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Engineering Evaluation of teh 6/3/89 Flood in
4954
OSMP Studies
STUDY
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ENGINEERING EVALUATION OF THE JUNE 3, 1989 FLOOD IN GUNBARREL/HEATHERWOOD

Prepared for:
OFFICE OF THE CITY ATTORNEY
BOULDER, COLORADO

Prepared by:
WRIGHT WATER ENGINEERS, INC.
ENGINEERING CONSULTANTS
DENVER, COLORADO

JUNE 1990

Wright Water Engineers, Inc.

DENVER OFFICE
2490 West 26th Ave., Suite 100 A
Denver, Colorado 80211
(303) 480-1700

GLENWOOD SPRINGS OFFICE
818 Colorado Avenue
P. O. Box 219
Glenwood Springs, Colorado 81602
(303) 945-7755
Denver Direct Line: 893-1608

June 8, 1990

Walter Fricke, Esq.
Office of the City Attorney
Municipal Building
Post Office Box 791
Boulder, Colorado 80306

Re: Engineering Evaluation of the June 3, 1989 Flood in Gunbarrel/Heatherwood

Dear Mr. Fricke:

Attached is an engineering evaluation of the June 3, 1989 flood in the Gunbarrel/Heatherwood area prepared by Wright Water Engineers, Inc. Our findings are presented in the beginning of the report and are documented in subsequent sections.

We have appreciated the opportunity to be of service and are prepared to answer questions concerning our findings.

Very truly yours,

WRIGHT WATER ENGINEERS, INC.

COLORADO REGISTERED JONATHAN E. JONES 27802 PROFESSIONAL ENGINEER

By _____
Jonathan E. Jones, P.E.
Vice President

By _____
Dwight W. Kimsey
Senior Scientist

By _____
David B. Mehan
Project Manager

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891-072.020
Encls.
(BOS:18)

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PURPOSE OF ENGINEERING EVALUATION

Wright Water Engineers was retained by the Boulder City Attorney to conduct an engineering evaluation of the characteristics of the flood event which occurred in the Gunbarrel/Heatherwood area northeast of the City of Boulder on June 3, 1989 as these characteristics relate to nine damage claims. Figure 1 is a vicinity map and Figure 2 depicts the three specific drainage basins (labeled Basins A, B and C) on which our study is focused.

The City of Boulder owns land in Basins A, B, and C. Owners of properties in these basins allege that activities of the City's Open Space Department on City lands resulted in damage to their properties during the June 3 flood.

FINDINGS

A. Findings which relate to claims in all three studied basins are as follows:

1. Through hydrologic studies, we have quantified the peak flood flows that actually occurred on June 3, 1989 and have contrasted these peak flows with those that would have occurred on June 3 under the "historic" condition (for the purpose of this report, the "historic" condition consists of north-south strip-cropping). It is our opinion that no significant increase in peak discharge resulted from activities of the City. Furthermore, those who have filed complaints against the City of Boulder would have sustained comparable property damage from the flood under "historic" conditions.

2. The probability of occurrence of the hydrologic conditions that existed on June 3, 1989 is less than 1 in 100. Based on actual measurements in the Gunbarrel/Heatherwood area and on Urban Drainage & Flood Control District's frequency data for Zone 1 of the "Boulder County Storm Drainage Criteria Manual," the rainfall from the June storm exceeded that of the 100-year event.

