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MADISON / WAHSATCH
DRAINAGE IMPROVEMENTS
FINAL DRAINAGE STUDY

Oct. 1972

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DRAINAGE STUDY
MADISON/WAHSATCH DRAINAGE IMPROVEMENTS

OCTOBER 1985
REVISED APRIL 1986

Prepared For:

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DEC JOB NO. 307.001

ENGINEER'S STATEMENT

The attached drainage plan and report were prepared under my direction and supervision and are correct to the best of my knowledge and belief. Said drainage report has been prepared according to the criteria established by the City for drainage reports and said report is in conformity with the master plan of the drainage basin. I accept responsibility for any liability caused by the negligent acts, errors or omissions on my part in preparing this report.

Prepared by:

Michael T. Stift, P.E. — 10/18/85
Project Engineer — Date

Bruce Prommersberger, P.E. — 10-18-85
Water Resources Manager — Date
Denver Engineering Corporation

CITY OF COLORADO SPRINGS

Filed in accordance with Section 15-3-906 of the Code of the City of Colorado Springs, 1980, as amended.

Gary R. Haynes — Date: August 8, 1986
Gary Haynes, P.E.
City Engineer

Subject to review of design and cross gutter location

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NOTE: A portion of Appendix A, Figures 1 through 8, have also been included in this book. See the "Technical Addendum" for the complete Appendixes.

INTRODUCTION

The Madison/Wahsatch drainage area, as defined by this Drainage Study is approximately bounded by Cache La Poudre on the south, Nevada Avenue on the west, Chicago/Rock Island Railroad tracks on the north and Shook's Run on the east in north central Colorado Springs, Colorado (Appendix A, Figure 1). This drainage study area was roughly defined by the "Shook's Run Master Drainage Basin Study", dated December 1972. The December 1972 report generalized the overall plan for drainage of 50-year and 100-year storm events within the Shook's Run watershed by means of various drainage improvements and roughly delineated subbasin drainage boundaries for each major drainage improvement. The Madison/Wahsatch drainage area is one of these subbasins and is fully developed with residential housing, schools and parks. It has severe flooding problems due to antiquated and underdesigned drainage facilities. The worst flooding is reported to be occurring at the street intersections of Madison/Wahsatch and Wahsatch/Caramillo. However, flooding is not limited to these specific areas and an overall drainage study to determine specific drainage improvement recommendations has been conducted by Denver Engineering Corporation to relieve or eliminate flooding. We wish to formally extend our appreciation to the many people and the various City of Colorado Springs Divisions in providing the required information to complete this engineering report.

BOUNDARY DELINEATION

The Drainage Study boundaries were chosen based on the following:

a. Existing inlets and storm sewer system on Nevada Avenue.
b. "Shook's Run Master Drainage Basin Study" dated December 1972.
c. Review of topographic maps.
d. Field reconnaissance of existing curb and gutter flow and overland drainage patterns.

West Boundary: Beginning at the Chicago/Rock Island Railroad tracks, the west boundary travels southerly along the east Weber Street right-of-way line where an existing berm separates Weber Street and the railroad right-of-way to Jackson Street. At Jackson Street, the boundary follows along the centerline of Weber Street to Fontanero Street. All land west of this boundary drains to Nevada Avenue. In accordance with the "Shook's Run Master Drainage Basin Study", if drainage facilities are installed within the Madison/Wahsatch Drainage Area, then existing drainage facilities along Nevada Avenue are adequate to drain the 50-year storm. South of Fontanero Street the west boundary is Nevada Avenue. Again it was assumed that the Nevada Avenue inlets and storm sewer system can safely and adequately convey major storm events.

South Boundary: The south boundary is Cache La Poudre as defined by the Scope of Work. This boundary was chosen due to the intersection of Shook's Run, an abandoned railroad right-of-way and Cache La Poudre.

The abandoned railroad right-of-way may be an excellent location to install a storm sewer with an outfall at Shook's Run.

North Boundary: The north boundary is the Chicago/Rock Island Railroad tracks which is a manmade boundary and cuts off any flow from the north flowing south.

East Boundary: Beginning at the Chicago/Rock Island Railroad tracks, the east boundary follows the centerline of Magellan Street to Jackson Street, then crosses Bonny Park to just west of Royer Street. The boundary then travels south and southeast following the limits of "Shook's Run Master Drainage Basin Study" Subbasin 3 and connects to Shook's Run at its intersection with Columbia Street. The boundary then follows Shook's Run to its intersection with Cache La Poudre.

A portion of Subbasin 3 shown as Offsite Basin AA in Appendix A, Figure 3, has also been included in this analysis. The area bounded on the north by the Chicago/Rock Island Railroad tracks, on the east by Templeton Gap and El Paso Street, on the south by Madison Street and Jefferson Street, and on the west by Subbasins A and B of this study also drains into the Madison/Wahsatch drainage area and, therefore, was analyzed as part of this drainage study.

EXISTING FACILITIES AND HISTORICAL USAGE

The following description of existing drainage facilities is based on City maps, interviews with City staff, and field reconnaissance. A plan view of the existing drainage facilities is shown in Appendix A, Figure 2. The drainage system drains from north to south/southeast to Shook's Run and Cache La Poudre. Most storm runoff is generally handled by curb and gutter flow to existing storm sewers located as follows:

	Storm Sewer	Limits From	Limits To	Size (in.)
1.	Uintah Street	Weber Street	Shook's Run	33 to 45
2.	Wahsatch Avenue	Caramillo Street	Platte Avenue	18**
3.	Weber Street	Yampa Street	Dale Street*	18
4.	Royer Street	North Jr. High School Roof Drain	Dale Street*	18

*Dale Street is the next street south of the study area and is a 45 inch storm sewer.
**Assumed per interviews with City Maintenance staff.

All these storm sewers are located in the southern third of the study area. Therefore, no drainage facilities are located in the northern two-thirds of the drainage area. Storm flows in the north area of the drainage basin from the Chicago/Rock Island Railroad tracks to Caramillo Street generally drain along curb and gutter either ponding

in the abandoned railroad right-of-way that splits the study area or ponding in the street gutters. The southerly drainage area from Caramillo Street to Cache La Poudre drains along existing curb and gutter to the existing storm sewer system and into Shook's Run. This area has not had the flooding problems that the northerly area has had.

The abandoned railroad right-of-way historically had a system of ditches, culverts and bubblers or yard inlets with a siphon pipe system to drain runoff along either side of the railroad tracks down to the intersection of the railroad right-of-way and Shook's Run. This drainage network has been eliminated or plugged with the abandonment of the railroad and the installation of a bike trail along the old railroad tracks. As a result and as verified in interviews with City Park Maintenance Crews, water ponds in this right-of-way and is eliminated only through infiltration and evaporation.

Flooding has occurred in some streets even during moderate storm events. Some street grades are less than 0.5 percent. General engineering design standards require a minimum of 0.5 percent grade to drain concrete sections as ponding and deposition of dirt and debris impedes the flow of water along the gutter. In addition, successive street overlays have reduced the curb height of some vertical curbs to less than eight inches which is the City standard curb height. Some vertical curbs are only 4 or 5 inches in height. Ramp curbs are located in the area north of Jackson Street between Wahsatch and Royer Streets. Successive street overlays have covered the road and gutter sections eliminating some ramp curbs or reducing the ramp curb height to between 1 and 4 inches.

There has also been flooding problems at intersections that have caused traffic accidents. Most intersections have concrete crosspans that flow perpendicular to the flow of traffic. However, there are no inlets or storm sewer system to eliminate water from the street and as a result, the intersection floods. Fontanero Street at Wahsatch Avenue has a 12 foot wide concrete crosspan and when flowing full has a depth of flow that would flood into the bottom of a compact car door. In addition, some intersections have bubblers which have drop grated inlets along the curb radii and water passes through the upstream grated inlet, through a pipe siphon and out the other grated inlet to the other side of the street. The street intersections are crowned between curb radii and if inlets or the pipe are plugged then water ponds and floods the upstream curb radius. Lastly, some intersections have neither crosspans nor bubblers and sheet flow occurs across intersections which has impeded traffic in the past.

HYDROLOGY

Runoff volumes and peak rates of discharge were determined utilizing the methodology presented in the Soil Conservation Service's "Urban Hydrology for Small Watersheds, Technical Release No. 55" (TR-55). All hydraulic and hydrologic parameters used in this study and all storm water routings were determined using existing conditions as of September, 1985. Subsequent street overlays, paving of concrete gutters with asphalt and other factors will alter the existing street capacities and routing calculations.

The drainage study area was broken into ten Subbasins, A through J, to provide better accuracy in routing of storm flows. Subbasins A through E generally drain to the abandoned railroad right-of-way where water is ponded to be removed through infiltration and evaporation. The old railroad track bed within the right-of-way is a high point that ponds water behind it. Some of the Subbasins have bubblers or small culverts to pass flows under the high point, but these facilities are inadequate to handle even minor storm flows without ponding due to the plugging with debris or inadequate capacity. Subbasin F drains to the Uintah Street storm sewer which drains to Shook's Run. There have not been any reports of flooding in this area except for where bubblers have been installed to pass water under the crown of a street. Subbasins H and I drain into the remainder of the existing storm sewer system. Again, in the investigation no evidence of flooding problems was found except at bubbler locations. Therefore, it appears that the existing storm sewer system is adequately draining these areas. Subbasin G drains into Shook's Run and Subbasin J is the abandoned railroad right-of-way and immediately adjacent tributary areas. These major drainage Subbasins are delineated in Appendix A, Figure 3.

Each city block within a Subbasin was assigned a block number and the 5-year and 100-year design flows were determined. In cases where a single block was found to drain to two separate Subbasins, that block was broken into two blocks, i.e. 17 and 17A, and the flows for each was determined and applied to the appropriate Subbasin runoff calculations. A preliminary hydrologic analysis was performed for each block to estimate the probable design flows and assist in calculation of the final hydrologic design flows and hydraulic routing analysis for each Subbasin.

