WAYNE CLARK

REPORT ON

STORM DRAINAGE FACILITIES

FOR THE CITY OF

CANON CITY, COLORADO

OCTOBER 1974

M & I, INC
CONSULTING ENGINEERS
FORT COLLINS COLORADO

M & I, INC. CONSULTING ENGINEERS
4710 SOUTH COLLEGE, FORT COLLINS, COLORADO 80521 • PH. 482-8249

October 10, 1974

Honorable Mayor, City Council and City Manager
City of Canon City, Colorado
Box 711
Canon City, Colorado 81212

Gentlemen,

In accordance with our agreement, we have completed our study and submit this report and Master Plan for the storm sewer system in the Canon City area.

This report summarizes the findings of our study and suggests a recommended program to alleviate the storm damage potential now being experienced in the Canon City area. If there are areas which need further explanation or assistance is needed to activate such recommendations, we would be happy to furnish such services.

We would also like to thank those individuals who offered their help in our research and preparation of this study and report.

Very truly yours,

M & I, INC.

Michael L. Maxwell, P.E.

MLM/sw

REPORT ON STORM

DRAINAGE FACILITIES FOR

CITY OF CANON CITY, COLORADO

I N D E X

F I G U R E S

INTRODUCTION

A. Purpose - The purpose of this report is to present the findings of an engineering study to the City of Canon City. This investigation looked at the existing storm sewer system, a new master plan of storm sewers and flow-ways to provide adequate facilities for storm water runoff within the Canon City area and the drainage basins draining through the city. Also included is the estimated cost of required facilities.

B. Scope - This report includes studies and findings as follows:

1. Development of design data for use in determining the quantity and rate of runoff and the design criteria for sizing storm water facilities. This design data included rainfall - depth - duration - frequency - maps, time - intensity - frequency curves, runoff coefficients, and runoff hydrographs.

2. Development of a master plan showing location and size of storm water sewer facilities for the initial design storm within the City limits.

3. Development of a master plan for handling of the major runoff from the major basins tributary to the City.

4. Development of storm drainage criteria to be used as design criteria for future development and storm water runoff.

5. Estimate of cost for all major storm water drainage facilities.

6. Development of a priority and construction schedule.

SUMMARY OF FINDINGS AND RECOMMENDATIONS

A. Findings

1. Once the hydrology was completed, it was determined the existing storm sewer system could no longer satisfy the drainage requirements.

2. It was determined that the Fruitland, Hydraulic and Oil Creek irrigation ditches, which are presently being used as flow-ways for storm water runoff, could not handle this additional water above the quantity of normal irrigation water now being transported by the ditch.

3. A majority of ditches and culverts now installed in the East Canon area are being used and sized to transport irrigation water and do not provide adequate storm water runoff capabilities.

4. The open channel or gulch between the Hydraulic Ditch and the Arkansas River running east of and parallel to E. Circle Drive is quite inadequate to handle the major storm runoff.

5. A major flood retarding system must be considered to protect the City from the major storm runoff from the drainage basins north of the City.

6. The adoption of storm drainage criteria is necessary to prevent future compounding of the existing drainage problems from future development and land use.

7. There are methods available for the City to finance any adopted storm drainage program. All have advantages and disadvantages. A method will have to be selected by the City after adoption of the storm drainage program and determination of the revenue requirements. Any method for financing storm drainage facilities should, if possible, meet the tests of administrative simplicity, revenue adequacy, economic efficiency and equity.

B. Recommendations - The recommendations resulting from this study are summarized below:

1. It is recommended that a long range construction program be adopted to implement a storm sewer system to facilitate the 5 year initial storm as outlined on Figure 1.

2. Street improvements in the future should comply with the recommended cross section as shown on Figure C-7 to assure adequate street carrying capacity.

3. In the design and sizing a storm sewer system, all systems should collect and transport all runoff to the Arkansas River and allow no water to enter into any of the irrigation ditches crossing the City.

4. There are three possible alternatives to be considered in the East Canon area. 1) Abandon all irrigation laterals and improve existing ditches and culverts to handle only storm runoff. 2) Increase the size of culverts and ditches to handle both the irrigation water and storm water runoff. 3) Implement a dual system for transporting storm water runoff and irrigation water separately. Alternate 1 would be the most economical and present fewer problems when street pavement, curbs and gutters and a storm sewer system are constructed. Alternate 2 would not be economically feasible as street pavement, curbs and gutters and a storm sewer system were implemented. This alternative would be the least efficient and cause the most maintenance problems. Alternate 3 would allow storm water runoff to be transported to the storm sewer system and provide for the irrigation laterals. This alternate would also be the most expensive. See Figure 3 for alternate cross section.

5. After reviewing and verifying the findings in the report prepared for the Canon City Watershed by the Soil Conservation District in February, 1968, it is our recommendations that such a program be adopted to provide adequate protection from the major drainage runoff from the basins north of the City. This program included the construction of a flood retarding structure and channel improvements on the gulch running south from the Fruitland Ditch to the Arkansas River as shown on Figure No. 4.

6. It is recommended that the 5 year storm be adopted as the initial storm design criteria for designing and constructing the future

subsurface storm sewer system within the service area. It is also recommended that the 100 year storm be adopted as the criteria for designing and constructing major storm facilities.

7. The cost estimates for the recommended program are as follows:

Phase I -	$ 3,344,790.00
Phase II -	2,400,000.00
Phase III -	1,741,465.00
Phase IV -	1,527,212.00
TOTAL COST	$ 9,013,467.00

The above cost estimates are based upon present day prices and include an allowance for contingencies and engineering. Land, right-of-way, and easement costs are not included as well as legal fees and court costs.

New storm sewer system and drainage facilities shall be paid for by the developer.

8. To implement the recommendations made in this report, the City should take the following actions in the near future.

   a. Purchase, or obtain an option to purchase the lands necessary for the recommended facilities.

   b. Start final design on the first phases of the recommendations set forth in this report.

   c. Immediately implement the drainage criteria on new development to prevent additional drainage to be added to the existing drainage problems.

AREA DESCRIPTION

The service area of the report encompasses Canon City, East Canon, and the undeveloped contiguous areas from Skyline Drive on the west to the eastern boundary of East Canon and from the Arkansas River on the south and north to the upper boundaries of the basin. The total area within this service area is approximately 6,520 acres.

From Skyline Drive on the west the terrain drops sharply for a short distance. The western and northern boundaries elevations are approximately 6,000 feet. The terrain slopes from these boundary elevation south and southeast to an elevation of approximately 5,300 feet at the southeast corner of the service area.

Three open irrigation ditches cross the service area. They are the Fruitland Ditch on the north, the Hydraulic Ditch crossing through the middle of the City, and the Oil Creek Ditch running basicly parallel and just north of the Arkansas River. These ditches are basically filled to capacity, yet at present they are used to intercept much of the storm runoff.

PHYSIOGRAPHY AND GEOLOGY

The northwestern boundary of the service basin are areas of hogback ridges formed by resistant sandstone beds of sedimentary origin of Cretaceous and Paleocene Age. In the central and northeastern parts of the watershed there are relatively flat plain areas underlain by shales of Upper Cretaceous Age. Unconsolidated surficial deposits consisting of alluvial and colluvial materials of Quaternary Age mantle the shales in most of the central and northeastern parts of the watershed.

Soils of the hogback ridge area consist mainly of Lithosols, Regosols, and rock outcrops. Soils are shallow to moderately deep with sandy loam to loamy surface soils and widely variable subsoils. Moisture holding capacity is low. Slopes range from 10 to 40 percent.

The plains area consists mainly of soils developed on alluviam derived from shale and sandstone. They are moderately deep to deep soils of varying textures but dominantly clay loams or loams. Many of the clay loam soils have slow permeability and are usually somewhat saline. The loams and sandy loams have moderate permeability and moisture holding capacity is good. Slopes range from 2 to 5 percent.

COVER CONDITIONS

Blue grama, galleta, three-awn, sand dropseed, indian ricegrass, wheatgrass, and a little bluestem appear in the uplands. The bottom of drainage and other low-land areas have saltgrass, alkail sacaton, western wheatgrass and sedge.

CLIMATE

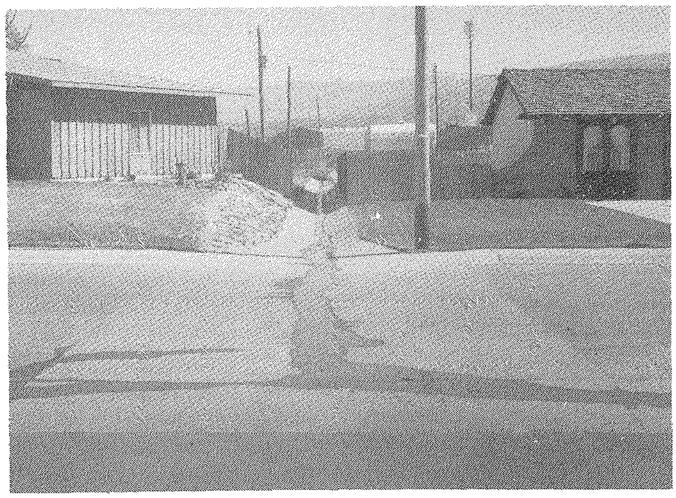
The climate is semiarid. Average annual precipitation is 12.66 inches as recorded at the official U. S. Weather Bureau Station since 1888 at Canon City. The greatest daily precipitation of 4.31 inches was recorded in 1894. The recorded temperatures have ranged from a high of 107 degrees to a low of -30 degrees Fahrenheit. The mean daily temperature is 54.8 degrees. The average frost-free growing season is 164 days.

The principal problem is floodwater and sediment damages to agricultural crops, land and equipment, urban and suburban residential areas, county, State, and Federal highways and bridges and to railroad tracks.

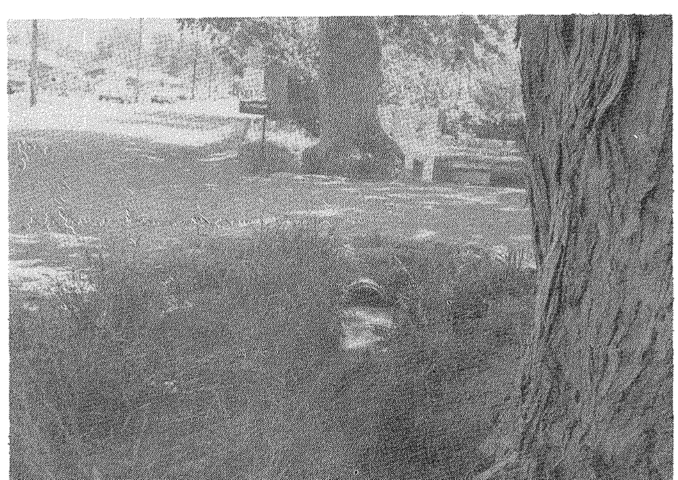
These damages result from runoff from high intensity thunderstorms occuring in the watershed during the period from April through September. Seventy-six percent of these intense thunderstorms have occured during June, July, and August. This is the major crop production period.

LAND USE

Development is occuring and will probably continue to occur to the north as the City expands. This trend of development could have major impact on storm water runoff if drainage criteria is not adopted to compensate for it. Additional development is presently occuring to the east along Highway 50. This area is located east of the service area covered in this report. It will have no effect on the service area under study, but should not be over-looked because it has the potential of being annexed in the future. It is our recommendation that the drainage criteria be implemented in these areas in order to eliminate some future drainage problems.



The existing outlet draining directly into the Hydraulic Ditch at Ohio Avenue and Barr Avenue.



Example of the conditions of road side ditches used for transporting irrigation and restricting storm runoff carrying capacity.

EXISTING STORM DRAINAGE FACILITIES

The existing storm sewer system is no longer adequate to handle the storm water runoff due to the growth of the City.

The location and sizes of the existing system is shown on Figure No. 5. Generally, the majority of the existing system will probably be abandoned as the recommended systems are constructed.

Until such time as the old system is replaced, steps should be taken to clean and recondition portions of the old system. This old system will function to relieve some drainage runoff but it will not meet the flood protection requirements set forth in this report. At final design, the portions of the old system which can be salvaged will be designated.

DESIGN CRITERIA

A. Rainfall Intensity - In establishing the design criteria for use in the Canon City area, it is realized the intensity of rainfall is more important than total daily rainfall. Studies have shown that short intense storms cause more runoff than do long less intensive storms which may eventually produce more rainfall.

Precipitation-frequency maps have been developed for this area with the use of U. S. Weather Bureau's Technical Publication #40 and the Special Studies Branch, Office of Hydrology and Environmental Services Administration, Weather Bureau's publication for the State of Colorado. These precipitation-frequency maps cover the following storms: Figure No. C-1

5 Year - 1 hour, 6 hour and 24 hour
25 Year - 1 hour, 6 hour and 24 hour
50 Year - 1 hour, 6 hour and 24 hour
100 Year - 1 hour, 6 hour and 24 hour

There is an official U. S. Weather Bureau Station at the State Penitentiary in Canon City. This station is only a daily recorder and therefore information on record was not used to develop the precipitation-frequency map.

The precipitation-frequency maps were developed for an area much larger than the service area of this report. They should be referred to when working in those areas.

Rainfall intensities are classified according to the average frequency with which they occur. An intensity occurring on the average of once every two years is designated as a two year storm. Similarily, storm intensities appearing in this report at average intervals of 5, 25, 50, and 100 years are designated as 5-year, 25-year, and 50-year and 100-year storms. It should not be construed that the 5 year storm will occur only once every five years. It may occur in successive years; but over a long period of time, say 50 years, it would be expected such a storm would occur only ten times.

The selection of the 5-year storm as being the initial design storm was made because it results in additional carrying capacity and higher flood protection over the 2 year storm without substantial increases in cost. This 5-year storm was used as the design criteria for sizing storm sewer through the residential area. The 25-year storm was used for the commercial, industrial, business and public areas.

It is not felt that the stipulation; runoff from the 100-year storm shall not inundate the floor elevations of existing or proposed dwellings, businesses, or commercial establishments, could be economically justified. One of the reasons for this decision is as follows: Some existing structures are constructed at elevation below present street grades. To prevent flooding of these structures would require lowering streets and oversizing storm sewers and culverts to collect the 100-year runoff. Although these lower structures would sustain major damage during a 100-year storm, most areas would have some flooding. If the 100-year storm was adopted as our design storm, drainage structure would increase many times that which are recommended in this report at substantially higher cost than those already incurred. It has been demonstrated in the past that designing for a 100-year storm for non-major drainage basins is uneconomical from a cost-benefit ratio. For example, it would be foolish to construct a $100,000 storm sewer system to prevent destruction of a $20,000 house that had the possibility of being destroyed once each 100 years.

STORM WATER RUNOFF

A. General - The quantity of runoff from a given storm varies with the intensity, duration, and distribution of rainfall; the slope, shape, and dimensions of the drainage area; the infiltration and absorption capacity of area surfaces, evaporation and transpiration, surface detention, and interception by vegetation. With all the above different ways to affect runoff, quantity of runoff can only be an approximation. Throughout the years, many formulas and methods have been developed to convert rainfall to runoff. One of the oldest, and one still widely used today, is known as the Rational Method. A new method, gaining favor among authorities for specific cases, is the Unit Hydrograph Method.

B. Rational Method - The Rational Method is based on the Rational Formula:

$$Q = C\,I\,A$$

Q = the maximum rate of runoff in cubic feet per second.

C = runoff coefficient which is the ratio between the maximum rate of runoff from the area and the average rate of rainfall intensity, in inches per hour for the period of maximum rainfall of a given frequency of occurrance having a duration equal to the time of concentration.

I = the average intensity of rainfall in inches per hour for a duration equal to the time of concentration.

A = area in acres tributary to the point of design.

The time of concentration usually is the time required for water to flow from the most remote point of the area to the point being investigated.

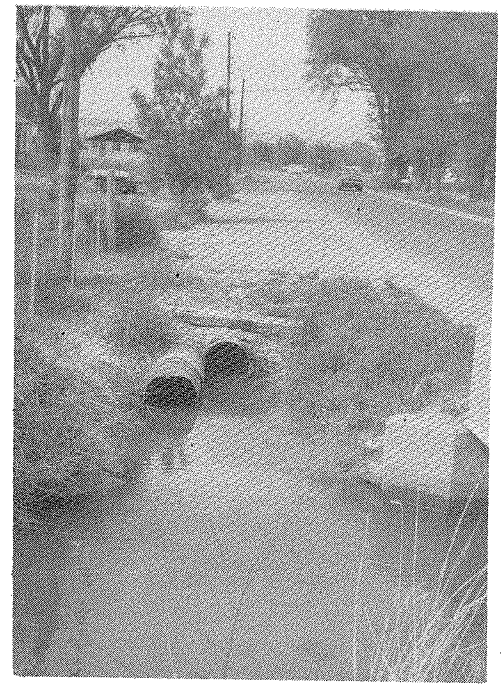
The runoff coefficient, C, is the variable of the Rational Method least susceptible to precise determination and requires judgment and understanding on the part of the engineer. The coefficient represents the integrated effects of infiltration, detention storage, evaporation, retention, flow routing, and interception which all affects the time distribution and peak rate of runoff. The following table shows typical runoff coefficients for various types of areas.

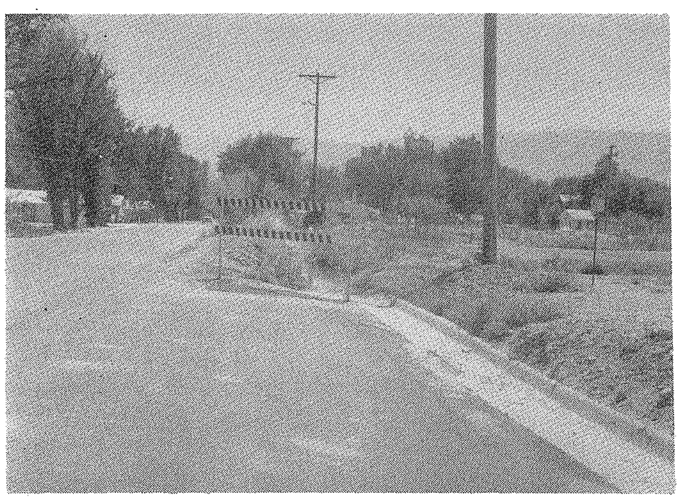
RATIONAL METHOD RUNOFF COEFFICIENTS

Description of Area	Runoff Coefficients
Business:	
Downtown areas	0.70 to 0.95
Neighborhood areas	0.50 to 0.70
Residential:	
Single-family areas	0.35 to 0.50
Multi units, detached	0.40 to 0.60
Multi units, attached	0.60 to 0.74
Residential (1/2 acre lots or more)	0.30 to 0.45
Apartment dwelling areas	0.50 to 0.70
Industrial:	
Light areas	0.50 to 0.80
Heavy areas	0.60 to 0.90
Parks, cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Railroad yard areas	0.20 to 0.40
Unimproved areas	0.10 to 0.30

One of the drawbacks to the Rational Method is that it provides only one point on the runoff hydrograph. Thus, it cannot be used if routing runoff through drainage facilities or detention basins is desired or necessary.

The existing outlet draining directly into the Hydraulic Ditch along Orchard Avenue.





The existing outlet draining directly into the Fruitland Ditch at 9th Street and Candlewood Road.

C. Unit Hydrograph Method

A unit hydrograph is defined as the hydrograph of one inch of direct runoff from the tributary area resulting from a unit storm. A unit storm is a rainfall of such duration that the period of surface runoff is not appreciably less for any rain of shorter duration. The unit hydrograph thus represents the integrated effects of factors such as tributary area, shape, street pattern, channel capacities, and street and land slopes.

To apply the unit hydrograph, the effective precipitation depth for the "unit storm" periods are multiplied by the ordinates of the unit hydrograph and added to obtain a design storm runoff. The basic premise of the unit hydrograph is that individual hydrographs resulting from the successive increments of rainfall excess that occur throughout their length, and that when properly arranged with respect to time, the ordinates of the individual unit graphs can be added to give ordinates representing the total storm discharge. The hydrograph of total storm discharge is obtained by summing the ordinates of the individual hydrographs. For the methods used to arrive at the synthetic unit hydrograph, reference is made to Urban Storm Drainage Criteria Manual, Volume 1, Denver Regional Council of Governments.

The synthetic unit hydrograph was used to determine the runoff from basins 1, 2, 3, 4, 5, 6, and 7 as shown on Figure No. 6. This procedure was also used to verify the results reported in by the Soil Conservation District in February, 1968.

RECOMMENDED STORM DRAINAGE FACILITIES

A. Proposed Plan

The recommended program for storm drainage facilities is a combination of street and subsurface sewer flow, open channel, and flood retarding structures. The existing storm sewer system within the City limits has been found to be quite inadequate to handle the initial design storm. This existing system will probably be abandoned and replaced with a new system. Most inlet structures will be replaced with properly sized inlets to assure adequate functioning of the new system. The 5 year storm has been recommended as the initial design storm frequency and the outline of the new system, as shown on Figure No. 1, was designed accordingly. It is apparent that all drainage north of the Hydraulic Ditch is being released into the irrigation ditch. The ditch cannot handle any additional water above what is being diverted from the Arkansas River for irrigation purposes. Although the Ditch Company has made attempts to close the inlet to the ditch at the point of its diversion during thunderstorms to accept some of the released storm runoff, it cannot handle the quantity of runoff from these storms. This action by the Ditch Company may have some effect to relieve flooding, but it creates additional problems by diverting storm runoff water from one basin to another. Flooding of the ditch causes damage to the ditch itself and may cause flooding of areas which may not have had to experience it. This "good guy" action by the Ditch Company may create additional liability on the Ditch Company that was not forseen nor are they wishing to assume. It is, therefore, recommended that a subsurface system be implemented to collect and transport the storm runoff around the 3 ditches and into the Arkansas River. The outlined subsurface system shown on Figure No. 1 was designed for the 5 year storm. Some of the parameters assumed in this design procedure are as follows:

1. Rational Method used in these areas of the City.

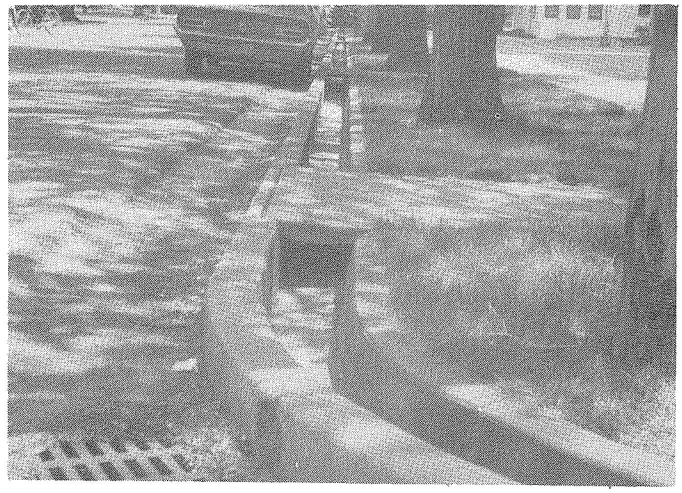
2. C = .5 for residential areas
   .9 for commercial areas

3. I = 5 year storm for residential and undeveloped areas, 25 year storm for commercial, business, industrial and public areas.

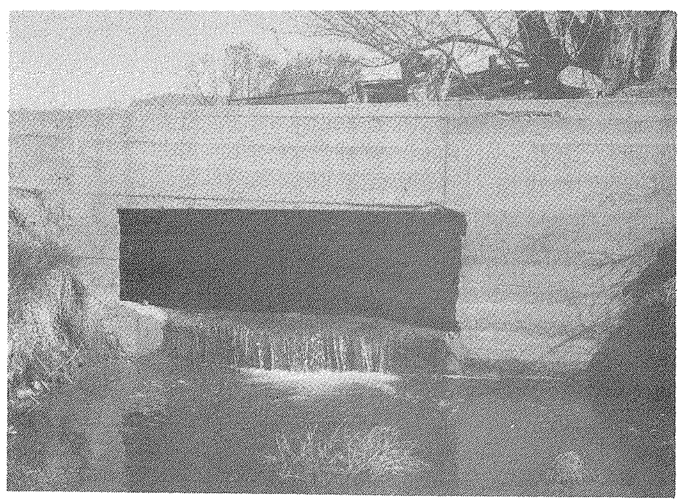
4. Typical street cross section as shown on Figure No. 2.

5. Typical street capacity chart as shown on Figure No. C-2.

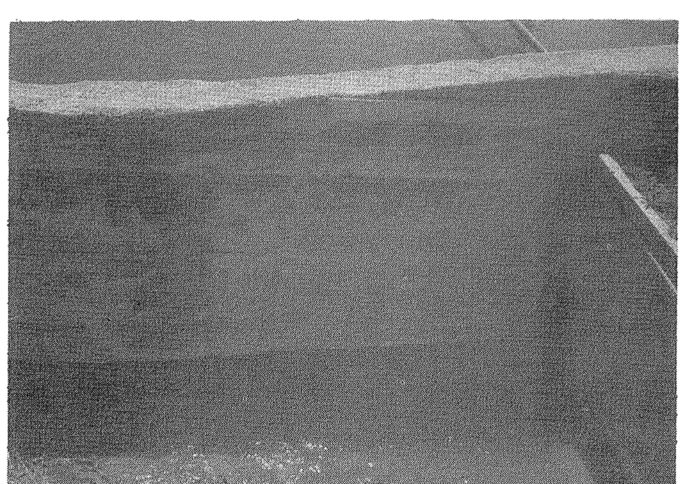
6. Pipe flow and velocity charts from the "Design Charts for



Example of a dual storm and irrigation collection and transport system. Taken in Florence, Colorado.



The concrete box culvert outlet at Frazier and the Arkansas River. Existing outlet near the C1-F floodway extension.



The restricted crossing of the major drainage C1-F floodway beneath the Hydraulic Ditch.

Open-Channel Flow" by U. S. Department of Commerce, Bureau of Public Roads.

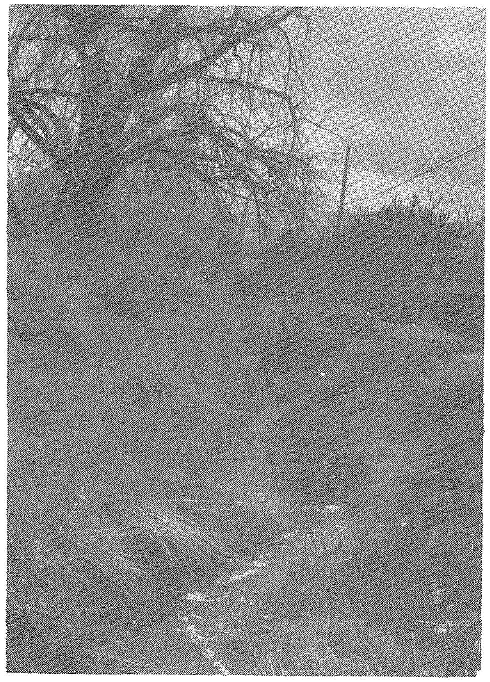
7. It was assumed that the flood retarding structure would be implemented north of the City limits. This would collect and detain the runoff from the northern basins and therefore reduce the subsurface system needed to collect and transport this additional runoff from those areas.