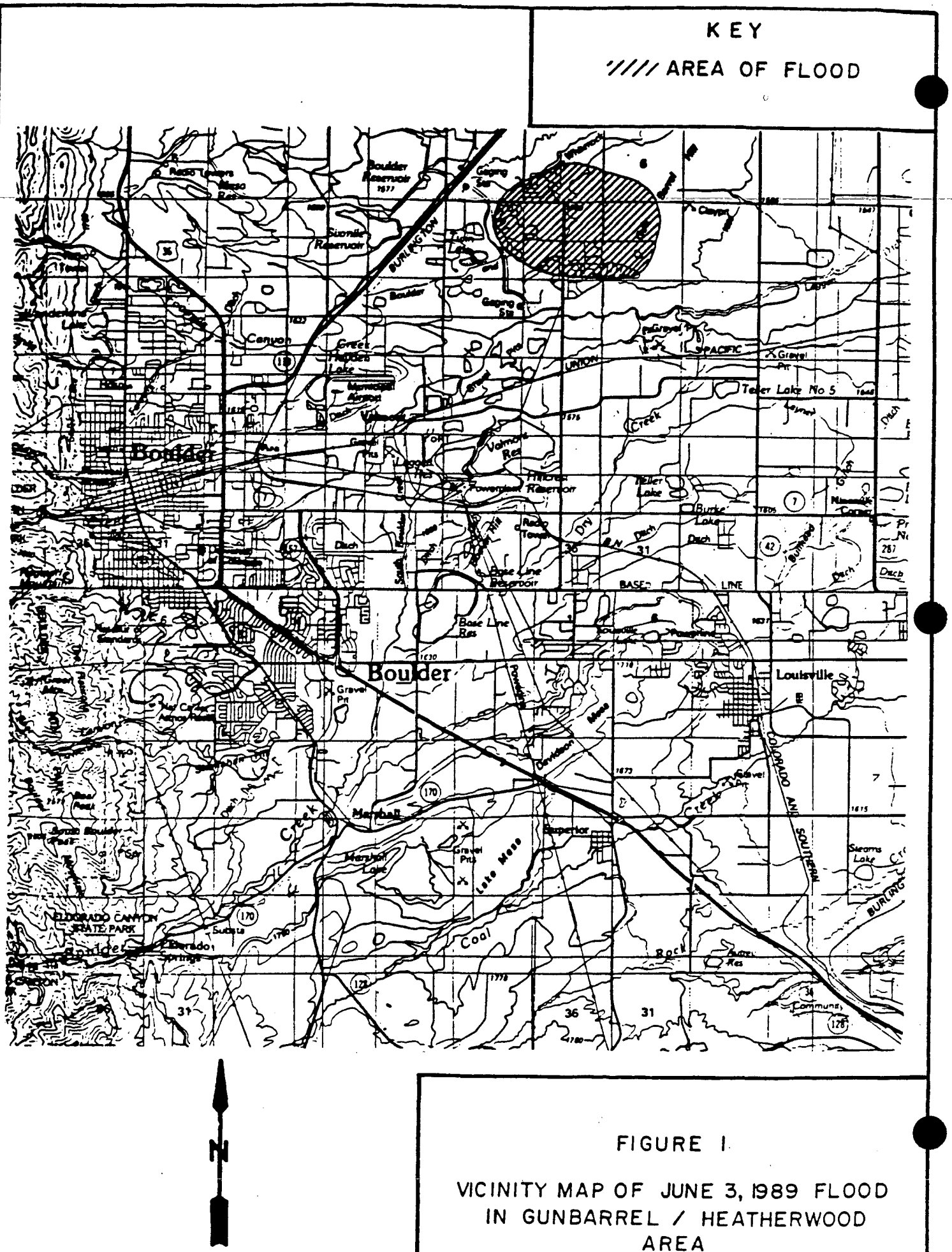


FIGURE 1

VICINITY MAP OF JUNE 3, 1989 FLOOD IN GUNBARREL / HEATHERWOOD AREA

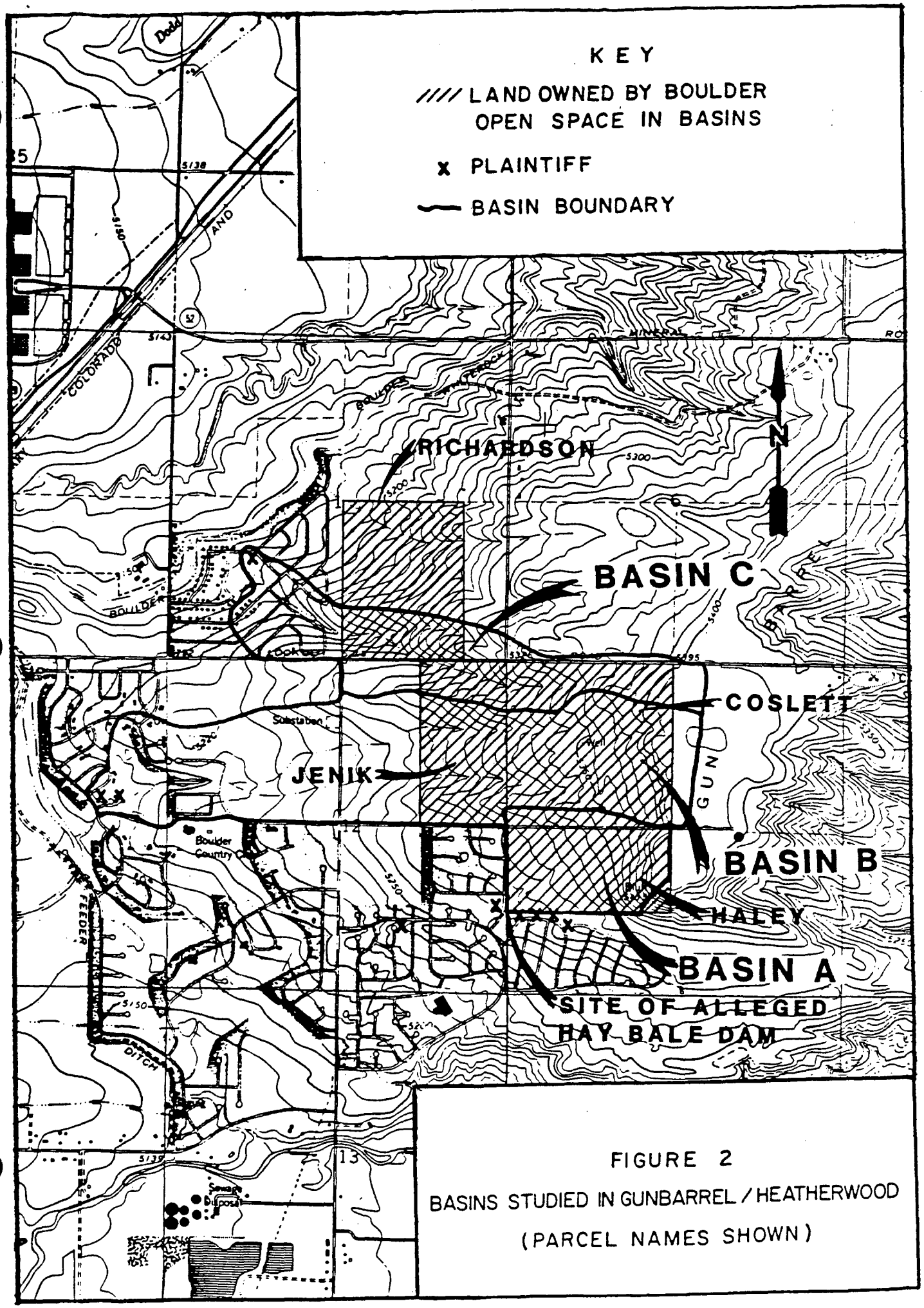


FIGURE 2

BASINS STUDIED IN GUNBARREL / HEATHERWOOD

(PARCEL NAMES SHOWN)

Furthermore, due to unusually wet conditions in the five days prior to the June 3 storm, moisture conditions were higher than normal.

3. The historic land use of City Open Space lands in Basins A, B, and C was agricultural. Seasonal tilling of the ground surface and resulting increase in erosion and runoff potential were historic occurrences that could reasonably have been anticipated by downstream property owners.

4. At the time of the June 3 flood, City staff members were in the process of transforming land used historically for strip-cropping to native rangeland. This restoration process was being conducted under the auspices of the U.S. Soil Conservation Service (SCS)-"Conservation Reserve Program" (CRP). The CRP reimburses agricultural landowners for converting their wheat fields to rangeland, provided that program criteria are followed and that the conversion takes place within 10 years. The CRP contract between the City and the SCS contains specific requirements that must be followed relative to converting agricultural land to native rangeland. Boulder staff strictly followed SCS requirements in conversion efforts in Basins A, B, and C.

5. One of the requirements of the SCS-CRP program involves implementation of erosion control measures. Boulder staff had actually implemented a number of erosion control measures including: construction of water bars, cultivating on the contour, removing debris from the ditch on the south side of Basin A, selective hay bale placement for intercepting sediment, and other measures. According to national erosion control literature and in conjunction with review of erosion control guidelines common to the Denver metropolitan area, designs for erosion control measures are commonly based on a

2-year storm and a conservative design is based on a 5-year storm. Consequently, the June 3, 1989 rainfall (which exceeded a 100-year return frequency) would have overwhelmed even a state-of-the-art erosion control program such as the one in Basins A, B, and C. It is also important to note that the Boulder County Drainage Criteria Manual[1] specifically states that agricultural lands are exempt from erosion control requirements. We consider the City lands in Basins A, B, and C to be agricultural lands.

6. Our research regarding flood history in the Gunbarrel/ Heatherwood area indicates that damage-producing floods are relatively common in the area. Specifically:

   - Reported flood events have occurred in the area on a number of occasions over the past twenty years. A major factor in the floods has been runoff from agricultural lands east of the development from Gunbarrel Hill.

   - Subdivision flooding has occurred prior to the acquisition of lands in the Gunbarrel Hill area by the City of Boulder department.

   - There has been acknowledgment of historic flooding in the Gunbarrel area by the Boulder County and local residents. The document, Outfall System Planning - Boulder Gunbarrel Area[2], includes a study of historic flooding problems in the Gunbarrel area. In the study, floods are attributed to "piecemeal development and the lack of comprehensive master drainage planning in the area" and, "inadequately sized culverts, storm sewers and channels." Also stressed in the document is the fact that future development is likely to aggravate existing problems and create additional problems.

7. Drainage systems in the relevant subdivisions are inadequate in many respects. For example:

   - o Major drainageways have been obliterated for the sake of development.
   - o Buildings have been placed in historic drainages.
   - o The Gunbarrel/Heatherwood area is replete with violations of adopted Boulder County stormwater management criteria.
   - o A 100-year floodplain map, if prepared, would indicate that many homes lie within the 100-year floodplain.

   If the affected subdivisions had properly conceived, designed and constructed major drainage systems and maintained those systems already in place, flood damages due to the June 3, 1989 storm would have been substantially smaller.

8. Private developers are responsible for the proper design and construction of drainage systems. The drainage systems in question were approved by Boulder County staff; City of Boulder staff did not review and did not approve drainage plans for the area.

In summary, it is our opinion that City of Boulder staff acted reasonably with respect to their activities on City lands in Basins A, B, and C. The various activities of City staff were not responsible for the flood damages incurred by those parties who have filed complaints against the City of Boulder. These parties would have sustained flood flow damages in the absence of any activities by the City staff.

B. The following summarizes our findings regarding the specific allegations of the claimants in Basin A.

1. It has been alleged in complaints to the City that City staff altered a ditch located along the southern boundary of Basin A (Figure 2) and that this alteration aggravated flooding and sediment damages to properties on Grasmere Drive and Cambridge Street. It is our opinion that there was no measurable increase in damages to the properties from the alleged activity. Furthermore, there are a number of issues with respect to this ditch, including:

   - The ditch is not officially recognized and sanctioned as a drainage facility.

   - At the time of construction of the ditch no approval from the required regulators was sought.

   - There is not a drainage easement associated with this ditch.

   - The ditch channels waters that historically flowed in a south-southwest direction (almost due west). This subjects properties downgradient from the ditch to increased flood hazards. For example, the ditch directs runoff to the St. Mary Magdalene Church on Cambridge Street.

   - The ditch has not been recognized in any master drainage plans of the area.

- o No one is responsible for ditch maintenance and assurance of proper ditch function.

2. It has been alleged that the activities of the City in Basin A increased sediment flow. It is our opinion that activities of City staff did not cause significant increases in sediment discharges, and, that under "historic" conditions, approximately the same volume of sediment would have been generated by the June 3 storm. Those who have filed complaints against the City of Boulder would have sustained comparable sediment-related damages under "historic" conditions.

3. It has been alleged that during the June 3 flood, straw bales floated against the corner of the fence at the southwest end of Basin A. The bales allegedly piled atop one another and created a dam that ultimately collapsed the fence unleashing a wave of water and sediment through the area. We have evaluated this scenario under "worst case" assumptions and have concluded that downgradient properties could not have been subjected to increased flood or sediment hazards due to dam failure. We have also evaluated such a dam's potential to flood properties along Grasmere Drive by backwater, and we have concluded that no damages could have occurred by water ponded behind the alleged dam.