Hydrologic volume parameters were determined for each block. These parameters are soil type and type of cover or land use. Soil information was taken from Soil Survey of El Paso County Area, Colorado, prepared by the Soil Conservation Service (SCS) and dated June, 1981. The soil group boundaries are delineated in Appendix A, Figure 4. The soils throughout the study area are all well draining soils. Soils found in the study are as follows:

Soil Name	Map* Symbol	SCS Hydrologic Soil Group	Description
Ascalon	2	B	Sandy loam, 1 to 3 percent slopes
Blakeland	8	A	Loamy sand, 1 to 9 percent slopes
Blendon	10	B	Sandy loam, 0 to 3 percent slopes
Chaseville	16	A	Gravelly, sandy loam, 1 to 8 percent slopes

*Map symbol corresponds with referenced SCS map symbols

Land use was taken from City base maps, compiled on January 5, 1973, and field verified as a part of this drainage study for the study area from Cache La Poudre to Caramillo Street. The area from Del Norte Street to the Chicago/Rock Island Railroad tracks was taken from

base maps prepared by Denver Engineering Corporation and IntraSearch Inc. during August 1985.

Both the hydrologic soil group designation and land use were used to determined the runoff curve number utilizing Table 1 in Appendix A, "Runoff Curve Numbers for Selected Agricultural, Surburban, and Urban Land Use". Curve numbers for each block were determined and a weighted curve number for each block was then calculated to determine storm runoff volumes.

The hydraulic time parameters of elevation difference, flow length and slope for all blocks were determined from the base maps. The velocity of overland flow was determined utilizing the TR-55 graph, "Average Velocities for Estimating Travel Time for Overland Flow" as presented in Appendix A, Figure 5. From this information, the time of concentration for each block was calculated and results are presented in Appendix A, Table 2.

The time of concentration was then used to determine the peak runoff in cubic feet per second per square mile per inch of runoff resulting from the incremental summation of the six hour Type IIA storm per the City of Colorado Springs Drainage Criteria and as presented in Appendix A, Figure 6. Runoff in inches was determined for the 5-year and 100-year storm event as a function of the runoff curve number and precipitation as shown in Appendix A, Figure 7. The following storm events were used in accordance with the City of Colorado Springs Drainage Criteria:

Design Flow	Precipitation (inches)
Q_5	2.1
Q_{100}	3.5

From this data, the 5-year and 100-year peak flows for each block were calculated. The results of this preliminary hydrologic analysis are presented in Appendix A, Table 3.

HYDRAULICS

Streets serve an important and necessary service when calculating and sizing drainage facilities. Gutter flow in streets transports runoff to inlets and storm sewers. The capacity of street flow may reduce sizing or eliminate the need for storm sewers in particular areas within a drainage basin. Curb and gutter flow capacities were calculated assuming zero depth of flow at the street centerline providing emergency vehicles with a minimum of one lane of traffic open for access during the design storm event. Street capacities and a discussion on determining street capacities for the various street sections are presented in Appendix B.

Surface conditions were determined from field observation. The following Mannings roughness coefficients (n) were used:

Unlined Channel	0.040
Asphalt Channel	0.019
Street Section, generalized composite section	0.016
Concrete Channel	0.015
Concrete Pipe	0.013

There are no records of City maps showing slopes for any of the existing storm sewer facilities in the study area. Each storm sewer has cleanouts along the storm sewer for maintenance. However, through the years, successive asphalt overlays have covered the 24 inch diameter cleanout covers limiting access to the storm sewer system.

All street flows were considered to be in the gutter, along concrete crosspans and drained into storm inlets. In discussions with the City Maintenance staff, bubbler siphon pipes are always full of water creating noxious odors and mosquito problems. Grass cuttings and other debris easily collect in the bubblers such that rarely do they operate at capacity. Therefore, it is recommended and the routing analysis assumes that all bubblers used to pass drainage under the crown of a street be abandoned by removal or conversion to a grated drop inlet.

Hydraulic calculations indicate that new drainage inlets are required to alleviate flooding problems. This report utilizes the City standard D10R curb opening inlet for all vertical curb locations where a new inlet is required. Existing curb opening inlet dimensions were measured in the field and used to determine calculated inlet capacities. Bubbler locations were also identified through field reconnaissance. The existing bubbler grated drop in et was used in place of a D10R inlet to save on construction costs when sufficient inflow capacity could be provided. Final design will include analysis of these bubblers to see if they can actually be converted to a grated drop inlet. If they cannot, a D10R inlet should be installed. The City standard grated inlet was reviewed only for areas where rollover curb and gutters are present and no other drainage facilities are present. Curb capacity is limited in these areas due to successive street overlays and curb heights are generally 4 inches or less, making installation of D10R inlets impractical. In all cases, a 60 percent pickup of street flow was used for inlets on straight grades in accordance with the City's "Subdivision Policy Manual". New and existing curb opening and drop inlet capacities, dimensions, calculations, and criteria used in this report are presented in Appendix C.

DRAINAGE IMPROVEMENTS AND RECOMMENDATIONS

Currently, flows overtop street corners and flow from one Subbasin to another. With the criteria as set forth in previous sections of this report, storm sewer inlets, locations, and sizes were chosen to prevent this type of flooding. Therefore, each Subbasin was analyzed individually. The existing drainage patterns indicate that the major storm sewer should follow the abandoned railroad right-of-way. Ponding occurs to the north of the right-of-way and most curbs overtop in areas immediately adjacent to the right-of-way. The Subbasin hydraulic routing indicates that a storm sewer is required from Jackson Street

to Corona Street to alleviate flooding.

Very few improvements are required south of the railroad right-of-way. These improvements are either street improvements or are inlets that connect to existing storm sewers.

Currently, no existing underground utilities were found in the railroad right-of-way, except at road crossings. An existing overhead electric line is located along the entire west boundary line of the abandoned railroad right-of-way and along the east boundary line from Espanola Street to the Chicago/Rock Island Railroad tracks. An asphalt bike path has been installed and the greenbelt is maintained by the City Parks Division from Cache La Poudre to the Chicago/Rock Island Railroad tracks. Only the area immediately north and south of Fontanero Street is sodded and has underground sprinklers. The remaining greenbelt is native grasses. The minimum width of the abandoned right-of-way is 80 feet and the bike path generally bisects the right-of-way.

A major storm sewer could be installed on either side of the bike path and would be the most cost efficient alternative. However, the City Electrical Division has indicated that they have purchased this right-of-way for a major electrical trunk line to be installed in the mid-1990's. No construction plans have been engineered to date, but it appears there is room for both the storm sewer and electrical trunk line. Therefore, if a storm sewer is to be installed in the right-of-way the design engineer, City Engineering Division, City Parks Department, and City Electric Division must coordinate alignments.

If the abandoned railroad right-of-way can not be used for installation of a major storm sewer, then the pipeline should be installed in Wahsatch Avenue from Jackson Street to Columbia Street and then down Columbia Street to Shook's Run. This alternative would be much more expensive due to numerous utility conflicts, pavement replacement costs, and traffic and pedestrian safety hazards. Estimated construction costs for each alternative are presented later in this text.

As a result, the hydrological and hydraulic routing analysis considers a future storm sewer within the abandoned railroad right-of-way. The routing calculations are presented in Appendix D. In addition, a summary of new and existing inlet capacities used in the routing analysis and comparison of remaining street flow to curb capacity for the 100-year design flow are presented at the end of Appendix D. Where curb capacity upstream of an inlet is insufficient to handle the 100-year design flow, it was felt that the small amount of flow that will overtop the curb is not enough to require another inlet upstream. In all cases, curb capacities are sufficient to handle the 5-year design flow. A summary of the recommended improvements in each Subbasin are presented in Appendix A, Figure 8 and are as follows.

Subbasin A

All drainage flows to the southwest corner of the Subbasin to the abandoned railroad right-of-way and northeast corner of Weber and Fontanero Streets. Bubblers located at the right-of-way and at the northeast corner are intended to pass flow into the right-of-way or

south along Weber Street to be eventually drained into the Uintah Street storm sewer. As all flows drain to a street sump condition, storm inlets were sized for the 100-year design flows.

Recommended drainage improvements are as follows:

1. Install a concrete crosspan parallel and east of the Corona Street centerline at Madison Street to eliminate sheet flow across the street.

2. Install D10R inlets at the following locations:

   a. A 4 foot D10R at the northeast and southeast corners of Madison Street and Wahsatch Avenue.

   b. A 6 foot D10R at southwest corner of Wahsatch Avenue and the southerly entrance to the adjacent strip mall.

   c. A 10, 8 and 14 foot D10R at the northeast, southeast and northwest corners of Washington Street and Wahsatch Avenue, respectively.

   d. A 22 foot D10R at the northeast and northwest corners of Fontanero Street and Wahsatch Avenue.

   e. A 4 foot D10R at the north and south intersection of Fontanero Street and the railroad right-of-way.

   f. An 8 foot D10R at the northeast corner of Weber Street and Fontanero Street.

Note that additional drainage facilities should be installed in Subbasin A as a result of drainage from Subbasin AA. These facilities are discussed in Subbasin AA recommendations.

Subbasin B

All drainage is to the south and west to the abandoned railroad right-of-way and Jackson Street where bubblers drain all water into the railroad right-of-way. Therefore, the storm inlet system for Subbasin B was sized for the 100-year design flow.

The existing curb and gutter is a ramp curb that has been overlayed with asphalt and is therefore only 1 to 4 inches deep from the top of curb to gutter flowline. Options discussed with the City Staff include:

1. Installation of a standard 8 inch vertical curb and gutter to match existing pavement grade. However, this will pond water behind the new curb and cause drainage problems for homeowners.

2. Lower street grades by removal and reinstallation of existing asphalt pavement and concrete curb and gutter.

3. Install a non-uniform street cross section.

4. Install city standard grated inlets along existing ramp curb and gutters. Very little head will be on top of inlet to develop a flow into the inlet.

In discussions with the City staff, the first two options were eliminated due to drainage problems and high construction costs, respectively. Option 4 is not recommended as any grated inlet system will be obsolete if another asphalt overlay is installed. Option 3 or installation of a non-uniform street cross section would require installation of the city standard ramp curb and gutter resulting in a grade break from street crown to gutter of 2.0 to 2.8 percent. The 8 inch vertical curb is not considered feasible as the grade break would be from 2.0 to 9.3 percent and would be too severe for vehicular traffic.