This outlined system, Figure No. 1, will solve some of the flooding problems the City is now experiencing. It will not satisfy the request that a system be designed to transport a 100 year storm so it does not inundate the floor elevation of any structure. This requirement would be totally unfeasible.

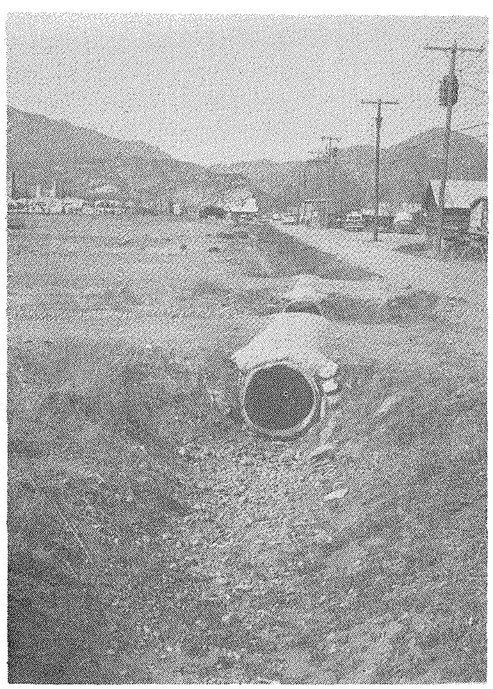
In the East Canon area where the irrigation laterals run along the streets, there exists a problem of collecting storm water runoff. At present, all runoff drains into the irrigation laterals. Most of the culverts and ditch crossings are just adequate to handle the flow created by the irrigation water. Upon adding storm water runoff, most of these culverts would be inadequate.

The irrigation water is generally used by property owners who use it for non-livelyhood activities. These areas are serviced by public water supplies and are assessed at a very reasonable rate. The increased use of public water for the replacement of water taken from the irrigation ditches would not increase their water bills substantially. Therefore, the recommendation to abandon the irrigation laterals and replace them by curb and gutter and a subsurface system to handle storm water runoff would be an economical solution to storm drainage. If such an alternative would not be acceptable, then a system would have to be designed to handle both the irrigation water and the storm runoff water.

Two alternatives could be adopted to satisfy the above demands. One program would be to design a system of open channels and subsurface sewers to transport both the irrigation water and storm water in one system. One idea is shown in Figure No. 3 as Alternative No. 2. The other alternative is to incorporate two separate systems, one for irrigation water and the other for storm water runoff. An example of such a dual system would be as those in Florence, Colorado. See Figure No. 3, Alternate No. 3. There are advantages and dis-



Existing C1-F floodway south of the Hydraulic Ditch.



Existing C3-F floodway south of Water Street.

advantages to each of the above alternatives. The disadvantage to the first alternative would be the objection to the abandanment of the irrigation laterals. Although the streets may not be paved nor curb and gutters constructed in the near future, the earth ditches could be used to transport storm water to collection inlets to the subsurface system. This alternative would be the most economical. The advantages to the second alternative of using one system to transport both storm and irrigation water would be the luxury of allowing the irrigation laterals to remain. This type of system of surface and subsurface collection would be costly because the pipe sizes would be much larger due to the added volume of water it must carry at very low gradient to supply the existing irrigation water flows. This type of system would be very inefficient and would cause the most maintenance problems. The last alternative would compare reasonably close to the second alternative's advantages and disadvantages. But in addition to the mentioned disadvantages, this system does not allow runoff to drain directly into the street curb and gutter and subsurface system. As shown in Figure No. 3 Alternate No. 3, runoff water would first drain into the irrigation lateral then flood the lateral to reach the gutter where it would be picked up in the subsurface system. For this alternative to be implemented, curb and gutter and irrigation channel would have to be built immediately where the other two alternatives could possibly use the earth ditches presently and convert to curb and gutter as demand warrants. Although the gradient in the pipe line for Alternative 3 could be increased while decreasing the size of the pipe, the additional cost of the concrete irrigation channel would probably offset any difference between cost of Alternatives 2 and 3 for pipe size reduction in Alternate 3.

PROPOSED MAJOR DRAINAGE STRUCTURE

It is recommended that first priority be placed on implementing a major drainage flood protection program. After much research and analysis to verify the finding in a report prepared by the Fremont Soil Conservation District called the Watershed Work Plan, Canon Watershed, dated February, 1968, we concur basically with the recommendations set forth in that report. Costs for implementing this project have been revised in the cost estimate section of this report.

This project is formulated to provide a solution for the floodwater, sediment, and erosion damages occurring within the watershed.

The desired level of protection to be provided by the project works of improvement would eliminate damages produced by storms having a chance of occurrence of one to 100 years.

Studies indicate that a system of land treatment measures supplemented by floodwater retarding structure and floodways would meet objectives and would maximize project benefits. It was also decided that the floodwater retarding structure should have capacity to contain in excess of the estimated 100 year storm runoff and provide for 100 year sediment deposition.

The floodwater retarding structure will be compacted earthfill with reinforced concrete pipe principal spillway having covered inlet risers. An ungated drawdown tube will drain the sediment pool. This flooding retarding structure, location shown on Figure 7, would have approximately 1,516 acre feet. It will provide capacity for the expected sediment accumulation over a 100 year period (383 acre feet) plus four inches of storm runoff (1,133 acre feet), which is about to the floodwater runoff volume expected from the 100 year frequency storm event.

The open floodway extension between the railroad and the Arkansas River is required to carry floodwater flows of 620 CFS in excess of the present 250 CFS capacity of the existing 1,310 foot underground concrete conduit from Kountz Street to the Arkansas River.

Floodway crossings include realignment of the Fruitland Ditch, enlargement of the combined county road and Hydraulic Irrigation Ditch culvert; Franklin Street; two service roads into the shopping center, U. S. Highway 50 and the service roads on each side; East Main Street and the main tracks of the Denver and Rio Grande Western Railroad, and the tail of the railroad "y". New crossings for the floodway extension are a siphon for the Oil Creek Ditch and a crossing for Kountz Street.

CONSTRUCTION PHASING

The costs of such recommendations as those made in this report will be a major undertaking. Therefore, we would like to suggest the following construction phasing.

The arrangement of these phases was based upon their importance as flood protection for the Canon City Area. Each phase is outlined in Figure 12 through 15 respectfully:

Phase I - Construction of the flood retarding structure and their related floodways.

Phase II - Construction of the subsurface system which collects and transports most of the runoff north of Hydraulic Ditch.

Phase III - Construction of the subsurface system within the Canon City area.

Phase IV - Construction of the subsurface system within the East Canon area.

The implementation of Phases I and II should be undertaken immediately. Phases III and IV have a lesser priority because the potential for major damage due to runoff is much less. This is due to the existing system and the low density of East Canon.

The following cost estimates are based upon present day prices. If delays occur in activating these recommendations, this cost estimate will have to be escalated to account for price changes. Also, the land costs used in this estimate are only estimates and will have to be verified by appraisals and/or actual sale prices.

Phase I cost estimate was based upon quantities taken from the report published by the Soil Conservation Service dated February, 1968. Unit costs have been revised to account for price changes. Although we presently concur with the approach the Soil Conservation Service has taken, both the SCS and M & I, Inc., agree that a majority of the work done previously will have to be duplicated to activate the Public Law 566 financing.

ESTIMATE OF COST
PHASE I CONSTRUCTION
100 YEAR STORM
(Per Figure No. 12)

Flood Retarding Structure

Item	Quantity	Units	Unit Price	Amount
Excavation	1,017,600	Cu.Yd.	$ 1.50	$1,526,400
Principal Spillway	150	Cu.Yd.	100.00	15,000
60" Ø Reinforced Concrete Pipe	260	L.F.	58.00	15,800
24" Ø Reinforced Concrete Pipe	90	L.F.	14.00	1,260
Internal Drain System				10,000
60" Ø Reinforced Concrete Division Pipe	2,200	L.F.	58.00	127,600

Total Estimated Construction Cost	$1,696,060
Engineering and Contingencies	452,450
Land	875,000
Total Estimated Project Cost	$3,023,510

CI-F and CI-F Extension

Item	Quantity	Units	Unit Price	Amount
Excavation	34,390	Cu.Yd.	$ 1.50	51,585
Drop Structure	911	Cu.Yd.	100.00	91,100
36" Ø Reinforced Concrete Pipe	30	L.F.	25.50	765
42" Ø Reinforced Concrete Pipe	100	L.F.	32.00	3,200
60" Ø Reinforced Concrete Pipe	210	L.F.	58.00	12,180
66" Ø Reinforced Concrete Pipe	315	L.F.	68.00	21,420
72" Ø CMP	100	L.F.	55.00	5,500
84" Ø CMP	30	L.F.	69.00	2,070

Total Estimated Construction Cost	$ 187,820
Engineering and Contingencies	73,460
Land	60,000
Total Estimated Project Cost	$ 321,280

TOTAL ESTIMATED PROJECT COST	
PHASE I	$3,344,790

ESTIMATE OF COST

PHASE II CONSTRUCTION
5-YEAR STORM
(Per Figure No. 13)

Item	Quantity	Unit	Unit Price	Amount
84" Reinforced Concrete Pipe	2,911	L.F.	$ 112.00	$326,032
72" Reinforced Concrete Pipe	350	L.F.	79.00	27,650
60" Reinforced Concrete Pipe	3,820	L.F.	58.00	221,560
54" Reinforced Concrete Pipe	2,330	L.F.	48.00	111,840
48" Reinforced Concrete Pipe	3,365	L.F.	38.50	129,552
42" Reinforced Concrete Pipe	2,810	L.F.	32.00	89,920
36" Reinforced Concrete Pipe	1,425	L.F.	25.50	36,338
33" Reinforced Concrete Pipe	980	L.F.	23.00	22,540
30" Reinforced Concrete Pipe	260	L.F.	19.50	5,070
27" Reinforced Concrete Pipe	4,850	L.F.	17.00	82,450
24" Reinforced Concrete Pipe	460	L.F.	14.00	6,440
21" Reinforced Concrete Pipe	1,680	L.F.	12.80	21,504
18" Reinforced Concrete Pipe	660	L.F.	11.00	7,260
15" Reinforced Concrete Pipe	800	L.F.	10.00	8,000
Manholes	83	Each	800.00	66,400
Inlet strucutres	104	Each	900.00	93,600
Cross Pans	19	Each	450.00	8,550
Removal of Curb Inlets	21	Each	100.00	2,100
Channel C3-F	675	L.F.	30.00	20,250
Asphalt Replacement	40,750	S.Y.	5.50	224,125
Miscellaneous Relocation of Utilities				400,000

Total Estimated Construction Cost	$1,911,181
Engineering and Contingency	485,619
Land	3,200
Total Estimated Project Cost	$2,400,000

ESTIMATE OF COST
PHASE III CONSTRUCTION
5-YEAR STORM
(Per Figure No. 14)

Item	Quantity	Units	Unit Price	Amount
54" Ø Reinforced Concrete Pipe	1,780	L.F.	$ 48.00	$ 85,440
48" Ø Reinforced Concrete Pipe	890	L.F.	38.50	34,265
42" Ø Reinforced Concrete Pipe	6,170	L.F.	32.00	197,440
36" Ø Reinforced Concrete Pipe	1,770	L.F.	25.50	45,135
33" Ø Reinforced Concrete Pipe	3,440	L.F.	23.00	79,120
30" Ø Reinforced Concrete Pipe	4,595	L.F.	19.50	89,602
27" Ø Reinforced Concrete Pipe	4,555	L.F.	17.00	77,435
24" Ø Reinforced Concrete Pipe	3,060	L.F.	14.00	42,840
21" Ø Reinforced Concrete Pipe	2,690	L.F.	12.80	34,432
18" Ø Reinforced Concrete Pipe	3,310	L.F.	11.00	36,410
15" Ø Reinforced Concrete Pipe	1,400	L.F.	10.00	14,000
12" Ø Reinforced Concrete Pipe	1,360	L.F.	8.60	11,696
Manholes	99	Each	800.00	79,200
Inlet Structures	137	Each	900.00	123,300
Asphalt Replacement	45,300	S.Y.	5.50	249,150
Removal of Curb Inlets	140	Each	100.00	14,000
Channel C3-F	900	L.F.	30.00	27,000
Concrete Cross Pans	2	Each	450.00	900
Miscellaneous Relocation of Utilities				300,000

Total Estimated Construction Cost	$1,541,365
Engineering and Contingencies	195,800
Land	4,300
Total Estimated Project Cost	$1,741,465

ESTIMATE OF COST
PHASE IV CONSTRUCTION
5-YEAR STORM
(Per Figure No. 15)

Item	Quantity	Units	Unit Price	Amount
72" Ø Reinforced Concrete Pipe	1,800	L.F.	$ 79.00	$ 142,200
60" Ø Reinforced Concrete Pipe	1,440	L.F.	58.00	83,520
54" Ø Reinforced Concrete Pipe	500	L.F.	48.00	24,000
48" Ø Reinforced Concrete Pipe	3,010	L.F.	38.50	115,885
42" Ø Reinforced Concrete Pipe	1,310	L.F.	32.00	41,920
36" Ø Reinforced Concrete Pipe	500	L.F.	25.50	12,750
30" Ø Reinforced Concrete Pipe	1,150	L.F.	19.50	22,425
27" Ø Reinforced Concrete Pipe	1,660	L.F.	17.00	28,220
24" Ø Reinforced Concrete Pipe	640	L.F.	14.00	8,960
21" Ø Reinforced Concrete Pipe	2,615	L.F.	12.80	33,472
18" Ø Reinforced Concrete Pipe	5,610	L.F.	11.00	61,710
15" Ø Reinforced Concrete Pipe	2,745	L.F.	10.00	27,450
Manholes	59	Each	800.00	47,200
Inlet Structures	86	Each	900.00	77,400
Asphalt replacement	35,000	S.Y.	5.50	192,500
Removal of Curb Inlets	30	Each	100.00	3,000
Channel C2-F Construction	3,000	L.F.	30.00	90,000
Concrete Cross Pans	8	Each	450.00	3,600
Miscellaneous Relocation of Utilities				200,000

Total Estimated Construction Cost	$1,216,212
Engineering and Contingencies	286,500
Land	24,500
Total Estimated Project Cost	$1,527,212

GRAND TOTALS

PHASE I	$ 3,344,790
PHASE II	2,400,000
PHASE III	1,741,465
PHASE IV	1,527,212
TOTAL ESTIMATED PROJECT COST	$ 9,013,467

The following is a breakdown of cost of which a portion could possible be funded through Public Law 566 as described in the report by SCS, February, 1968.

			Canon City's Portion	Soil Conservation Service Public Law 566 Participation*
Phase I				
	C-1:	Construction	$ 16,650	$ 2,131,860
		Land	875,000	00
			$ 891,650	$ 2,131,860
	C-1F:	Construction	$ 9,700	$ 251,580
		Land	60,000	00
			$ 69,700	$ 251,580
		TOTALS	$ 961,350	$ 2,383,440
Phase II				
	Construction		$2,396,800	00
	Land		3,200	00
		TOTALS	$2,400,000	00
Phase III				
	Construction		$1,737,165	00
	Land		4,300	00
		TOTALS	$1,741,465	00
Phase IV				
	Construction		$1,502,712	00
	Land		24,500	00
		TOTALS	$1,527,212	00

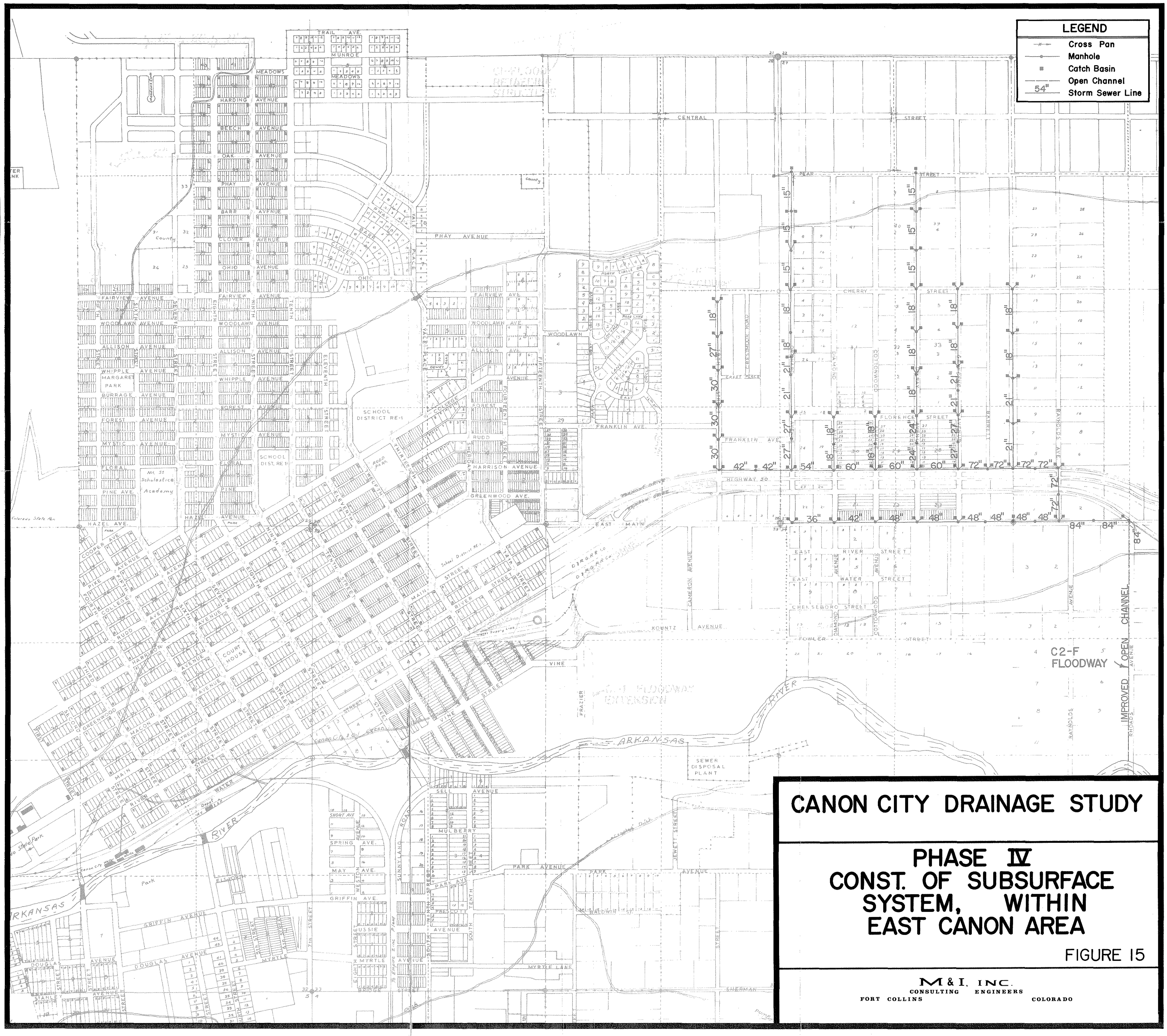
*NOTE: At this time it is felt that participation by the Soil Conservation Service through Public Law 566 can still be applied for and received.

A breakdown of the acreage needed and the estimated unit costs are as follows:

C-1	250 acres	@ $3,500/acre	=	$ 875,000
C-1F	8 acres	@ $5,000/acre	=	40,000
C-1F ext.	4 acres	@ $5,000/acre	=	20,000
C-2F	7 acres	@ $3,500/acre	=	24,500
C-3F	1.5 acres	@ $5,000/acre	=	7,500
		Estimated Land Costs	=	$ 967,000

EXISTING STORM SEWER:

It is estimated that the 26,200 L.F. of existing storm sewer could be cleaned and portions reconditioned for a fee of approximately $35,000.00.


LEGEND
Cross Pan
Manhole
Catch Basin
Open Channel
54"
Storm Sewer Line
CENTRAL STREET
CHERRY STREET
FLORENCE STREET
FRANKLIN AVE
HIGHWAY 50
EAST MAIN
EAST RIVER STREET
EAST WATER STREET
CHEESEBORO STREET
KOUNTZ AVENUE
FOWLER STREET
C2-F FLOODWAY
IMPROVED OPEN CHANNEL
RIVER
ARKANSAS
SEWER DISPOSAL PLANT
COURT HOUSE
SCHOOL DISTRICT RE-1
CANON CITY DRAINAGE STUDY
PHASE IV
CONST. OF SUBSURFACE SYSTEM, WITHIN EAST CANON AREA
FIGURE 15
M&I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

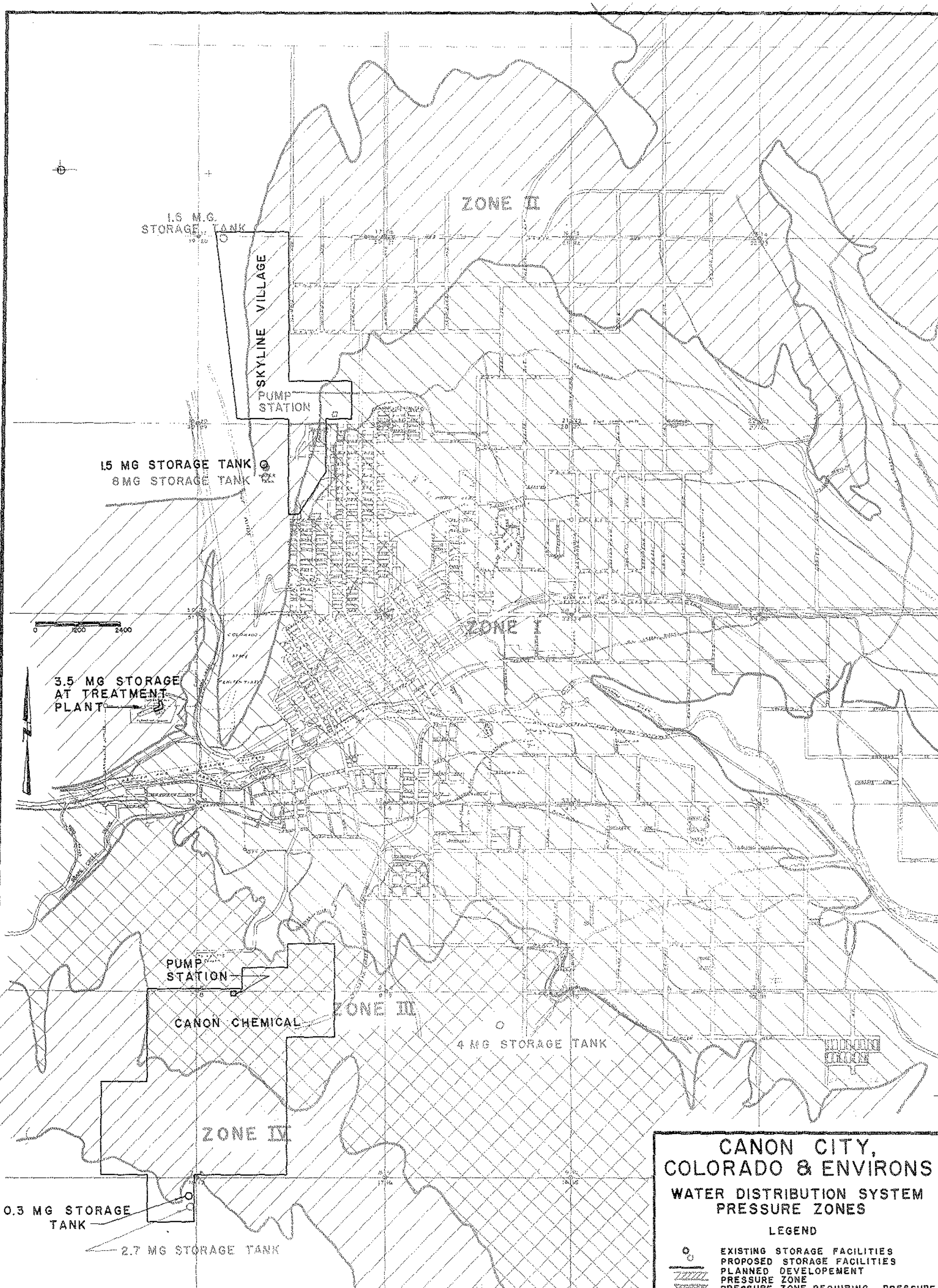
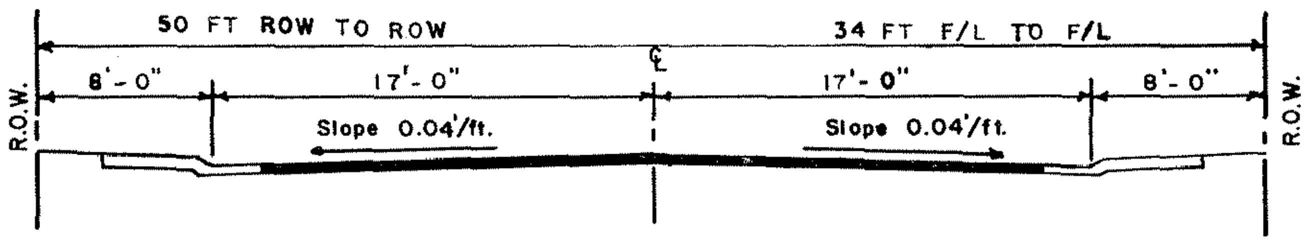


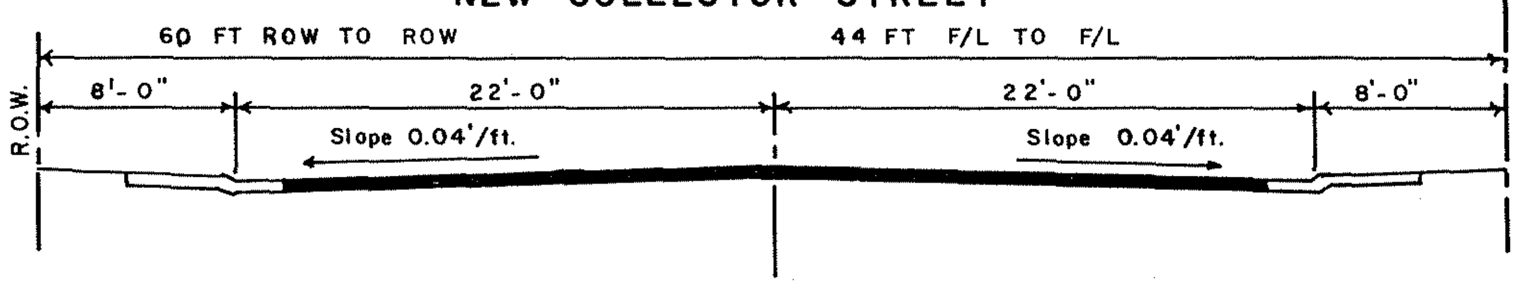
EXHIBIT NO. 11

FIGURE

NEW LOCAL STREET



NEW COLLECTOR STREET



NOTE: 6" vertical curb and gutter with 0.04'/ft. slope was assumed for existing streets