4. It has also been alleged that . construction of facilities, properly termed "water bars" aggravated flooding damages to properties on Grasmere Drive. Construction of these water bars is an accepted and widely used erosion control practice and did not contribute to the claimant's damages.

BASIS OF OPINION

To arrive at the findings listed above, Wright Water Engineers has relied on the following interviews, documents, field investigations, computer models and engineering studies.

A. Documents

1. Outfall System Planning - Boulder Gunbarrel Area, Urban Drainage & Flood Control District, et al., December 1987.

2. Informal Report of the Evaluation of Alternatives for Outfall Systems Boulder Gunbarrel Area, Urban Drainage & Flood Control District, et al., February 1986.

3. Urban Storm Drainage Criteria Manual (Volumes 1 and 2), Denver Regional Council of Governments, March 1969 (as currently revised).

4. Soil Survey of Boulder County, Soil Conservation Service, U.S. Department of Agriculture, January 1975.

5. Erosion Handbook - Water and Wind, Soil Conservation Service, U.S. Department of Agriculture, June 1988.

6. Applied Hydrology and Sedimentology for Disturbed Lands, Barfield, B.J., et al., Oklahoma Technical Press, 1981.

7. National Engineering Handbook, Section 4 - Hydrology, Soil Conservation Service, U.S. Department of Agriculture, August 1972.

8. "HKA/UDFCD F2P2 Quantitative Precipitation Forecast - Date 06/03/89 (Kelly/11:30)," on file at office of Urban Drainage & Flood Control District.

9. "Henz Kelly and Associates/Internal Alert Status Report, dated June 3, 1989 ... 12:30 p.m." on file at office of Urban Drainage & Flood Control District.

10. Climatological Data - Colorado, June 1989, Volume 94, Number 6, and May 1989, Number 5, National Oceanic and Atmospheric Administration, Asheville, North Carolina.

11. Personal Record of Rainfall Measurement by Peter Stamus - May 1989, 7378 Glacier View Road, Longmont, Colorado.

12. Personal Record of Rainfall Measurement by Barrel Frost - May-June 1989, 559 Colt Drive.

13. Personal Record of Rainfall Measurement by Jack Banberg - May-June 1989, 5641 Gunbarrel Road.

14. Personal Record of Rainfall Measurement by Tim Switzer - May-June 1989, 7486 Park Lane Road.

15. Personal Record of Rainfall Measurement by Ed Szoke - May-June 1989, 7670 Berwick Court.

16. Design Criteria and Standards Specifications, City of Boulder Department of Public Works, adopted November 9, 1982 (most recent version).

17. Guidelines for Determining Flood Flow Frequency, United States Water Resources Council, Washington, D.C., June 1977.

18. Appendix to Form CRP-1 - Conservation Reserve Contract for City of Boulder, Form OMB No. 0560-0125, U.S. Department of Agriculture, 2/2/89.

19. Conservation Plan - Schedule of Operations for City of Boulder, Form OMB No. 0579-0013 for Gunbarrel Farm, SCS, U.S. Department of Agriculture.

20. Conservation Plan Map for City of Boulder, Form SCS-CONS-10, SCS, U.S. Department of Agriculture, October 1974.

B. Interviews

During the preparation of this report, the following people were interviewed about various aspects of the June 3, 1989 flood:

1. Peter Stamus, Gunbarrel resident, 7378 Glacier View Road.
2. Bonnell Frost, Gunbarrel resident, 559 Colt Drive.
3. Jack Banberg, Gunbarrel resident, 5641 Gunbarrel Road.
4. Tim Sweitzer, Gunbarrel resident, 7486 Pa( )ane Road.
5. Ed Szoke, Gunbarrel resident, 7670 Berwick Court.
6. John Henz, Henz Kelly Associates.
7. Tim Feehan, Boulder County Public Works Department.
8. Bruce Johnson, Boulder County Public Works Department.
9. Richard Antonio, City of Boulder Open Space Department.
10. Jim Crain, City of Boulder Open Space Department.
11. Debbie Kemmerer, Revegetation Consultant.
12. Don Woodward, U.S. Soil Conservation Service.
13. Delwin Andrews, Farm Operator.
14. Ben Urbonas, Urban Drainage & Flood Control District.
15. Alan Taylor, City of Boulder Public Works.

C. Field Evaluations and Surveying

Field evaluations related to the June 3, 1989 flood include surveying work conducted on the following dates:

1. September 9, 1989
2. September 20, 1989
3. March 21, 1990

D. Engineering Analyses

The conclusions of this report were derived based on the following methodology. Firstly, data and facts related to the flood event were obtained from City of Boulder Open Space Department staff, Boulder County, and other sources cited in this document. Field evaluations were conducted to verify facts and data and/or to collect additional data. These evaluations included surveying of selected areas.

Checks were then conducted to determine the reasonableness and accuracy of the facts and data collected. This was done to prevent subsequent analyses on erroneous data.

Alternative methods of analyses of matters at hand were then investigated. For example, various state-of-the-art methods to predict soil loss were investigated to determine which method was most applicable to the June 3, 1989 flood. Nationally recognized experts and documents were consulted in this effort.

Analyses were then conducted using selected procedures. To assure that the results were reasonable and within expected ranges, analysis results were checked using data available from other documents, cross checks with alternative procedures, available data from the flood event, and all other known available data.

The following models and methods were used to derive the findings of this report:

- Hydrologic Engineering Center Model I (HEC-1), U.S. Army Corps of Engineers.

- Modified Universal Soil Loss Equation, U.S. Soil Conservation Service, U.S. Department of Agriculture.

- Conventional hydraulic formulas (such as the *Manning formula*) and calculation techniques as presented in a standard hydraulics text.

- Methods for determination of the runoff curve number as described in "National Engineering Handbook, Section 4 - Hydrology," Soil Conservation Service, U.S. Department of Agriculture.

BACKGROUND

The remainder of this report describes the analyses conducted to arrive at the findings listed in the beginning of this report.

Study Area Description

The study area is located in Boulder County northeast of the Boulder City limits. Figure 1 is a vicinity map of the Gunbarrel/Heatherwood area.

Figure 2 shows the three drainage basins studied in this report (labeled Basins A, B, and C). Figure 2 also indicates the location of the nine parties (as of the date of preparation of this report) filing claims against the City of Boulder.

The general study area is bounded by Dry Creek No. 2 on the north, Boulder Creek on the south, the Boulder and Left Hand Ditch on the west, and Gunbarrel Hill on the east. Runoff generally flows to the south and west, unless intercepted by agricultural ditches in the area.

Land in the basins studied is both residential development land and private agricultural and agricultural (owned by the City of Boulder and managed by the City's Open Space Department) land. Residential development is concentrated at the western (lower) ends of the basins. Agricultural lands occupy the majority of the basins. Most of this land was used historically for strip cropping wheat and grains. Some was used for rangeland. These

uses have continued on lands purchased by the City. Land use and the City's native land conversion program are discussed in more detail in subsequent sections of this report.

National Flood Insurance Program (FIRM) mapping[3] exists for the area, but the mapping addresses only large drainages (e.g., Boulder Creek). The 100-year floodplain within the pertinent subdivisions has not been defined and customarily would not be defined by the federal government.

Based on the SCS soil survey for Boulder County[4], the soils in the three basins fall within three general soil associations: Weld-Colby, Nunn-Heldt, and Ascalon-Otero. The characteristics of these soils are summarized in the following:

- o Weld-Colby: This association consists of deep, well-drained soils on upland slopes or plateaus with slow to moderate permeability rates. Nearly all of the acreage of this soil is used for agricultural purposes.

- o Nunn-Heldt: These are deep, moderately well- to well-drained soils on terraces, uplands, and plateaus with slow to moderately slow permeability rates. Most of the acreage of this soil is used for agricultural purposes.

- o Ascalon-Otero: These are deep, well-drained soils formed on terraces and upland areas with moderate permeability. Most of these soils are used for agriculture.