Recommended drainage improvements for Subbasin B are:

1. Install concrete cross pans at the following locations:

   a. Parallel and west of the Magellan Street centerline at LaSalle Street.

   b. Parallel and north of Jackson Street centerline at Wahsatch Drive.

   c. Replace the asphalt crosspan with concrete west of the "T" intersection of Corona and LaSalle Streets.

2. Install D10R inlets at the following locations:

   a. A 10 foot D10R at the northwest corner of Royer and Jackson Streets.

   b. A 12 and 20 foot D10R at the northwest and northeast corners of Corona and Jackson Streets, respectfully.

c. A 4 and 20 foot D10R at the northwest and northeast corners of Balboa and Jackson Streets, respectfully.

d. A 20 foot D10R at the northwest and northeast corners of Wahsatch Drive and Jackson Street.

e. A 4 and 6 foot D10R at the south and north intersections of Jackson Street and the abandoned railroad right-of-way.

3. Replace the existing curb and gutter on LaSalle and Corona Streets with a non-uniform street cross section. Asphalt overlays have reduced top of curb to flowline depths to less than 3 inches and existing conditions have very little curb capacity.

4. Replace approximately 145 linear feet of existing 4 inch vertical curb located immediately east of the intersection of Jackson Street and Wahsatch Drive on the north side of Jackson Street with a standard 8 inch vertical curb and gutter.

Subbasin C

All drainage is to the south and west to a sump at the abandoned railroad right-of-way and Espanola Street. Therefore, the storm inlet system for Subbasin C is sized for the 100-year design flow.

Recommended drainage improvements for Subbasin C are:

1. Abandon the existing bubbler parallel and north of the Espanola Street centerline at Wahsatch Avenue and install a 6 foot D10R inlet at the northeast corner. Calculations for converting the bubbler to a grated drop inlet show that it would have insufficient capacity to handle the 100-year design flow, but could handle the 5-year design flow. As an alternative, a concrete crosspan could be installed, however, Wahsatch Avenue traffic will be impeded due to slowing of traffic due to the dip in the crosspan. There are no existing stop signs or traffic signals along Wahsatch Avenue at this intersection so the D10R inlet is recommended.

2. Convert the median bubbler into a grated drop inlet.

3. Install a concrete crosspan parallel and north of the Espanola Street centerline at Corona Street to eliminate sheet flows across the street crown.

Subbasin D

All drainage is to the south and west to existing inlets at Wahsatch Avenue and Caramillo Street and to an existing bubbler that passes

water under the railroad right-of-way onto Wahsatch Avenue where it drains to the Uintah Street storm sewer. This bubbler is to be abandoned and the storm inlet system for Subbasin D is sized for the 100-year design flow.

Recommended drainage improvements for Subbasin D are:

1. Install concrete crosspans parallel and east of the Corona Street centerline at Del Norte Street and parallel and north of the Caramillo Street centerline at Corona Street to eliminate sheet flow over the street crown. Replace existing asphalt crosspan parallel and west of the Wahsatch Avenue centerline at Del Norte Street.

2. Convert the existing bubbler on the northeast corner of Del Norte Street and Wahsatch Avenue into a grated drop inlet and connect to the existing storm sewer in Wahsatch Avenue. If the grated drop inlet is structurally inadequate, then install a 4 foot D10R.

3. Convert the bubbler on Buena Ventura Street into two curb opening inlets and connect to the proposed storm sewer to be installed in or in the vicinity of the abandoned railroad right-of-way.

4. Buena Ventura Street is a gravel road that drains to the two curb openings. This street should be paved and a concrete crosspan installed to eliminate large amounts of dirt and gravel from entering the storm sewer. A standard 8 inch vertical curb and gutter should also be installed on the north and northeast side of Buena Ventura Street. An 8 inch curb and gutter exists on the opposite side and should be left in place.

5. Remove the existing curb opening inlet at the northeast corner of Caramillo Street and Wahsatch Avenue. The existing 2 foot 7 inch long inlet has insufficient capacity to drain the 100-year design flow. Replace with a 6 foot D10R.

Subbasin E

Drainage is to the south and west to the intersection of the abandoned railroad right-of-way and Corona Street where drainage ponds, enters the railroad right-of-way, or passes through an existing 18 inch culvert draining under the railroad right-of-way southerly to the Uintah Street storm sewer system. Therefore, design the storm inlet system to drain the 100-year design flow.

Recommended drainage improvements for Subbasin E are:

1. Abandon the 18 inch culvert located parallel and west of Corona Street centerline at the abandoned railroad right-of-way and Columbia Street.

2. Install D10R inlets in the following locations:

   a. A 4 and 8 foot D10R at the northwest and southeast corners of Corona and Columbia Streets, respectively.

   b. A 4 foot D10R immediately west of the abandoned railroad right-of-way on Columbia Street to drain a sump condition.

3. An alternative to the D10R to be installed immediately west of the railroad right-of-way would be to install a new standard 8 inch curb and gutter and pave Columbia Street to drain to Wahsatch Avenue.

Subbasin F

All drainage is to the south to the Uintah Street storm sewer and east to existing storm inlets at Shook's Run, except for along Caramillo Street immediately west of the railroad right-of-way and east of Weber Street drain to a depression in Caramillo Street. A second storm sewer in Wahsatch Avenue drains the medians from the abandoned railroad right-of-way to Uintah Street. The existing storm sewers and inlet system is adequate to handle the 100-year design flows.

Recommended drainage improvements for Subbasin F are:

1. Abandon all the existing bubblers and install concrete crosspans at the following locations:

   a. Parallel and on both sides of the Weber Street centerline at Columbia Street.

   b. Parallel and on both sides of the Weber Street centerline at San Miguel Street.

   c. Parallel and on both sides of the Wahsatch Avenue centerline at Columbia Street.

   d. Parallel and east of the Wahsatch Avenue centerline at San Miguel Street.

   e. Parallel and west of the Franklin Street centerline at San Miguel Street.

2. Install a concrete crosspan parallel and north of the San Miguel Street centerline at Franklin Street to eliminate sheet flow across the street crown.

3. Remove existing inlets and install two 6-foot D10R inlets at the depression on the north and south sides of Caramillo Street west of the railroad right-of-way.

The existing sump curb opening inlets on the north and south sides of San Miguel Street at Shook's Run and Uintah Street at Shook's Run are inadequate to handle the 100-year design flow contributed by the study area. Additional flow to these inlets is contributed by the area to the east of the study area. Calculation of these contributing flows is not a part of the Scope of Work for this study. Therefore, it is recommended that these additional contributing flows be determined and new inlets sized for all 100-year design flows. The San Miguel Street 100-year design flow from the study area is 20.0 cubic feet per second. The Uintah Street 100-year design flow from the study area is 3.1 cubic feet per second. Both inlets are sumps and would require a 10 foot and 4 foot D10R inlet at San Miguel and Uintah Streets, respectively, if the inlets were to be installed and sized for only the 100-year design flows from the study area and not the flows from east of the study area. By installing these inlets, smaller frequency storm events can adequately drain runoff from both areas until the future study is completed to determine all the required 100-year design flow inlet facilities.

Subbasin G

All drainage is to the south and east to an existing 18 inch culvert which discharges directly to Shook's Run at San Rafael Street. The culvert can safely convey the 5-year design flow, but can not convey the 100-year flow. Two solutions are possible if the 100-year design flow is to be adequately drained without flooding. A second 18 inch culvert should be constructed next to the existing 18 inch culvert or the existing culvert should be removed and a grouted riprap rundown should be installed. The recommended drainage improvement is the grouted riprap rundown.

Subbasins H and I

All drainage is to the south to existing bubblers which all drain to Cache La Poudre and discharge through two grated drop inlets at Shook's Run.

Recommended drainage improvements for Subbasins H and I are:

1. Abandon the existing bubbler and install concrete crosspans at the following locations:

   a. Parallel and on both sides of the Weber Street centerline at San Rafael Street.

   b. Parallel and on both sides of the Corona Street centerline at San Rafael Street.

   c. Parallel and on both sides of the Corona Street centerline at Yampa Street.

2. The bubblers at the northeast and northwest corner of Wahsatch Avenue and San Rafael Street and the bubbler at the northwest corner of Wahsatch Avenue and Yampa Street should be converted to grated drop inlets. The curb opening bubbler at the northeast corner at Wahsatch Avenue and Yampa Street should be converted to a curb opening inlet. These inlets would connect to the existing storm sewer in Wahsatch Avenue. The area that drains to these grated drop inlets currently drain to this same storm sewer through curb opening inlets. If these grated drop inlets are structurally inadequate, install 4 foot D10R inlets at each location.

3. The bubbler located at the "T" intersection of Royer and Yampa Streets should be abandoned and a concrete crosspan installed. Currently, there is an asphalt crosspan at this location. Installation of a concrete crosspan will provide better street flow hydraulics and asphalt crosspans are undesirable due to deterioration of the asphalt at flowline.

4. Remove the existing bubblers on the northwest and northeast corners of El Paso Street and Cache La Poudre as and install a 6 foot and 4 foot D10R, respectively.

5. Remove the existing bubbler on the northwest corner of Corona Street and Cache La Poudre as the existing inlet is in a sump condition and has insufficient capacity to drain the 100-year design flow and install an 8 foot D10R.

6. Convert the existing curb opening bubblers at Royer and Cache La Poudre to curb opening inlets.

The two proposed D10R inlets, Items 4 and 5 above, are required only to drain the 100-year design flow. The existing curb opening inlet system can handle the 5-year design flow. If the new D10R inlets are not installed, then it is estimated that half the flow of 2.0 and 2.7 cubic feet per second will overtop the street crown of Cache La Poudre at Corona and El Paso Streets respectively and flow into the drainage area south of the study area. The remaining half of this flow will flow to the sump grated drop inlets at the intersection of Cache La Poudre and Shook's Run.

The calculated 100-year design flow from the study area that flows to the two sump grated drop inlets at Cache La Poudre Shook's Run is 2.7 cubic feet per second. Additional flow to these grated drop inlets is contributed by the area to the east of the study area. Calculation of these contributing flows is not a part of the Scope of Work for this study. However, the two existing drop inlets have a calculated sump capacity of 36.5 and 37.4 cubic feet per second under ideal conditions when the inlets are completely free of debris and therefore, can adequately handle smaller frequency storm events from both areas.