ASSUMED STREET CROSS SECTION FOR STUDY, figure 2

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

EAST CANON STREET CROSS SECTIONS

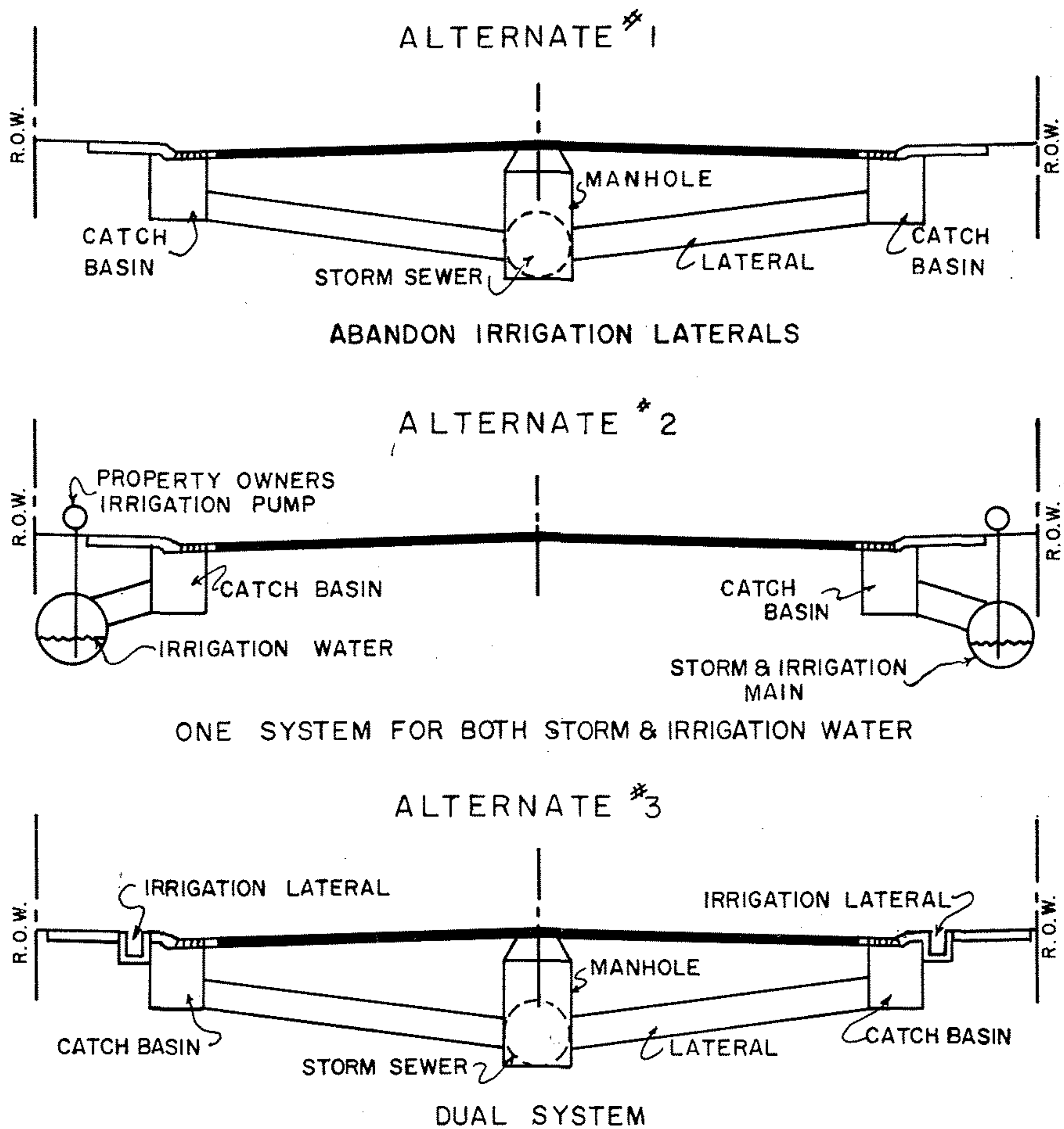
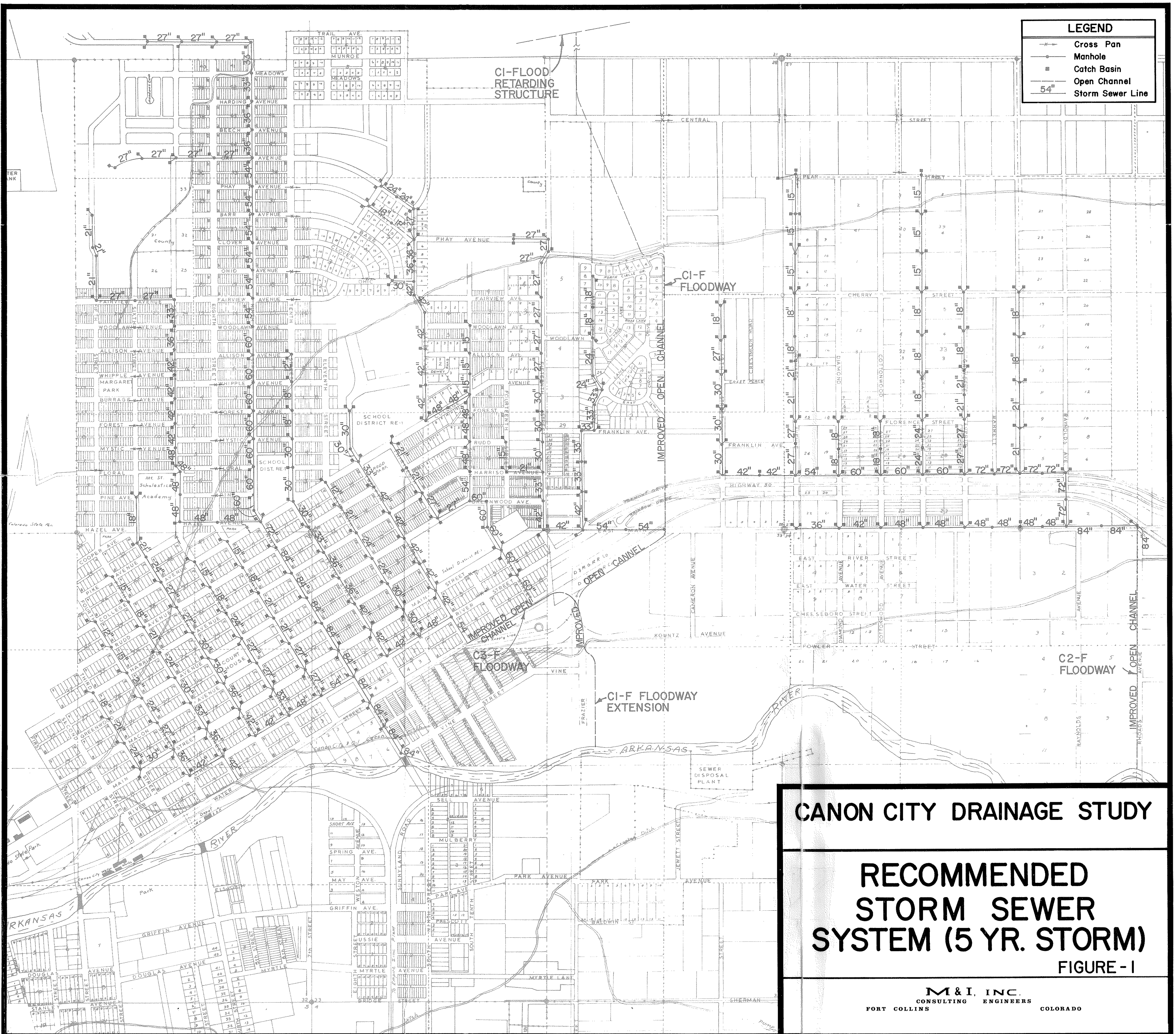


figure 3

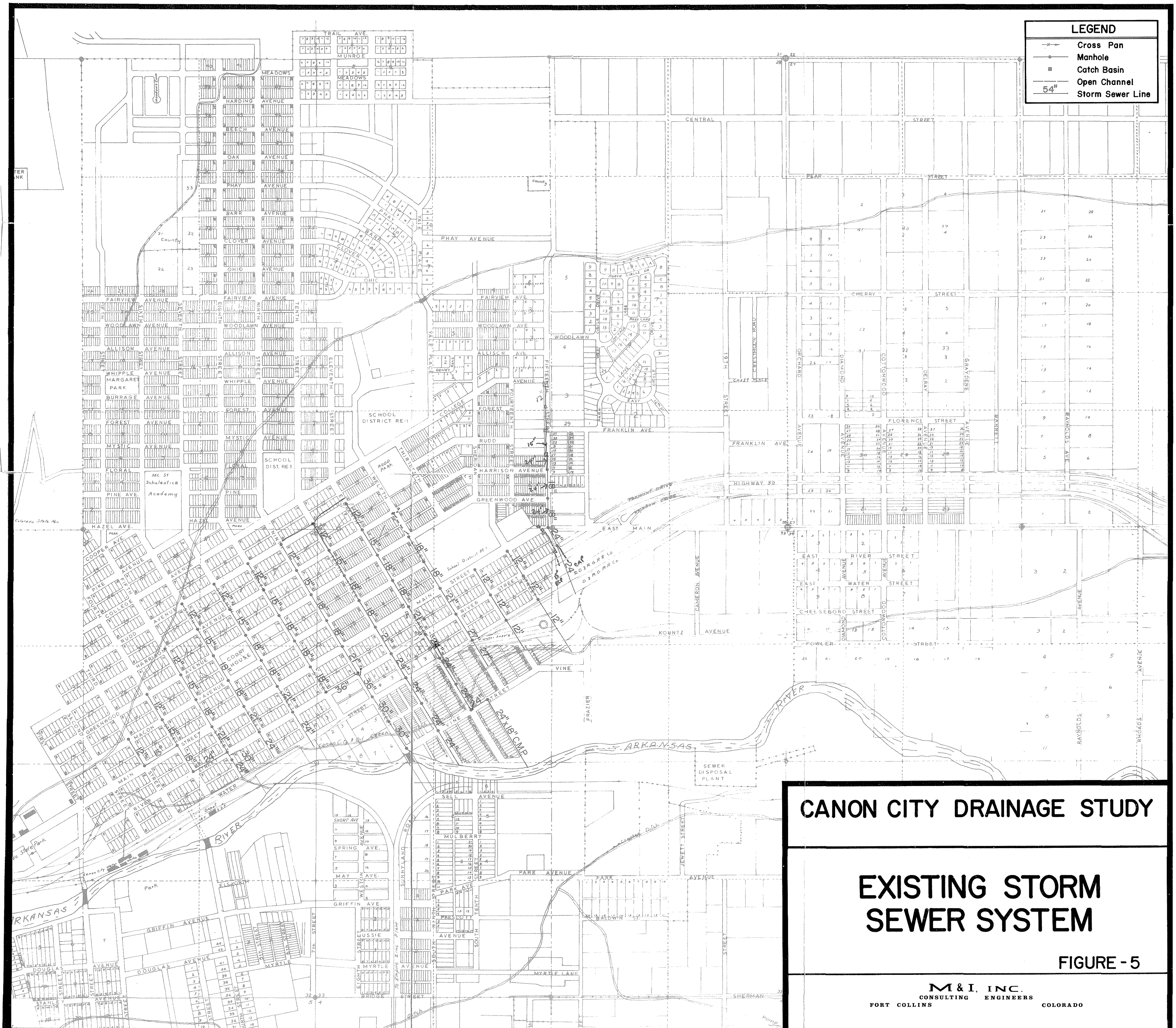
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

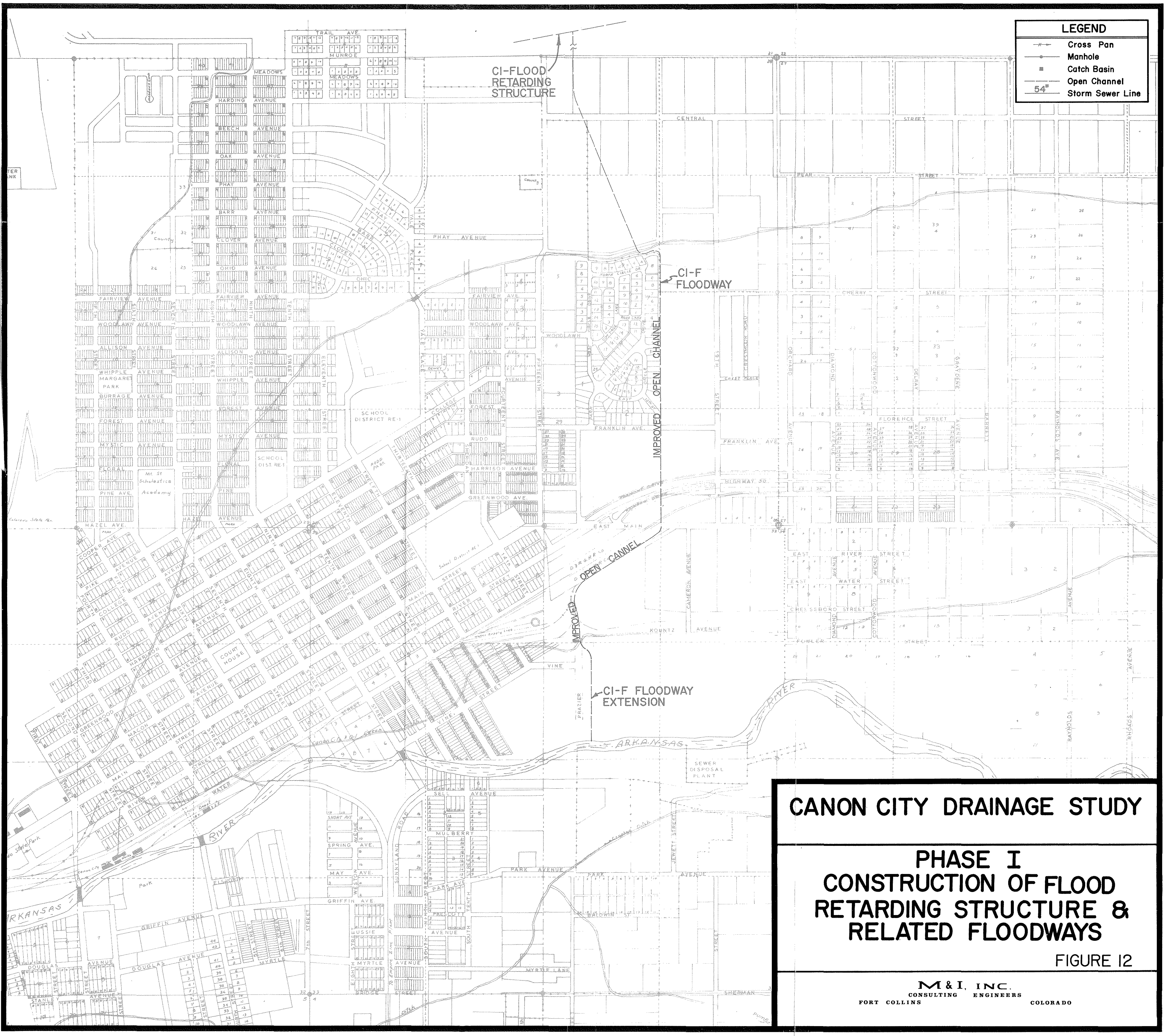


CANON CITY DRAINAGE STUDY

RECOMMENDED STORM SEWER SYSTEM (5 YR. STORM)

FIGURE - I


LEGEND
Cross Pan
Manhole
Catch Basin
Open Channel
54"
Storm Sewer Line
ARKANSAS
RIVER
SEWER DISPOSAL PLANT
SCHOOL DISTRICT RE-1
COURT HOUSE
Mt. St. Scholastica Academy
CANON CITY DRAINAGE STUDY
EXISTING STORM SEWER SYSTEM
FIGURE - 5
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

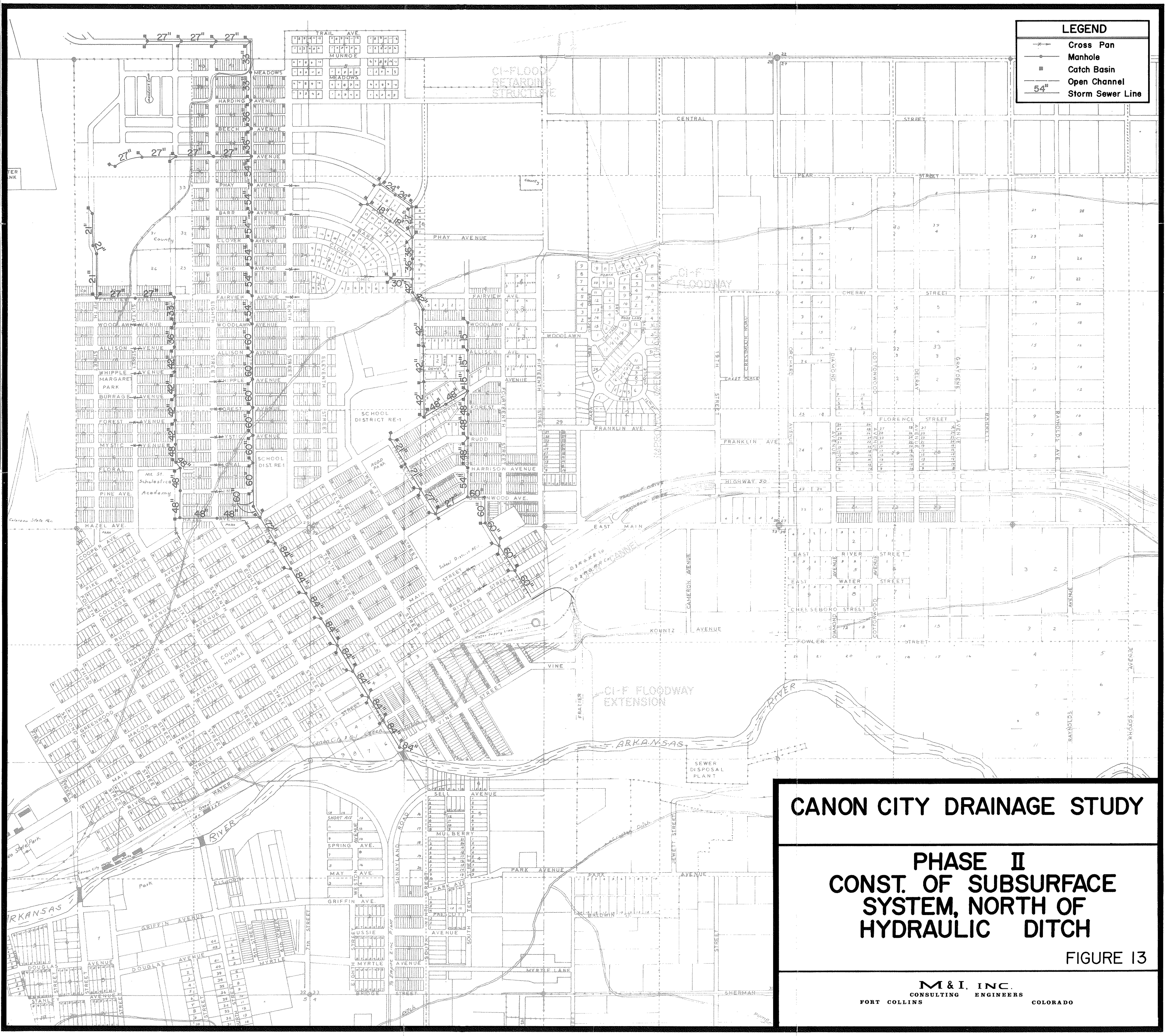


CANON CITY DRAINAGE STUDY

PHASE I
CONSTRUCTION OF FLOOD RETARDING STRUCTURE & RELATED FLOODWAYS

FIGURE 12

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

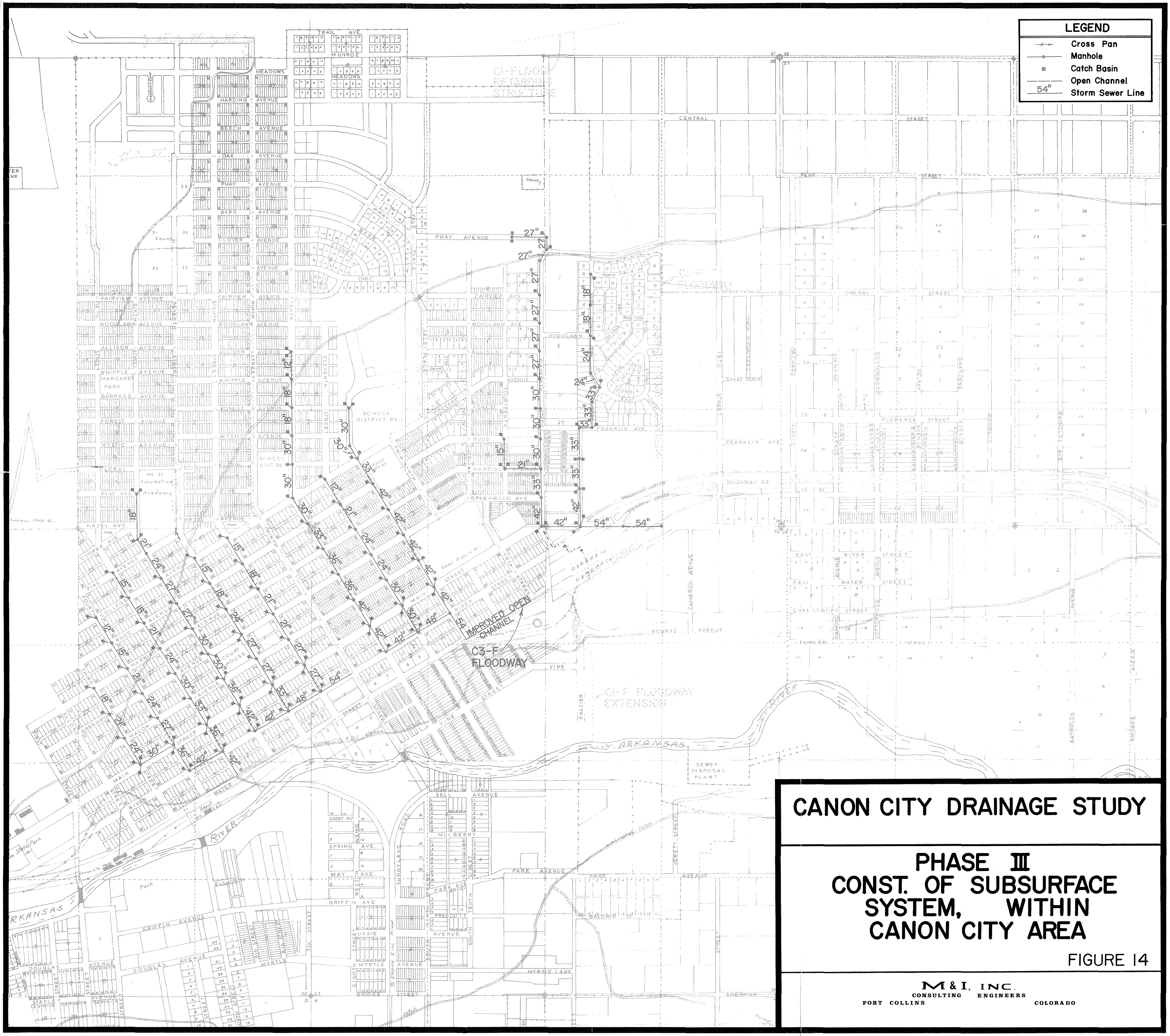


CANON CITY DRAINAGE STUDY

PHASE II
CONST. OF SUBSURFACE SYSTEM, NORTH OF HYDRAULIC DITCH

FIGURE 13

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO



CANON CITY DRAINAGE STUDY

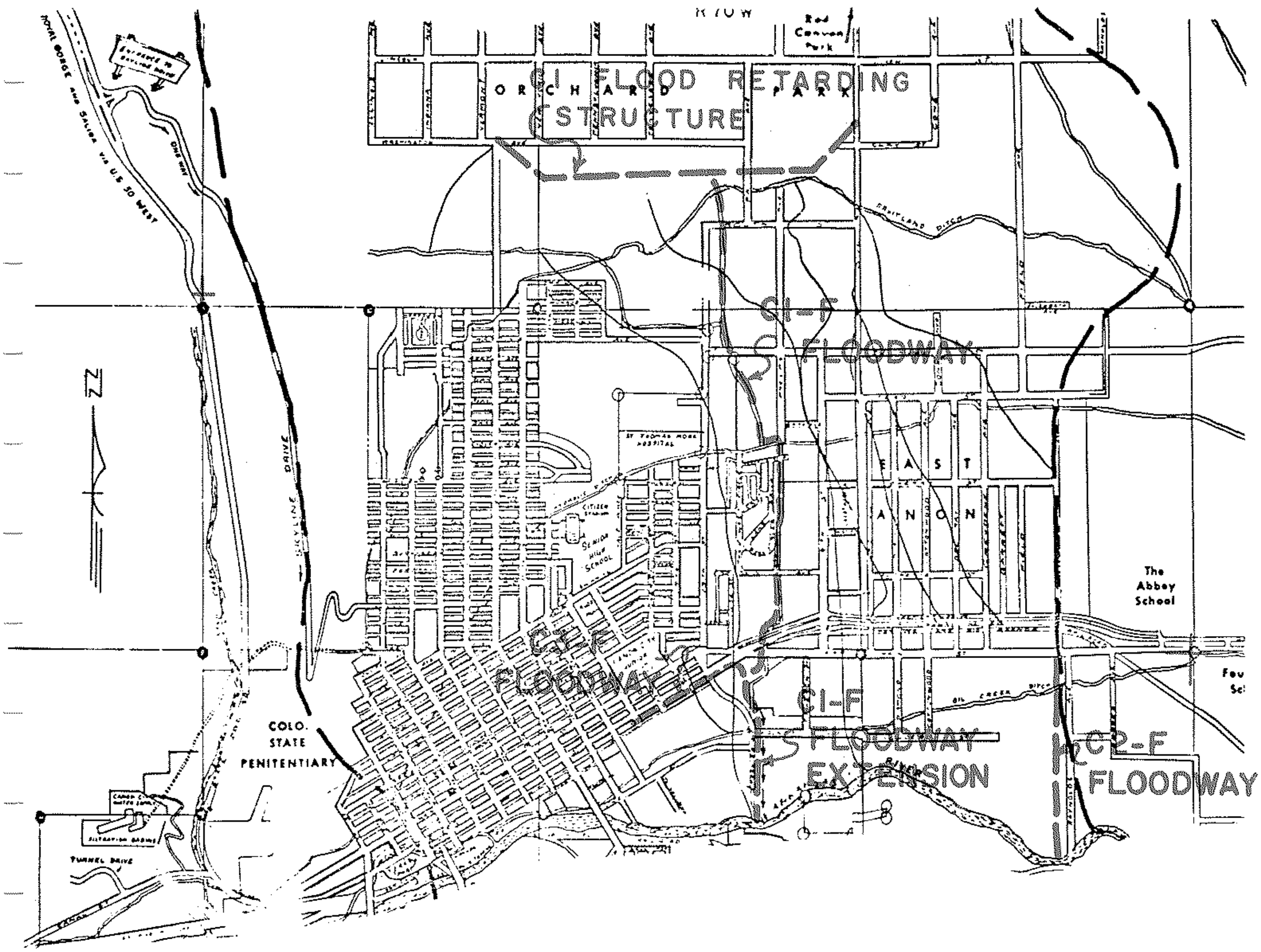
PHASE III
CONST. OF SUBSURFACE SYSTEM, WITHIN CANON CITY AREA

FIGURE 14

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

FLOODWAY MAP

CI-F, C2-F & C3-F



CANON WATERSHED

FREMONT COUNTY, COLORADO

0 1/4 1/2 3/4 1

SCALE IN MILES

M & I, INC.