Based on the permeability rates and characteristics of the soils listed in the SCS soil survey for Boulder County, all three soil types are Hydrologic Group C soils (per the US SCS methodology)[5]. This is consistent with the analysis conducted for the Outfall System Planning-Boulder Gunbarrel Area[2] study in which the soils were considered to be in Hydrologic Group C. Practically speaking, this means that the soils naturally produce substantial runoff per unit of rainfall.

The erosion hazard for the three soil types is moderate to high. A high hazard is associated with the soils on steep slopes such as the slopes in the eastern portion of the basins (Figure 2).

History of Flooding in Area

Flood events that have caused damages have been reported in the Gunbarrel/ Heatherwood area since initial development of this area in the late 1960's and early 1970's. In a December 20, 1989 memorandum to Jim Crain[6], Boulder County staff notes that the Gunbarrel Estates area historically has flooded on a regular basis. As stated in the Outfall System Planning — Boulder Gunbarrel Area[2] study, the flooding problems have been due to "piecemeal development and the lack of comprehensive master drainage planning in the area" and "inadequately sized culverts, storm sewers, and channels." As is also stressed in this document, future development is likely to aggravate existing problems and create additional problems.

The following brief history of recent flooding events in the Gunbarrel/ Heatherwood area is based on records available from Boulder County and on accounts found in local newspapers.

At least four individual flood events have been documented in the Gunbarrel/Heatherwood area in addition to the June 3, 1989 storm. The first of these, a flood in 1971, occurred in the Gunbarrel Estates area. A portion of Gunbarrel Estates is located in Basin C. Boulder County staff were contacted by a homeowner and the County has documentation of the date and magnitude of this flood event. According to Mr. Tim Feehan[7] of Boulder County, the 1971 flood was treated as an isolated event.

On July 26, 1977, several accounts of flooding in the Gunbarrel Estates area appeared in the Longmont Times. In an article by Pat Jorgenson entitled "Drought Breaking Rain Leaves Mud[8]," it is stated that "Niwot and Brownsville Fire Departments worked throughout the night pumping out basements, and damages occurred in the 7400 block of Mount Sherman Street

in Gunbarrel Estates." In another article, "Sun Cakes Gunbarrel Mud[9]," the same author states that "Monday night's flash flood of 2 to 3 inches caused water and silt from Gunbarrel Hill to rush down a gully into the homes. Hardest hit were the Rev. Wallace Turner, 7488 Mount Sherman Road, and John Paulovic, 5866 Park Lane Road." According to Boulder County[7], following this flood the Gunbarrel Estates Homeowners Association visited the Boulder County Planning Office to see who was responsible. Rev. Turner is quoted in the article as saying that "it's obvious that somewhere along the line this development should have been required to have a provision for drainage of floodwaters."

A memorandum on file at Boulder County from a A.J. Ariniello dated July 27, 1977[10] includes discussion of a reported flood on June 15, 1977 in the Gunbarrel Estates area. The following details appear in the memorandum: "Homes located in the northeast portion of the development were built in a natural drainage swale that drained 200 acres of farmland to the east. Several houses were built in a manner that their lots drained toward the house instead of away. It is estimated that the storm was a 5-year event."

A memorandum on file with Boulder County, dated November 14, 1977, from Mr. D.J. Galloway (resident) to Ann Raisch (of Boulder County)[11] states, "I think it is important that you know that the department was aware of a potential problem before it happened." The 1977 county file contains a plat map showing the location of 1977 storm damages[12]. Most of the damages occurred along Mount Sherman Road, Park Lane, and Gunbarrel Road, all within the Gunbarrel Estates area.

The November 14, 1977 memorandum was not the only one which identified known drainage deficiencies in the Gunbarrel/Heatherwood area. In a memorandum in Boulder County's files dated June 6, 1978, entitled "Conway Property Drainage Problem on Simmons Drive,[13]" it is stated that "At the present time, there are no drainage culverts on the side of Simmons Drive capable of carrying this flow. Therefore, sheet flows cross the road and concentrate through the Conway property which is graded lower than the

road." Included in this memorandum was a recommendation to construct a drainage ditch along the side of the road.

According to Mr. Feehan of Boulder County[7], a significant flooding event occurred around 1981. This storm event was approximately a 2- to 5-year storm.

The accounts of the previously described flood events in the Gunbarrel/ Heatherwood area indicate the following:

1. Reported flood events have occurred in the area over the past 20 years. A major factor in the floods has been runoff from agricultural lands to the east of the development on Gunbarrel Hill.

2. Flooding occurred prior to Boulder Open Space acquiring lands in the Gunbarrel Hill area.

3. There has been acknowledgment by Boulder County and local residents of past flood events.

4. Some local drainage system deficiencies were recognized.

The flood which occurred on June 3, 1989 was reported in two articles in the Boulder Daily Camera. The articles (June 4, 1989), "Rains Cause Flooding, Gunbarrel Homeowners Have to Bail Out Basements[14]," and, "Heatherwood Wants Drainage Fixed, Flooding Sparks Complaints[15]," were written by Monica Powers. These articles discuss examples of individual damages incurred by homeowners in the area, and stress the need to arrive at solutions to area drainage problems.

Summary of Drainage Plans and Authority

The studied basins lie within unincorporated Boulder County. Boulder County is the authority for stormwater drainage, including approval of individual drainage plans for subdivisions and new development.

For many years, Boulder County has had ordinances which address stormwater drainage. The 1969 Urban Storm Drainage Criteria Manual[16] was applicable to Boulder County. The urban stormwater management criteria and guidelines in this document remain pertinent today. In 1984, Boulder County adopted the Boulder County Storm Drainage Criteria Manual[1] (Manual) as Article 12 of the Boulder County Subdivision Regulations[17]. The Manual provides data, policies and criteria related to stormwater control in unincorporated Boulder County. The Manual also specifies a drainage report review and approval process for all subdivisions and development, and addresses problems with existing drainage facilities.

Before 1984, Boulder County required that subdivision drainage plans be prepared by a registered engineer. The engineer was the developer's agent. This requirement reflected established nationwide practice that remains common in rural areas.

It has been the policy of Boulder County to pursue a "jurisdictionally unified" approach to storm drainage and to involve other political entities (e.g., the City of Boulder) in its planning and approval processes. Consistent with this planning, the City of Boulder participated and provided guidance in recent studies addressing drainage in the Gunbarrel/Heatherwood area. These studies include the following:

1. Outfall Systems Planning — Boulder Gunbarrel Area[2], and
2. Informal Report of the Evaluation of Alternatives for Outfall Systems — Boulder Gunbarrel Area[18].

All drainage plans for subdivisions in the Gunbarrel area were approved by Boulder County. Personnel with the City of Boulder Utilities Department[19] could find no requests by the County to review any drainage plans for the Gunbarrel/Heatherwood area. Furthermore, City records indicate that no reviews on behalf of the County were performed in areas pertinent to this matter.

EVALUATION OF JUNE 3, 1989 FLOOD

Meteorologic Conditions

Based on conditions reported by Henz Kelly Associates (flood forecasting contractor to the Urban Drainage & Flood Control District), the June 3, 1989 flood was caused by an "upslope condition with an approaching upper level disturbance containing significant moisture.[20]" According to a bulletin issued by Henz Kelly Associates at 11:30 a.m. on June 3, 1989[11], thunderstorms embedded in the system could produce precipitation in the range of 1.5 to 2.5 inches per hour, (or possibly even 2.5 to 4.0 inches per hour if the system slows down)[20]. An updated bulletin issued at 12:30 p.m. on June 3, 1989 called for "storms with downpours/flooding and possible hail" with precipitation amounts potentially exceeding 5.0 inches[21]."

As stated in the bulletin at 11:30 a.m., "The focus [will] first [be] in the Boulder northern Jefferson County foothills then gradually become district-wide with a focus going south along the foothills and then south in southern Jefferson County, Arapahoe County and Douglas County."

Records of precipitation for June 3, 1989 and the five days preceding June 3 were obtained from the National Oceanic and Atmospheric Administration (Boulder Weather Station)[22] and several Gunbarrel area citizens[23] who recorded rainfall with rain gages. Available rain gage data are summarized in Table 1.

Table 1 shows that precipitation depth varied greatly between the Boulder weather station gage (located approximately 6 miles to the southwest of the Gunbarrel/Heatherwood area) and the Gunbarrel/Heatherwood area. An average of 3.0 inches of rainfall was reported from local rain gages in the Gunbarrel area while 0.69 inches of rain was reported at the official Boulder weather station. This diversity is typical of summer thunderstorms along the Front Range. These storms often result in a concentration of precipitation immediately beneath the thundercloud(s) while nearby areas are left dry.