Subbasin J

Subbasin J is the abandoned railroad right-of-way which splits the study area running from the northwest drainage area boundary corner at the Chicago/Rock Island Railroad tracks to the southeast drainage area boundary corner at Shook's Run and Cache La Poudre. It is recommended that the runoff in the right-of-way be cut off from entering the cross streets by mean of both an earthen ditch installed on both sides of the bike path and yard inlets installed along each earthen ditch that would operate in sump condition between each cross street. The right-of-way behind the strip mall at Jackson Street and Wahsatch Avenue is a known problem for standing water and muddy conditions that necessitate these improvements. In addition, plug the curb drain that allows flow from abandoned right-of-way to enter Fontanero Street and install a yard inlet to work as a sump to drain the right-of-way.

If the major storm sewer is located within the right-of-way, then yard inlets should be installed within the right-of-way down to Cache La Poudre. If the major storm sewer is located in the street section, then the yard inlets should be installed from above Jackson Street to just above Corona Street. The remaining areas would pond and water would drain from infiltration and evaporation as currently occurs, or curb chases could be installed to allow water to drain to the street and, eventually, to an existing storm sewer system.

An existing 2 foot by 1 foot concrete box storm sewer drains the railroad right-of-way located immediately north of Caramillo Street. This storm sewer connects to the existing 18 inch storm sewer that is located in Wahsatch Avenue. It is recommended that the existing box storm sewer be abandoned and replaced with yard inlets, as described above.

Offsite Basin AA

Offsite Basin AA shown in Figure 3 is a portion of Subbasin 3, as delineated in the "Shook's Run Master Drainage Basin Study". This area contributes to the flooding problems on Wahsatch Avenue between Fontanero Street and Jackson Street. The area is bounded on the north by the Chicago/Rock Island Railroad tracks, on the east by the Templeton Gap and El Paso Street centerlines, on the south by the Madison Street and Jefferson Street centerlines, and on the west by Subbasin A and B of this study. Calculations of the 100-year design flow indicates that by constructing inlets in this area, the flooding problems in Subbasin A and B and Offsite Basin AA should be alleviated. From conversations with the City Staff, flooding in the past in Subbasin 3 has been reported north of Fontanero Street, but major flooding has not been a problem south of Fontanero Street. Therefore, the proposed storm sewer, as delineated in the "Shook's Run Master Drainage Basin Study" for Subbasin 3, may be reduced in length or eliminated. It is recommended that additional inlets be installed as shown in Figure 8 and connected to the proposed Madison/Wahsatch Drainage Facilities to save on future storm sewer construction costs and alleviate flooding along Wahsatch Avenue.

Recommended drainage improvements for Offsite Basin AA are:

1. Remove the existing asphalt crosspan parallel and west of Royer Street at Madison and install a concrete crosspan.

2. Install D10R inlets at the following locations:

   a. A 12 foot D10R at the southeast corner of Madison Street and Corona Street.

   b. A 12 foot D10R at the northeast corner of Madison Street and Royer Street.

   c. A 12 foot D10R at the northeast corner of Madison Street and El Paso Street.

   d. A 20 foot D10R at the downstream end of the existing concrete crosspan on the south side of Monroe Street, east of Magellan Street.

   e. Two 12 foot D10R inlets at the northeast corner of Magellan Street and Monroe Street; one on either side of the existing concrete crosspan.

   f. Two 14 foot D10R inlets on the northwest and northeast corner of Monroe Street and El Paso Street.

   g. A 4 foot and 12 foot D10R inlet on the northwest and northeast corner of Monroe Street and Franklin Street, respectively.

   h. A 12 foot D10R on the east side of Magellan Street at the intersection of Jackson Street.

Existing Storm Sewers

Access to the existing storm sewers is through cleanouts. However, these access points are overlayed with successive layers of asphalt. It is recommended for maintenance purposes that all the cleanout rims be raised to grade.

STORM SEWER IMPROVEMENTS

The proposed storm sewer should follow the abandoned railroad right-of-way as the new inlets are located in the vicinity of the right-of-way. The Hydrologic Base Maps, Existing and Proposed Drainage Facilities, shows the alternative alignments for the storm sewer trunk line. The storm sewer is required to pick up street flows at inlets at the abandoned railroad right-of-way from Jackson Street to Corona Street. Two alignments are shown. One is along the abandoned railroad right-of-way and the second is located in existing paved streets that follow the railroad right-of-way. From Corona Street to Shook's Run, two alternatives are also available. Existing drainage facilities are generally adequately sized to handle the design flows along this area.

Therefore, the storm sewer trunk line can continue south along the railroad right-of-way for approximately 2800 linear feet and outfall at Shook's Run just upstream of the Cache La Poudre arch culvert crossing. An alternative would be to install the storm sewer easterly along Columbia Street for approximately 2400 linear feet to just downstream of the Columbia Street culvert crossing.

The railroad right-of-way alignment from Jackson Street to Cache La Poudre at Shook's Run is the preferred alignment for the following reasons:

1. Least cost alternative.

2. There are less utilities to cross. Major crossings are generally only at road crossings. Utility plat maps indicate that there are no individual service lines to cross. If constructed in the street section, there are numerous gas, sanitary sewer and water service crossings.

3. There appears to be only electrical poles that run parallel to and inside the proposed railroad right-of-way alignment. However, these poles are just inside the right-of-way and should not be a problem during construction of a major storm sewer. If constructed in the street section, sheeting and shoring requirements to protect parallel utilities will significantly add to installation costs.

4. Open cuts in the railroad right-of-way in ground instead of pavement will lessen the time to construct the project.

5. Asphalt replacement is very costly and is kept at a minimum in the railroad right-of-way alignment.

6. The possibility that pavement removal and heavy construction traffic might damage individual property owners improvements by cracking concrete, damaging grass sod, etc., is greater if the storm sewer is installed in the streets. Generally, each home has a back fence that would help protect a home from noise, dust, and property damage.

7. Traffic disruption will be minimized as the railroad right-of-way alignment will impact traffic only at street crossings. If the storm sewer is installed in the street, some streets will probably be closed to traffic during pipe installation and one side of Wahsatch Avenue will probably be closed. Traffic control and safety requirements and costs will be significantly higher.

8. Pedestrian safety and neighborhood impact will be less if the storm sewer is installed in the railroad right-of-way. The right-of-way generally faces the back of residential homes in the area and has a bike path. Portions of the bike path would be closed during construction, but pedestrian traffic would primarily be effected only at street crossings. A storm sewer in the street sections would be in

front of individual homes, may create frequent citizen complaints, and pedestrian safety precautions would be a prime concern.

The storm sewer hydraulics, pipe sizing and proposed alternate alignments are presented in Appendix E.

Reinforced concrete pipe was used for all storm sewers. The City Corrosion Foreman has indicated in telephone conversations that the railroad right-of-way is a very corrosive soil and that corrosion protection measures should be used for any construction in this area. The initial cost of corrugated steel pipe is competitive. Any steel pipe design would probably require pipe coating and an extensive cathodic protection system. Therefore, the total cost of steel pipe installation would be higher and the design life shorter than for concrete pipe.

Ribbed polyethylene pipe was also reviewed due to the pipe's smooth interior which provides a lower pipe roughness coefficient and a higher flow capacity than other types of pipe. As a result, smaller polyethylene than concrete pipe sizes can generally be installed for equivalent flows. In addition, polyethylene pipe is corrosion resistant, which is desirable along the pipe alignments shown for the proposed storm sewer. The City of Colorado Springs is currently installing some polyethylene on an experimental basis to test the manufacturer's claims about this product. Therefore, until the results of the test are complete and ribbed polyethylene pipe becomes a City-accepted standard pipe material, reinforced concrete pipe is the recommended pipe material.

The following utility agencies were contacted relative to existing and future facilities located along the railroad right-of-way and the possible construction at a storm sewer trunk line in this area:

1. Cablevision
2. City of Colorado Springs, Electrical Division
3. City of Colorado Springs, Engineering Division
4. City of Colorado Springs, Gas Division
5. City of Colorado Springs, Wastewater Division
6. City of Colorado Springs, Water Division
7. Mountain Bell

The only existing utilities found in and running parallel to the railroad right-of-way are overhead electric lines located on the west boundary along the entire right-of-way and on the east boundary from Espanola Street to the Chicago/Rock Island Railroad tracks. There are underground and overhead utilities located at the railroad right-of-way street crossings. The utility plat maps do not provide any indication of buried cover depth for existing facilities. There are

numerous small pipeline crossings. However, major utility crossings 10 inch and larger are as follows:

Street Crossing	Facility
Madison Street	20 inch water
	Telephone line
Fontanero Street	10 inch gas
Del Norte Street	24 inch water
Caramillo Street	Telephone line
Wahsatch Avenue	10 inch gas
Columbia Street	12 inch water
	24 inch sanitary sewer
Uintah Street	30 inch water

It is recommended that these major utilities and all other utility crossings be potholed to determine pipe elevations to facilitate design of a gravity storm sewer.

The Shook's Run Master Drainage Basin Study proposed an open channel from Jackson Street to Fontanero Street. A review of existing street grades at Madison and Washington Streets at Wahsatch Avenue, where inlets are required to alleviate flooding problems, indicates that there is insufficient grade differences to construct an open channel located in the railroad right-of-way. It is estimated that an open channel would have to have a depth of 7 feet allowing a 0.8 percent slope from proposed inlets to the channel. Therefore, a storm sewer pipeline is recommended for the entire length of the drainage improvements.

CACHE LA POUDRE EXISTING ARCH CULVERT

The existing Cache La Poudre street crossing at Shook's Run is a concrete arch culvert with a dirt bottom. The arch opening is approximately 20 feet wide at the base, 6 feet up from the base it is 18.5 feet wide, and is 12.5 feet in height. An earth berm with brush and trees partially blocks the arch culvert inlet and restricts the flow. Flow in Shook's Run must go around this berm and then enters the culvert. The culvert has two 45 degree bends in it which offset the culvert inlet and outlet by approximately 10 feet. There are numerous utilities exposed that span inside the culvert. These utilities may be "washed out" and fail during a large flood event.