CONSULTING ENGINEERS

FORT COLLINS COLORADO

figure 4

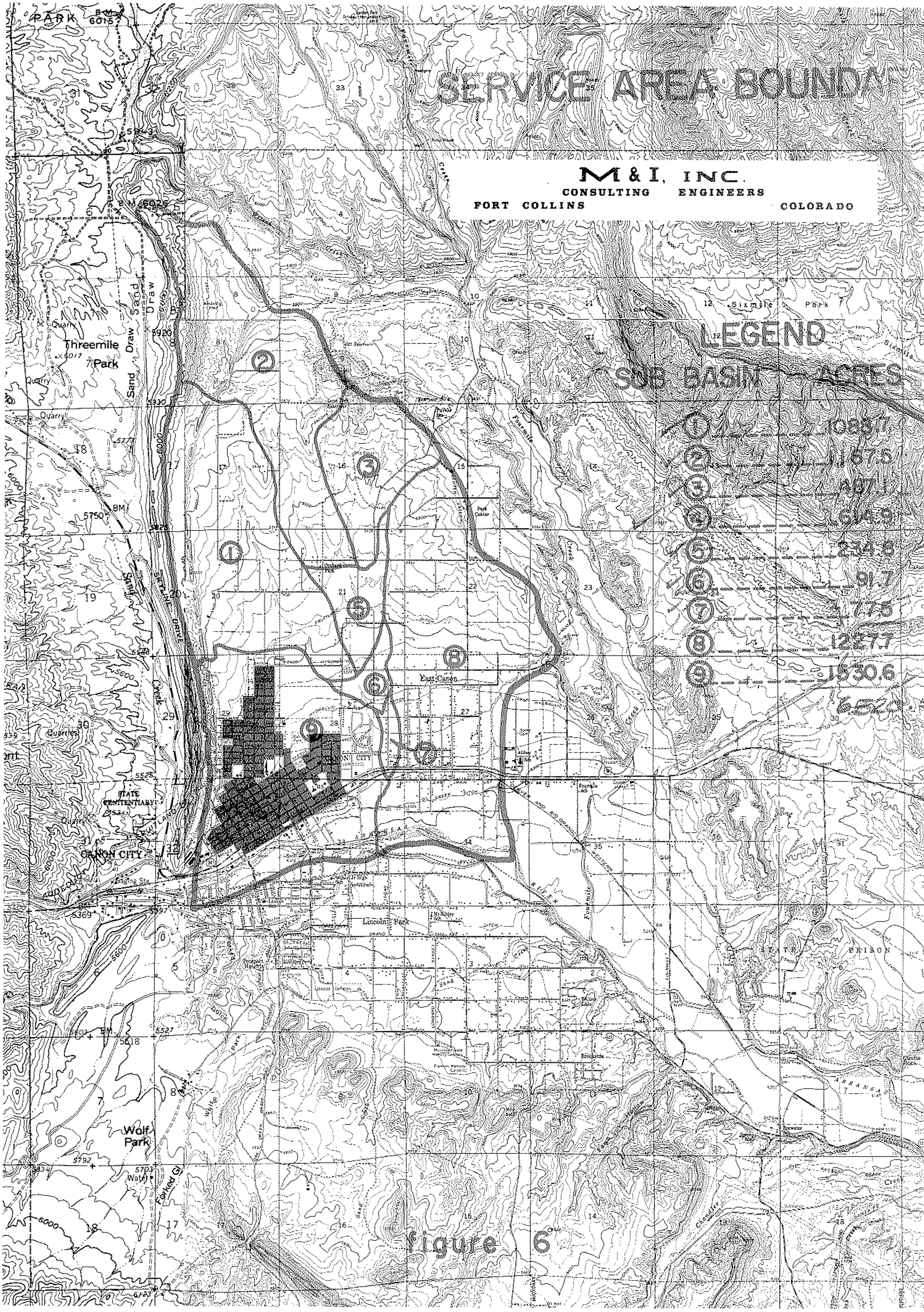
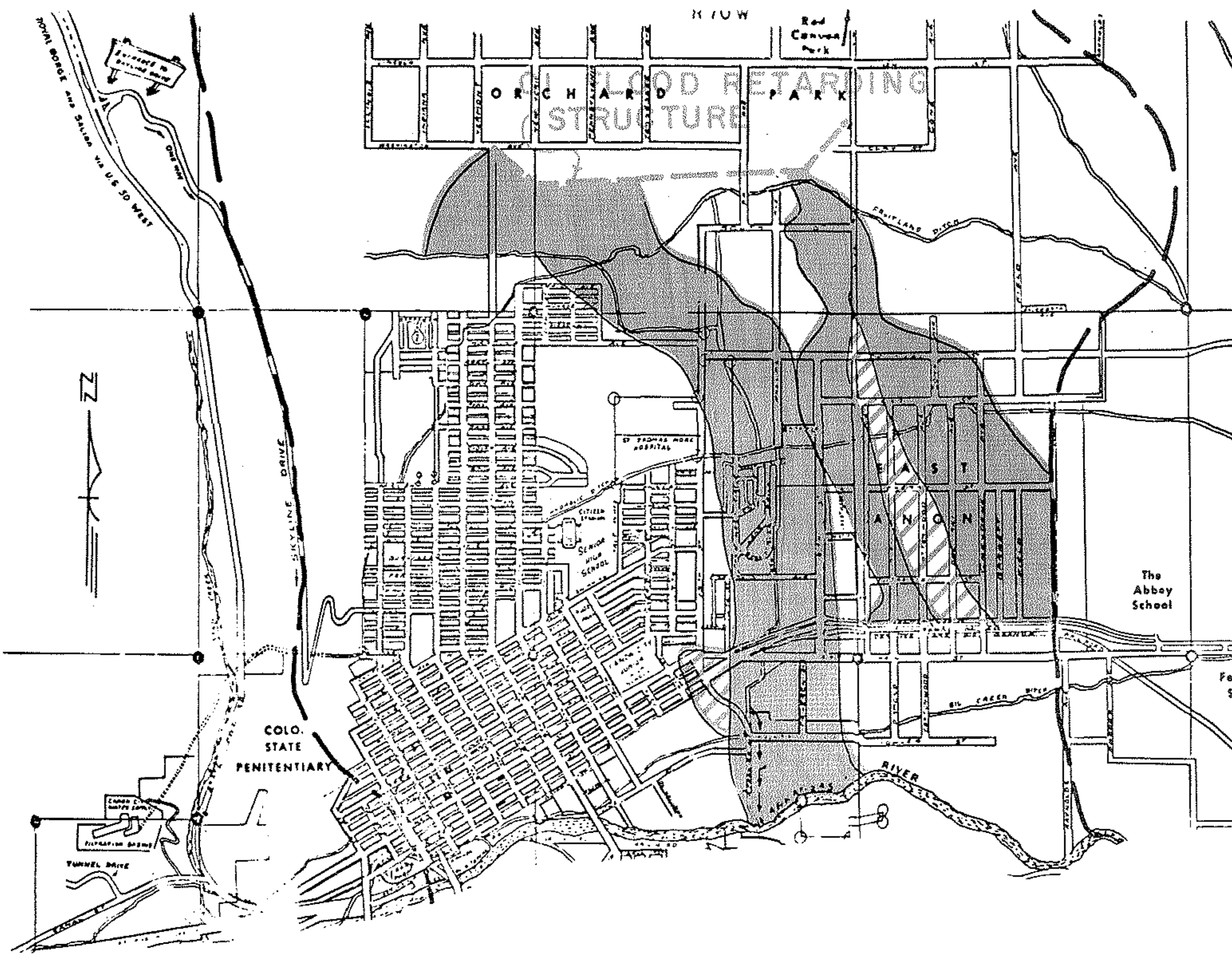

SERVICE AREA BOUNDA
M&I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO
LEGEND
SUB BASIN - ACRES
1 - 1088.7
2 - 1167.5
3 - 407.1
4 - 614.9
5 - 234.8
6 - 91.7
7 - 77.5
8 - 1227.7
9 - 1530.6
Threemile Park
Sand Draw
Skyline Drive
Sand Creek
East Canon
Canon City
State Penitentiary
Lincoln Park
Sixmile Park
Fourmile Creek
State Prison
Wolf Park
Forked Gl
Brookside
Brewster

figure 6

AREA BENEFITED BY MAJOR DRAINAGE STRUCTURE



LEGEND

100 Yr. Flood without Project

100 Yr. Flood with Project

Project Boundary

CANON WATERSHED

FREMONT COUNTY, COLORADO

0 1/4 1/2 3/4 1
SCALE IN MILES

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

figure 7

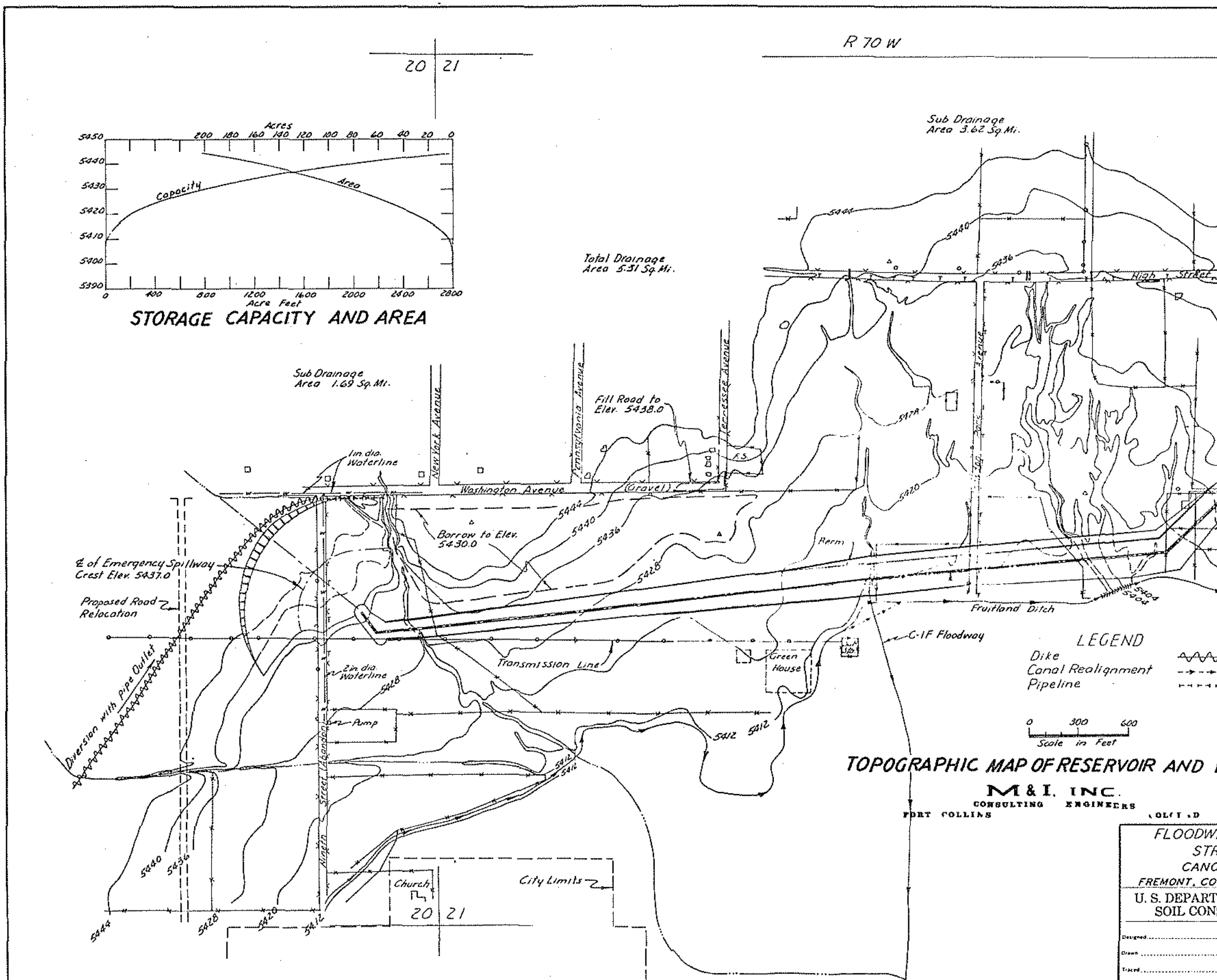


figure 8

FLOODWATER RETARDING STRUCTURE C-1
CANON WATERSHED
FREMONT COUNTY COLORADO
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

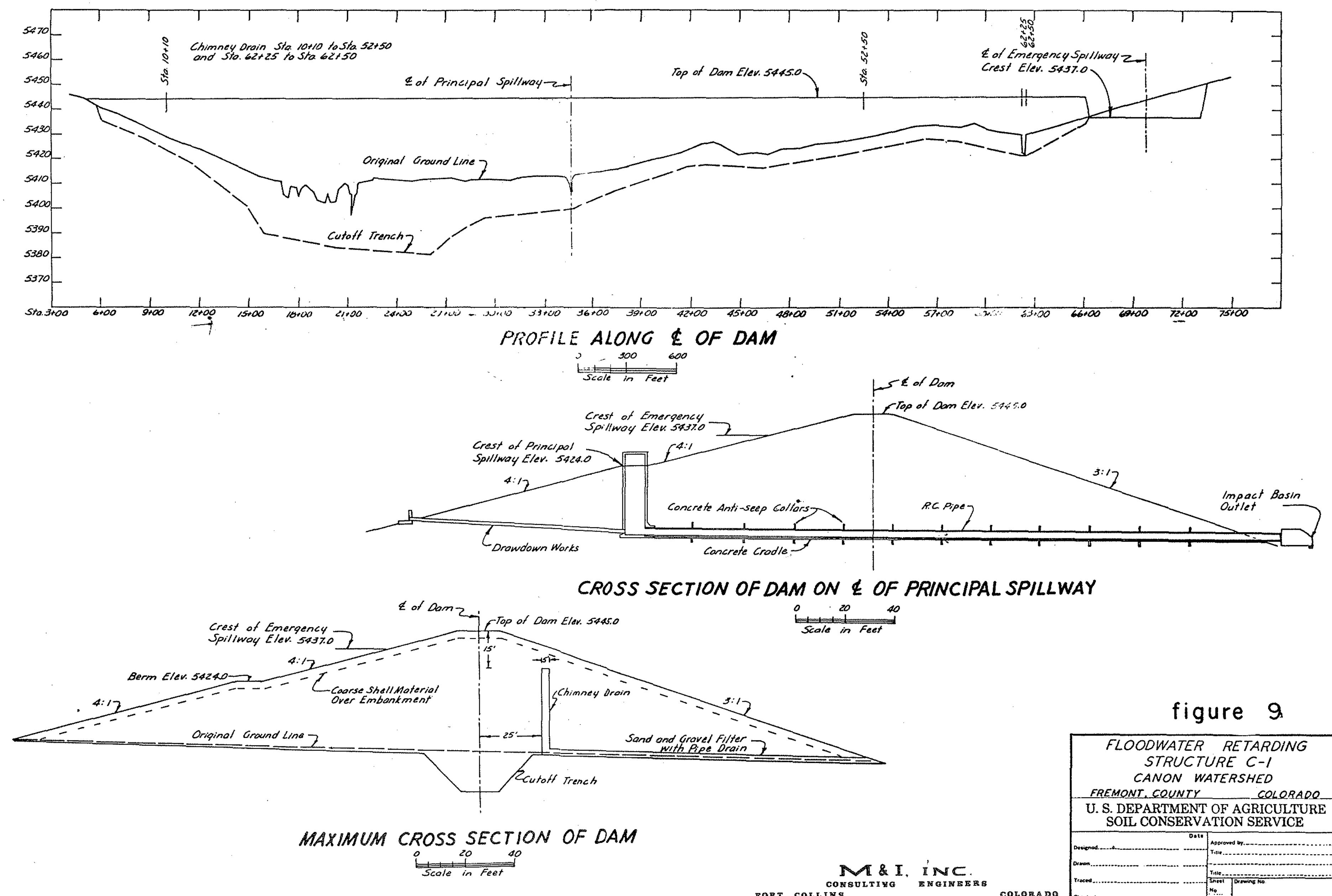
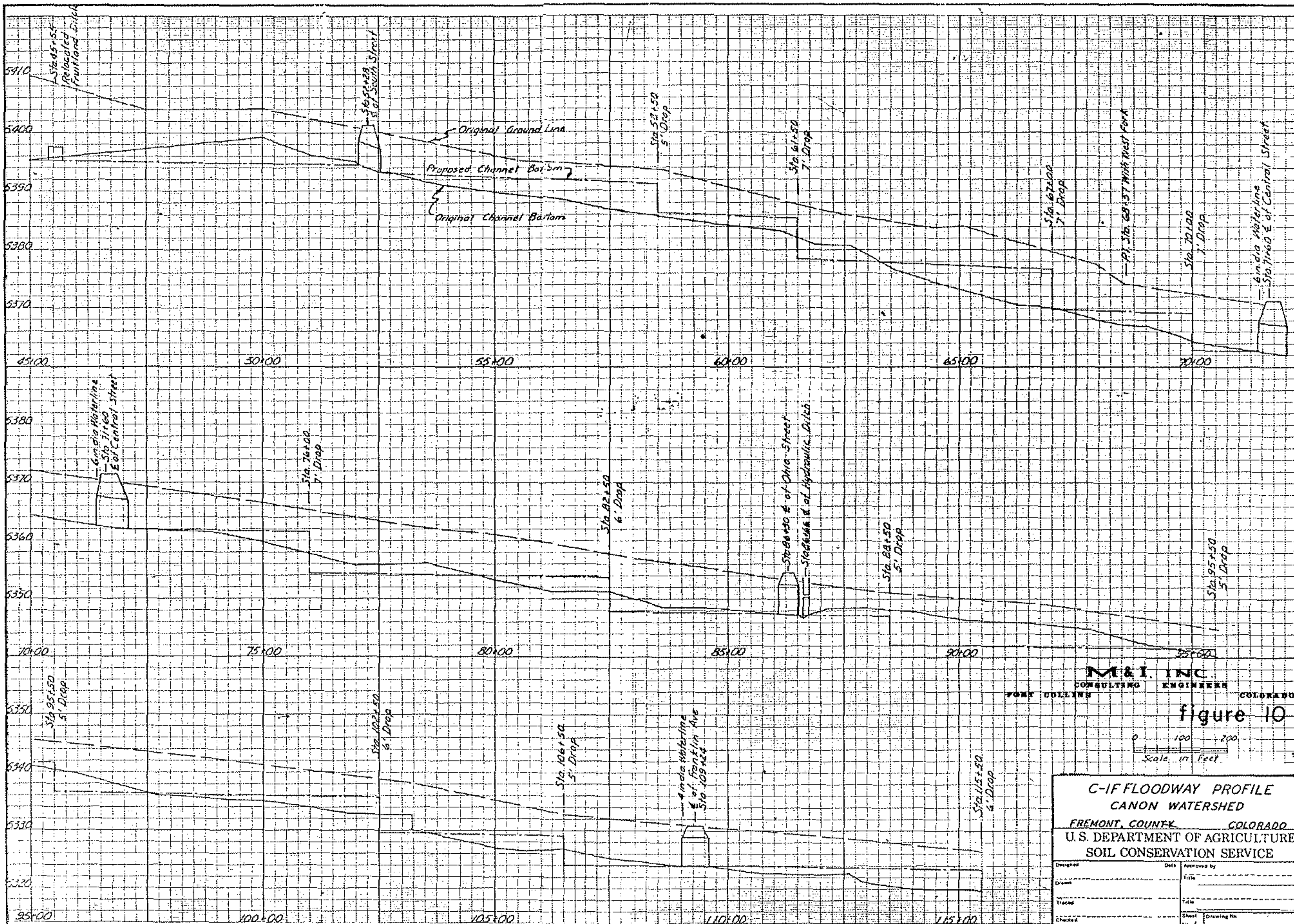

Chimney Drain Sta. 10+10 to Sta. 52+50 and Sta. 62+25 to Sta. 62+50
Sta. 10+10
Sta. 52+50
62+25
62+50
℄ of Principal Spillway
Top of Dam Elev. 5445.0
℄ of Emergency Spillway Crest Elev. 5437.0
Original Ground Line
Cutoff Trench
5470
5460
5450
5440
5430
5420
5410
5400
5390
5380
5370
Sta. 3+00
6+00
9+00
12+00
15+00
18+00
21+00
24+00
33+00
36+00
39+00
42+00
45+00
48+00
51+00
54+00
57+00
66+00
69+00
72+00
75+00
PROFILE ALONG ℄ OF DAM
0
300
600
Scale in Feet
℄ of Dam
Top of Dam Elev. 5445.0
Crest of Emergency Spillway Elev. 5437.0
Crest of Principal Spillway Elev. 5424.0
4:1
4:1
3:1
Concrete Anti-seep Collars
R.C. Pipe
Impact Basin Outlet
Drawdown Works
Concrete Cradle
CROSS SECTION OF DAM ON ℄ OF PRINCIPAL SPILLWAY
0
20
40
Scale in Feet
℄ of Dam
Top of Dam Elev. 5445.0
Crest of Emergency Spillway Elev. 5437.0
4:1
Berm Elev. 5424.0
15'
15'
Coarse Shell Material Over Embankment
Chimney Drain
4:1
3:1
Original Ground Line
25'
Sand and Gravel Filter with Pipe Drain
Cutoff Trench
MAXIMUM CROSS SECTION OF DAM
0
20
40
Scale in Feet
FLOODWATER RETARDING STRUCTURE C-1
CANON WATERSHED
FREMONT COUNTY COLORADO
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed
Drawn
Traced
Checked
Date
Approved by
Title
Sheet No.
of
Drawing No.
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

figure 9



Original Ground Line
Proposed Channel Bottom
Original Channel Bottom
Sta. 45+55 Relocated Fruitland Ditch
Sta. 51+29 ℄ of South Street
Sta. 57+50 5' Drop
Sta. 61+50 7' Drop
Sta. 67+00 7' Drop
P.I. Sta. 68+37 With West Fork
Sta. 70+00 7' Drop
6 in. dia. Waterline
Sta. 71+60 ℄ of Central Street
Sta. 76+00 7' Drop
Sta. 82+50 6' Drop
℄ of Ohio Street
℄ of Hydraulic Ditch
Sta. 88+50 5' Drop
Sta. 95+50 5' Drop
Sta. 102+50 6' Drop
Sta. 106+50 5' Drop
4 in. dia. Waterline
℄ of Franklin Ave
Sta. 109+24
Sta. 115+50 6' Drop
45+00
50+00
55+00
60+00
65+00
70+00
75+00
80+00
85+00
90+00
95+00
100+00
105+00
110+00
115+00
5410
5400
5390
5380
5370
5360
5350
5340
5330
5320
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO
Scale in Feet
0
100
200
C-1F FLOODWAY PROFILE
CANON WATERSHED
FREMONT COUNTY COLORADO
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

figure 10

Sta 115+50 6' Drop
Sta 118+99 ℄ of Service Rd.
Sta 119+81 ℄ of US Hwy 50
Sta 120+36 ℄ of Service Rd.
8 in dia. Gasline
6 in dia. Water line
Sta 122+51 ℄ of East Main St.
℄ of Railroad Tracks
Original Ground Line
Proposed Channel Bottom
Original Channel Bottom
Sta 128+00 6' Drop
New Alignment Sta 129+95 to Sta 134+50
Sta 131+50 9' Drop
Sta F132+80 Floodway Extension
Sta 134+38 ℄ of Railroad Track
Sta 136+70 Inlet of Concrete Conduit
Sta 136+77 ℄ of Oil Creek Ditch
115+00
120+00
125+00
130+00
135+00
140+00
5335
5330
5320
5310
5300
5290
5280
Sta 149+80 Outlet of Conc. Conduit ℄ Arkansas River
140+00
145+00
150+00
C-1F FLOODWAY
Sta F132+80 Floodway Extension
Sta 133+20 Floodway
Dike
Sta F136+50 8' Drop
Sta F137+18 ℄ of Oil Creek Ditch
Sta F137+40 ℄ of Kountz Road
Sta F139+25 8' Drop
Sta F149+00 5' Drop
Sta F149+85 Edge of Arkansas River
Sta F160+00 Bottom of River
F132+50
F135+00
F137+50
F140+50
F142+50
F145+00
F147+50
F150+00
C-1F FLOODWAY EXTENSION
M&I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO
0 100 200
Scale in Feet
C-1F FLOODWAY PROFILE
CANON WATERSHED
FREMONT COUNTY COLORADO
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed
Date
Approved by
Drawn
Title
Traced
Checked
Sheet
Drawing No.

figure 10

STRUCTURE DATA

CHANNELS

Canon Watershed, Colorado

Channel Designation	Length of Channel (ft.)	Watershed Area (sq. mi.)	Planned Channel Capacity (c.f.s.)	Average Bottom Width (ft.)	Average Side Slope	Average Depth (ft.)	Average Slope (ft./ft.)	Average Velocity in Channel (ft./sec.)	Volume of Excavation (cu. yds.)	Estimated ROW Needed (ft.)
C-1F Floodway	2357	0.203	40	4	1.5:1	6	.0030	3.5	1540	25
	1753	0.260	160	8	1.5:1	7	.0010	2.9	2280	30
	2290	0.297	197	10	1.5:1	7	.0009	3.3	7340	35
	966	0.311	224	12	1.5:1	7	.0009	3.4	940	35
	1054	0.358	270	14	1.5:1	8	.0009	3.5	1150	40
	400	2.022	870	24	1.5:1	13	.0005	3.8	6670	70
	345	2.022	250	14	1.5:1	13	.0009	3.5	1080	70
C-1F Floodway Expansion	370	2.022	620	50	3:1	4	.0009	3.4	2560	100
	1350	2.022	620	30	3:1	6	.0006	3.3	10830	100
C-2F Floodway (Main to River)	3000	1.051	950	50	3:1	5	.0008	3.5	36000	100
C-3F (Parallel to Water Street)	1575	0.50	450	20	1.5:1	5	.0009	3.5	8020	40

figure II

STORM DRAINAGE CRITERIA
FOR CANON CITY AND SURROUNDING AREA

I N D E X

F I G U R E S

CANON CITY, COLORADO

STANDARDS AND SPECIFICATIONS

MINIMUM DESIGN STANDARDS FOR STORM DRAINAGE

STORM DRAINAGE DESIGN: All design and analysis of storm drainage systems in the City of Canon City shall be done in accordance with the following specifications:

METHODS OF ANALYSIS: Two acceptable methods of flow analysis are the Rational Method and the Colorado Urban Hydrograph Procedure (CUHP).

A - Rational Method: Flows may be determined by the extended form of the rational formula:

$$Q = C_f C i A$$

Storm Frequency in Years	C_f
2 - 10	1.00
11 - 25	1.10
26 - 50	1.20
51 - 100	1.25

Q - Flow in cubic feet per second

C - Runoff factor

A - Area of basin in acres

i - Average rainfall intensity

(1) Rainfall intensities shall be taken from Figure C-3.

