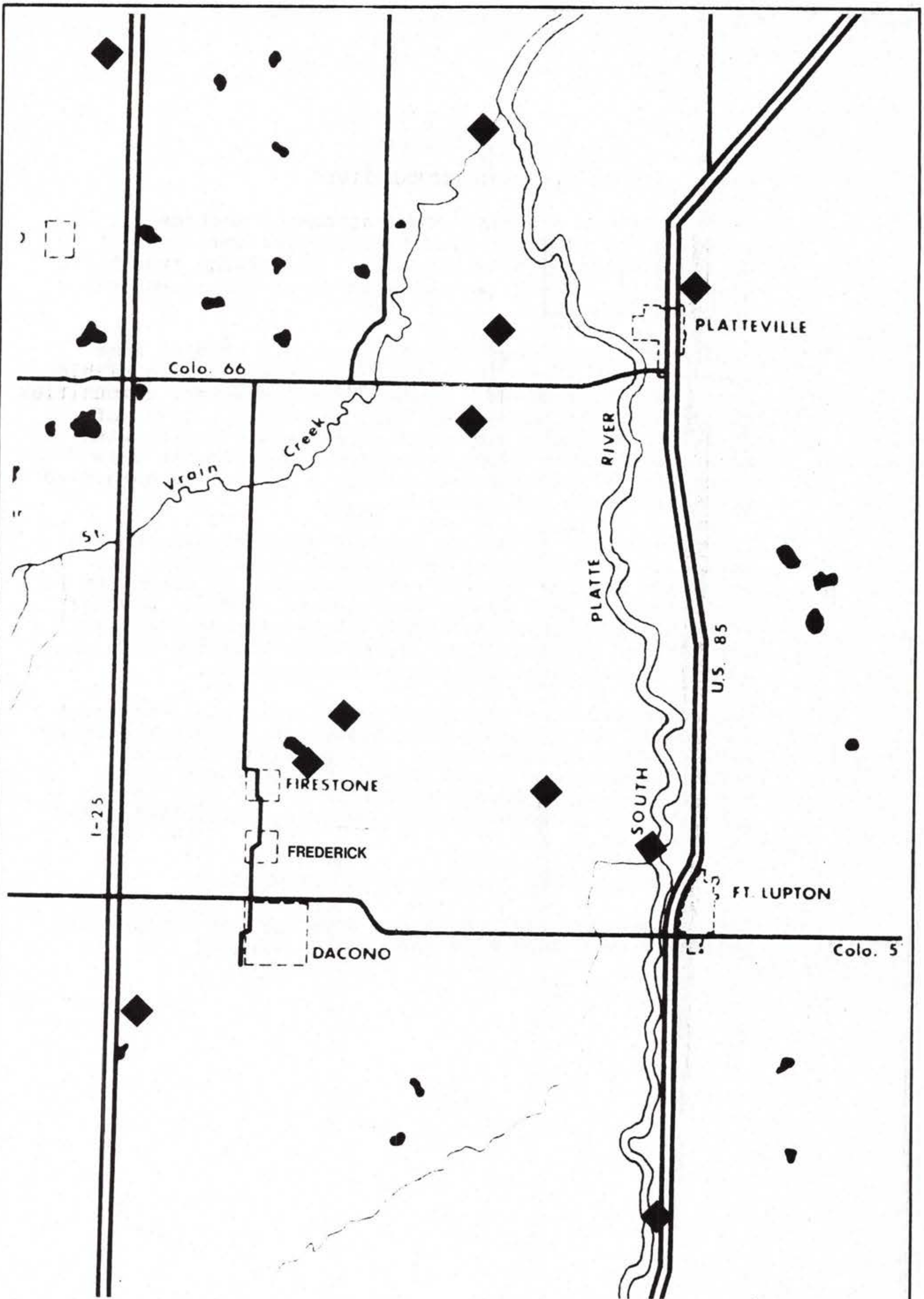


FIG. 6.1.2-A. DRILLING MUD DISPOSAL SITES

6.2 SLUDGE DISPOSAL ALTERNATIVES

Although there are many combinations of methods for treating and handling sludge, there are very few ultimate disposal alternatives. The sludge must be disposed of on land, in the atmosphere (incineration), or to surface water.

Ocean dumping is the disposal technique used by some coastal communities, but obviously this is not a viable option for Larimer-Weld communities. However, communities can legally discharge suspended solids at a level of 30 mg/l. Assuming the communities in the region with mechanical plants discharge suspended solids at this rate, almost three tons of sludge a day is discharged to rivers in these two counties.

Incineration of sludge is another disposal alternative. Residual ash must still be disposed of on land. Air pollution control devices are required. No community in Larimer or Weld County incinerates sludge. Several years ago the Denver Metropolitan Sanitation District incinerated sludge. They halted this practice with the advent of stringent air pollution standards.

Land disposal does have some beneficial value, although no process has been demonstrated which produces revenues exceeding processing costs. The nutrient value of sewage sludge is not sufficient to supply the entire demand of crops. Sewage sludge is a very good soil conditioner, particularly for the clay soils common in the area.

6.3 RECOMMENDED IMPLEMENTATION STRATEGY

The recommended implementation strategy for controlling pollution from sludge is included in Section 7.8.

7.0 IMPACTS OF SOLID WASTE MANAGEMENT IN LARIMER-WELD REGION

7.1 GENERAL

Analysis of solid waste management facilities within the two-county region involves a complex intertwining of economic, ecological, safety, political and hydrogeologic factors. This chapter provides an overview of the solid waste facilities in the two-county region. The relative level of effort expended on this aspect of 208 water quality planning reflects the degree of funding it has received. The solid waste management within Larimer County is outlined by a Solid Waste Management Plan for Larimer County developed in 1974 [Briscoe and Maphis, 1974]. A document of similar scope is not available for Weld County.

The water quality impacts of solid waste management are the subject of this chapter. Figure 7.1-A illustrates how solid waste degradation can impact water quality. Complex organic acids and ions are leached by water passing through the waste and carried to the groundwater. This polluted groundwater can then move laterally where it may enter a stream or be pumped to the surface for consumption or other beneficial uses. Such water quality impacts can be controlled by a number of methods. The most often used control measure is preventing the solid waste leachate from getting to the groundwater. Prevention can be achieved by locating a site over impermeable strata, installing an impervious clay layer before operation at a disposal site, or lining the site with a plastic film.

7.2 SANITARY LANDFILL

When methods for control of waste on site and prevention of groundwater contamination are systematically employed, a solid waste site is promoted from an open dump to a sanitary landfill. Sanitary landfilling involves engineered site selection, site planning, high quality operation, and daily maintenance of facilities. The operational level must include thorough compaction, daily dirt cover and methods to control litter. Such operation increases cost of solid waste management at a landfill and hence encourages regionalization of facilities to reduce total operational cost.

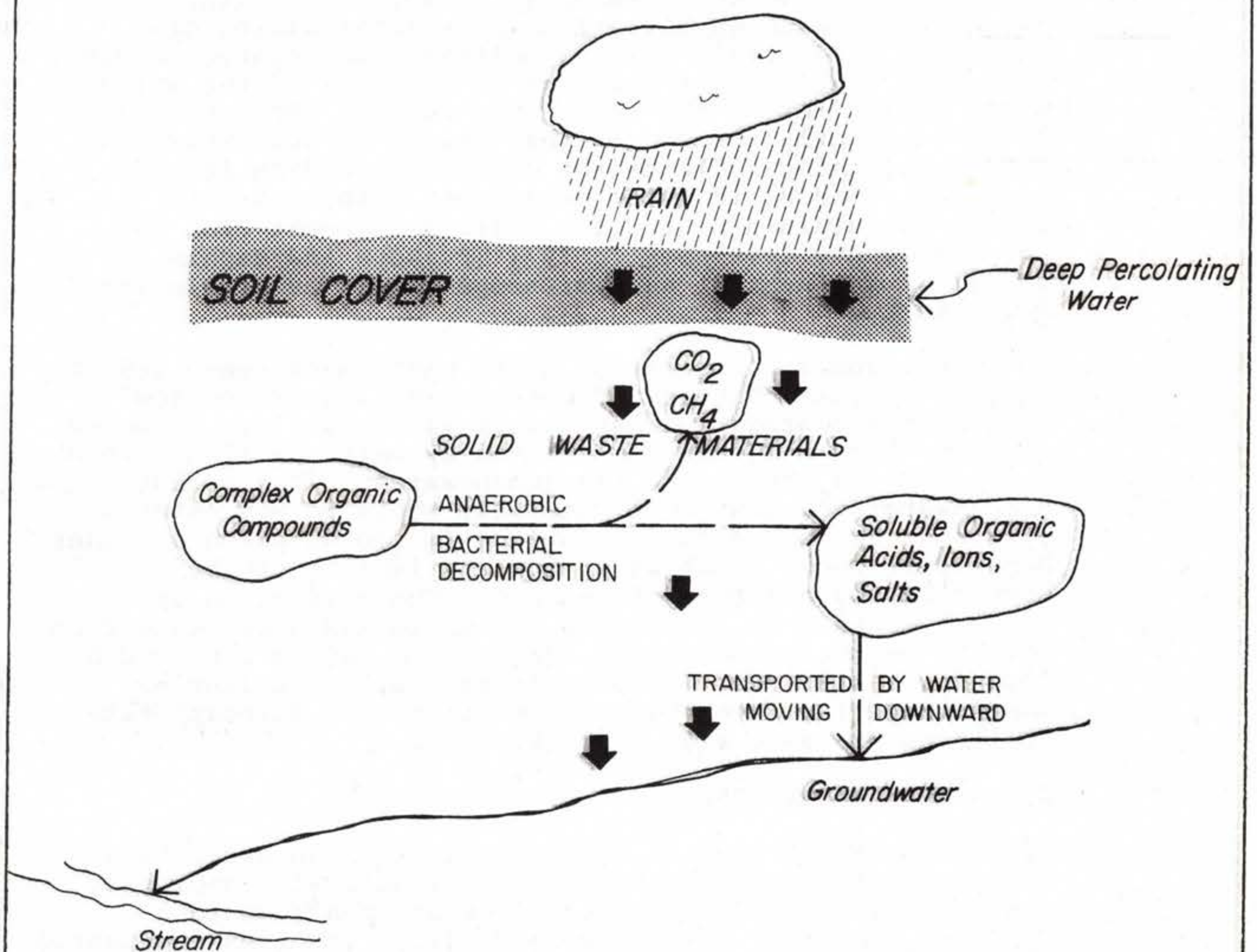


FIGURE 7.1-A. HOW SOLID WASTE MATERIALS IMPACT WATER QUALITY

7.2.1 Site Selection

Primary emphasis in selection of a sanitary landfill site should be given to:

1. Hydrogeologic conditions and surface waters;
2. Cover material availability and soil type;
3. Accessibility of site to collection area;
4. Public opposition.

Sanitary landfill sites should avoid areas where surface and underground flows combine with geologic characteristics to allow downward or lateral water movement. A good site will prevent the movement of waste contaminated waters and maintain surrounding water quality.

Use of a good cover material and sufficient cover helps to prevent the percolation of rain waters into the waste material. The best cover material will be comprised of a tight clay-like soil that is impervious. The cover will be applied with a slight grade to encourage runoff.

Accessibility is very important. By reducing haul distances and time in truck, considerable savings in labor, fuel and maintenance costs can be experienced. Accessibility also involves avoidance of the traffic obstacles presented by lights, bridges, railway gates and left turns. Measures should be taken that provide all weather accessibility.

Public opposition to landfill sites in the Larimer-Weld region is justifiable. Of thirteen sites visited, only two did not present large quantities of roadside litter before arrival at the landfill. A properly operated sanitary landfill includes constant compaction and sufficient daily cover to prevent much of this litter and help ease concerns about lowering of property values. Public opposition should decrease when citizens are made aware that disposal facilities will always be necessary even with a thorough resource recovery operation. Finally, use of prime land for a sanitary landfill does not permanently destroy the revenue producing capabilities of these lands. Public acceptance of disposal sites on marginal lands (swamps, used gravel operations, flood plains, etc.) does not reflect an understanding of the hazards a poorly selected site may impose.

7.2.2 Operation

Like a sewage disposal facility, the single most important aspect of a good sanitary landfill can be operation. Operation of a sanitary landfill extends far beyond placing of waste at the proper point and covering with dirt. Good operation includes:

1. Spreading and compacting the waste into six-inch layers over the area to be filled for the day;
2. Compaction and collection into discrete daily volumes called cells;
3. Adequate cover that prevents fly emergence, rodent burrowing, and litter spread;
4. Adequate fencing to prevent wind blown litter;
5. Final cover sloped to allow drainage;
6. Maintenance of a sufficient barrier between landfill and groundwater level to guarantee that leachate does not get into water resources;
7. Facilities that protect landfilling equipment and allow good working space for maintenance of grounds and equipment;
8. Operational records and a scale house that provides for an equitable fee schedule;
9. Deposition of septic tank sludges only where an area provides safe dewatering before incorporation into a landfill.

The costs of such operation should be assumed by the waste generator. Operating costs for landfills in California were reported as $4 per ton (72 tons per day-TPD) to $8 per ton (18 TPD). Other operations vary from $2.75 to $7.20 per ton.

A well designed and operated solid waste disposal area can therefore protect the public from health hazards that may be caused by dumps lacking a good design and management scheme.

7.2.3 Larimer-Weld Landfills

A visit to most of the landfill sites in the Larimer-Weld region was made in May 1977. The results of this visit indicate that most of the landfill operations in the two-county area fail to qualify as sanitary landfills. This failure is due to inadequate compaction, insufficient daily cover, poor soils, insufficient operation level, poor wind control, and/or poorly placed septic tank disposal area. The locations of these landfills is shown on Figure 7.2.3-A.

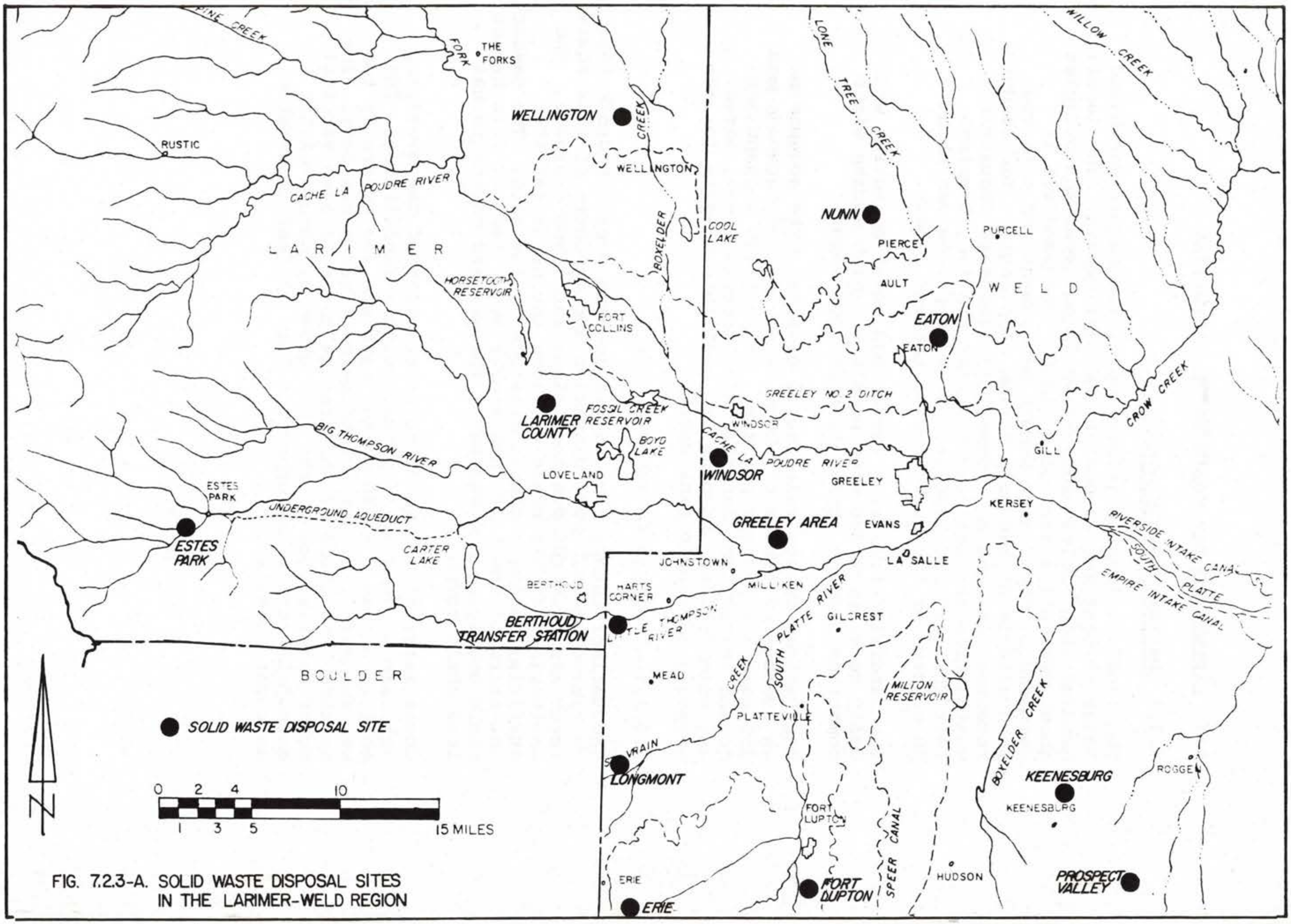


FIG. 7.2.3-A. SOLID WASTE DISPOSAL SITES IN THE LARIMER-WELD REGION

7.3 LARIMER COUNTY SOLID WASTE FACILITIES

7.3.1 Larimer County Landfill

The landfill located in Section 9, Township 6 North and Range 69 West serves most of Larimer County. The landfill handles about 85,000 tons of waste per year and occupies about one-half a section of land. The landfill is operated by the County Health Department and a foreman is available at the dump during open hours. The landfill receives residential, commercial, and some industrial wastes from the Berthoud Transfer Station, Loveland, Fort Collins, and Laporte. This dump receives about 80 percent of the wasteload of Larimer County.

The landfill utilizes a trench and cover operation with daily cover provided when possible. High spring winds sometimes prevent application of good cover.

The Larimer County solid waste disposal site accepts on an average 60 trucks of about 20 cubic yard capacity and 350 cars and pickups per day. In addition to handling normal refuse, the landfill also accepts trees, tires, and automobiles. Lagoons are available on-site for the disposal of septic tank wastes.

7.3.1.1 Geologic Characteristics

The Larimer County landfill is located over a bedrock layer of Pierre shale. Some disection and exposure of this shale layer has occurred due to a minor fault and drainage. The weathering of this shale provides the basis for the surficial geologic characteristics of the site. The eastern one-third of the tract has nearly seven feet of this broken shale overlying the bedrock. The western one-third has less shale cover.

Cover material and soil characteristics of the overlying soil are of good quality for sanitary landfilling. The soil is a clay. Soils on the east end are generally too wet for effective extraction below five to six feet. The northern one-third of the tract's cover is also marginal cover material due to the more gravelly nature of the material; still, the uppermost 7 to 10 feet is useable as cover material.

7.3.1.2 Possible Groundwater Impact

Overlying the impermeable Pierre shale, the site cannot impact deep groundwater basins unless fractures exist within the shale layer. Some outcroping of water can be observed at the eastern end of the site. There are two possible sources of this discharge: (1) hydraulic pressure executed by Horsetooth Reservoir to the west, or (2) septic tank effluent from drainage beds about one-fourth mile southwest.

7.3.1.3 Adjoining Lands

Lands adjoining the solid waste disposal site to the north has a drainage system and would not provide a very good expansion area. Land to the south is also wet but some areas show excellent feasibility for expansion sites. Use of an area fill method of operation utilizing material from wet areas could provide extended, useful life to this area.

7.3.1.4 Water Balance

A water balance for the Larimer County landfill was developed. This water balance required the utilization of the following basic assumptions:

1. The landfill has been completed with 0.6 meters (2 feet) of final cover and graded with a 2 to 4 percent slope over most of the surface area.
2. The solid waste, cover soil, and vegetative cover were emplaced instantaneously at the beginning of the first month of the computation initiation. Practically speaking, this ignores any percolation that may occur prior to the placement of the final cover soil.
3. The final use of the site is an open green area to be used for recreation or pasture.
4. The surface is fully vegetated with a moderately deep-rooted pasture grass, the roots of which draw water directly from all parts of the soil cover but not from the underlying solid waste.
5. The sole source of infiltration is precipitation falling directly on the landfill's surface. All surface runoff from adjacent drainage areas is diverted around the landfill surface. All ground water infiltration is prevented through proper site selection and design.
6. The hydraulic characteristics of the soil cover and compacted solid waste are uniform in all directions.
7. The depth of the landfill is much less than its horizontal extent. Thus, all water movement is vertically downward.

The water balance utilized to predict leachate generation uses the following parameters:

1. Basic equation: PERC = P - R/O - AST - AET.
2. PET = Potential Evapotranspiration. These values were determined for Fort Collins utilizing net consumptive use data developed for pasture grass.
3. P = Precipitation. Mean monthly values based upon climatological data published by National Oceanic and Atmospheric Administration, Asheville, North Carolina.
4. $C_{R/O}$ = Surface Runoff Coefficient. Based upon runoff coefficients used in the rationale method of runoff calculation (see Table 2.2.1-A). This represents the fraction of rainfall that would flow from the solid waste site.
5. R/O = Surface Runoff. Multiplication of the runoff coefficient by precipitation gives the amount of water that fails to enter the soils.
6. I = Infiltration. The difference between precipitation and the surface runoff (I = P - R/O).
7. (I-PET) = Infiltration minus potential evapotranspiration determines periods of moisture excess. A negative I-PET means the amount of infiltration fails to meet the vegetative needs. A positive value indicates excess water which recharges soil content or percolates.
8. [E NEG (I-PET)] = Accumulated Potential Water Loss. Use of Thornthwaite's method of successive approximations gives an initial value of [E NEG (I-PET)] from which other values are based.
9. ST = Soil Moisture Storage. This factor is the moisture retained in the soil. As seen, soil moisture at Fort Collins is almost always below field capacity. Excess above field capacity percolates.
10. Δ ST = Change in Soil Moisture Storage. Represents the change in soil moisture from month to month.
11. AET = Actual Evapotranspiration. Represents the actual water lost during a given month. With low soil moisture the evapotranspiration will be less. AET accounts for this.
12. PERC = Percolation. Water in excess of plant, soil and evaporation uses will percolate through the solid wastes.

Results of this water balance analysis indicate that the Larimer County solid waste landfill should have no percolation caused leachate. These results are shown in Table 7.3.1-A. It would be possible to irrigate the land above the landfill after use of the landfill is discontinued and continue to provide groundwater protection.

TABLE 7.3.1-A. WATER BALANCE DATA FOR FORT COLLINS, COLORADO, SANITARY LANDFILL - PASTURE GRASS COVER

PARAMETER [a]	J	F	M	A	M	J	Jy	A	S	O	N	D	YEAR
PET	0	0	0	33	82	124	156	135	82	41	0	0	
P	11	11	26	46	74	54	37	39	24	33	14	9	378
$C_{R/O}$	.17	.17	.15	.15	.15	.15	0	0	0	.13	.15	.11	
R/O	2	2	4	7	11	8	0	0	0	4	2	2	42
I	9	9	22	39	63	46	37	39	24	29	12	7	336
I-PET	9	9	22	6	-19	-78	-119	-96	-58	-12	12	7	-317
[E NEG (I-PET)]					-19	-97	-216	-312	-370	-382			
ST (Table C)	39	48	70	76	76	76	35	18	12	11	23	30	
ΔST	9	9	22	6	0	0	-41	-17	-6	-1	12	7	
AET	0	0	0	33	63	46	118	56	30	30	0	0	376
PERC	0	0	0	0	0	0	0	0	0	0	0	0	

PET - Potential Evapotranspiration
P - Precipitation
$C_{R/O}$ - Surface Runoff Coefficient
ΔST - Change in Storage
PERC - Percolation
ST - Soil Moisture Storage
I - Infiltration
R/O - Surface Runoff
AET - Actual Evapotranspiration
[a] Data given in milimeters.

