Sand Creek Master Drainage Planning Study

CITY OF COLORADO SPRINGS & EL PASO COUNTY

Development of Alternate Plans

JULY 1985

PREPARED BY

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July 31, 1985

City of Colorado Springs
Department of Public Works
Engineering Division
30 South Nevada Avenue, Suite 403
Colorado Springs, Colorado 80903

Re: Sand Creek Master Drainage Planning Study (SLA Project Number PCO-FA-01)

Gentlemen:

In accordance with the City of Colorado Springs' request for an update of the Sand Creek Drainage Basin, a detailed engineering study has been completed on the entire basin. The results of the study are included herein.

If you have any questions or desire further information, please feel free to call.

Respectfully submitted,

SIMONS, LI & ASSOCIATES, INC.

Richard N. Wray

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Enclosures

D23/R632CL-1

Sand Creek Drainage Basin and Bridge Fees approved by Drainage Board 12-20-84.

Sand Creek Master Drainage Basin Report Technical Data effective as of July 31, 1985.

Also See Technical Addendum.

Executive Summary

This report summarizes the results of the Sand Creek Master Drainage Basin Planning Study, in Colorado Springs and El Paso County, Colorado. The planning included hydrologic, hydraulic and economic analysis of drainageway improvement alternatives, as well as an evaluation of basin fees to cover future costs of drainage facilities and bridge construction. Alternatives were developed to minimize the impact to the floodplains and adjacent existing development by future urbanization within the Sand Creek Basin. The work was performed as part of the annexation agreement between the developers of the Colorado Springs Ranch and the City of Colorado Springs, Colorado. A technical addendum has been prepared under a separate cover.

Basin Characteristics

The study area is located in west-central El Paso County, Colorado, and includes part of the City of Colorado Springs. The total basin covers approximately 55 square miles of residential, commercial, light industrial, and rural areas of which the latter is the most predominant current land use. Proposed development within the basin has forced the reevaluation of the 1977 Sand Creek Master Drainage Plan hydrologic analysis, so that future drainage and bridge improvements can be sized according to ultimate development condition peak 100-year flow rates.

Hydrologic Analysis

Peak flow rates for the 5- and 100-year frequencies, 6- and 24-hour rainfall events were determined. Flows for major design points are summarized on Exhibit 2, and sub-basin hydrologic data is presented on Table 21 in the Appendix. The hydrologic method used was the Soil Conservation Services Procedures for Determining Peak Flow Rates in Colorado, as modified in the City of Colorado Springs "Storm Runoff Determination Criteria Manual". Peak 100-year flow rates for existing development conditions corresponded well with the peak flows for Sand Creek used in the Preliminary Flood Insurance Study for El Paso County, and the City of Colorado Springs.

The effect on peak flow rates of onstream detention was also analyzed as part of the hydrologic analysis. In general, introducing onstream detention within certain sub-basins of Sand Creek can reduce the peak flow rates for the ultimate development condition to historic levels, and extend the design life of existing drainage structures along Sand Creek and its major subtributaries. Currently, detention ponding is not contained within the guidelines of the Colorado Springs Storm Runoff Criteria Manual.

Hydraulic Analysis

The floodplains for Sand Creek, East Fork Sand Creek, the East Fork Subtributary of Sand Creek, and the Central Tributary of Sand Creek were previously defined, for existing development conditions, by the Federal Emergency Management Agency (FEMA), in the Preliminary Flood Insurance Studies for El Paso County, and the City of Colorado Springs. The hydraulic analysis performed for this study included the delineation of existing and ultimate development condition floodplains for Sand Creek and its major tributaries. The existing condition floodplain delineation effort utilized the same base topographic mapping contained on the FEMA Flood Insurance Study, and supplemented this information with current mapping in areas such as the Colorado Springs Ranch and Stetson Hills.

The floodplain for Sand Creek varies from narrow, deep (greater than seven feet) and high velocity (greater than 15 feet per second) segments where channelization occurs to unimproved segments where the depth is shallow (five feet and less), with low overbanks which experience wide, shallow, low velocity flooding. The potential for erosion and sedimentation is high due to the meandering nature of the stream thalweg, and the highly erodable soils characteristic of the Sand Creek Basin.

An inventory of existing bridge structures in the Sand Creek basin was conducted. This information was used to guide the alternative design process, and to check the adequacy of each structure to convey the ultimate development condition peak 100-year flow rates.

Evaluation of Alternatives

Drainage improvement alternatives were developed to reduce existing flooding, mitigate the damages from potential future flooding, and to allow for the conveyance of the 100-year flood. Three basic alternatives were developed for the Sand Creek Basin, namely, (1) full channelization of the ultimate development condition peak 100-year flow rates, (2) full channelization with segments of Sand Creek left in its natural and existing condition, and

(3) full channelization of existing development condition peak 100-year flow rates, combined with onstream detention. Drainage improvements were analyzed on a reach-by-reach basis to allow the provision of different levels of protection depending upon flood damages, and the characterics of future development within the basin.

Each alternative was evaluated qualitatively for aspects such as damage reduction, impact to private land, aesthetics, multiple use opportunities, erosion and sedimentation, implementation and conformance with existing facilities.

Economic Analysis

Costs of drainage and bridge improvements were estimated for each alternative. Costs included construction, engineering, and contingency costs. Long-term operations and maintenance costs were also estimated for each alternative.

A discussion of the impact of land value upon each of the three alternatives was included. Alternatives 2 and 3 are adversely effected when the value of land is included in the considerations for selection of the best alternative design.

Selected Alternative

As a result of the review of the Draft Sand Creek Master Drainage Planning Study submitted to the City of Colorado Springs and El Paso County in October, 1984, and ensuing discussions concerning the Draft Study, the selected plan for the Sand Creek Basin, decided upon was Alternative 1, the channelization of the 100-year, ultimate development condition flows. The scope of the improvements are shown on Exhibit 1, and summarized in Table 20. This plan would reduce the existing flooded areas to channels, sized to convey the 100-year flow. Bridge crossings were sized to convey the 100-year peak flow, and are also shown on Exhibit 1.

Fees for drainage and bridge improvements have been summarized below. The fees for drainage have been based upon the unplatted acreage in the Sand Creek Basin. The acreage within the Colorado Springs Municipal Airport/ Peterson Air Force Base was included in hydrologic calculations but was not included in basin fee determination. Likewise, the "Black Forest Area" as defined in Chapter III was also excluded from the basin fee determination.

City and County bridge fees have been calculated using only those costs which would be the responsibility of local developers as per the methodology contained in Chapter 15, Article 3, Part 10 of the City of Colorado Springs Subdivision Policy Manual (1980).

Determination of Basin Fees for Selected Plan
Sand Creek Drainage Basin Planning Study

Fee Type**	Estimated Total Construction Cost	Acreage	Fee $/Acre
Drainage			
City and County	97,289,900	20,322*	4794
Bridge			
City	9,419,200	12,032	400
County	7,722,400	15,131	462

* Unplatted acreage derived for zoning maps for the City of Colorado Springs and El Paso County, Colorado. Refer to Table 12 for acreage breakdown used for fee determination.

** Refer to Table 19 for fee calculations.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES AND EXHIBITS

LIST OF TABLES

LIST OF TABLES (continued)

I. INTRODUCTION

Authorization

This study titled the "Sand Creek Master Drainage Planning Study," was authorized as per the annexation agreement between the City of Colorado Springs and the developers of the Colorado Springs Ranch. The study is an update of the "Master Drainage Study, Sand Creek Drainage Basin," prepared by United Western Engineering Company in 1977. An addendum, summarizing technical data has also been prepared under a separate cover.

Purpose and Scope of Study

The purpose and scope of the study is to analyze drainage conditions within the Sand Creek drainage basin, determine the potential drainage problems, determine the impacts of future development, and to develop alternative drainage improvements to reduce future impacts due to flooding.

The specific scope of work for this study includes the following tasks:

1. Meet initially and biweekly with the City of Colorado Springs to insure compliance with existing information, and to solicit the desires of the participating entities.
2. Contact the county, individuals, and other agencies who have knowledge and/or interest in the study area.
3. Utilize existing City of Colorado Springs criteria and hydrologic information where possible.
4. Perform hydraulic analyses for Sand Creek and its tributaries within the study area.
5. Define drainage problems and flood hazard areas and give the City and County technical data for ongoing and future drainage planning.
6. Determine impacts to floodplain areas resulting from future improvements such as channelization and crossings.
7. Prepare an inventory of existing drainage facilities.
8. Develop improvement alternatives to reduce existing and potential flooding problems.
9. Evaluate each major drainage alternative with respect to cost, mitigation of flood problems, land use, and environmental consideration.
10. Examine the operation and maintenance aspects of the alternatives.
11. Conduct an economic analysis of each alternative.
12. Prepare a written report discussing all items examined in the study.

Summary of Data Obtained

Listed below are the sources of technical information collected for use in this study:

1. U.S. Department of Agriculture Soil Conservation Service, "Flood Hazard Analyses, Sand Creek," Appendix II, 1973 (Reference 1).
2. "Sand Creek Drainage Basin Study," prepared by United Western Planning and Engineering Company, dated October, 1977 (Reference 2).
3. "Preliminary Flood Insurance Studies for Colorado Springs, and El Paso County, Colorado", prepared by the Federal Emergency Management Agency (FEMA), 1983 (Reference 3).
4. "Master Drainage Study for Stetson Hills," prepared by Greiner Engineering Sciences, Inc., August 1984 (Reference 4).
5. "Preliminary Master Drainage and Flood Plain Study for the Banning Lewis Ranch," prepared by MSM Consultants, Inc., dated June 1981 (Reference 5).
6. "Impact Study of the Sand Creek Drainage Basin," prepared by Finn and Associates, Ltd., dated June 1984 (Reference 6).
7. Design Drawings for culvert crossings at Chelton Road, Galley Road, Constitution Avenue, Powers Boulevard and North Carefree Drive.
8. City of Colorado Springs "Determination of Storm Runoff Criteria Manual," dated 1979 (Reference 7).
9. Soil Survey for El Paso County, Colorado, U.S. Department of Agriculture, dated June 1980 (Reference 8).
10. Design Guidelines and Criteria for Channel and Hydraulic Structures on Sandy Soil," Urban Drainage and Flood Control District, June 1981 (Reference 9).

Listed below are the sources of planning information collected for use in this study:

1. "Master Plan for the Colorado Springs Ranch", prepared by Finn and Associates, Ltd., amended May 1984.

2. "Master Plan for Stetson Hills", prepared by PGAV, Inc., dated 1984.

3. "East Corridor Concept Study" prepared by Resource Development Engineering, dated February 1984.

4. "Master Drainage Plan for the Colorado Springs Science Park", prepared by R. Keith Hook and Associates, Inc., dated May 1984.

The above reports have been used for information purposes only, some of which have not been approved by the City of Colorado Springs or El Paso County.

Mapping and Surveying

Various sources of topographic mapping were used to compile the flood plain maps presented herein. Listed below are the topographic maps used in this study.

1. Two-foot contour interval, 1-inch to 200-foot scale topographic maps, prepared by Landmark Mapping, Ltd., Lakewood, Colorado, dated June 1981.

2. Colorado Springs Ranch Development, two-foot contour, 1-inch to 100-foot scale topographic maps, prepared by Scharf and Associates, Denver, Colorado, dated June through August 1984.

3. Stetson Hills Development, five-foot contour interval, 1-inch to 400-foot scale, topographic maps prepared by Analytical Surveys, 1984.

4. 7.5 minute quadrangle maps prepared by the U. S. Geological Survey.

Acknowledgements

During the course of the preparation of this study, officials from the City of Colorado Springs, and El Paso County and others provided technical input and guidance. Specifically, we would like to thank the following departments:

City of Colorado Springs
Engineering Department

Department of Transportation
El Paso County

Department of Land Use
El Paso County

Pikes Peak Area Council
of Governments

We would also like to thank the development teams of the Colorado Springs Ranch, Stetson Hills, Mobil Land and the Colorado Springs Science Park, for their provision of planning and technical documents associated with each of their developments.

II. BASIN CHARACTERISTICS

Study Area Description

The Sand Creek drainage basin is a left-bank tributary to the Fountain Creek lying on the west-central portions of El Paso County. Sand Creek's drainage area above Fountain Creek is approximately 55 square miles of which approximately 18.8 square miles are inside the City of Colorado Springs corporate limits. The basin is divided into five major sub-basins, the Sand Creek mainstem, the East Fork Sand Creek, the Central Tributary to East Fork, the West Fork, and the East Fork Subtributary. Figure 1 shows the Sand Creek study area and the major sub-basins.

The Sand Creek basin is currently experiencing development pressure in areas immediately upstream of the present City of Colorado Springs corporate limits. Most of the development calls for single- and multi-family residential building, mixed with office-park, commercial and light industrial areas. The majority of the existing development, similar to that described above, is within the City of Colorado Springs. Current development in the County consists largely of 2 and 1/2- and 5-acre subdivisions.

For purposes of analyzing the drainage problems and potential hazards, the basin was divided into eight stream reaches. These are described in Table 1, and shown graphically on Figure 1. The study reaches vary slightly from the 1977 Sand Creek Study, however, this update encompasses the same planning area.

Basin Description

The Sand Creek basin covers 55 square miles in El Paso County and Colorado Springs, Colorado. The basin trends in generally a south to southwesterly direction, entering the Fountain Creek approximately two miles upstream of the Academy Boulevard bridge over Fountain Creek. Two main tributaries drain the basin, those being the mainstem of Sand Creek and East Fork Sand Creek. Development presence is most evident along the mainstream, with the easternmost sub-basins. At this time, approximately 15 percent of the basin is developed.

The maximum basin elevation is approximately 7,620 feet above mean sea level, and falls to approximately 5,790 feet at the confluence with Fountain Creek. The headwaters of the basin originate in the conifer covered areas of The Black Forest. The middle eastern portions of the basin are typified by

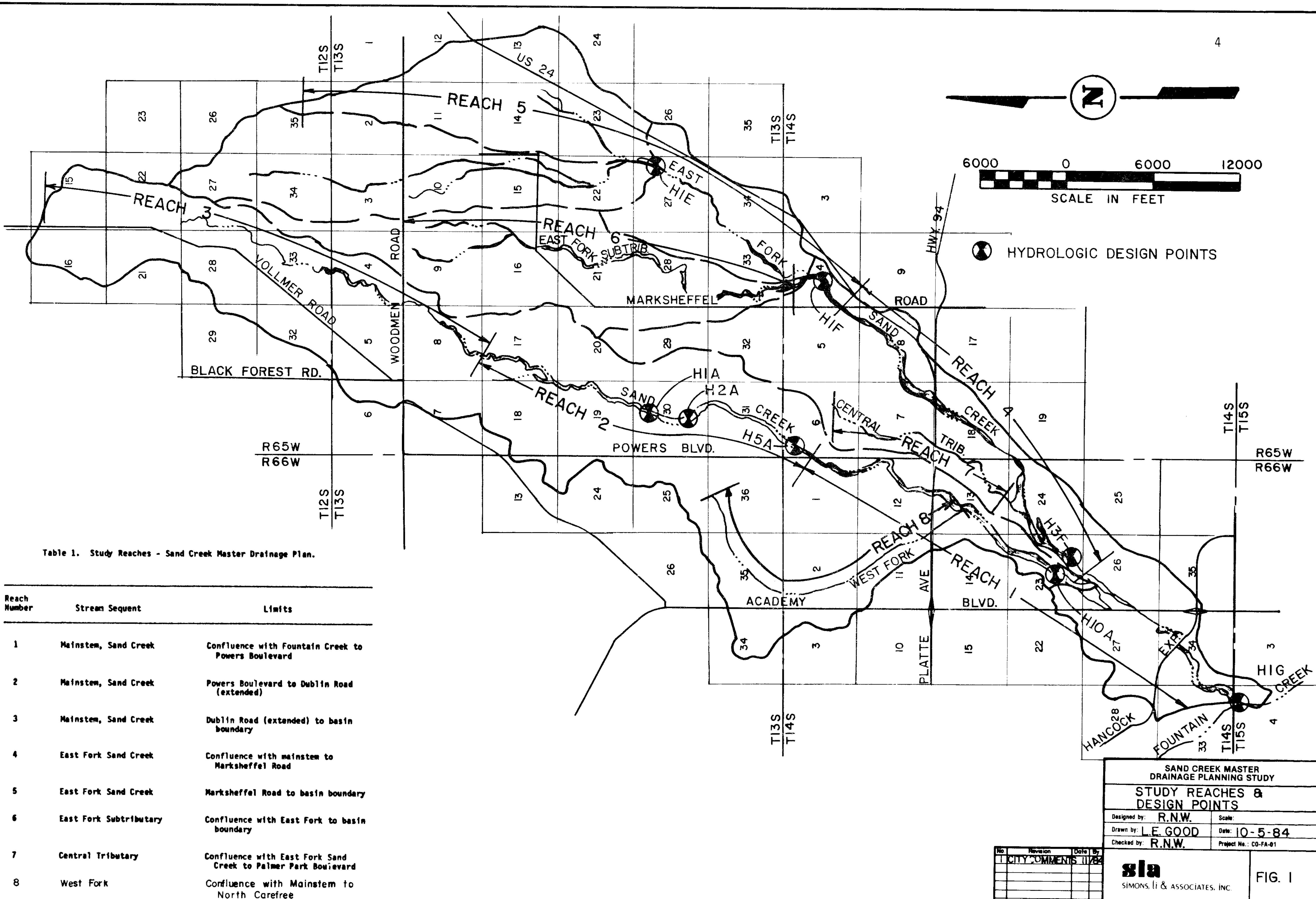


Table 1. Study Reaches - Sand Creek Master Drainage Plan.

Reach Number	Stream Sequent	Limits
1	Mainstem, Sand Creek	Confluence with Fountain Creek to Powers Boulevard
2	Mainstem, Sand Creek	Powers Boulevard to Dublin Road (extended)
3	Mainstem, Sand Creek	Dublin Road (extended) to basin boundary
4	East Fork Sand Creek	Confluence with mainstem to Marksheffel Road
5	East Fork Sand Creek	Marksheffel Road to basin boundary
6	East Fork Subtributary	Confluence with East Fork to basin boundary
7	Central Tributary	Confluence with East Fork Sand Creek to Palmer Park Boulevard
8	West Fork	Confluence with Mainstem to North Carefree

rolling range land with fair to good vegative cover associated with semi-arid climates.

Climate

This area of El Paso County can be described, in general as high plains, with total precipitation amounts typical of a semi-arid region. Winters are generally cold and dry, and summers relatively cool and dry. Precipitation ranges from 14 to 16 inches per year, with the majority of this precipitation occurring in spring and summer in the form of rainfall. Thunderstorms are common during the summer months, and are typified by quick-moving low pressure cells which draw moisture from the Gulf of Mexico into the region. Average temperatures range from about 30°F in the winter to 75° in the summer. The relative humidity ranges from about 25 percent in the summer to 45 percent in the winter.

Soils and Geology

Soils within the Sand Creek basin vary between soil types A through D, as identified by the U. S. Department of Agriculture, Soil Conservation Service, (Reference 8). The predominant soil groupings are in the Truckton and Bresser soil associations. The soils consist of deep, well drained soils that formed in alluvium and residium, derived from sedimentary rock. The soils have high to moderate infiltration rates, and are extremely susceptible to wind and water erosion where poor vegetation cover exists. In undeveloped areas, the predominance of Type A and B soils give this basin a lower runoff per unit area as compared to basins with soil dominated by Types C and D.

Flood History

The eastern portions of El Paso County have a history of severe flooding, with several events directly impacting the Sand Creek basin. Flooding along Sand Creek has occurred as a result of both short- and long-duration rainfall events. The June, 1965, flood could be classified a long-duration event, with several days of moderate to intense rainfall followed by a day of intense, localized rainfalls. The 1965 flood caused extensive damages to range and farm land due to heavy deposition of sand along the flood plain. Structural damages were limited to roadway crossings and embankments, particularly downstream of Fountain Boulevard.

The July, 1970, flood event on Sand Creek was caused by a brief but intense rainfall. Estimates were that 1-1/4 inches fell in a two hour period. Damage included culvert washouts, and damage to roadway embankments at Powers and Fountain Boulevards. One life was lost in this flood.

Both of these events clearly show that the potential for severe flooding is present in the Sand Creek basin. Long-term events will have the ability to cause extensive transport of sediment. The cost of clean up of such sediment flows will be substantially higher (assuming the same size of storm event), as the basin moves towards full development. The potential for debris flow damage is presently most pronounced in Reach 1.

The potential for flash flooding will increase as urbanization continues in the Sand Creek basin. Urban development tends to shorten the time to peak and increase the volume of runoff as compared to existing conditions. Conversely, the potential for widespread sediment deposition in a brief, but intense rainfall event, is high with the basin in its current condition, but as urban development continues, the sediment supply will tend to decrease. This change in the development characteristics may result in channel degradation and bank erosion being the most common type of damages in the long-term future.

Sediment

Grain size distributions for several bed and bank samples taken from Sand Creek (mainstem) were analyzed as part of this study. For Reaches 1 and 2 of Sand Creek, the largest percentage of sediment size occurs in the range of .2 millimeters to 4 millimeters. This range is generally classified as fine to medium sand. Very coarse sand and cobbles are not generally found in the Sand Creek alluvium material. Sampling revealed that the bed material has a median particle size of 1.5 millimeters. All of the soils analyzed can be easily transported by flows equal to the mean annual storm.

For Reach 1 and 2, an equilibrium slope analysis performed as part of this study. From the analysis, it is estimated that the river system is in a long-term steady degradation, with the creek seeking slopes between 1 and 1.5 percent. The lower reaches of the mainstem of Sand Creek are presently aggrading because of the flatter slope (as compared to slopes on upstream reaches), and the heavy sediment loading due to erosion from construction sites. Because of urbanization, the long-term degradation will largely be the result of a decreasing sediment supply combined with larger, more frequent average discharges, see Chapter VII, Recommended Plan.

III. HYDROLOGIC ANALYSIS

The hydrologic analysis of the Sand Creek basin focused on establishing the existing and future condition peak flow rates and volumes for the 5- and 100-year frequency storm events. The hydrologic analysis considered the effect of regional detention on peak flows. Finally, the hydrology provided herein establishes peak flow rates for smaller sub-basins, which can be later used in the design of local drainage systems and collector channel/pipes as the basin develops. Calculations conducted during the hydrologic analysis have been included in the Technical Addendum to this study, and summarized in this report.

Rainfall

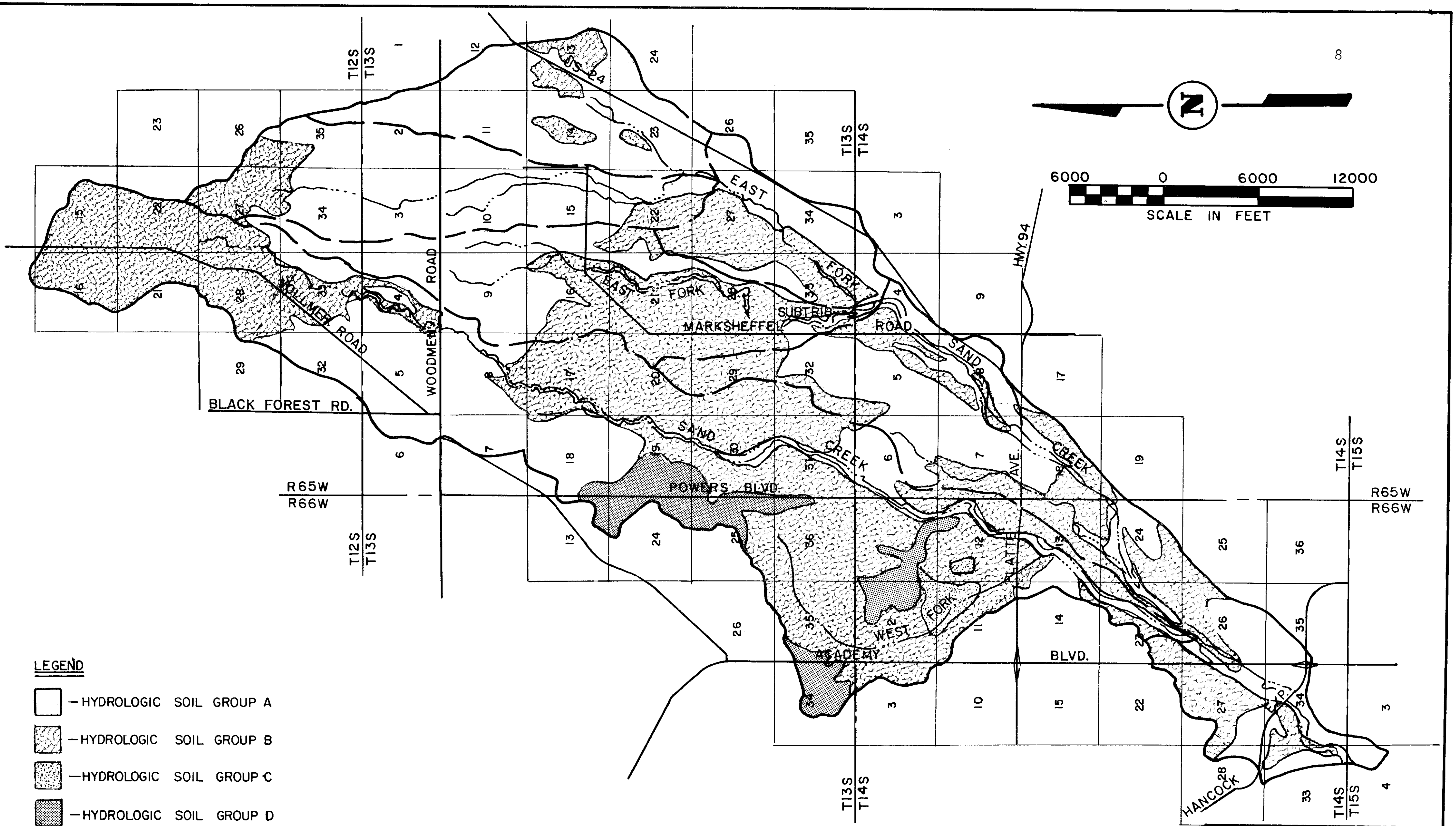
Rainfall amounts for the 5- and 100-year storm events were compiled using the Precipitation-Frequency Atlas of the Western United States, Volume III, Colorado, (Reference 10). Precipitation amounts used were 2.7 inches and 4.5 inches for the 24 hour storm of 5- and 100-year frequences, respectively. The precipitation amounts used for the six-hour duration, 5- and 100-year storm were 2.1 inches and 3.0 inches respectively. The 24-hour storm Type-IIA rainfall distribution was used for modelling the major and sub-basins of Sand Creek, however, the six-hour, Type-IIA rainfall pattern was modelled for all sub-basins, primarily to provide peak flow rates for the design of local storm drainage systems. The use of these storms in storm drainage design is in conformance with Reference 7.

It should be noted that the Sand Creek flood history would indicate that the long-duration storm has caused major flooding to occur on the mainstem. Short-duration rainfall events have typically caused local flooding along tributaries to the mainstem and the East Fork, such as the Central Tributary defined as Reach 7 in this study.

Soils and Land Use

In order to establish the runoff amounts from the Sand Creek basin, soils and land use data were evaluated. This data is then input into the hydrologic model to generate peak flow data for various land use patterns.

As discussed above, the Sand Creek basin is predominantly made up of Type A and B soil groups, as described in the El Paso County Soil Survey. Figure 2



SAND CREEK MASTER DRAINAGE PLANNING STUDY

SOILS MAP

Designed by:	J.R.L.	Scale:	
Drawn by:	E.K.	Date:	9/84
Checked by:	R.N.W.	Project No.:	CO-FA-01

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1	CITY COMMENTS	11/84	

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FIG. 2

shows the extent of the various soil groups which occur in the Sand Creek basin.

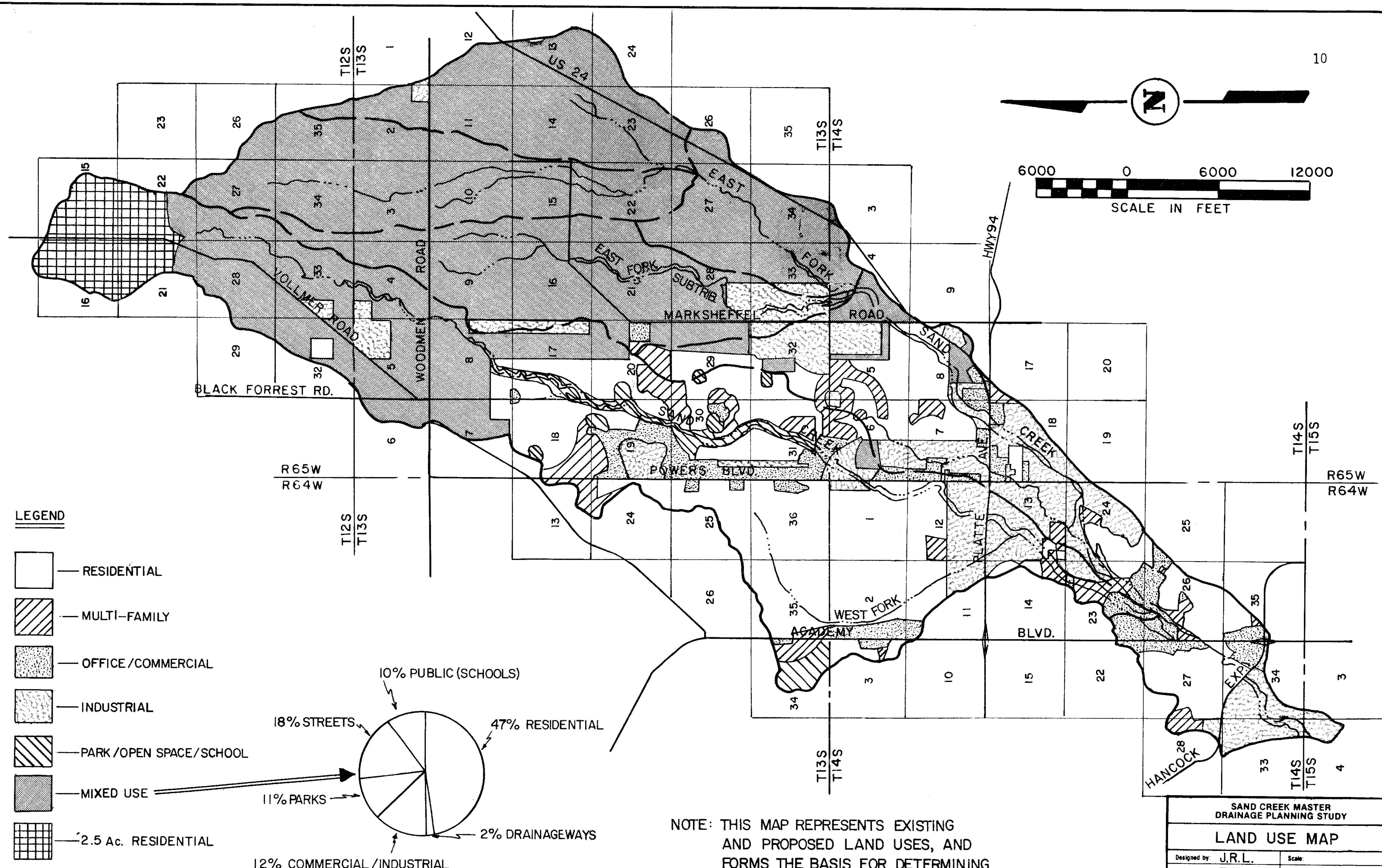
Land use data was generated from various planning reports and through discussions held with the County, City and local developers. The Land Use Map shown on Figure 3 was used to aid in the estimation of curve numbers (or CN-values), for input into the hydrologic model. The intent of this map is not to set land use policy, but to provide future drainage planners with a guideline to establish CN-values for various land uses, consistent with this master plan. The Land Use Map is based upon existing development (1984), and projected land uses obtained from the planning studies itemized in Chapter I.

The Black Forest Area which consists of that portion of the Sand Creek Basin being within Sections 15, 16, 21, and 22, all being within Township 12 South, Range 65 West of the 6th P.M., El Paso County, Colorado, with the exception of the S-1/2 of the S-1/2 of said Section 21 and 22, was assumed to have a fully developed density of one dwelling unit per 2-1/2 acres.

Hydrologic Results

To develop runoff information for the major sub-basins of Sand Creek, the TR-20 Project Formulation-Hydrology Computer Program was used. This program was used to evaluate the 5- and 100-year peak flows. Peak flow rates were evaluated at key design points and are listed on Table 2, (presented on Exhibit 2), for existing and future development conditions. Exhibit 2 illustrates the location of design points throughout the basin, and each points ultimate development condition peak 5- and 100-year discharges. The design points shown coincide with existing or proposed roadway crossings and at confluence points of the major sub-tributaries. The results for the existing development condition compare favorably with the peak flows predicted in the FEMA preliminary Flood Insurance Study for Colorado Springs and the 1977 Sand Creek Master Plan. Small differences in the peak flows for the existing conditions are attributable to assumptions of land uses, soils data, and differences in design point locations.