(2) The runoff "C" factor for undeveloped land shall be 0.1.

(3) Concentration times for flow analysis should never be less than 10 minutes.

(4) Use of the STORM DRAINAGE SYSTEM PRELIMINARY DESIGN DATA form Figure C-5 & C-6 is requested as a summary of the Engineer's design and flow analysis.

B - Colorado Urban Hydrograph Procedure: Flows may be calculated by the Colorado Urban Hydrograph Procedure as outlined in the Denver Regional Council of Government's Drainage Criteria Manual.

(1) Infiltration rates for pervious area should be 1/2 inch per hour through the entire 100-year storm. The first 1/2 hour of the 5-year storm can have an infiltration rate of 1 inch per hour. For the remainder of the storm the rate shall be 1/2 inch per hour.

(2) Depression detention should be taken from the Drainage Criteria Manual.

(3) Perviousness of undeveloped land shall be taken as 95 percent.

FACILITY CAPACITY AND DESIGN: All drainage facilities must be approved by the City Engineer.

(1) Curb flow capacity is reached when the flow crosses the back of the curb or the crown of the street is reached, whichever is less (see Figure C-2).

(2) Transfer of water from one flow line to another, by flow over the crown, will not be allowed for the initial design storm.

(3) Minimum size for storm drainage pipe shall be 15 inches.

(4) Pipe under streets shall be designed for soil and live loads in accordance with acceptable highway design criteria. The D-Load method is an acceptable method of design.

(5) Collector and arterials shall be drained so that the center 22 feet are clear of water during the 5-year storm.

(6) Major arterials shall be drained so that the center 24 feet are clear of water during the 100-year storm.

(7) Local streets shall have the catch basins at the point where either side of the street reaches its capacity for the 5-year frequency storm.

(8) Catch Basin Capacity in Cubic Feet per Second for typical catch basin shown Figure C-14.

Single 8.5 cfs

Double 16 cfs

(9) Culverts under streets (excepting major arterials) shall be designed with an emergency overflow for passing the 100-year storm. In determining the required capacity of the overflow, the culvert shall be assumed blocked unless its cross-sectional area exceeds 20 square feet, in which case 60 percent of its flow capacity may be used.

(10) Major channels shall be designed to safely pass the 100-year storm. Design and improvements shall be made in accordance with the recommendations of the Drainage Criteria Manual.

(11) Velocities in any conduit or channel shall be controlled so that the conduit or channel will not be damaged by flows from the 100-year flood, unless otherwise instructed by the City Engineer.

(12) Suggested values of Manning's "n" appear in Table 1.

(13) The hydrology and hydraulic calculations must accompany all drainage studies submitted to the City for approval by the City Engineer.

TABLE 1

Character of Section	Mannings 'n'
Concrete Pipe (RCP)	0.012
Corrugated Metal	
2-2/3" x 1/2" Corrugations	0.024
3" x 1" Corrugations	0.027
Structural Plate	
6" x 2" Corrugations	0.033
Reinforced Plastic Mortar (RPM)	0.010
Open Channels	
Undisturbed	0.035
Earth Reshaped	0.020
Grassed and Shaped	0.030
Concrete Lined	0.013
Rip Rap Lined	0.035

RUNOFF DETENTION REQUIREMENTS: The City Engineer requires that additional runoff caused by development be detained on the development site. The following section shall be used in volumetric determination and design of the detention structure.

(1) Detention Volume: The volume of water to be stored will be the difference in runoff volume between the existing undeveloped state and the proposed developed state as shown in Figure C-15. This volume shall be calculated for the 100-year storm in one of the following ways:

A. Hydrograph Method: Using the rearranged incremental rainfall data, determine both the undeveloped historic hydrograph and the developed/proposed hydrograph. The volume to be detained should be that volume labeled "Dentention Volume", unless otherwise specified by the City Engineer.

B. Triangular Method: The following method may be used as an alternate calculation of volume.

For this method, T_c is the time of concentration for the entire historic basin, but shall be restricted as follows:

$$10 < T_c < 45 \text{ Min.}$$

The average 100-year rainfall intensity for the time of concentration determined shall be taken from Figure C-3.

See Figure C-16 for a graphical representation of this method.

(2) Detention Time: No specific detention time is required under normal conditions. However, if the City Engineer determines that a longer detention time is in the City's best interest, he may require the "Detained Hydrograph" (See Figure C-15) to flow at a rate less than half the historic peak flow rate ($Q_H/2$) before 2 times the historic concentration time ($2T_c$) is reached.

(3) Maximum Release Rate: The maximum release rate from the detention facility shall not exceed the historical peak runoff rate for the same frequency storm.

When it is in the City's best interest to alter this release rate, the City Engineer may request a specific release rate.

(4) Detention Structures: The type and design of the detention structure must be approved by the City Engineer.

Generally acceptable examples of detention facilities are ponds, buried pipe, or roof top storage.

Release structures shall be provided where the design capacity of the detention structure can be exceeded. This overflow structure shall return the overflow water to the historic channel without causing damage to either the detention or overflow structures.

IRRIGATION DITCHES:

(1) Required ditch flow shall be determined by existing water rights below the design point and certificate of water rights flowing across and below the property shall be submitted to the City Engineer. Alternatively, the ditch pipe and/or structures shall be designed to carry a consistent flow of water as existing ditch is capable.

(2) All irrigation ditch piping must be approved, signed and dated by the President or other authorized officer of the ditch company, prior to approval of the City Engineer.

FIGURE


RAINFALL
DEPTH, DURATION, FREQUENCY MAP
M&I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO
1.2
1.3
1.35
1.35
PRECIPITATION
IN INCHES
5 YEARS
1 HR RAINFALL
Threemile Park
Wolf Park
CANON CITY
East Canon
Lincoln Park
STATE PENITENTIARY
figure C-1

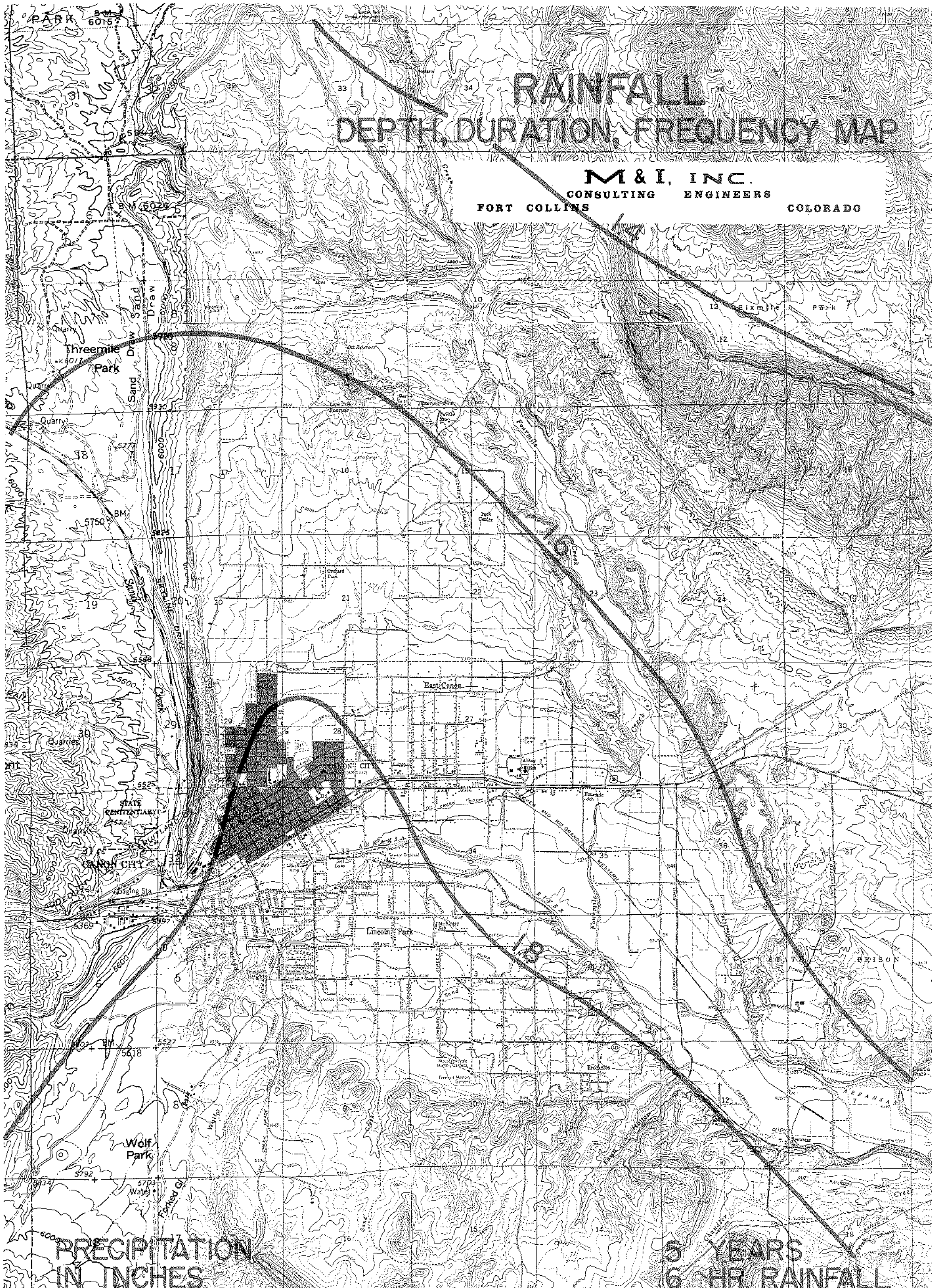

RAINFALL
DEPTH, DURATION, FREQUENCY MAP
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO
/4
/6
/8
Threemile Park
Sand Draw
STATE PENITENTIARY
CANON CITY
East Canon
Lincoln Park
Wolf Park
Sixmile Park
STATE PRISON
PRECIPITATION
IN INCHES
5 YEARS
6 HR RAINFALL

figure C-1

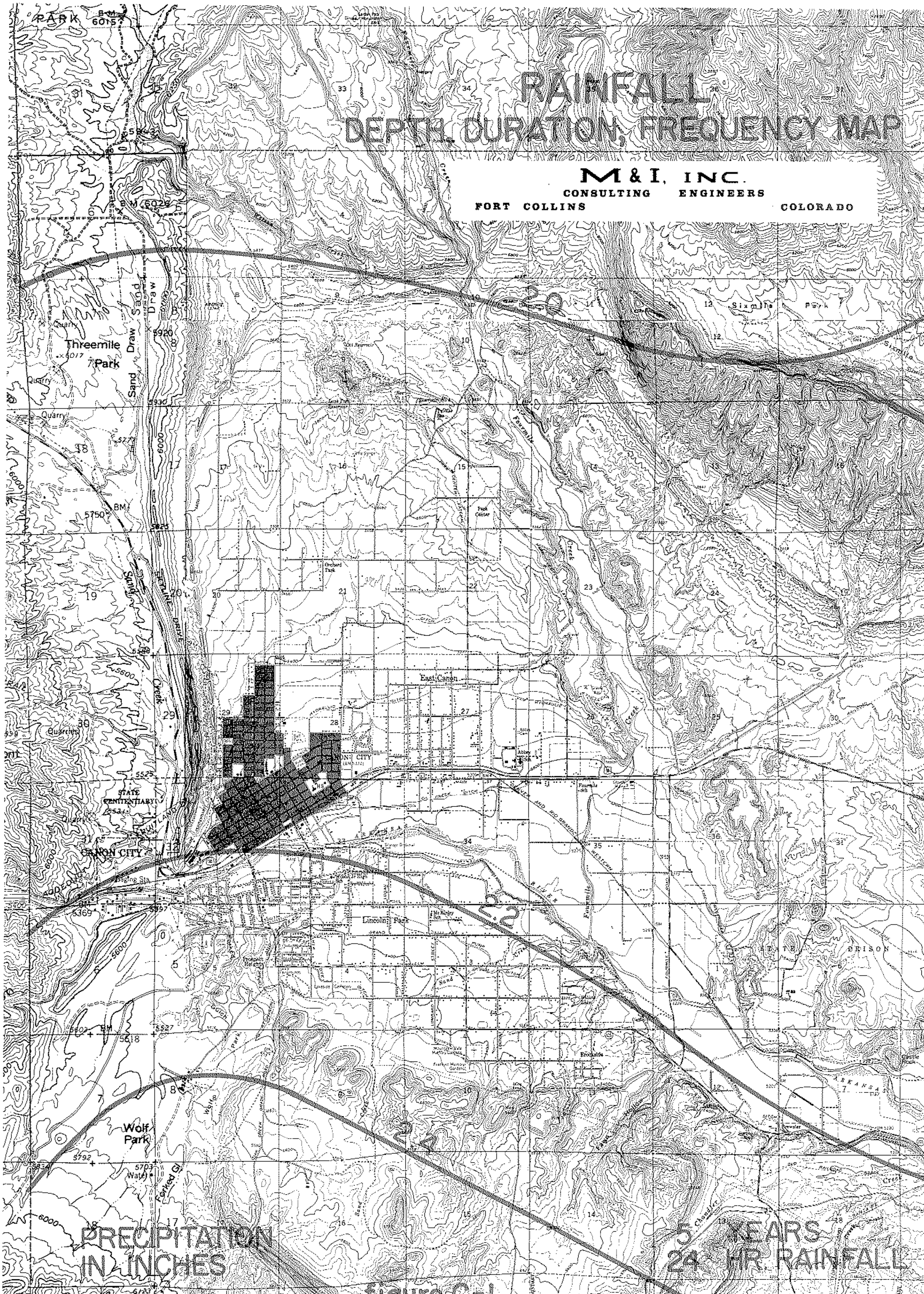
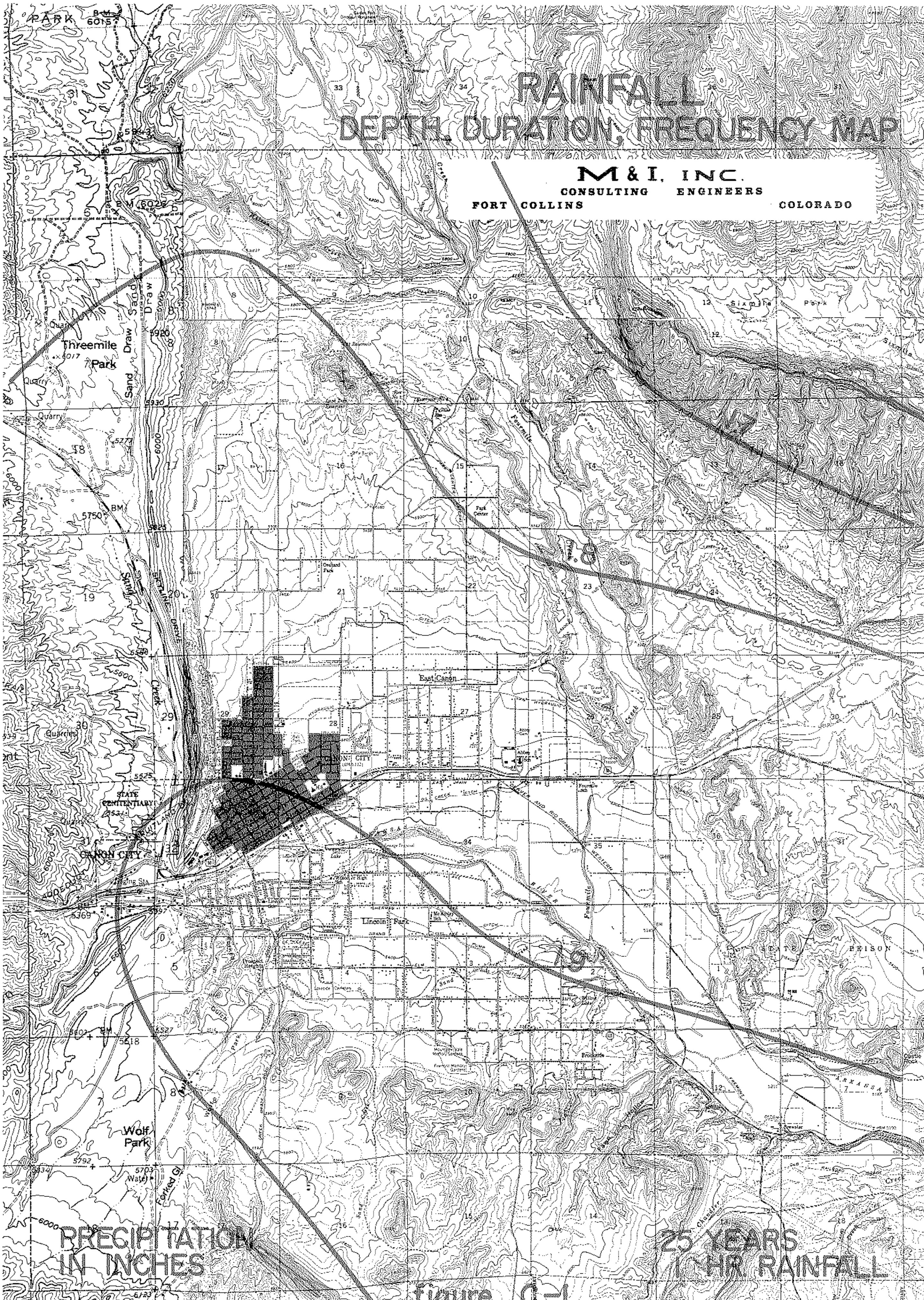

RAINFALL
DEPTH, DURATION, FREQUENCY MAP
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS
COLORADO
2.0
2.2
Threemile Park
Wolf Park
CANON CITY
East Canon
Lincoln Park
PRECIPITATION
IN INCHES
5 YEARS
24 HR. RAINFALL

figure C-1


RAINFALL
DEPTH, DURATION, FREQUENCY MAP
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO
1.7
1.8
1.9
PRECIPITATION
IN INCHES
25 YEARS
1 HR RAINFALL
figure C-1

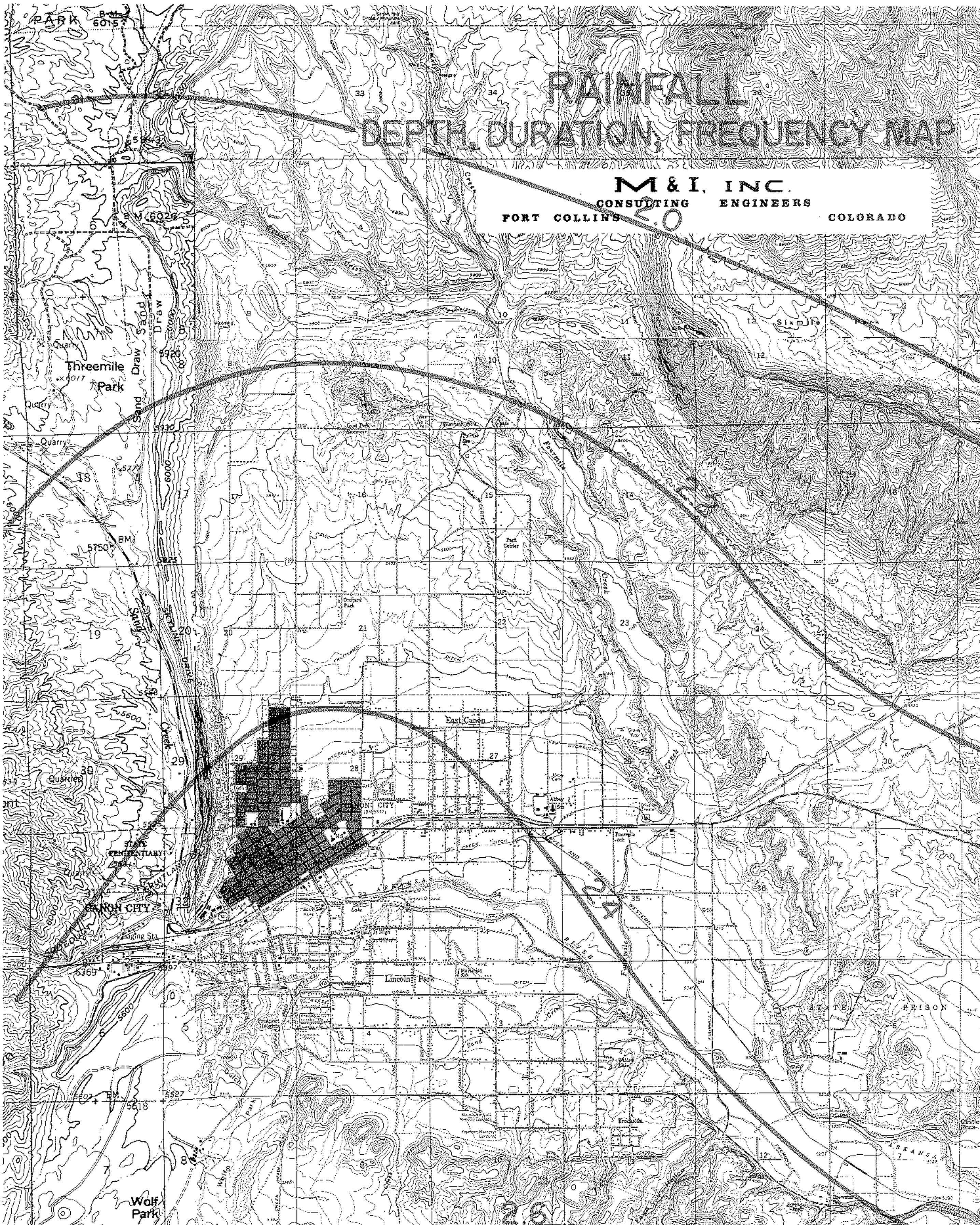

RAINFALL
DEPTH, DURATION, FREQUENCY MAP
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO
2.0
2.4
2.6
PRECIPITATION
IN INCHES
25 YEARS
6 - HR RAINFALL
Threemile Park
Wolf Park
Lincoln Park
East Canon
CANON CITY
STATE PENITENTIARY
STATE PRISON

figure C-I

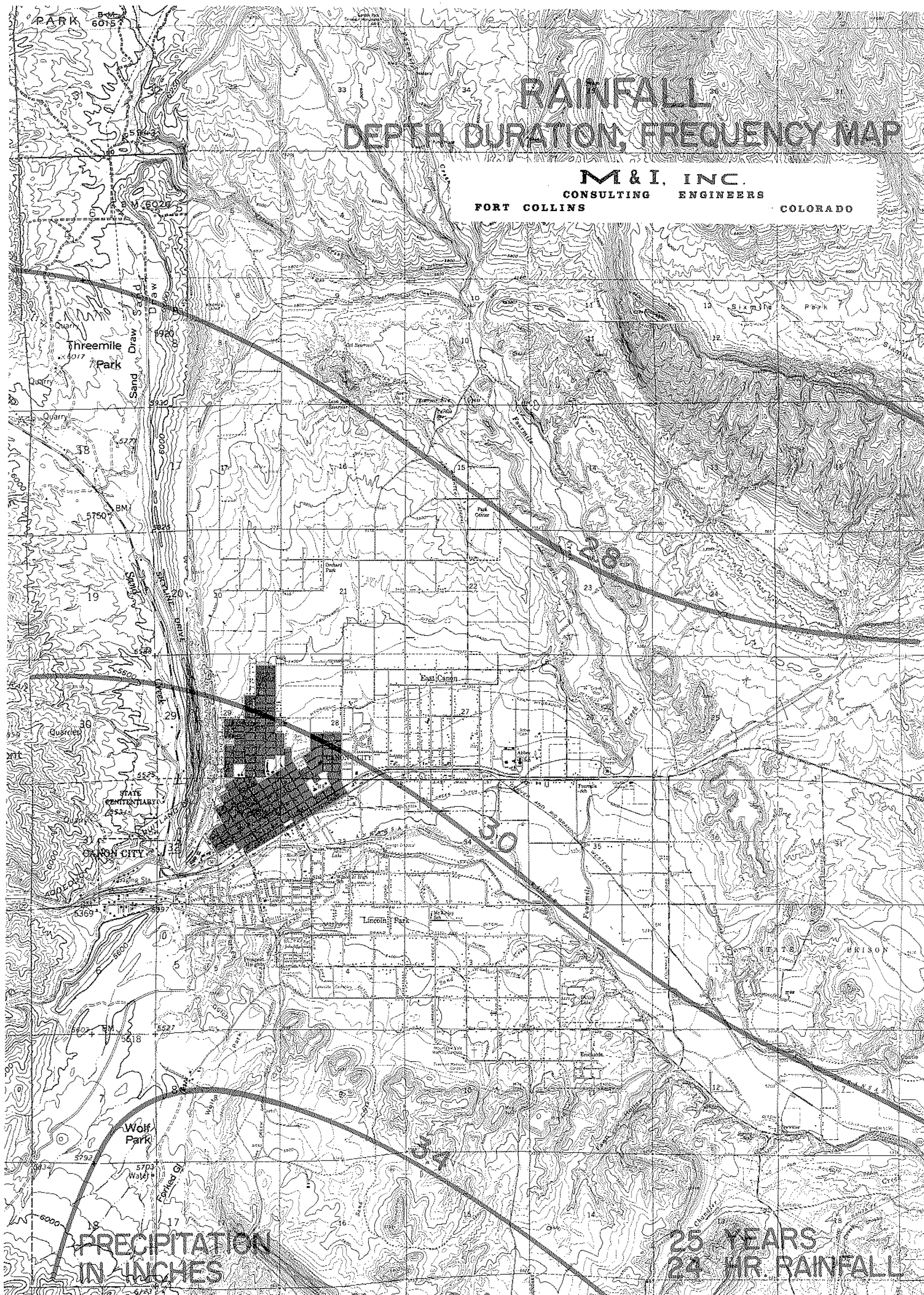

RAINFALL
DEPTH, DURATION, FREQUENCY MAP
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO
28
30
34
Threemile Park
CANON CITY
Lincoln Park
East Canon
STATE PENITENTIARY
Wolf Park
PRECIPITATION IN INCHES
25 YEARS
24 HR. RAINFALL