The Shook's Run Master Drainage Basin Study" 100-year design flow hydrograph indicates that the peak flow is 2196.5 cubic feet per second at a time to peak of 1.10 hours. The calculations for this hydrograph appear to assume continuous surface runoff and do not account for ponding at inlets and sumps, storage in bubblers, or detention storage in the railroad right-of-way left to evaporate or infiltrate.

With the recommended design, the total volume of runoff will not vary from the volume calculated in the "Shooks Run Master Drainage Basin Study," since the same drainage area is under consideration. What

will vary is the shape of the hydrograph. The area will have storm sewers, so the hydrograph rising limb should be steeper and, with a constant volume, the peak discharge should be smaller.

Therefore, for existing and proposed conditions, peak discharge in Shook's Run at Cache La Poudre will be somewhat smaller than predicted in the "Snook's Run Master Drainage Basin Study." A conservative culvert capacity analysis would use the peak discharge of 2196.5 cfs. Channel shape and slope were taken from the base maps used for the study. It was assumed that the culvert inlet restrictions were removed. It was determined from the culvert capacity calculations presented in Appendix E that inlet control will approximate the capacity of the culvert, since the culvert is close to the inlet control/outlet control transition. The existing crossing should safely pass the peak discharge.

It is recommended that the earthen berm and trees be removed from blocking the concrete arch culvert inlet. In addition, the inlet channel banks should have riprap installed for bank stabilization.

NORTH JUNIOR HIGH SCHOOL FLOODING

North Junior High School, a part of El Paso County School District 11, is located on Yampa Street at the "T" intersection with Royer Street. The school roof drains are connected to an 18 inch storm sewer that is located in Royer Street and connects to an existing 45 inch storm sewer in Dale Street where it outfalls at the channel invert of Shook's Run.

The school district maintenance staff has indicated in transmittal letters to City Engineering Division that flooding in the school boiler room occurs during periods of heavy rainfall or snowmelt. Sump pumps have been installed by the school district to discharge water out of the boiler room to control the flooding. However, on at least one occasion the water level approached 4 inches below the electrical equipment which would have caused an electrical failure and potentially could have closed the school.

The school district maintenance staff reports that the water entering the boiler room sump is full of leaves and sticks. In addition, it appeared that the water rises in the sump faster than water could be collected and drained from the school roof and therefore it is felt that the existing storm sewer system is backing up from Shook's Run into the boiler room sump. The school staff has also reported that they have rodded the school's drain system including from the last cleanout in the school to beyond the property line on Yampa Street and no obstructions were found.

The city maintenance staff is currently raising all the cleanouts to grade in the pavement sections and completed cleaning the storm sewer from the last cleanout in the school prior to entering Yampa Street to the Shook's Run outfall at Dale Street on Thursday, September 19, 1985. The city maintenance staff reports removing 3 to 5 gallon

buckets of asbestos-type material from the Yampa Street cleanout to the school cleanout. The city staff believes that this material was blocking the flow into the storm sewer and that the school roof drain should now function without flooding.

A review of the grade difference between the Shook's Run outfall and the school sump was taken from the base maps. The outfall elevation is approximately 6009 feet. The storm sewer cleanout located in Yampa Street immediately in front of the school is approximately 8 to 10 feet deep and the street grade is approximately 6042 feet. Therefore, the storm sewer invert is approximately at elevation 6032 feet. This provides a drop in elevation of 23 feet. The top of bank elevation of Shook's Run at the outfall is approximately 6020 feet. This is 12 feet below the storm sewer invert in front of the school.

As a result of the elevation difference and recent storm sewer cleaning by the city maintenance staff, we recommend that the school district observe through the 1985-1986 winter snowmelt and see if flooding continues in the boiler room sump. If flooding does continue, we recommend two alternatives. First, the roof drains could be disconnected from the storm sewer and drained to outside on the school grounds. All drainage inside the building that is below the ground outside the school would drain to the existing boiler room sump pump which would pump to outside the school. The existing 18 inch storm sewer would be plugged at Yampa Street and disconnected from the school roof drainage system.

Secondly, the outfall invert and all cleanout invert elevations could be verified by field survey. The slopes of existing storm sewers could be calculated as there are no record drawings on this storm sewer system except for pipe sizes. Then the elevation difference could be verified. This would produce a record to indicate if there is a problem within the school roof drain system or a problem in the city storm sewer system.

COST ESTIMATE

The engineer's construction cost estimate is provided in Appendix F. Unit prices were determined from review of the following cost information:

1. "1983 Cost Data," Department of Highways, State of Colorado.
2. Recent bid tabulations published by the Colorado Contractors Association.
3. Solicitation of estimates from various contractors for the various items of work.
4. Past City of Colorado Springs Engineering Division bids.

The following items were assumed for the cost estimate:

1. No utility relocation costs are included in the cost estimate as potholing of existing utility locations is to be completed as a part of final design. The impact of utility interference cannot be determined until the potholing has been completed.
2. An 8 inch thick asphalt pavement over 12 inches of Class 5 road base is assumed for all new pavement or pavement replacement. Unit weights of 133 and 145 pounds per cubic feet for road base and asphalt pavement, respectively, were used.
3. Storm sewer installation costs are based on Class III pipe with an average of 5 feet of cover. Final design will determine actual cover requirements for the pipe.
4. Unit prices are September 1985 prices.

The least construction cost estimate for the Madison/Wahsatch Drainage Improvements is $3,070,920 for a major storm sewer located in the abandoned railroad right-of-way from Jackson Street to Shook's Run at Cache La Poudre and appurtenant drainage facilities. The average estimate cost per linear foot of pipeline is $145 for installing the storm sewer trunk line in the abandoned railroad right-of-way. This compares to an average estimated cost of $240 per linear foot (no sheeting costs have been included) for construction of the storm sewer trunk line in the paved street sections.

The estimate costs of construction are intended to provide an indication of the costs involved and are considered to be an estimate only. We, as engineers, have no control over the cost of materials, equipment and labor, or competitive bidding, and cannot guarantee the accuracy of the construction costs. The unit prices used in the estimate reflect estimated current costs and do not provide for inflation.

CONCLUSIONS

The study area has experienced localized flooding in the past. A system of crosspans, inlets, and storm sewers is planned to alleviate this situation. The area north of Jackson Street, Subbasin B, will require street improvements to improve gutter capacity.

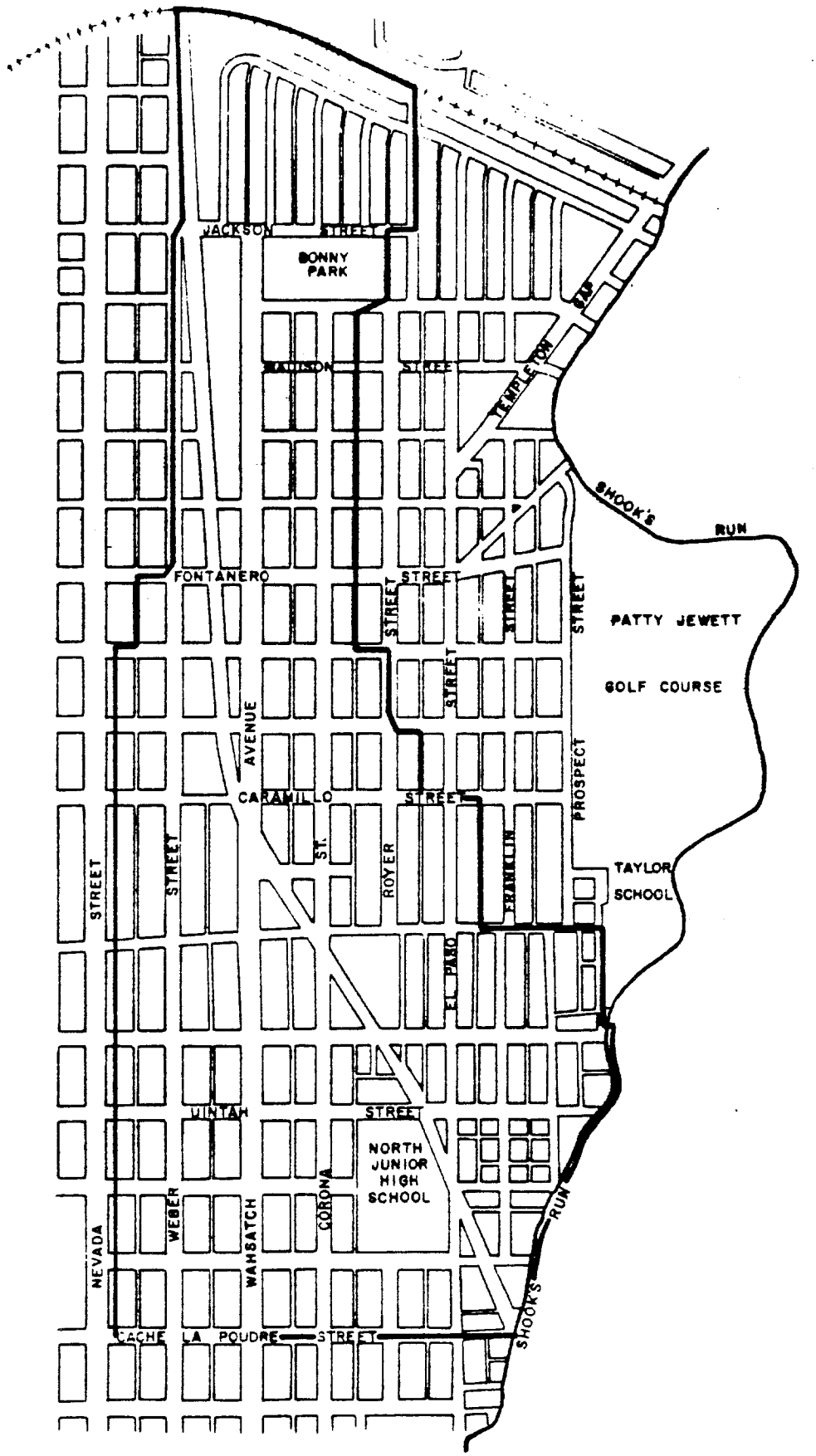
Part of the study area drains south and west towards the abandoned railroad right-of-way. The elevated abandoned railroad track bed creates a sump condition for the drainage area located northeast of the old railroad track bed. The storm sewer has been sized for the 100-year event to provide adequate protection in this area.