Clay soil field capacity 375; Wilting point - 125; Available water - 250
Methodology from:

Fenn, Dennis G., Keith J. Hanely, and Truet V. DeGeare, 1975. "Use of the Water Balance Method for Predicting Leachate Generation from Solid Waste Disposal Sites", EPA.

Other sites in the Larimer-Weld region would also fail to generate leachate if managed in a like manner; however, other sites in the region may:

1. Have insufficient cover;
2. Lack vegetative cover;
3. Have nearby water leaching from a canal or natural waterway;
4. Improper cover compaction or type;
5. Lack sufficient depth;
6. Contain a loose permeable bottom soil.

Many of the following described landfills do fail to meet the criteria for good sanitary landfill practice as described in Section 7.2. Poor operation and maintenance of any facility violates the assumptions outlined earlier and therefore would fail to provide groundwater protection as any well operated landfill in the Larimer-Weld region should.

7.3.2 Estes Park Landfill

This facility is located in Section 26 of Township 5 North, Range 73 West, southwest of the city. The site receives wastes from the city of Estes Park and waste loads from urbanized areas, recreational locations, and from Rocky Mountain National Park. Heavy waste loads due to tourist traffic in the area is shortening the life of this fill. A private firm operates and manages the site. The site receives nearly 12,000 tons of waste materials per year. Operational funding of the site is accomplished by charging a disposal fee which fails to adequately cover all costs.

The site had a number of operational problems. The loose granite soil fails to provide a high quality cover material and greater amounts than are presently available are needed. Strong winter and spring winds often blow waste out and away from the site. Fencing is not available to prevent this material from being scattered and management fails to adequately confront the problem. Septic tank wastes are also deposited at the site. Table 7.3.2-A shows the general operation scheme of the Estes Park landfill.

7.3.3 Wellington Landfill

The Wellington sanitary landfill is located about 3.5 miles north of Wellington along Owl County Road west of the railroad tracks. The site handles waste carried by private individuals from the north rural parts of Larimer County and is owned and operated by the county on Fridays, Saturdays, and Sundays.

TABLE 7.3.2-A LANDFILL SITES IN LARIMER AND WELD COUNTIES

LANDFILL NAME	GEOLOGIC AND OPERATIONAL DESCRIPTION								
	DAILY COVER	OPERATOR ON DUTY	BURNING ALLOWED	WIND FENCE PRESENT	SOIL CHARACTER	ACCEPTS SEPTIC TANK WASTES	DAYS OPEN	ESTIMATED ACRES	TYPE OF WASTES
Larimer County	Yes	Yes	Yes	Yes	Good	Yes	Daily	300	R/C/I
Wellington	No	Yes	No	Yes	Poor	Yes	Weekends	40	R/C/I
Estes Park	No	Yes	Yes	No	Poor	Yes	Daily	20	R/C
Berthoud	-	Yes	No	No	-	No	Daily	2	R/C
Nunn	Yes	N/A	Yes	Yes	Poor	N/A	Weekends	5	R/C
Eaton	Yes	Yes	No	No	Poor	N/A	Daily	40	R/C/I
Windsor	No	No	N/A	No	Good	N/A	Weekends	10	R/C/I
Milliken	Yes	No	No	Yes	Good	N/A	Daily	150	R/C/I
Keenesburg	No	No	No	Yes	Good	No	Weekends	20	R/C
Prospect Valley	No	Yes	Yes	Yes	Poor	No	Weekends	5	R/C
Hudson	-	No	No	No	-	No	Daily	0.2	R/C/I
Fort Lupton	Yes	No	No	Yes	Poor	Yes	Daily	50	R/C/I
Erie	Yes	No	No	Yes	Good	N/A	Daily	80	R/C/I
Longmont	Yes	No	No	No	Poor	Yes	Daily	80	R/C/I

N/A = Data not available.
R = Residential wastes.
C = Commercial wastes.
I = Industrial wastes.

7.3.3.1 Geology

The landfill is located within the excavation pit of a gravel mine. The Colorado Geological Survey completed a study in 1975 for parts of the Larimer-Weld region and calls these areas valley-fill deposits. They are generally composed of alluvial gravel, sand and silt underlain by shallow aquifers. These types of areas are considered the poorest areas for landfill sites. Alluvial sites provide poor underlying material to prevent leachate transport and cover material that fails to prevent percolation. Additional concern is warranted because the site lies within the flood plain of Boxelder Creek and there is intermittent stream flow in the area. An irrigation canal is located on the west end of the fill area.

7.3.3.2 Operation

There is not sufficient equipment on site to provide the necessary compaction for these wastes. The presence of appliances, trees, tires, and other materials that do not compact well prevent the equipment on site from doing an adequate job. Cover materials are not applied in sufficient quantities to prevent fly emergence, keep rodents from getting into the wastes, prevent percolation and provide odor control. On the east end there is a black pond which apparently receives oil waste. Operational characteristics of the Wellington landfill are presented in Table 7.3-A.

7.3.3.3 Conclusions

The operation and geologic characteristics of the Wellington landfill may fail to meet the requirements of PL 94-580 (see Section 7.6) for sanitary landfills. Failure to comply will possibly mean closure or a Federal fine. Only improved management and possible site relocation will protect groundwater in the area and provide the residents of Wellington with a disposal facility.

7.4 WELD COUNTY SOLID WASTE FACILITIES

During May 1977 all of the landfills listed below and in Table 7.3.2-A in Weld County were visited. The data presented in Table 7.3.2-A reflects the operational procedures observed during the unannounced visit. Solid waste disposal areas in the eastern communities were not visited because of time restrictions. Known landfill sites are shown on Figure 7.2.3-A.

7.4.1 Milliken Landfill

The Milliken landfill accepts waste from Greeley, Evans, LaSalle, Johnstown, and Milliken. This comprises most of the solid waste of Weld County. The site is west of 77th Street, 4 miles west and 3 miles south of Greeley on Jackrabbit Trail Road.

The site is immediately above the valley fill deposits of the Big Thompson River on the Pierre shale transition zone bedrock. This zone is composed of shale, siltstone, and silty sandstone. When not fractured, these materials provide an excellent seal from water percolation. The cover soil is generally weathered shale and silty sandstone and should provide excellent cover characteristics.

Present operation of the site is oriented toward filling of the deep draw on the west end of the landfill. Daily cover is applied. However, compaction does not appear to be adequate to prevent fly emergence and presence of rodents. Items difficult to compact (trees, tires and appliances) are separated before compaction. The operation utilizes two compactors and a scrapper.

The Milliken site appears to be the best operated within Weld County. Wind fencing is present and the operation does not allow waste to be dumped when winds are high. Before the site is developed any further, the hydrogeologic characteristics of the draw on the west end of the fill should be analyzed. Water flow through this area may prevent further westward development of the site.

7.4.2 Nunn Landfill

On the south side of town, Nunn operates a small landfill on weekends. The site accepts residential waste from town residents only. Mixed refuse and garbage are burned before burial into a deep (12 ft.) trench. White goods, trees and cars are deposited in an open area. A low wind fence is available.

The landfill lies within the flood plain of a small drainage area on loose sandy soils. The site has an ability to impact the quality of ground and surface waters of the area; however the size of the landfill may make it undetectable.

7.4.3 Eaton Landfill

The underlying geologic characteristics of the Eaton landfill are created by the Laramie formation of interbeded silty sandstone, siltstone and calcareous shale. This material would be acceptable for most landfill operations; however, loose alluvial sandy soils overly the bedrock. These soils are not a high quality cover material that can prevent lateral movement of leachate. The presence of a high groundwater table and a nearby irrigation canal should generate concern over possible health hazards and water quality preservation.

The Eaton landfill receives wastes of a residential and commercial nature from the towns of Pierce, Nunn, Ault, Eaton, and some other areas in central Weld County.

Operation of the site is apparently quite good. An operator is on duty who assesses the appropriate fee and compacts and covers the delivered waste. The site accepts all types of waste including liquid septic sludges and carcasses. Some scavenging does occur. Present operation the north end of the site, thus avoiding the ponded water on the south end. Litter does not appear to be as great a problem as at other sites in the county. A detailed environmental analysis of this site should be made to evaluate the possible water quality impacts and public health hazards that may exist or be instigated by operation at this location.

The old Eaton dump has been covered and trees have been established at the site.

7.4.4 Keenesburg Landfill

The landfill is located one mile east and two and a half miles north of the municipality on fairly tight clay loam-looking soil. The cover, when applied, is a loose, wind-blown soil. There are no wind barriers on the south, north and west ends of the dump. The site is north of a large salvage operation that handles antiques, car bodies, construction equipment and anything else the manager deems appropriate.

A small tractor is on the site but daily compaction and cover of the site is not an operational characteristic. The site is open Wednesday and Saturday only to Keenesburg water users. The groundwater level is adequately below the fill area and if operational methods are improved to provide adequate litter control, the site should continue to be an acceptable and economic affordable disposal means for the residents of Keenesburg.

7.4.5 Prospect Valley Landfill

South of Weld County Road #8 and west of Weld County Road #67, this dump accepts the small volume of wastes from Prospect Valley and the surrounding farm area. The dump is not open on a daily basis. Wastes are thrown into a pit and covered. Burning is not allowed but charred material is present. Adjacent to the waste pit is a dried up wet area. Around this area is a loose sandy soil that will provide easy lateral and downward water movement if water is available.

7.4.6 Hudson Transfer Station

A large roll-off trailer is located within the town. A commercial hauler picks up this container on a weekly basis and transports it to the nearest landfill.

7.4.7 Fort Lupton-Brighton Landfill

Three miles south of Fort Lupton and two and one-half miles north of Brighton on the east side of Highway 85 is the Fort Lupton-Brighton Landfill. This large pit accepts waste from Fort Lupton, Brighton, Firestone, Frederick, Dacono, Wattenburg, and the surrounding farm areas.

The site is located on the alluvial soils of the South Platte River less than one mile from the river. These gravel-sand soils are very poor for containment of leachate. The nature of these soils and operational procedures at the dump are believed to be the cause of well pollution near Fort Lupton. Three or four wells near Fort Lupton have recently been polluted with manganese (values up to 7 ppm were measured) causing taste and odor problems. The dumping of wet concrete is believed to have caused this condition. Other problems could soon develop from dump-generated leachate and the disposal of septic tank sludges on site.

The Fort Lupton-Brighton landfill has on site five tractor dozers capable of pushing and compacting wastes. However, tight compaction in six-inch layers to prevent flies, odors and rodents is not done. Large trees and appliances are separated by the operator on duty. Conditions at the dump allow litter to scatter along Highway 85 and do not prevent uncontrolled dumping at night or other hours when an operator is not on duty.

From a public health standpoint and from a water quality perspective, this site should be evaluated. Any delay in improving site utilization (or movement) and upgrading of operational procedures could impair public health and may involve considerable litigation expenses. Landfill leachate damage in the past has cost individual communities over 0.2 million dollars.

7.4.8 Erie Landfill

The town of Erie utilizes a deep, dry draw with tight clay soils for solid waste disposal. This site at the intersection of County Roads 5 and 6 has an operator on duty and utilizes a large tractor dozer for compaction and cover. The site receives residential, commercial, and industrial wastes from the general area around Erie, including Firestone, Frederick, Dacono, and farm operations. Close proximity of an electrical transformer distribution center has provided the site with many loading pallets. These pallets are utilized as a litter fence and work quite well. This site appears to be an excellent location and with increased operational levels, could provide long life without concern over possible water quality problems.

7.4.9 Longmont Landfill

Located just south of Highway 119, the Longmont landfill overlooks the confluence of the St. Vrain and Boulder Creeks. Inadequate litter control allows the wind to scatter waste into St. Vrain Creek and across to Highway 119. The site is just above the alluvial bed of St. Vrain Creek and therefore the soils are somewhat more suitable for a landfill than alluvial sands and gravels. This Weld County site receives wastes from most of northern Boulder County.

Daily compaction and cover is normal operation for the site; however, compaction is not done in tight six-inch layers and fails to control litter. Adjacent to the landfill are three septic tank waste disposal ponds. These ponds are located over St. Vrain Creek and percolating water has easy access to this creek.

A one-time visit to a landfill is not a detailed site evaluation. A detailed site evaluation of this site is necessary to remove existing doubts about the landfill's operational impacts on public health and water quality. A description of a detailed site evaluation is provided within the implementation section of this chapter.

7.4.10 Berthoud Transfer Station

The final Weld County waste disposal facility is located at the previous landfill site for Berthoud. The landfill has been adequately covered and the current operation of the roll-off trailer transfer site appears to be quite good. A manager is present and the site is clean.

7.4.11 Private Dumps

The above survey fails to evaluate the impacts and characteristics of private dumps located throughout the two counties. Many of these private facilities are not operated at a high enough level to prevent leachate problems. The small nature of these private dumps, however, significantly reduces the possible groundwater impacts. Poorly located dumps that may affect water quality should be shut down by County officials.

7.4.12 Review

The above summary of landfills does not intend to be totally accurate in details of soils, operation, and general characteristics of each site. It does attempt to provide an overview of the potential water quality impacts that each site may contribute. A more detailed survey does need to be taken, especially at the four larger sites of Milliken, Fort Lupton-Brighton, Eaton, and Longmont. Such a survey should critically review bedrock geology, surface geology, soil characteristics, operational level and possible leachate hazards. Such a precautionary move could help alleviate many potential problems and reduce worry where none should exist. State geologists have already determined that landfills may be polluting the major underground aquifers of east central Colorado.

7.5 SOLID WASTE FROM FEEDLOT OPERATIONS

Manure disposal represents a major aspect of agricultural solid waste management. In recent years, its significance has become even more pronounced with the development of large confined animal feeding operations, and the siting of many such facilities in relatively close proximity to one another. Present practice in the region does not generally involve hauling manure long distances from its source. Hence, manure application rates to soils in areas of dense feedlot concentrations may be excessive.

The report of the water quality management plan entitled "Concentrated Animal Feeding Operations, Waste Management And Resource Recovery" concluded that the potential for groundwater quality degradation resulting exclusively from manure loading does not appear to be significant on many of the lands managed by feedlot operators. Some fields are overloaded, however, on a long-term basis. It was not possible to evaluate application rates employed by area farmers due to lack of data. Because of the increased magnitude of the regional manure management problem, livestock waste application to fields by individual farmers could be occurring at rates conducive to water quality impairment in the long-term.

A great many uncertainties exist concerning the direct relationship between existing manure and commercial fertilizer use and observed degradation in surface waters of the region. Localized groundwater problems could exist on any field where the nutrient value of manure is excessively supplemented with commercial fertilizers. It is recommended that additional investigation be conducted in known areas of concentrated animal feeding to determine on-farm manure and fertilizer application practices and associated water quality impacts. This is especially critical in areas of concentrated animal feeding. Such an investigation should include an inventory of manure and a comprehensive water sampling program oriented toward identifying total dissolved solids and nitrate levels in groundwater.

7.6 THE RESOURCE CONSERVATION AND RECOVERY ACT (RCRA) OF 1976 (PL 94-580).

In October of 1976 the 94th Congress specifically addressed the problems of solid waste by passing PL 94-580. The Act is designed to approach the problems of:

- Increased waste generation;
- Financial, managerial, govermental and technical problems of waste management;
- Air and water quality degradation caused by open dumping;
- Waste increasing public health dangers;
- Increasing burden upon the land caused by tighter air and water quality standards;
- Loss of resources at landfills;
- Energy shortages and possibilities of solid waste as supplimental energy.

Although not obvious, the RCRA can have a number of impacts on non-point sources of water quality pollution. By providing technical and financial assistance to the state, regional, and local governments, development and implementation of solid waste management plans will be made available. The

RCRA also prohibits the use of open dumps to help insure groundwater quality. Grants will be made available for training of sanitary disposal facility operators.

The Act also will provide funds for research and development as well as demonstration projects to generate necessary resource conservation and recovery system information. Implementation of resource conservation and recovery systems will lower the volume of waste discarded annually and hence reduce leachate generation. Hazardous waste management is a large aspect of the Act.

The Act provides monies for demonstration projects in the solid waste field. Opportunities exist for the two-county region to request money to assist in development of a total management scheme for the region. The Act further provides that all open dumps will be closed or upgraded to protect community health and provide environmentally sound methods of disposal.

It is suggested that the Larimer-Weld Regional Council of Governments and other local political entities keep abreast of current solid waste management techniques. Economic reasons may suddenly alter the viability of existing practices and Federal governmental monies may be made available.

7.7 HAZARDOUS WASTE DISPOSAL

The vast amount of agriculture production in the Larimer-Weld region nessitates extensive use of pesticides. Indiscriminate disposal of emptied pesticide containers can constitute a serious public health threat. These containers can be found in fields, canals, roadside dumps and even adjacent to waterways. The fact that children play and swim near such sites should illustrate that a danger to human health does exist. Rodents and other small animals can also assimilate and transport this hazardous material.

Material of this nature should only be discarded at officially designated hazardous waste disposal sites. Presently there are no such sites within the two-county region. An alternate solution may be to require a substantial deposit on containers, sufficient to apply the economic leverage needed to guarantee proper, safe disposal.

7.8 RECOMMENDED IMPLEMENTATION STRATEGY

7.8.1 Long-Range Program

Objectives:

The objectives of the long-range program for controlling pollution from disposal of sludge and solid waste are as follows:

- To define the extent, nature, and location of significant existing or potential ground and surface water degradation resulting from solid waste (and sludge) management;
- To establish policies, programs, and appropriate regulatory measures to abate and prevent pollutant loadings from solid waste management;
- To fully integrate water quality management with solid waste management planning;
- To improve the management of manure as a resource through improved technical assistance and education;
- To develop guidance and education for the handling, transport, disposal and spill prevention of hazardous substances.

Discussion:

Evaluation of water quality impacts caused by solid waste disposal practices is a complex and difficult assignment which was beyond the scope of this initial assessment. Determination of solid waste management practices which result in resource recovery is a formidable challenge. To meet this challenge, the United States Congress has enacted the Resource Conservation and Recovery Act of 1976 (P.L. 94-580). Solid waste management planning should be coordinated fully with ongoing water, air, and land use planning activities or local government.

This assessment has provided a general overview of the potential problems associated with current management practices for sanitary land fills and dumps, sewage, sludge, and hazardous materials. A more thorough analysis has been conducted regarding feedlot wastes. The analysis and recommendations are contained in "Concentrated Animal Feeding Operations, Waste Management and Resource Recovery," (Larimer-Weld COG, July 1977).

At this time, there is insufficient documentation to justify an aggressive program to improve solid waste management (excluding feedlot wastes) in the Larimer-Weld region for water quality purposes alone. The lack of data and information could pose a significant problem for regulatory agencies to insure public health protection. However, limited field inspections indicate that accepted land fill operation and maintenance practices are not being carried out. Further, that such practices (and siting) could serve to prevent water pollution problems. Stricter county ordinances and enforcement activities seem warranted and should be studied as part of a regional solid waste management planning process.

7.8.2 One-Year Action Plan - Areawide Planning

Task 1: Develop a detailed work program to define water quality impacts of solid waste management practices and technical, institutional, and financial, and educational requirements to abate and/or prevent such pollution. The work plan will also reflect requirements for defining resource conservation and recovery opportunities and measures.

Task 2: Develop a handbook to guide the location, design, and operation and maintenance of solid waste management facilities.

Task 3: Develop a handbook to guide the handling and disposal of hazardous substances. The handbook will define what are considered hazardous substances and their potential health and environmental effects. Handling and conveyance procedures will be outlined. Instructions will be developed to guide owner, operators, or handlers of hazardous substances in the event of a spill. An inventory of disposal facilities and commercial carriers will be included. In coordination with the Larimer-Weld Regional COG Transportation Department major transit routes will be identified to decrease the risk of accidents or impacts of spills. Regulations and guidance materials resulting from the Toxic Substance Control Act will be used as resource material.

Management and Operation: No additional requirements are recommended at this time.

Regulation: (County Health Department)

Task 1: Reporting Requirements. The County Health Departments will provide the following information to the Areawide Planning Agency on a timely basis:

1. Hazardous substance spills;
2. Plans for construction of sanitary land fills and public and private dumps;
3. Complaints regarding the operation of land fills and dumps.

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APPENDIX A

WASTE LOAD CALCULATIONS
URBAN RUNOFF

A-1. ANNUAL RUNOFF

Annual runoff was calculated as per the methodology in Appendix A of EPA Report EPA-600/2-77-083 which uses the following equations:

$$AR = [0.15+0.75(I/100)]P - 5.234DS^{0.5957} \quad \text{(Eqa A-1)}$$

$$DS = 0.25 - 0.1875(I/100) \quad \text{(Eqa A-2)}$$

$$I = 9.6\ PDd^{(0.573-0.0391\ \log PDd)} \quad \text{(Eqa A-3)}$$

Where PDd is the urban population density expressed in people per acre and P is the annual precipitation in inches. The resulting AR is the inches of water that will runoff from the lands. This number when divided by 12 and multiplied by the number of acres results in the acre-feet per year of runoff.

A-2. STORM SEWER POLLUTANT LOADS

Storm sewer annual pollution loads are calculated as follows:

$$SF = a(i,j) \cdot P \cdot fi(PDd) \quad \text{(Eqa A-4)}$$

Where SF = storm sewer pollution flow, lb/ac-yr;
P = annual precipitation, in/yr;
fi(PDd) = population density function for land use i
a(i,j) = coefficient for storm and unsewered areas for pollutant j on land use i, lb/ac-yr-in.

Values of a(i,j) and fi(PD) are shown in Table A-1.

TABLE A-1. POLLUTANT LOADING FACTORS

Land Uses:
- i = 1 Residential
- i = 2 Commercial
- i = 3 Industrial
- i = 4 Other (assume $PD_d = 0$)

Pollutants:
- j = 1 BOD_5, Total
- j = 2 Suspended Solids (SS)
- j = 3 Total N

Population Function:
- i = 1 $f_i(PD_d) = 0.142 + 0.218 \cdot PD_d^{0.54}$
- i = 2,3 $f_i(PD_d) = 1.0$
- i = 4 $f_i(PD_d) = 0.142$

Storm factor a has units of lb/ac-yr-in.

		Pollutant, j		
		1. BOD_5	2. SS	3. N
Storm Areas, a	1. Residential	0.799	16.3	0.131
	2. Commercial	3.20	22.2	0.296
	3. Industrial	1.21	29.1	0.277
	4. Other	0.113	2.70	0.0605

Source: Heaney, J.P., Huber, W.C., and Nix, S.J., "Storm Water Management Model: Level I--Preliminary Screening Procedures," USEPA Report EPA-600/2-76-275, October, 1976, p. 17.

APPENDIX B

COST OF STRUCTURAL AND NON-STRUCTURAL POLLUTANT CONTROL OPTIONS URBAN RUNOFF

B.1 STREET SWEEPING

Analysis of street sweeping as a stormwater pollutant management option is based on the methodology developed in Stormwater Management Model: Level 1 - Comparative Evaluation of Storage-Treatment and Other Management Practices [Heaney & Nix, 1977].