figure C-1

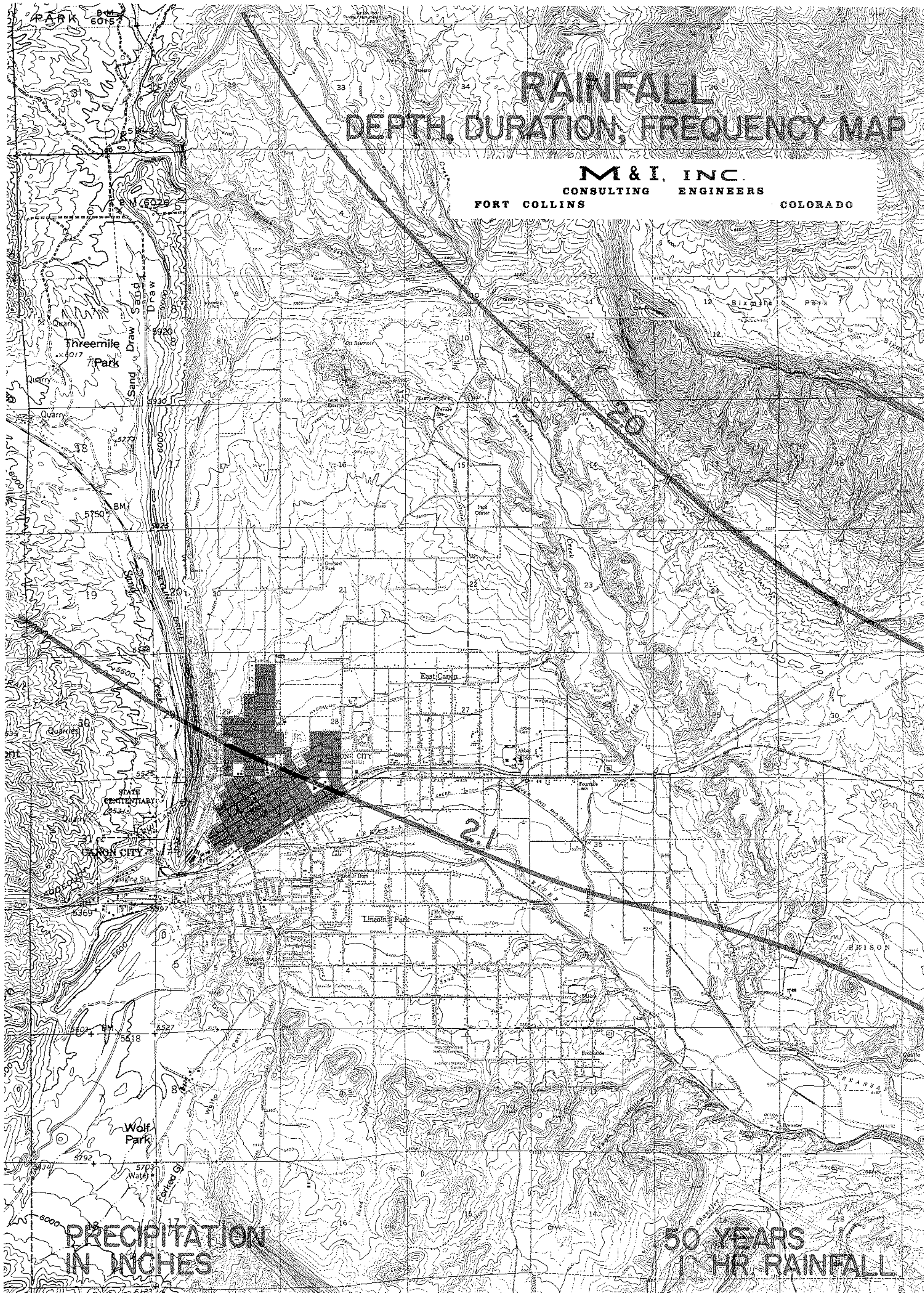
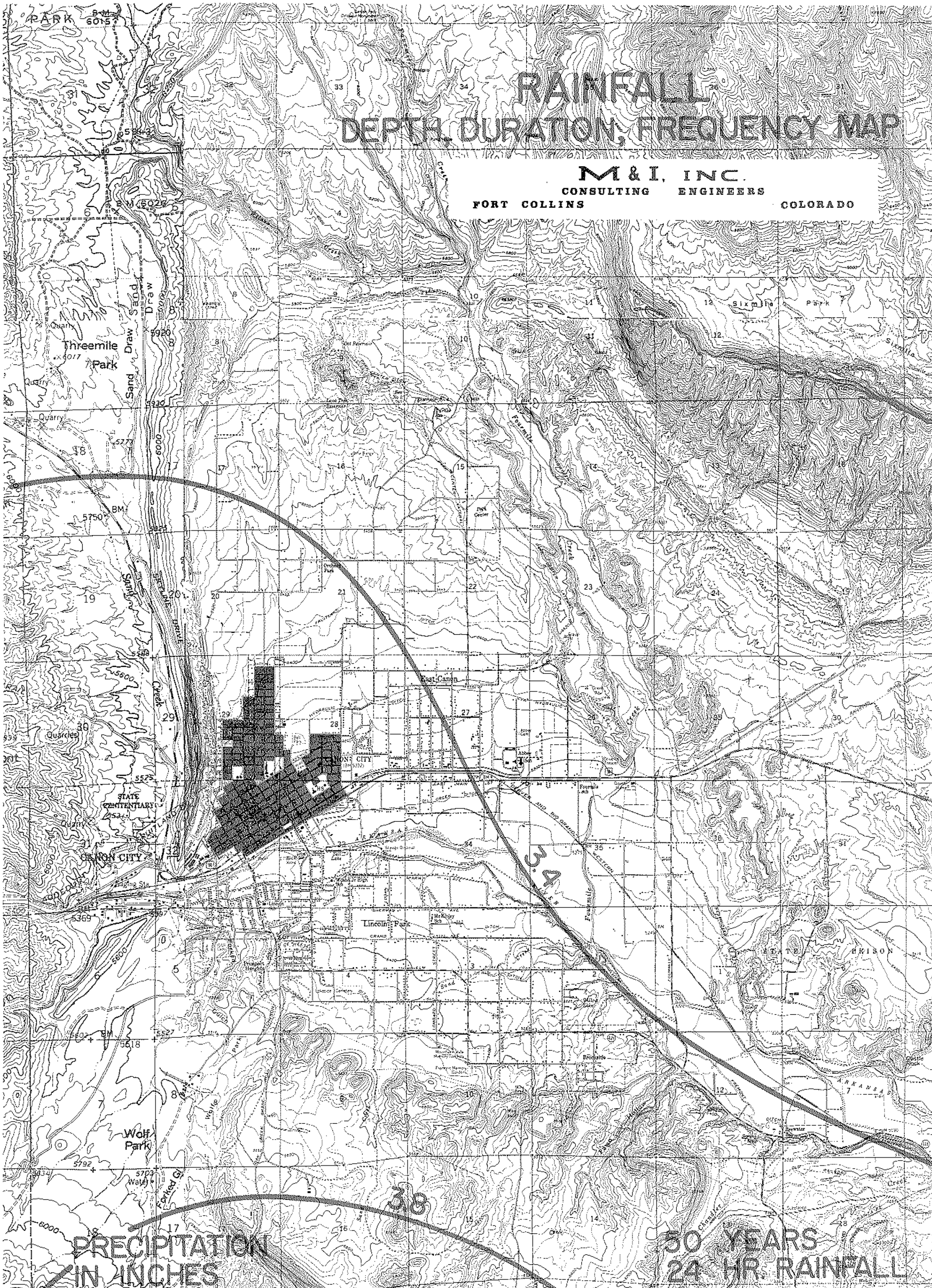
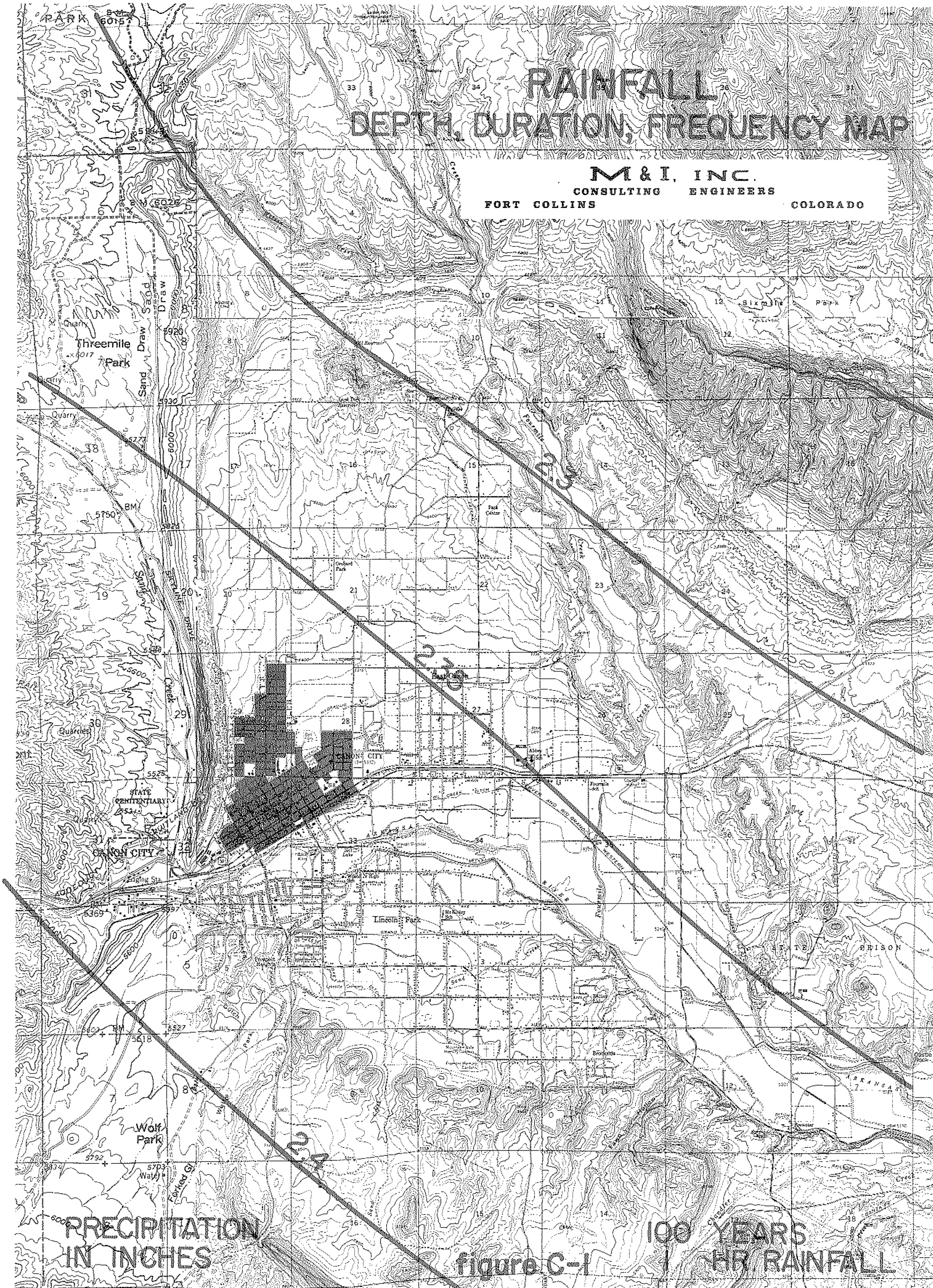

RAINFALL
DEPTH, DURATION, FREQUENCY MAP
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO
20
21
Threemile Park
East Canon
CANON CITY
STATE PENITENTIARY
Lincoln Park
Wolf Park
PRECIPITATION IN INCHES
50 YEARS
1 HR. RAINFALL

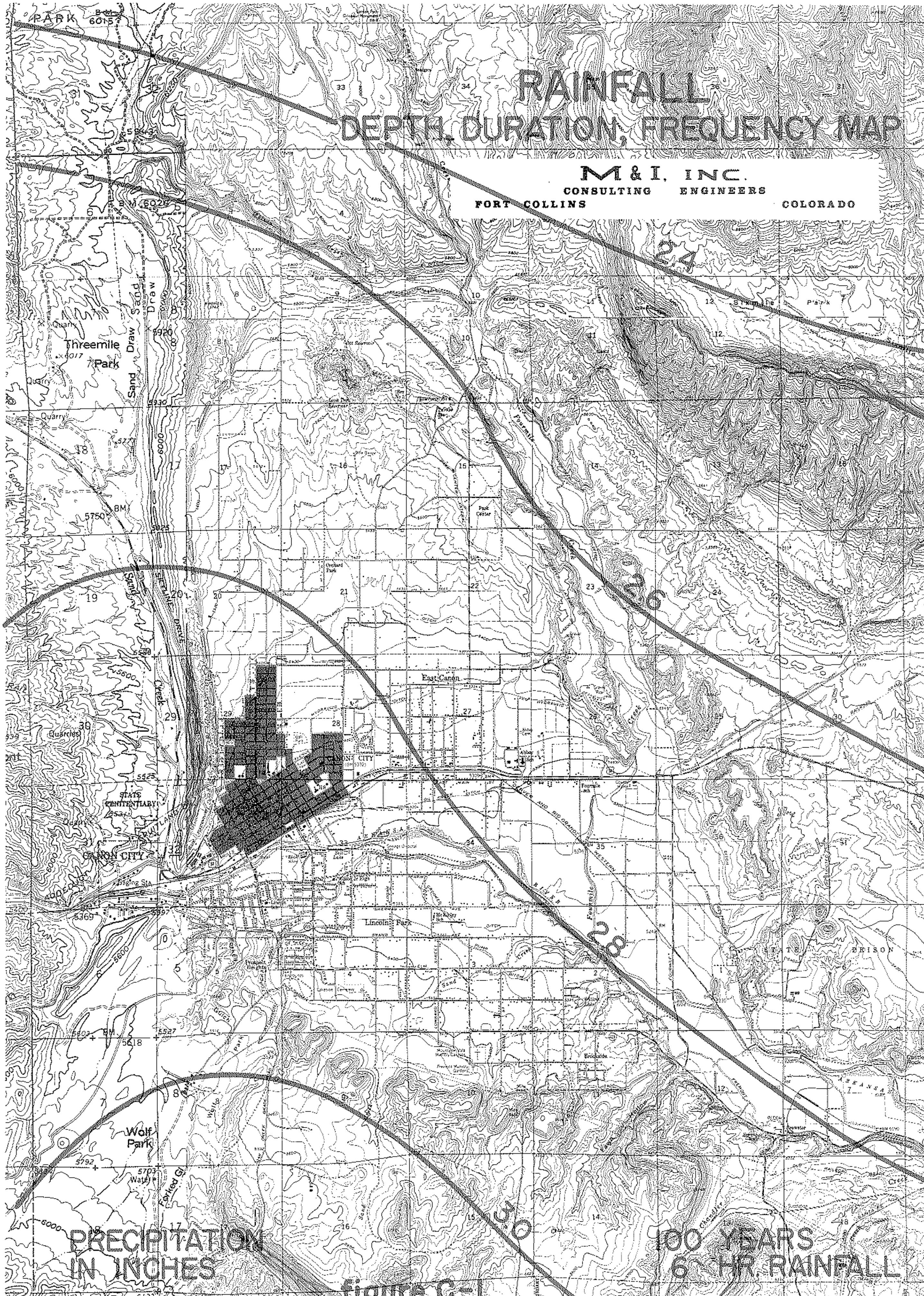
figure C-1


RAINFALL
DEPTH, DURATION, FREQUENCY MAP
M&L, INC.
CONSULTING ENGINEERS
FORT COLLINS
COLORADO
PRECIPITATION
IN INCHES
50 YEARS
6 HR RAINFALL
Threemile Park
Wolf Park
CANON CITY
East Canon
Lincoln Park
STATE PENITENTIARY

figure C-1


RAINFALL
DEPTH, DURATION, FREQUENCY MAP
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO
3.4
3.8
PRECIPITATION
IN INCHES
50 YEARS
24 HR. RAINFALL
Threemile Park
Wolf Park
Lincoln Park
East Canon
CANON CITY
STATE PENITENTIARY
figure C-1


RAINFALL
DEPTH, DURATION, FREQUENCY MAP
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS
COLORADO
2.3
2.4
Threemile Park
Sand Draw
Wolf Park
Lincoln Park
CANON CITY
STATE PENITENTIARY
PRECIPITATION
IN INCHES
figure C-1
100 YEARS
1 HR. RAINFALL



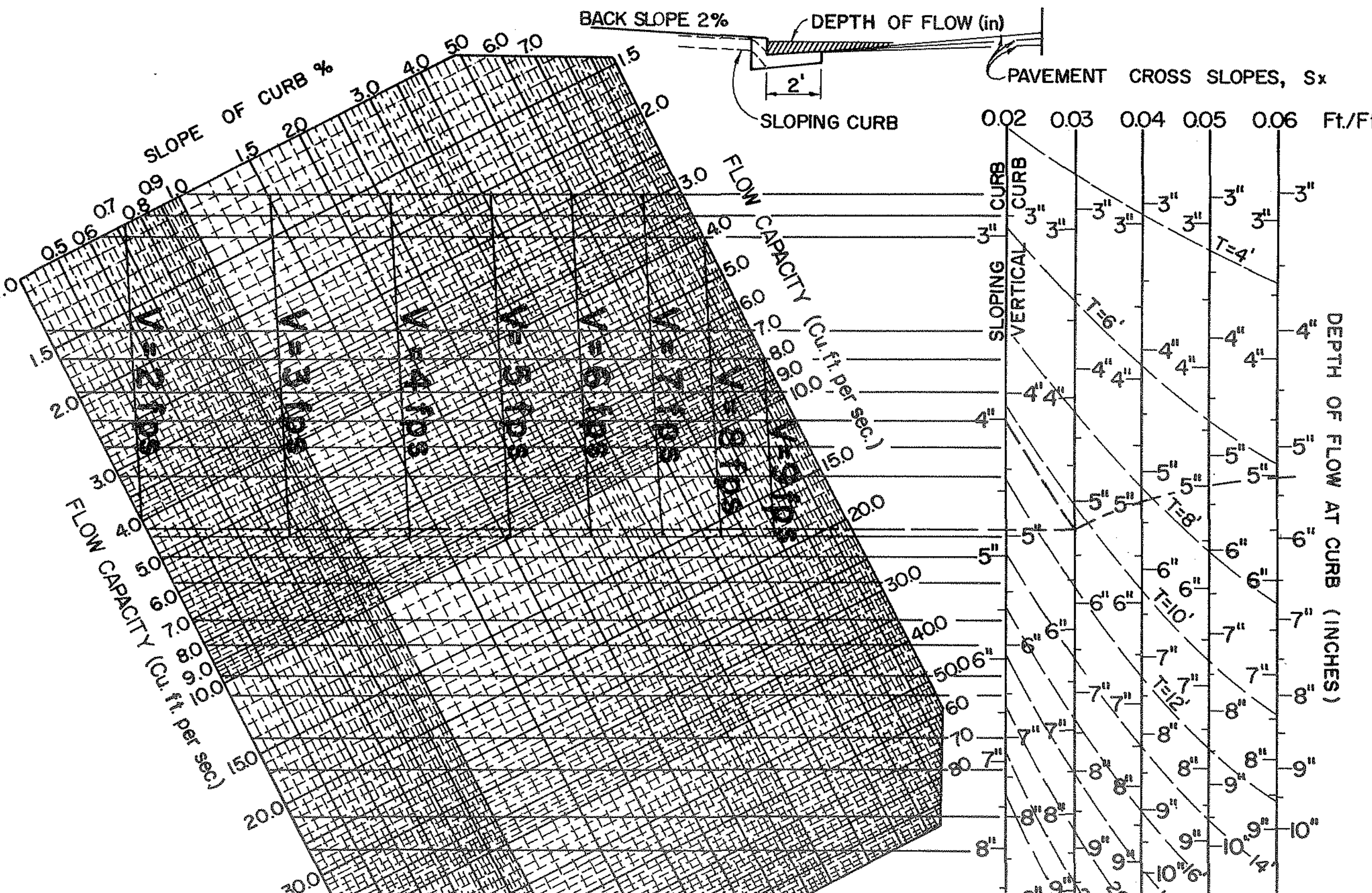
RAINFALL
DEPTH, DURATION, FREQUENCY MAP
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO
24
26
28
30
Threemile Park
Wolf Park
East Canon
Lincoln Park
CANON CITY
STATE PENITENTIARY
STATE PRISON
PRECIPITATION
IN INCHES
100 YEARS
6 HR. RAINFALL

figure C-1


RAINFALL
DEPTH, DURATION, FREQUENCY MAP
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS
COLORADO
3.4
3.8
4.2
PRECIPITATION IN INCHES
100 YEARS
24 HR. RAINFALL
Threemile Park
Wolf Park
CANON CITY
STATE PENITENTIARY
East Canon
Lincoln Park
Sixmile Park

figure C-1

figure C-2

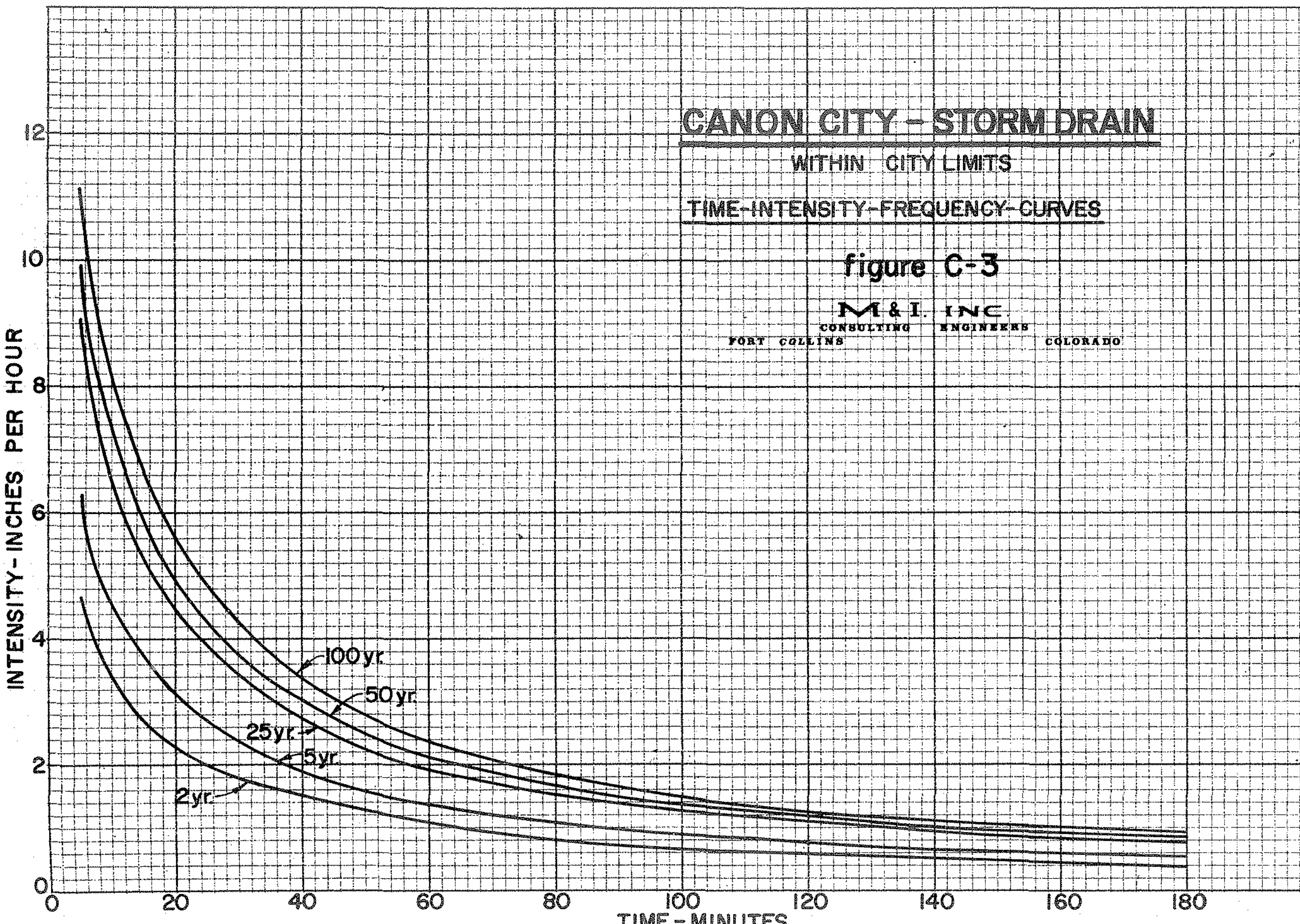


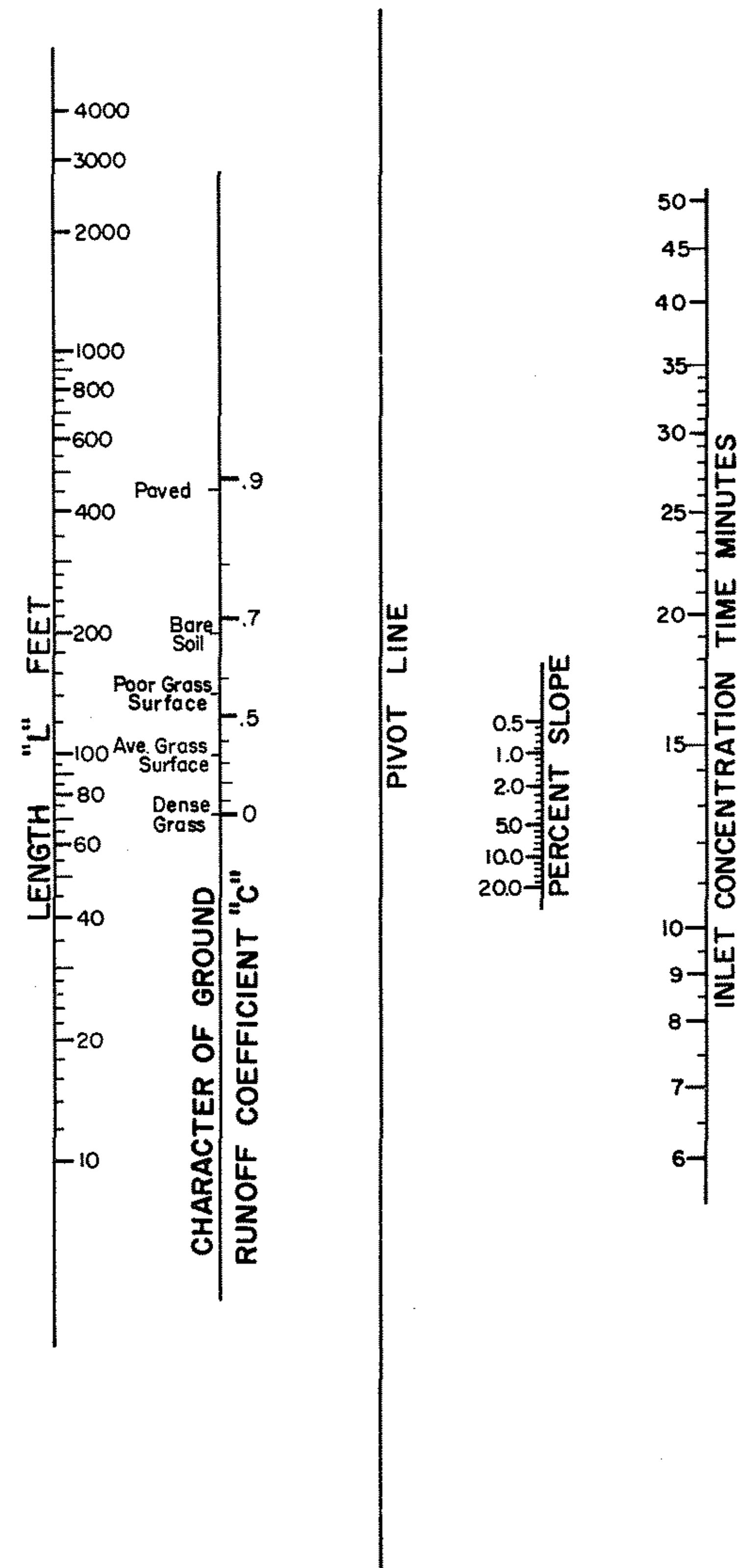
MODIFIED MANNINGS FORMULA
Q = 0.56 (Z/n) (S 1/2) (D 8/3)
V = Q/A Velocity in Feet / Sec.
Velocity Shown For Gutter With Pavement Slope 0.03-0.04 Ft./Ft.