Peak flow rates at the confluence with Fountain Creek for the future condition shown in Table 2 are approximately 30 percent higher than the peak flows presented in Reference 2. The variance is due to land use assumptions made in the 1977 Master Planning study, which assumed all areas outside of the Colorado Springs corporate limits as agriculturally zoned. Land development



NOTE: THIS MAP REPRESENTS EXISTING AND PROPOSED LAND USES, AND FORMS THE BASIS FOR DETERMINING RUNOFF CHARACTERISTICS OF SUB-BASINS WITHIN THE SAND CREEK BASIN.

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SAND CREEK MASTER DRAINAGE PLANNING STUDY

LAND USE MAP

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Drawn by: E.K. Date: 9/84
Checked by: R.N.W. Project No.: CO-FA-01

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FIG. 3

projects which have been proposed since the completion of the 1977 Master Plan have resulted in a significant change in land use assumptions for the Sand Creek Basin.

Alternative Hydrologic Analysis

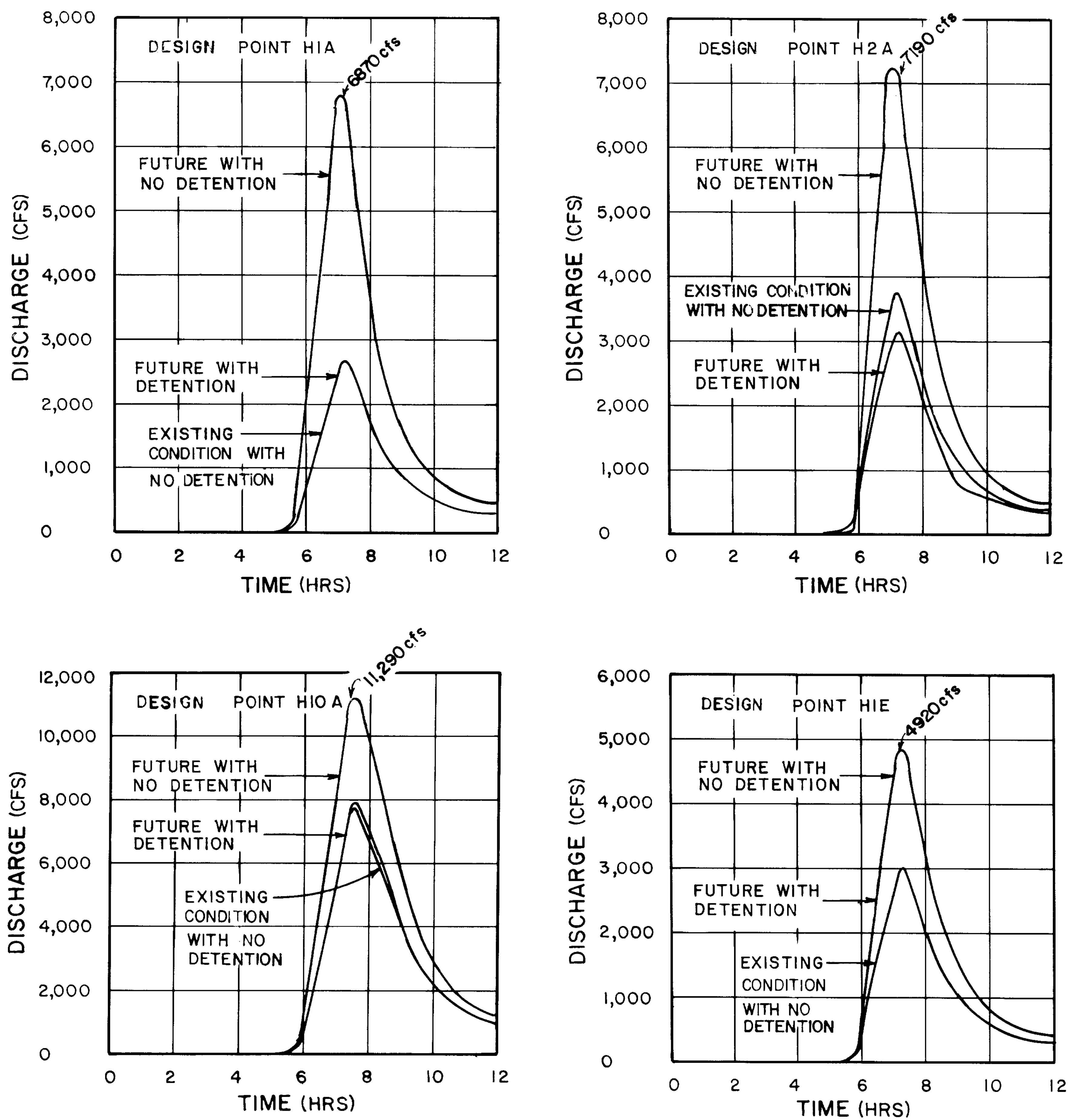
The increase in future condition runoff estimates from the 1977 Master Plan have brought about the need to examine what effects the use of stormwater detention could have on the existing and future drainage facilities in the Sand Creek basin. As will be pointed out in later sections of this study, several existing stream crossings over the mainstem of Sand Creek are of insufficient capacity to convey the 100-year, ultimate development condition runoff as calculated herein. Additionally, the crossings currently under construction at Chelton Road and proposed at Galley Road have been sized according to the peak flow rates as per the 1977 Master Plan. The alternative hydrologic analysis, therefore, focuses on the ability of stormwater detention to reduce peak flows and potential flooding depths, damages, and to reduce the sizes and costs of drainage improvements needed as the basin develops.

The Sand Creek basin has already developed to a point where the sites for onstream detention are limited to Reaches 2 and 3 on mainstem, and Reaches 5 and 6 on the East Fork. Stock ponds and other depression areas exist on the East Fork and the East Fork Subtributary, however, these are not of sufficient size to detain 100-year peak discharges. For the purpose of analyzing the potential for stormwater detention in the Sand Creek basin, two detention schemes were analyzed. These were:

1. Detention of fully-developed flows tributary to Reaches 2 and 3 of the mainstem, (Alternate 3) and

2. Detention of fully-developed flows tributary to Reaches 2 and 3 of the mainstem, and to the East Fork of Sand Creek, Reaches 5 and 6. (Alternate 3).

No attempt was made to select potential sites for onstream detention ponds, rather is was assumed that peak discharges from these ponds would not exceed the existing development condition flow rates. Outlet works considered for detention and the size of onstream detention ponds could further reduce the peak flows estimated in this study. Figure 4 presents 100-year Flood Hydrographs for the future development, detention scheme 2, (Alternate 3) and



NOTES: 1.) "FUTURE" REFERS TO THE PROJECTED RUNOFF AMOUNTS WITH FULL BASIN DEVELOPMENT AS PER FIGURE 3.

2.) HYDROGRAPHS FOR THE "FUTURE WITH DETENTION" CONDITION CONSIDERS DETENTION WITHIN REACHES 2,3,5 & 6.

SAND CREEK MASTER DRAINAGE PLANNING STUDY

100 YR. FLOOD HYDROGRAPHS

Designed by: J.R.L.	Scale:
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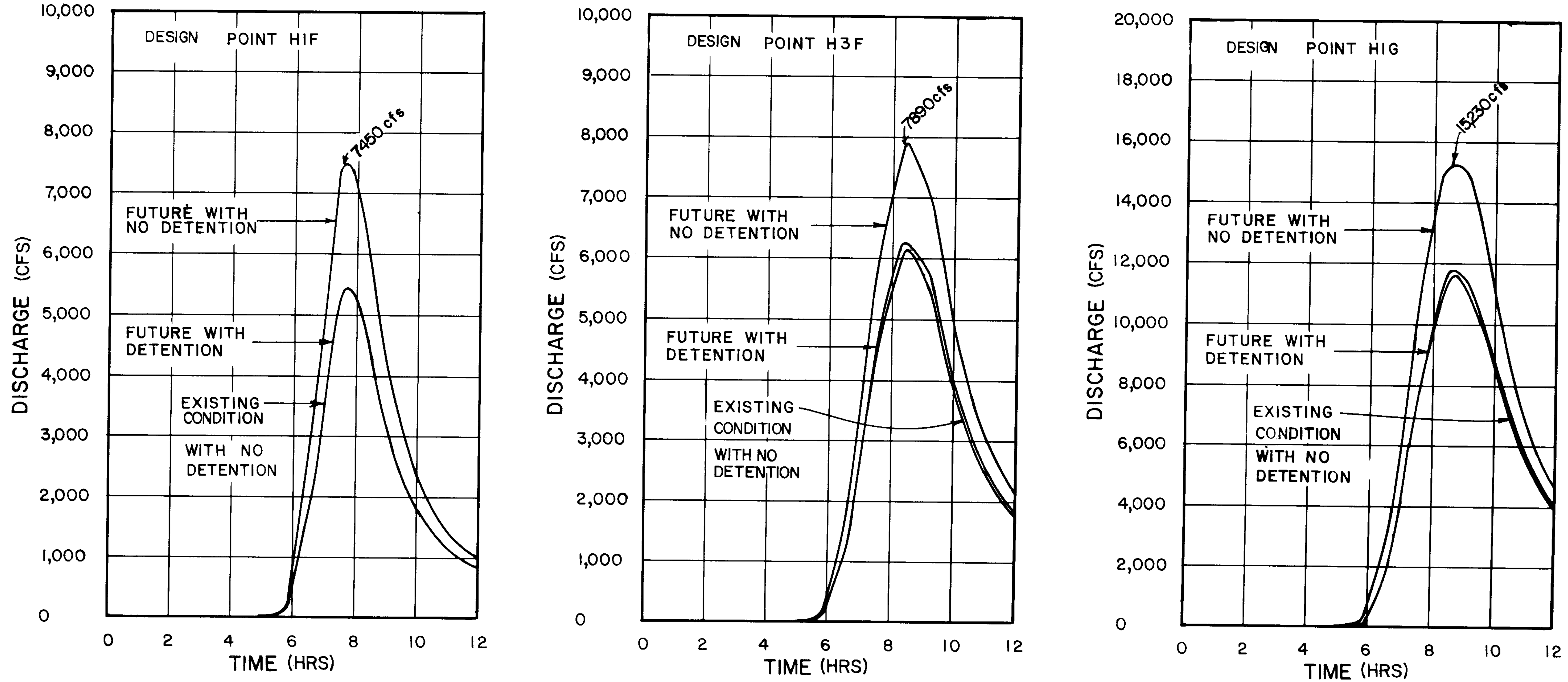
FIG. 4



SAND CREEK MASTER DRAINAGE PLANNING STUDY

100 YR. FLOOD HYDROGRAPHS

Designed by: J.R.L.	Scale:
Drawn by: L.E. GOOD	Date: 10-2-84
Checked by: R.N.W.	Project No.: CO-FA-01

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FIG. 4, CONT'D.

for existing development conditions at selected design points.

The affect on peak discharges is small when detention is considered for Reaches 2 and 3 alone, and thus the size and general configuration of downstream structures would not be altered substantially as compared to the channel sections necessary to convey future development flows. Right-of-way construction costs, and maintenance would also not be significantly reduced for drainage structures downstream of Reaches 2 and 3. Detention scheme 2 however does cause a significant decrease in peak flows, and the associated size of channel right-of-way.

In general, existing channel sections, within Reaches 1, 4, and 8, are of adequate capacity to convey the future condition 100-year peak flow, assuming rigid channel boundaries, except at crossings. In reaches with existing channels, therefore, the use of detention, as previously discussed, is of little significance, if the drainage right-of-ways along main channels remain unchanged in the future.

Hydrologic Analysis for Sand Creek Sub-basins

The hydrologic data contained in the "Impact Study of the Sand Creek Drainage Basin" prepared by Finn & Associates, Ltd., (Reference 6), was reviewed as part of this master plan. Ultimate development conditions, peak flow rates for minor sub-basins were estimated for the 5- and 100-year, 6- and 24-hour rainfall events. The results of this analysis can be used in the sizing of local storm sewer collection systems, in areas which are currently undeveloped. This data is contained in the Appendix of this study.

IV. HYDRAULIC ANALYSIS

General

The hydraulic analysis conducted as part of this Master Plan focused on establishing the existing stream flooding problems, as well as estimating areas of future potential flood hazard for Sand Creek. Available hydraulic data was used and modified where necessary to reflect existing channel and bridge crossings. Specifically, stream cross-section data from the Colorado Springs and El Paso County Preliminary Flood Insurance Study, the Colorado Springs Ranch Master Drainage Plan and the Stetson Hills Master Drainage Plan were used in the evaluation of the existing and future condition 100-year water surface elevations. Differences of less than one-foot were noted in areas of overlap between the three map sources. All mapping was compiled using the National Geodetic and Vertical Datum (NGVD). The Flood Hazard Area Maps are presented on Plates 1 through 22 at the end of this report.

The U.S. Army Corps of Engineers HEC-2, Water Surface Profile Program (Reference 11) was used to evaluate the water surface profiles. Data presented in the preliminary Flood Insurance Studies were duplicated herein in order to establish a baseline condition. Future condition peak discharges presented herein were then input into the program. Locations where bridges are proposed, under construction, or built since the Flood Insurance Study was completed were modelled. The HEC-2 data and detailed printouts are provided in the Technical Addendum to this report.

The basic assumptions followed during the hydraulic modelling process was that the channel sections were rigid and no changes due to scour or aggradation occur. Roughness values ranged from .025 to .040 in the channel, to .035 to .060 on overbanks. Bridges were modelled assuming a 20 percent blockage due to debris and/or siltation.

The purposes of presenting flood plain information within the Sand Creek basin study are:

1. To give the City of Colorado Springs and El Paso County a reference tool from which to plan and design drainage structures along the main channels of Sand Creek.
2. To focus the alternative analysis toward flood control improvements which are the most needed.
3. To consolidate flood plain information for Sand Creek in the El Paso County and City of Colorado Springs Flood Insurance Studies into one document.
4. To give the general citizenry an awareness of where flood hazards exist within the Sand Creek basin.
5. Assist in the design of public facilities and establishment of basin fees.

Existing Channel and Flood Plain Description

Plates 1 through 22 present the existing and future condition, 100-year Flood Hazard Areas, for Reaches 1, 2, 4, 6 and 7. Flood hazard data for Reach 5 can be found in the Soil Conservation Service Flood Hazard Analysis of Sand Creek, and the Preliminary Banning-Lewis Ranch Master Drainage Plan. A discussion of each reach follows. The existing condition 100-year flood plain and profile coincides with the Preliminary Flood Insurance Study. In that there is a good correlation in flooding depths and boundaries between the Flood Hazard Area Maps and the Preliminary Flood Insurance Study, the Flood Hazard Area Maps should not be used to establish flooding depths in lieu of the FEMA data.

Reach 1 - Mainstem, Confluence with Sand Creek to Powers Boulevard (Station 0+00 to 366+25)

The existing channel between Hancock Expressway and the confluence with the East Fork of Sand Creek is generally 100 to 200 feet wide, with a natural sand invert. Channel improvements consist of riprap lined banks, however, there are some banks which are still unprotected. Upstream of the mainstem's confluence with the East Fork Sand Creek to Airport Road, the channel is improved, however low-lying overbanks are present. Upstream of Airport Road the stream is lined with riprap for approximately one-half mile, and transitions into a natural channel. North of U.S. Highway 24 to Galley Road, the natural channel is 100- to 600-feet wide. At this point some channel shaping and riprap protection has been installed, and a steeper and narrower channel extends to Powers Boulevard.

The flood plain characteristics for both the existing and future development condition vary greatly in the upper and lower portions of Reach 1. Flood plains in the lower portions (below Airport Road) of Reach 1 are generally 100- to 350-feet wide with depths of four to eight feet and velocities of be-tween seven and 12 feet per second. 100-year velocities in excess of 14 feet per second are estimated at crossings. In the upper portions of Reach 1 (above Airport Road) the lower natural channel banks make possible for areas of shallow overbank flooding. Average stream velocities vary from five to ten feet per second and depth range from four to seven feet deep. Overbank flooding would consist of one to three foot depths of standing water.

The Flood Hazard Areas for the ultimate development flow condition vary only slightly in depth and velocity in-stream, due to the large top-width and associated cross-sectional flow area. Overbank flooding is increased in area but depths are still limited to three feet or less.

Damages in Reach 1 would largely be to existing drainage and roadway crossing structures. Structures where the backwater effect is sufficient to cause overbank flooding include, Hancock Expressway, Airport Road, Galley Road, and Palmer Park Boulevard.

Reach 1 is currently aggrading as evidenced by the dredging of sand from the stream channel and culverts, particularly in areas downstream of the East Fork confluence. This is the result of historically flatter stream slopes and an increase in sediment supply to the stream due to land development and other construction activities. In the case of a 100-year event, deposition of sediments could occur in all areas upstream of restricted stream crossings.

Reach 2 - Mainstem, Powers Boulevard to Dublin Road (Extended) (Station 366+25 to Station 101+20, Stetson Hills North)

The existing channels in this reach can be characterized as natural with the exception of rough channel shaping extending from Powers Boulevard to the Chicago Rock Island Railroad crossing. Upstream of the railroad crossing the stream is wide and shallow with natural banks four to six feet high. The east bank is generally stable as it follows a very steep rock outcrop from the railroad crossing to approximately Station 465+00. From this point the stream has no well-defined channels until approximately Station 483+00. From this point to the upper limit of Reach 2, the stream is steeper and confined to a narrower, deeper channel section. Numerous outcrops of bedrock have been noted from Station 485+00 and upstream along the channel invert.

The flood plain characteristics for this reach are very similar for both the existing and future condition discharges. From Powers Boulevard to the railroad crossing, the flood plain is confined to a 200- to 250-foot wide channel. For the 100-year event, depths range from three to five feet with average velocities of six to ten feet per second. Upstream of the railroad to approximately Station 485+00 (Plate 5), the flood plain approaches 500- to 1,000-feet wide, with depths of two to four feet and average velocities of six to nine feet per second. Flood plains upstream of Station 485+00 are generally 300 to 700 feet wide, with depths of two to four feet and velocities of seven to ten feet per second.

Damage in this reach would be limited to debris deposition and siltation of overbank areas, and the possible washouts of Powers Boulevard and Wanoka Road. Both of these crossings are undersized and in need of replacement. Aggradation is occurring in the areas downstream of the Chicago Rock Island railroad bridge. The limited capacity of culverts under Powers Boulevard and Wanoka Road cause frequent flows to back up and drop their sediment load. The construction of the Constitution Avenue culvert currently underway has contributed to the increase in sediment supply to this area.

Reach 3 - Mainstem, Dublin Road (Extended) to Basin Boundary (Station 101+20 to Basin Boundary)

The areas tributary to Reach 3 are still rural with a typical land use of 2-1/2 acre, single-family lots. The existing channel is generally steep, having a gradient of two percent or greater, narrow and well defined until it disappears into the Black Forest area.

The flood plain characteristics were not examined in detail during this study, however, a portion of this Reach has had flood areas delineated as part of the Soil Conservation Service Flood Hazard Analysis of Sand Creek. Little variance in flood widths, depths, and velocities between the existing and future condition flood plains are anticipated, because of the steepness and narrowness of the natural stream channel.

Damages in this Reach would be limited to soil loss, debris deposition, and the washout of small dirt road crossings.

Reach 4 - East Fork, Confluence with Mainstem to Marksheffel Road (East Fork Station 0+00 to Station 254+00)

The channel, from the confluence to the confluence with the Central Tributary, has been improved with riprap banks and has a natural sand invert. The top width varies from 100- to 150-feet wide. Upstream of the Central Tributary to Peterson Road, the channel is in its natural state with widths varying from 200- to 400-feet. A deep channel occurs immediately upstream of Powers Boulevard extending for approximately one mile upstream. Above Peterson Road to Marksheffel Road the channel is again wide. The west bank, above Peterson Road has been shaped and riprapped as part of a residential development.

The flood plain characteristics vary greatly between the upper and lower portions of Reach 4, however, little variance is seen in the extent or depth of flooding between the existing and future flow condition. In the channelized portions, the flood plain is 100- to 150-feet wide, with depths ranging from five to seven feet, and velocities of seven to ten feet per second. From Powers Boulevard to Peterson Road, the flood plain varies from 200- to 600-feet wide, with depths averaging six feet and velocities ranging from seven to ten feet per second. Above Peterson Road the flood plain varies from 400 to as much as 900-feet wide, in areas where low-lying overbanks are flooded. Depths in this portion of Reach 4 average five feet and velocities range from four to eight feet per second.

Damages in Reach 4 are again associated with the loss of roadway and drainage structures, debris deposition, and siltation along low-lying overbanks. The potential for the flow to cause changes in the general stream channel section could result in damages not readily apparent from viewing the Flood Hazard Area maps. Damage to the residential area near the confluence of Reach 4 and the Central Tributary (Reach 7), and to the residential development east of Peterson Road could result from stream migration.

This reach is generally stable and showing no signs of aggradation or degradation along the main stream. Little development has occurred upstream of Peterson Road to add to the sediment supply. Bedrock upstream of Peterson Road is controlling the invert in this location.

Reach 5 - East Fork Sand Creek, Marksheffel Road to Basin Boundary (Station 254+00 to Station 285+00, and north to basin boundary)

The channel section in the vicinity of Marksheffel Road is very wide and poorly defined, resembling section typical of a dry wash. The section generally narrows in higher portions of the basin, however, areas of meandering and poorly-defined segments occur. Several stock ponds occur in this reach, however, they would have a negligible storage effect during the 100-year event.

The flood plain in the vicinity of Marksheffel Road varies from 150- to 1,000-feet wide, with depths averaging three to five feet, for both the existing and future flow condition. Additional flood plain information can be found in the Soil Conservation Service Flood Hazard Analysis of Sand Creek, and in the Preliminary Master Drainage Plan of the Banning-Lewis Ranch.

Debris and sediment deposition, soil loss, the potential loss of the Marksheffel Road embankment and the wash out of small dirt road crossings typify the damages which could occur in Reach 5.

Reach 6 - East Fork Subtributary to Sub-basin Boundary (Station 285+00 to Station 523+70, north to basin boundary)

The existing channel throughout this reach is wide and poorly defined along some segments of the East Fork Subtributary. The channel is crossed at two locations, at the Chicago Rock Island Railroad and at Tamlin Road. The railroad crossing is of adequate capacity. The railroad's embankment forms the south channel bank for approximately 2,600 feet upstream of the crossing.

The 100-year flood plain is generally shallow with stream velocities averaging four to six feet per second. The flood plain ranges from 400 feet wide in lower segments of Reach 6 to less than 100 feet wide along upper segments.

Damages within this Reach are currently limited to debris and sediment deposition with areas of soil loss. The Chicago Rock Island railroad crossing and embankment could also be damaged in a 100-year flood event.

Reach 7 - Central Tributary Sand Creek (Station 0+00 to Station 138+05)

The channels along the Central Tributary are natural below U.S. Highway 24 and improved above this point. The improvements consist of a concrete lined, trapezoidal channel, 30 to 40 feet wide at the top. The improved channel has been relocated from the historic flow line. Along the west overbank, between Palmer Park Road and U.S. Highway 24, the existing elevations are at or below the channel invert. The stream below U.S. Highway 24 is generally natural with areas of channelization adjacent to crossings.

The 100-year flood plain ranges from 100 to 200 feet wide along the natural channel segments of the stream with ponding at crossings. Areas of shallow overbank flooding occur upstream of U.S. Highway 24. The under-capacity culverts at U.S. Highway 24, and Galley Road back up the flow in the lined channels, forcing water to the low overbank areas.

The potential damages for Reach 7 include closure and loss of public and private roadways, shallow flooding of buildings and debris deposition. The movement of floodwaters across U.S. Highway 24, west of the existing culvert, has the potential to damage the roadway embankment, and at a minimum, force the closure of the highway. The shallow flooding which has occurred frequently at Powers Boulevard and Bijou Street is mainly from brief and intense thunderstorms, which resulted in the overtopping of these roadways.

Reach 8 - West Fork Sand Creek

The West Fork of Sand Creek has both improved and unimproved segments. From the confluence with the mainstem of Sand Creek to Galley Road, the West Fork is in its natural condition with the exception of a riprap lined segment downstream of U.S. 24. A concrete lined channel has been constructed above the Chicago, Rock Island and Pacific Railroad to convey the 100-year flow as per the 1977 Sand Creek Master Plan and is in generally good repair. Riprap channels are currently constructed or proposed below the Railroad.

Potential damages include the shallow flooding of residential areas adjacent to the drainageway in the upper portions of the basin. This would most likely be caused by a brief, intense rainfall. In lower portions of the basin, erosion damage could occur, along with debris deposition on low lying overbanks. No flood hazard area mapping has been carried out along the West Fork of Sand Creek. A detailed description of the existing channel improvements along the West Fork follows.

Inventory of Structures

Major drainage structures which have been constructed within the Sand Creek basin were reviewed as part of the master planning effort. This was done to help quantify the existing operation of a given structure, its general repair, and its adequacy to convey future development condition peak discharges. Information collected during the inventory was used in the development of alternative drainage plans, and in the economic analysis portions of this study. Only structures occurring within the mainstream reaches defined for the purpose of this report were reviewed.

Table 3 presents a listing of the structures reviewed during this study.

Erosion and Sedimentation Analysis

A qualitative sedimentation and erosion analysis was performed to assess the channel stability and to identify problem areas. Within a naturally channelized segment of Reach 2, a field investigation was conducted to: (1) identify channel bed and bank material size, (2) identify areas subject to scour or deposition, (3) examine channel side slopes, and (4) locate areas where channel migration or headcutting has occurred.

The testing of the soils sampled during this analysis revealed that the channel bed is medium to coarse sands, with a median particle size of 1.5 millimeters. No evidence of armoring was seen, primarily due to the limited supply of such soils within the basin. Bedrock outcrops occur at several locations along the reach investigated. Stream bank samples revealed much the same size of particles. These types of soils are easily eroded by storm flows, creating the potential for areas of stream bank erosion and channel migration.

Scouring problems were in general, not seen during the inventory of structures. Scouring problems are sometimes most pronounced at bridge piers and culvert outlets. Flood velocities along the mainstem of Sand Creek range from four to 15 feet per second at several culvert crossings. Debris blockage at U.S. Highway 24, Fountain Boulevard and at the Airport Road crossings over

Table 3. Inventory of Existing Structures - Sand Creek Master Drainage Study.

Structure	Description	General Repair	100-Year Design* Flow (cfs)	100-Year Capacity Existing	100-Year Capacity Future	Flow Type for Existing Condition	Comments
Reach 1							
Las Vegas Street	Steel Bridge	Good	15,230	Adequate	Adequate	Low Flow	Debris build-up under bridge.
D&RGW Railroad	Steel Bridge	Poor	15,230	Adequate	Adequate	Low Flow	Debris build-up under bridge.
Hancock Expressway	Concrete Boxes	Good - Large amounts of sediment under crossing	15,230	Inadequate	Inadequate	Pressure & Weir	Overtops road; should plan on expanding structure.
Academy Boulevard	Concrete Bridge	Good - Large amounts of sediment under crossing	15,230	Inadequate due to blockage	Inadequate due to blockage	Pressure	Regular cleaning recommended. Bridge is not overtopped but damage could occur during a major flood event. Expansion recommended .
Chelton Boulevard	Concrete Boxes	New - under construction	15,230	Inadequate	Inadequate	Pressure	Additional box recommended.
Fountain Boulevard	Concrete Bridge	Good- Moderate amount of of sediment under bridge	15,230	Adequate	Adequate	Low Flow	Regular cleaning recommended.
Airport Road	Concrete Bridge	Fair	11,290	Adequate	Inadequate	Pressure & Weir	Flow overtops road; replacement of structure necessary.
Platte Avenue/U.S. Hwy. 24	Concrete Bridge	Fair -Moderate amount of sediment under bridge	8,650	Adequate	Adequate	Low Flow	Regular cleaning recommended.
Galley Road	2, 48-inch CMP Culverts	Fair	8,650	Inadequate	Inadequate	Pressure & Weir	New structure is recommended, which is sized for developed flows.
Palmer Park Boulevard	Concrete Bridge	Good	8,650	Adequate	Adequate	Low Flow	
Powers Boulevard	4, 36-inch CMP Culverts	Fair - clogged with sediment	8,620	Inadequate	Inadequate	Pressure & Weir	New structure is recommended, which is sized for developed flows.
Reach 2							
Waynoka Road	3, 36-inch CMP Culverts	Poor - clogged with sediment	8,520	Inadequate	Inadequate	Weir	New concrete box structure is recommended.
C.R.I. & P. Railroad	Steel Bridge	Fair	8,520	Adequate	Adequate	Low Flow	
Constitution Boulevard	Concrete Boxes	Good	8,520	Adequate	Adequate	Low Flow	
Woodmen Road	Steel Bridge	Fair	3,150	Adequate	Adequate	Low Flow	Widening recommended due to future traffic considerations.

*Design flows refer to those shown on Exhibit 2, Table 2 Basin Design Points and Discharges, for the ultimate development condition (Alternate No. 1).

Table 3 (continued)

Structure	Description	General Repair	100-Year Design* Flow (cfs)	100-Year Capacity Existing	Future	Flow Type for Existing Condition	Comments
Reach 4							
Platte Avenue/U.S. Highway 24	Concrete and Wood Bridge	Fair/Poor	7,490	Adequate	Adequate	Low Flow	Widening due to future traffic considerations.
Peterson Road	4 - CMP Culverts	Poor	7,490	Inadequate	Inadequate	Pressure & Weir	Future replacement with concrete box culverts recommended.
Marksheffel Road	2 - CMP Culverts	Poor	7,450	Inadequate	Inadequate	Pressure & Weir	
Powers Road (Proposed East Fork)	2 - CMP Culverts	Fair	7,450	Inadequate	Inadequate	Pressure & Weir	New structure is recommended when Powers is widened.
Constitution Boulevard (East Fork)	Concrete Boxes	New Under design	4,850	--	--		
Reach 6							
Constitution Boulevard and Akers Road (East Fork)	Concrete Boxes	New Under design	2,480	--	--		
C.R.I. & P. Railroad	Steel Bridge	Fair	2,770	Adequate	Adequate	Low Flow	
Reach 7							
Airport Road	5 - RCB Culverts	Clear	1,670	Adequate	Adequate	Pressure & Weir	
Powers Boulevard	CMP Culverts	Clogged with sediment	1,670	Inadequate	Inadequate	Pressure & Weir	New structure and channel transitions recommended.
Platte Avenue and Central Tributary	Concrete Boxes (2 locations)	Good	1,670	Inadequate	Inadequate	Pressure & Weir	New structure is recommended for developed flows.
Galley Road and Central Tributary	3-CMP Culverts	Good	1,670	Inadequate	Inadequate	Pressure & Weir	Improved culvert and inlet condition is recommended.
Terminal Avenue	3-CMP Culverts	Good	1,670	Adequate	Adequate	Pressure & Weir	New transition structure is recommended.
Concrete Channel, Galley Road to U.S. 24	Trapezoidal	Good		Inadequate	Inadequate		Channel is overtopped at Galley Road Culvert

*Design flows refer to those shown on Exhibit 2, Table 2 Basin Design Points and Discharges, for the ultimate development condition.

Table 3 (continued)

Structure	Description	General Repair	100-Year Design* Flow (cfs)	100-Year Capacity Existing	Future	Flow Type for Existing Condition	Comments
Reach 8							
U.S. Highway 24 @ West Fork	Concrete Box Culverts	Fair	3,830	Adequate	Adequate	Low Flow and Pressure	No replacement recommended until flood hazard potential identified.
Lined Channel, U.S. Highway 24 to Confluence	Riprap Lined Trapezoidal Channel	Poor	3,830	Adequate	Adequate		Scour and washouts are degrading channel improvements.
Galley Road	5, 4'x10' Concrete Box Culverts	Fair	3,830	Inadequate	Inadequate	Pressure & Weir	New box culverts recommended.
Murray Boulevard	3, 8'x4' and 2, 7'x4' Concrete Box Culverts	Fair	3,400	Inadequate	Inadequate	Pressure & Weir	New box culverts recommended.
Palmer Park Boulevard	5, 4'x10' Concrete Box Culverts	Poor - clogged with sediment	3,400	Inadequate	Inadequate	Pressure & Weir	New box culverts recommended.
Constitution Ave.	4, 4'x8' Concrete Box Culverts	Poor	2,980	Inadequate	Inadequate	Pressure & Weir	New box culverts recommended.
CRI&P RR @ West Fork	Bridge	Poor	2,980	Inadequate	Inadequate	Pressure & Weir	Abandonment recommended if railroad tracks remain unused.
Lined Channel and Grade Control, Constitution Avenue to Oro Blanco	Concrete Trapezoidal Channel	Good - Fair	2,980 (est)	Adequate	Adequate	Super critical	Maintenance of drainageway suggested on an annual basis.

*Design flows refer to those shown on Exhibit 2, Table 2 Basin Design Points and Discharges, for the ultimate development condition.

the mainstem of Sand Creek, creates the potential for localized scouring because of a reduction of effective flow area.