Graphical solutions are presented in Figures B.1-A through B.1-I for residential, commercial, and industrial areas of Fort Collins, Greeley, and Loveland. Marginal cost curves (Figures B.1-J, K, and L) were prepared which depict the relationship between level of BOD removal and cost per pound of BOD removal. A composite curve was developed for each city which depicts the aggregated relationship for the total urban area (residential, commercial, and industrial). Information is shown on Figures B.1-M, N, and O.

TABLE B-1. COST FUNCTIONS FOR WET-WEATHER CONTROL DEVICES [a,b,i]

		Annual Cost: $/yr					
		Amortized Capital $CA = lT^m$ or lS^m		Operation & Maintenance $OM = pT^q$		Total $TC = sT^z$ or sS^z	
Device	Control Alternative	l	m	p	q	s	z
Primary	Swirl Concentrator[c,d,e]	1,971.0	0.70	584.0	0.70	2,555.0	0.70
	Microstrainer[e,f]	7,343.8	0.76	1,836.0	0.76	9,179.8	0.76
	Dissolved Air Flotation[e]	8,161.4	0.84	2,036.7	0.84	10,198.1	0.84
	Sedimentation[a]	32,634.7	0.70	8,157.8	0.70	40,792.5	0.70
	Representative Primary Device Total Annual Cost = $4,000 per mgd ($1.05/m³/day)						
Secondary	Contact Stabilization[g]	19,585.7	0.85	4,894.7	0.85	24,480.4	0.85
	Physical-Chemical[e]	32,634.7	0.85	8,157.8	0.85	40,792.5	0.85
	Representative Secondary Device Total Annual Cost = $15,000 per mgd ($3.93/m³/day)						
Storage	High Density (15 per/ac)	---	---	---	---	51,000.0	1.00
	Low Density (5 per/ac)	---	---	---	---	10,200.0	1.00
	Parking Lot[h]	---	---	---	---	10,200.0	1.00
	Rooftop[h]	---	---	---	---	5,100.0	1.00
	Representative Annual Storage Cost[j] ($ per ac-in) = $122 $e^{0.16(PD)}$						

T[k] = Wet-Weather Treatment Rate in mgd; S = Storage Volume in mg; PD = Population Density, persons/acre

[a] ENR = 2200. Includes land costs, chlorination, sludge handling, engineering and contingencies. Table compiled by Heaney, Huber, & Nix, 1976.
[b] Sludge handling costs based on data from Battelle Northwest, 1974.
[c] Field et al., 1976.
[d] Benjes et al., 1975.
[e] Lager and Smith, 1974.
[f] Maher, 1974.
[g] Agnew et al., 1975.
[h] Wiswall and Robbins, 1975.
[i] For T ≤ 100 mgd. No economics of scale beyond 100 mgd (378,500 m³/day).
[j] PD = gross population density, persons/acre.
[k] One mgd = 3,785 m³/day.
[L] One mg - 3,785 m³.