Two alternative alignments for the main storm sewer system were investigated. The favored alignment follows the railroad right-of-way, and would cost approximately $3.1 million. Coordination will be required with the City Electrical Division and City Parks Department, since they claim ownership of the right-of-way. The other alignment would be installed in the street, but this would entail numerous utility service crossings, extensive asphalt pavement replacement,

greater traffic and neighborhood disturbances and higher construction costs.

MADISON/WAHSATCH DRAINAGE IMPROVEMENT STUDY

APPENDIX A



SCALE: 1" = 1/4 MI

FIGURE 1

MADISON / WAHSATCH DRAINAGE IMPROVEMENTS
STUDY AREA BOUNDARIES

DEC
Denver Engineering Corporation
1626 Cole Boulevard
Suite 300 • Building 7
Golden, Colorado 80401
(303) 233-0533

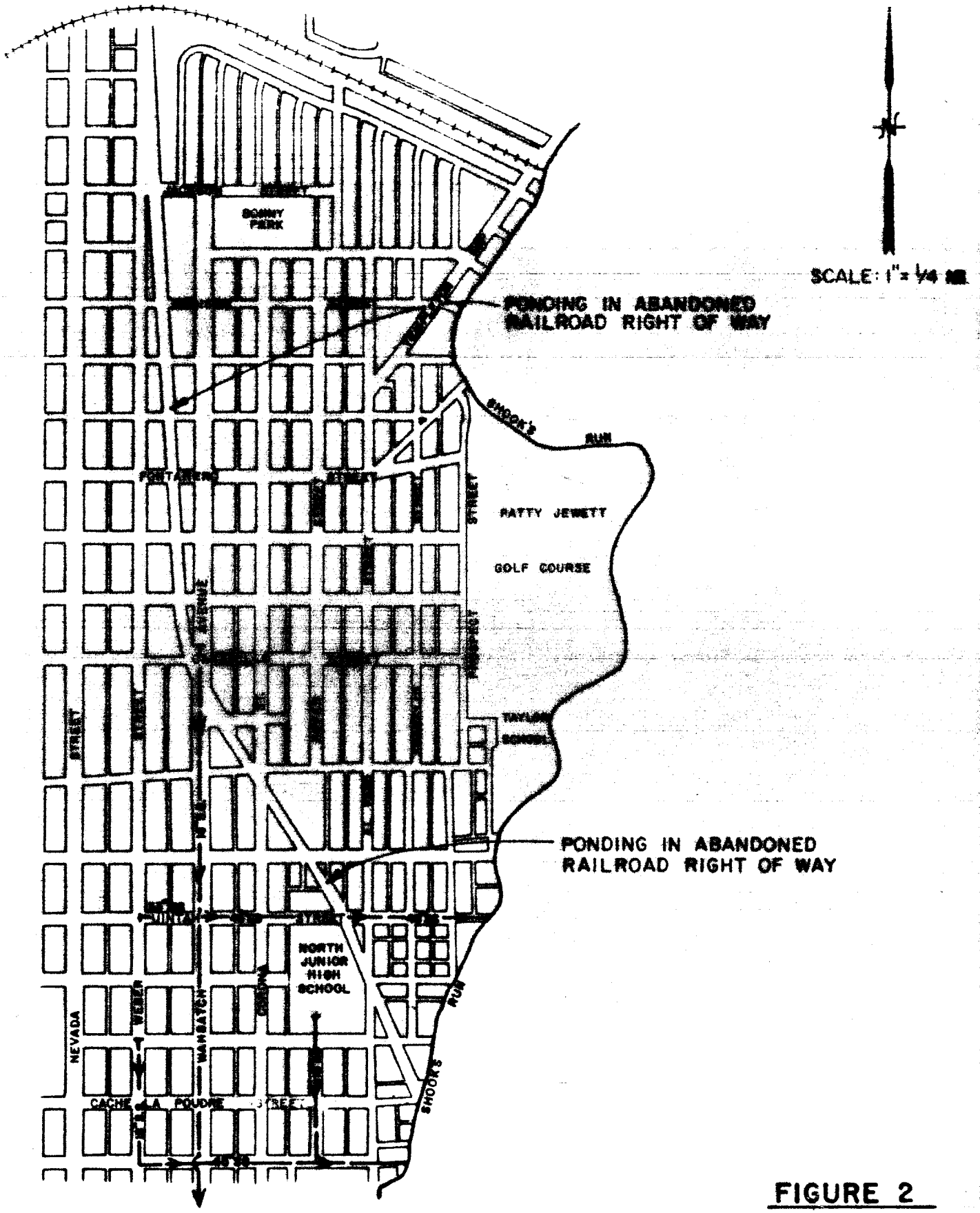
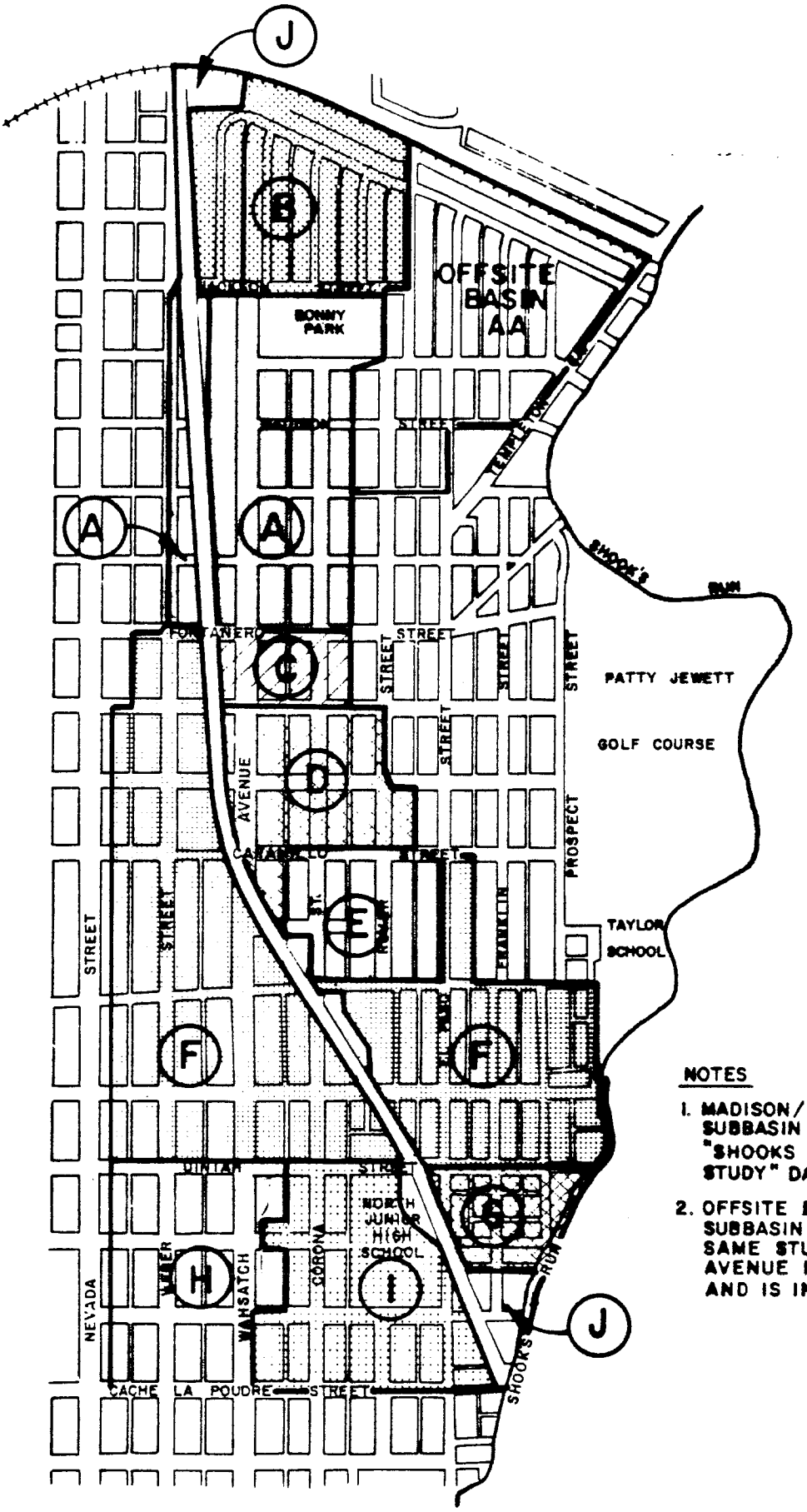


FIGURE 2

EXISTING DRAINAGE FACILITIES

Denver Engineering Corporation
1626 Cole Boulevard
Suite 300 • Building 7
Golden, Colorado 80401
(303) 233-0533



SCALE: 1" = 1/4 MI.