TABLE 1
SUMMARY OF PRECIPITATION RECORDS FOR JUNE 3, 1989
AND PREVIOUS FIVE DAYS IN GUNBARREL/HEATHERWOOD AREA

(All figures in inches)

Source	Day of Flood 6/3/89	Antecedent Rainfall Period 6/2/89	6/1/89	5/31/89	5/30/89	5/29/89	Total Antecedent Rainfall (5/29-6/2)	5-Day[1] Precip. for 5/30-6/3/89
NOAA, Boulder[2] Weather Station	0.69		0.38	0.57	0.11		1.06	1.75
Peter Stamus[3] (Gunbarrel resident)	3.22	0.93	0.16	0.44	0.03	Trace	1.56	4.78
Barrel Frost[4] (Gunbarrel resident)	2.9							
Jack Banberg[5] (Gunbarrel resident)	3.6	1.0	0	0.66	0	0	1.66	5.26
Tim Switzer[6] (Gunbarrel resident)	3.0							
Ed Szoke[7] (Gunbarrel resident)	2.43							
Avg. in Gunbarrel area =	3.0						1.61	5.02

[1] Trace amount treated as zero in 5-day total.

[2] From: *Climatological Data, Colorado* May and June 1989 (Vol. 94, Nos. 5 and 6), National Oceanic and Atmospheric Administration.

[3] NOAA employee with raingage at 7378 Glacier View Road.

[4] Raingage at 559 Colt Drive.

[5] Raingage at 5641 Gunbarrel Road.

[6] Raingage at 7486 Park Lane Road.

[7] Raingage at 7670 Berwick Court.

Table 1 also shows that the Gunbarrel/Heatherwood area received rainfall in the five days previous to June 3, 1989. Such rainfall would wet soils and increase the surface runoff generation potential. Based on the records of local observers, the total 5-day antecedent rainfall was between 1.56 and 1.66 inches.

Table 2 summarizes rainfall measurements taken on June 3, 1989 in the Gunbarrel area. As can be seen from Table 2, the period of maximum precipitation reportedly lasted between 30 to 120 minutes and occurred between 3:30 p.m. to 5:30 p.m. Maximum precipitation depths reported during this period varied between 1.22 and 4.0 inches per hour. For the purposes of hydrologic modeling, a total depth of 3.0 inches was uniformly distributed over a period of 90 minutes. The model represents the average rainfall recorded in the Gunbarrel/Heatherwood area over the average storm duration (Table 2).

Two aspects of rainfall return frequency are relevant to the June 3, 1989 flood: (1) the return frequency of the June 3 rainfall event itself, and (2) the return frequency of the 5-day total precipitation from 5/29/89 to 6/2/89. The June 3 flood was the result of two statistically independent conditions: (1) several consecutive days of rainfall prior to June 3 which raised the moisture content of local soils, reduced initial infiltration losses and increased surface runoff potential, and (2) the high intensity rainfall that occurred over a duration of 30 minutes to 120 minutes.

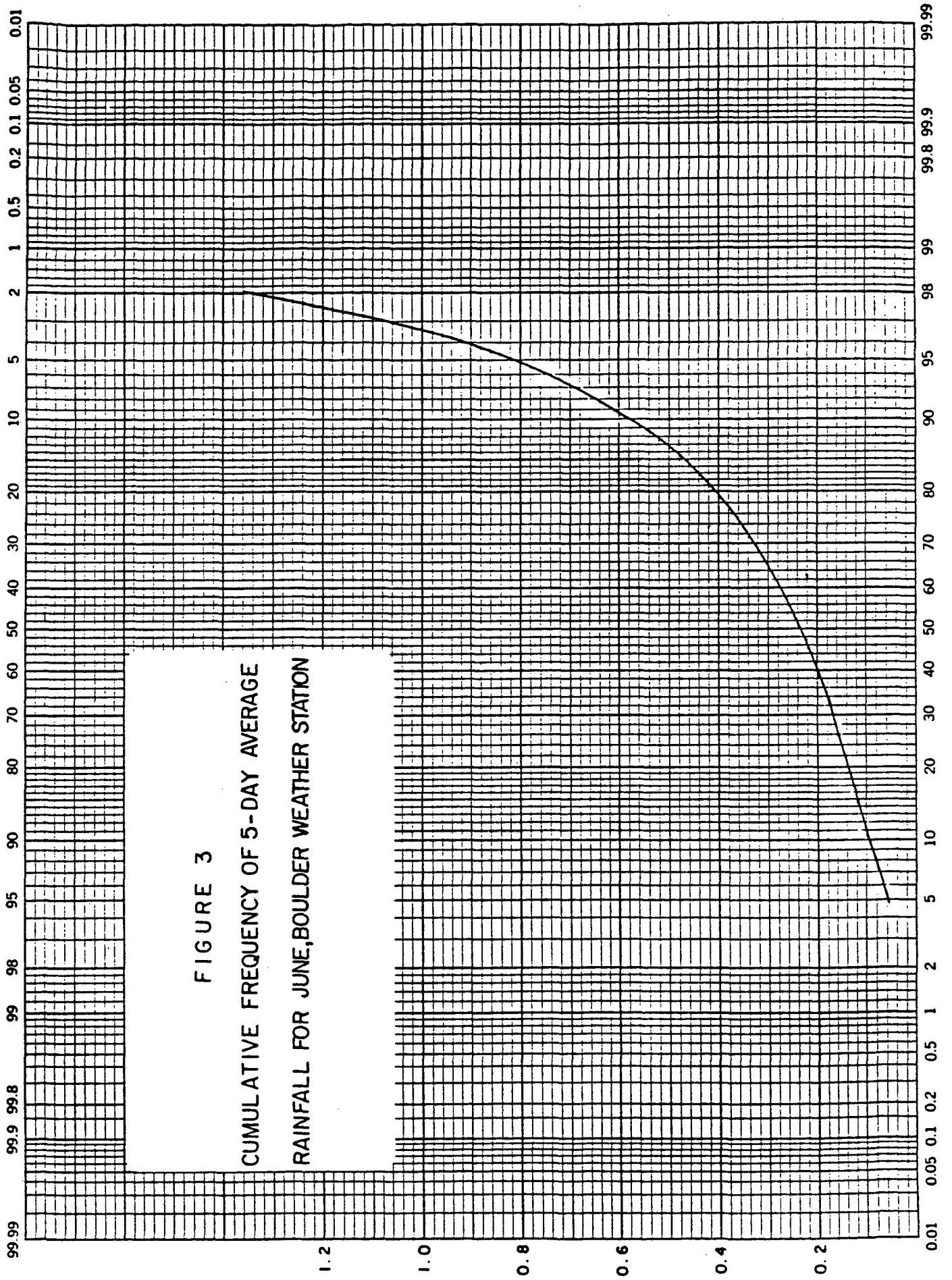
To assign a return frequency (probability) to the 5-day total precipitation from 5/29 to 6/2, Boulder weather station precipitation records from 1949-1987 were analyzed[22]. This station was selected because it is the closest station to the Gunbarrel area with long-term data. Figure 3 illustrates the frequency distribution for 5-day precipitation depths at the Boulder station and indicates that the 5-day antecedent rainfall was approximately a 3-year event. (In other words, the average total amount of rainfall, 1.61 inches, experienced from May 29, 1989 to June 2, 1989 would occur in June on the average of once every three years.)

TABLE 2
SUMMARY OF PRECIPITATION RECORDS FOR JUNE 3, 1989 STORM IN GUNBARREL/HEATHERWOOD AREA

Source[1]	Total Depth (inches)	Period	Maximum[2] Intensity (inches/Hour)
Peter Stamus	2.92 0.30	3:35-5:15 p.m. 5:15 p.m.-12:30 a.m.	1.75
Bonnell Frost	2.9	3:30-5:30 p.m.	1.45
Jack Banberg	3.6	3:30-5:00 p.m.	2.4
Tim Sweitzer	1.0 2.0	3:30-4:30 p.m. 4:30-5:00 p.m.	4.0
Ed Szoke	0.61 1.82	3:30-4:00 p.m. 4:00-5:30 p.m.	1.22
Average	3.0		2.16

[1] All sources private citizens in Gunbarrel area. See Table 1 for addresses.