Areas of aggradation were noted along the lower segments of Reach 1 and at stream crossings of insufficient capacity. Aggradation occurs because of two factors: (1) stream slopes are mild and therefore velocities necessary to transport sediment is reduced, and (2) an increase in sediment supply to the stream system. Within the lower, improved portions of Sand Creek channel drops have been constructed to control the grade of the invert. Due to the development activities in the basin, the sediment supply has increased over historic levels, and when coupled with slower stream velocities, the sediment is dropped. The long-term erosion potential, however, is still one of degradation since the build-out of the basin will ultimately reduce the supply of sediment to the stream system.

Aggradation of the crossings over the mainstem, at Fountain Boulevard, Hancock Boulevard, Platte Avenue and Airport Road, is a continuing problem. This is most likely because these crossings have not experienced storm flows sufficient to scour the culverts out. Continued development in the basin will result in more frequent flows in Sand Creek which will be transporting less sediment as time goes on. This could eventually lessen the need for dredging of these culverts than currently is required, (refer to Chapter VII for recommendations).

V. EVALUATION OF DRAINAGE ALTERNATIVES

General

Conceptual level improvement alternatives were developed to reduce flooding damages while maximizing the use of public and private funds. Those alternates were developed for comparison purposes only. The improvement alternatives considered include the following:

1. Maintaining existing channel and flood plain conditions.
2. An enlarged or improved channel cross section to limit the width of right-of-way, basically following the alignment.
3. Provision of onstream detention to reduce peak discharges in downstream reaches.
4. Increased sizes of stream crossings at locations evaluated to be undersized for future development peak discharges.
5. Non-structural methods such as flood plain regulation and management, as currently provided in City of Colorado Springs flood plain ordinances.
6. Combinations of the above.

These alternatives were evaluated for each reach. The comparison purpose, three basic alternatives were devised for the Sand Creek basin. They are:

1. Improved channelization of flood flows for the 100-year future development condition along all reaches.
2. Improved channelization in combination with reaches of "natural" channel and flood plain management.
3. Improved channelization in combination with onstream detention in Reaches 2, 3, 5 and 6.

These alternatives were evaluated keeping the objectives of the City of Colorado Springs and El Paso County in mind. The use of private land was also considered in an effort to develop a plan that would be acceptable to local developers, planners and engineers. Currently the use of on-stream detention is not allowed by the City of Colorado Springs, however, is acceptable under El Paso County drainage criteria.

Basic objectives guiding this evaluation included: (1) the ability to safely pass the 100-year, future basin condition peak discharge, (2) the ability to convey annual stream flows with limited damages to public drainage facilities, (3) reduction of maintenance cost, (4) improve or enhance adjoining property, (5) reduce erosion and improve water quality, (6) preserve, where feasible, natural flood plain areas, and (7) to provide multiple use of the flood plain area.

During the development of the alternative plans 1, 2, and 3, a wide variability in stream hydraulics occurred along the mainstem of Sand Creek. The typical sections and grade control structures used to estimate construction costs and general stream hydraulic characteristics may not be the recommended design in all portions of the basin. As part of the design process, each reach of channelization must be evaluated in detail in order to establish the best channel lining for a specific segment of Sand Creek.

Basis of Design

The hydraulic analysis of each alternative combined the HEC-2 analysis discussed in Chapter IV with normal-depth calculations for proposed channel crossings. The analysis enabled the planning of improved channel sections, drop structures, and crossings for later cost estimation.

Channel sections were sized for all sub-basins with a 100-year discharge of 500 cubic feet per second or greater. Concrete channel linings were sized for basins with peak flows ranging from 500 to 1500 cubic feet per second, and where slopes were considered to be too steep for riprap linings. Riprap channels were sized for sub-basins with flows in excess of 1000 cubic feet per second, and in reaches where the Froude Number could be kept below 0.8. The sizing of channels for minor drainageways carried out in a conceptual manner, and the results were used only to estimate costs of drainage improvements. All drainageway improvements defined on this study are subject to change and are provided for informational purposes only.

Basic design criteria contained in the City of Colorado Springs Criteria Manual and the El Paso County Areawide Runoff Control Manual were followed when designing drainage facilities for the alternative evaluation process. All facilities were designed to convey the 100-year, future condition flow rates. Roughness values for the hydraulic calculations ranged from .025 for natural stream bedding to .035 in areas where "natural channels" were evaluated.

Methods presented in the "Design Guidelines and Criteria for Channels and Hydraulic Structures on Sandy Soil", issued by the Urban Drainage and Flood Control District were used during the development conceptual plans (Reference 9). These criteria are suggested for use when designing structures within the Sand Creek basin, or in any situation where the predominant soil type is sand. Procedures for determining a stream's equilibrium slope, scour potential and design of channel lining are contained in the above referenced manual.

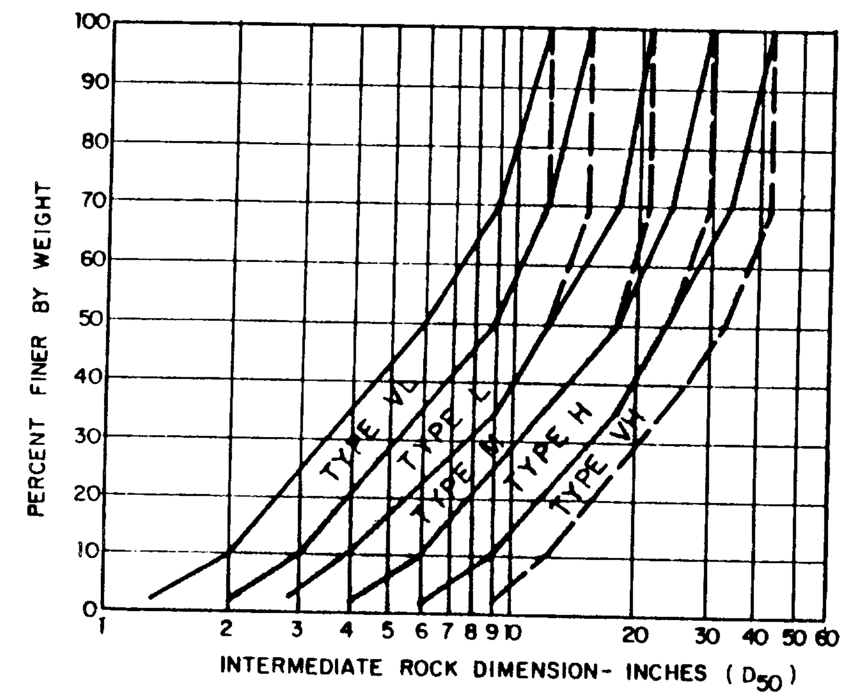
The typical channel section shown in Figure 5 was used to estimate costs of major drainageway channel improvements. A depth of five to six feet was maintained in all reaches, and therefore the height of the channel lining is the same in all segments. Improved channel sections were assumed to be riprap lined, with side slopes not exceeding 2.5 horizontal:1 vertical (2.5 H:1V). The medium riprap size assumed was 18 inches, however, this must be carefully anlayzed during final design of channels. Toe-down depths for riprap channels were determined by calculating the total scour potential for a given section. The methods for estimating the total scour depth in and around various hydraulic structures are explained in Reference 9. It is suggested that for the design of channels in the Sand Creek basin, a minimum toe-down depth equal to the design flow depth be required, unless adequate engineering analysis confirms otherwise. The use of riprap for channel linings should be limited to these segments of Sand Creek flowing at sub-critical depth.

Upgraded stream crossings were sized according to normal depth calculations. Velocities were limited to ten feet per second and all culverts were assumed to have invert slopes of one percent or greater.

Riprap for channel lining has been used extensively along the developed portions of Sand Creek. It is recommended that rock with a minimum specific gravity of 2.6 be used for all riprap installations, and that it be angular in nature. Designers should be aware of the variability of rock with respect to specific weight, even within a single quarry. Lighter rock with specific gravities ranging from 2.2 to 2.6 must be accounted for in the design of channels. Additionally, placement techniques can cause rock to fracture and destroy the gradation of the riprap lining.

Drop structures were assumed to be of riprap construction with a maximum drop of four feet for cost estimation purposes only. The number of drops were

GRADATION OF ORDINARY RIP-RAP



SOURCE: URBAN DRAINAGE & FLOOD CONTROL DISTRICT, DRAINAGE CRITERIA MANUAL.

RIPRAP REQUIREMENTS FOR CHANNEL LININGS **

**** $VS^{0.17}/(S_s-1)^{0.66}$* ($ft^{1/2}/sec$)	Rock Type ***
1.4 to 3.2	VL
3.3 to 3.9	L
4.0 to 4.5	M
4.6 to 5.5	H
5.6 to 6.4	VH

* Use S_s = 2.5 unless the source of rock and its densities are known at the time of design.

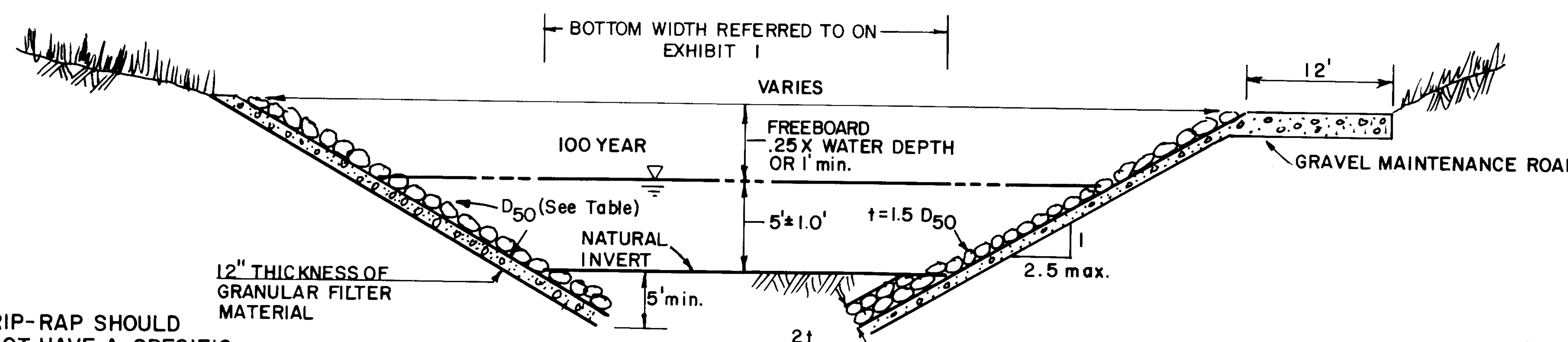
** Table valid only for Froude number of 0.8 or less and side slopes no steeper than 2h:1v.

*** Type VL and L riprap shall be buried after placement to reduce vandalism.

SMS slope mattress with toe protection may be substituted for Type VL or L riprap.

G12 gabion with toe protection may be substituted for Type M and Type H riprap.

**** Velocity in feet per second S is the Stream slope in feet/foot.



NOTE: RIP-RAP SHOULD NOT HAVE A SPECIFIC GRAVITY OF LESS THAN 2.5.

TYPICAL RIP-RAP CHANNELIZED SECTION

SAND CREEK MASTER DRAINAGE PLANNING STUDY	
TYPICAL CHANNEL SECTION	
Designed by: RNW	Scale: NTS
Drawn by: EAK	Date: 11-21-84
Checked by: RNW	Project No.: CO-FA-81
sla SIMONS, LI & ASSOCIATES, INC.	FIG.5

No.	Revision	Date	By

estimated by calculating an average invert equilibrium slope of 1.3 percent in all reaches, however, the equilibrium is dependent upon flow rate, channel geometry, and local sediment sizes. Median rock size for the drops was assumed to be 18 inches. Typical drops used for cost estimation are also shown on Figure 6.

For comparison of the natural channel concept (Alternate 2) to Alternates 1 and 3, general planning and design criteria was used to guide the determination where "natural" channel reaches were feasible. These were:

1. Adjacent existing or proposed drainage facilities should be compatible in concept and design.

2. Reaches where past evidence of horizontal or vertical channel migrations should be avoided. The possibility of stream migration can be evaluated from aerial photographs compiled by the Soil Conservation Service and private aerial mapping firms.

3. In areas where shallow and wide overbank flooding is possible, "natural" channels should be protected from overtopping, by use of earthen berms, or filling of low areas as part of the development process.

4. 100-year velocities should be less than seven feet per second for "natural" reaches.

5. Areas where unstable banks occur should be avoided in the natural channel concept. Unstable banks can be classified as those banks where lateral stream migration has occurred where underlying rock formations are deep, or where surface runoff has caused head cutting.

6. An equitable land reimbursement scheme for the buffer zones must be developed during the design of "natural" reaches, (see the Economic Analysis, Chapter VI).

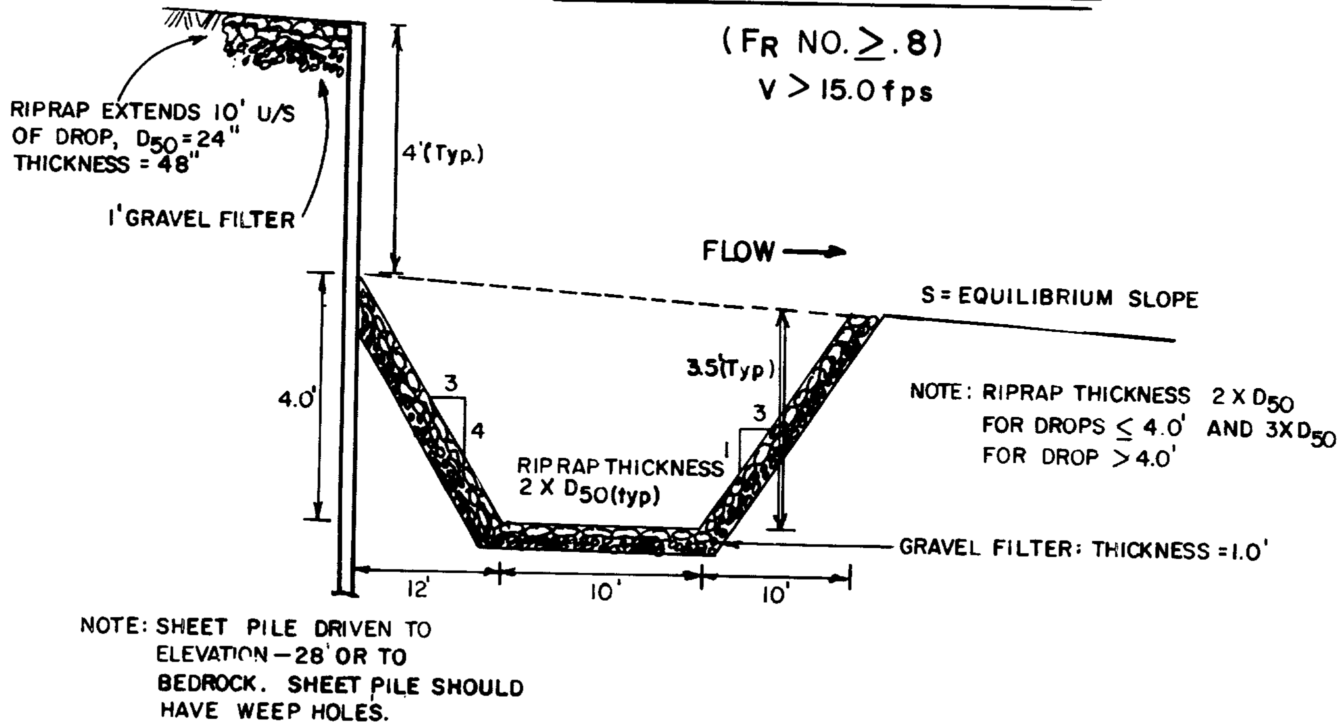
<u>Alternative Evaluation</u>

The evaluation process for each of the three conceptual alternatives by stream reach is summarized in Tables 4 through 11, by stream reach. These tables contain comments which are the result of both quantitative and qualitative information collected during the course of the planning process. Input from the City of Colorado Springs and El Paso County was included during the development and review of the alternative drainage plans.

SHEET PILE DROP STRUCTURE

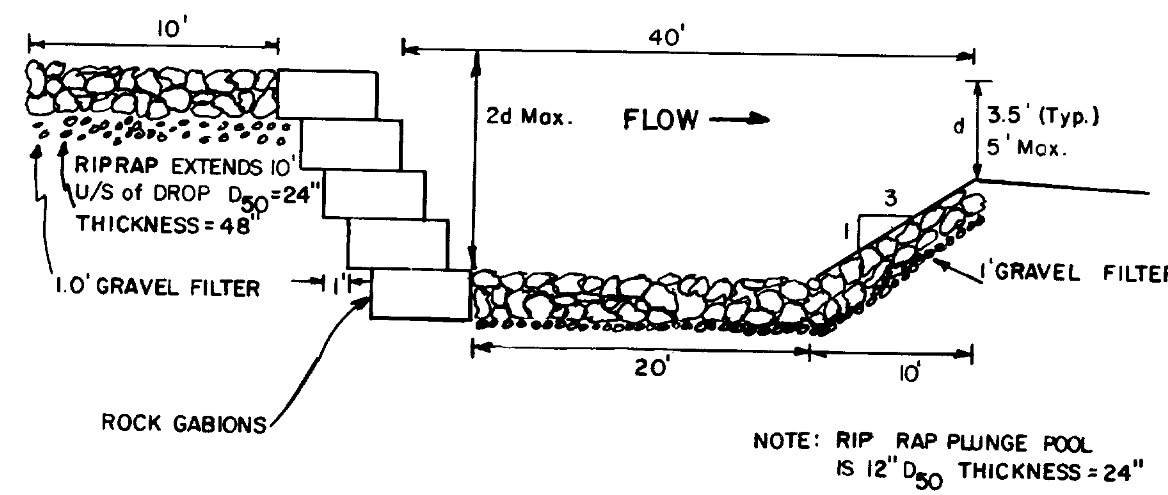
(F_R NO. $\geq .8$)

V > 15.0 fps



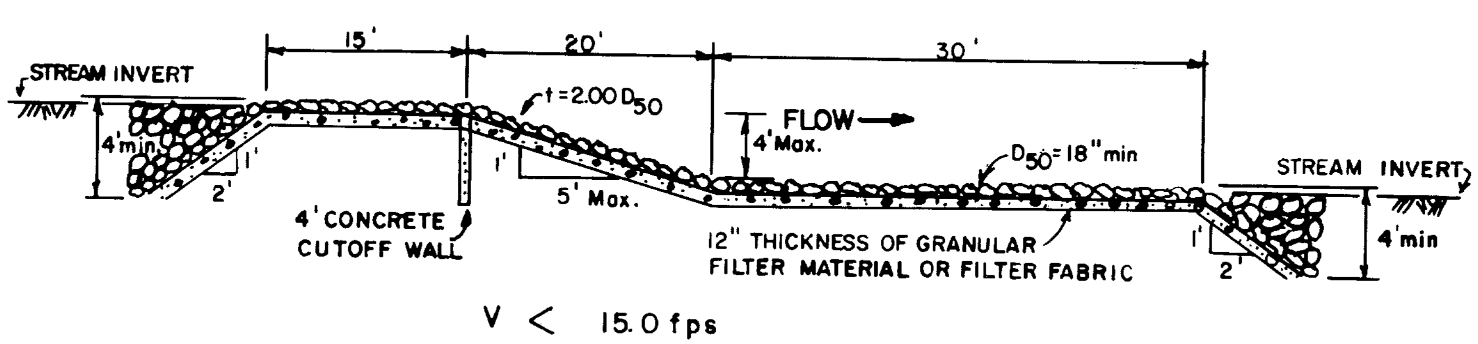
GABION DROP STRUCTURE

(F_R NO. $\geq .8$)



SLOPED RIPRAP DROP STRUCTURE

(F_R NO. $\leq .8$)



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No.	Revision	Date	By
1	As per City	1/85	

SAND CREEK MASTER
DRAINAGE PLANNING STUDY

TYPICAL DROP STRUCTURES

Designed by:	RNW	Scale:	N.T.S.
Drawn by:	EAK	Date:	11-20-84
Checked by:	RNW	Project No.:	CO-FA-01

sla
SIMONS, LI & ASSOCIATES, INC.

FIG. 6

Table 4. Matrix Display of Benefits of Alternatives.*

Reach 1: Mainstem of Sand Creek

Alternate Benefit	1. Channelization +	1. Channelization -	2. Channelization With "Natural" Reaches +	2. Channelization With "Natural" Reaches -	3. Channelization With On-Stream Detention +	3. Channelization With On-Stream Detention -
Damage Reduction	Shallow flooding is eliminated at Airport Road, Fountain Boulevard, and Platte Avenue.		NATURAL CHANNELS NOT RECOMMENDED IN REACH 1.		Shallow flooding at crossings reduced when compared to future condition flood plain.	
Aesthetics	Pleasant if overbanks are landscaped.				Same as Alternate 1.	
Multiple-Use Opportunities	Trails for hiker/biker and maintenance on overbanks.	Steep channel banks and linings limit access to stream bottom.			Same as Alternate 1.	
Impact on Private Land		Right-of-ways varying from 100 to 300 feet required.			Decreased right-of-way required, particularly upstream of Platte Avenue.	
Erosion and Sedementation	Limited degradation and scour at crossings if properly designed.	Near-term aggradation at over-sized structures.		Deep sands not conducive to "natural" channel concept.	Lower peak discharges would reduce the potential for localized erosion.	Long-term degradation due to cut-off of sediment supply.
Operation and Maintenance	Limited maintenance of rip-rap banks if installed properly.	Dredging at major crossings - near-term.			Reduction in maintenance compared to Alternate 1.	
Conformance with Existing Facilities	Good conformance with existing right-of-way and drainage structures.			Majority of Reach 1 has been channelized.	Bridges and culverts design life would be increased.	Existing channels would be oversized for detained flows

* The alternates presented in this table have been analyzed for comparison and informational uses only.

Table 5. Matrix Display of Benefits of Alternatives.*

Reach 2: Mainstem of Sand Creek

Alternate Benefit	1. Channelization +	1. Channelization -	2. Channelization With "Natural" Reaches +	2. Channelization With "Natural" Reaches -	3. Channelization With On-Stream Detention +	3. Channelization With On-Stream Detention -
Damage Reduction	Sediment and debris deposition limited on overbanks.	Powers Boulevard and Wanoka Road crossings seriously under capacity.	Damages mitigated by flood plain regulation.	Potential for wide buffer zone from the C&R.I Railroad to Barnes Road.	DETENTION NOT RECOMMENDED FOR THIS REACH	
Aesthetics	Pleasing if overbanks are graded into adjacent greenbelts.		Natural reaches would maintain historic vegetation.	Natural reaches may not blend with some types of development.		
Multiple Use Opportunities	Trails for maintenance, hiking and biking, combined into one trail.	Access points to stream channels are limited.	Nature trails in flood plains, with improved trails along buffer zones.			
Impact of Private Land		Right-of-ways varying from 100 to 200 feet required.		Flood plains and buffer zones would limit large areas from development.		
Erosion and Sedementation		Aggradation possible adjacent to new crossings, in the near-term.	Natural stream system would limit deposition to flood plain areas.	Bank erosion due to lateral migration possible.		
Operation and Maintenance	Limited maintenance along improved channel banks.	Dredging at crossings necessary in the near-term.	Cleanup of natural flood plains limited.	Points of access should be limited in natural reaches.		
Conformance with Existing Facilities	Drainageway downstream of C&R.I Railroad to Powers Boulevard of sufficient right-of-way.		Most of this reach is natural at this time. Bedrock outcrops frequently.	Protection of natural bends and outlets of culverts required.		Small impact on the size of channel facilities.
Implementation	Existing criteria for drainage design is adequate.			"Natural" reaches must be compatible with adjacent and uses and drainage improvements.		

* The alternates presented in this table have been analyzed for comparison and informational uses only.

Table 6. Matrix Display of Benefits of Alternatives.*

Reach 3: Mainstem of Sand Creek

Alternate / Benefit	1. Channelization +	1. Channelization -	2. Channelization With "Natural" Reaches +	2. Channelization With "Natural" Reaches -	3. Channelization With On-Stream Detention +	3. Channelization With On-Stream Detention -
Damage Reduction	No significant areas of damage at present time.		Flood plain management and regulation to mitigate the potential for future damage.		DETENTION NOT RECOMMENDED IN THIS REACH.	
Aesthetics		Steepness of banks and invert would require regrading and disturbance of natural vegetation.		Leaves steep slopes adjacent to stream natural.		
Multiple Use Opportunities		"Greenbelt" areas limited.	Steepness of channel sections lends itself well to limited access; i.e. hiker and equestrian trails.			
Impact on Private Land	Limits flood plain widths to less than 100-feet.			Flood plain and buffer zone would limit larger areas from development as compared to Alternate 1.		
Erosion and Sedimentation		Steepness of invert could require heavy rip-rap, or numerous drop structures.	Bedrock outcrops, and rock banks in several locations would act as control points for degradation and aggradation.	Buffer zone must be established to encompass areas of lateral migration.		
Operation and Maintenance		Steepness of invert would require close maintenance of rip-rap banks and drop structures.	Minor maintenance at crossings required, as compared to Alternate 1.			
Conformance with Existing Facilities		Channel transitions necessary at all existing crossings.	Natural channels generally well defined and in good conformance with existing crossings.			Small impact on peak discharges from detention in this reach.
Implementation		Channelized segments could impact "natural" reaches, as development proceeds.	Area is currently undeveloped with few drainage facilities.	"Natural" channels must be compatible with adjacent land uses and drainage improvements.		

* The alternates presented in this table have been analyzed for comparison and informational uses only.

Table 7. Matrix Display of Benefits of Alternatives.*

Reach 4: East Fork Sand Creek to Marksheffel Road

Alternate / Benefit	1. Channelization +	1. Channelization -	2. Channelization With "Natural" Reaches +	2. Channelization With "Natural" Reaches -	3. Channelization With On-Stream Detention +	3. Channelization With On-Stream Detention -
Damage Reduction	Reduces the potential for channel migration and sediment deposition.		NATURAL CHANNELS NOT RECOMMENDED IN THIS REACH		Flood plain areas reduced somewhat over future condition of flood plain.	Flood potential increased due to embankment failure.
Aesthetics	Pleasant if overbanks landscaped.				Same as Alternate 1.	"Dry" detention areas would limit the aesthetic value
Multiple Use Opportunities	Channel grades and depth adequate for hiker, biker and maintenance trails.			May not conform well with land use of areas. adjacent to flood plain.		Detention concept not viable if not built for multiple uses.
Impact on Private Land	Flood plain is limited to small areas; re-claiming of flooded overbanks possible.			Wide, shallow flood plain areas, up to 800 feet wide would be left undevelopable.	Smaller channels, thus right-of-ways for drainage facilities required.	Siting of pond(s) could be difficult depending upon land owners.
Erosion and Sedimentation	Overbank erosion and resultant damages could be mitigated.	Channel drops would be required to control invert grade.		Developed areas could be threatened by channel migration and sediment deposition.	Lower peak discharges and velocities lessen the potential for erosion of banks.	Detention ponds may cut-off sediment supply to lower portions of basin.
Operation and Maintenance		Channel banks, drops and culverts main-tenance required. Potential for aggradation in near-term.			Channel maintenance reduced, as compared to Alternate 1.	Potential for channel degradation exists for the long-term due to reduction in sediment supply. Dredging required.
Conformance with Existing Facilities	Drainageways, where present, are of adequate right-of-way.	Existing crossings are inadequate, and need sizing for 100-year event.			Small channels and right-of-way required as compared to Alternate 1.	No existing areas sufficient for siting pond. Equitable reimburse-ment scheme required before detention site is designed.
Implementation	This reach has long portions of channel, and well-defined drainageway.					

* The alternates presented in this table have been analyzed for comparison and informational uses only.

Table 8. Matrix Display of Benefits of Alternatives.*

Reach 5: East Fork Sand Creek Above Marsheffel Road

Alternate / Benefit	1. Channelization +	1. Channelization -	2. Channelization With "Natural" Reaches +	2. Channelization With "Natural" Reaches -	3. Channelization With On-Stream Detention +	3. Channelization With On-Stream Detention -
Damage Reduction	Channel would limit areas of debris and sediment deposition.		Damages would be mitigated through non-structural measures.	Siltation of crossings and overtopping increased as compared to Alternates 1 and 3.		Pond creates new flood threat due to possible embankment failure.
Aesthetics	Pleasing if overbanks landscaped.		Leaves natural vegetation in place.	May not conform well with adjacent land uses.	Same as Alternate 1.	"Dry" detention areas would limit a pond's aesthetic value.
Multiple Use Opportunities	Hiker, biker, and maintenance trails possible.		Hiker and equestrian trails well suited.	Steepness in upper portions of Reach 5 limited.		Detention areas not viable unless built for multiple uses.
Impact on Private Land	Flood plain would be confined to smaller areas. Right-of-way up to 150 feet required.			Wide flood plains with buffer zones up to 1,000 feet wide.	Smaller downstream channels as compared to Alternate 1.	Siting of ponds could be difficult depending upon owners and land values.
Erosion and Sedimentation	Debris deposition could be reduced compared to present conditions.	Increased velocities would require channel drops.	Natural channels would be unaffected by debris deposition.	Channel migration could threaten structures if buffer zone not provided.	Lower velocities and discharges in channels downstream of ponds.	
Operation and Maintenance		Channel banks, drops and culverts would require maintenance. Aggradation possible in near-term.		Access to some steeper reaches could be restricted.	Channel maintenance reduced somewhat as compared to Alternate 1.	Maintenance of ponds required regularly to keep sediment pools clear. Also, same as Reach 4.
Conformance with Existing Facilities		New roadway crossings must be constructed.	Drainageway is natural, with bedrock outcrops occurring frequently along invert.		Roadway crossings would be smaller as compared to Alternate 1.	Small detention sites currently exist, but they would need extensive modification.
Implementation				"Natural" reaches must be compatible with adjacent land uses and drainage improvements.		Mechanism for the reimbursement of areas "lost" to ponds not in place.

* The alternates presented in this table have been analyzed for comparison and informational uses only.

Table 9. Matrix Display of Benefits of Alternatives.*

Reach 6: East Fork Subtributary

Alternate / Benefit	1. Channelization +	1. Channelization -	2. Channelization With "Natural" Reaches +	2. Channelization With "Natural" Reaches -	3. Channelization With On-Stream Detention +	3. Channelization With On-Stream Detention -
Damage Reduction	Same as Reach 5.			Protection of C&R.I Railroad necessary to avoid damage to embankment.	Same as Reach 5.	
Aesthetics	Same as Reach 5.		Same as Reach 5.		Same as Reach 5.	
Multiple Use Opportunities	Same as Reach 5.		Same as Reach 5.		Same as Reach 5.	
Impact on Private Land	Same as Reach 5.		Same as Reach 5.		Same as Reach 5.	
Erosion and Sedimentation	Same as Reach 5.		Same as Reach 5.		Same as Reach 5.	
Operation and Maintenance	Same as Reach 5.		Same as Reach 5.		Same as Reach 5.	
Conformance with Existing Facilities		Protection of C&R.I Railroad necessary because of higher flow rates.	Upper reaches have several locations of bedrock outcrops, stabilizing natural channel.	Same as Alternate 1.	C&R.I Railroad would be adequate.	No existing pond sites in this reach.
Implementation			Same as Reach 5.	Mechanism for the reimbursement land "lost" to buffer zones not in place.		

* The alternates presented in this table have been analyzed for comparison and informational uses only.

Table 10. Matrix Display of Benefits of Alternatives.*

Reach 7: Central Tributary

Alternate / Benefit	1. Channelization +	1. Channelization -	2. Channelization With "Natural" Reaches +	2. Channelization With "Natural" Reaches -	3. Channelization With On-Stream Detention +	3. Channelization With On-Stream Detention -
Damage Reduction	Shallow flooded overbanks could be eliminated.		NATURAL CHANNELS NOT RECOMMENTED FOR THIS REACH		DETENTION NOT RECOMMENDED FOR THIS REACH	
Aesthetics	Pleasing if overbanks landscaped.					
Multiple Use Opportunities	Hiker, biker and maintenance trails have sufficient access.					
Impact on Private Land	Narrow channels less than 100 feet required.			Current urbanization would not allow for flood plain and buffer zone.		
Erosion and Sedimentation	Channelization would reduce potential for debris deposition along existing low overbanks.	Aggradation in near-term possible.		Current development could be threatened by channel migration.		
Operation and Maintenance	Maintenance limited to crossings above U.S. Highway 24.	New rip-rap lined channels and drops would require maintenance.				
Conformance with Existing Facilities	Channels and right-of ways have been established.	Several crossings and channels need upgrading (Upstream of U.S. Highway 24).				On-stream detention sites not present in this reach.

* The alternates presented in this table have been analyzed for comparison and informational uses only.