NOTES

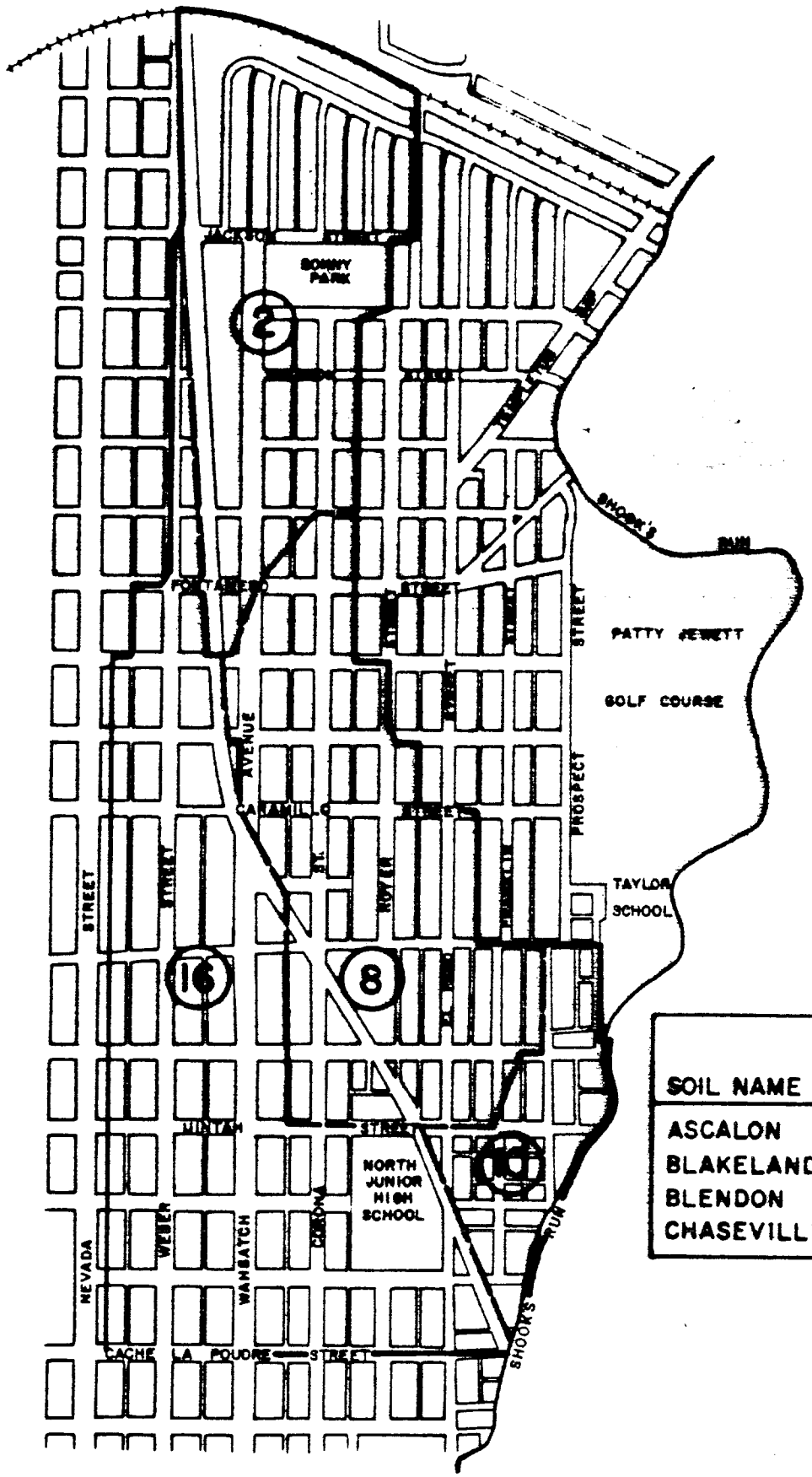
1. MADISON/WAHSATCH DRAINAGE AREA IS SUBBASIN 4 AS DELINEATED IN THE "SHOOKS RUN MASTER DRAINAGE BASIN STUDY" DATED DECEMBER 1972.
2. OFFSITE BASIN AA IS A PORTION OF SUBBASIN 3 AS DELINEATED BY THE SAME STUDY, BUT DRAINS TO WAHSATCH AVENUE NORTH OF FONTANERO STREET AND IS INCLUDED IN THIS REPORT.

FIGURE 3

MADISON / WAHSATCH DRAINAGE IMPROVEMENTS

MAJOR DRAINAGE SUBBASINS

DEC
Denver Engineering Corporation
1626 Cole Boulevard
Suite 300 - Building 7
Golden Colorado 80401
(303) 233-0533



SCALE: 1" = 1/4 MI.

SOIL NAME	MAP SYMBOL	SCS HYDROLOGIC GROUP
ASCALON	2	B
BLAKELAND	8	A
BLENDON	10	B
CHASEVILLE	16	A

FIGURE 4

HYDROLOGIC SOILS GROUPS

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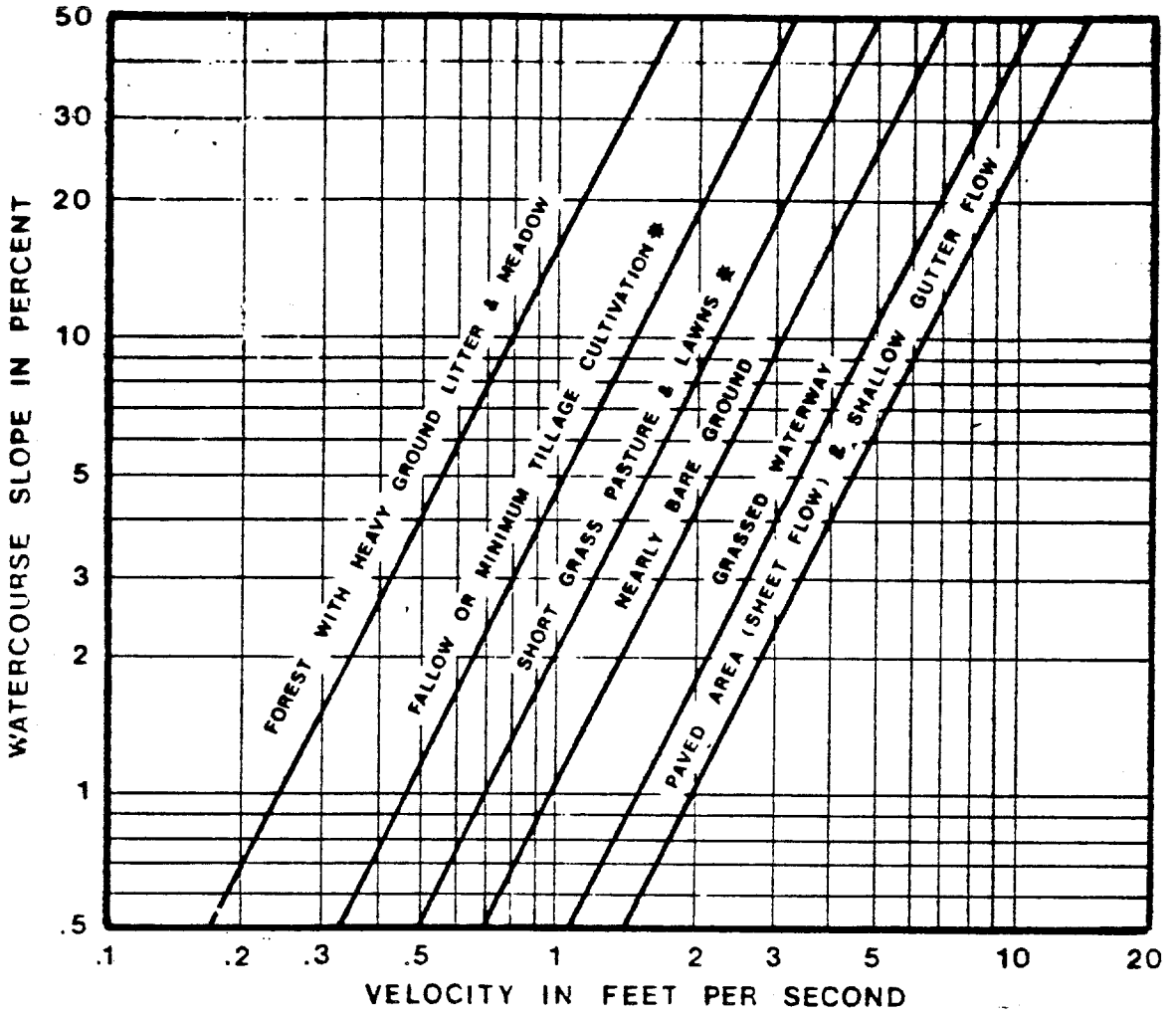
(303) 233-0533



REFERENCE: "Urban Hydrology For Small Watersheds" Technical Release No. 55. USDA. SCS Jan. 1975.

FIGURE 5

AVERAGE VELOCITIES FOR ESTIMATING TRAVEL TIME FOR OVERLAND FLOW

DEC
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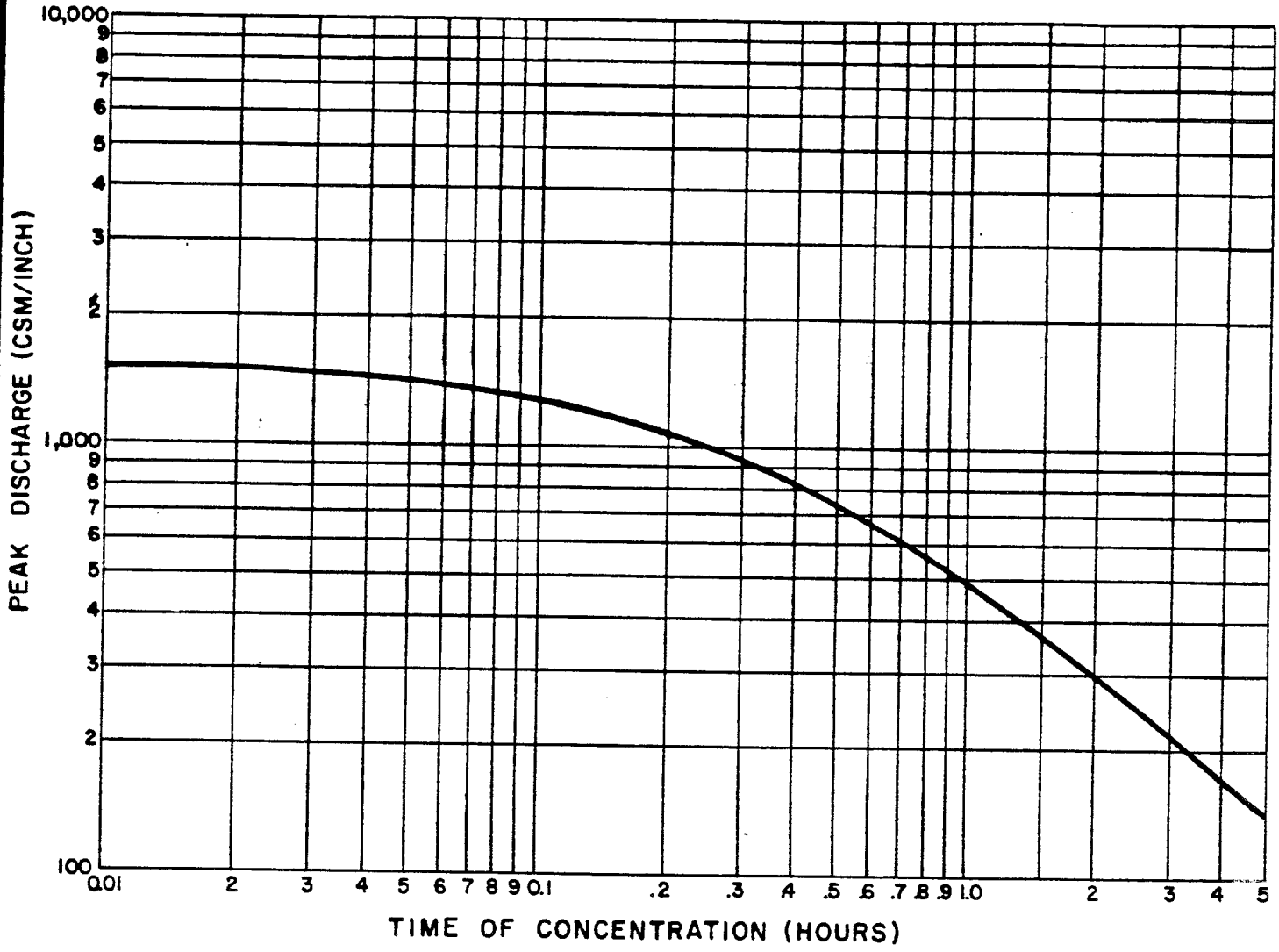
Golden, Colorado 80401
(303) 233-0533