[2] Apparent maximum based on data of observer.


5-DAY AVERAGE PRECIPITATION (INCHES)
1.2
1.0
0.8
0.6
0.4
0.2
PROBABILITY OF EXCEEDENCE (%)
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
FIGURE 3
CUMULATIVE FREQUENCY OF 5-DAY AVERAGE
RAINFALL FOR JUNE, BOULDER WEATHER STATION
K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003

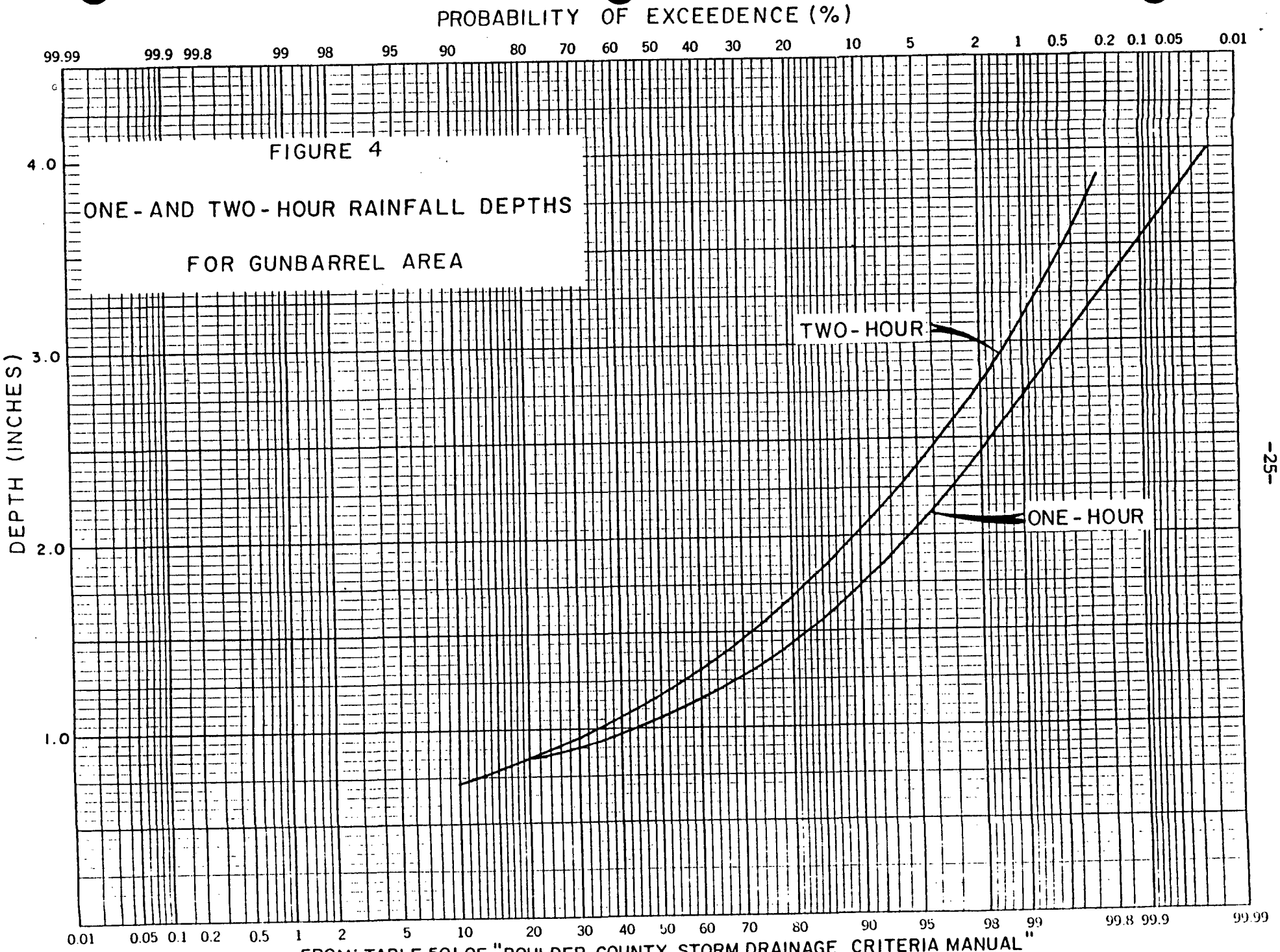
The second aspect of the rainfall probability evaluation centered on comparing the observed precipitation intensities against design rainfall data in the Urban Storm Drainage Criteria Manual[16] and the Boulder County Drainage Criteria Manual[1]. Figure 4 shows the probabilities associated with 1-hour and 2-hour duration rainfalls in the June 3 flood area from the Boulder County Drainage Criteria Manual. As shown on Figure 4, the average of 3.0 inches of rainfall (Table 2) in the Gunbarrel/Heatherwood area which occurred over an approximately 90-minute duration (which on Figure 4 would lie between the 1-hour and 2-hour lines) represents approximately a 125-year rainfall event.

The combined return frequency of an event the size of the June 3, 1989 flood occurring immediately after a five-day antecedent rainfall of 1.61 inches in the Gunbarrel/Heatherwood area is 379 years, or approximately 400 years.

Figure 5 shows the maximum rainfall recorded on each day at the Boulder Weather Station for the period between 1949 and 1988. This figure shows that significant rainfall events greater than the 2-year or 5-year daily rainfall have occurred periodically during the March through October period and are not limited to the month of June.

It should be noted that Figure 5 is based on daily (24-hour) rainfall depths and cannot be used to determine the return frequency of the June 3, 1989 flood. This is because both storm duration and intensity must be considered in assigning a return frequency to an event. The rainfall on June 3, 1989 occurred over an unusually short period of approximately an hour and one-half. The probability of receiving 3 inches of rain in one and one-half hours is much lower than the probability of receiving the same amount of rain in a 24-hour period. Figure 5 only indicates return frequencies of rainfall occurring in 24-hour periods.

K&E PROBABILITY X [illegible] KEUFFEL & ESSER CO. MADE IN U.S.A.