Table 11. Matrix Display of Benefits of Alternatives.*

Reach 8: West Fork

Alternate / Benefit	1. Channelization +	1. Channelization -	2. Channelization With "Natural" Reaches +	2. Channelization With "Natural" Reaches -	3. Channelization With On-Stream Detention +	3. Channelization With On-Stream Detention -
Damage Reduction	Shallow flooding is eliminated.		NATURAL CHANNELS NOT RECOMMENDED WITHIN REACH 8.		DETENTION NOT RECOMMENDED WITHIN 8.	
Aesthetics	Pleasant if overbanks are landscaped.					
Multiple-Use Opportunities						
Impact on Private Land	Narrow channels less than 100-feet wide.			Current level of urbanization would not allow for buffer zone along natural waterways.		
Erosion and Sedementation		Degradation of natural invert possible, long term.				
Operation and Maintenance		New channels and drop structures require maintenance.				
Conformance with Existing Facilities	Channels and right-of-ways have been established.					On-stream detention sites not present in this reach.

* The alternates presented in this table have been analyzed for comparison and informational uses only.

VI. ECONOMIC ANALYSIS

General

The economic analysis conducted as part of this study, included the estimation of capital improvement, and operations and maintenance costs for each alternative drainage plan. The economic analysis of each alternate was conducted for comparison purposes only. Using the design criteria outlined in the previous section, conceptual improvements were considered for each reach of Sand Creek. These improvements included riprap-lined channels, culvert crossings, selective protection of existing channel banks, and on-stream detention ponds. Unit prices used to estimate construction costs were obtained from the 1983 Colorado Department of Highways Bid Tabs, (Reference 12), and from similar construction projects in the Colorado Springs area. The unit prices are shown on Table 12A.

Operations and maintenance (O&M) unit costs were obtained from the Urban Drainage and Flood Control District Maintenance Section, as well as actual O&M costs obtained from the City of Colorado Springs Engineering Department. These costs were used in determining unit operations and maintenance costs, and are shown on Table 12A.

Maintenance activities which are anticipated for Sand Creek could vary greatly from year-to-year, and throughout the design-life of the drainage facilities themselves. Currently, most maintenance which is conducted is associated with dredging of sand from the channel adjacent to major stream crossings and from beneath bridges and culverts. As the basin develops, higher, more frequent discharges will occur, which will force storm flows through channels and culverts at higher velocities, scouring the collected sand from crossings and potentially reducing the need for dredging. However, other segments of Sand Creek and its tributaries which are currently aggrading, may begin to degrade as the stream system reacts to higher, more frequent storm flows, and a smaller sediment supply.

The O&M costs associated with each alternative was converted to 1984 dollars for comparison purposes. In performing the present value calculations, a six percent rate of inflation and a 12 percent rate of interest was used. A design life of 50-years for all drainage improvements was used in the evaluation.

The determination of bridge sizes was estimated using normal depth calculations. The locations of future bridge crossings for major and minor

Table 12A. Unit Construction and Maintenance Costs.

Item	Unit	Unit Cost
CONSTRUCTION		
Rip-Rap	Cubic Yard	$ 23.40
Granular Bedding for Rip-Rap	Cubic Yard	12.00
Excavation and Embankment	Cubic Yard	2.00
Drop Structure	each	20,500.00
Bridge - New and Replacement	Square Foot	46.43
Minor Storm Sewer Systems**	Acre	1,764.00
Pond Outlet Structures	each	60,000.00
Grouted Riprap Channel**	Linear Foot	95.00
Concrete Lined Channel**	Linear Foot	145.00
ANNUAL MAINTENANCE*		
Channel - Lined	Linear Foot	0.78
Channel - "Natural", Developed Areas	Linear Foot	0.25
Removal of Sediment from Detention Pond and Hauling	Cubic Yard	5.00

* Maintenance costs obtained from Urban Drainage and Flood Control District, Maintenance Section, 1983.
** Minor System defined as those systems conveying less than 500 cfs, to a designated drainageway.

Table 12B. Summary of Acreages.

Location	Platted (ac)	Unplatted (ac)	Total (ac)
City	6,841*	5,191	12,032
County	6,851	15,131	21,982
Colorado Springs Airport	440		
Black Forest Area (Platted)	1,250		1,250
Total Basin Acreage			35,264
Total Unplatted Basin Acreage		20,322**	

*Includes Colorado Springs Municipal Airport
**Excludes Black Forest Area

arterials were obtained from the El Paso County Department of Transportation (see Exhibit 1). The bridges were sized for the future development flow condition and then proportionally reduced reflecting the peak discharges for the on-stream detention alternative. A detailed design would be required for each crossing to determine the most efficient structure, both hydraulically and with respect to cost. Ten percent was added to the estimated bridge construction costs to cover engineering, and an additional five percent to cover contingencies.

A minor storm sewer system is defined as any storm system that will be installed to convey the minor storm runoff to the major drainage structures. The estimated cost per acre for minor storm sewer systems was determined by averaging the construction cost estimates as stated in recent drainage studies in the Colorado Springs area and dividing by the total amount of sewered acres. Cost estimates from ten studies encompassing a total of 859 acres were used in the evaluation of the unit storm sewerage charge.

Cost of Improvements

Construction costs for each alternative were based on 1984 prices and includes engineering and contingency costs. The cost of land acquisition has not been included in the cost estimation, but will be discussed later in this section.

The following alternatives were analyzed in detail:

Alternate 1: Fully channelized for all reaches.

Alternate 2: Channelization combined with "natural" channel and buffer zone, with selective bank improvements.

Alternate 3: Fully channelized with onstream detention ponds.

Each alternative's respective cost is shown in Tables 13 through 15. The presentation of these costs is for comparison and information purposes only.

Although Operation and Maintenance costs are not included in the City of Colorado Springs Drainage Fees, they have been analyzed in this study for comparison purposes when selecting the best alternative on a long term basis. An alternative with a lower capital costs but a higher operational cost may not

Table 13. Total Cost for Alternate 1* - Channelized, Ultimate Development Condition Flows.

Item	Quantity**	Total Cost
A. Channel Improvements		
1. Rip-Rap	993,319 C.Y.	$ 23,243,700
2. Granular Bedding	440,873 C.Y.	5,290,500
3. Excavation & Embankment	1,586,240 C.Y.	3,172,500
4. Drop Structures	84	1,722,000
Subtotal		$ 33,428,700
B. Other Systems		
1. Storm Sewer Systems (Minor)	20,322 acre	$ 35,848,000
2. Grouted Riprap Drainageways	66,300 L.F.	6,298,500
3. Concrete Lined Drainageways	59,700 L.F.	8,656,500
Subtotal		$ 50,803,000
Subtotal A & B		$ 84,231,700
C. Contingencies	5%	4,211,600
D. Engineering	10%	8,844,300
TOTAL (A through D)		$ 97,287,600

*Selected Alternative.
**See Table 12A for Unit Costs.

Table 14. Total Cost for Alternate 2 - Channelized with "Natural" Reaches.

Item	Quantity*	Total Cost
A. Major Channel Improvements		
1. Rip Rap	629,747 C.Y.	$ 14,736,100
2. Granular Bedding	286,737 C.Y.	3,440,800
3. Excavation & Embankment	1,164,000 C.Y.	2,328,000
4. Drop Structures	60	1,230,000
Subtotal		$ 21,734,900
B. Other Systems		
1. Storm Sewer Systems (Minor)	20,322 acre	$ 35,848,000
2. Grouted Riprap Drainageways	66,300 L.F.	6,298,500
3. Concrete Lined Drainageways	59,700 L.F.	8,656,500
Subtotal		$ 50,803,000
Subtotal A & B		$ 72,537,900
C. Contingencies	5%	3,626,900
D. Engineering	10%	7,616,500
TOTAL (A through D)		$ 83,781,300

*See Table 12A for Unit Costs.

Table 15. Total Cost for Alternate 3 - Channelized with Detention of Fully Developed Flows.

Item	Quantity*	Total Cost
A. Channel Imporovements		
1. Rip Rap	993,319 C.Y.	$ 23,243,700
2. Granular Bedding	440,873 C.Y.	5,290,500
3. Excavation & Embankment	2,365,056 C.Y.	4,730,100
4. Drop Structures	84	1,722,000
Subtotal		$ 34,986,300
B. Other Systems		
1. Storm Sewer Systems (Minor)	20,322 acre	$ 35,848,000
2. Grouted Riprap Drainageways	66,300 L.F.	6,298,500
3. Concrete Lined Drainageways	59,700 L.F.	8,656,500
Subtotal		$ 50,803,000
C. Detention Ponds		
1. Excavation & Embankment	673,529 C.Y.	1,347,100
2. Outlet Structure	3	180,000
Subtotal		$ 1,527,100
Subtotal A through C		$ 87,316,400
D. Contingencies	5%	4,365,800
E. Engineering	10%	9,168,200
TOTAL (A through E)		$ 100,853,000

*See Table 12A for Unit Costs.

be more cost effective than an alternative which minimizes O&M costs. Table 16 presents the estimated O&M costs for each alternative. Channel maintenance was based upon a total length of improved major channels of 309,800 feet.

Table 16. Operations and Maintenance Costs - Major Drainageways

Alternatives 1, 2 and 3

Alternate Number	Procedure	Total Cost *
1	Channel Maintenance	$3,996,900
2	Channel and Overbank Maintenance	$1,281,000
3	Channel and Detention Pond Maintenance	$4,873,000

* Total Operation and Maintenance assuming 50-year design life of facilities.

Cost for bridge improvements required on Alternatives 1 and 2 have been summarized in Tables 17A and 17B. The estimated bridge improvement costs for the onstream detention concept, Alternative 3, are shown in Tables 18A and 18B. These tables show "City Costs", as defined in Chapter 15, Article 3, Part 10 of the City of Colorado Springs Subdivision Policy Manual (1980).

Drainage and Bridge Fee Determination

Drainage and bridge fees for each alternative drainage plan are presented in Table 19. Alternative 2 the channelization concept in combination with reaches of "natural" stream channels, is the most inexpensive from the construction cost standpoint. All of the drainage basin fees are within 15 percent of each other, which reflects the influence of local systems on the fee structure, in combination with a small variance in the typical channel sections between each of the alternatives.

Operations and maintenance costs are again the lowest for Alternative 2. The lineal feet of channel is reduced in Alternative 2, which should generally lessen the required amount of time spent maintaining channel linings. Alternative 3, while having a decreased channel width in general, still requires approximately the same length and depth of improved channel as

Table 17A. City Bridge Costs - No Detention - Alternates 1 and 2.

Item	Hydrologic Point*	Culvert Number*	Unit Cost	Quantity	Unit	Cost	City Costs**
Bridge and Culvert Construction (W x L of assumed Right-of-Ways)							
Mainstem							
Hancock Expressway - 25' x 120' Expansion	H3G	1	$60.00	3,000	SF	$ 180,000	$ 72,500
Airport Road - 12' x 120' Expansion	H10A	2	60.00	1,440	SF	86,400	34,800
Galley Road - 120' x 125' New	H8A	3	46.43	14,400	SF	668,600	269,500
Chelton Road - 18' x 100' Expansion	H1G	4	60.00	1,800	SF	108,000	43,500
Powers Boulevard - 180' x 210' New	H6A	5	46.43	37,800	SF	1,755,000	1,104,100
North Carefree Circle - 80' x 120' New	H3A	7	46.43	9,600	SF	445,700	179,700
Barnes Road - 70' x 120' New	H1A	8	46.43	8,400	SF	390,000	152,200
Lariat Drive - 60' x 120' New	H16A	9	46.43	7,200	SF	334,300	134,800
Peterson Road - 60' x 120' New	H16A	10	46.43	7,200	SF	334,300	134,800
Dublin Road - 60' x 120' New	H14A	11	46.43	7,200	SF	334,300	134,800
East Fork							
Powers Boulevard - 150' x 210' New	H3FE	13	46.43	31,500	SF	1,462,500	920,000
Platte Ave., U.S. 24 - 150' x 45' Replacement	H2F	14	46.43	6,750	SF	313,400	291,600
Platte Ave., U.S. 24 Central Tributary - 2x(40'x45') Replacement	H4F	28	46.43	3,600	SF	167,100	155,400
Powers Boulevard - 36' x 150' New	H4F	36	46.43	5,400	Sf	250,700	137,900
West Fork							
Galley Road - 72' x 80' Replacement	H17A	32	60.00	5,760	SF	345,600	58,100
Murray Boulevard - 72' x 80' Replacement	H17A	33	60.00	5,760	SF	345,600	58,100
Palmer Park Boulevard - 72' x 80' Replacement	H17A	34	60.00	5,760	SF	345,600	58,100
Constitution Avenue - 60' x 80' Replacement	H17A	35	60.00	4,800	SF	288,000	43,200
Subtotal						8,155,100	3,983,100
5 Percent Contingency						407,800	199,200
10 Percent Engineering						856,300	418,200
TOTAL						9,419,200	4,600,500

* Refer to Exhibit 1 for location of bridges and number designation.
** Cost of Bridge in excess of 68-feet.

Table 17B. County Bridge Costs - No Detention - Alternates 1 and 2.

Item	Hydrologic Point**	Culvert Number**	Unit Cost	Quantity	Unit	Cost	County Costs*
Bridge and Culvert Construction (W x L of assumed Right-of-Ways)							
Mainstem							
Woodmen Road - 60' x 120' Replacement	H2A	12	46.43	7,200	SF	334,300	--
Upstream of Woodmen Road - 2' x (50' x 120') - New	H12A, H11A	30, 31	46.43	12,000	SF	557,200	--
East Fork and East Fork Subtributary							
Waynoka Road - 120' x 60' Replacement	H5A	6	46.43	7,200	SF	334,300	180,500
Peterson Road - 100' x 120' New	H2F	17	46.43	12,500	SF	580,400	232,200
Palmer Park (2 Bridges) - 2x(40'x80') New	H5F	16, 39	46.43	6,400	SF	297,200	--
Marksheffel Road - 100' x 120' New	H1F	17	46.43	12,000	SF	557,200	189,400
Lariat Drive - 35' x 120' New	H1D	24	46.43	4,200	SF	195,000	--
Lariat Drive - 80' x 120' New	H2B	26	46.43	9,600	SF	445,700	--
Lariat Drive - 35' x 120' New	H1C	20	46.43	4,200	SF	195,000	--
Lariat Drive - 40' x 120' New	H2C	21	46.43	4,800	SF	222,900	--
Dublin Boulevard - 2x(35'x120') New	H1B	25, 25A	46.43	8,400	SF	390,000	--
Barnes Avenue - 65' x 120' New	H1D	23	46.43	7,800	SF	362,200	--
Barnes Avenue - 2x((70'x120') New	H1EE, H1EW	19, 27	46.43	16,800	SF	780,000	--
North Carefree Circle - 70' x 120' New	H2D	18	46.43	8,400	SF	390,000	--
North Carefree Circle - 100' x 120' New	H1E	22	46.43	12,000	SF	557,200	--
2 Major Crossings on Mobil Land - 2x(35'x120') New		37, 38	46.43	8,400	SF	390,000	--
Galley Road Central Tributary - 35' x 60' Replacement	H4F	29	46.43	2,100	SF	97,500	31,200

	Total Cost	Total County Costs
Cost Summary	$6,686,100	$ 633,300
5 Percent Contingency	343,300	31,700
10 Percent Engineering	702,000	66,500
TOTAL	$ 7,722,400	$ 731,500

* County Cost = $\frac{\text{(Improvement or Replacement Cost) X (Ex. Flow - Ex. Capacity)}}{\text{Fully Developed Flow}}$, for existing arterial crossings only

**Refer to Exhibit 1 for location of bridges.

Table 18A. City Bridge Costs - With Detention - Alternate 3.

Item	Hydrologic Point*	Culvert Number**	Unit Cost	Quantity	Unit	Cost	City Costs**
Bridge and Culvert Construction (WXL)							
Mainstem							
Hancock Expressway - Adequate Capacity	H3G	1	$ 0.00			$ 0	$ 0
Airport Road - 12' x 120' Expansion	H10A	2	60.00	1,440	SF	86,400	34,800
Galley Road - 75' x 120' New	H8A	3	46.43	9,000	SF	417,900	181,100
Chelton Road - 18' x 100' Expansion	H1G	4	60.00		SF	108,000	43,500
Powers Boulevard - 130' x 210' New	H6A	5	46.43	27,300	SF	1,267,500	857,100
Carefree Road - 60' x 120' New	H3A	7	46.43	7,200	SF	334,300	144,900
Barnes Road - 70' x 120' New	H1A	8	46.43	8,400	SF	390,000	169,000
Lariat Drive - 60' x 120' New	H16A	9	46.43	7,200	SF	334,300	144,900
Peterson Road - 60' x 120' New	H16A	10	46.43	7,200	SF	334,300	144,900
Dublin Road - 60' x 120' New	H14A	11	46.43	7,200	SF	334,300	144,900
East Fork							
Powers Boulevard - 120' x 210' New	H3FE	13	46.43	25,200	SF	1,170,000	791,200
Platte Avenue., U.S. 24 - 120' x 45' Replacement	H2F	14	46.43	5,400	SF	250,700	250,700
Platte Avenue., U.S. 24 Central Tributary - 2x(40' x 45') Replacement	H4F	28	46.43	3,600	SF	167,100	167,000
Powers Boulevard - 36' x 150' New	H4F	36	46.43	5,400	SF	250,700	137,900
West Fork							
Galley Road - 72' x 80' Replacement	H17A	32	60.00	5,760	SF	345,600	58,100
Murray Boulevard - 72' x 80' Replacement	H17A	33	60.00	5,760	SF	345,600	58,100
Palmer Park Boulevard - 72' x 80' Replacement	H17A	34	60.00	5,760	SF	345,600	58,100
Constitution Avenue - 60' x 80' Replacement	H17A	35	60.00	4,800	SF	288,000	43,200
Cost Summary						$ 6,770,300	$3,429,400
5 Percent Contingency						338,500	171,500
10 Percent Engineering						710,900	360,100
TOTAL						$ 7,819,700	$3,961,000

* Refer to Exhibit 1 for location of bridges and number designation.
** Cost of Bridge in excess of 68-feet.

Table 18B. County Bridge Costs - With Detention - Alternate 3.

Item	Hydrologic Point**	Existing Capacity (CFS)	Culvert Number**	Unit Cost	Quantity	Unit	Cost	County Costs*
Bridge and Culvert Construction (WXL)								
Mainstem								
Woodmen Road - 60' x 120' Replacement	H2A	3110	12	46.43	7,200	SF	334,300	--
2 More Bridges Upstream of Woodmen Road - 2x(50'x120') New	H12A, H11A	--	30, 31	46.43	12,000	SF	557,200	--
East Fork and East Fork Subtributary								
Waynoka Road - 120' x 60' Replacement	H5A	100	6	46.43	7,200	SF	334,300	327,600
Peterson Road (East Fork) - 80' x 120' New	H2F	--	17	46.43	9,600	SF	445,700	445,700
Palmer Park (East Fork, 2 Bridges) - 2x(35'x80') New	H1F	--	16, 39	46.43	5,600	SF	260,000	--
Marksheffel Road - 70' x 120' New	H1F	--	17	46.43	8,400	SF	390,000	390,000
Lariat Drive - 35' x 120' New	H1D	--	24	46.43	4,200	SF	195,000	--
Lariat Drive - 80' x 120' New	H2B	--	26	46.43	9,600	SF	445,700	--
Lariat Drive - 35' x 120' New	H1C	--	20	46.43	4,200	SF	195,000	--
Lariat Drive - 40' x 120' New	H2C	--	21	46.43	4,800	SF	222,900	--
Dublin Boulevard - 2x(35'x120') New	H1B	--	25, 25A	46.43	8,400	SF	390,000	--
Barnes Avenue - 65' x 120' New	H1D	--	23	46.43	7,800	SF	362,200	--
Barnes Avenue - 2x((70'x120') New	H1EE, H1EW	--	19, 27	46.43	16,800	SF	780,000	--
North Carefree Circle - 70' x 120' New	H2D	--	18	46.43	8,400	SF	390,000	--
North Carefree Circle - 100' x 120' New	H1E	--	22	46.43	12,000	SF	557,200	--
2 Major Crossings on Mobil Land - 2x(35'x120') New	N/A	--	37, 38	46.43	8,400	SF	390,000	31,200
Galley Road Central Tributary - 35' x 60' Replacement	H4F	250	29	46.43	2,100	SF	97,500	--

	Total Cost	County Costs
Cost Summary	$ 6,346,800	$1,194,500
5 Percent Contingency	317,300	59,700
10 Percent Engineering	666,400	125,400
TOTAL	$ 7,330,500	$1,379,600

$$\text{* County Cost} = \frac{\text{(Improvement of Replacement Cost) (Ex. Flow - Ex. Capacity)}}{\text{Fully Developed Flow}}$$

**Refer to Exhibit 1 for location of bridges.

Table 19. Basin Fees.

Alternative	Drainage Fees $/Acre	City Bridge Fee $/Acre	County Bridge Fee $/Acre
1. Alternate 1, Fully Channelized No Detention	$4,794	$400	$462
2. Alternate 2, Fully Channelized with "Natural" Reaches	$4,129	$400	$462
3. Alternate 3, Fully Channelized with Detention	$4,963	$259	$393

Example Fee Calculation: Alternate 1

1. $$\text{Drainage Fee} = \frac{\text{Total Construction Cost}}{\text{Total Unplatted Acreage in Basin}} + \frac{\text{Drainage Fee Deficit}}{\text{Total Unplatted Acreage in Basin}}$$

$$= \frac{\$97,287,600}{20,322 \text{ ac.}} + \frac{136,700}{20,322} = 4794$$

2. City Bridge Fee = (Refer to Table 17a)

$$\frac{(\text{Total Cost - City Costs})}{\text{Total Basin Acreage in City}} + \text{Deficit}$$

$$= \frac{\$\ 9,419,200 - 4,600,500}{12,032 \text{ ac.}} = \$400 \text{ acre}$$

3. County Bridge Fee (Refer to Table 17b)

$$\frac{\text{Total Cost - County Costs}}{\text{Total Unplatted Acreage in County}}$$

$$= \frac{\$7,722,400 - 731,500}{15,131 \text{ ac.}} = \$462 \text{ acre}$$

Alternative 1. Additionally, the operations and maintenance of onstream detention facilities could be significant, and vary widely from year-to-year.

Bridge fees are significantly reduced for Alternative 3, because of peak discharges which have been reduced by onstream detention. Bridge fees for the Alternatives 1 and 2 would be the same.

Impact of Land Value on Fee Determination

The Alternative 2 appears to be the most economical from a construction cost perspective. However, the impact of land values should be taken into account as part of the evaluation process and discussed for comparison purposes. For the use of "natural" channels to be viable, it is recommended that a "buffer zone" be established to protect public and private structures from erosion due to stream migration. The nature of Sand Creek is that of a meandering stream, with an invert which can change in location during a flood event. Because of the meandering nature, a buffer zone following both sides of the existing channel should be implemented as part of the natural channel concept. This buffer zone could be as wide as 200 to 300 feet on each side of the developed condition flood plain. The width of the buffer zone should be determined for each site based on the erosion potential of the existing banks, surrounding land, and on the flow characteristics. The buffer zone could be designated as a greenbelt, or open space by the developer.

The question of land value arises since the buffer zone will prevent land located along the channel from having development potential. The foregone potential profit and tax base should be considered as part of evaluation of Alternative 2. If a fully channelized section were constructed in lieu of the natural channel concept, a developer would have more developable acreage and thus the governing body would have a larger tax base.

In order to quantify the significance of the land value, an estimate of land value gained and lost for each alternative was compared. Estimates of land values for different types of land uses were obtained by averaging the square foot "list" price for numerous properties. The following are the average unit land value for different land uses; used in the evaluation.

Single Family Residential - $1.10/square foot

Industrial - $3.65/square foot

Commercial - $6.00/square foot

For analysis purposes it was assumed that all land that might be lost would have a commercial land value, whereas all land that might be gained would have a residential land value. This is a "worst" case scenario used to illustrate the effect that land value will have on each alternative.

Alternative 2 versus Alternative 1: For the economic analysis it was assumed that an additional strip of land approximately 150 feet wide located along both sides of the flood plain would make up the buffer zone/greenbelt. Since this land cannot be developed the owner should be reimbursed for the land as if Alternative 2 was selected. Assuming that the land would be worth $6.00 per square foot when fully platted and improved the owner should be able to sell the land for that market value.

Based on the existing unimproved channel length suitable for "natural" channels of 102,600 linear feet for the total basin, the total value of lost land with the "natural" channel alternative will be approximately $184.7 million. Divided by the total unplatted area yields on "additional" fee of $9,088 per acre.

The width of the buffer zone can vary because of site conditions. If the buffer width for a particular site is small compared to the overall site, and the site has land uses with a relatively low value, then the economics for that particular site could justify the "natural" channel concept. However, for a basin wide policy, the Alternative 2 would not be economical if land values are taken into account.

Alternative 3 versus Alternative 1: Detention ponds involves large areas of land, particularly for regional ponds. As in the case discussed above, a land owner should be reimbursed for the fair market value of the land lost to the detention ponds minus the historic flood plain area. If a reimbursement is not provided, little incentive is created to build detention ponds. However, the land owners downstream of detention facilities can reduce the size of major drainage improvements across their site. The reduced channel section enables the downstream owners to recapture a land historically lost to the flood plain. Two problems immediately arises with Alternative 3. First, the land gained downstream would not offset the amount of land needed for the regional detention ponds. And second, how can an equitable reimbursement be established between those who lost land and those who gained land.

Since the land lost for the detention ponds is larger than the land gained from the smaller channel sections, the basin fees should reflect the cost of purchasing the land for detention ponds. Assuming $6.00 per square foot as the value of the land lost to detention, and $1.10 per square foot for the land gained, minus the historic flood plain areas, the land cost subject to reimbursement has been estimated to be approximately $34.20 million. This converts to a $1,683 per acre cost that should be added to the drainage fee.

In order to offset the increased drainage fee, the land owners located downstream of the detention facilities could pay a "land" fee for the area gained because of detention. Estimates developed during the course of this study showed that the average land gained per foot of channel, as a result of regional detention, to be approximately 38 feet. Based on a $1.10 per square foot land value, a land fee of approximately $42.00 per linear foot of historic channel was estimated.

The drainage fees for Alternative 3, in order to reflect for land values, would be $6,580/acre plus a recommended land fee of $42.00 per linear foot of historic channel downstream of the detention facilities.

VII. RECOMMENDED PLAN

The selection of an improvement alternative has been based upon many factors, including the results of the economic analysis; advantages and disadvantages of plan implementation; construction and maintenance considerations; and aesthetic and land use considerations. The qualitative results presented in Tables 4 through 11, along with the quantitative results such as the hydraulic calculations and cost estimates, were used to formulate the best alternative plan. The recommended plan discussed in this Chapter has been formulated from the analysis and carried out in the study.

Discussion

Alternative 1 is the most economical solution for a basin wide plan, when the value of land is entered into the calculation of the basin fee. This plan provides for the lowest total basin fee and is seen as being the easiest to administer, and maintain since land values and the reimbursement for land lost or gained is not an issue to be considered. "Natural" reaches with selected channel improvements can be permitted on a site specific basis where the stream characteristics make the use of "natural" channels possible or where private systems are proposed. It is again stressed that if a natural channel concept is proposed a "buffer zone" or greenbelts outside of the fully developed 100-year flood plain area should be established, based upon an erosion potential analysis for each given site. Developers should note, however, that no reimbursement of costs for work done on "natural" channels would be given by the City of Colorado Springs.

Recommendations

Presented on Table 20 is a listing of recommended improvements for the mainstem Reaches 1 through 8. The information presented in the table is for general planning use, and the actual channel geometry, slope, and lining protection proposed for a given segment of Sand Creek or any of the tributary reaches must be designed using more exact site specific data, with the exception of Reaches 7 and 8, all channel sections (and right-of-ways), are adequate to convey the 100-year, fully developed flow, within the historic banks. Again, this assumes rigid boundaries conditions for each channel.

For the sub-basins with flows exceeding 500 cubic feet per second, the

Table 20. Summary of Recommendations.

Reach No.	Segment	Approximate Station	Description of Improvements
1	Fountain Creek to D&RGW Railroad Crossing	0+00 to 33+65	General maintenance of channel, debris cleanup, cutting of trees and shrubs in channel. Filling of low-lying overbanks subject to 100-year flooding should be accomplished as development proceeds. Removal of railroad trestle upstream of Las Vegas Street.
	D&RGW Railroad to Hancock Expressway	33+65 to 62+00	General cleanup of construction debris dumped along banks, upstream of the D&RGW Railroad crossing. Repair of riprap linings, cutting of trees and shrubs on banks adjacent to the Hancock Expressway crossing. Clearing of sediment from under the Hancock Boulevard culvert should be carried out annually.
	Hancock Expressway to Academy Boulevard	62+00 to 97+70	Installation of riprap lining, STA 62+00 to STA 75+00 ∓ on east bank, and from STA 62+00 to STA 97+70. Dredging of sediment in channel adjacent to Academy Boulevard necessary. The expansion of culverts at Hancock and Academy Boulevards is recommended.
	Academy Boulevard to Confluence with East Fork of Sand Creek	97+70 to 167+50	Control of weeds and shrubs growing in riprap banks, upstream of Chelton Boulevard. Debris and trash needs clearing, upstream of Fountain Boulevard to Confluence with East Fork. Expansion of the Chelton Boulevard box culvert (2 bays) is recommended.
	Confluence with East Fork to Airport Road	167+50 to 204+90	Dredging of sediment from channel and repair of riprap channel lining downstream of Airport Road. Annual cleaning of culvert suggested. Filling of low west overbanks, upstream of Airport Road recommended.
	Airport Road to U.S. Highway 24	204+90 to 272+10	As development proceeds, riprap channel linings and grade control structures should be constructed. Filling of low overbanks east of channel, STA 255+00 ∓ to U.S. Highway 24 should take place as part of development process.
	U.S. Highway 24 to Galley Road	272+10 to 302+55	Construction of riprap channel linings and grade control structures, both banks confining of the flow a 100- to 150-foot width at U.S. 24 recommended. New concrete box culvert or bridge recommended at Galley Road sized to pass to 100-year future development condition flow rate.
	Galley Road to Palmer Park Boulevard	302+55 to 346+35	Clearing of trees and shrubs at outlet of Palmer Park Boulevard crossing recommended. Riprap lining of east bank, STA 330+00 to 346+35 recommended as development proceeds.
	Palmer Park Boulevard to Powers Boulevard	346+35 to 366+25	Riprap channel linings and grade control structures recommended, after the completion of Powers Boulevard crossing.
2	Powers Boulevard to Constitution Avenue	366+25 to 402+00	Riprap (or equal) channel linings and grade control structures recommended. Abandonment of Waynoka Road weir crossing suggested. General weed and debris cleanup near-term.

Table 20. (continued).

Reach No.	Segment	Approximate Station	Description of Improvements
2	Constitution Avenue to Barnes Road (Proposed)	402+00 to 503+00	Riprap (or equal) channel linings and grade control structures recommended as development proceeds. New crossings at North Carefree Circle and Barnes Road recommended. Filling of low-lying overbanks to elevation above the future condition 100-year flood plain recommended.
	Barnes Road to Dublin Road	503+00 to 640+00∓	Riprap (or equal) channel linings and grade control structures as development proceeds. Stream crossings to be sized to pass the 100-year future development condition peak flow rates.
3	Dublin Road to Black Forest	640+00, North	Channel linings are recommended for all drainageways with flows in excess of 500 cubic feet per second (see Exhibit 1). Crossings should be sized to pass the 100-year future condition peak flow rates.
4	Confluence with Mainstem of Sand Creek to Powers Boulevard	0+00 to 81+90	Riprap (or equal) channel linings and grade control structures recommended. New crossing at Powers Boulevard necessary when Powers is extended. Filling of low overbanks STA 50+00 to 81+90 suggested, as development proceeds.
	Powers Boulevard to U.S. Highway 24	81+90 to 152+70	Riprap (or equal) channel linings recommended, STA 119+50 (Stewart Avenue) to U.S. Highway 24. Filling of low-lying overbanks, STA 119+50 to 151+70 recommended as development proceeds. Clearing of weeds and debris suggested, STA 81+90 to 119+00, annually.
	U.S. Highway 24 to Confluence with East Fork Subtributary (Reach 6)	152+70 to 285+00	Riprap (or equal) channel linings and grade control structures recommended. Filling of low-lying overbanks suggested as part of the development process, to eliminate shallow flooding areas. New crossings at Peterson Road and Marksheffel Road suggested, sized to convey the 100-year, future condition peak runoff rate.
5	East Fork Sand Creek from Confluence with Reach 6 to Basin Boundary	N/A	Channelization of major drainageways with flows in excess of 500 cubic feet per second recommended (see Exhibit 1). New crossings for major arterials sized to pass the 100-year, future development condition flows suggested (see Exhibit 1).
6	East Fork Subtributary	285+00, North	Channelization of major drainageways with flows in excess of 500 cubic feet per second recommended (see Exhibit 1). New crossings for major arterials sized to pass the 100-year, future development condition flows suggested (see Exhibit 1).
7	Central Tributary, Sand Creek	0+00 to 60+40	Riprap (or equal) channel linings, Airport Road to Powers Boulevard. Annual clearing of box culvert at Airport Road recommended. New box culvert at Powers Boulevard, sized to pass the 100-year future condition peak flow suggested.
	Powers Boulevard to U.S. Highway 24	60+40 to 81+00	Riprap (or equal) channel linings and grade control structures recommended as development proceeds. New crossing at U.S. 24 recommended (see Exhibit 1).