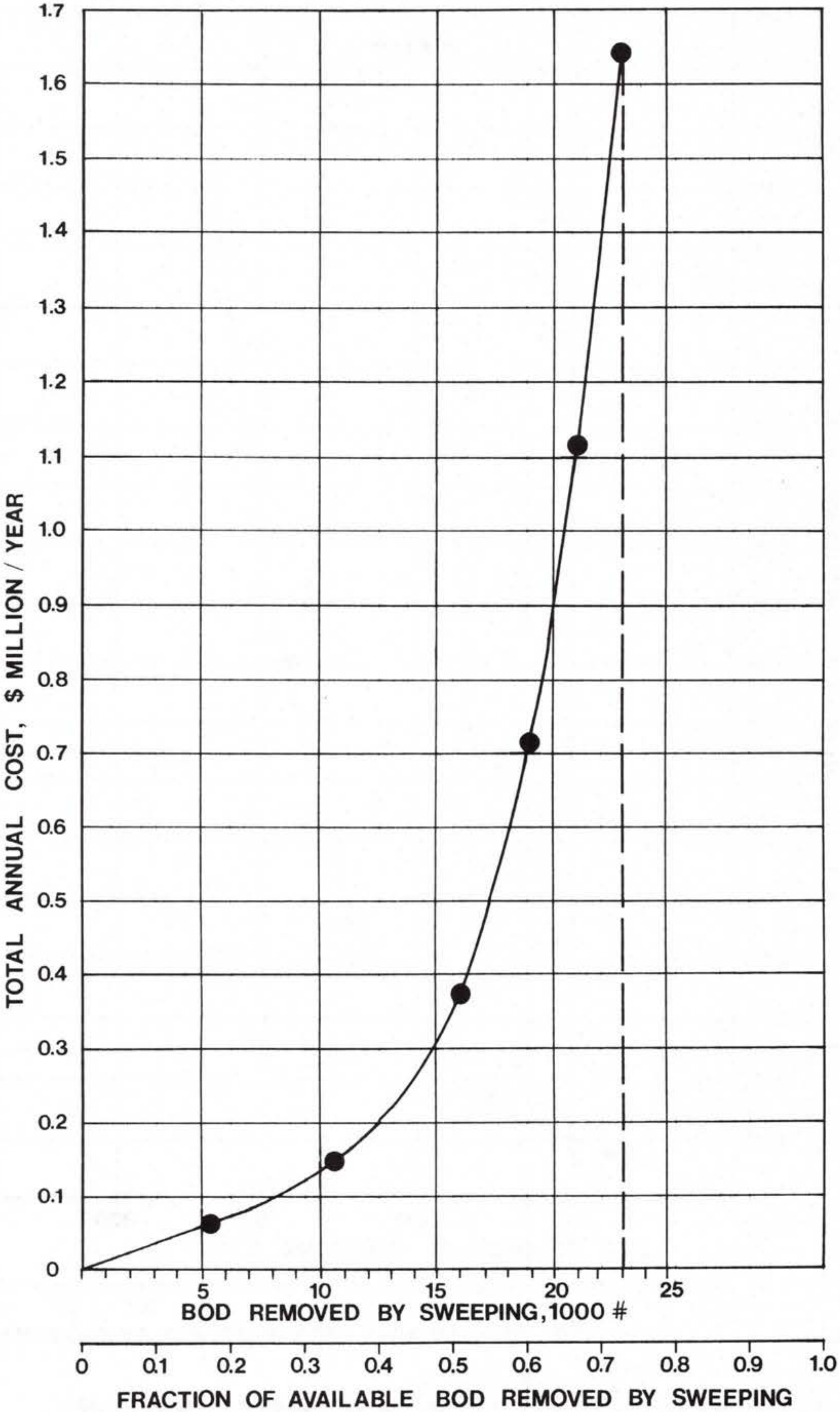


FIG. B.1-A. TOTAL COST CURVE FOR STREET SWEEPING FORT COLLINS, RESIDENTIAL AREAS

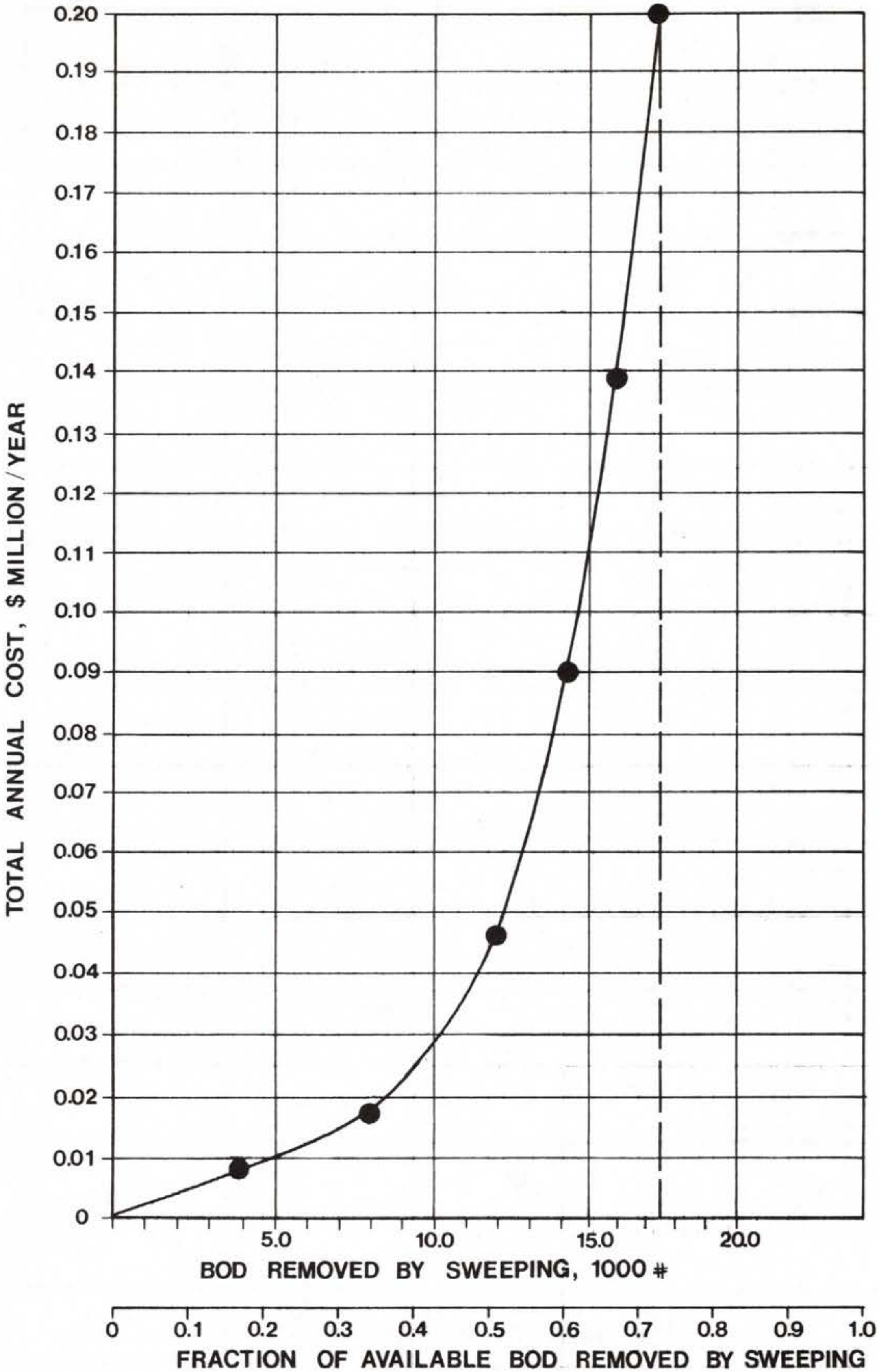


FIG. B.I-B. TOTAL COST CURVE FOR STREET SWEEPING FORT COLLINS, COMMERCIAL AREAS

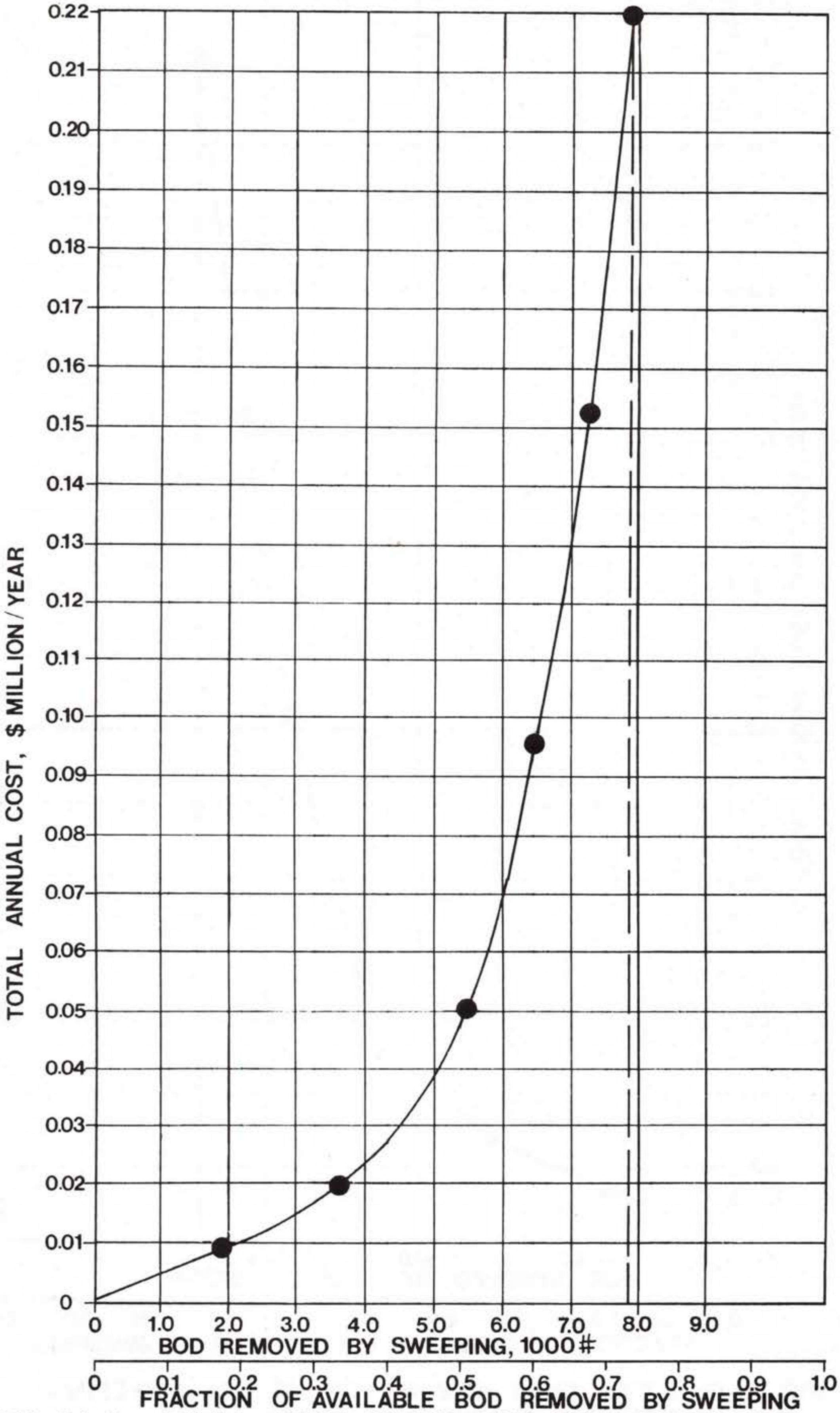


FIG. B.1-C. TOTAL COST CURVE FOR STREET SWEEPING FORT COLLINS, INDUSTRIAL AREA

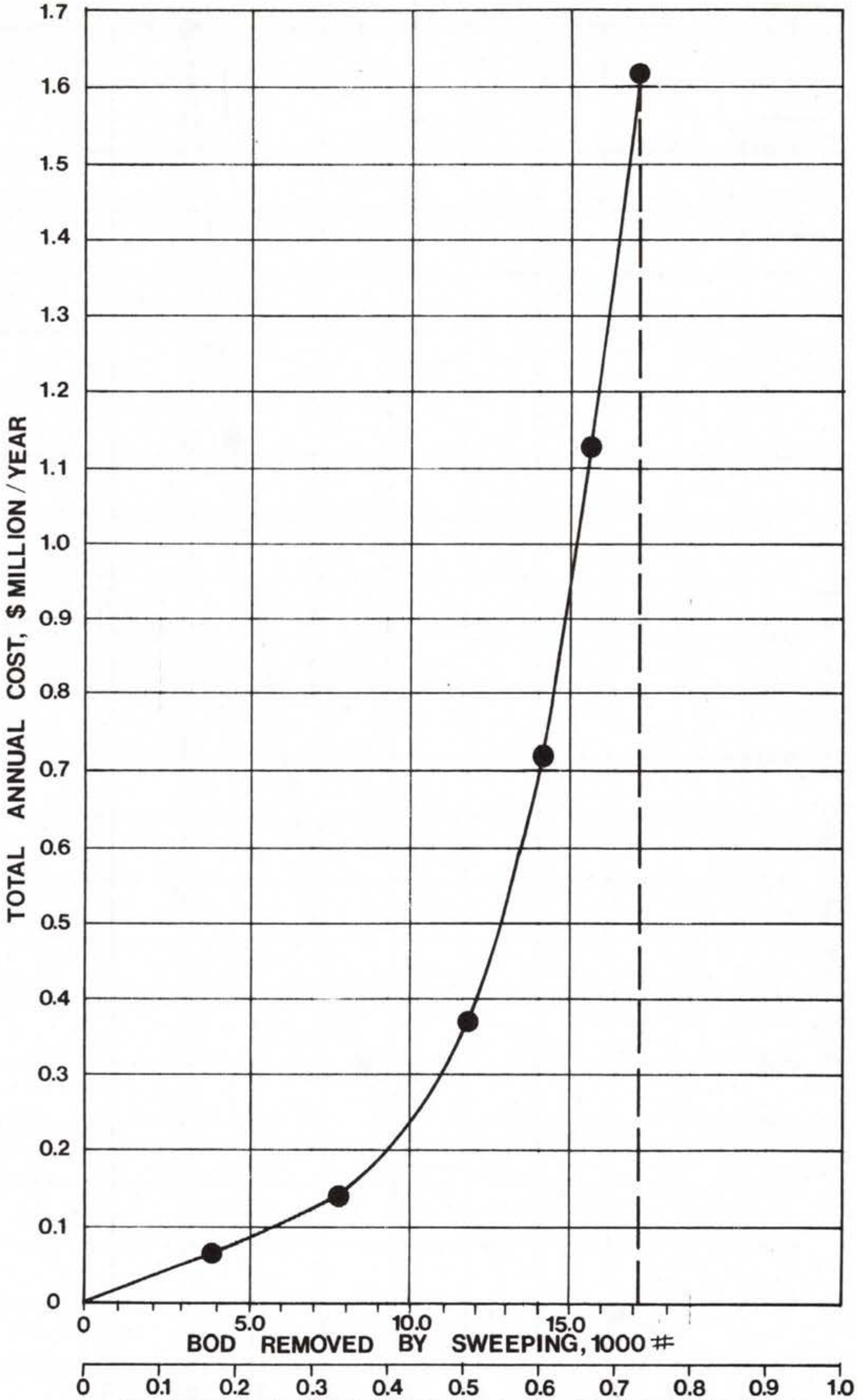


FIG. B.I-D. TOTAL COST CURVE FOR STREET SWEEPING GREELEY, RESIDENTIAL AREAS

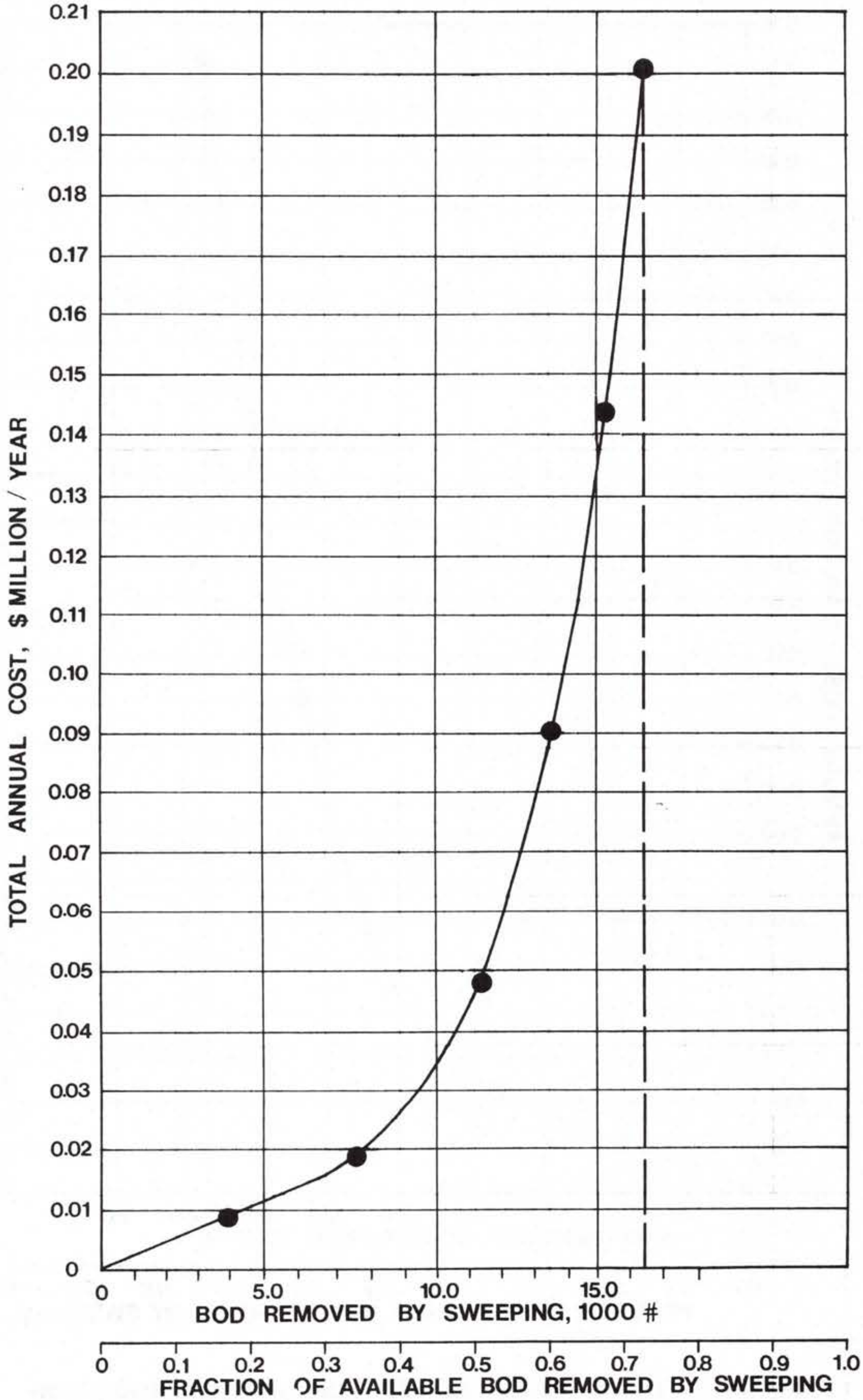


FIG. B.I-E. TOTAL COST CURVE FOR STREET SWEEPING GREELEY, COMMERCIAL AREAS

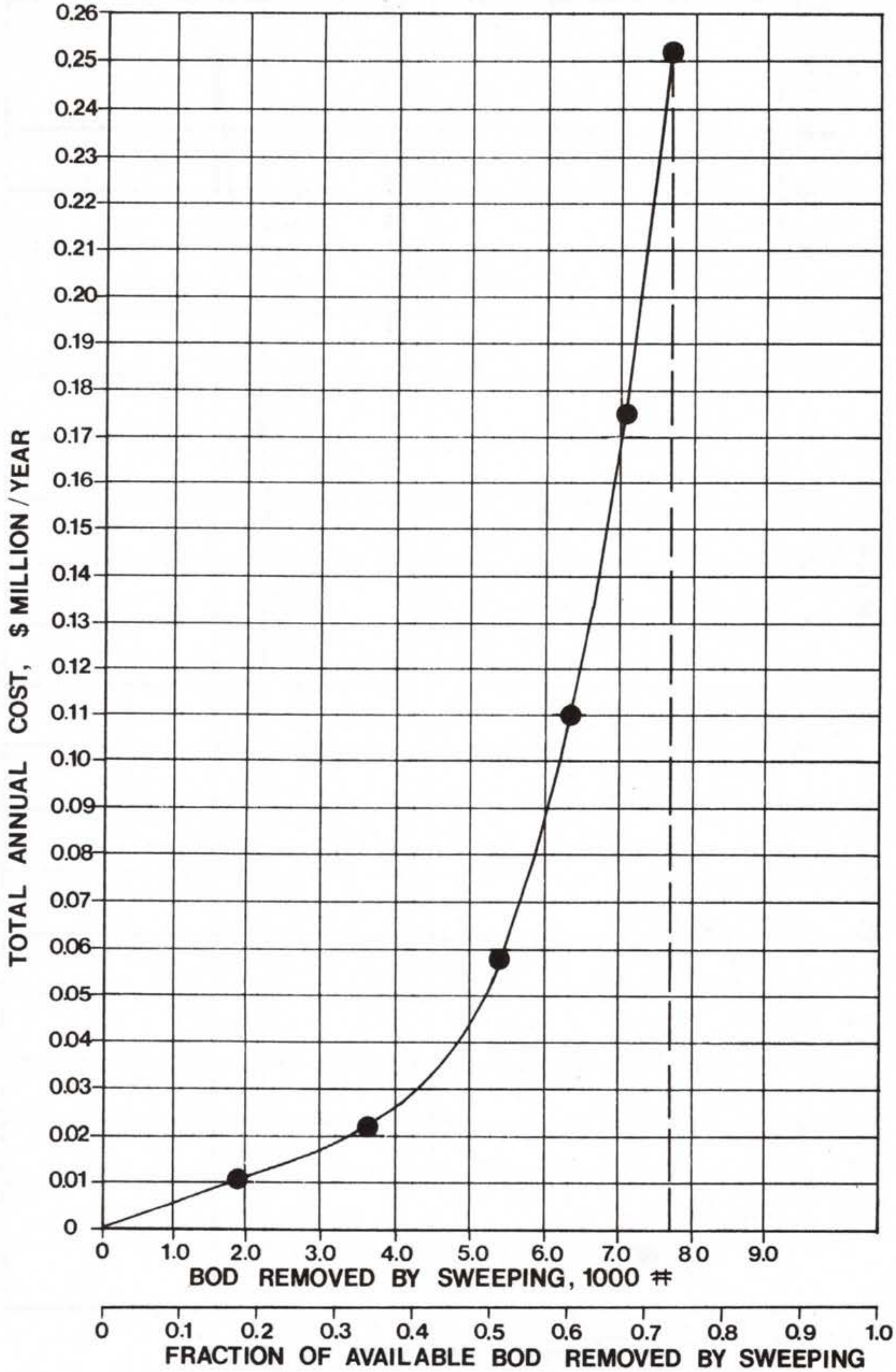


FIG. B.I-F. TOTAL COST CURVE FOR STREET SWEEPING GREELEY, INDUSTRIAL AREA

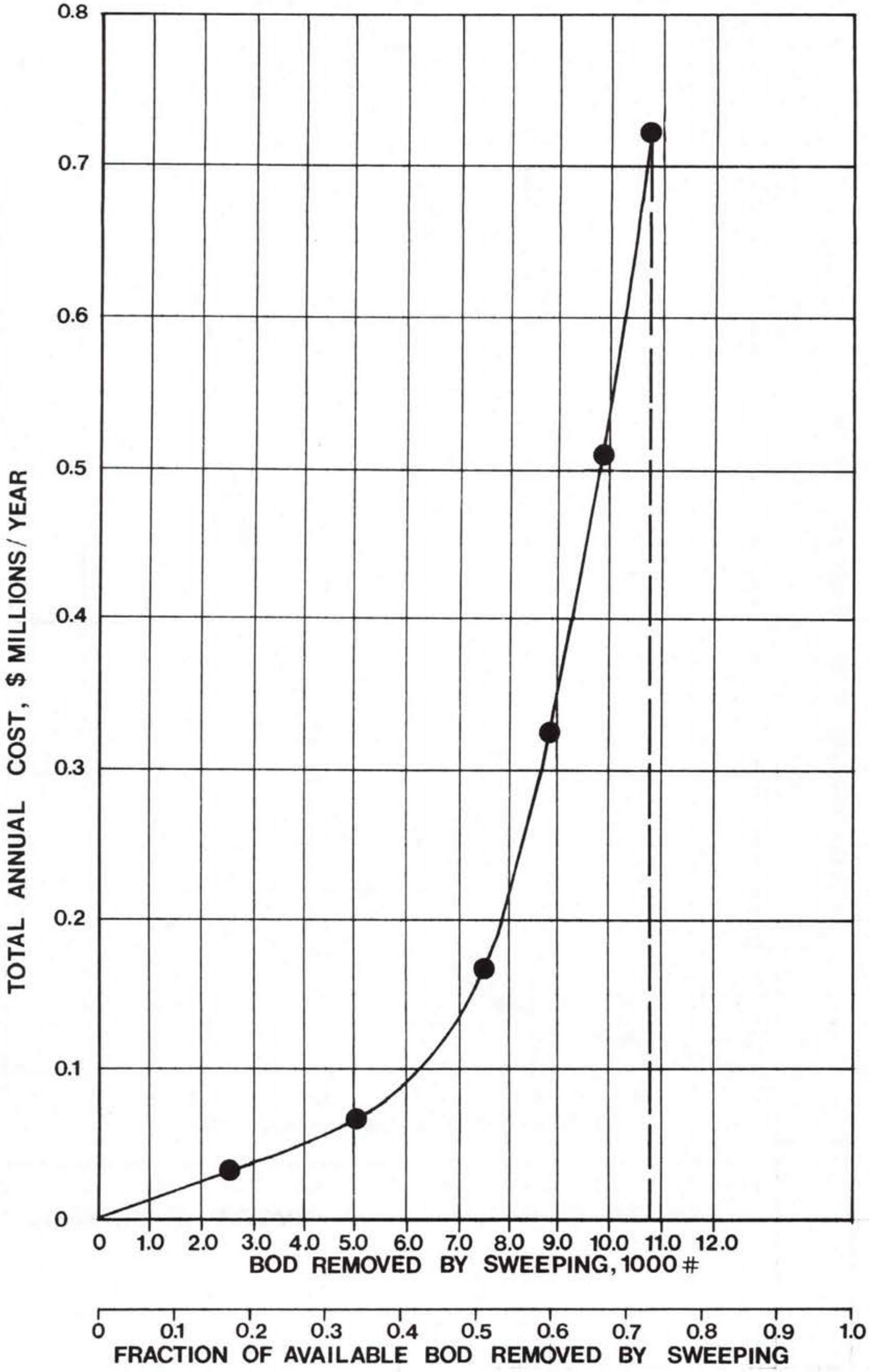


FIG. B.I-G. TOTAL COST CURVE FOR STREET SWEEPING LOVELAND, RESIDENTIAL AREAS

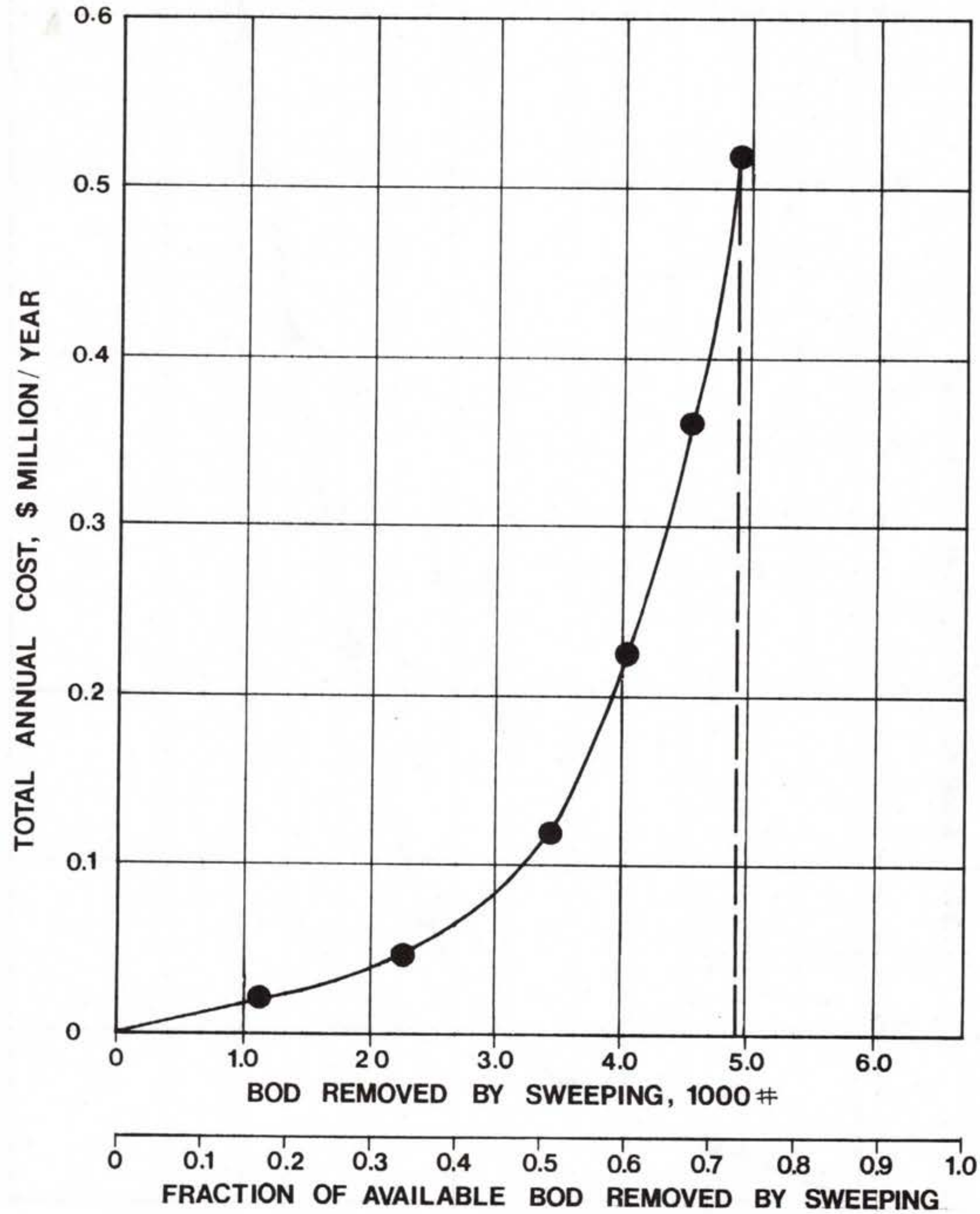


FIG. B.I-H. TOTAL COST CURVE FOR STREET SWEEPING LOVELAND, COMMERCIAL AREAS

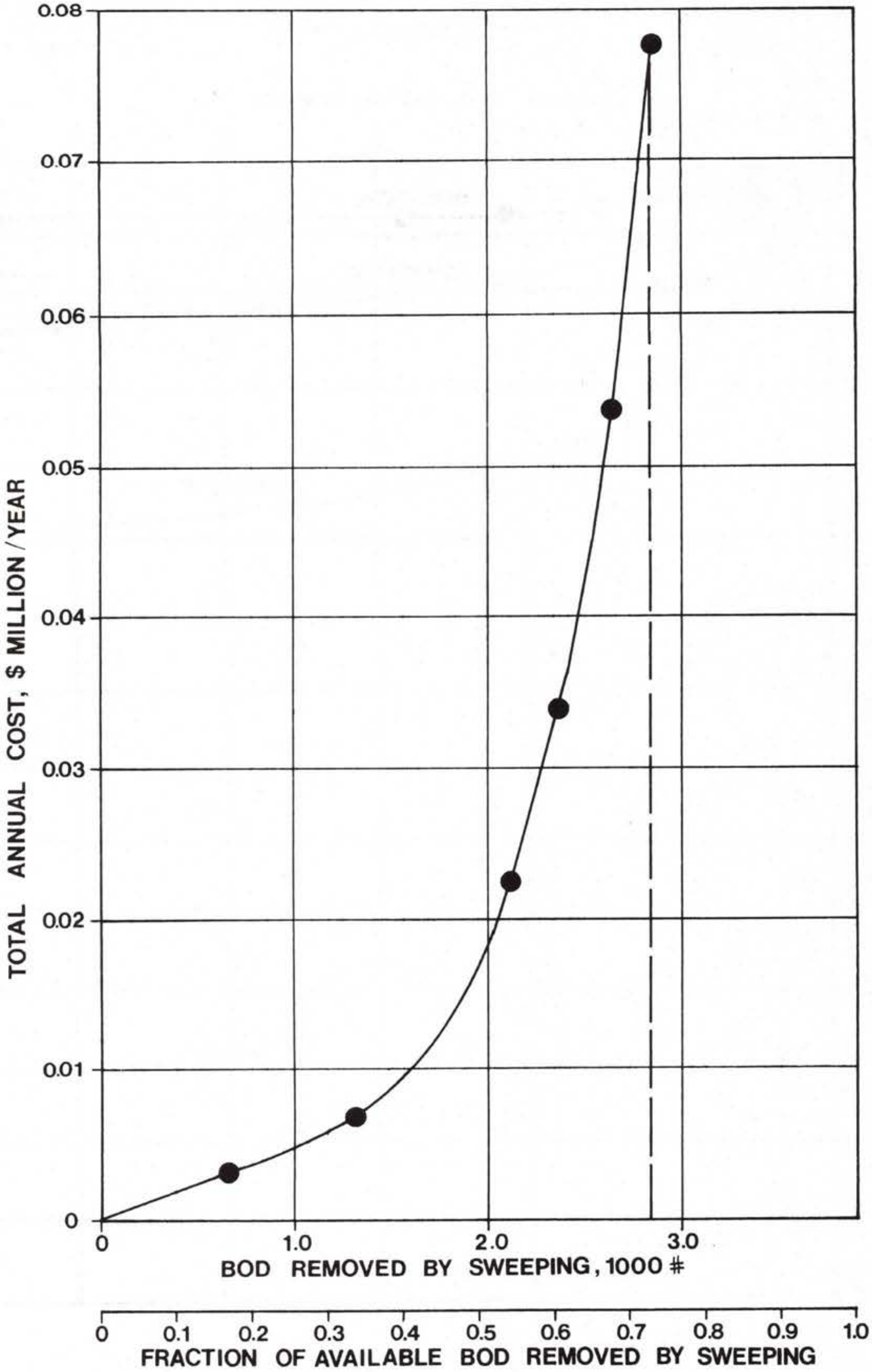


FIG. B.1-1. TOTAL COST CURVE FOR STREET SWEEPING LOVELAND, INDUSTRIAL AREA

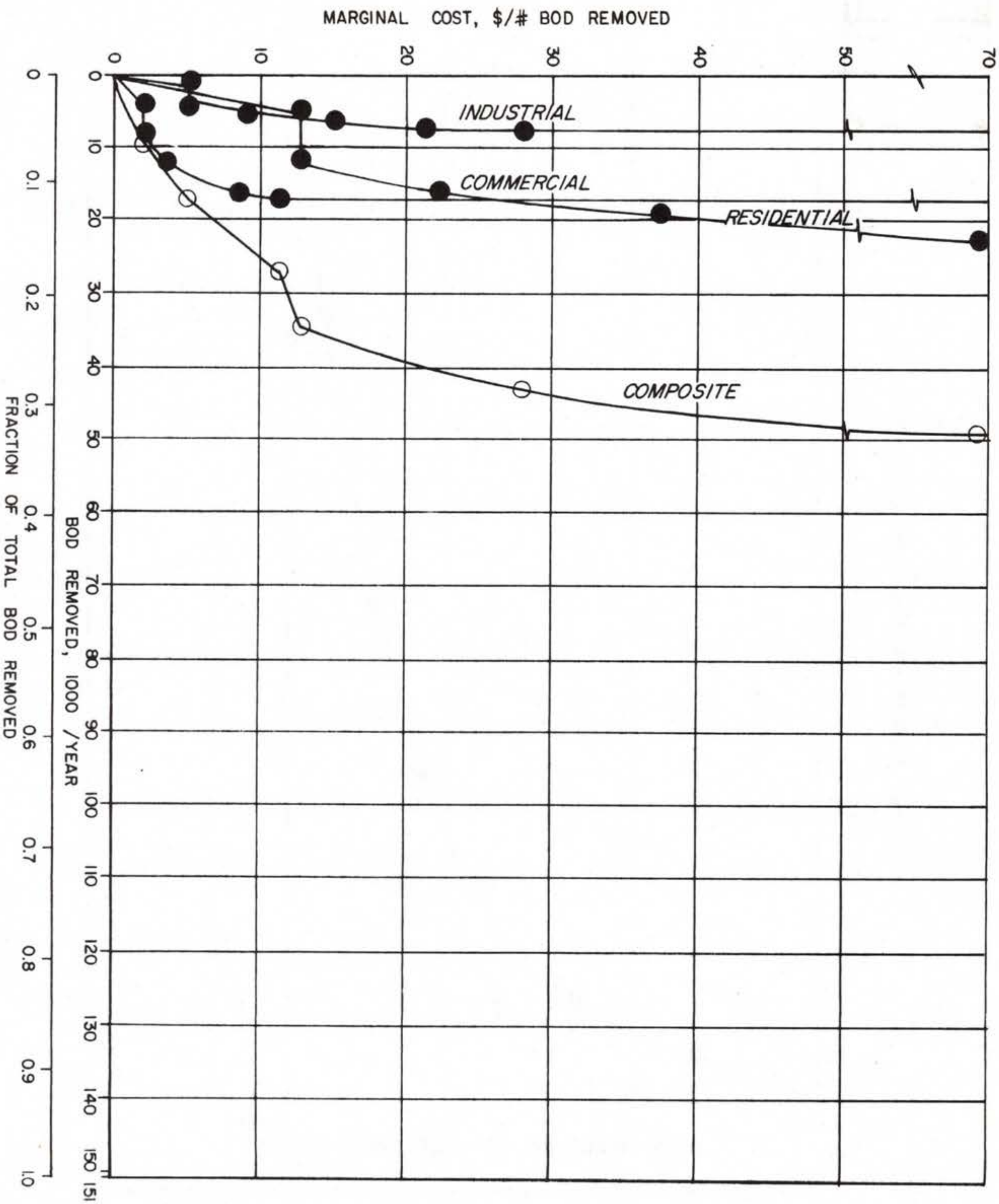


FIG.B.I-J. MARGINAL COST CURVES FOR STREET SWEEPING - FORT COLLINS

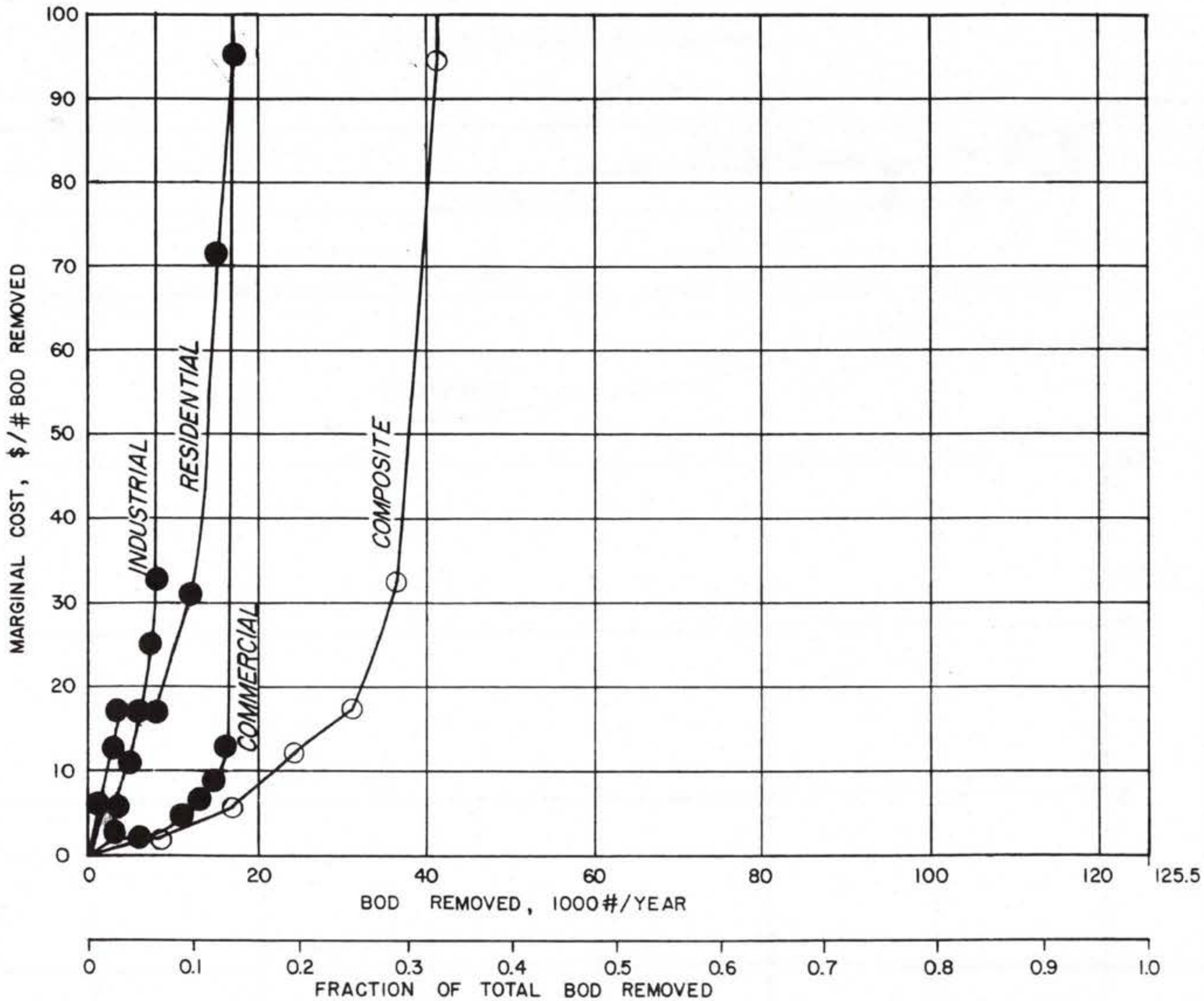


FIG. B.1-K. MARGINAL COST CURVES FOR STREET SWEEPING - GREELEY

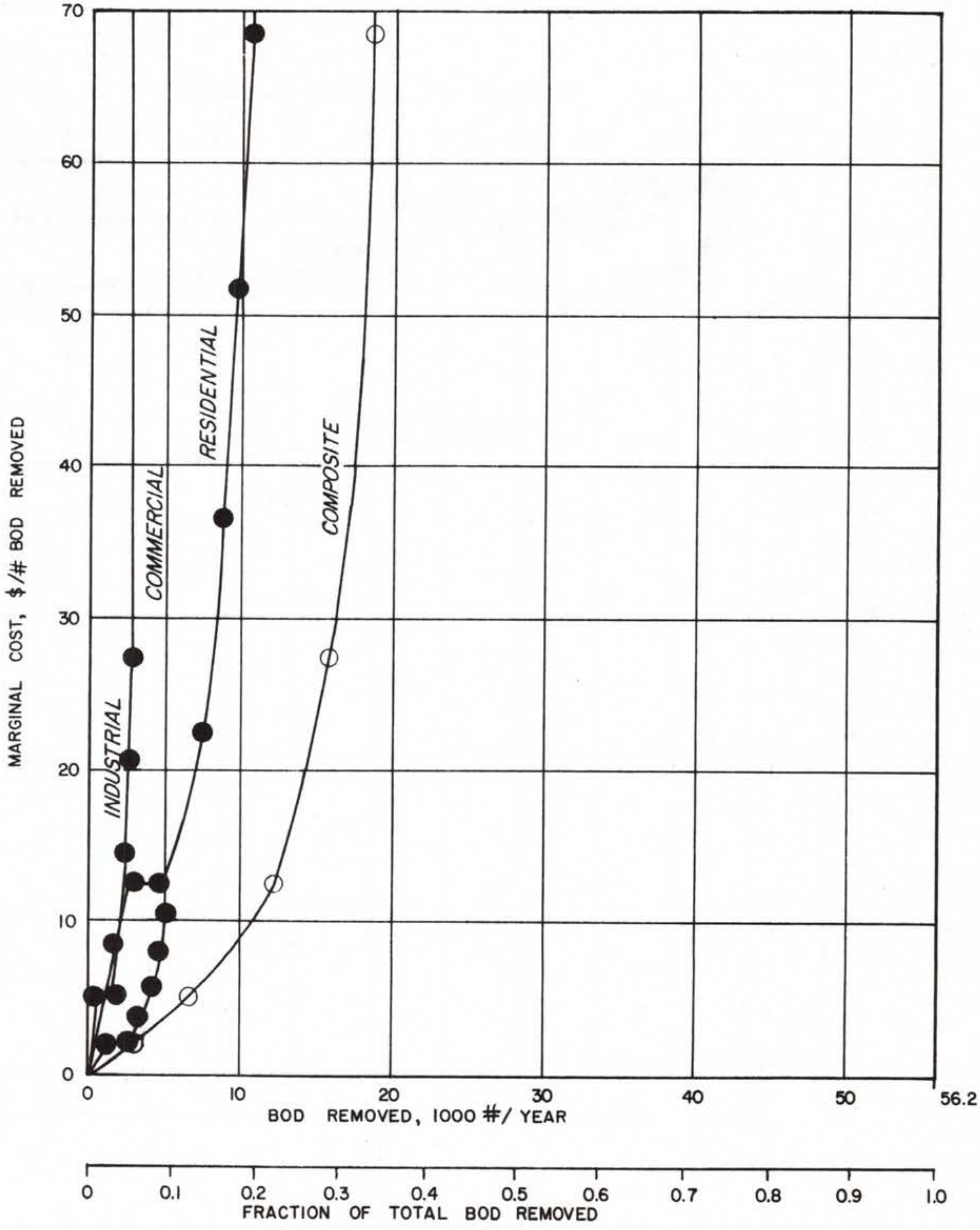


FIG. B.1-L. MARGINAL COST CURVES FOR STREET SWEEPING - LOVELAND

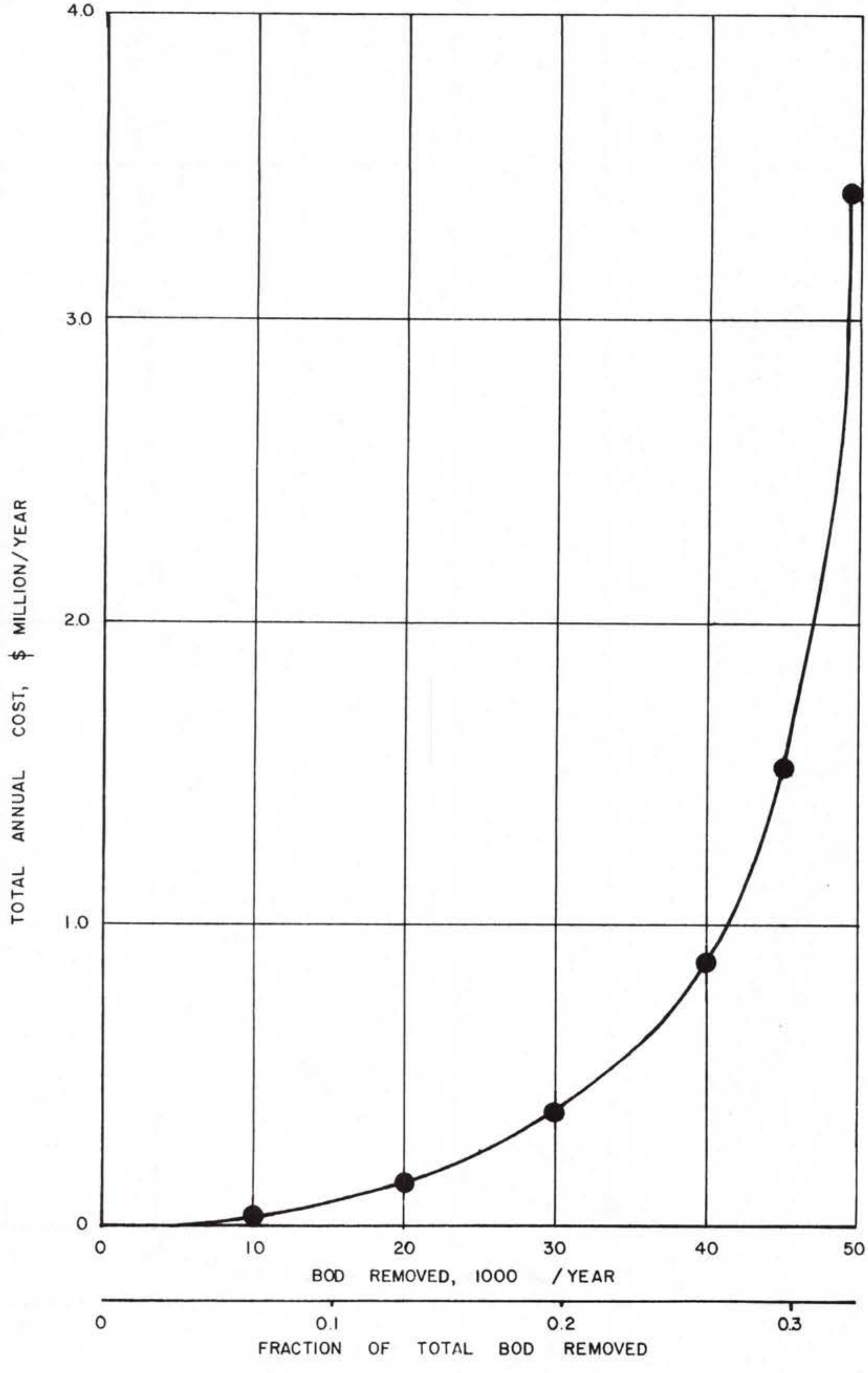


FIG.B.I-M. COMPOSITE TOTAL COST CURVE FOR ALL PARALLEL OPTIONS STREET SWEEPING – FORT COLLINS

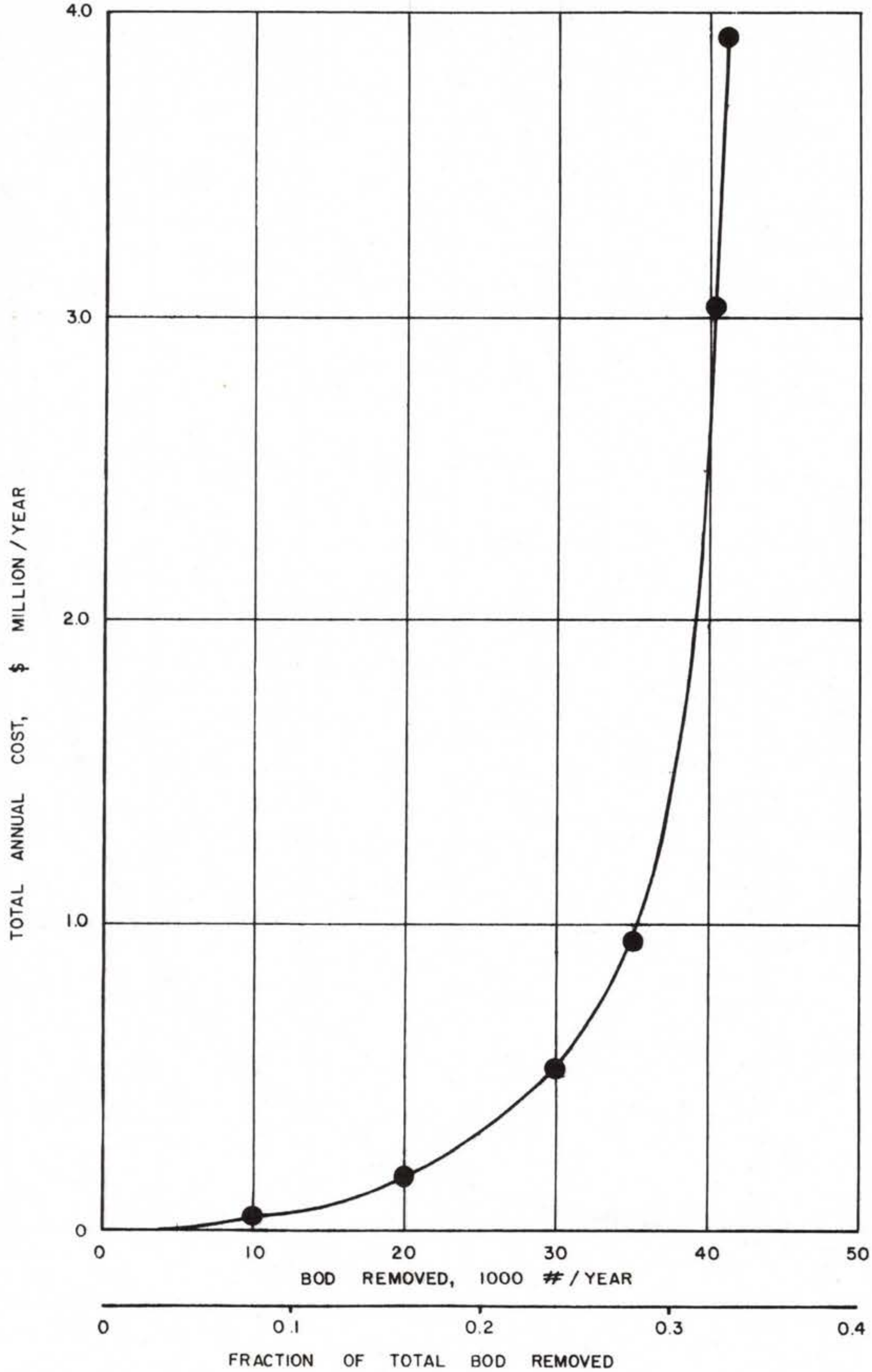


FIG. B.1-N. COMPOSITE TOTAL COST CURVE FOR ALL PARALLEL OPTIONS
STREET SWEEPING — GREELEY

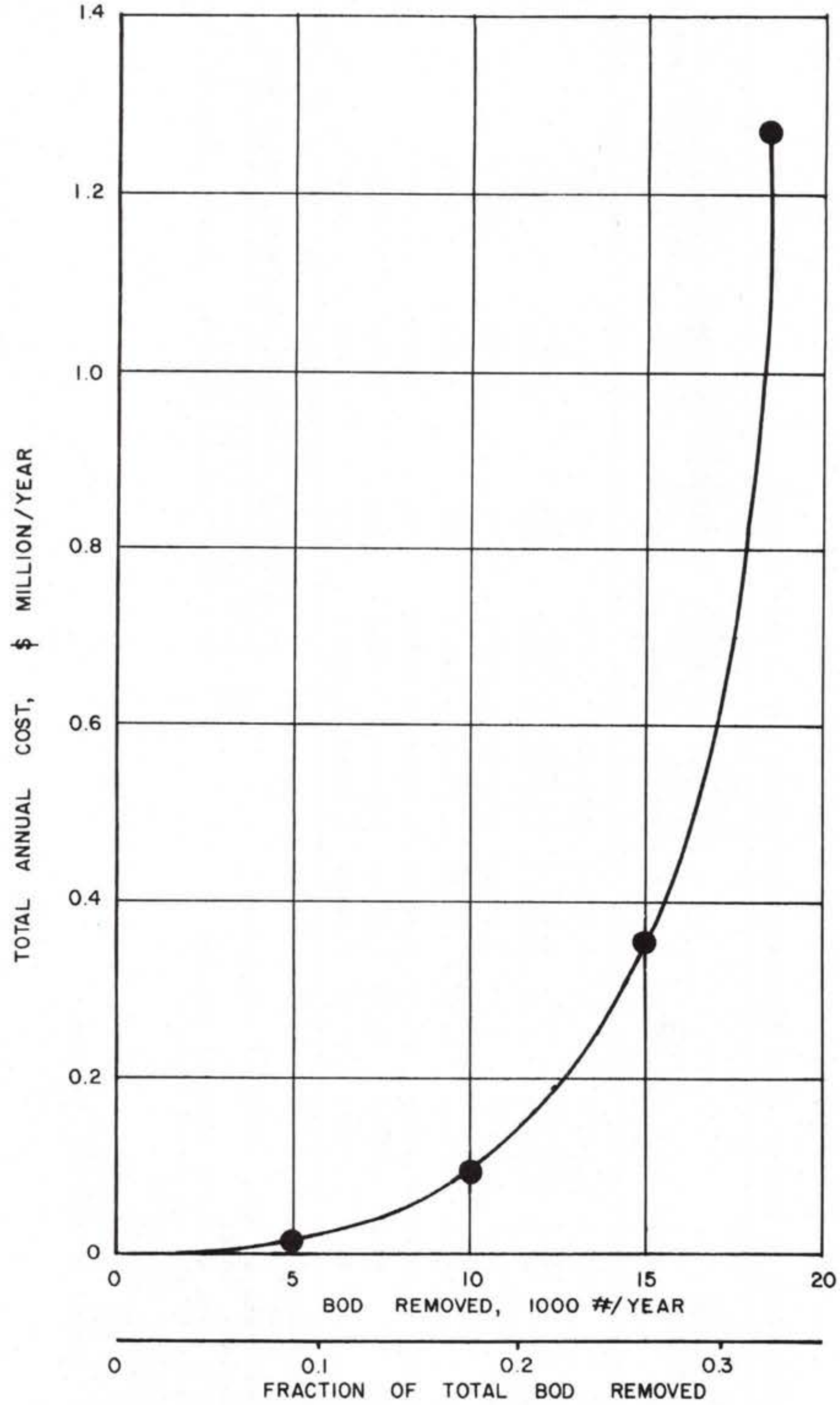


FIG. B.1-0. COMPOSITE TOTAL COST CURVE FOR ALL PARALLEL OPTIONS STREET SWEEPING — LOVELAND

TABLE B.2-1. CALCULATION OF OPTIMAL STORAGE-TREATMENT SOLUTION [a] - FORT COLLINS

TYPE OF CONTROL	GROSS LEVEL OF TRIBUTARY BOD CONTROL R	K [b]	T_2-T_1 [c]	$\frac{CT}{CS}$ [d]	T_1 [c]	OPTIMAL STORAGE S* [e] IN/ACRE	OPTIMAL TREATMENT T* [f] IN/HR-AC	UNIT COSTS STORAGE [g] C_S [d2 $/AC-IN	UNIT COSTS TREATMENT C_T [d] $/AC-IN/HR	OPTIMAL CONTROL COST Z* [h] ANNUAL $/AC	EFFICIENCY OF UNIT	NET BOD CONTROL R_1
Primary	10	195.5	0.00152	9.92	0.00005	0.00554	0.00056	263	2,610	2.92	0.4	4
	25	128.6	0.00294	9.92	0.00011	0.01029	0.00090	263	2,610	5.06	0.4	10
	50	64.0	0.00884	9.92	0.00023	0.02700	0.00180	263	2,610	11.80	0.4	20
	75	31.8	0.02653	9.92	0.00034	0.06683	0.00351	263	2,610	26.74	0.4	30
Secondary	10	195.5	0.00152	37.30	0.00005	0.01232	0.00018	263	9,810	5.01	0.85	8.5
	25	128.6	0.00294	37.30	0.00011	0.02059	0.00032	263	9,810	8.56	0.85	21.2
	50	64.0	0.00884	37.30	0.00023	0.04766	0.00065	263	9,810	18.91	0.85	42.5
	75	31.8	0.02653	37.30	0.00034	0.10847	0.00119	263	9,810	40.20	0.85	63.8

[a] Based on methodology, Heaney, Huber & Nix, 1976.
[b] K = constant, $inch^{-1}$
[c] T_2 = Treatment rate at which isoquant intersects the abscissa, in/hr
T_1 = Treatment rate at which isoquant becomes asymptotic to the ordinate, in/hr
[d] CT = Unit cost of treatment
CS = Unit cost of storage
[e] $S^* = \text{Max} [\frac{1}{K} \ln [\frac{CT}{CS} [(K)(T_2-T_1)], 0]$
S* = Optimal amount of storage, in/acre
[f] $T^* = T_1 + (T_2-T_1) e^{-KS^*}$
T* = Optimal amount of treatment, in/hr-acre
[g] Gross population density = 4.8 persons per acre