Q = Cubic Feet Per Second
Sx = Pavement Cross Slope Ft./Ft.
Z = Reciprical Of Cross Slope Sx
n = Friction Factor 0.017
S = % Slope Of Curb & Gutter
D = Depth Of Flow At Curbline (Feet)
T = Width Of Flow From Curbline (Ft. Avg.)

CAPACITY CHART
CURB GUTTER FLOWS vs. DEPTH & PAVEMENT SLOPE
DRAINAGE STUDY

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

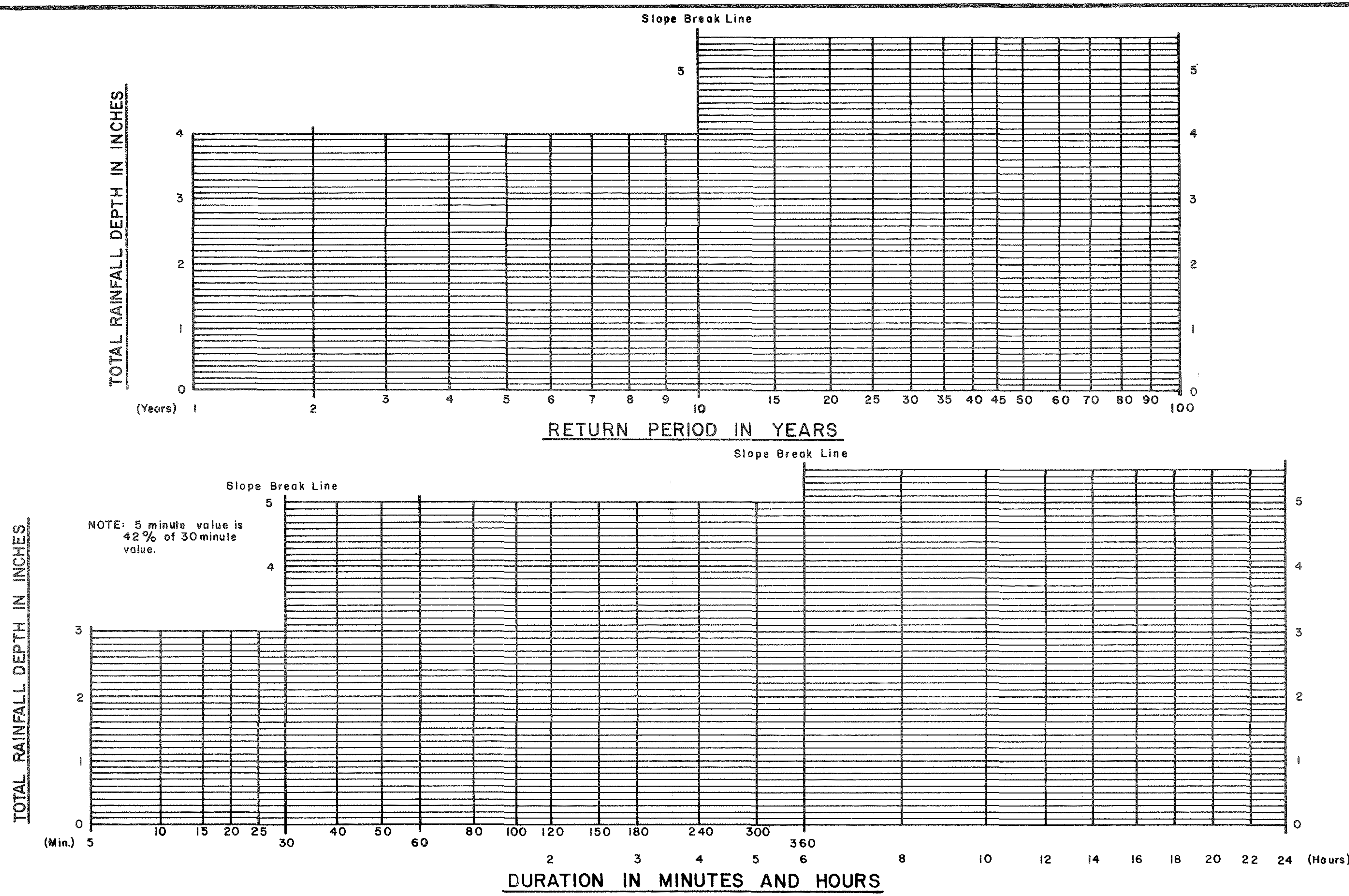

CANON CITY - STORM DRAIN
WITHIN CITY LIMITS
TIME-INTENSITY-FREQUENCY-CURVES
figure C-3
M & I. INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO
INTENSITY - INCHES PER HOUR
TIME - MINUTES
100 yr.
50 yr.
25 yr.
5 yr.
2 yr.
0
2
4
6
8
10
12
0
20
40
60
80
100
120
140
160
180



OVERLAND FLOW TIME

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

figure C-4



DENVER REGIONAL COUNCIL OF GOVERNMENTS

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

Section ___, T. ___, R. ___ W.

RAINFALL
DEPTH - DURATION - FREQUENCY GRAPHS

figure C-5

STORM DRAINAGE SYSTEM PRELIMINARY DESIGN DATA

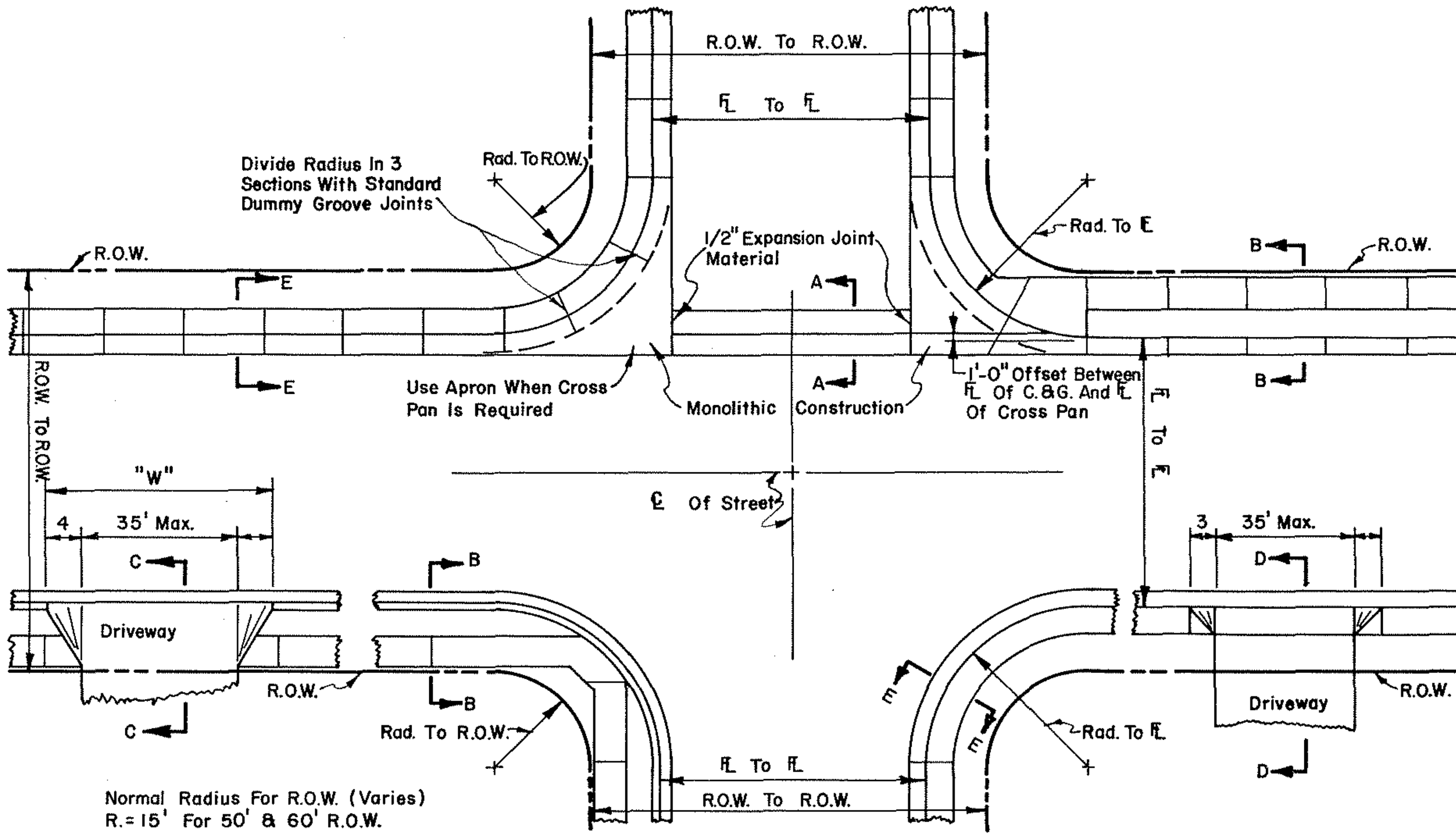
Location of Design Point	Basins	Length ft.	Inlet Time min.	Flow Time		Time of Concentration min.	Coefficient "C"	Intensity "I" in./hr.	Area "A" acre	Direct Runoff cfs	Other Runoff cfs	Summation Runoff cfs	Street		Pipe			Street		Pipe		Remarks
				Street min.	Pipe min.								Slope %	Allowable Capacity cfs.	Slope %	Size in.	Capacity cfs	Design cfs	Velocity fps	Design cfs	Velocity fps	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

figure C-6

STORM DRAINAGE SYSTEM PRELIMINARY DESIGN DATA

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

CROSS PAN AND CURB & GUTTER DETAILS



Normal Radius For R.O.W. (Varies)
R.= 15' For 50' & 60' R.O.W.

Radius To Flowline (FL):
R.= 20' For 50' R.O.W.
R.= 23' For 60' R.O.W.

NOTES:

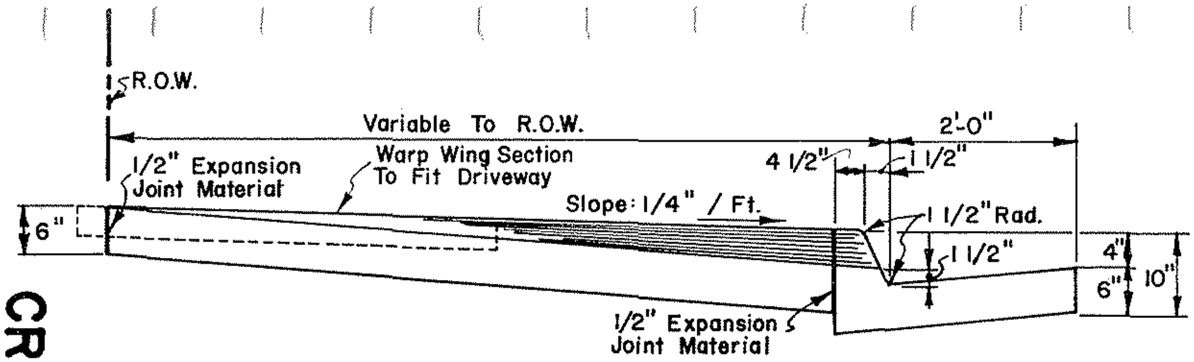
1. Right Of Way Line (R.O.W.) May Also Be Known As Property Line (PL)
2. Warped Wing Sections Shall Extend From FL To Back Of Sidewalk.

TYPICAL INTERSECTION PLAN

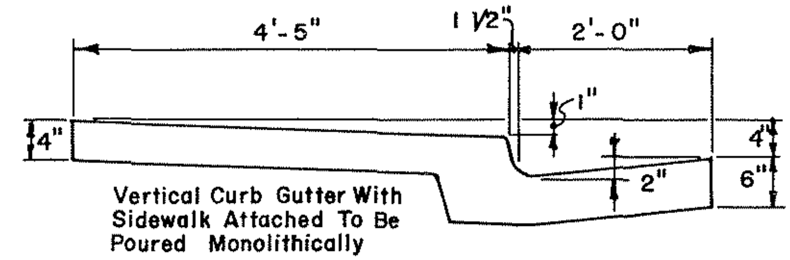
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

figure C-7

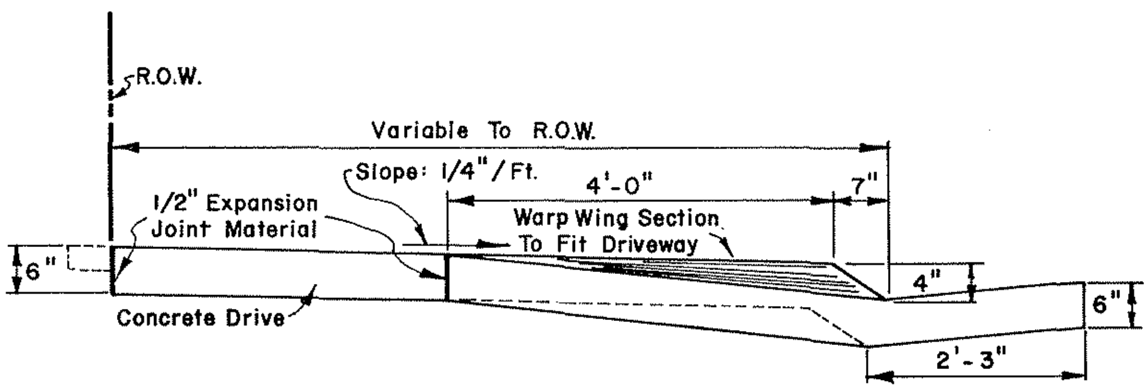
CROSS PAN & C. & G. DETAILS



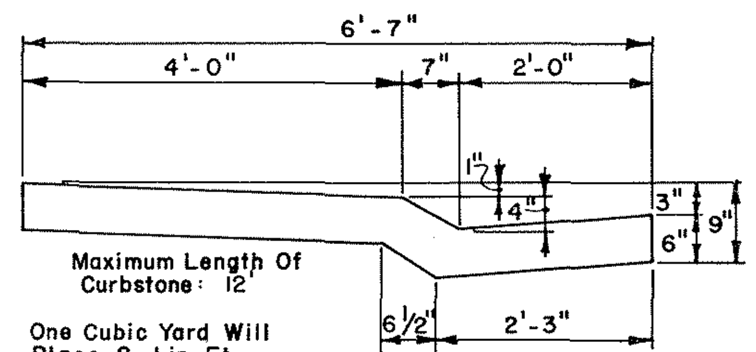
DRIVEWAY SECT. – 6" VERT. C. & G.
SECTION C–C



6" VERT. C. & G. W/MONOLITHIC SIDEWALK
SECTION E–E



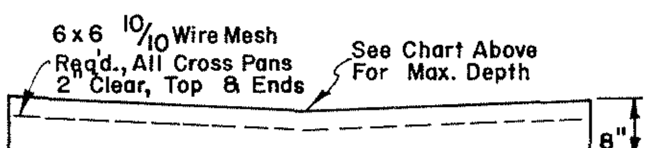
DRIVEWAY SECT. – COMB. C., G. & SIDEWALK
SECTION D–D



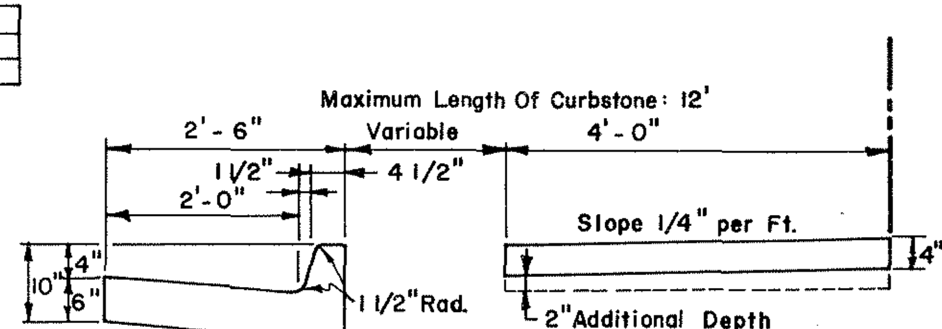
(Common Names: "Hollywood" C. & G.
4" Mountable C. & G.)

COMB. CURB, GUTTER & SIDEWALK
SECTION E–E

6' Width — Cross Street Grade 0.3% To 2.0%	Max. Depth 1 1/2"
10' Width — Cross Street Grade 2.0% To 4.0%	Max. Depth 2 1/2"
15' Width — Cross Street Grade 4.0% And Over	Max. Depth 3 1/2"



CROSS PAN
SECTION A–A



One Cubic Yd. Will Place 18 L.F.

(Common Name: 6" Highback)

COMB. 6" VERT. C. & G.

(Common Name: Detached Walk)
One Cu. Yd. Will Place 20 L.F.

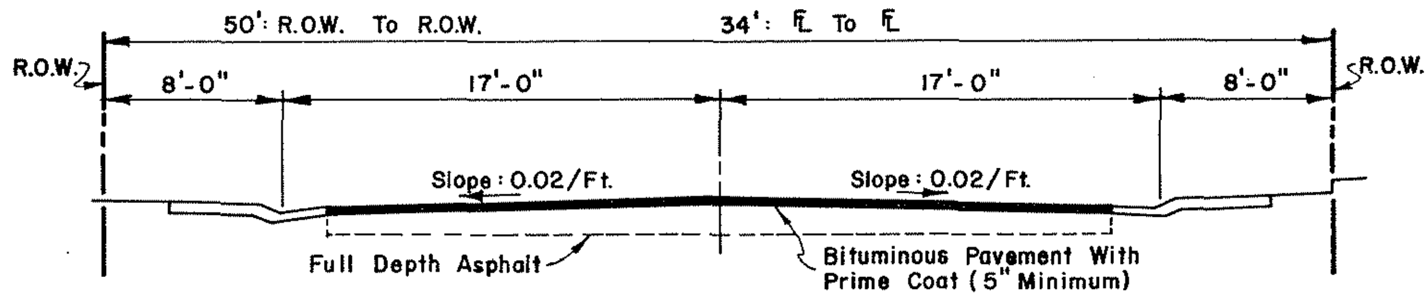
SIDEWALK SLAB

SECTION B–B

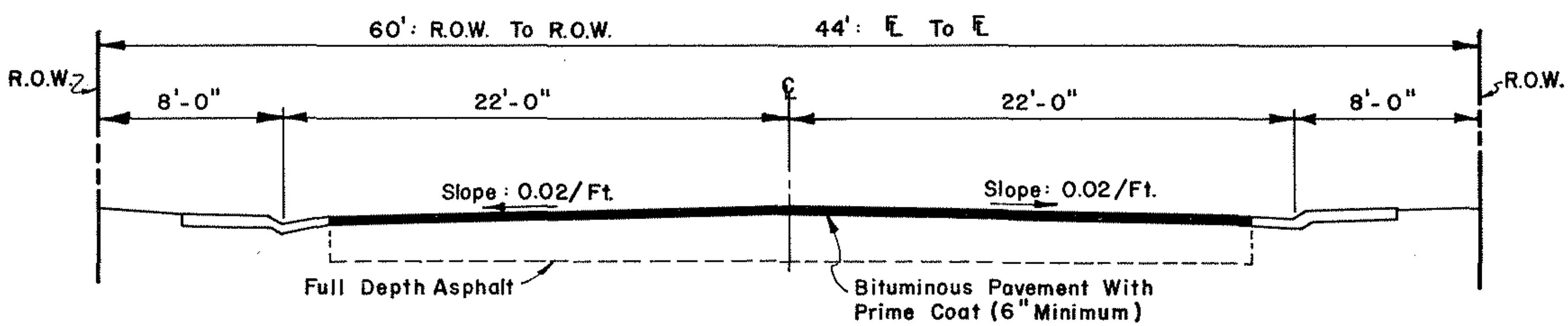
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

figure C-7

STREET CROSS SECTIONS



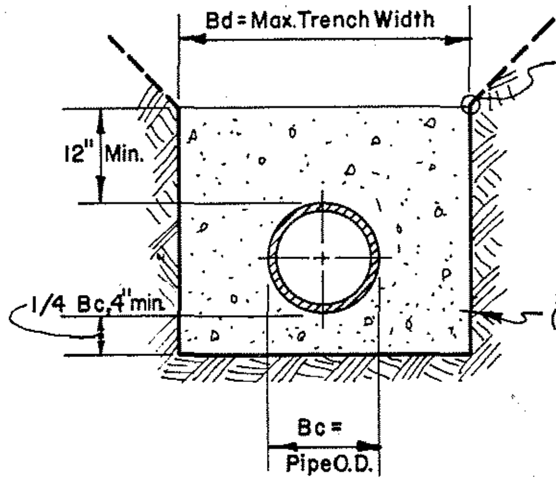
LOCAL STREET



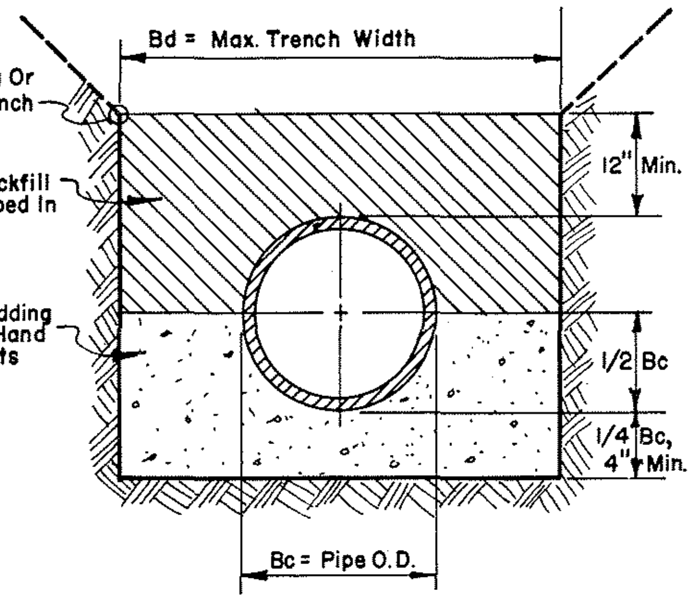
COLLECTOR STREET

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

figure C-8



15" DIAM. & SMALLER



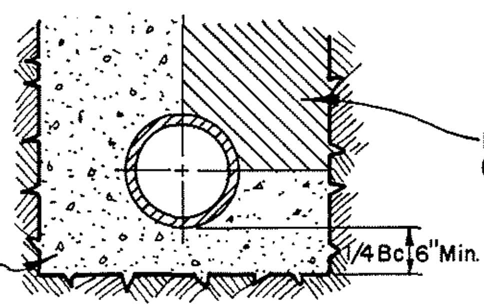
18" DIAM. & LARGER

Nominal Diameter	Max. Trench Width At A Point 12" Above Pipe
33" & Smaller	Bd = O.D. + 16"
36" & Larger	Bd = O.D. + 30"

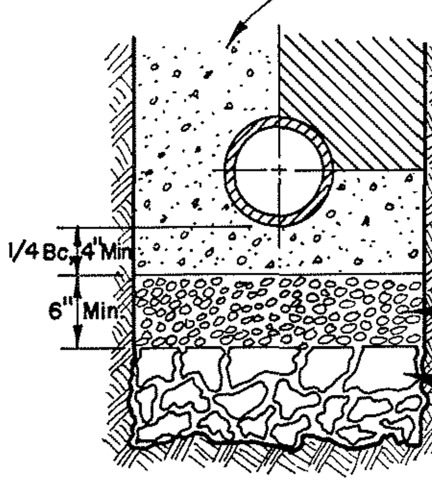
NOTES:

1. Bell Holes Shall Be Excavated At All Bell & Spigot Joints

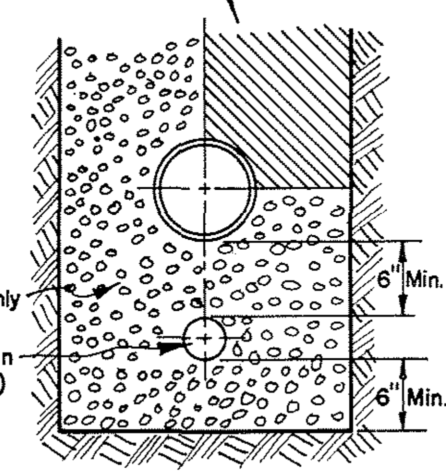
IDEAL TRENCH CONDITIONS



ROCK EXCAVATION



UNSTABLE SUBGRADE CONDITION



SUB-DRAIN

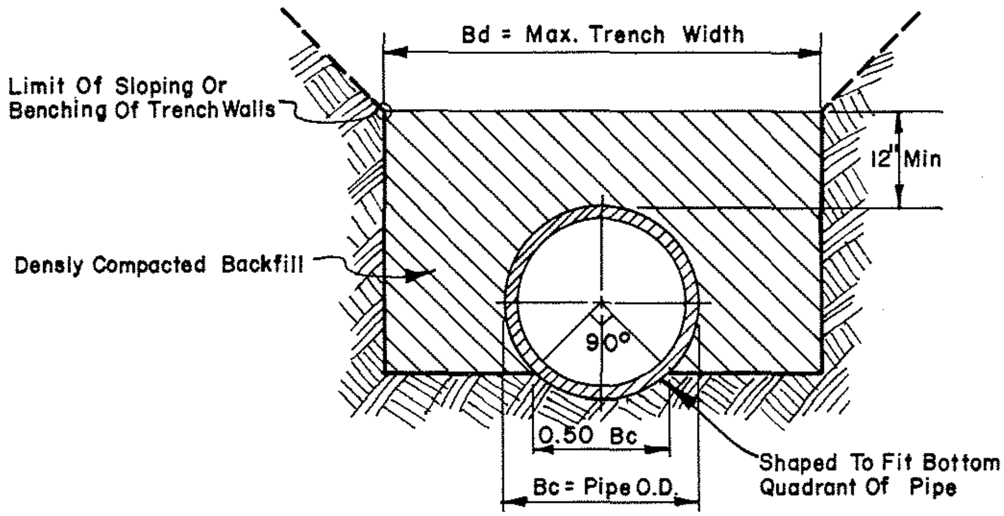
LOAD FACTOR: 1.9

NOT TO SCALE

STORM SEWER BEDDING DETAILS

figure C-9

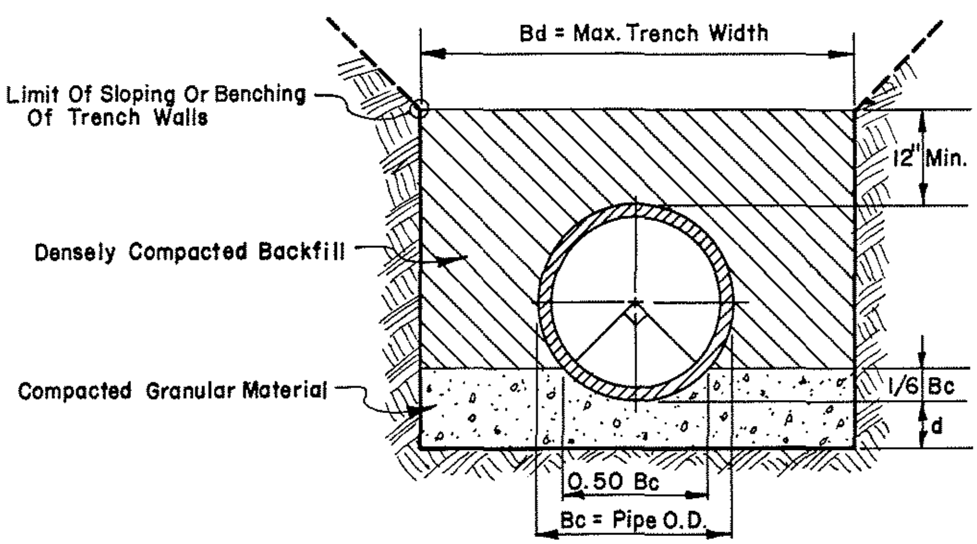
M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO



SHAPED SUBGRADE
NOT TO SCALE

Nominal Diameter	Max. Trench Width At A Point 12" Above Pipe
33" & Smaller	Bd = O.D. + 24"
36" & Larger	Bd = O.D. + 30"

Nominal Diameter	Minimum d
18" & Smaller	2"
21" To 36"	3"
42" & Larger	4"



NOTES:
1. This Type Of Bedding Shall Only Be Used Upon Specific Approval Of The City Engineer.
2. Bell Holes Shall Be Excavated At All Bell & Spigot Joints.