Table 20. (continued).

Reach No.	Segment	Approximate Station	Description of Improvements
	U.S. Highway 24 to Omaha Boulevard	81+00 to 138+05	New crossing at Galley Road, and elimination of double 90° bends recommended. General clearing of debris and trash suggested along existing concrete lined drainageway.
8	West Fork Sand Creek Confluence with Sand Creek to U.S. Highway 24	N/A	Construction of riprap lined channels, recommended. Erosion is apparent on both sides of channel, and riprap washouts at bridge outlets have occurred. Remedial actions are recommended to repair scour damage at the grade control structure downstream of U.S. Highway 24, and at the outlet of the existing concrete box culvert under U.S. Highway 24.
	U.S. Highway 24 to Galley Road	N/A	Clearing of weeds and debris from channel upstream of U.S. Highway 24 recommended. Grade control and channel lining installation is recommended along the channel, downstream of Galley Road. Clearing of sediment upstream of Galley Road box culvert should be carried out regularly. New box culvert at Galley Road recommended.
	Galley Road to Palmer Park Boulevard	N/A	Clearing of sediment and debris as necessary is recommended. New box culverts at Murray Boulevard and Palmer Park Boulevard are recommended.
	Palmer Park Boulevard to Constitution Avenue	N/A	Abandonment of existing railroad crossing recommended if tracks remain inactive. Channel lining and grade control recommended for drainageway between railroad and Constitution Avenue. Debris walls at Constitution Avenue should be cleared as necessary. Construction of a new box culvert at Constitution is recommended.

recommended channel improvements have been presented on Exhibit 1. It should be noted that the sizing of channels within sub-tributary basins to Sand Creek again depends upon site specific data. Where possible, riprap, grouted riprap or concrete channels have been sized and summarized herein. "Natural" channels, and grasslined channels have not been considered, but are feasible in those systems designated as private and site constraints promote the use of such channels.

It is recommended that the peak discharges estimated in this report be used for the planning and design of future drainage facilities. A typical channel and drop section, as presented on Figures 5 and 6, should be used as a general design guide. To ensure the long-term stability of the channel, each stream segment should be analyzed to determine its equilibrium slope and scour potential for both short- and long-term scenarios, according to Reference 9. Basic design guidelines were presented in Chapter V.

With respect to design criteria, it is recommended that the City of Colorado Springs and El Paso County, review and update existing drainage criteria manuals. Specific criteria related to the design of drainage structures on sandy soil is needed. This criteria could be provided to developers with projects in the Sand Creek Basin. Various documents are currently in use by municipalities in Colorado for the design of drainage facilities which could be reviewed and updated as necessary to meet the needs of the City and County.

The scope of this criteria manual should not rule out certain types of materials for use in lining channel banks. Rather, an updated manual should provide minimum design criteria for natural, riprap, concrete or other materials, and thus the use of a given lining material would be based upon specific design and site constraints.

In order to minimize future O&M associated with the dredging of culverts and channel sections, it is recommended that the City of Colorado Springs and El Paso County require developers working in the Sand Creek basin, to control the loss of soil from construction areas. The preparation of a general design criteria for the control of erosion during construction is suggested to be provided to area developers and builders, particularly for projects adjacent to the Sand Creek channel. Temporary siltation basins can be effective in controlling erosion from disturbed areas.

Engineers and developers proposing major channelization projects within the Sand Creek basin should be aware of the rules and regulations contained in the U.S. Army Corps of Engineers 404 Permitting program, and the proper notifications made of local agencies during preliminary design phases of a project.

VIII. REFERENCES

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2. "Sand Creek Drainage Basin Study", United Western Planning and Engineering Company, October, 1977.

3. Preliminary "Flood Insurance Study for Colorado Springs and El Paso County, Colorado", Federal Emergency Management Agency, 1983.

4. "Master Drainage Study for Stetson Hills", Graner Engineering Services, Inc., August, 1984.

5. "Master Drainage Planning Study for the Banning-Lewis Ranch", MSM Consulting Engineers, Inc., June, 1981.

6. "Impact Study of the Sand Creek Drainage Basin", Finn and Associates, Ltd., June, 1984.

7. "Determination of Storm Runoff Criteria", City of Colorado Springs, revised 1979.

8. "Soil Survey for El Paso County, Colorado", U.S. Department of Agriculture, Soil Conservation Service, June, 1980.

9. "Design Guidelines and Criteria for Channel and Hydraulic Structures on Sandy Soil", Urban Drainage and Flood Control District, June, 1981.

10. "Precipitation-Frequency Atlas of the Western United States", Volume 3, U.S. Department of Agriculture, National Oceanic and Atmospheric Administration, 1977.

11. "HEC-2, Water Surface Profile Program", Department of the Army, U.S. Army Corp of Engineers, updated 1982.

12. 1983 Cost Data, Colorado Department of Highways, January, 1984.

APPENDIX

Table 21: Summary of Sub-Basin Hydrologic Data

Exhibit 1 - Existing and Proposed Major Drainage

Exhibit 2 - Sand Creek Basin Design Points and Discharges

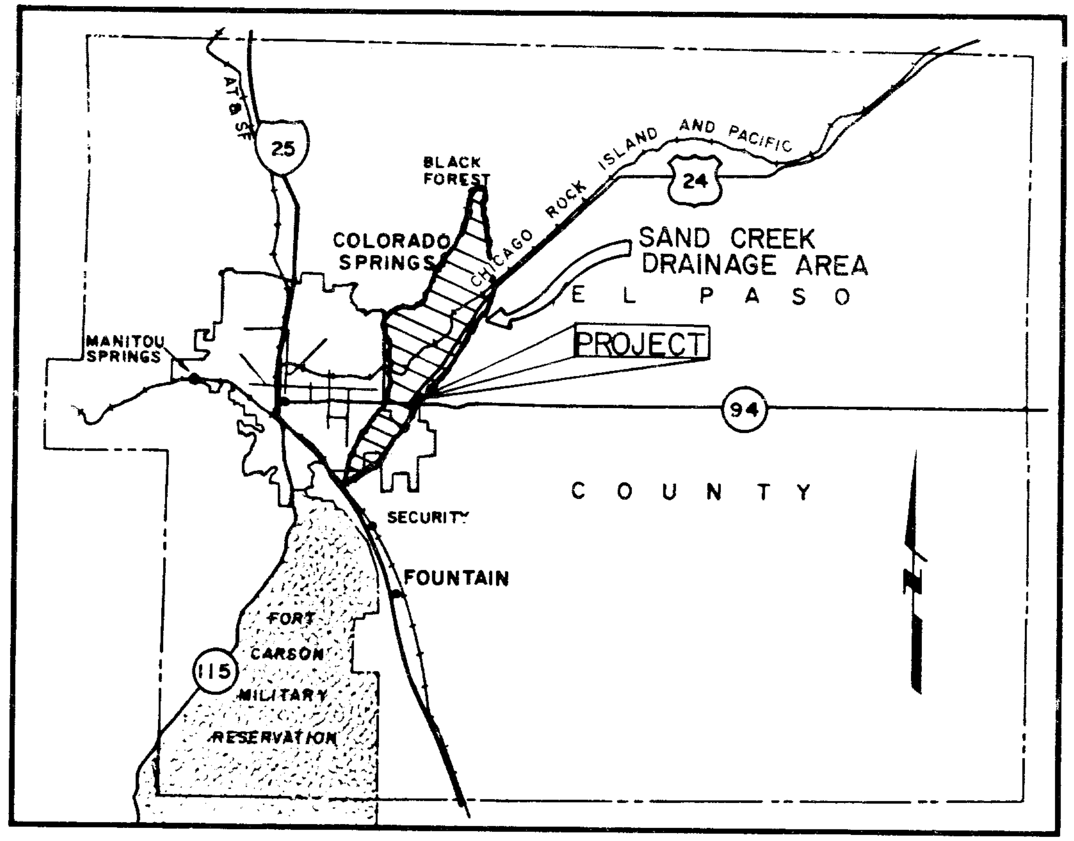
Flood Hazard Area Maps (Plates 1 through 22)

TABLE 21 - Summary of SUB-Basin Hydrologic Data

Basin No.	Area Sq. Miles	CN	Tc Hr.	6-Hr Peak Runoff 5-Year cfs	6-Hr Peak Runoff 100-Year cfs	24-Hr Peak Runoff 5-Year cfs	24-Hr Peak Runoff 100-Year cfs
A1	0.836	67.0	0.66	68	394	133	567
A2	0.232	67.0	0.49	23	140	47	198
A3	0.316	67.0	0.49	32	190	64	269
A4	0.554	67.0	0.61	49	279	94	404
A5	0.121	67.0	0.29	18	113	31	130
A6	0.165	83.3	0.36	132	358	144	338
A7	0.405	83.3	0.62	209	556	265	638
A8	0.126	83.3	0.28	124	330	124	287
A9	0.029	83.3	0.24	31	87	31	70
A10	0.070	83.3	0.31	65	172	65	152
A11	0.567	76.4	1.03	107	350	154	450
A12	0.132	83.3	0.33	116	309	119	280
A13	0.100	83.3	0.31	92	246	93	218
A14	0.132	83.3	0.40	97	260	111	258
A15	0.197	83.3	1.15	61	160	80	195
A16	0.432	76.4	1.14	75	245	108	318
A17	1.073	78.7	0.87	285	869	399	1,090
A18	0.113	77.7	0.58	37	120	53	148
A19	0.590	75.0	0.85	112	392	170	523
A20	0.696	75.1	0.91	126	442	186	573
A21	0.264	74.4	0.45	77	289	117	350
A22	0.044	74.4	0.22	21	85	27	78
A23	0.172	74.4	0.32	66	250	85	257
A24	0.197	74.4	0.36	67	253	95	279
A25	0.148	74.4	0.29	61	232	77	232
A26	0.237	74.4	0.41	74	278	110	324
A27	0.260	72.8	0.42	67	271	104	325
A28	0.230	73.8	0.53	55	210	85	267
A29	0.211	79.1	0.64	74	223	100	272
A30	0.136	77.0	0.84	32	103	46	131
A31	0.286	84.3	0.44	213	546	246	561
A32	0.166	81.0	0.33	119	344	130	322
A33	0.670	79.2	0.66	229	694	315	853
A34	0.132	77.0	0.25	79	263	91	248
A35	0.102	80.9	0.38	64	184	76	186
A36	0.433	83.1	0.86	168	444	219	534
A37	0.656	86.4	0.59	451	1,090	540	1,200
A38	0.560	82.4	0.65	259	705	329	823
A39	0.506	90.2	0.56	482	1,050	538	1,090
A40	0.112	93.2	0.37	191	382	166	313
A41	0.218	86.9	0.36	236	567	235	507
A42	0.169	84.4	0.33	162	418	163	373
A43	0.136	87.7	0.35	161	377	155	328
A44	0.396	89.1	0.47	409	921	434	891
A45	0.772	87.5	0.84	432	1,010	527	1,150
A46	0.489	81.6	0.42	304	854	365	885
A47	2.257	86.0	1.53	680	1,630	864	1,960
A48	0.610	86.4	0.60	415	1,000	503	1,120
A49	2.152	82.1	0.79	821	2,240	1,100	2,730
A50	3.217	84.7	1.12	1,150	2,870	1,460	3,440
A51	0.857	82.8	1.13	260	689	344	846
A52	0.682	86.5	0.97	312	748	390	884
B1	1.583	76.7	1.17	277	896	396	1,150
B2	0.293	81.6	0.55	145	407	189	468
B3	0.288	76.7	0.53	93	313	135	382
B4	0.597	74.7	0.68	131	471	197	601
B5	0.379	74.7	0.71	79	287	121	371
B6	0.323	74.7	0.32	128	478	163	490
B7	0.502	74.7	0.95	84	300	126	390
B8	0.803	74.7	1.14	118	413	175	544
B9	0.277	74.7	0.71	58	210	89	271
B10	0.405	75.3	0.59	104	370	155	466
B11	0.535	79.3	0.64	190	572	256	695
C1	0.664	74.6	1.20	93	328	137	426
C2	0.524	74.7	0.99	85	303	128	395
C3	0.911	75.7	1.01	162	548	237	709
C4	0.415	75.0	0.71	89	320	136	412
C5	0.149	82.8	0.34	122	331	129	306
C6	0.214	75.0	0.45	67	243	100	291
C7	0.605	75.7	0.75	135	465	201	598
C8	0.710	74.7	0.64	162	582	241	745
C9	0.538	74.7	0.51	146	533	222	669
D1	1.344	74.7	1.36	172	599	253	786
D2	0.496	74.9	0.89	90	316	134	412
D3	0.512	69.1	0.78	52	250	91	353
D4	0.165	74.7	0.37	57	211	80	234
D5	0.082	74.7	0.34	30	115	41	120
D6	0.798	69.1	0.81	79	378	135	528
D7	1.099	79.6	1.12	259	758	354	946
D8	0.215	83.3	0.50	132	354	164	378
D9	0.752	83.3	0.74	335	883	433	1,040
D10	0.849	83.3	0.76	369	971	479	1,150
E1	0.479	83.3	0.65	238	631	299	730
E2	0.267	81.6	0.54	133	374	174	430
E3	0.855	74.8	0.83	161	574	243	748
E4	0.502	80.6	0.66	194	561	260	679
E5	0.610	75.5	0.62	154	542	225	684
E6	0.317	83.3	0.45	216	576	258	602
F1	1.076	81.2	1.03	310	863	415	1,060
F2	0.522	76.1	0.78	118	399	175	515
F3	0.220	76.3	0.67	57	191	83	241
F4	0.469	78.2	0.65	150	470	207	575
F5	0.294	77.0	0.47	108	362	152	421
F6	0.286	74.7	0.51	77	283	118	356
F7	0.235	74.7	0.46	69	255	104	308
F8	1.967	81.0	1.30	461	1,280	617	1,590
F9	1.311	80.1	1.11	323	932	446	1,180
F10	0.977	83.4	0.88	381	997	502	1,220
G1	0.694	80.9	0.71	262	747	352	895
G2	0.466	72.5	0.73	75	299	121	400
G3	0.491	85.4	0.57	324	808	393	890
G4	0.821	85.1	0.57	529	1,330	646	1,470
G5	0.861	82.7	0.61	425	1,150	556	1,350

* The peak 100-year, 24-hour discharge is to be used for the design of major facilities (greater than 500-cubic feet per second) on Sand Creek and its tributaries. The 6-hour, 5-year frequency flows are to be used for the design of minor systems.

NOTE: ALL HYDROLOGIC INFORMATION FOR EXISTING CONDITIONS OBTAINED FROM THE PRELIMINARY FLOOD INSURANCE STUDY FOR COLORADO SPRINGS, AND EL PASO COUNTY, COLORADO. HYDROLOGIC DATA FOR FUTURE DEVELOPMENT CONDITIONS PREPARED AS PART OF THIS STUDY.



VICINITY MAP
NO SCALE

LEGEND:

PLAN:

EXISTING 100 YEAR FLOODPLAIN
PROJECTED CONDITION 100 YEAR FLOODPLAIN
AREA OF SHALLOW FLOODING
CROSS SECTION LOCATION
1+00 CENTERLINE OF EXISTING STREAM AND STATIONING

PROFILE:

EXISTING CHANNEL INVERT
EXISTING 100 YEAR WATER SURFACE PROFILE
PROJECTED 100 YEAR WATER SURFACE PROFILE

GENERAL NOTES

1. All mapping based upon the National Geodetic and Vertical Datum of 1929 (NGVD).
2. Flood plain information contained in this study are for informational purposes only. Water surface elevations and channel inverts adjacent to a specific project should be field verified during the drainage planning phases.
   This information herein should not be used in lieu of the Preliminary FEMA Study for Colorado Springs and El Paso County.
3. 100-year flood plain and profile data based upon the 24-hour, 100-year rainfall.
4. In areas where the existing and future condition 100-year flood plain and profile coincides, the 100-year existing limits have been shown.
5. All existing and future development flows have been routed through existing, or under construction facilities, to determine the flood hazard areas.
6. 100-year existing development condition plan and profile correspond to the hydraulic data contained in the Preliminary Flood Insurance Studies for El Paso County and Colorado Springs, 1982.

PLATE INDEX

Plate 1	Index Map
Plate 2	Main stem Stetson Hills North
Plate 3	Main stem Stetson Hills Central
Plate 4	Main stem Stetson Hills South
Plate 5	Main stem STA 448 + 75 to STA 503 + 00
Plate 6	Main stem STA 387 + 25 to STA 448 + 75
Plate 7	Main stem STA 319 + 30 to STA 387 + 25
Plate 8	Main stem STA 263 + 00 to STA 319 + 30
Plate 9	Main stem STA 197 + 00 to STA 263 + 00
Plate 10	Main stem STA 128 + 00 to STA 197 + 00
	East fork STA 00 + 00 to STA 23 + 00
Plate 11	Main stem STA 67 + 80 to STA 128 + 00
Plate 12	Main stem STA 00 + 00 to STA 67 + 80
Plate 13	East fork STA 448 + 50 to STA 523 + 70
Plate 14	East fork STA 380 + 75 to STA 448 + 50
Plate 15	East fork STA 307 + 50 to STA 380 + 75
Plate 16	East fork STA 257 + 00 to STA 307 + 50
Plate 17	East fork STA 191 + 20 to STA 257 + 00
Plate 18	East fork STA 126 + 50 to STA 191 + 20
Plate 19	East fork STA 58 + 40 to STA 126 + 50
Plate 20	East fork STA 23 + 00 to STA 58 + 40
	Central tributary STA 00 + 00 to STA 37 + 30
Plate 21	Central tributary STA 102 + 60 to STA 138 + 05
Plate 22	Central tributary STA 37 + 30 to STA 102 + 60

No.	Revision	Date	By

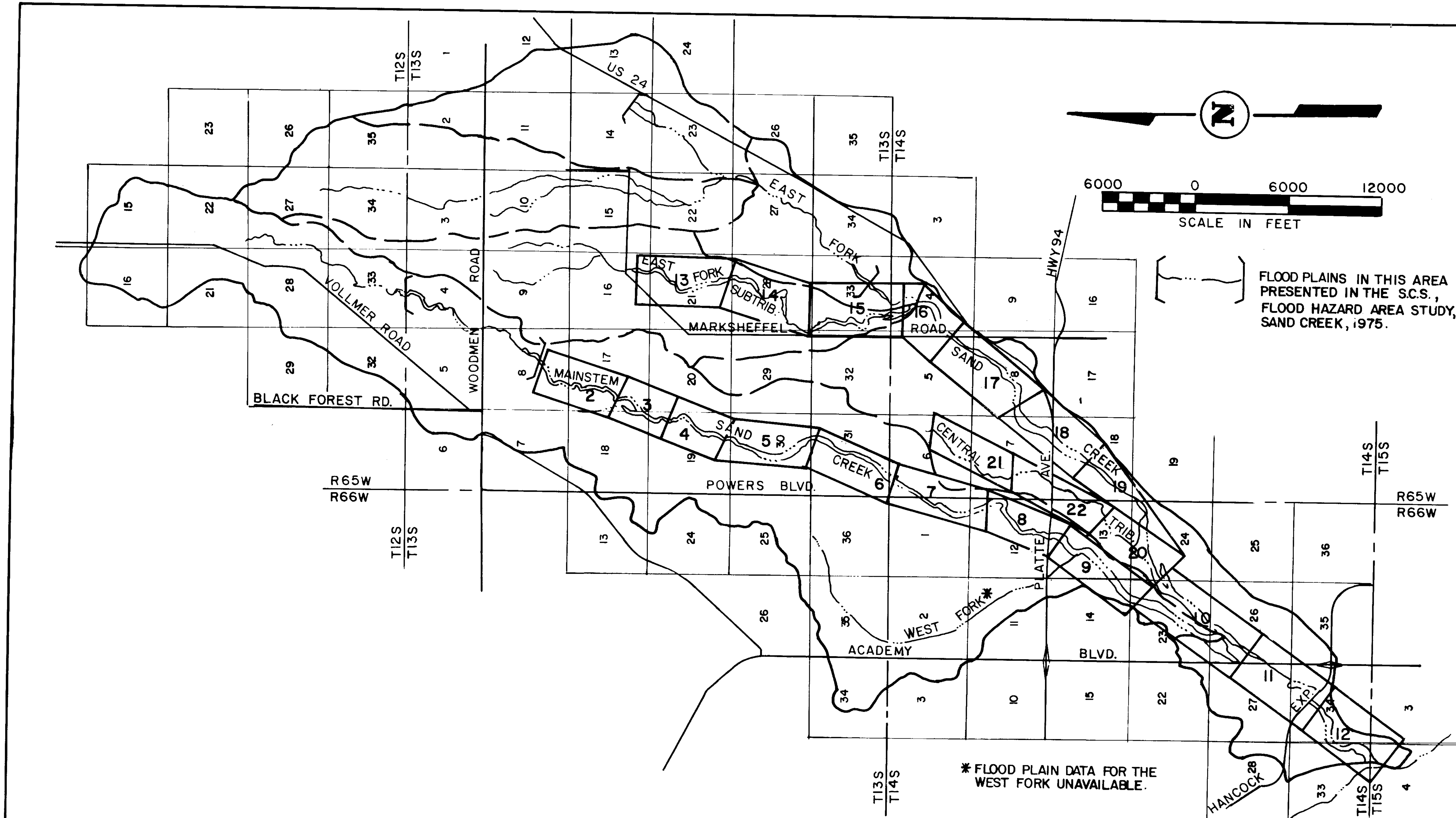
FLOOD HAZARD AREAS

SAND CREEK MASTER DRAINAGE PLANNING STUDY

LEGEND AND VICINITY MAP

Designed by: R.N.W.
Drawn by: E.K. Date: 10/4/84
Checked by: R.N.W. Project No.: CO-FA-01

sla
SIMONS, LI & ASSOCIATES, INC.



SAND CREEK MASTER DRAINAGE PLANNING STUDY

INDEX MAP

Designed by: R.N.W.
Drawn by: L.E. GOOD
Checked by: R.N.W.
Scale:
Date: 10-2-84
Project No.: CO-FA-81

No.	Revision	Date	By
1	CITY COMMENTS	11/7/84	

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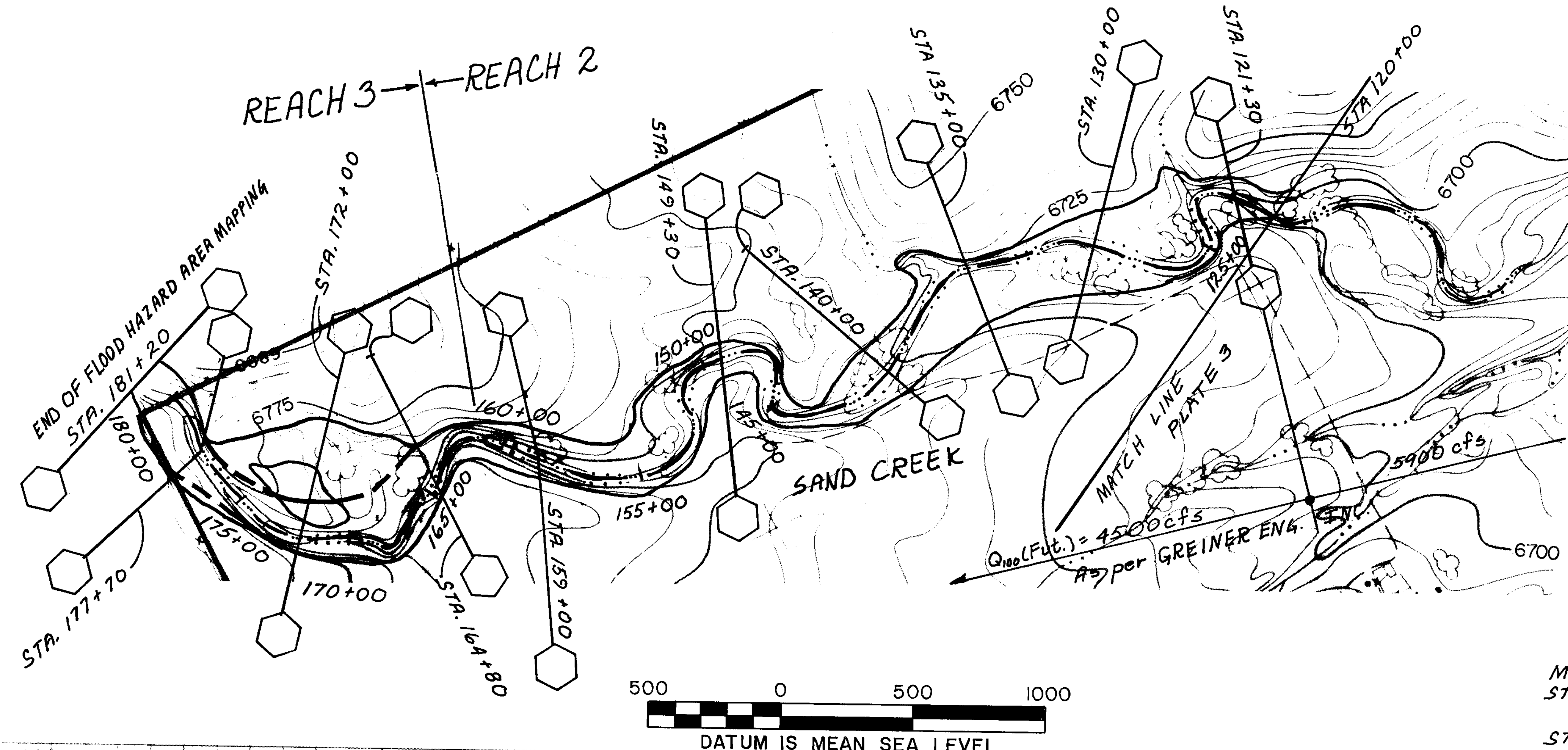
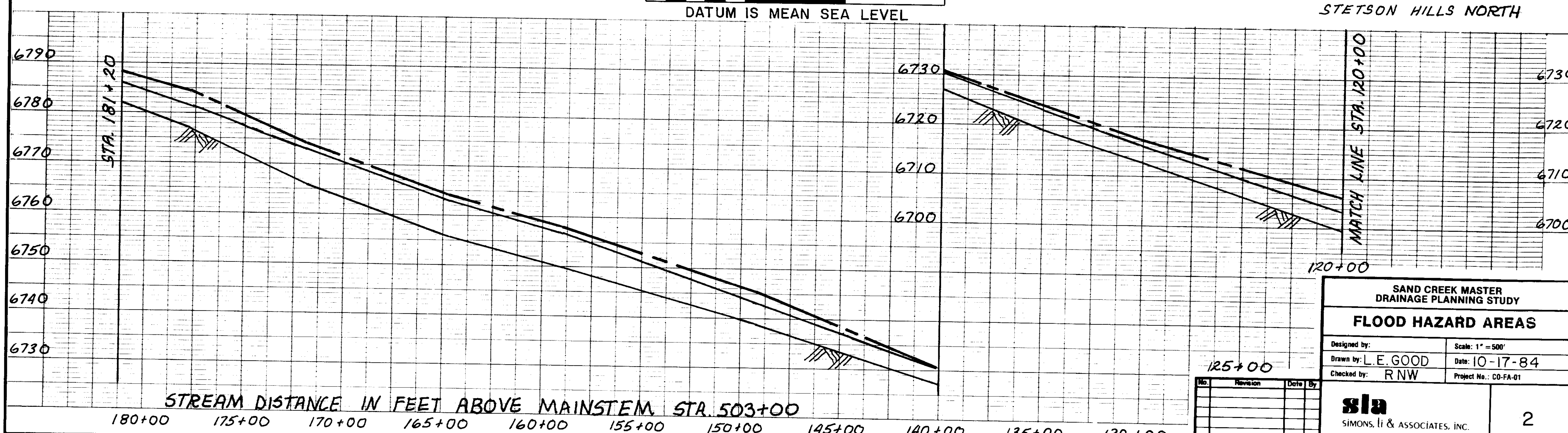
PLATE 1



NOTES:
1. TOPO, FLOOD PLAIN & WATER SURFACE ELEVATIONS PROVIDED BY GREINER ENGINEERING, INC FOR THIS PLATE.
2. CROSS SECTION NUMBERS ARE DENOTED BY STATIONS FOR THIS PLATE.

MAINSTEM SAND CREEK
STA. 120+00 TO STA. 181+20

STETSON HILLS NORTH



SAND CREEK MASTER DRAINAGE PLANNING STUDY

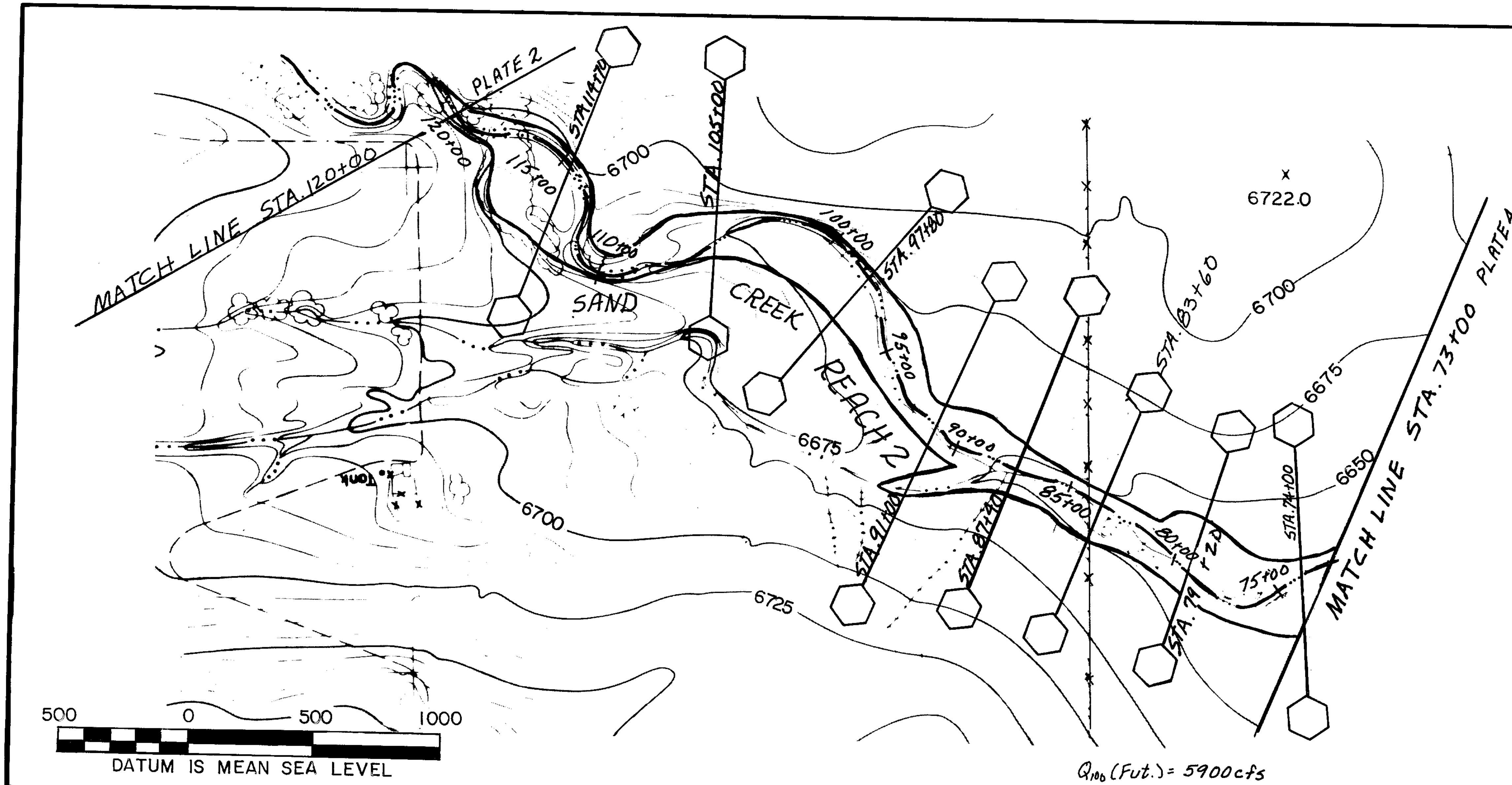
FLOOD HAZARD AREAS

Designed by:	Scale: 1" = 500'
Drawn by: L.E. GOOD	Date: 10-17-84
Checked by: RNW	Project No.: CO-FA-01

No.	Revision	Date	By

sla SIMONS, LI & ASSOCIATES, INC.