[h] $Z^* = C_S (S^*) + C_T (T^*)$
Z* = Total annual cost for optimal solution, $/acre

TABLE B.2-2. CALCULATION OF OPTIMAL STORAGE-TREATMENT SOLUTION [a] - GREELEY

TYPE OF CONTROL	GROSS LEVEL OF TRIBUTARY BOD CONTROL R	K[b]	T_2-T_1[c]	$\frac{CT}{CS}$[d]	T_1[c]	OPTIMAL STORAGE S* [e] IN/ACRE	OPTIMAL TREATMENT T* [f] IN/HR-AC	UNIT COSTS: STORAGE[g] C_S [d2 $/AC-IN	UNIT COSTS: TREATMENT C_T [d] $/AC-IN/HR	OPTIMAL CONTROL COST Z*[h] ANNUAL $/AC	EFFICIENCY OF UNIT	NET BOD CONTROL R_1
Primary	10	252.3	0.00118	10.92	0.00004	0.00467	0.00040	239	2,610	2.16	0.4	4
	25	166.0	0.00228	10.92	0.00009	0.00855	0.00064	239	2,610	3.71	0.4	10
	50	82.6	0.00685	10.92	0.00018	0.02205	0.00129	239	2,610	8.64	0.4	20
	75	41.1	0.02057	10.92	0.00027	0.05408	0.00249	239	2,610	19.42	0.4	30
Secondary	10	252.3	0.00118	41.05	0.00004	0.00992	0.00013	239	9,810	3.65	0.85	8.5
	25	166.0	0.00228	41.05	0.00009	0.01653	0.00024	239	9,810	6.30	0.85	21.2
	50	82.6	0.00685	41.05	0.00018	0.03808	0.00047	239	9,810	13.71	0.85	42.5
	75	41.1	0.02057	41.05	0.00027	0.08630	0.00086	239	9,810	29.07	0.85	63.8

[a] Based on methodology, Heaney, Huber & Nix, 1976.
[b] K = Constant, $inch^{-1}$
[c] T_2 = Treatment rate at which isoquant intersects the abscissa, in/hr
T_1 = Treatment rate at which isoquant becomes asymptotic to the ordinate, in/hr
[d] CT = Unit cost of treatment
CS = Unit cost of storage
[e] $S^* = \text{Max} \left[\frac{1}{K} \text{ in } \left[\frac{CT}{CS} [(K)(T_2-T_1)], 0\right]\right]$
S* = Optimal amount of storage, in/acre
[f] $T^* = T_1 + (T_2-T_1)e^{-KS^*}$
T* = Optimal amount of treatment, in/hr-acre
[g] Gross population density = 4.2 persons per acre
[h] $Z^* = C_S(S^*) + C_T(T^*)$
Z* = Total annual cost for optimal solution, $/acre

TABLE B.2-3. CALCULATION OF OPTIMAL STORAGE-TREATMENT SOLUTION [a] - LOVELAND

TYPE OF CONTROL	GROSS LEVEL OF TRIBUTARY BOD CONTROL R	K [b]	T_2-T_1 [c]	$\frac{CT}{CS}$ [d]	T_1 [c]	OPTIMAL STORAGE S* [e] IN/ACRE	OPTIMAL TREATMENT T* [f] IN/HR-AC	UNIT COSTS STORAGE [g] C_S [d2 $/AC-IN	UNIT COSTS TREATMENT C_T [d] $/AC-IN/HR	OPTIMAL CONTROL COST Z* [h] ANNUAL $/AC	EFFICIENCY OF UNIT	NET BOD CONTROL R_1
Primary	10	190.8	0.00155	10.92	0.00005	0.00614	0.00053	239	2,610	2.85	0.4	4
	25	125.5	0.00300	10.92	0.00012	0.01127	0.00085	239	2,610	4.91	0.4	10
	50	62.4	0.00902	10.92	0.00023	0.02910	0.00170	239	2,610	11.39	0.4	20
	75	31.1	0.02707	10.92	0.00035	0.07133	0.00330	239	2,610	25.66	0.4	30
Secondary	10	190.8	0.00155	41.05	0.00005	0.01308	0.00017	239	9,810	4.80	0.85	8.5
	25	125.5	0.00300	41.05	0.00012	0.02182	0.00031	239	9,810	8.25	0.85	21.2
	50	62.4	0.00902	41.05	0.00023	0.05032	0.00062	239	9,810	18.11	0.85	42.5
	75	31.1	0.02707	41.05	0.00035	0.11391	0.00113	239	9,810	38.31	0.85	63.8

[a] Based on methodology, Heaney, Huber & Nix, 1976.
[b] K = Constant, inch $^{-1}$
[c] T_2 = Treatment rate at which isoquant intersects the abscissa, in/hr
T_1 = Treatment rate at which isoquant becomes asymptotic to the ordinate, in/hr
[d] CT = Unit cost of treatment
CS = Unit cost of storage
[e] $S^* = \text{Max}\ [\frac{1}{K} \text{ in } [\frac{CT}{CS} [(K)(T_2-T_1)],0]$
S* = Optimal amount of storage, in/acre
[f] $T^* = T_1 + (T_2 - T_1)e^{-KS^*}$
T* = Optimal amount of treatment, in/hr-acre
[g] Gross population density - 4.2 persons per acre
[h] $Z^* = C_S\ (S^*) + C_T\ (T^*)$
Z* = Total annual cost for optimal solution, $/acre