REFERENCE: 1. Colorado Springs Drainage Criteria Figure I for T_C between 0.1 and 5 hours for 6 hour Type II A storm.

2. T_C between 0.01 and 0.1 hours is extrapolated.

FIGURE 6

TIME OF CONCENTRATION AS A FUNCTION OF PEAK DISCHARGE

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Denver Engineering Corporation
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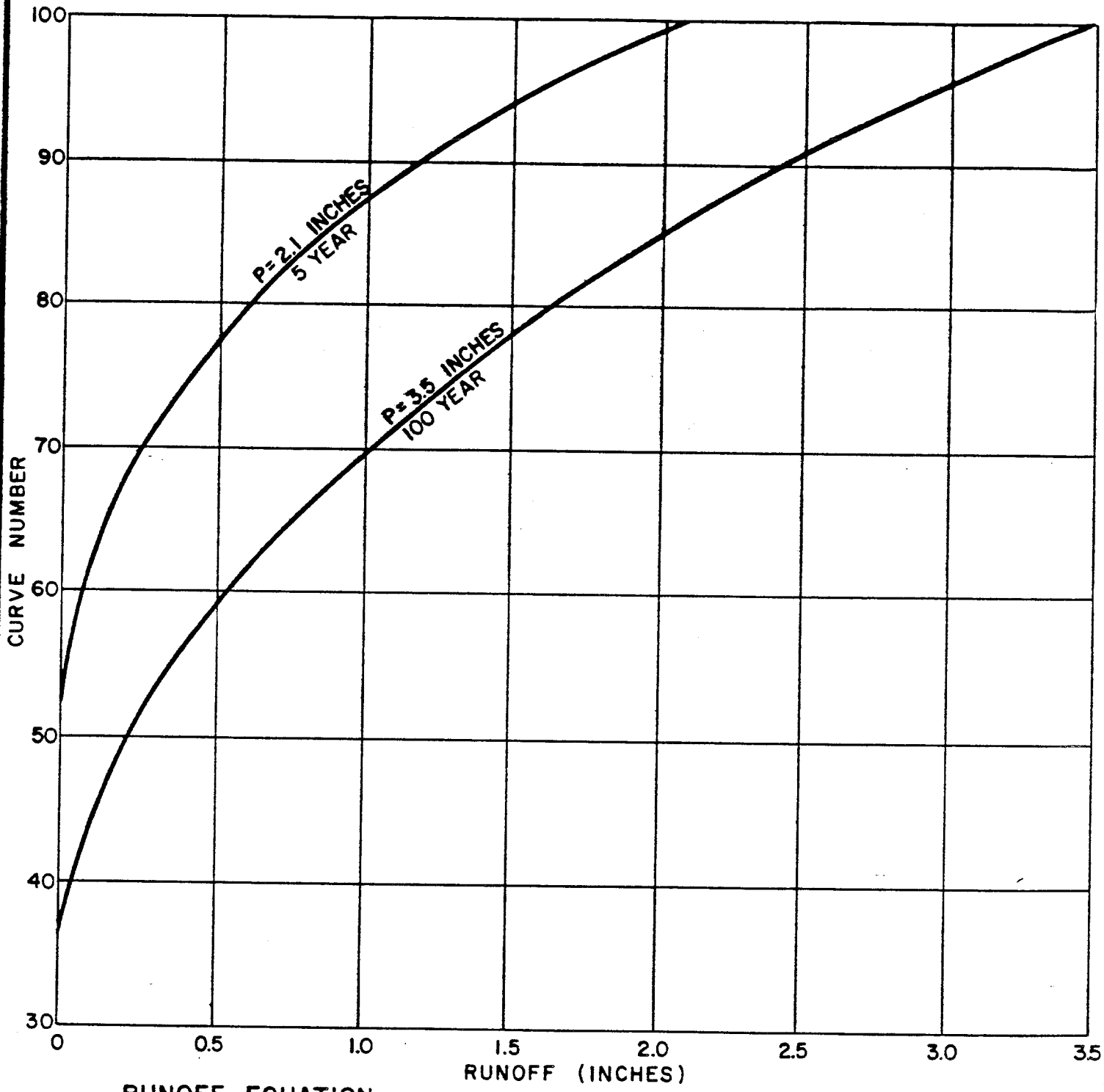
Golden, Colorado 80401
(303) 233-0533



RUNOFF EQUATION

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad S = \frac{1000}{CN} - 10$$

POINT OF ZERO RUNOFF	CN
5 YEAR STORM	48.8
100 YEAR STORM	36.4

FIGURE 7

RUNOFF AS A FUNCTION OF CURVE NUMBER & PRECIPITATION

Denver Engineering Corporation
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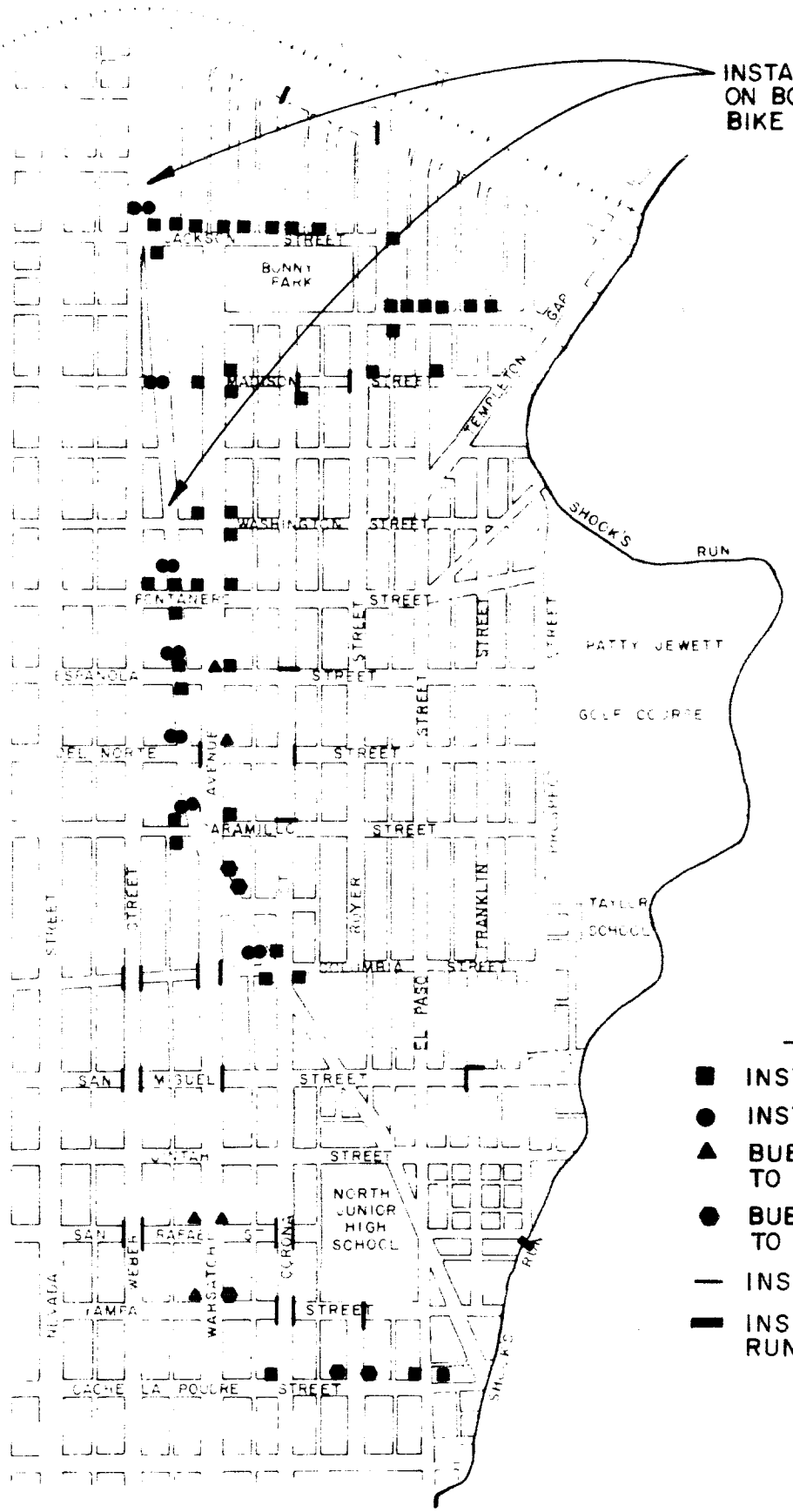

FIGURE 8

RECOMMENDED SURFACE DRAINAGE IMPROVEMENTS

Denver Engineering Corporation
1626 Cole Boulevard
Suite 300 • Building 7
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(303) 233-0533