2



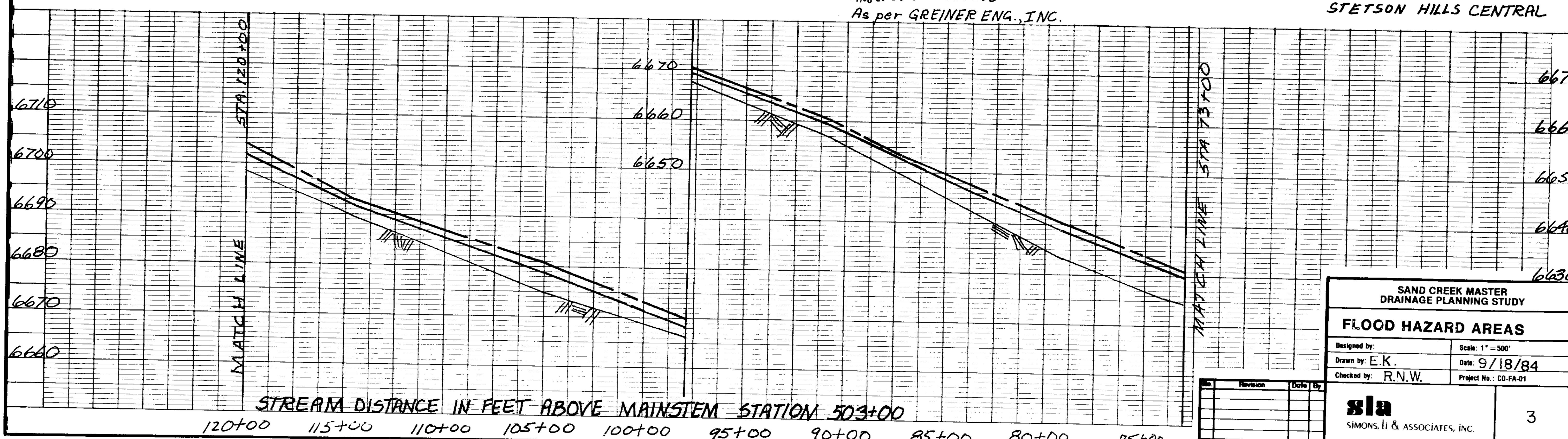
NOTES: 1. TOPO, FLOOD PLAIN, & WATER SURFACE ELEVATIONS PROVIDED BY GREINER ENGINEERING FOR THIS PLATE.

2. CROSS SECTION NUMBERS ARE DENOTED BY STATIONS FOR THIS PLATE.

MAINSTEM SAND CREEK
STA. 73+00 TO STA. 120+00

STETSON HILLS CENTRAL

Q_{100} (Fut.) = 5900 cfs
As per GREINER ENG., INC.



SAND CREEK MASTER DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by:	Scale: 1" = 500'
Drawn by: E.K.	Date: 9/18/84
Checked by: R.N.W.	Project No.: CO-FA-01

No.	Revision	Date	By

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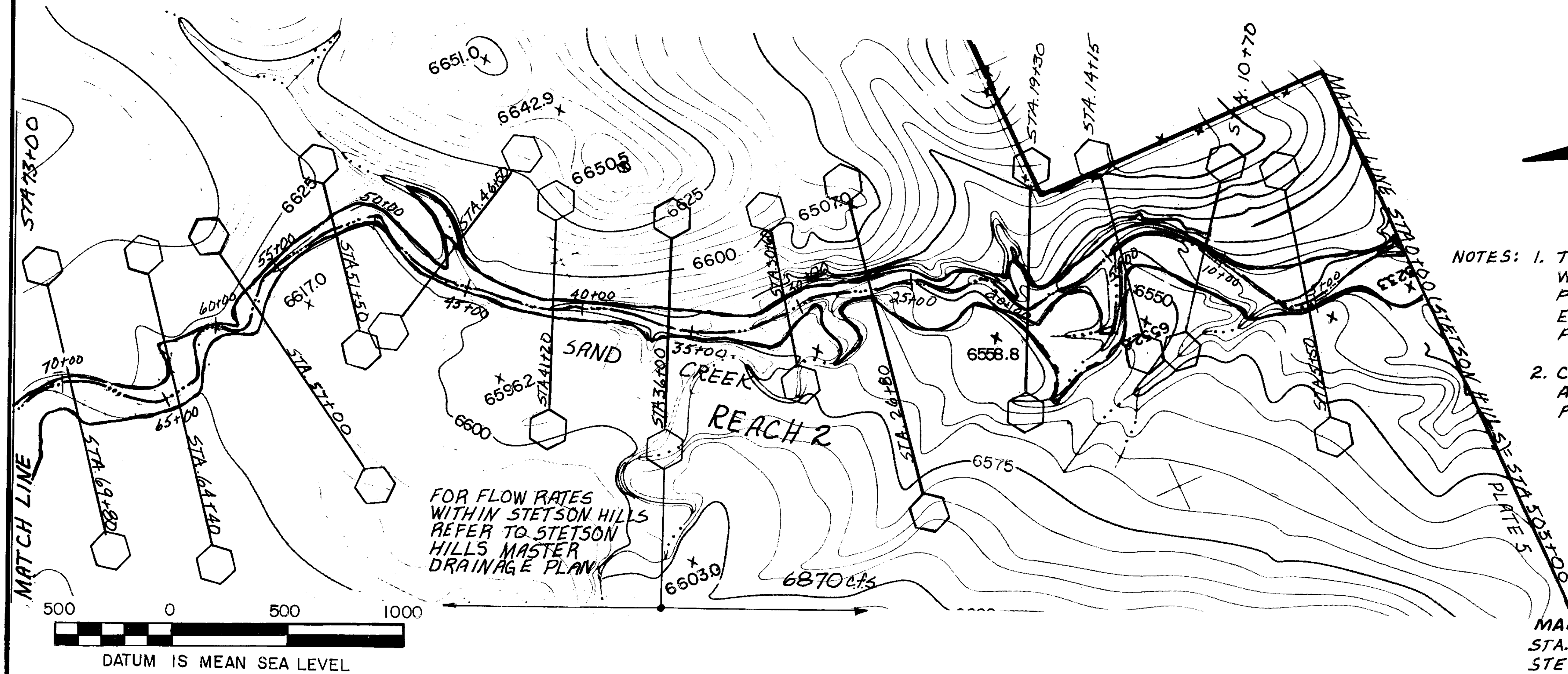
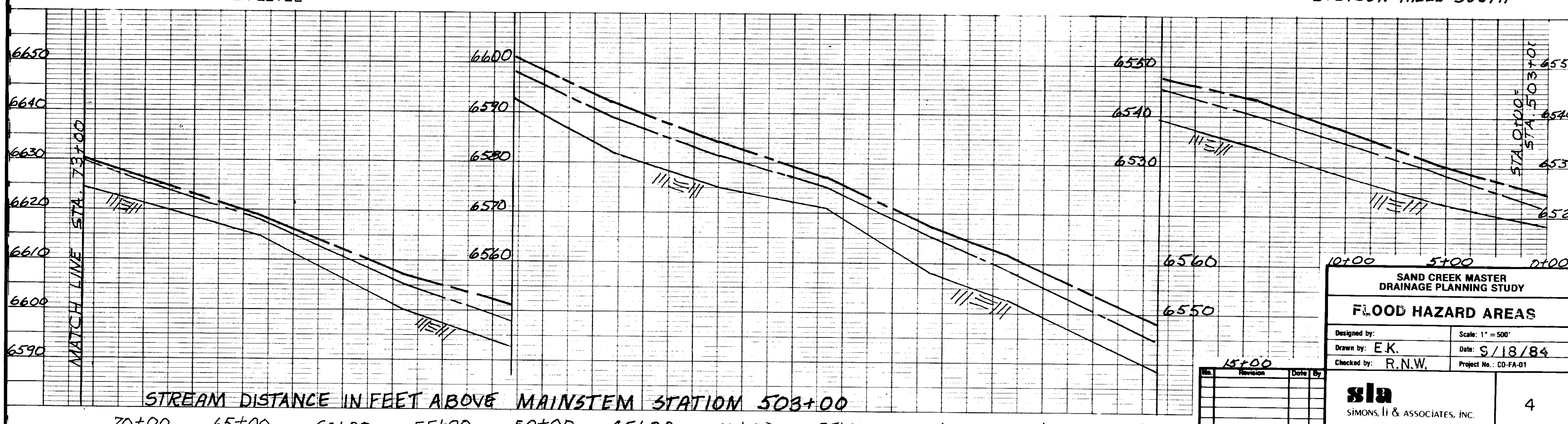
SIMONS, LI & ASSOCIATES, INC.



NOTES: 1. TOPO, FLOOD PLAIN & WATER SURFACE ELEVATIONS PROVIDED BY GREINER ENGINEERING FOR THIS PLATE.

2. CROSS SECTION NUMBERS ARE DENOTED BY STATIONS FOR THIS PLATE.

MAIN STEM SAND CREEK
STA. 0+00 TO STA. 73+00
STETSON HILLS SOUTH



No.	Revision	Date	By

SAND CREEK MASTER
DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by:	Scale: 1" = 500'
Drawn by: E.K.	Date: 5/18/84
Checked by: R.N.W.	Project No.: CO-FA-01

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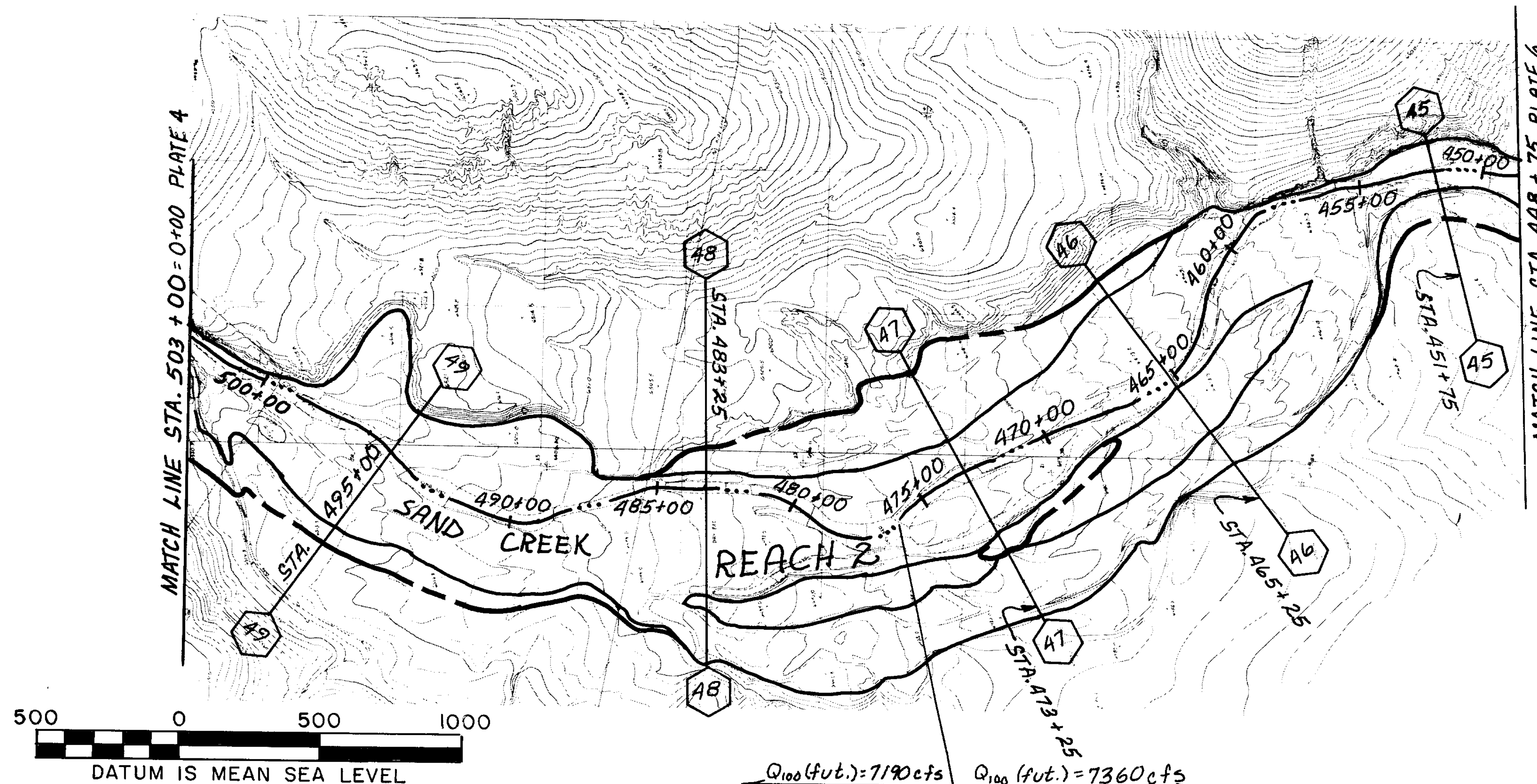
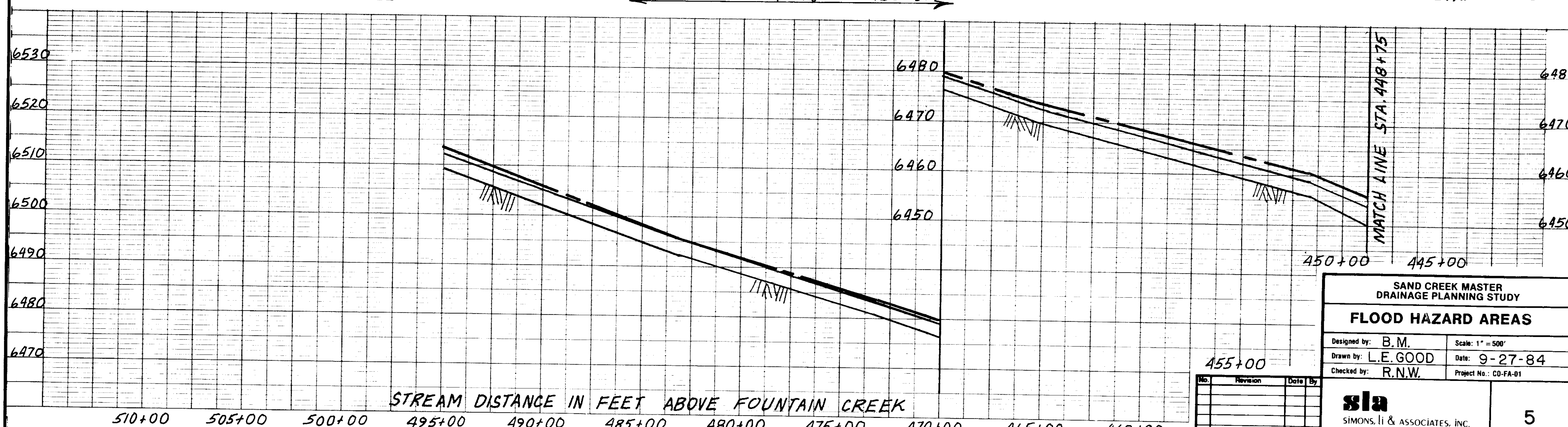


MAINSTEM SAND CREEK
STA. 448 + 75 TO STA. 503 + 00



No.	Revision	Date	By

SAND CREEK MASTER DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by: B.M. | Scale: 1" = 500'
Drawn by: L.E. GOOD | Date: 9-27-84
Checked by: R.N.W. | Project No.: CO-FA-01

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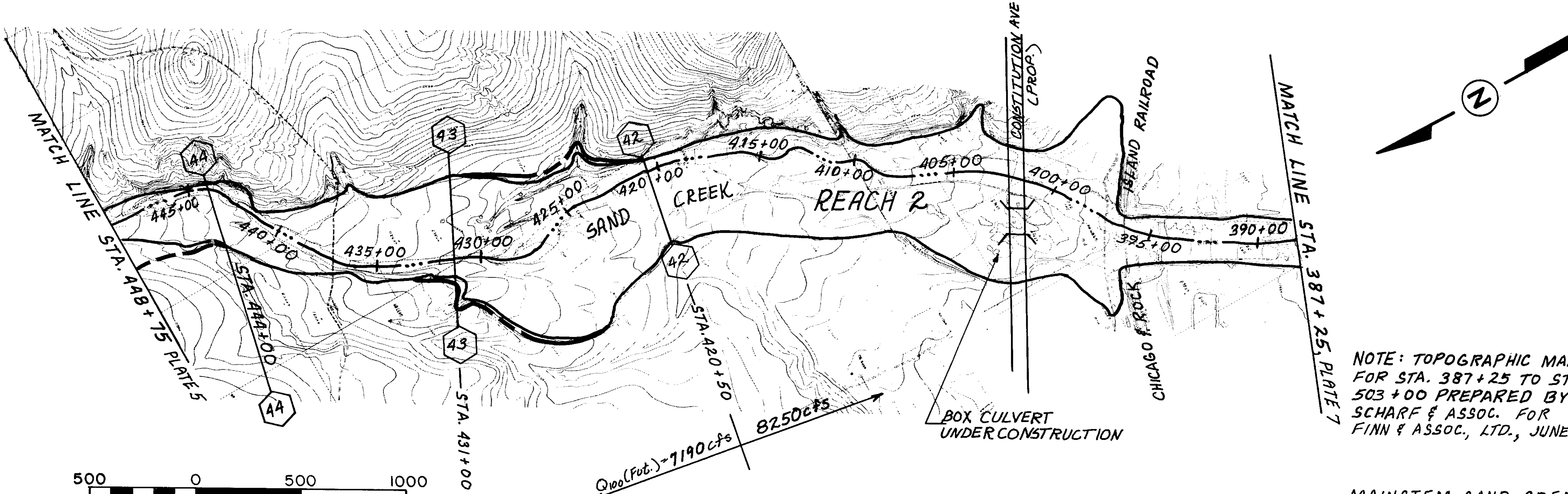
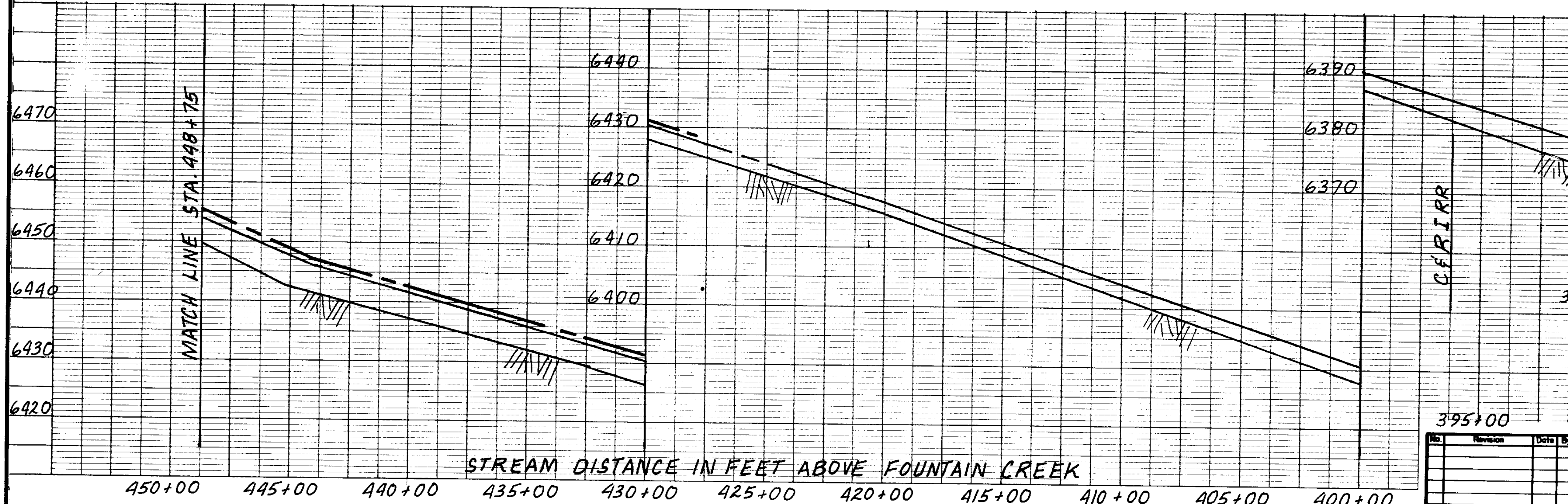
5



NOTE: TOPOGRAPHIC MAPPING FOR STA. 387+25 TO STA. 503+00 PREPARED BY SCHARF & ASSOC. FOR FINN & ASSOC., LTD., JUNE 1984

MAINSTEM SAND CREEK
STA. 387+25 TO STA. 448+75



SAND CREEK MASTER DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by:	B.M.	Scale: 1" = 500'	
Drawn by:	L.E. GOOD	Date:	9-26-84
Checked by:	R.N.W.	Project No.: CO-FA-01	

No.	Revision	Date	By

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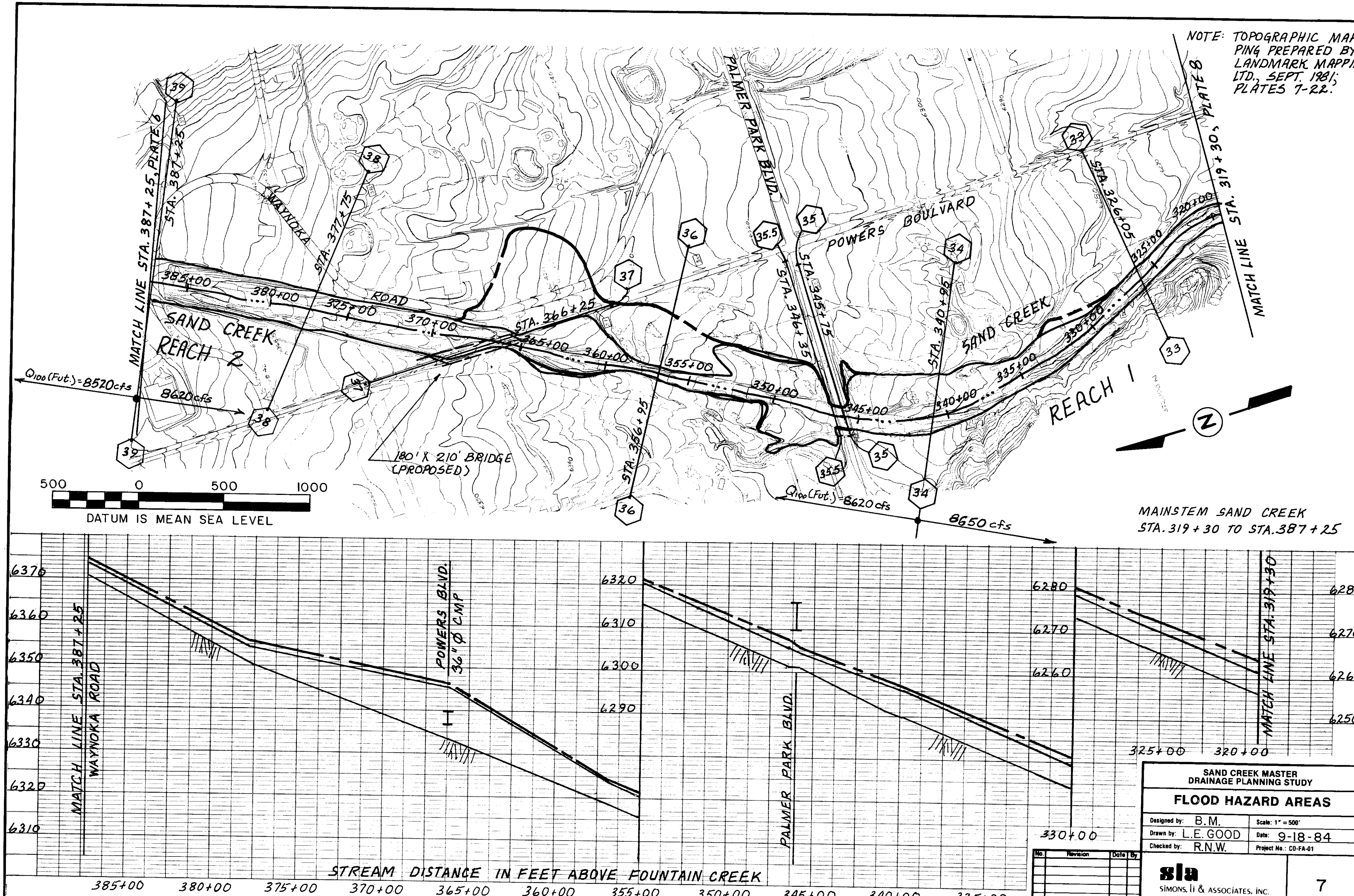
SIMONS, LI & ASSOCIATES, INC.

6



SAND CREEK MASTER DRAINAGE PLANNING STUDY

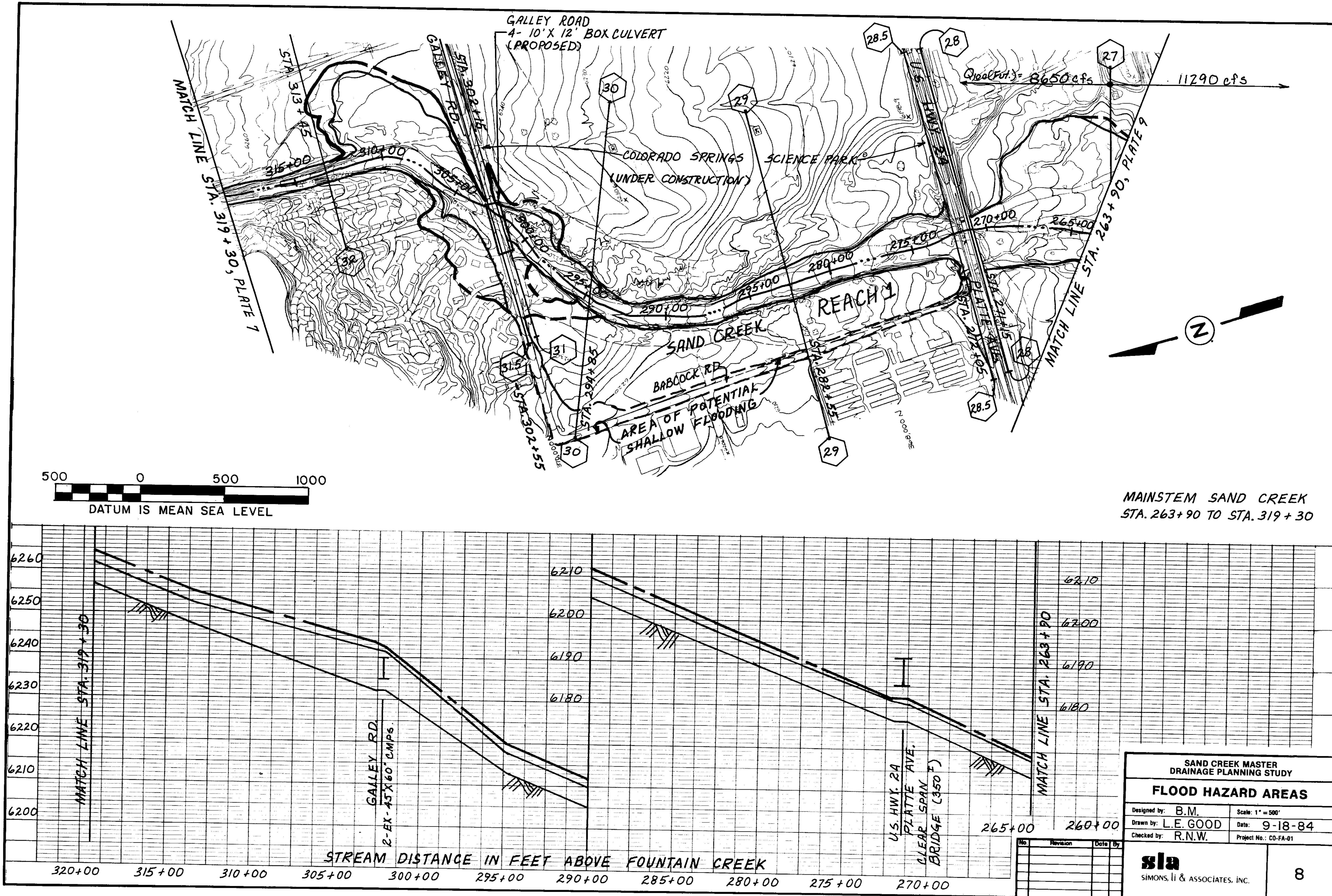
FLOOD HAZARD AREAS

Designed by: B.M.	Scale: 1" = 500'	
Drawn by: L.E. GOOD	Date: 9-18-84	
Checked by: R.N.W.	Project No.: CO-FA-01	

No.	Revision	Date	By

sla SIMONS, LI & ASSOCIATES, INC.

7



SAND CREEK MASTER DRAINAGE PLANNING STUDY

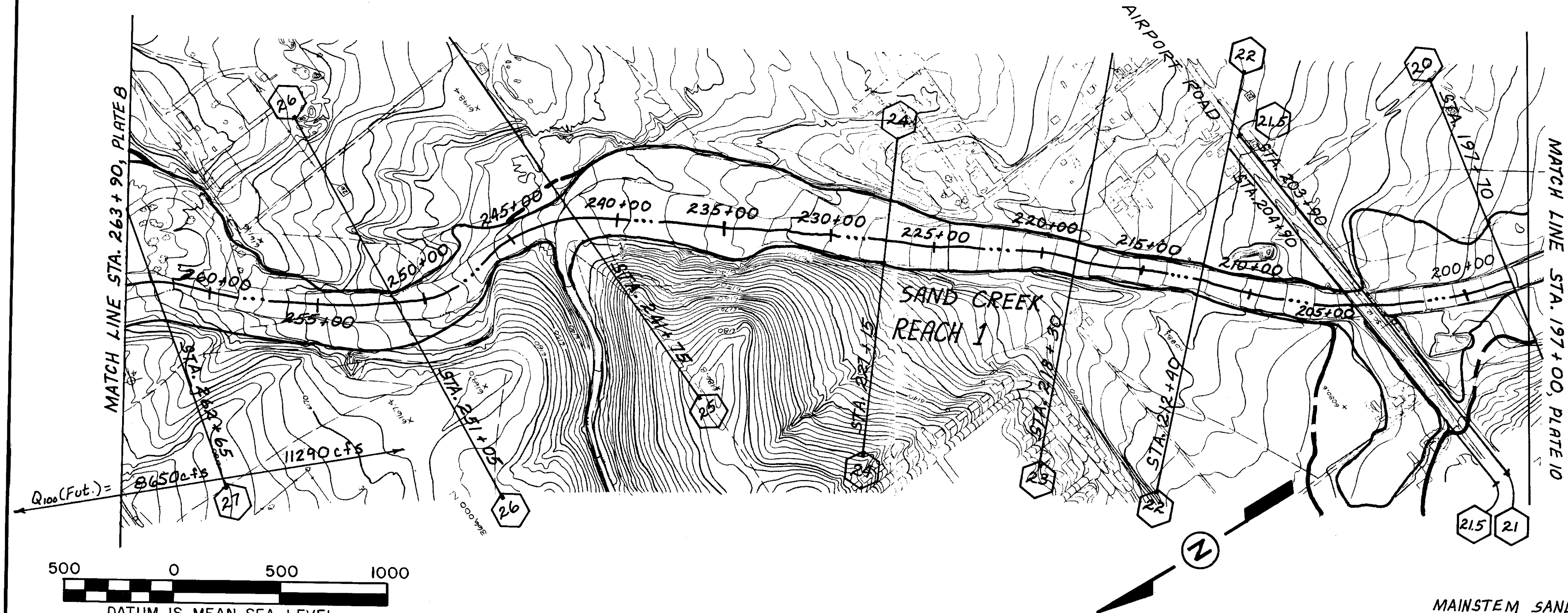
FLOOD HAZARD AREAS

Designed by:	B.M.	Scale:	1" = 500'
Drawn by:	L.E. GOOD	Date:	9-18-84
Checked by:	R.N.W.	Project No.:	CO-FA-01

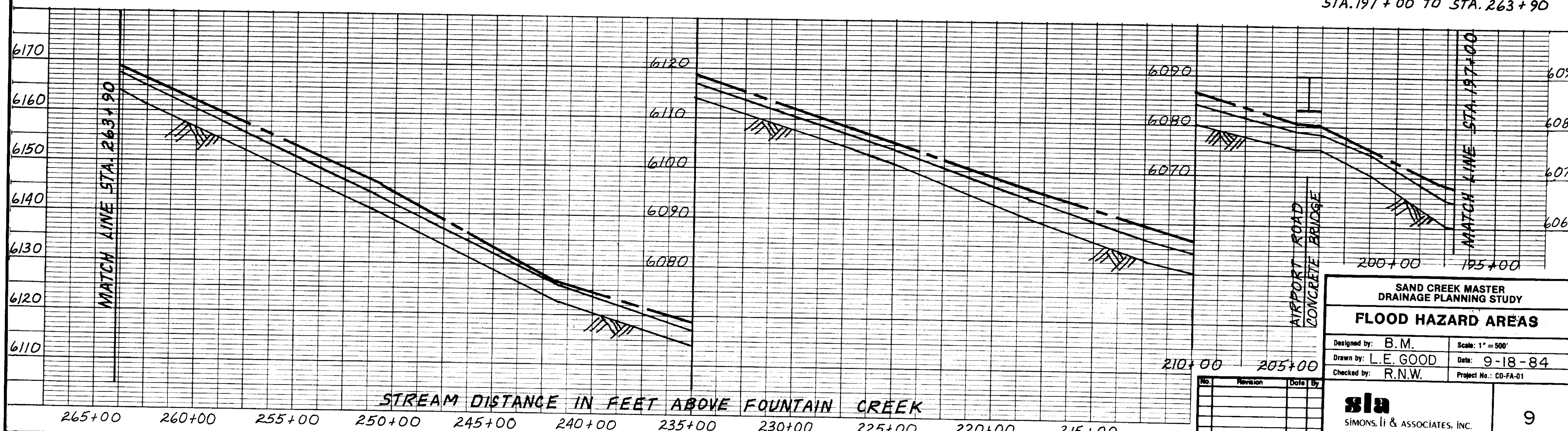
No.	Revision	Date	By

sla SIMONS, LI & ASSOCIATES, INC.