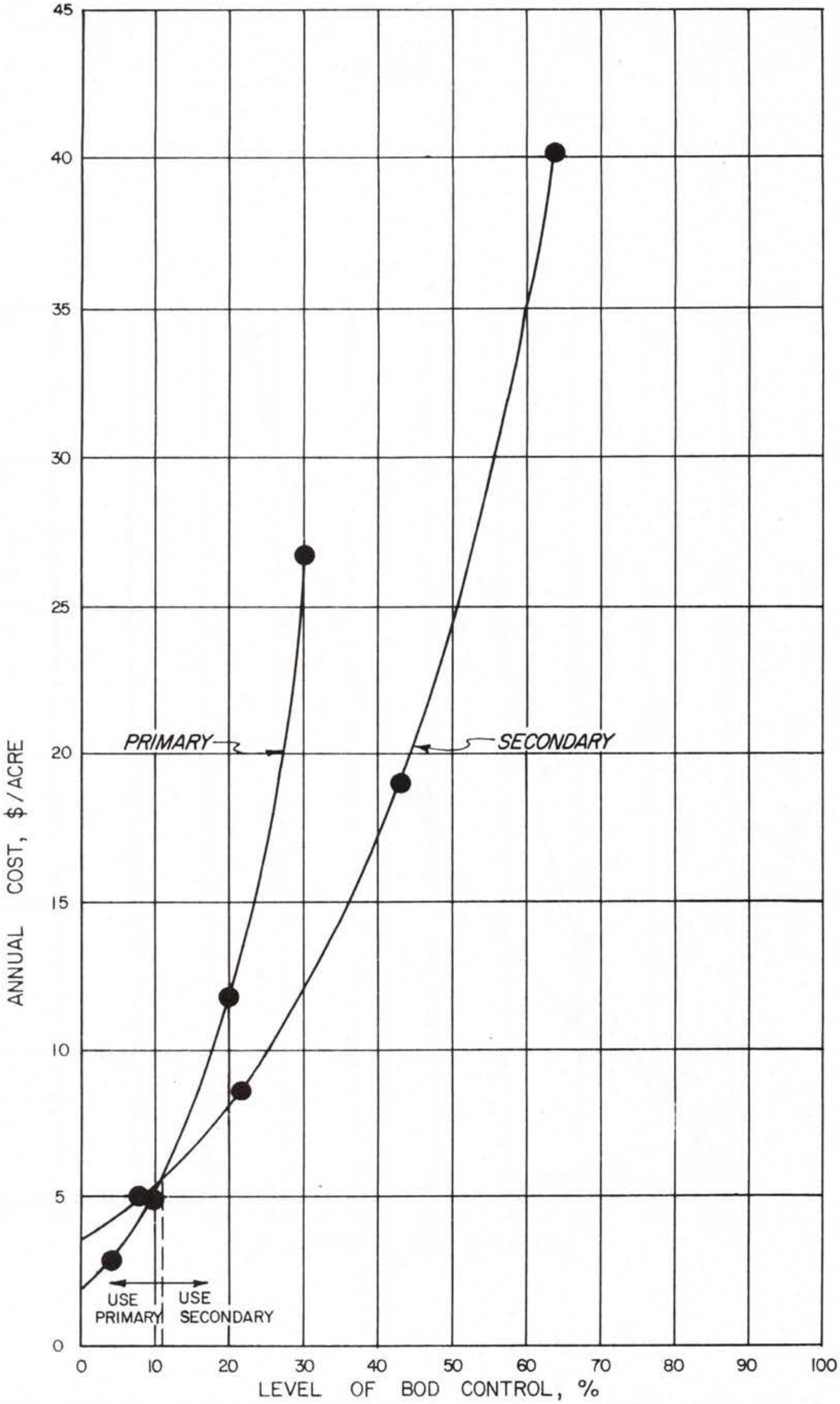


FIG. B.2-A. ANNUAL COST AS A FUNCTION OF LEVEL OF BOD CONTROL
STORAGE-TREATMENT - FORT COLLINS

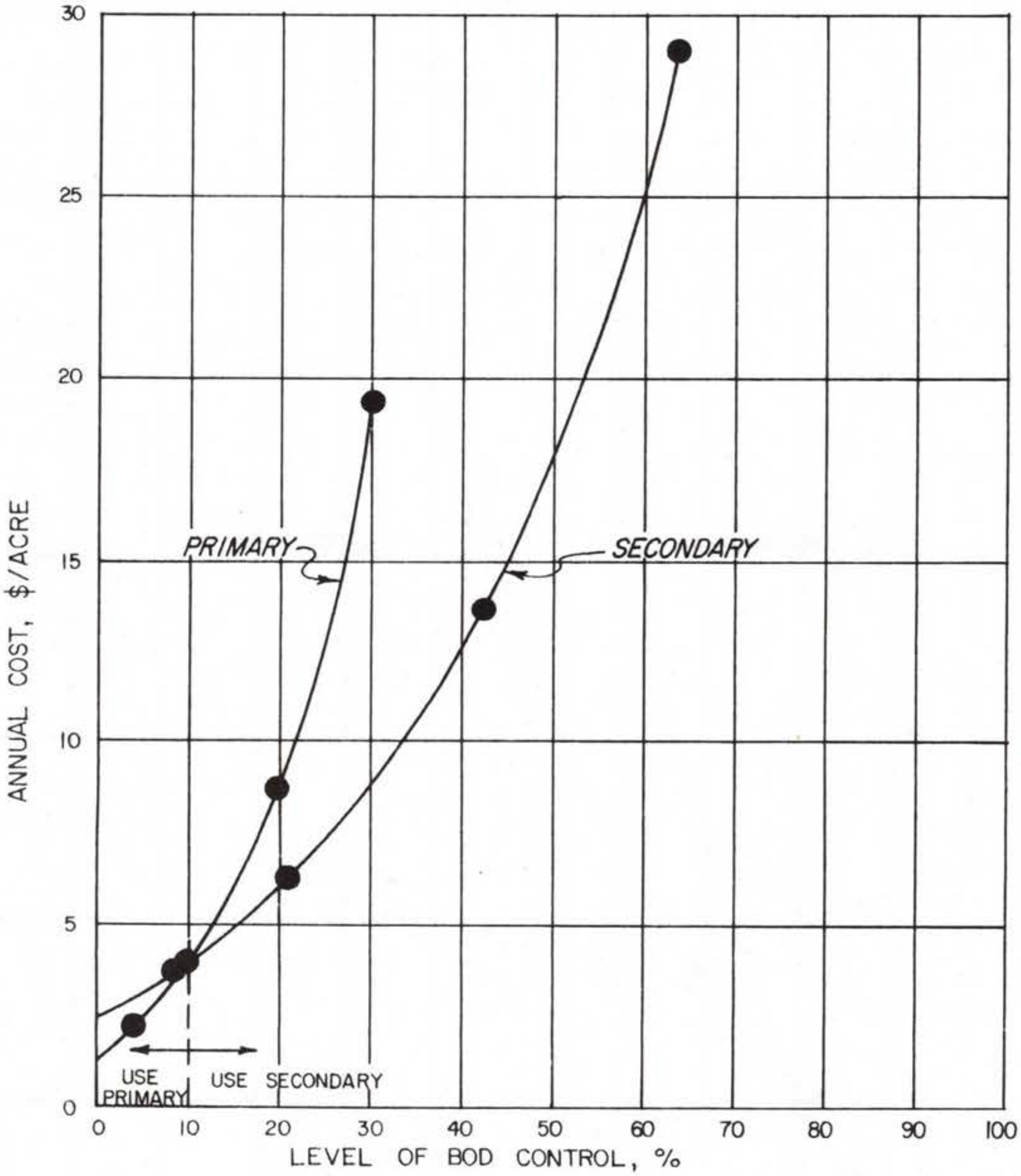


FIG. B.2-B. ANNUAL COST AS A FUNCTION OF LEVEL OF BOD CONTROL STORAGE-TREATMENT - GREELEY

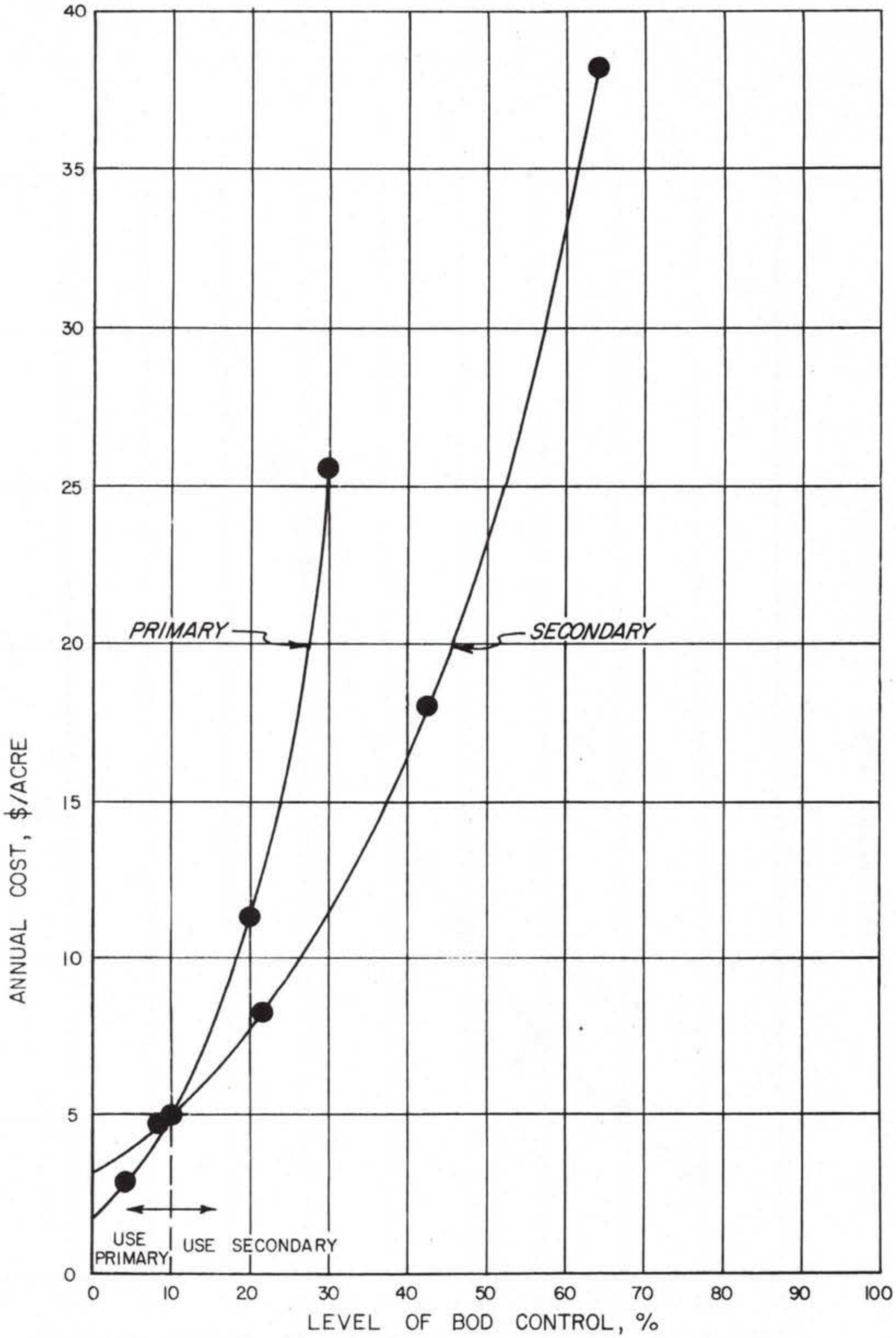


FIG. B.2-C. ANNUAL COST AS A FUNCTION OF LEVEL OF BOD CONTROL STORAGE—TREATMENT - LOVELAND

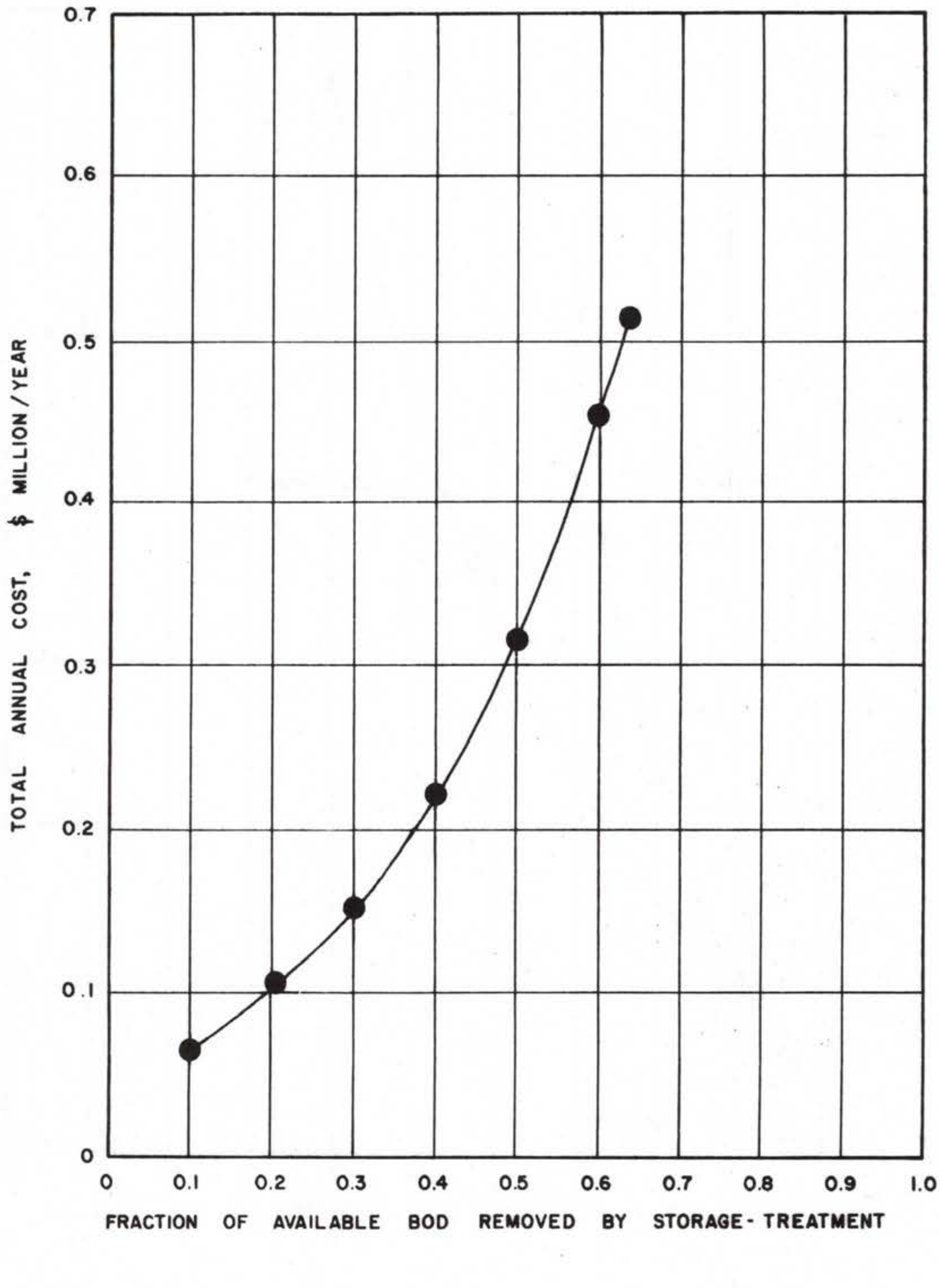


FIG. B.2-D. TOTAL COST CURVE FOR STORAGE - TREATMENT - FORT COLLINS

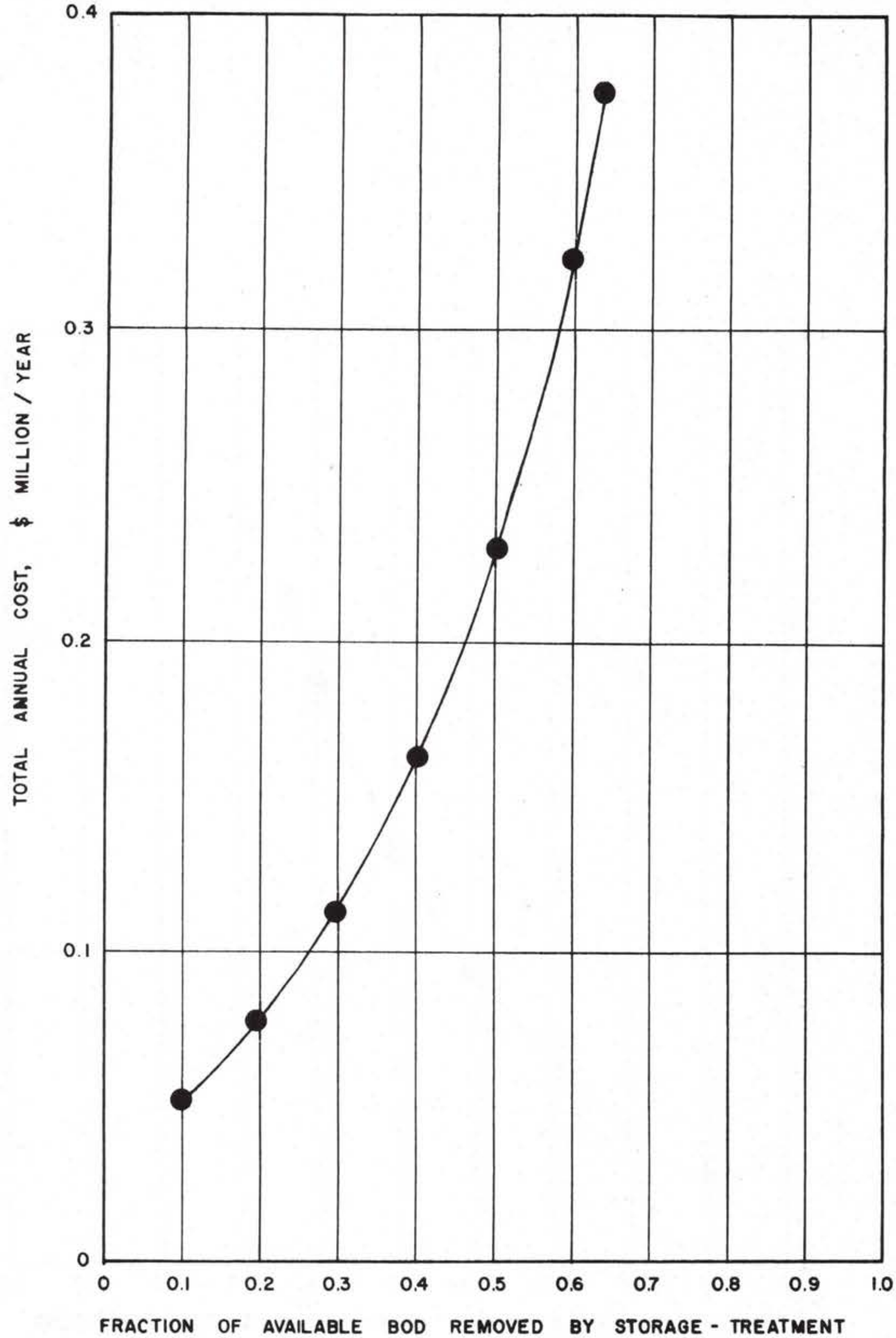


FIG. B.2-E. TOTAL COST CURVE FOR STORAGE-TREATMENT - GREELEY

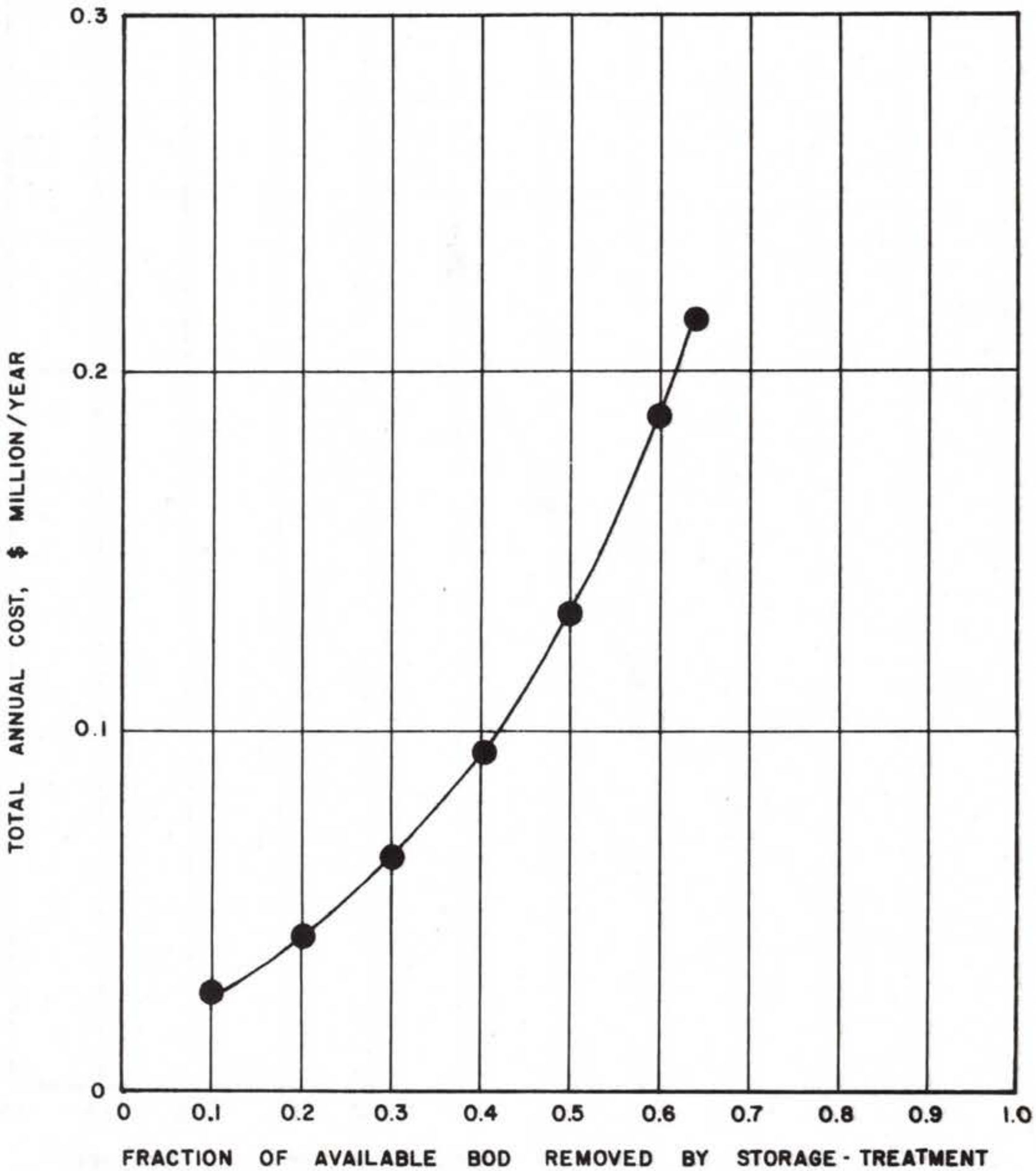


FIG. B.2-F. TOTAL COST CURVE FOR STORAGE-TREATMENT - LOVELAND

APPENDIX C

WORK PROGRAM FOR IDENTIFICATION OF THE TECHNICAL AND INSTITUTIONAL FEASIBILITY OF DEVELOPING AND IMPLEMENTING BEST MANAGEMENT PRACTICES FOR URBAN RUNOFF POLLUTION CONTROL

WORK PROGRAM FOR IDENTIFICATION OF THE TECHNICAL AND INSTITUTIONAL FEASIBILITY OF DEVELOPING AND IMPLEMENTING BEST MANAGEMENT PRACTICES FOR URBAN RUNOFF POLLUTION CONTROL

INTRODUCTION

Federal, State, and local agencies have put considerable effort into the understanding of urban runoff and its impacts on water quality throughout the nation. In some locations, urban runoff control measures have been successfully implemented. Like other non-point source problems, feasible solutions to the urban runoff problem are highly site specific. This necessitates a formalized program of problem identification, identification of potential measures and analysis of institutional relationships as an integral part of implementation planning. In order to accomplish this in the Larimer-Weld Region, a work program has been developed which will lead to development of an implementation plan for control of urban runoff in the region. Prior to implementation, this plan should be reviewed and commented upon by all parties affected, and modified as necessary.

The work program includes the following tasks:

1. System Identification and Design Criteria
2. Hydrologic Analysis
3. Define Water Quality Sampling Program
4. Water Quality Sampling Program
5. Comparison of Existing and Future Wasteloads
6. Relationship of Urban Runoff to Other Discharges
7. Water Quality Modeling
8. Water Quality Impact Assessment
9. Urban Drainage Planning by Municipalities
10. Evaluation of Potential Control Measures

11. Alternative Technical Control Plans

12. Recommended Technical Control Plan

13. Institutional Analysis

14. Assignment of Institutional Responsibilities

15. Development of Implementation Plan

These tasks are described in detail below.

TASK 1 - SYSTEM IDENTIFICATION AND DESIGN CRITERIA

The major objective of this task is to define the urban drainage systems in the major municipalities, i.e., Fort Collins, Greeley, and Loveland, which cause discharge of urban runoff, the location of discharge points, the area draining to specific discharge points, and the types of land use within specific areas. Design criteria applied to develop existing systems will be defined, and current design criteria used by individual cities and the two counties will be documented.

In addition to the three major cities, other sources of urban runoff will also be identified using 208 land use information. This will include small towns within the two-county area. The relative magnitude of runoff and impacted water bodies will be identified.