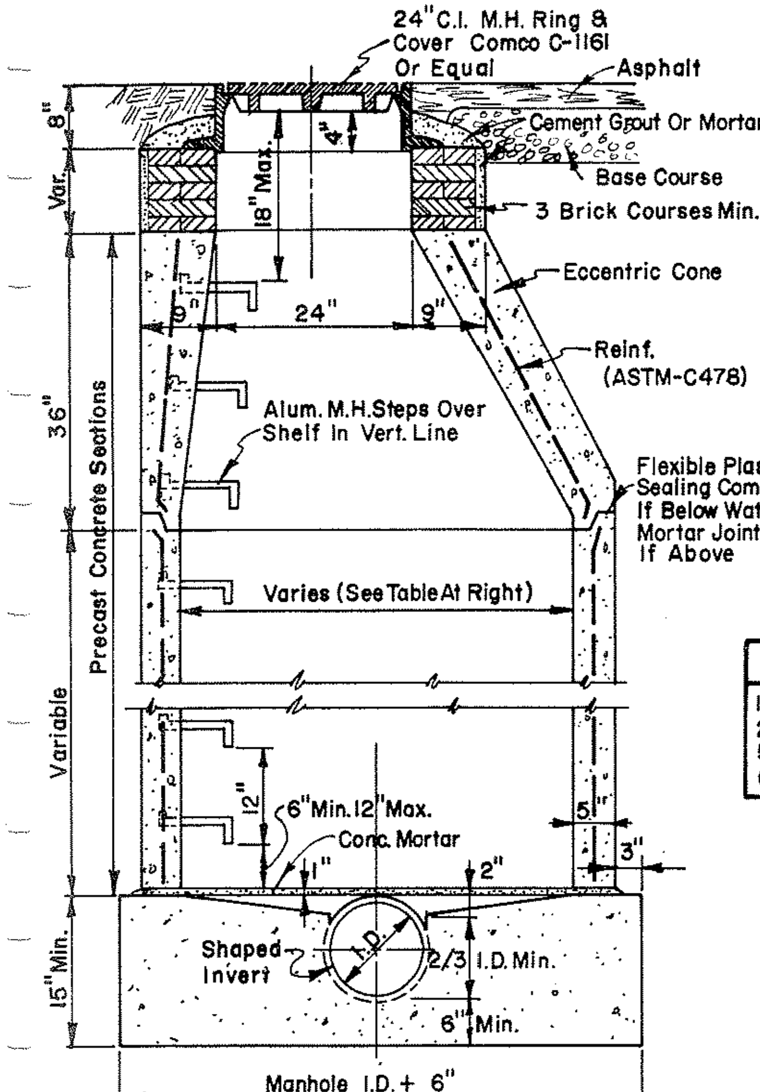
GRANULAR FOUNDATION
NOT TO SCALE

Load Factor = 1.5

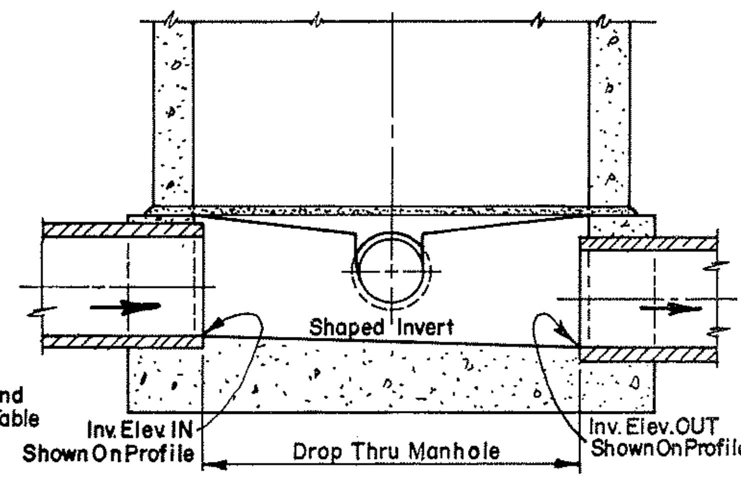
STORM SEWER BEDDING DETAILS

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

figure C-10



TYPICAL MANHOLE

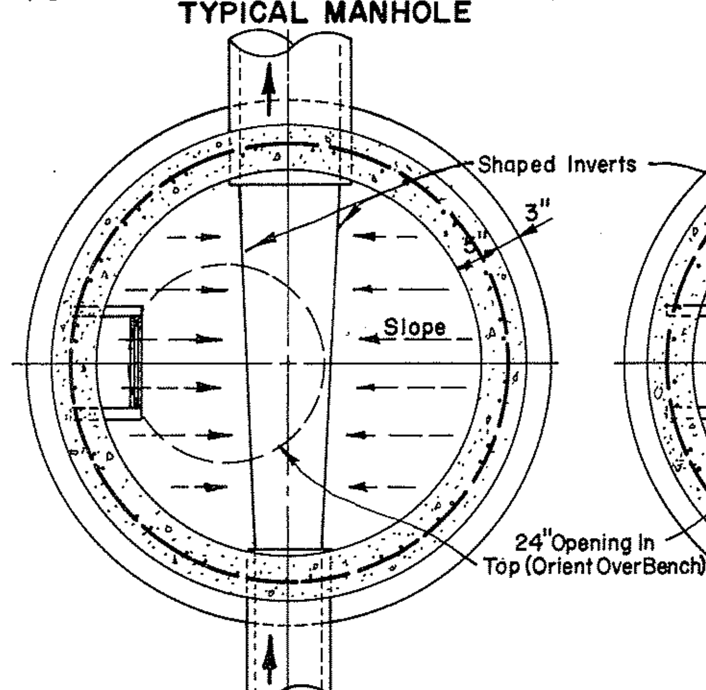


SECTION

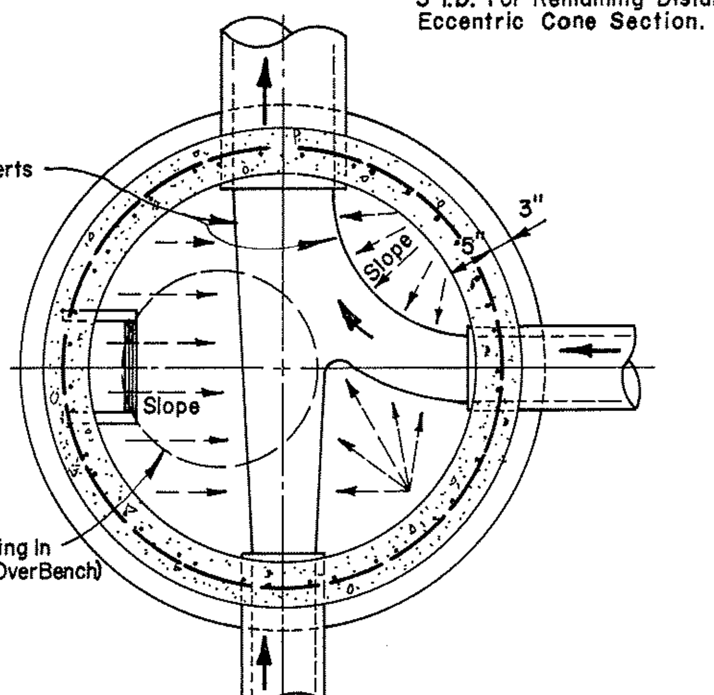
Pipe I.D.	Manhole I.D.
18" & Smaller	4'-0"
21" To 48"	5'-0"
54"	6'-0"
60" & Larger	Special Design

NOTES:

1. Manhole Barrel Minimum Diameter Shall Conform To Table Above
2. Shaping For Smooth M.H. Inverts May Be Done With Cement Mortar
3. The Manhole Steps Shall Be Similar And Equal To Alcoa Alum. Co. No. 12653 B
4. Precast Sections To Conform To ASTM C-478
5. 6'-0" M.H. Barrels Shall Be 6' I.D. To A Point 6'-6" Above M.H. Base, Then Reduce To 5' I.D. For Remaining Distance Or To Eccentric Cone Section.



CHANGE IN PIPE SIZE

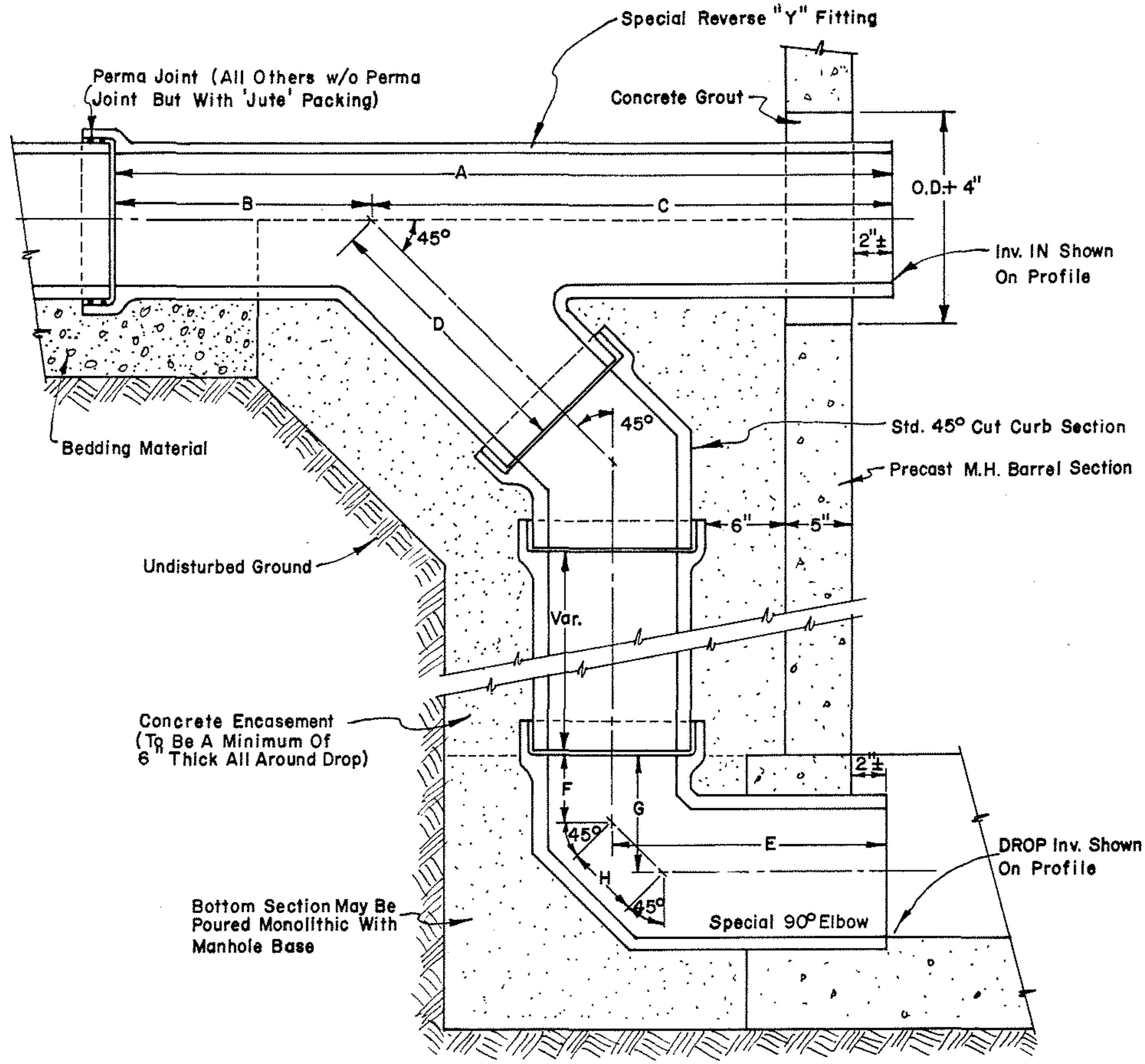


JUNCTION M.H. ALIGNMENT CHANGE

MANHOLE DETAILS

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

figure C-11



Pipe I.D.	A	B	C	D	E	F	G	H
8"	60"	26"	34"	18"	21"	4½"	8"	4⅝"
10"	60"	20"	40"	21"	21"	5⅛"	9"	5½"
12"	60"	18"	42"	24"	21"	5⅞"	10¾"	5⅞"
15"	78"	38"	50"	30"	24"	7"	12½"	7¾"

SECTION THRU DROP

NOTES:

1. Vit. Clay Pipe & Fittings (ASTM C-700-71T) Shown, Details Similar For Concrete Pipe (ASTM C-14 & C-76)

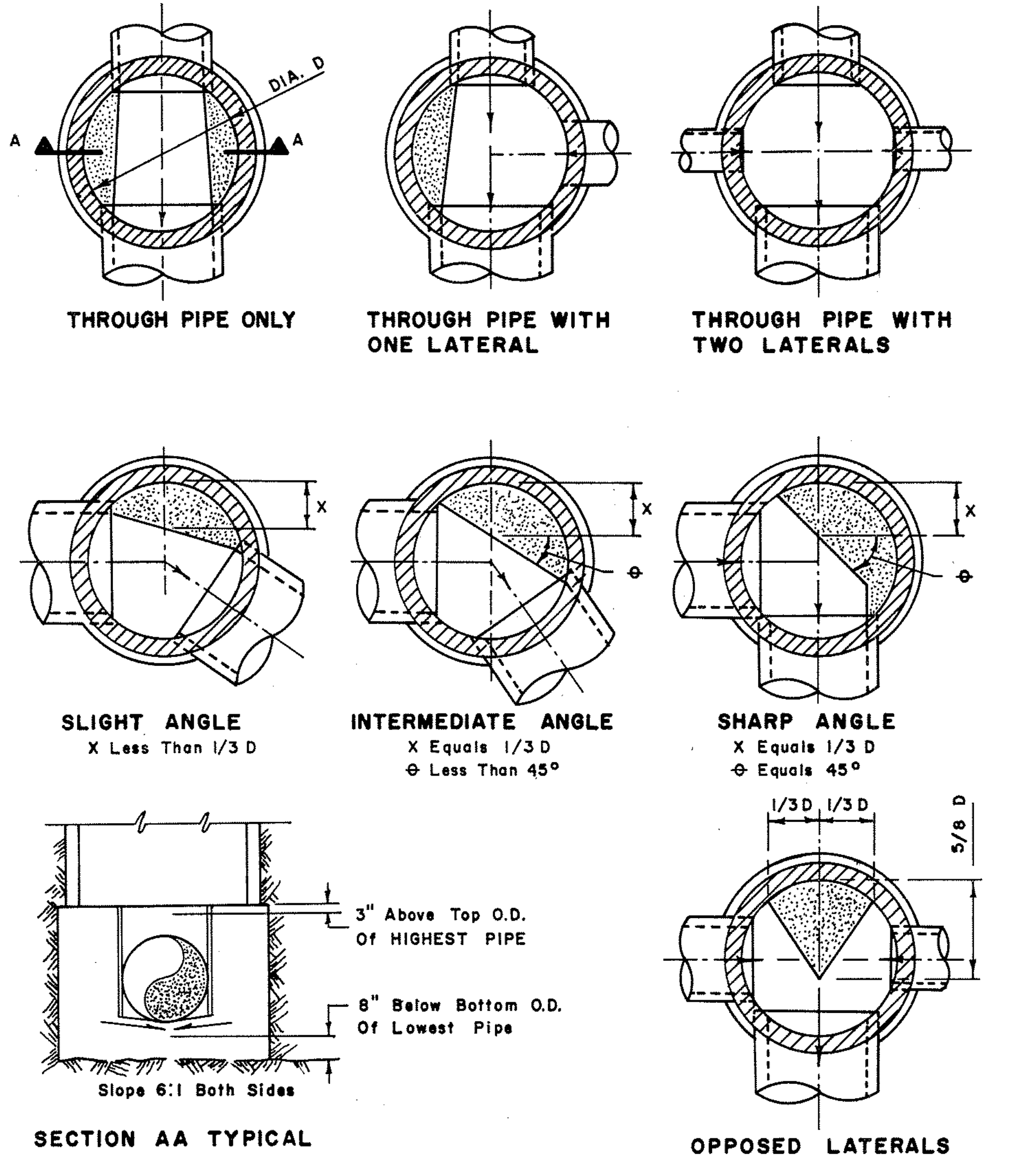
2. For Payment Purpose; All Fittings, Pipe & Concrete Encasement Except Special "Y" Fitting Shall Be Included In The Cost Of Outside Drop. The Cost Of The Special "Y" Fitting Shall Be Included In The Unit Price Bid For Line Pipe.

3. Diameter Of Drop Shall Not Be Less Than The Line Pipe Diameter.

DROP MANHOLE DETAIL

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

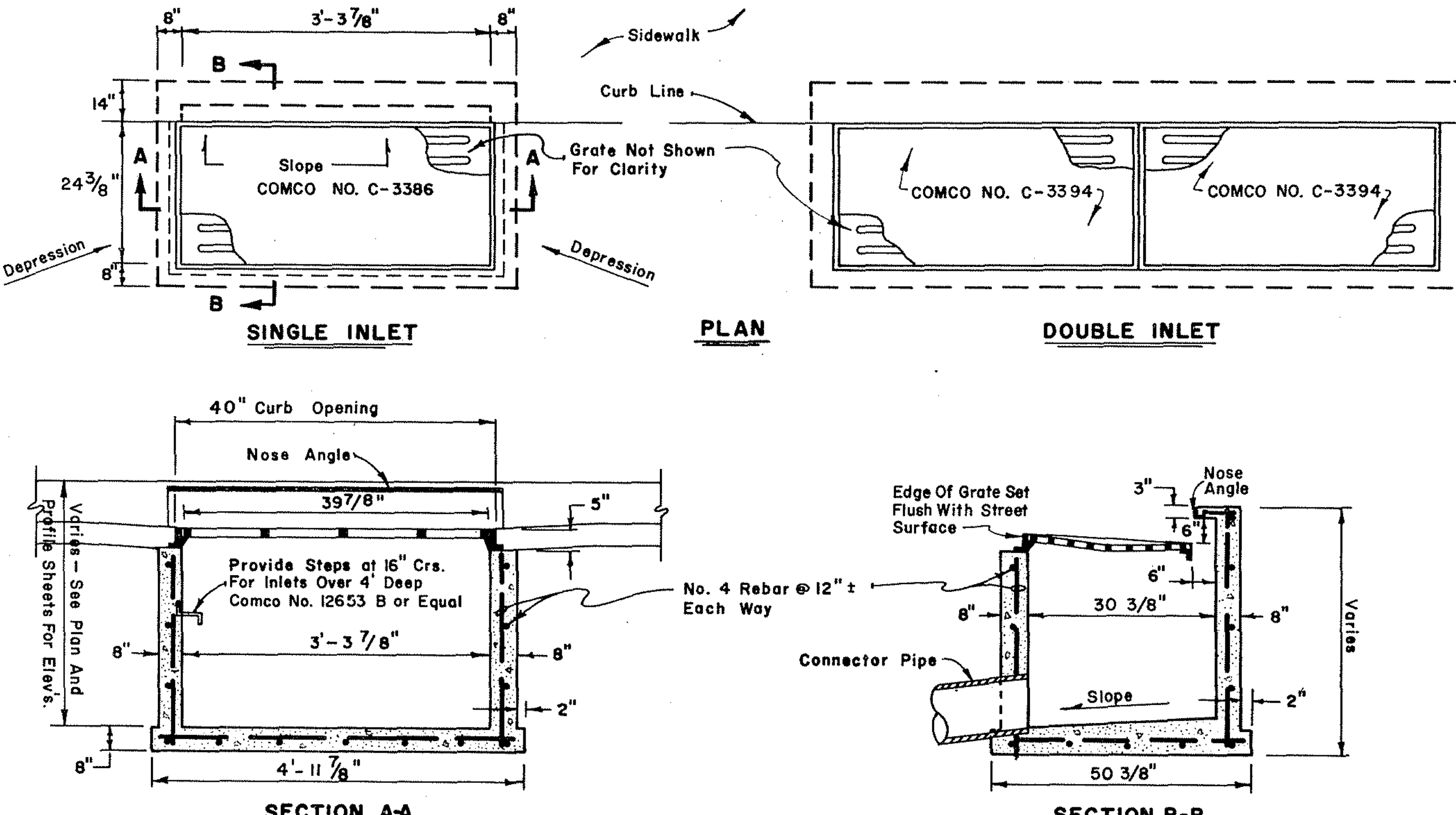
figure C-12



STORM SEWER
DEFLECTOR DETAILS

figure C-13

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO



GRATED INLET DETAILS

No Scale

M & I, INC.
CONSULTING ENGINEERS
FORT COLLINS COLORADO

figure C-14

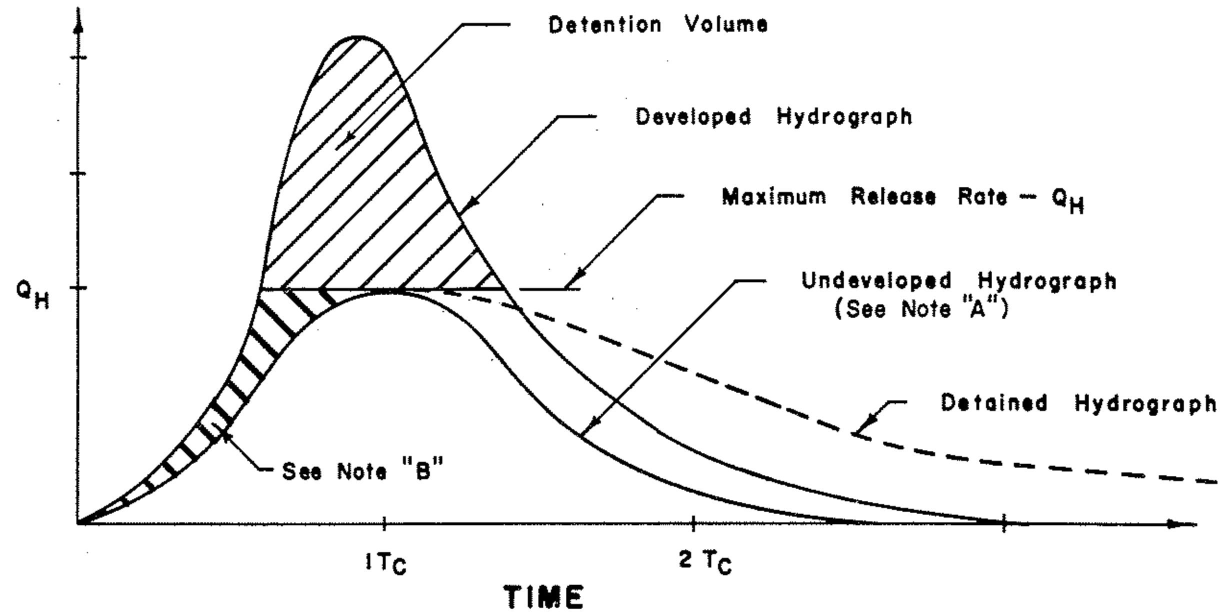


FIGURE C-15

T_c – Concentration Time Of Historic Basin

Q_H – Historic Peak Runoff Rate – 5 Year Storm

Notes:

A – The Maximum Release Rate From Any Detention Areas Shall Not Exceed The Maximum Historic Runoff For A 5 Yr. Storm

B – Additional Volume Which May be Required By The City Engineer

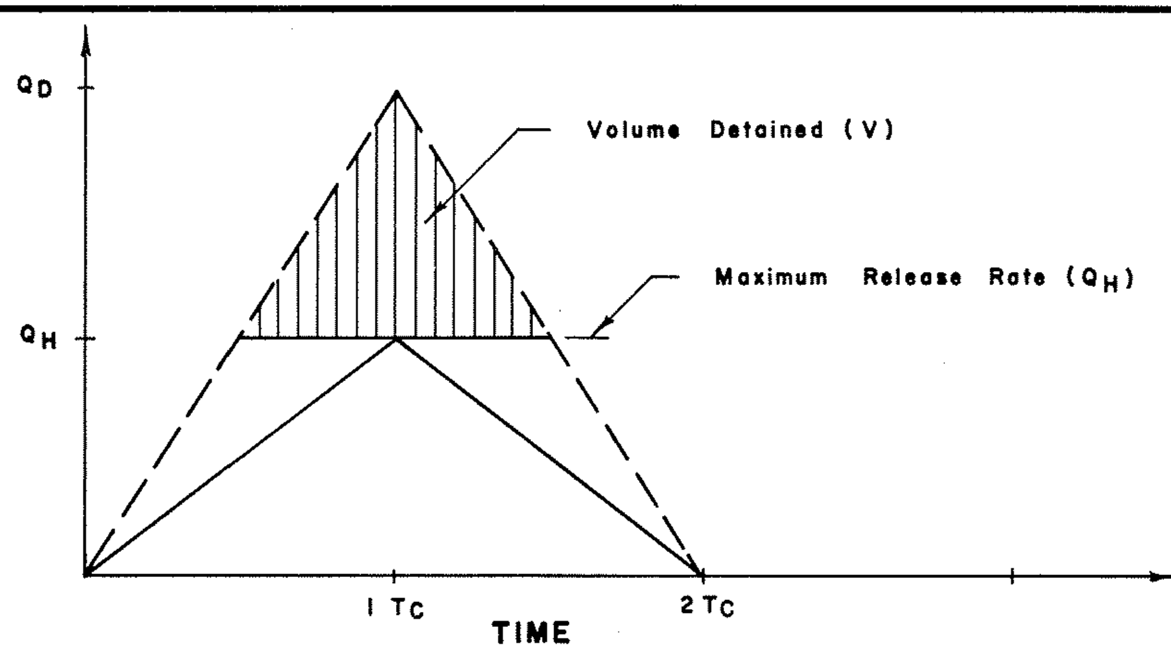


FIGURE C-16

$$V = \frac{T_C (Q_D - Q_H)^2}{Q_D} \quad \frac{(60)}{(43560)}$$

Where:

Q_D – Maximum Runoff Rate When Fully Developed (cfs) 100 Yr. Storm

Q_H – Maximum Runoff Rate When Under Historic Condition (cfs) 5 Yr. Storm

T_C – Time of Concentration of The Historic Basin