8



MAINSTEM SAND CREEK
STA. 197 + 00 TO STA. 263 + 90



No.	Revision	Date	By

SAND CREEK MASTER DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by: B.M.	Scale: 1" = 500'
Drawn by: L.E. GOOD	Date: 9-18-84
Checked by: R.N.W.	Project No.: CO-FA-01

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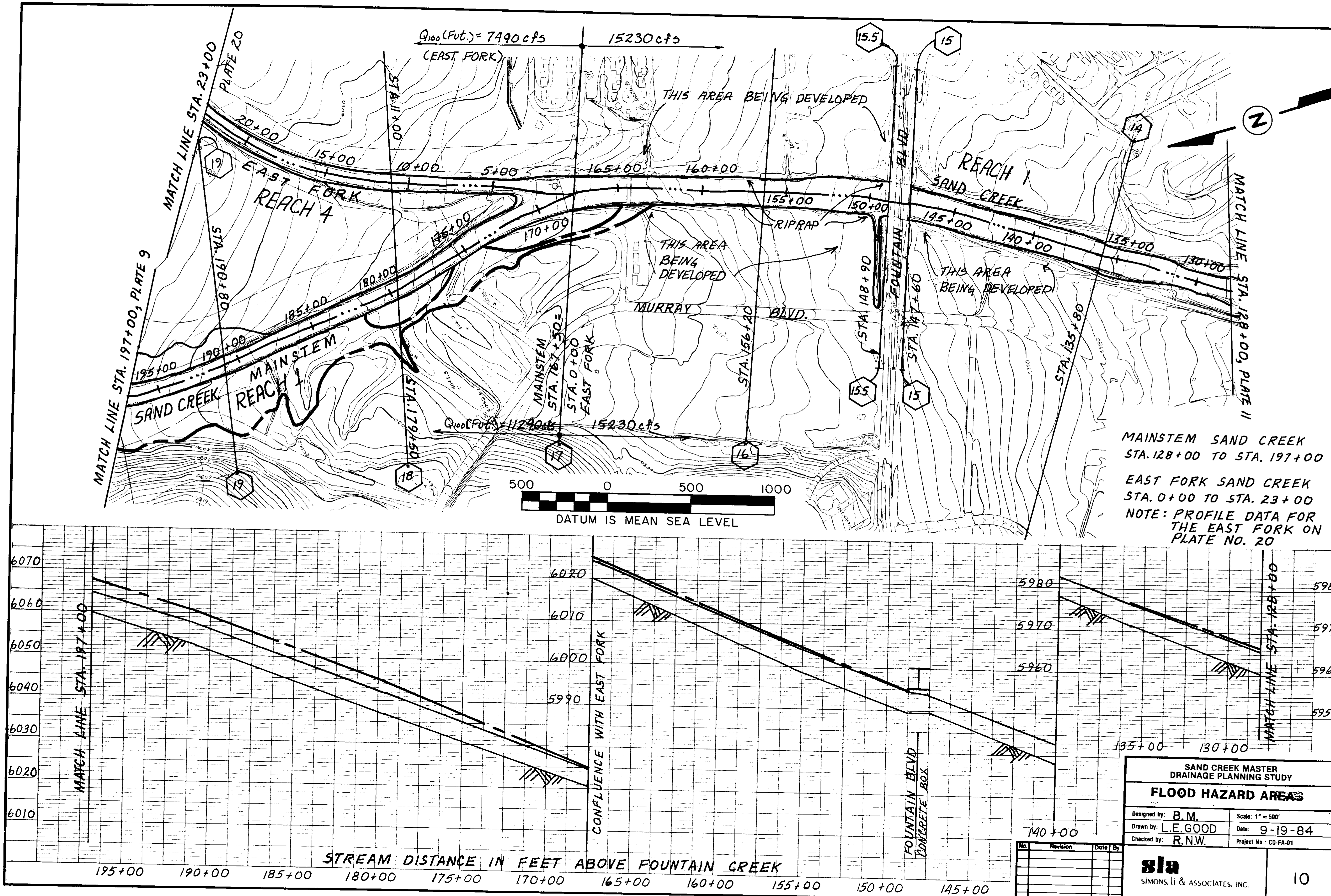

SAND CREEK MASTER DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by: B.M.	Scale: 1" = 500'
Drawn by: L.E.GOOD	Date: 9-19-84
Checked by: R.N.W.	Project No.: CO-FA-01

No.	Revision	Date	By

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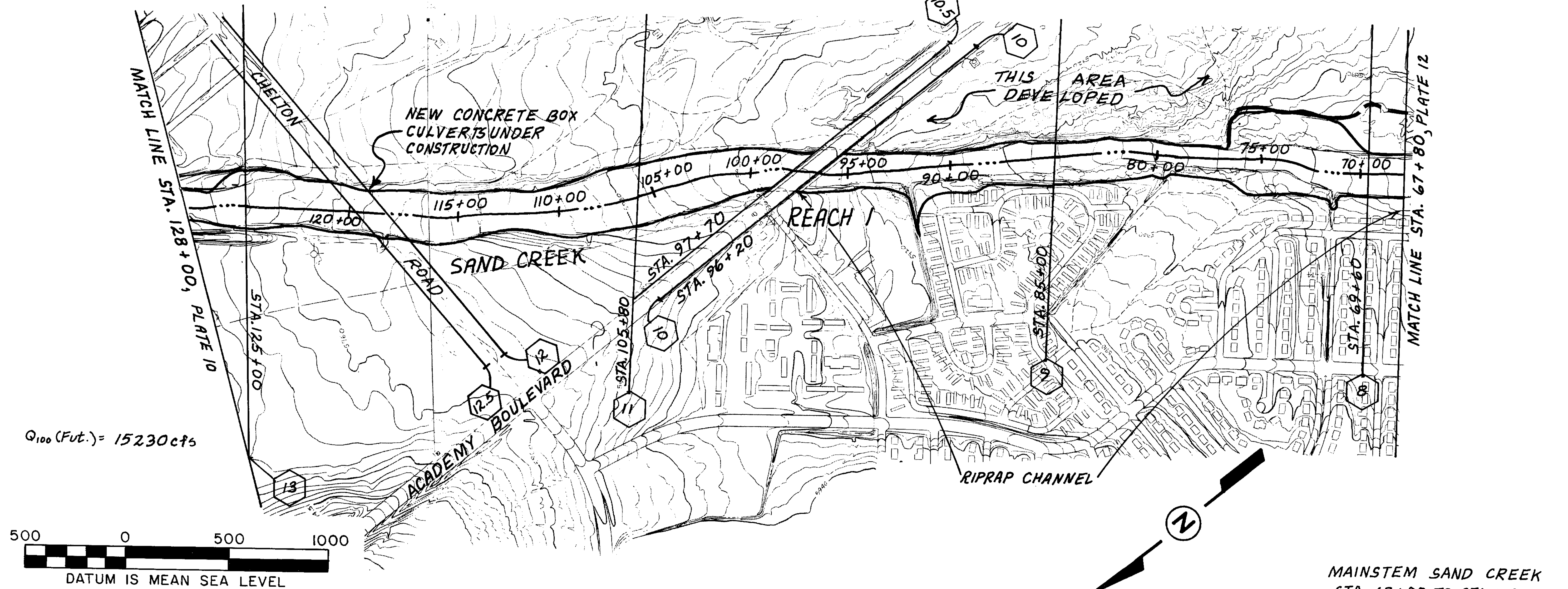
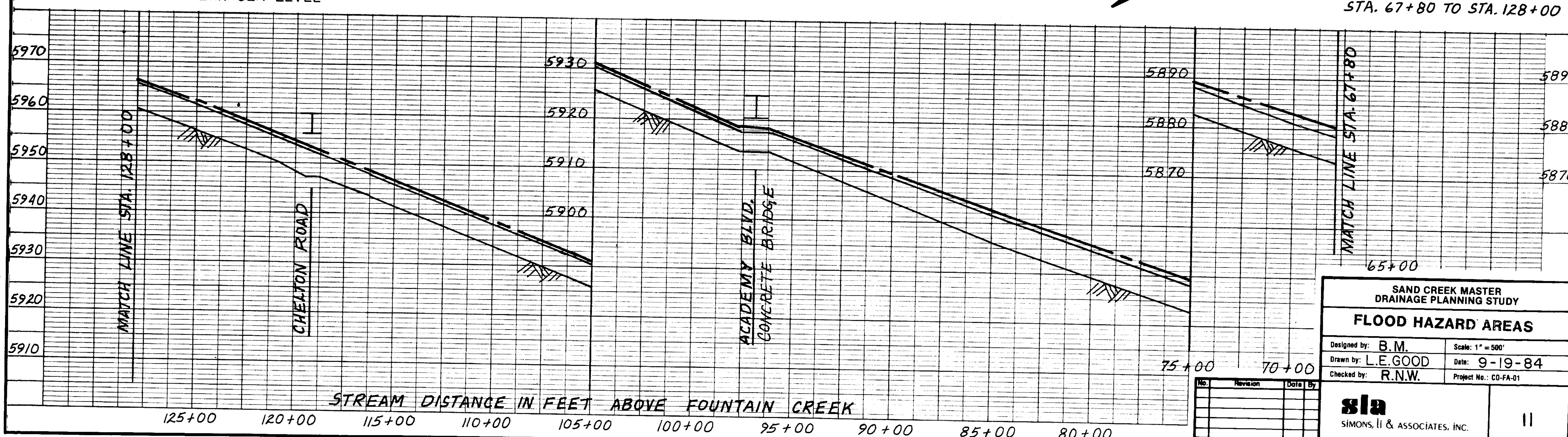
10



MAINSTEM SAND CREEK
STA. 67+80 TO STA. 128+00



SAND CREEK MASTER DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by:	B.M.	Scale:	1" = 500'
Drawn by:	L.E.GOOD	Date:	9-19-84
Checked by:	R.N.W.	Project No.:	CO-FA-01

No.	Revision	Date	By

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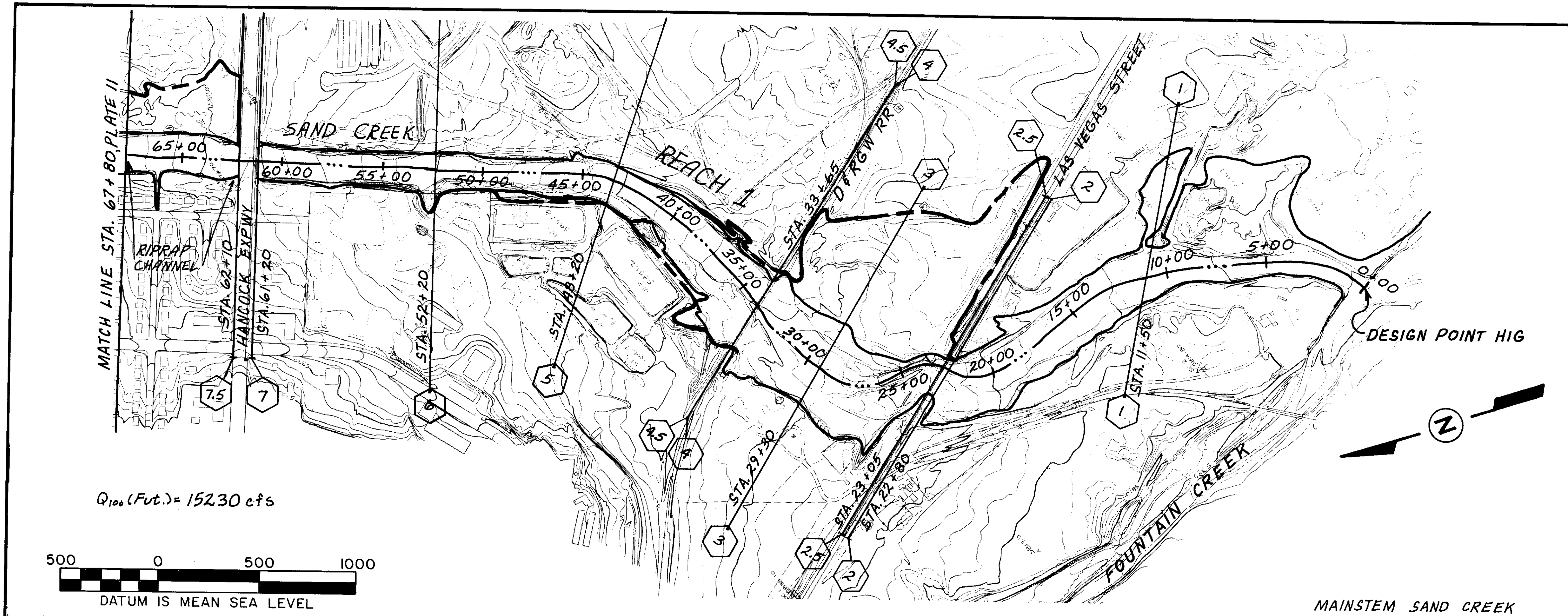
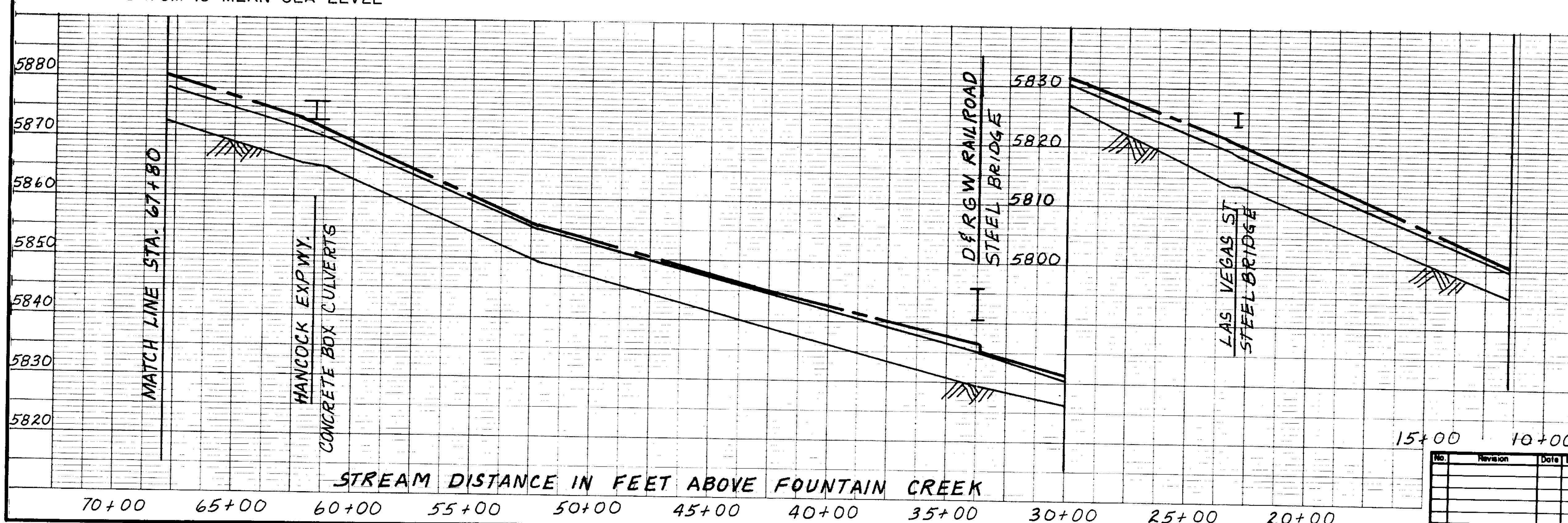
11





SAND CREEK MASTER
DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by: B.M.	Scale: 1" = 500'
Drawn by: L.E. GOOD	Date: 9-20-84
Checked by: R.N.W.	Project No.: CO-FA-01

No.	Revision	Date	By

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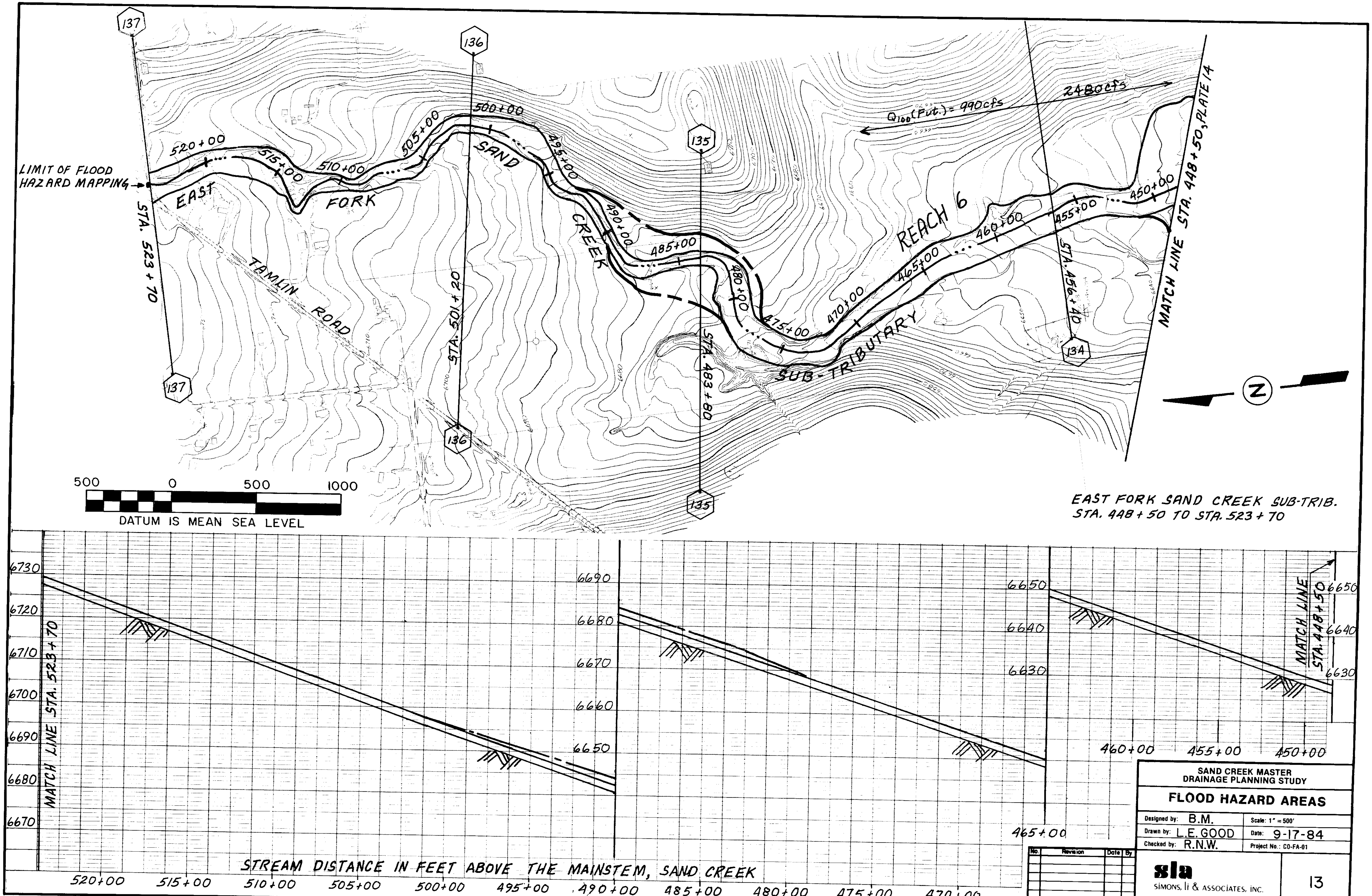
12



SAND CREEK MASTER DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by:	B.M.	Scale:	1" = 500'
Drawn by:	L.E. GOOD	Date:	9-17-84
Checked by:	R.N.W.	Project No.:	CO-FA-01

No.	Revision	Date	By

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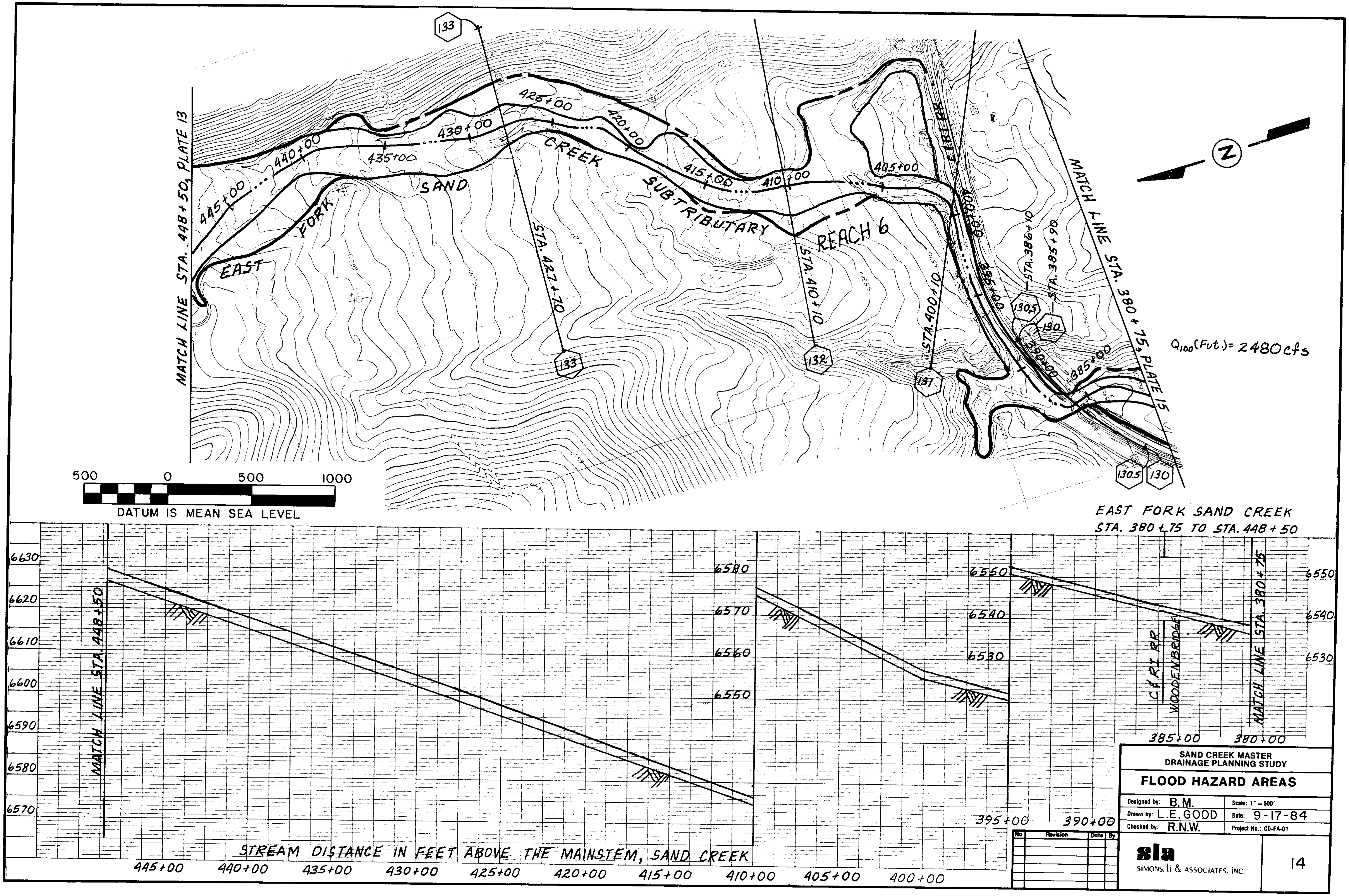
SIMONS, LI & ASSOCIATES, INC.



SAND CREEK MASTER DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by: B.M.	Scale: 1" = 500'
Drawn by: L.E. GOOD	Date: 9-17-84
Checked by: R.N.W.	Project No.: CO-FA-01

sla SIMONS, LI & ASSOCIATES, INC.

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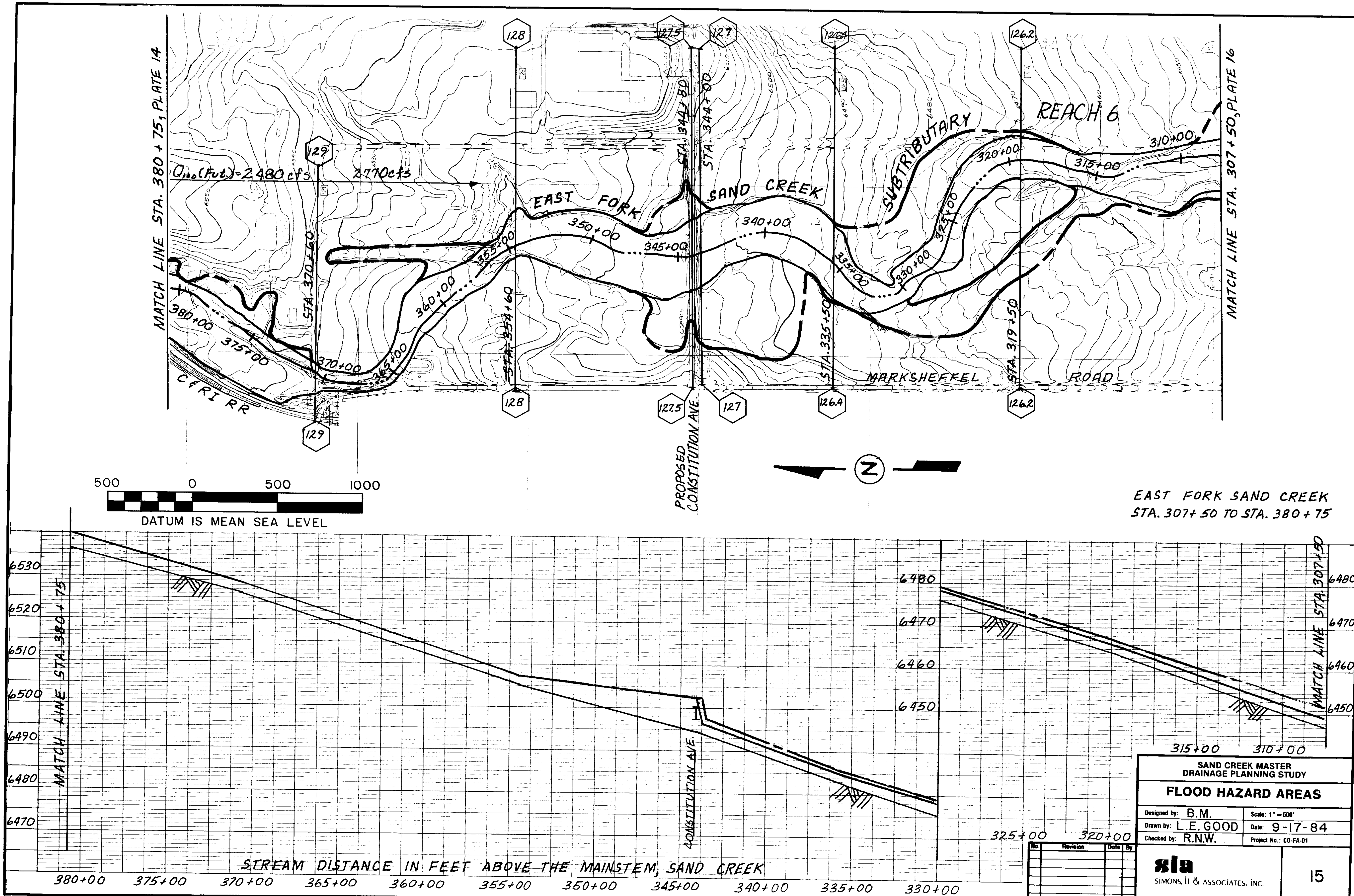


SAND CREEK MASTER DRAINAGE PLANNING STUDY

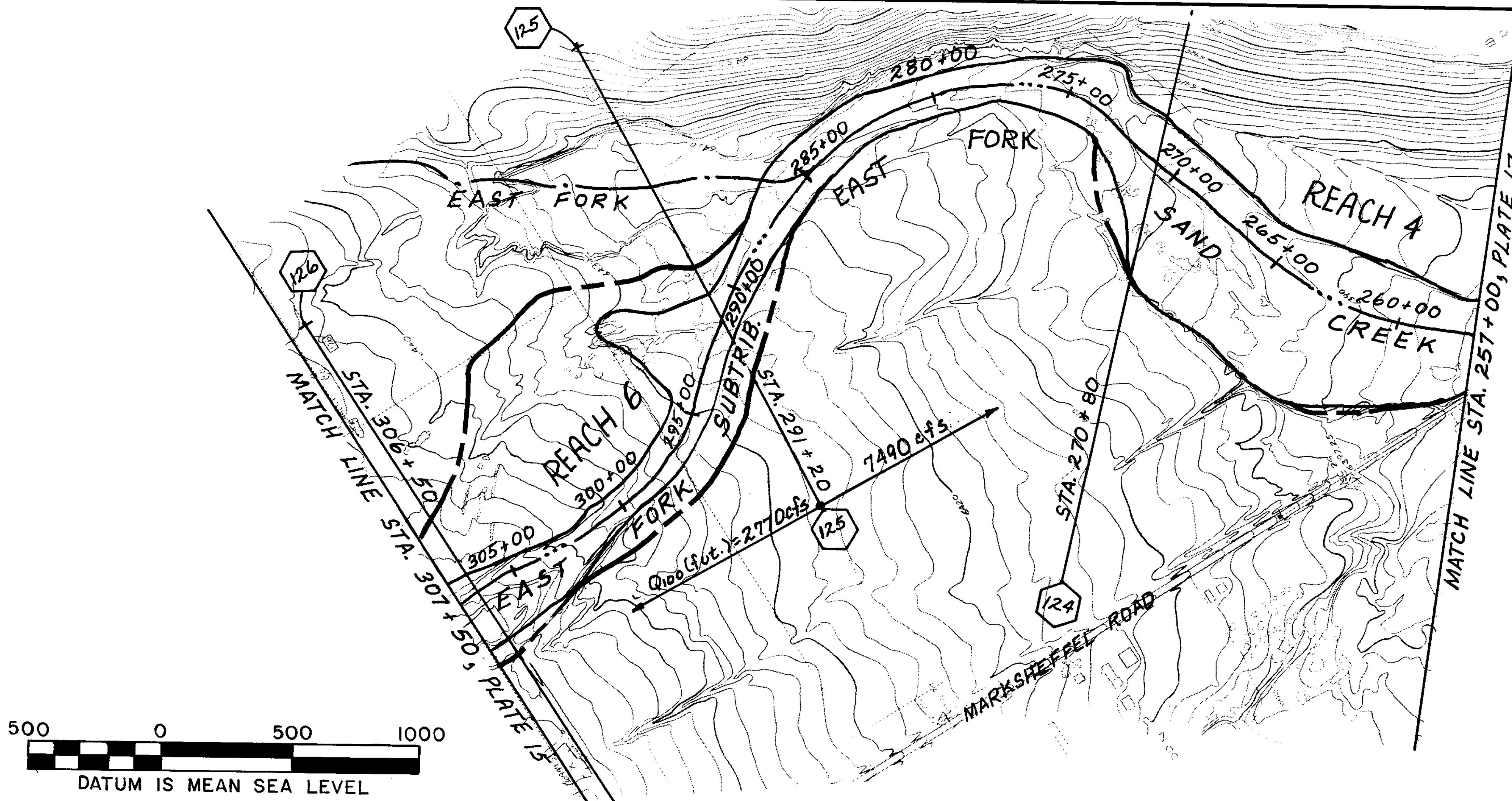
FLOOD HAZARD AREAS

Designed by: B.M.	Scale: 1" = 500'
Drawn by: L.E. GOOD	Date: 9-17-84
Checked by: R.N.W.	Project No.: CO-FA-01

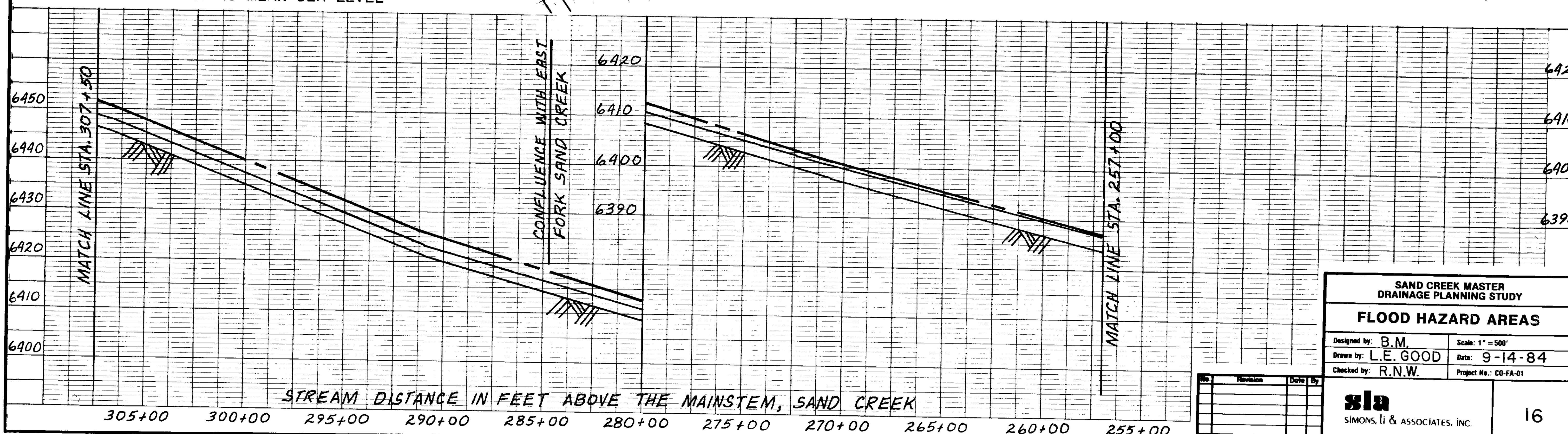
No.	Revision	Date	By

sla SIMONS, LI & ASSOCIATES, INC.