TASK 2 - HYDROLOGIC ANALYSIS

The hydrologic analysis deals with two aspects of urban runoff phenomena in the region:

1. Stream flow conditions following precipitation events;

2. Volume of runoff generated by precipitation events;

There are two types of climatic events which cause urban runoff in the Larimer-Weld area - snowmelt and rainfall. It is expected that pollutant loading and impacts on water quality are quite different under these two conditions.

Snowmelt events in the region occur sporadically between October and May with most events concentrated in the months of January, February, and March. This is also the time of extremely low stream flows. Irrigation diversion during this time consist mainly of those diversions which place water into storage. It is anticipated that much of the urban runoff which occurs during this period from Fort Collins, Loveland, and Greeley is eventually stored in irrigation reservoirs after it enters the stream system; however, due to the road maintenance practices common during this period, it is expected that this water is heavily loaded with pollutants.

Most of the rainfall events occurring in the region which produce runoff occur during the period of April, May, and June. This is also the period in which spring runoff occurs and is generally a maximum flow period in streams in the region. Isolated showers are more common in July and August.

During the early spring period when rainfall events occur simultaneously with the spring runoff, most irrigation diversion structures are removing water from the streams, either for storage or direct application to the land.

In order to define the water quality impacts of urban runoff, it will be necessary to develop a water budget for the two critical urban runoff periods, i.e., winter and early spring.

In the course of developing the 208 Plan, the Larimer-Weld Regional Council of Governments has defined the location of all diversion structures in the Big Thompson River Basin and the Cache la Poudre River Basin. It will be necessary to determine the seasonal operation of the river through analysis of diversion records, gaging data, and storage releases. Historical climatic data will be analyzed to determine typical weeks or days (as appropriate) to be used in defining a hydrologic budget. The budget will include estimates of discharges from both urban and non-urban areas. Application of standard methods of estimating runoff and snowmelt will be applied to specific surface conditions and climatic events within the region to develop an estimate of the volume of urban runoff entering streams. Development of the stream water budget will enable verification of these estimates to a reasonable degree of accuracy.

TASK 3 - DEFINE WATER QUALITY SAMPLING PROGRAM

The degree of success achieved in this program will depend greatly upon the definition and successful implementation of a water quality sampling program. The results of the water quality sampling program will provide fundamental information for determining:

1. The cost of potential pollution control measures, and

2. The effectiveness of those control measures in mitigating the impacts of urban runoff.

This combination of factors will determine the overall cost-effectiveness of urban runoff control measures in the region. Definition of the water quality sampling program will require integration of a number of factors, including:

1. Knowledge of the volume and location of urban runoff;

2. The type of land use from which the runoff is occurring;

3. Critical pollutant parameters associated with urban runoff;

4. Hydrologic impacts of the volume of runoff on stream flow;

5. Background levels of pollutants in the stream monitored;

6. Down stream concentrations of pollutants generated by urban runoff;

7. Impacts of pollutants generated by urban runoff on beneficial uses;

8. Variation of pollutant generation as the function of time, i.e., identifying the "fist flush" phenomena;

9. Impact of management activities, i.e., street sweeping, road salting, etc. on pollutant generation.

It is anticipated that the initial sampling program will include a broad range of pollutants and will subsequently focus on the narrower range of indicator pollutants, such as total coliforms, suspended solids, and BOD. The initial range of pollutants might include such items as phenols, oils, grease, total coliforms, suspended solids, BOD, etc.

An additional function of this task will be to define the methodology for carrying out the water quality sampling program. This will include:

1. Identification of the pollutants to be sampled in the initial and subsequent stages of the program;

2. Identification and preservation techniques for samples;

3. Identification of the water quality laboratories where the analyses will be conducted;

4. Definition of the cost of water quality sampling, both field and laboratory cost;

5. Identification of personnel responsible for sampling;

6. Identification of the specific data needed, including time, flow, etc., in addition to water quality data;

7. Identification of data to be collected in the field, such as temperature and suspended solids as opposed to data collected in the laboratory;

8. Identification of personnel who will conduct the sampling program.

Concerning the latter item, it is anticipated that municipal employees will be used to assist in water quality sampling. Due to the isolated nature of some storm events, this may be the only feasible way of collecting the required data. It may also prove to be the most economical in terms of cost and manpower utilization. A portion of the budget would be utilized for reimbursement of municipalities for this cost.

TASK 4 - WATER QUALITY SAMPLING PROGRAM

It is anticipated that the water quality program defined in Task 3 will be carried out over at least a 12-month period. This would provide some representative data to indicate the magnitude of the problem, variations in discharge and pollutant loading, and impact on water quality. During this period, samples will be collected and analyzed, and the frequency of storm events generating samples will be determined through standard hydrologic frequency analysis.

TASK 5 - COMPARISON OF EXISTING AND FUTURE WASTELOADS

Information on existing and projected land use will be analyzed to determine the impact of urban runoff on streams, reservoirs, and irrigation systems under existing conditions and projected future conditions. The initial analyses will include a comparision of existing and future land uses by category as developed in the 208 Program. Subsequently data developed in the water quality sampling program will be integrated to project the magnitude and volume of wasteloads anticipated and the impact of those wasteloads on water quality and beneficial uses, now and in the future.

TASK 6 - RELATIONSHIP OF URBAN RUNOFF TO OTHER DISCHARGES

A major factor in determining the cost effectiveness of urban runoff control measures will be the relative degree to which pollutant discharges from urban runoff can be mitigated as compared to pollutant discharges from other sources. It has been documented through the 208 Program that during low-flow conditions irrigation return flow is the major source of pollutant discharge in the Lower Poudre and Big Thompson River Basins. In addition both streams are impacted by point source discharges from municipalities and industries. Runoff from non-urban lands during snowmelt or storm conditions has not been defined nor analyzed. The water quality sampling program will provide an indication of the relationship between the magnitude of pollution impacts of urban runoff versus non-urban lands. This will occur primarily through the use of selected sampling points at locations upstream and downstream of urban runoff point source discharges. This data as well as data developed as part of the 208 Program will enable the definition of the relative impacts on beneficial uses of urban runoff and other sources of pollution.

TASK 7 - WATER QUALITY MODELING

Water quality modeling is at best an inexact application of scientific data to depict real world phenomena. However, water quality modeling does have the following advantages:

1. It provides a formalized structure for data analysis;

2. The relative impact of wasteloads can be determined by uniform methods;

3. The relative impact of Best Management Practices can be defined under uniform conditions.

For these reasons, it is recommended that the water quality model, i.e., Pioneer I (which was initially developed for the South Platte River Basin by the Environmental Protection Agency), be used to meet the above stated objectives. This would require the following steps:

1. The data collection program would have to be oriented toward providing data needed for model calibrations. No additional burden in the water quality sampling program is anticipated as this level of data would be required in any event;

2. Hydrologic analysis would have to be conducted of stream systems to determine flow conditions, i.e, depth, velocities, volumes under storm conditions. This would also be required under any adequate analysis of the urban runoff phenomena in the region;

3. Data would have to be applied to the model for calibration purposes. This is anticipated to be the only additional work required.

Previous experience indicates that modeling in itself provides insight into the cause-effect relationship, regardless of the ultimate value of the model in precise prediction of the real world phenomena. The model should also prove extremely valuable in analyzing the downstream water quality impacts of best management practices for urban runoff control. Such a formalized comparative analytical structure would not be possible without application of the model.

TASK 8 - WATER QUALITY IMPACT ASSESSMENT

The objective of this task is to identify the impacts of urban runoff on beneficial uses of water in the region. To achieve this objective, all information and techniques used in previous tasks will be integrated to provide an assessment of the water quality impacts of urban runoff - under existing and future conditions - on streams, reservoirs, and irrigation systems. The water quality model will be used extensively to define the impact of urban runoff on the stream systems. Impacts on irrigation systems and reservoirs will be defined as a function of both volume of wasteload generated and pollutant concentrations resulting in the irrigation system. Comparison of pollutant concentrations and volumes will be made with water quality requirements for beneficial uses to which waters are applied. The comparison will be made in terms of:

1. Existing and proposed water quality standards; and

2. Impacts on the use of water in the region, i.e., domestic supplies form surface and ground waters, irrigation, stock watering, fisheries, recreation, municipal and industrial use.

Violations of water quality standards which are known to occur under existing conditions and which are projected to occur under future conditions will be identified. Impacts on the beneficial use of water will also be described. Identification will be made on a pollutant-by-pollutant basis, and the magnitude of the violation or impact will be quantified to the maximum extent possible. This analysis will identify pollutants which are of major concern, and this in turn will affect the evaluation of potential control measures for urban runoff.

TASK 9 - URBAN DRAINAGE PLANNING BY MUNICIPALITIES

A number of growing communities in the Larimer-Weld Region have recognized the need for revising, modifying, and expanding urban drainage plans. Some communities have initiated such planning and others are considering plan updating in the near future. Population projections developed as part of the 208 Program indicate an approximate doubling of population within the next 22 years. Much of this growth will occur in the urban areas and will necessitate continued expansion of utilities plans, including those for urban runoff. This presents a unique opportunity to integrate urban drainage planning with water quality management planning for urban runoff control if water quality control measures for urban runoff are demonstrated to be cost effective. This process will be initiated within the context of this program. Urban drainage and flood control plans developed by individual communities will be reviewed to determine design criteria, service areas, facilities, discharge locations, and impacted waterways.

Review of urban drainage plans developed by individual communities will provide the information needed for meaningful integration of drainage planning with pollution control planning in a subsequent task.

TASK 10 - EVALUATION OF POTENTIAL CONTROL MEASURES

A variety of potential pollution control measures exist to reduce the concentration of pollutants in urban runoff or to mitigate the impacts of urban runoff on beneficial uses. These have been traditionally classified as structural and nonstructural measures. Nonstructural measures include such items as street sweeping, litter control ordinances, animal containment ordinances, etc. Structural control measures can be generally divided into practice and treatment options. For the purpose of this work plan, practice options are considered to be those control measures which are integrated by traditional urban drainage design techniques for the purpose of reducing or eliminating pollutant discharge while still meeting urban drainage requirements. These include modifications to existing design criteria or modified O&M practices to specifically reduce the concentration of pollutants generated by urban runoff. Treatment options include end-of-pipe treatment such as filtration, coagulation, etc. which has been applied on a limited basis in some areas to the so-called first flush of pollutants associated with urban runoff. Potential options to be included are listed in Table C-1.

The objectives of this task are to select those control measures which would have the most impact on mitigating pollutant discharges identified in Task 8, defining the cost of those control measures, their effectiveness in terms of pollutant reduction, applicability within the region, overall cost effectiveness, and practicality of implementation. Combinations of control measures will be considered, if appropriate, to define the overall least-cost options to the urban runoff problem. Potential control measures which can improve water quality and mitigate impacts of beneficial uses will be ranked according to cost and effectiveness in pollutant reduction.

TASK 11 - ALTERNATIVE TECHNICAL CONTROL PLANS

In order to insure maximum benefits of the lowest incremental cost, it will be necessary to integrate the results of all previous tasks and define a variety of control options. In particular, it would be necessary to integrate existing urban drainage planning with potential control measures and identify the specific control measures which could be applied to design of urban drainage facilities. The relationship between structural and nonstructural control measures in reducing pollutant loads to streams, irrigation systems, and reservoirs will also be defined in terms of cost effectiveness. The outcome of this task will be a list of alternatives ranked according to cost and effectiveness for each major community.

TASK 12 - RECOMMENDED TECHNICAL PLAN

A recommended technical control plan for major municipalities within the region in this task, as well as recommendations to be incorporated by smaller growing communities in the area are the objectives of this task. The technical control plan will include recommendations for structural and nonstructural measures, which will result in the control or mitigation of the impact or urban runoff on water quality within the region. It will include such items as recommended frequency and method of street sweeping, modifications of design criteria to better enable protection of pollutant discharges from future storm water facilities, and recommendations concerning operation or maintenance of storm water management facilities.

TABLE C-1

POLLUTION CONTROL OPTIONS
FOR URBAN RUNOFF

Non-Structural Options	Structural Options	
	Practice	Treatment
Street Cleaning	Detention Ponds	Swirl Concentrators
Domestic Animal Control	Retention Ponds	Microstrainer
Cleaning of Catch Basins and Storm Sewers	Rooftop Detention	Dissolved Air Flotation
Zoning Control	Porous Pavement	Sedimentation
Public Awareness Campaign	Filters	Contact Stabilization
Land Use Regulations		Physical-Chemical
Improve Garbage Collection		

In addition, treatment options will be recommended, if applicable.

TASK 13 - INSTITUTIONAL ANALYSIS

Institutional analyses conducted as part of the Larimer-Weld Regional Council of Governments' 208 Program firmly supported the designation of general purpose county and city governments as management agencies for non-point source pollution control. No change in this recommendation is anticipated; however, as a result of the urban runoff assessment conducted as part of this program, a refinement of institutional responsibilities will be possible. In addition, it will be necessary to analyze the financial impact of urban runoff control on planning, management, operations, and regulatory agencies. As a result of this planning process, adequate definition of technical assignments will be possible. In addition, the cost of control measures will be defined. Appropriate institutional and financial responsibilites can then be considered in the light of alternatives for these responsibilities. Management responsibilities will, in any case, fall upon counties and cities. Implementation responsibilities and operation responsibilities may fall upon cities, counties, individual subdividers, special districts, irrigation companies, and other parties involved in the control of storm water and urban runoff. The institutional analysis will result in a detailed definition of responsibilities and potential alternatives for assignment of these responsibilites.

TASK 14 - ASSIGNMENT OF INSTITUTIONAL RESPONSIBILITIES

Information developed in Task 13 will result in recommendations for assignment of institutional and financial responsibilities for control of urban runoff. These recommendations will be discussed with identified institutions as well as through the public hearing process prior to adoption of specific recommendations. Institutional/financial responsibilities definition and the acceptance of these responsibilities by individual agencies will have great bearing on the implementation of the technical control plan defined in Task 10.

TASK 15 - DEVELOPMENT OF IMPLEMENTATION PLAN

The final implementation plan will include:

1. Technical control measures to be implemented;

2. Institutional responsibilties for implementing control measures, both structural and nonstructural;

3. Timeframe for implementing specific control measures by various institutions;

4. Definition of responsibilities for planning, management, operations, and regulation of the process of implementing urban runoff control.

OTHER TASKS

In addition to the specific tasks defined above, necessary arrangements must be made for establishment of a technical advisory committee consisting of federal and state water pollution control officials, local public works officials, representatives of land development organizations, irrigation companies, state water commissioners, environmental groups, and other interested parties.

Upon conclusion of the project, an assessment of the methodology will be conducted as an additional task. The objective of this is to provide the Environmental Protection Agency with the following:

1. Detailed description of the methodology applied in developing urban runoff control measures;

2. An evaluation of that methodology as it applies to the Larimer-Weld Region;

3. Identification of strengths and weaknesses of the methodology applied;

4. Recommendations for improving methodology as applied to other regions within the United States.

APPENDIX D

NATIONAL FOREST SERVICE PLAN OF STUDY
FOR NON-POINT SOURCE POLLUTION
CONTROL IN THE MOUNTAIN
AREAS OF LARIMER COUNTY,
COLORADO

PRELIMINARY STUDY PLAN OUTLINE
LARIMER-WELD COUNTIES
208 Watershed Plan
-U.S. Forest Service-
Portion

There is presently a wide range of land use activities which occur on National Forest lands. Many of these activities could have a direct effect on water quality, varying by the location of the activity to stream courses, the type and intensity of the resource use, the natural sensitivities of the lands and streams which are influenced, and other complex interrelated factors.

In accordance with the emphasis of Public Law 92-500, accelerated base line data has been collected to determine some of the effects these land use activities have on existing water quality. Predictive models to determine the relative magnitude of water quality changes, prior to the initiation of land uses, has received attention through recent research efforts.

The potential to adversely affect water quality through road construction, timber harvest activities, grazing, mining, and other surface disturbance activities is well recognized. Adverse water quality changes can be effectively reduced or mitigated through the use of designed management practices such as erosion control, grazing management and special design criteria for road construction.

The water quality characteristic which has the greatest potential for change in relation to silvicultural, road construction and other surface disturbance activities is sediment production. Results of many recent studies have shown that accelerated sediment production is a predominant national water quality problem. Management prescriptions in the Forest Service have been implemented to minimize their potential sediment increases. The effectiveness of these prescriptions, however, need to be verified through a water quality monitoring program.

Surface disturbance activities also have the potential to affect changes in streamflow timing and amounts due to timber harvest, vegetation conversions, and irrigation diversions. These changes, if not mitigated, could contribute to accelerated channel erosion and resultant increases in sediment production. This increased sedimentation could adversely affect on-site and off-site fisheries production, irrigation, reservoir storage, domestic supply, aesthetics, and other downstream uses and values.

The Roosevelt National Forest has a wide variety of land use activities which have the potential for water quality changes. These activities include irrigation diversions, timber harvest, grazing, road construction, off-road recreational vehicle use, dispersed and concentrated recreation uses, mining and others. The magnitude and/or duration of change depend on the type and intensity of the activity, location in the watershed (proximity to live streams, etc.), the sensitivity of the soils and other site specific data. Existing sources of water pollution need to be identified and prediction models developed which will influence management practices related to these sources. The objectives of Public Law 92-500 and more directly the 208 planning effort on the Roosevelt National Forest will assist in this effort.

These objectives include:

- Identify sources of non-point water quality pollution.
- Identify in quantitative terms the relationship between non-point pollution sources and land use activities.
- Develop, through basic land and stream characterizations, prediction of water quality changes in response to various land use activities.
- Recommend management prescriptions to improve or maintain existing water quality--identification of "Best" management practices.
- Initiation of "baseline" water quality monitoring for assessment of effectiveness of "Best management" practices. (long term) Assessment of water quality changes beyond existing conditions over time.

Since the majority of the water produced on the Larimer-Weld designated watersheds is derived from National Forest land, it is important to determine the basic quality delivered downstream and assess the potential for maintaining or improving the water for downstream users.

A current general assessment of existing and proposed land use activites on the Roosevelt National Forest include:

a. Grazing Allotments

Within the proposed study area (hereafter recognized as that part of the Roosevelt National Forest within the confines of Larimer County) there are grazing allotments with a total area of approximately 182,000 acres. This acreage reflects both the "used" and the "vacant" allotments.

While most of these allotments have not had erosion or water quality studies conducted, at least one area that was observed had some serious erosion problems as a result of past overuse.

Water quality effects from existing and future grazing use needs to be assessed in order to initiate applicable grazing management techniques where problem areas exist.

b. Rawah Wilderness

This 27,000 acre tract of land in the northwest portion of the Roosevelt National Forest is showing signs of overuse. The elevation of the area ranges from 10,000 to 12,900 feet. The heavy use of this area by backpackers as well as those utilizing horses has created erosion and compaction problems on trails and campsites. Those areas that are best suited as sites for camping are being used beyond their capacity with the end result of compaction and loss of vegetative cover.

Lakes and streams within the Rawah Wilderness are used for drinking water by cattle and horses. This may possibly impair the water quality. However, the magnitude of bacteriological changes are not known.

c. Timber

The existing and planned activites on the Larimer County portion of the Roosevelt National Forests involve continued timber harvest, road construction, grazing, recreation (including off-road vehicle use) and a variety of other surface disturbance activities.

The timber plan for two Ranger Districts (Redfeather and Poudre) has approximately 57 M.M.B.F. planned for harvest for the next 5 years, or 11 M.M.B.F. per year. This amounts to 2,300 acres treated/year. The road construction planned in conjunction with these timber sales involves over 46 miles of road to be constructed or reconstructed for this period.

d. Private Developments

Development of private lands within the watersheds such as ski areas, homesites and road construction has had adverse effects on stream channels and resultant water quality. This can be readily detected in the Rist Canyon and Buckhorn areas. Monitoring above and below these impact areas will give a better evaluation of the quantitative effects of these uses.

e. Recreation

Recreation visitors days has increased on these two Districts from 1,123,700 in 1970 to over 1,852,000, or an increase of 39% in a 5 year period. The projected increase for 1980 involves over 2,574,000 recreation visitor days. The water quality impacts associated with such high density use in certain portions of the forest can be substantial, depending on type of recreation, concentration, land sensitivity, etc.

f. Off-road Vehicle Use

Off-road vehicle use on the Forest has increased considerably. Damage due to surface erosion, gullies, and resultant sedimentation is evident on certain tracts within the Poudre and Redfeather Districts.

The contribution of water quality change from this source has not been addressed quantitatively. Road closures, seeding and draining these areas is important in the restoration work needed.

Continued public use and product output demands on the National Forest will continue to place additional management constraints involving water quality changes.

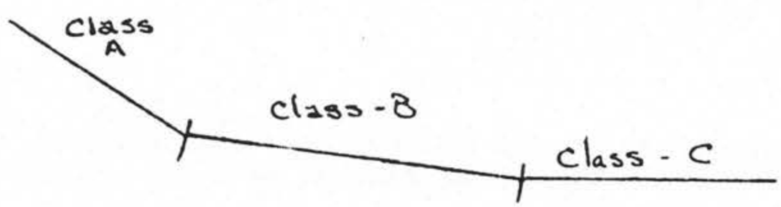
Synopsis of Work to be Performed

The design objectives of this water quality study is based on a stratification by stream location and type which can be extended by ownership for any given stream reach in the watershed. It is also stratified by a variety of types of land uses within each hydrophysiographic unit and by various flow regimes.

The water quality data will be used for prediction of water quality changes as a result of land use activities within the various hydrophysiographic areas. Base line water quality will be established for selected characteristics at permanent sample locations. The lands inventory data will be integrated with the water quality data to determine the effects of land use activities on on-site and off-site watershed damage. It will assist in identifying "sensitive" landforms, erosion and "roadability" for the watershed.

The basic water quality sampling network design is sketched below:

I. Hydrophysiographic Stratification



Class

A. Montane and subalpine--mountainous, timbered lands and alpine conditions. Steep gradient streams, coarse textured stream channels, straight to slightly meandering streams patterns.

B. Foothills zone--coarse textured alluvium, slight to moderately meandering streams with moderate stream gradients.

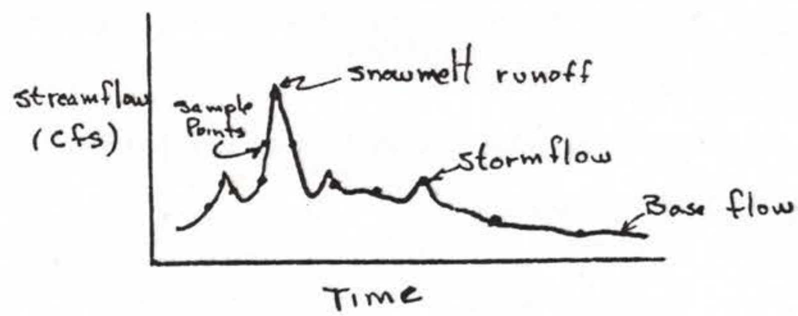
C. Plains--finer textured alluvium, moderate to strongly meandering streams with low stream gradients.

II. Land Use Activities Stratification

Sample stations to be initiated within each hydrophysiographic regime immediately above or below potential water quality impacting activities, i.e., above and below road crossings, clearcuts, mine dumps, etc.