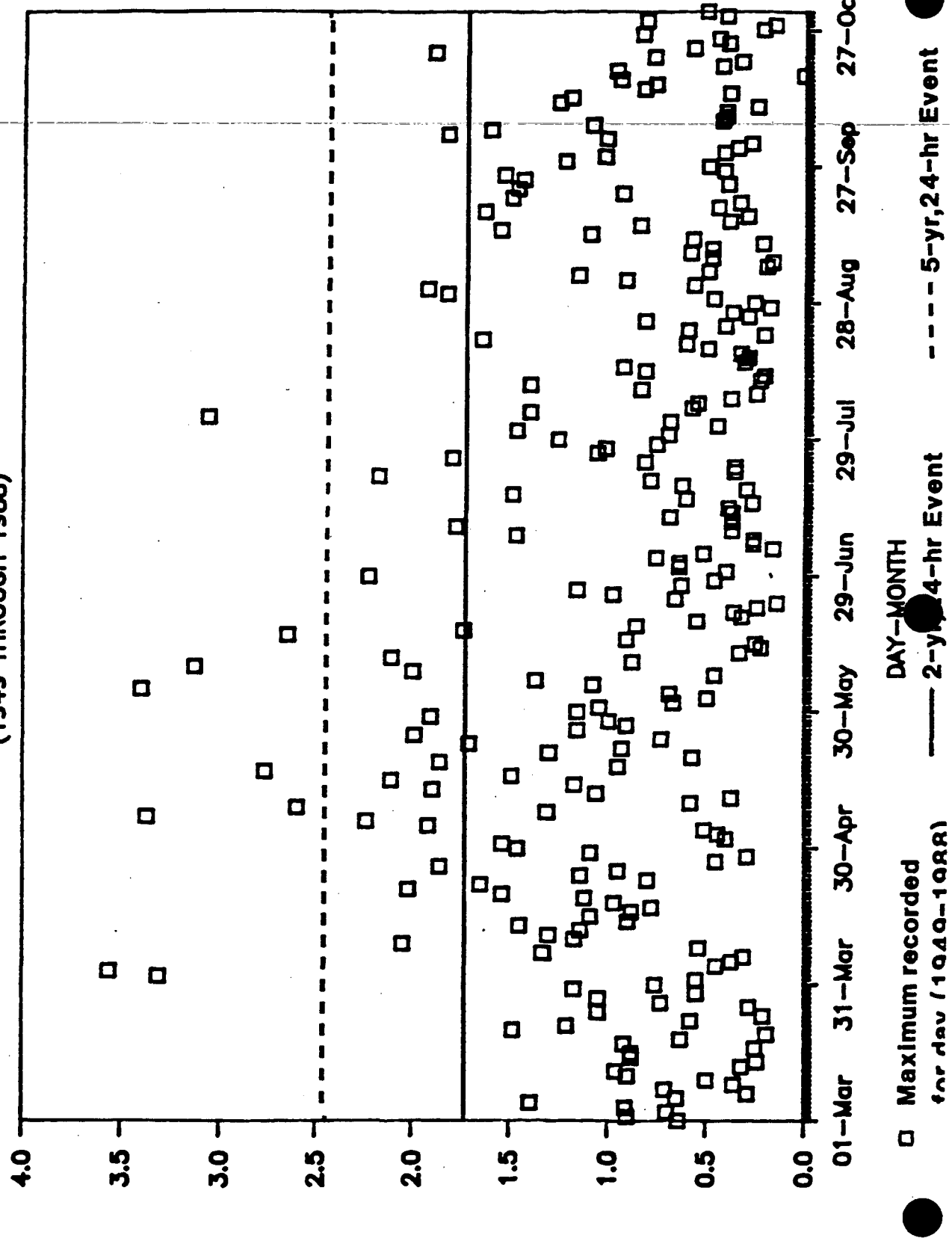


FROM: TABLE 501 OF "BOULDER COUNTY, STORM DRAINAGE CRITERIA MANUAL"
(ZONE 1) WHICH IS FROM THE DENVER STORM DRAINAGE CRITERIA MANUAL

FIGURE 5

MAXIMUM DAILY RAINFALL RECORDED AT BOULDER WEATHER STATION

(1949 THROUGH 1988)



Basin Land Use

Essential to the evaluation of the June 3, 1989 flood is an understanding of the conditions of the parcels and of specific activities by the City on the lands within the study basins. The lands purchased by the City were historically farmed in wheat strips. Consequently, half the land was fallow each year. The wheat strips are oriented north to south for wind erosion control. The relevant comparison to make is between the condition of agricultural lands owned by the City on June 3, 1989 and the condition of the land had the City continued north to south strip cropping.

Table 3 summarizes the current land use within each basin. This table shows that all of the land in Basin A is owned by the City and that a portion of the land in Basins B and C is owned by the City.

Table 4 indicates the dates that the City purchased land within the basins and shows the percent of each basin represented by the parcels. In summary, there are four separate parcels which the City has purchased in the flood area. The parcels were purchased between 1979 and 1986.

Following is a summary of the historic use of the parcels and a description of their status as of June 3, 1989. Table 5 contrasts the land use in existence on June 3, 1989 with the "historic" land use that would have been present had all the land been left in north-south strip cropping. Strips, oriented north to south, are designed for wind erosion control and not water erosion control. Strip-cropping involves planting one-half the land to wheat each year while leaving the other half fallow. The locations of the parcels are shown in Figure 2.

Haley (Basin A): This parcel encompasses nearly all of Basin A. Rangeland comprises 4.1 acres of the parcel; the remainder (87.7 acres in Basin A) historically has been cropped in wheat strips, one-half of which were fallow each year. The eastern 31.5 acres of the entire 87.7 acres being converted to native rangeland had been reseeded with native grasses in November of 1988. The balance (56.2 acres) was fallow and had been "duck-

TABLE 3
SUMMARY OF GENERAL LAND USE TYPES[1] IN STUDY BASINS

Basin[2]	Residential	Park/ Golf Course	Private Agricultural	City Agricultural	Total
A	0	0	0	91.8	91.8
B	73.7	21.2	152.1[3]	169.4	416.4
C	40.3	1.9	32.8	93.1	168.1

[1] Areas measured on 1984 aerial photograph of basins (scale: 1 inch = approximately 400 feet), confirmed with 9/15/89 aerial photograph (scale: 1 inch = approximately 660 feet).

[2] Basins shown on Figure 2.

[3] Agricultural land in Basin B is the sum of 90.6 acres currently farmed land and 61.5 acres of fallow land adjacent to residential area.

TABLE 4
PURCHASE DATES AND PERCENT OF BASINS COMPRISED OF CITY AGRICULTURAL LAND

Basin	Total Basin Acres	Name of[1] City Parcel	Location	Purchase[2] Date	Acres of Parcel in Basin	Percent of Basin City Land
A	91.8	Haley	N1/2 SW1/4 S17[3]	1984	91.8	100
B	416.8	Jenik	E1/2 NE1/4 S12[4]	1983	61.0	14.6
		Coslett	NW1/4 S17[3]	1986	70.0	16.8
					131.0	31.4
C	168.1	Jenik	N1/2 NE1/4 NE1/4 S12[4]	1983	19.8	11.8
		Coslett	N1/2 NE/14 S17[3]	1986	40.0	23.8
		Richardson	S1/2 SE1/4 S1[4]	1979	33.0	19.6
					92.8	55.2

[1] Based on name of historic farmer of parcel.

[2] Date parcel purchased by City of Boulder.

[3] In T.1N., R.69W.

[4] In T.1N., R.70W.

TABLE 5
SUMMARY OF CONDITION OF AGRICULTURAL LANDS OWNED BY THE CITY OF BOULDER

Basin[1]	Total Acres in Basin	City[2] Parcel	Total Acres of City Parcel	Land Use	"Historic[3]" Condition (acres)	6/3/89[4] Condition (acres)	Increases[5] in Fallow Acres in June 1989	Percent of Total Basin With Additional Fallow
A	91.8	Haley	91.8	Native	4.1	4.1		
				Reseeded range	0	31.5		
				Wheat[6]	43.9	0		
				Fallow	43.8	56.2		
TOTAL					91.8	91.8	12.4	13.5
B	416.4	Jenik	61.0	Wheat[6]	30.5	0		
				Fallow	30.5	61.0	30.5	7.3
				Subtotal	30.5	61.0		
		Coslett	70.0	Wheat[6]	35.0	35.0		
				Fallow	35.0	35.0	0	0
				Subtotal	70.0	70.0		
TOTAL							30.5	7.3

TABLE 5
(Continued)
SUMMARY OF CONDITIONS OF LANDS OWNED BY BOULDER OPEN SPACE

Basin[1]	Total Acres in Basin	City[2] Parcel	Total Acres of City Parcel	Land Use	"Historic[3]" Condition (acres)	6/3/89[4] Condition (acres)	Increases[5] in Fallow Acres in June 1989	Percent of Total Basin With Additional Fallow
C	168.1	Jenik	19.8	Wheat[6]	9.9	0		
				Fallow[6]	9.9	19.8		
				Subtotal	19.8	19.8	9.9	5.9
		Coslett	40.0	Wheat[6]	20.0	20.0		
				Fallow[6]	20.0	20.0		
				Subtotal	40.0	40.0	0	0
		Richardson	33.3	Wheat[6]	16.6			
				Fallow[7]	16.7			
				Pasture[7]	0	33.3	-16.7[8]	-9.9[8]
				Subtotal	33.3	33.3		
TOTAL							-6.8[8]	-4.0[8]

[1] See Figure 2 for basin areas. See text for description of land use changes.

[2] Named according to historic farmer of parcel.

[3] Average condition in early June based on historic agricultural practices as determined from interviews with farmers, review of ASCS records, and interpretation of aerial photographs. See Table 4 for location of parcel.

[4] Condition of June 3, 1989 determined from interviews with farmers, City of Boulder personnel, and records of the City.

[5] Additional acreage over the "historic" conditions which were fallow on June 3, 1989 due to the City's activities. Note that additional areas may have been revegetated by the City over the "historic," and they are not included in this column.

[6] Fallow areas were treated for weed control using a field cultivator during the spring period both under the "historic" condition and in 1989.

[7] Parcel seeded to pasture in 1984.