15



EAST FORK SAND CREEK
STA. 257+00 TO STA. 307+50



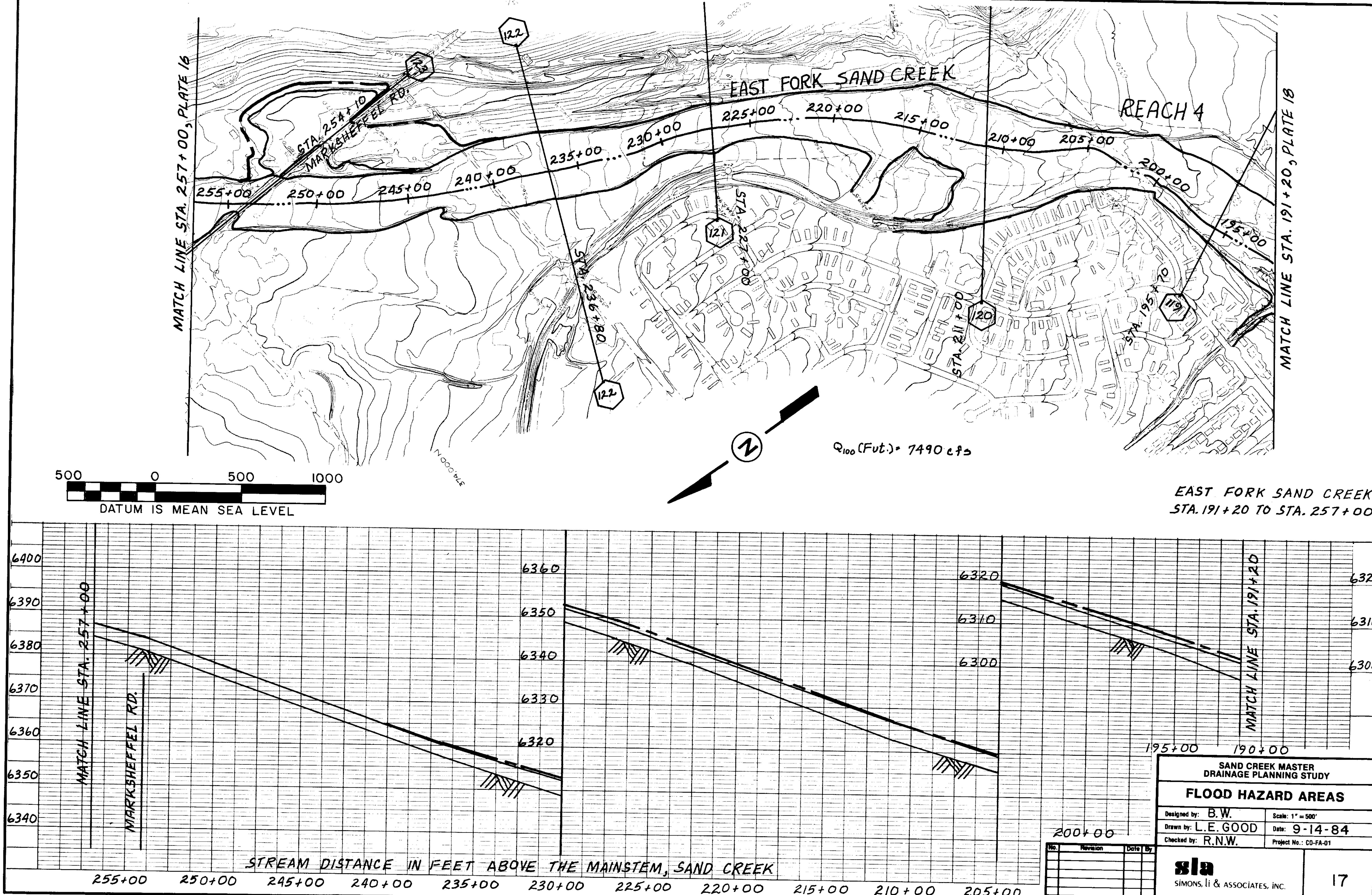
No.	Revision	Date	By

SAND CREEK MASTER DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by: B.M.	Scale: 1" = 500'
Drawn by: L.E. GOOD	Date: 9-14-84
Checked by: R.N.W.	Project No.: CO-FA-01

sla SIMONS, LI & ASSOCIATES, INC.



No.	Revision	Date	By

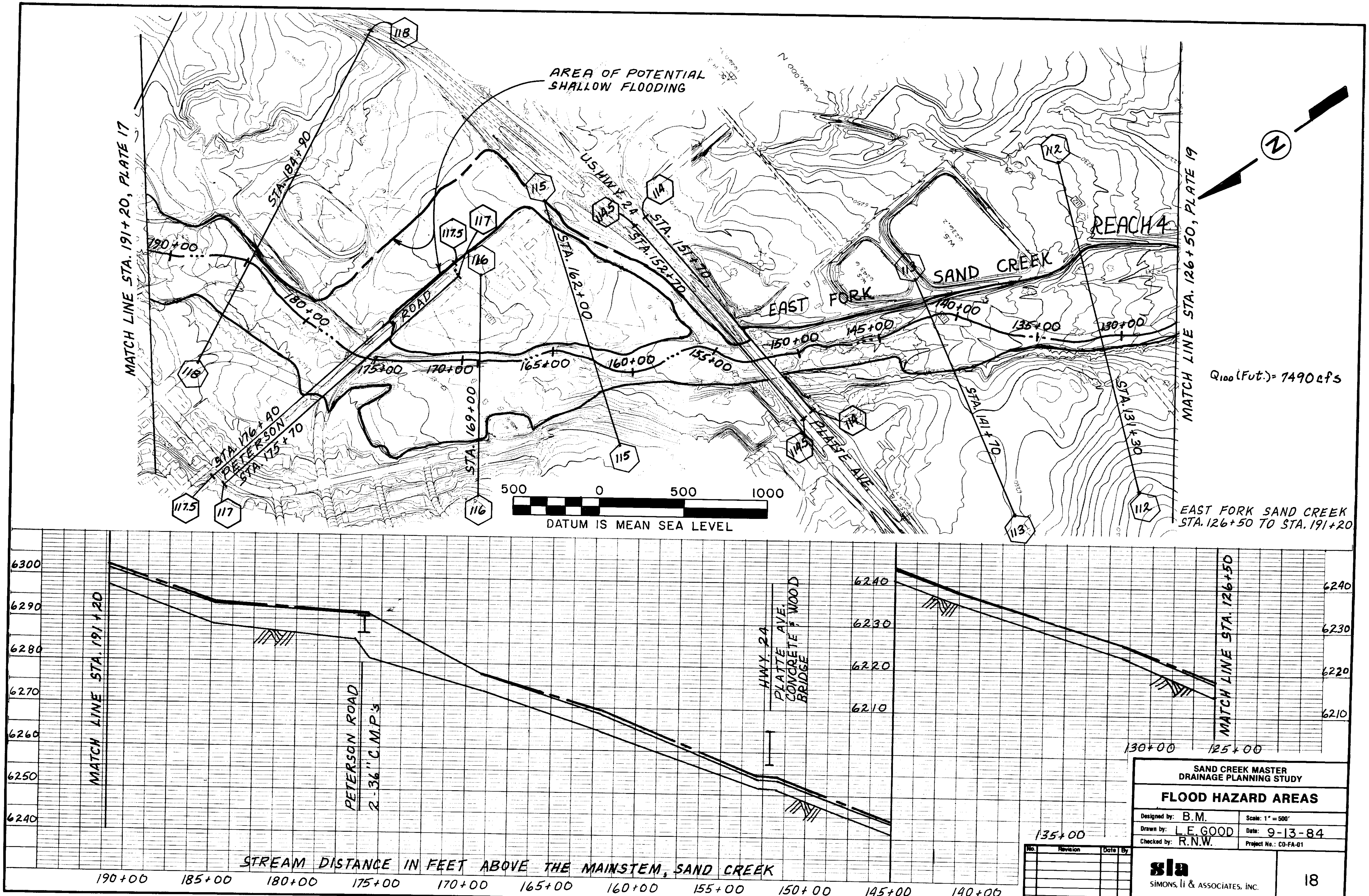
SAND CREEK MASTER
DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by: B.W.
Scale: 1" = 500'
Drawn by: L.E. GOOD
Date: 9-14-84
Checked by: R.N.W.
Project No.: CO-FA-01

sla
SIMONS, LI & ASSOCIATES, INC.

17



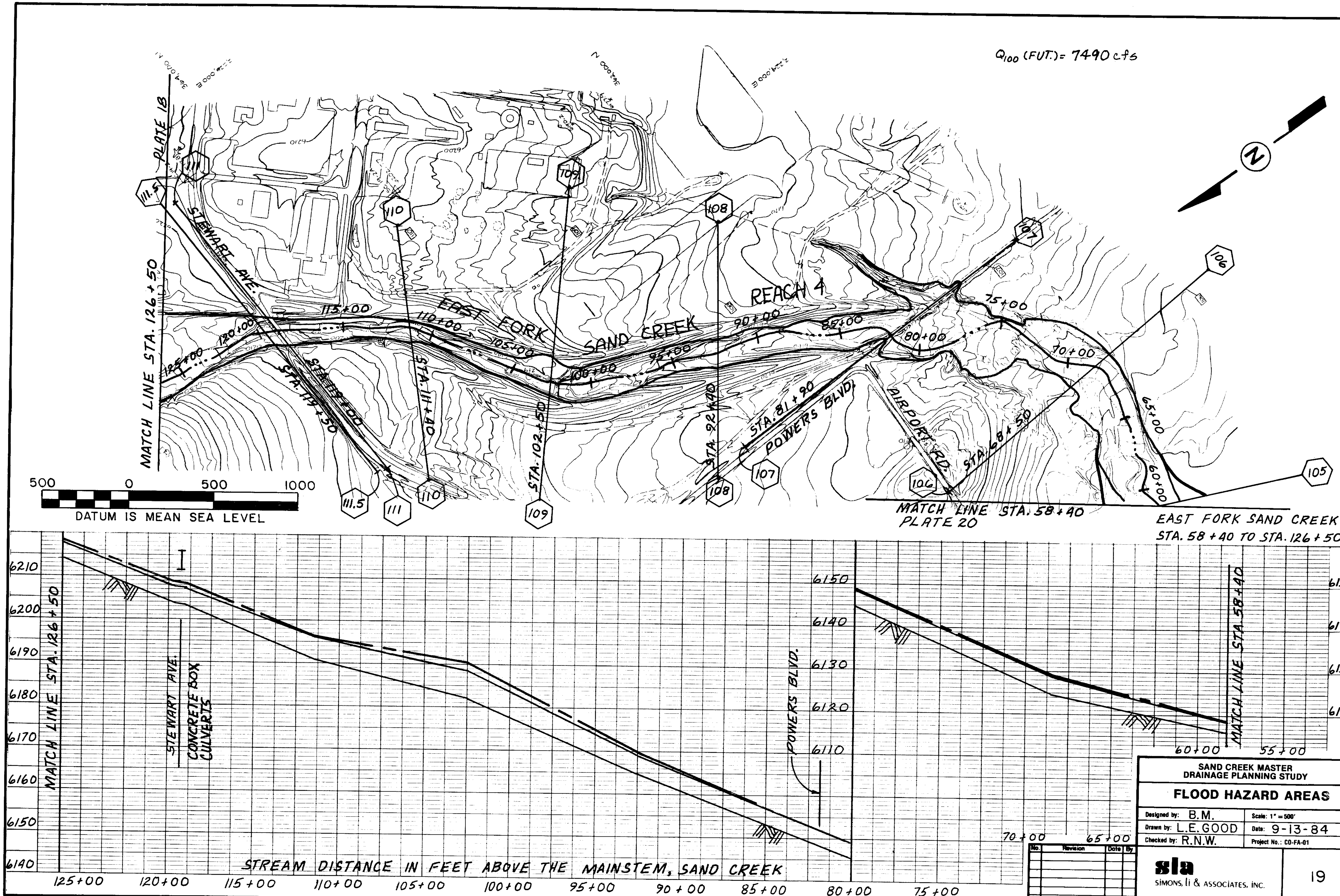
SAND CREEK MASTER DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by: B.M.	Scale: 1" = 500'		
Drawn by: L.E. GOOD	Date: 9-13-84		
Checked by: R.N.W.	Project No.: CO-FA-01		

No.	Revision	Date	By

sla SIMONS, LI & ASSOCIATES, INC.



SAND CREEK MASTER DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by: B.M.	Scale: 1" = 500'
Drawn by: L.E. GOOD	Date: 9-13-84
Checked by: R.N.W.	Project No.: CO-FA-01

No.	Revision	Date	By

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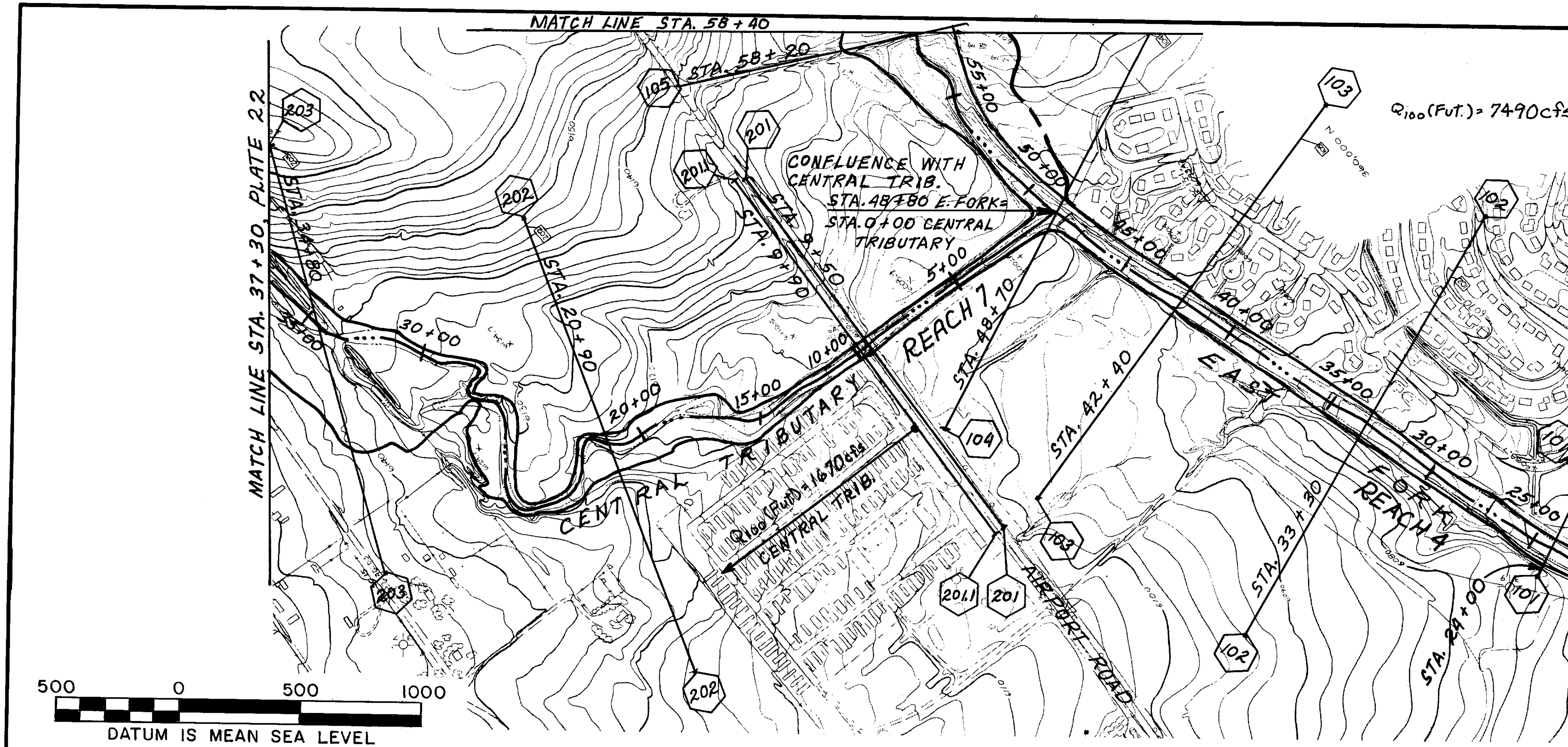
19

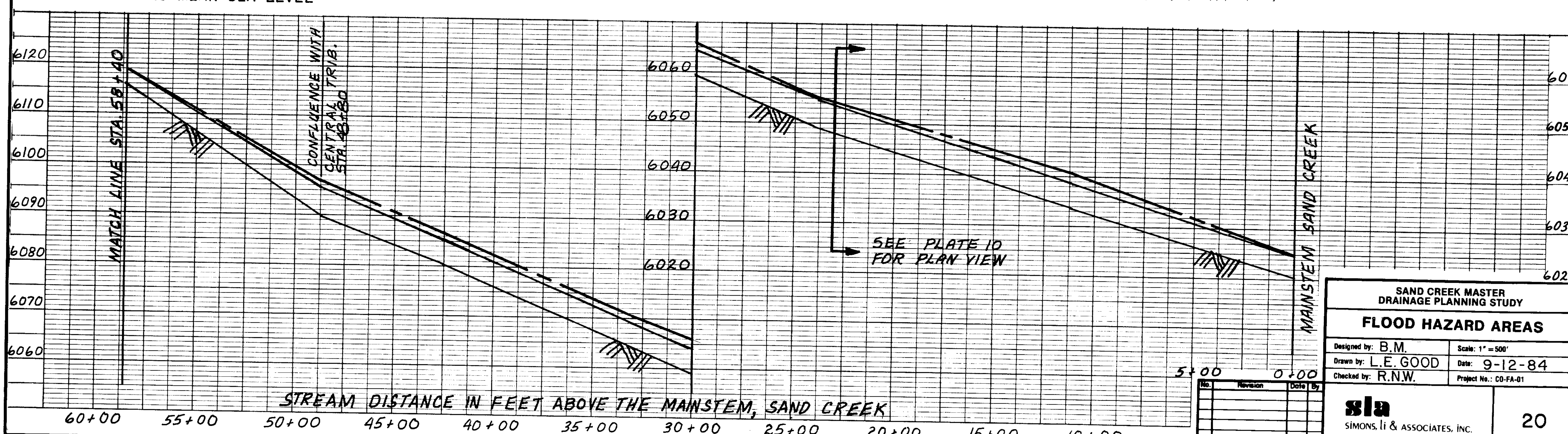


NOTE:

1. PROFILE DATA FOR THE CENTRAL TRIBUTARY ON PLATE NO. 22
2. FLOOD HAZARD AREAS FOR THE EAST FORK SAND CREEK, STA. 0+00 TO STA. 23+00 SHOWN ON PLATE 10

EAST FORK SAND CREEK
STA. 23+00 TO STA. 58+40

CENTRAL TRIB. SAND CREEK
STA. 0+00 TO STA. 37+30



No.	Revision	Date	By

SAND CREEK MASTER DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by: B.M.	Scale: 1" = 500'
Drawn by: L.E. GOOD	Date: 9-12-84
Checked by: R.N.W.	Project No.: CO-FA-01

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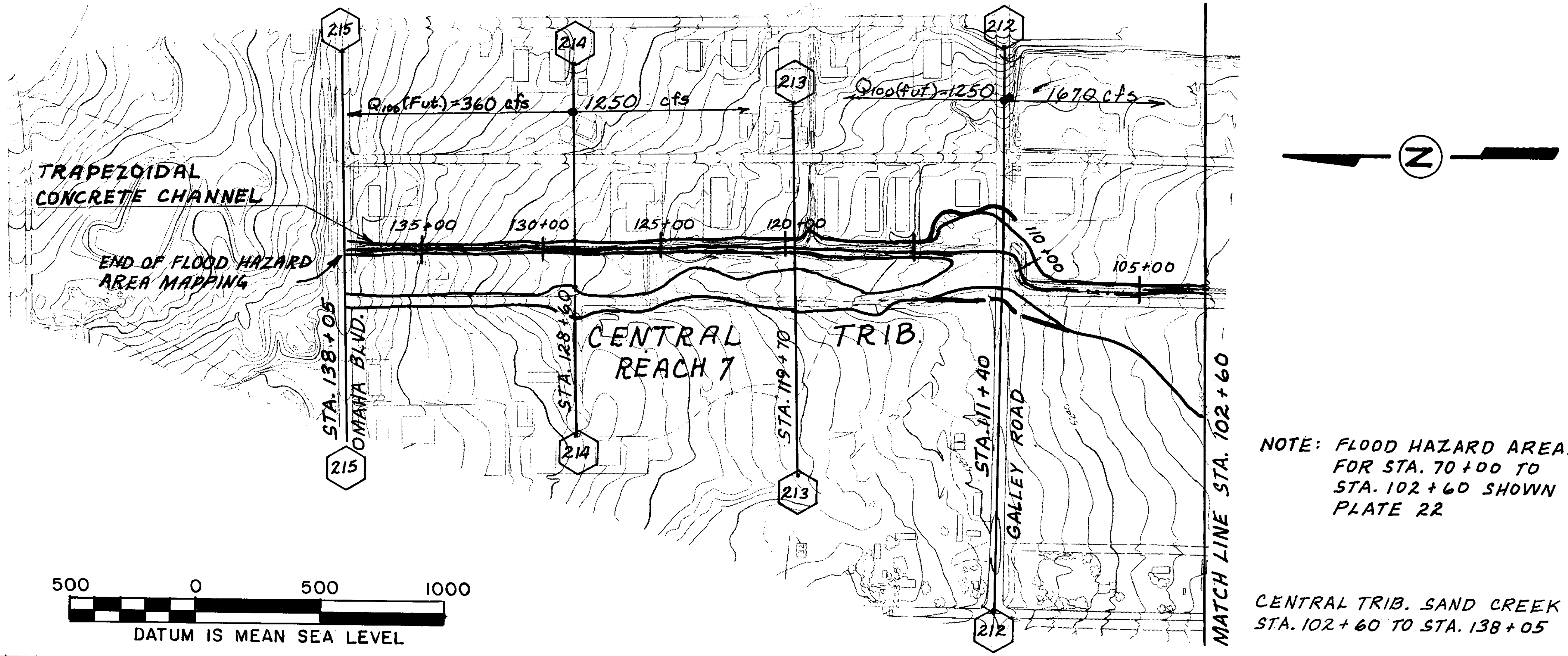
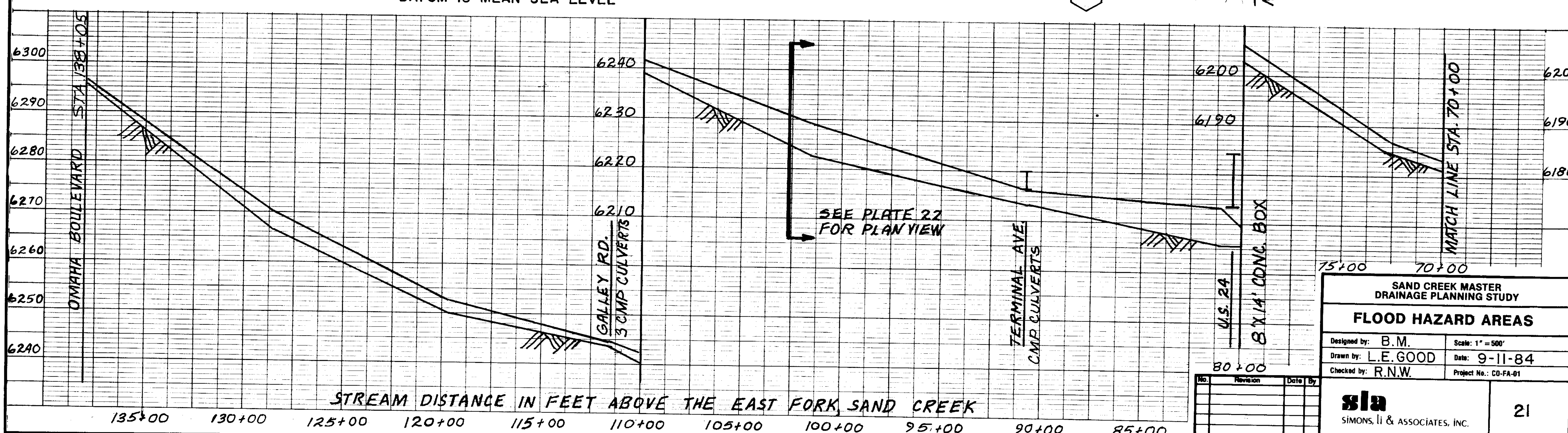


NOTE: FLOOD HAZARD AREAS FOR STA. 70+00 TO STA. 102+60 SHOWN ON PLATE 22

CENTRAL TRIB. SAND CREEK STA. 102+60 TO STA. 138+05



SAND CREEK MASTER DRAINAGE PLANNING STUDY

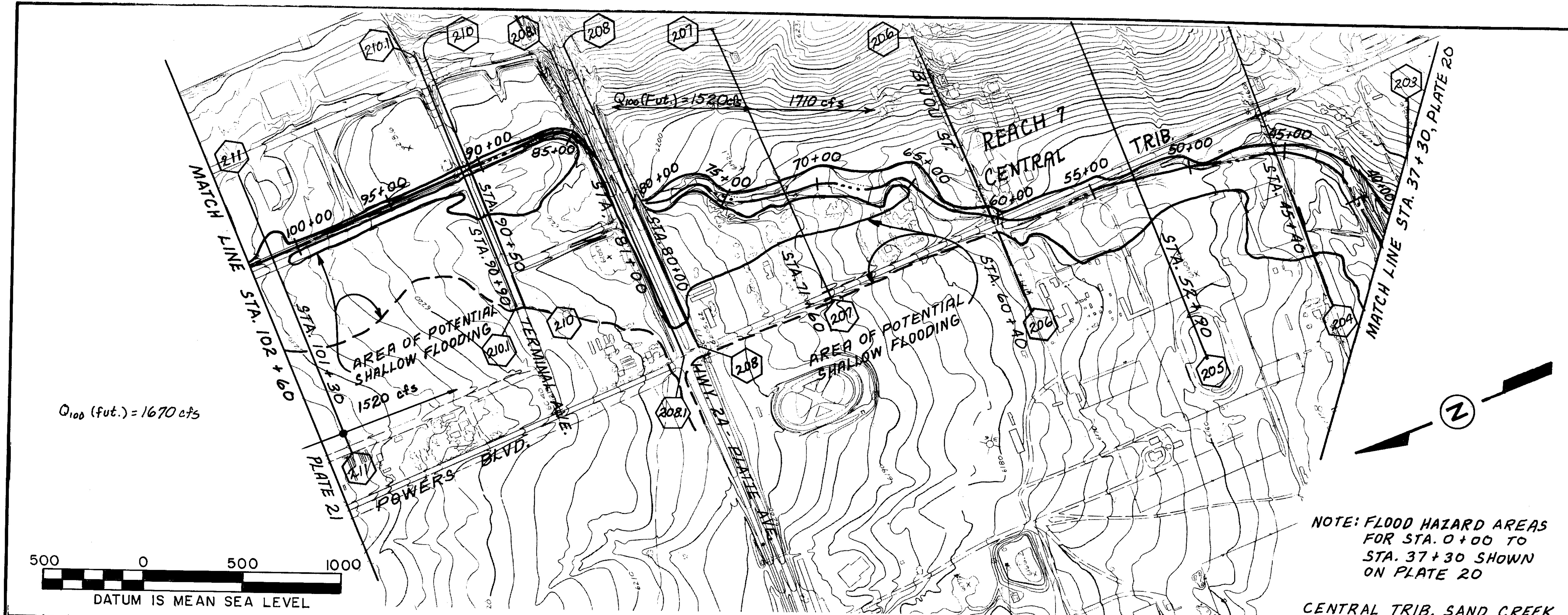
FLOOD HAZARD AREAS

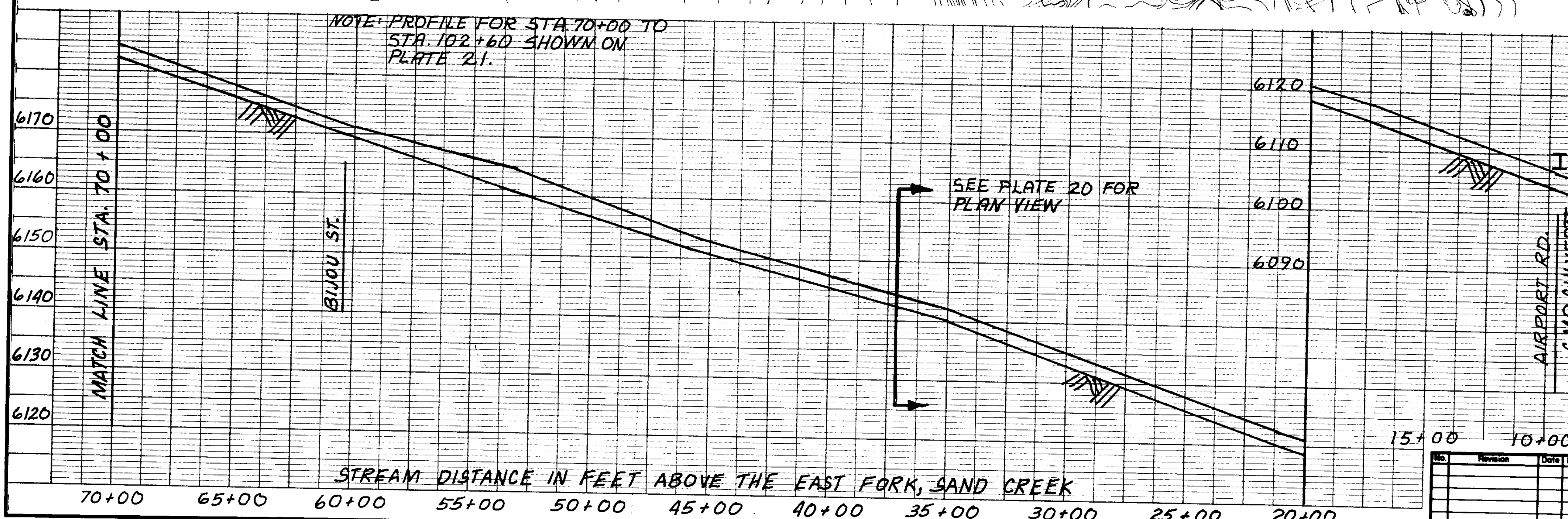
Designed by: B.M.	Scale: 1" = 500'
Drawn by: L.E.GOOD	Date: 9-11-84
Checked by: R.N.W.	Project No.: CO-FA-01

No.	Revision	Date	By

sla SIMONS, LI & ASSOCIATES, INC.

21





No.	Revision	Date	By

SAND CREEK MASTER DRAINAGE PLANNING STUDY

FLOOD HAZARD AREAS

Designed by: B.M.	Scale: 1" = 500'
Drawn by: L.E.GOOD	Date: 9-12-84
Checked by: R.N.W.	Project No.: CO-FA-01

sla SIMONS, LI & ASSOCIATES, INC.

22