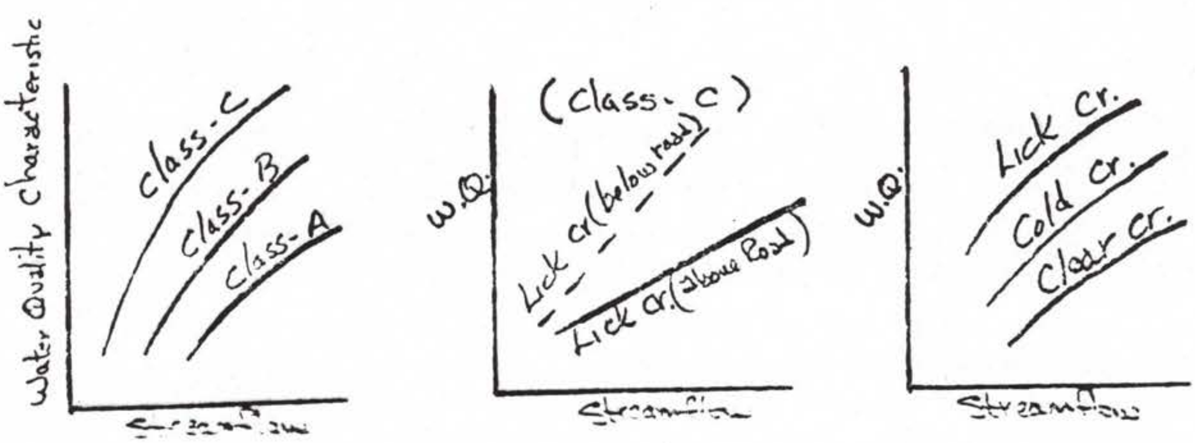
III. Data Collection and Analysis Procedures

Data collection will be conducted so as to represent the widest ranges of streamflow.



Data Analysis

The water quality data will be plotted primarily on a flow dependent basis showing differences by class and by activity for a given stream or groups of streams.



IV. Infrared Flight Objectives

A. Locate sources of pollution (physical characteristics)
B. Determine spatial distribution of physical pollutant
C. Establish a permanent record of channel morphology
D. Use for flood plain mapping, etc.

General Discussion of Work to be Performed

The work to be initiated involves a land and water quality characterization for the various hydrophysiographic regimes within the Roosevelt National Forest and Pawnee National Grasslands..

This characterization is to include the existing water quality conditions for each hydrophysiographic as it changes in relation to flow, season and downstream influences.

Effects of various activities on water quality and the relation to sources, including channel erosion, silvicultural activities, construction activities, mining, grazing and agriculture, recreation, etc., will be studied by strategically located monitoring stations and by remote sensing techniques during various runoff periods.

The combined land and water quality characterization is to provide the basis for predictive tools to be applied in assessing non-point source pollution loading as a result of various land use activities. The purpose of this work is to identify the best management practices or management prescriptions that will improve or maintain existing water quality. The water quality monitoring includes a variety of selected physical, chemical and bacteriological analysis.

The land characterization is to provide basic data of landform hazards of stability and erodability as related to various types of land use activities. This includes interpretations which relate land use activities on particular landforms to the potential for water quality changes (such as development of sediment delivery ratios, etc.) See soils inventory write-up attached.

The study area watershed has been broken into 3 major areas:

- Montane and subalpine--8,500'+
- Foothills--6,000-8,500'
- Plains and agricultural--less than 6,000'

Within each area, longitudinal profiles of the major drainages have been identified in order to characterize homogeneous stream morphological types.

Within each major subdrainage, land uses which contribute to changes in water quality will be monitored above and below the activity to quantitatively evaluate the magnitude of its effect.

A color infrared flight will be conducted during the peak snowmelt runoff period and during base flow to ascertain the sources and spatial distribution of physical water quality changes. This work is to be done concurrent with ground truth sampling in order to facilitate precise quantitative photo analysis.

The water quality data will be analyzed in relation to changes in streamflow, season of use, hydrophysiographic regime, channel type, and land uses directly affecting the water quality.

Water yield increases as influenced by vegetative cover conversions will be related to flow dependent water quality constituents to determine the effect on non-point pollution loading.

The overall analysis is designed to identify the sources of pollution and the relative magnitude of water quality change by hydrophysiographic regime that can be expected by various land use activities. Identification of management prescriptions and "Best" management practices that will improve or maintain existing water quality levels will be documented.

Colorado State University will be contracted to assist in the water sampling, lab analysis and data analysis; the remote sensing flight and analysis and interpretation of land types. A timestream plot of the timing and duration of the tasks to be performed is included in the appendix of this report.

Water Quality Sampling and Analysis

A. Field

1. Work to be completed at each station.

Site Characterizations

- Streamflow measurements with stage-discharge relationship established.
- Permanent bench mark data established on stream channel cross sections.
- Stream gradients measured.
- Bed material size determination (pebble count method).
- Channel stability ratings obtained.

Water Quality Tests 1/

- Suspended sediment (mg./l. and tons/day).
- Bedload sediment (tons/day).
- Turbidity (JTU).

B. Laboratory and Office

1. Sediment

- Sieve bed load material for particle size distribution and weigh (tons/day).
- Wash load vs. total sediment load.
- Visual accumulation tube to be used for suspend sediment particle size determination.
- Total suspended sediment mg./l. - (tons/day)
- Compute total sediment load (bedload and suspended load in tons/day and tons/day/mi^2)
- Calculate stream power - plot with sediment transport rate as a function in material size.

1/ To be sampled during representative portions of the hydrograph including raising and falling stage, low and high elevation snowmelt peaks, storm flow, base flow, troughs, etc. (Note: Only these tests have been selected as they are the most sensitive to possible non-point changes due to the types of land use activities encountered in the U.S. Forest Service portions of the study area)

2. <u>Water Discharge</u>

- Plot stage - discharge relationships.
- Plot water quality characteristics of sediment, turbidity, temperature, and specific conductance as a function of stream discharge.

3. <u>Other Physical</u>

- Plot turbidity as a function of suspended sediment.
- Correlate channel stability to sediment rating curves.

4. <u>Chemical Tests</u>

- Plot as a function of flow and of season.

5. Compare streamflow changes to land use activities then compare water yield increases (c.f.s.) to sediment rating curves (and other water quality criteria that are flow dependent) to project water quality changes as a result of these streamflow changes.

6. Plan for long term water quality monitoring to evaluate effect of predicted and actual responses of water quality changes related to land use activities.

Land System Inventory

The land system inventory is a procedure integrating the sciences of geomorphology, geology, soil science, hydrology and plant ecology to describe, map and classify the various kinds of land within an area.

Broad Objectives:

To provide the land manager the basic element for ~~allocating~~ Developing management prescriptions land for various resource uses. This includes:

a. Information about the inherent capability of the land.
b. A knowledge of its resources.
c. A basis on which specific land use planning objectican be met.
d. Evaluate potential and existing impacts from utilization.
e. Soil and water interpretation for land use allocation.

Inventory Procedure

Three levels or intensity of land inventory are feasible within the time frame allotted for this study. These are: the subsection level (Level III) which provides a minimum delineation of 25 square miles, the landtype association (Level II) with minimum delineation of 640 acres and the landtype (Level I) with delineation down to 40 acres in size. However, only one, the landtype level, will provide a suitable information base for the type of interpretations needed.

Utilizing the landtype level of inventory will involve the stratification (pre-mapping) of the study area into landforms. Landforms are identified and delineated by aerial photo interpretation. After completion of the pre-mapping, sufficient field checking is done to determine the composition of each landform with regard to soils, vegetation and lithology. Traverses will be made by foot utilizing helicopters to place the crews on vantage point for their walkouts. These features plus climate are the basis for determining the use and management of the particular mapping unit.

Some of the key features that are related to landforms are soil characteristics such as depth, texture, structure, thickness of A-horizon, slope and aspect. In addition, certain chemical and physical analysis necessary for the interpretation will be made. Certain drainage characteristics such as drainage density and gradient will also be recorded.

Black and white aerial photography at a scale of 1:50000 will be used for the initial stratification (pre-mapping). Color infrared also at a scale of 1:50000 will be used to obtain more detailed information than what can be obtained from black and white imagery. It is planned to utilize the Video-Con equipment as a means of obtaining the detail of specific signatures from the color infrared photography. This equipment and the lab technician will be supplied by Colorado State University.

The landtype level with its delineation of mapping units of definable composition permits an assessment of what types of land exist in the study area and allows predictions to be made regarding its behavior under specified use and management plans for any given area. In addition, it will serve as a guideline for the selection of monitoring stations wherever data collection is necessary.

Interpretations

Subsection (Level III)

Predictions of hazard and risks by comparison within the boundaries of the study area.

Landtype Association (Level II)

Qualitative ratings for productivity potentials, hazards, and risks by comparison of land units within broad areas of land units with geomorphic and soils descriptors. The limited field verification limits the interpretation to a relative rating of erosion mass failure and productivity potential.

Landtype (Level I)

Qualitative ratings for capabilities suitabilities, limitations, hazards, and risks in different uses and activities based on quantitative estimates. The more detailed soils and geologic data showing their identification and location will allow more precise interpretations. The following interpretations will be made at this level of inventory:

a. Hazard Ratings

Soil stability hazard ratings are defined in terms of intensity of management practices needed to prevent accelerated erosion or increased sedimentation of surface waters and the practicality of applying these practices. Hazards are the inherent ability of the landtype to produce onsite sediment through action of the rated processes. Risks are potential adverse impacts resulting from management practices applied to land with specific hazards. In the case of erosion hazards, the risks include such impacts as reduced site productivity, sediment pollution of surface waters, and sedimentation of lakes and reservoirs. Risk analysis commonly involves factors not measured in the land system inventory, such as location of the proposed practice relative to streams or lakes and the relative values of the practices proposed compared to the values of the resources being treated.

b. Cutbank Slough Hazard

This refers to relatively small slumps usually less than 10 cubic yards which remain in the road prism. These normally occur in landtypes with the following characteristics: 1) Loose unconsolidated mantles that are depositional in nature or which contain common inclusions of these types of mantles; 2) Year-round or near year-round perched water tables. Hazard ratings are given in three classes: 1) average; 2) above average; and 3) much above average. These classes will be defined at a later date.

c. Bare Natural Soil Erosion Hazard

Soil erosion associated with running water and raindrop splash. This type of erosion is normally thought of as sheet erosion or rilling and gullying. On this Forest, this type of natural erosion occurs on steep slopes where overland flow is common. Hazard ratings are based on:

1. incidence of overland flow;
2. mantle depth;
3. soil particle detachability characteristics; and
4. vegetative recovery rate.

d. Compacted Soils

This refers to soils that are compacted including skid trails, landings, and areas with heavy animal trampling, etc. Hazards are rated the same as above with consideration given to reduced infiltration rates, soil structure alteration, and changes in the vegetative recovery rate. The degree of compaction should be defined or the practice which creates the compaction described.

e. Road Prism Erosion Hazard

This rating is designed to estimate the amount of sediment produced by road construction on different landtypes. Criteria used to determine the hazard class are:

1. Slope gradient 1/
2. Road subgrade width 1/
3. Subsoil coherence or coefficient of friction between soil aggregate
4. Revegetation potential

See appendix for curves and additional data.

f. Surface Creep

This factor estimates the amount of surface soil particles slowly moving down slope due to gravity. This is the primary sediment source for many of our breaklands and other steep slopes. Criteria used to estimate surface creep are:

1. Slope gradient
2. Aspect
3. Soil coherence or coefficient of friction between soil aggregates
4. Mean soil particle size
5. Vegetative cover

g. Debris Avalanche Hazard

Debris avalanche refers to the rapid and usually sudden sliding and plowage of masses, initially incoherent, unsorted, mixtures of soil and rock material. This rating is used in conjunction with surface creep hazard. Criteria used to estimate debris avalanche hazard are:

1. Slope gradient
2. Slope shape
3. Aspect
4. Surface soil creep hazard
5. In practice, landtypes with this hazard will contain evidence of debris avalanches

1/ These factors are used to estimate the total area exposed in the road prism.

occurring in the past (i.e., talus slopes and colluvial cones or fans) which aid in identifying the hazard.

h. Sediment Delivery Ratio

Sediment delivery ratio is used to describe the rates at which water and sediment are transported from different landforms. Essentially, slope delivery ratio is a function of the amount of surface runoff produced by a landform and the gradient and ordering normality of the low-order channels which transport water and sediment from the landform. Components of delivery ratio are defined as:

1. Overall slope shape
2. Percentage of the landtype drained by low-order streams
3. Ordering normality of the streams
4. Average slope gradient of the landtype
5. Soil depth
6. Soil internal drainage

These factors are interdependent, however, and the relationships between them are likely to vary from place to place.

i. Soil Productivity Rating

This rating gives a relative assessment of soil moisture regimes and climate. It considers:

1. Available soil moisture as related to soil profile characteristics.
2. Soil mantle recharge as related to slope hydrologic characteristics
3. Slope energy relationships.
4. Climatic limitations.

j. Revegetative Potential Rating

This rating is to be used in conjunction with soil productivity ratings. The rating expresses relative soil moisture conditions in the upper 18 inches of the soil mantle. Characteristics considered are:

1. Soil texture
2. Aspect
3. Elevation
4. Slope solar energy

Land System Inventory

The land system inventory is a procedure integrating the sciences of geomorphology, geology, soil science, plant ecology and hydrology to describe, map and classify the various kinds of land within an area.

Broad Objectives:

To provide the land manager the basic element for allocating land for various resource uses. This includes:

a. Information about the inherent capability of the land.
b. A knowledge of its resources.
c. A basis on which specific land use planning objectives can be met.
d. Evaluate potential and existing impacts from utilization.
e. Soil and water interpretation for land use allocation.

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Some of the key features that are related to landforms are soil characteristics such as depth, texture, structure, thickness of A-horizon slope and aspect. In addition, certain chemical and physical analysis necessary for the interpretation will be made. Certain drainage characteristics such as drainage density and gradient will also be recorded.

Accomplishment By Levels
2 Year Program

Study Level I

- 40 Station locations
- 500 Station Samples
- Detailed Landtype and hazards mapping-quantitative evaluations
- Two color infrared flights for determining sources and spatial distribution of physical water quality.
- Detailed analysis for model development.

Study Level II

- 30 station locations
- 360 station samples
- Moderate intensity landtype and hazards assessment. General relationship for qualitative analysis.
- One color infrared flight at peak snowmelt runoff.
- Approximations of quantitative assessments for prediction techniques.

Study Level III

- 20 station locations
- 240 Station samples
- Broad, general lands stratification. Qualitative
- No color infrared flights
- General qualitative (some tests quantitative) Interpretations.

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PROJECT COST

EQUIPMENT NEEDS

Stream Discharge & On-site Needs	Unit Cost	I		II		III	
		No.	Cost	No.	Cost	No.	Cost
Direct reading current meters	1200.00	3	3600.00	2	2400.00	2	2400.00
Sounding reels (Stevens)	300.00	4	1200.00	3	900.00	2	600.00
Sounding weights (50+75 lbs.)	200.00	4	800.00	3	600.00	2	400.00
Porcelain staff gages	5.00	40	200.00	30	150.00	20	100.00
Sediment samplers							
DH 48	60.00	2	120.00	1	60.00	1	60.00
DH 59	150.00	4	600.00	3	450.00	2	300.00
DH 49	450.00	2	900.00	2	900.00	1	450.00
Bedload samplers Hand	70.00	4	280.00	3	210.00	2	140.00
(Helley-Smith) Suspension	200.00	4	800.00	3	600.00	2	400.00
pH meters (corning)	200.00	4	800.00	3	600.00	2	400.00
D.O. Samplers & Calibration	250.00	4	1000.00	3	750.00	2	500.00
D.O. meters (Yellowsprings)	500.00	4	2000.00	3	1500.00	2	1000.00
Conductivity meter (Beckman)	300.00	2	600.00	1	300.00	0	00

Stream Discharge & On-site Needs	Unit Cost	I		II		III	
		No.	Cost	No.	Cost	No.	Cost
ISCO continuous sampler	1500.00	4	6000.00	3	4500.00	2	3000.00
Ryon thermographs (recording)	300.00	10	3000.00	8	2400.00	6	1800.00
Hand thermometers	8.00	10	80.00	8	64.00	6	48.00
Jagg-tape equipment	80.00	2	160.00	2	160.00	1	80.00
Equipment transport boxes	450.00	4	1800.00	3	1350.00	2	900.00
Measuring tapes	20.00	4	80.00	3	60.00	2	40.00
Waders	50.00	4	200.00	3	150.00	3	150.00
Field incubators							
Fecal	900.00	3	2700.00	2	1800.00	1	900.00
Total	500.00	2	1000.00	2	1000.00	0	00
Turbidity Samplers	30.00	4	120.00	3	90.00	2	60.00
Turbidimeter	500.00	1	500.00	1	500.00	1	500.00
(Sample) Bottles							
Bacteria (20 ml)	.10	80	8.00	60	6.00	40	4.00
Chemical (500 ml)	.30	160	48.00	120	36.00	80	24.00
Sediment (500 ml)	1.00	160	160.00	120	120.00	80	80.00
Turbidity (10 ml)	.40	160	64.00	120	48.00	80	32.00
			$28,820.00		$21,704.00		$14,368.00

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Project Cost, con't.

Costs are for 2 year analysis period	I	II	III
Labor + lab cost* F.S. + C.S.U.			
includes 40% GS-11 time	14400	14400	7200
funded, 85% total time devoted to project.	(2 yr)	(2 yr)	(1 yr)
(45% contributed by F.S.)			
30% GS-9 Hydrol. Funded, 75% time devoted	6000.00	4000.00	3000.00
to project, or 45% contributed by F.S.	(50% for 2 yrs.)	(50% for 1.5 yrs.)	(50% for 1 yr.)
100% full time technician	18000.00	10800.00	8925.00
	(2 yrs)	(1.5 yrs)	(1 yr)

*Does not include soils survey figured in cost/acre of mapping.

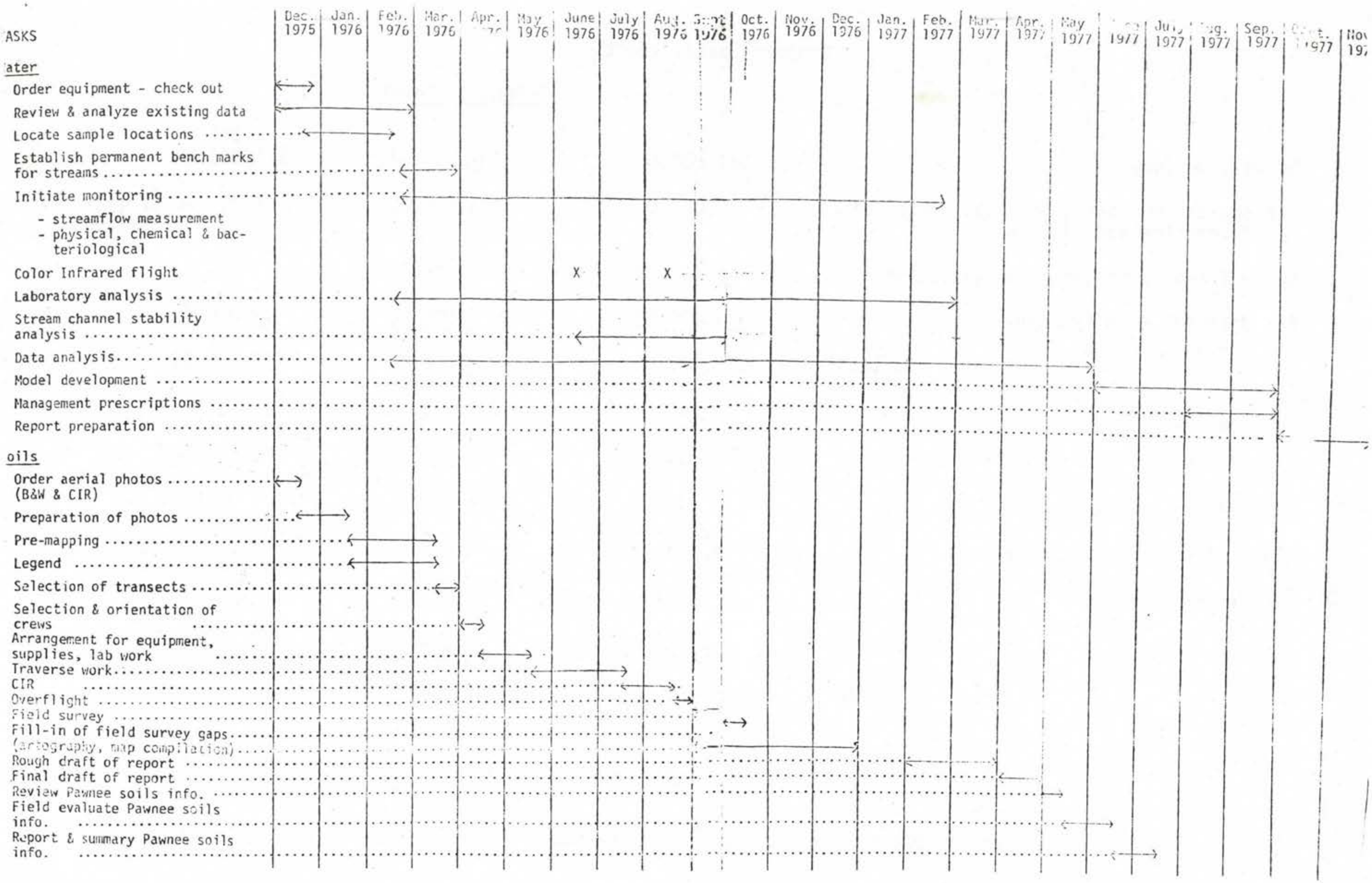
CSU student	8000.00	6500.00	5000.00
Lab + labor (field)			
Subtotals	$46400.00	$35700.00	$24125.00

Project Costs, con't.

		Intensity Level		
		I	II	III
Soils Inventory		$44,000.00	$32,000.00	$22,000.00
Transportation costs, includes rental of 3 vehicles and mileage		10,000.00	5,000.00	2,500.00 (1 vehicle rented)
Color Infrared flight - low elevation		8,000.00	4,000.00	--
Per diem for sampling crew		3,000.00	2,000.00	2,000.00
	Subtotal	$65,000.00	$43,000.00	$25,500.00
Equipment (Summary)		28,820.00	21,704.00	14,368.00
Computer time		4,000.00	2,000.00	1,000.00
Miscellaneous Supplies		500.00	500.00	500.00
Clerical-office management		9,000.00	7,000.00	5,000.00
Management Support		7,630.00	4,886.00	2,585.00
	Subtotal	49,950.00	36,090.00	23,453.00
Labor	Subtotal	46,400.00	35,700.00	24,125.00
Total C.O.G. cost for 2 year period	Total	161,350.00	114,790.00	73,078.00

Note: A savings in labor of $33,800 for analysis period contributed by Forest Service for Levels I and II.

Report and Analysis Prepared by: Dave Rosgen, Hydrologist and
Robert C. Malmgren, Soil Scientist
11/17/75



ASKS
Dec. 1975
Jan. 1976
Feb. 1976
Mar. 1976
Apr.
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Oct. 1976
Nov. 1976
Dec. 1976
Jan. 1977
Feb. 1977
Mar. 1977
Apr. 1977
May 1977
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Jul. 1977
1977
Sep. 1977
1977
ater
Order equipment - check out
Review & analyze existing data
Locate sample locations
Establish permanent bench marks for streams
Initiate monitoring
- streamflow measurement
- physical, chemical & bacteriological
Color Infrared flight
X
X
Laboratory analysis
Stream channel stability analysis
Data analysis
Model development
Management prescriptions
Report preparation
oils
Order aerial photos (B&W & CIR)
Preparation of photos
Pre-mapping
Legend
Selection of transects
Selection & orientation of crews
Arrangement for equipment, supplies, lab work
Traverse work
CIR
Overflight
Field survey
Fill-in of field survey gaps
(artography, map compilation)
Rough draft of report
Final draft of report
Review Pawnee soils info.
Field evaluate Pawnee soils info.
Report & summary Pawnee soils info.