[8] Negative sign indicates a decrease in fallow acres in 1989 compared ot the "historic" condition.

foot" cultivated along the contour for weed control between May 26-29, 1989 in preparation for planting of sorghum. The native plant conversion process is aimed at establishing a good cover of native plants on lands previously strip-cropped and is described in more detail in a subsequent section of this report.

As shown in Table 5, 43.8 acres would have been fallow historically, and 43.9 acres would have been in wheat. The wheat which would be approximately halfway through its growth for the year with an estimated cover of 25 percent. In 1989, 56.2 acres were cultivated for weed control and 31.5 acres were seeded to range. The estimated percent cover of the reseeded range was at least 25 percent (based on interviews with City personnel)[24]. The entire area was not stripped of all vegetation on June 3, 1989 as was alleged.

Jenik Parcel: Historically, all 80.8 acres of the Jenik parcel have been strip-cropped. This means that approximately 40 acres are typically fallow in early June of each year. The entire Jenik parcel was in the process of conversion in 1989 and had been plowed with a "duckfoot" field cultivator on May 27, 1989 for weed control. This type of implement is commonly used along the Front Range and only disturbs the upper 2-3 inches of soil. The entire parcel was seeded to sorghum on June 10, 1989. Three-quarters of the Jenik parcel is located in Basin B; 19.8 acres lie in Basin C.

Coslett Parcel: The Coslett parcel (110.0 acres in Basins B and C) was strip-cropped in June 1989 as it has been historically. This means that approximately 55 acres were fallow and 55 acres were wheat at the time of the June 3 flood.

Richardson Parcel: The Richardson parcel was converted to pasture by the City approximately 4 years prior to the June 3, 1989 flood. The pasture had not been cut or grazed in 1989. Therefore, it was reportedly in good to excellent condition on June 3, 1989. According to the City staff[25], the cover was near 100 percent; WWE assumed a cover of 75 percent in our evaluations to be conservative.

Prior to conversion to pasture, the Richardson parcel was strip-cropped. This means that approximately 16.5 acres were fallow each year.

Table 5 presents the additional acreage of City lands in each basin which were fallow in 1989, and which could thereby potentially affect the amount of runoff and sediment from the June 3, 1989 flood. As can be seen from Table 5, approximately 13.5 percent more of Basin A was fallow in June of 1989 than in the "historic" condition. An additional 7.3 and 5.9 percent of Basins B and C, respectively, were fallow in 1989.

The strip-cropping technique means that each spring approximately one-half the land is fallow, with stubble standing from wheat cut the previous fall. This wheat stubble acts as a mulch to reduce, to some extent, soil loss. However, the cover provided by the stubble is low (10-20 percent) and its effectiveness is greatly reduced a short time after cutting. The other one-half of the strip-cropped fields would be wheat (or another small grain) which, during the subject time period, would be at approximately the mid-point in its spring growth cycle. Typically, the wheat has been harvested in the period between mid-July and August.

In early June, the wheat would normally be around 6 to 10 inches high and would be in rows creating between 15 and 50 percent cover. In terms of erosion and runoff control, the areas planted to wheat would not offer significant protection from a rainfall event of the magnitude of the June 3, 1989 flood.

Weed control has been practiced on all strip-cropped lands. A field cultivating device (such as a "duckfoot") has been used to control weeds as needed, including during spring months. This cultivating device disturbs only the upper 2-3 inches of soil.

OPEN SPACE LAND MANAGEMENT

This section is a discussion of the nature of the land management activities used by the City on lands in the basins of interest. The specific practices used are addressed in regards to consistency with Soil Conservation Service (SCS) guidelines and generally accepted methods along the Front Range.

The Open Space lands in Basins A, B, and C have been included in the Conservation Reserve Program (CRP) of the SCS. The goal of the CRP is to convert land used for strip-cropping of wheat and small grains to pasture in order to reduce soil erosion. Under the CRP, a farmer (in this case, the City of Boulder) enters into a contract with the SCS. The contract includes specific steps which must be followed to convert lands. The contractee is usually allowed a period of 10-years for the conversion. The CRP has been used widely on lands east of the Front Range.

The City has entered into contracts with the SCS to convert lands it owns in the study basins to native pasture. The following summarizes the process the City follows pursuant to its contract[29]:

1. Land on which wheat was cut, usually in mid to late summer, is left with adequate stubble until the following spring.

2. The land is cultivated three or more times prior to seed bed preparation to control weeds. This is typically done using a field cultivator ("duckfoot") which results in significantly less soil disturbance than a plow.

3. A temporary cover crop of sorghum is planted based on seeding rates contained in the contract. The cover crop is planted in late May through early June following the frost season.

4. The sorghum is left standing to protect the soil until November.

5. In November, the sorghum is cut and mulched, and a rangeland drill is used to seed an approved mixture of native grasses. These grasses will germinate the following spring.

The contract with SCS also states that weeds will be controlled during seed bed preparation, while the fields are in a cover crop (sorghum, in this case), during the establishment of grass, and during the life of the contract. In addition, no harvesting, grazing or haying is allowed.

The methods used by the City have been approved by the SCS, and used successfully on City lands throughout Boulder County. City personnel have worked closely with the SCS to meet its contract obligations and assure successful revegetation. The following addresses several aspects of the City's program:

1. Sorghum is used as the temporary cover crop. Sorghum is widely used for this purpose and provides good cover for erosion control. It must not be planted if there is a danger of frost as it will naturally produce prussic acid (a form of cyanic acid) which is toxic to cattle. Therefore, the SCS suggests that sorghum not be planted until the danger of frost has passed.

2. The goal of the City's native pasture conversion program is to reduce soil erosion and provide more diverse vegetation conducive towards wildlife and City goals. To this end, a suitable mixture of grasses has been used which includes both early and late season species.

3. The City often implements additional measures which are necessary for erosion control. While not specifically required in its contract, these measures are fully consistent with the goals of the CRP and general principals contained in the contract which states

that the participant must: "take other actions that may be required by CCC [Commodity Credit Corporation] to achieve the reduction in erosion necessary to maintain production capability of the soil throughout the contract period[30]." To this end, the City often cuts water bars and uses hay bales and other measures to control erosion.

Table 6 indicates the various stages of the conversion process in which the City parcels in the study basins were as of June 3, 1989.

TABLE 6
STATUS OF THE CITY PARCELS
IN CONVERSION PROCESS AS OF JUNE 3, 1989

Parcel[1]	Status[2]
Haley	31.5 acres seeded with grass 11/88; 56.2 acres field cultivated on May 26-29, 1989 in preparation for sorghum planting
Coslett	No activities
Richardson	Process of revegetation was completed in 1984
Jenik	61 acres field cultivated for weed control on May 26-29, 1989

[1] Names refer to name of farmer who previously farmed the parcel. Parcels are shown on Figure 2 and described in Table 4 and 5.

[2] See text for discussion of approved conversion processes used.

Hydrologic Modeling of Flood Flows

The three basins of interest were modeled using the widely used "HEC-1"[27] hydrologic model. This was done to determine the magnitude of changes in peak flows and total storm volumes from the June 3, 1989 storm that could

be attributed to the activities of the City on their lands in the basins. Model results from the basin conditions which existed on June 3, 1989 were compared to results from average "historic" conditions which would have existed had the City not conducted any activities on the lands (Table 5).

The model HEC-1 was selected to simulate the June 3, 1989 storm because this model is widely used and generally accepted along the Front Range, and can be used with Soil Conservation Service "Curve Numbers" (CN) to evaluate differences in potential runoff generation from changes in land use. The CN was specifically developed to predict differences in runoff from changes in land use on agricultural lands.

Field inspections of the three basins were conducted and the basins were divided into subbasins as shown on Figures 6, 7, and 8. Subbasin delineations were based on soils, land ownership, type of land use, and existing topography. Model parameters were determined using recommended procedures in the Urban Storm Drainage and Criteria Manual[16].

The following procedures and assumptions were used in the modeling:

1. SCS runoff curve numbers were used to determine the runoff generation potential of the various lands.

2. The rainfall distribution of 3.0 inches over 90 minutes was used. This distribution is representative of the average of the reported values in the Gunbarrel area (Table 2).

3. Several field visits were made to check the reasonableness of the model configuration.

4. Manning's equation was used to calculate channel velocities and channels were assumed to be trapezoidal.

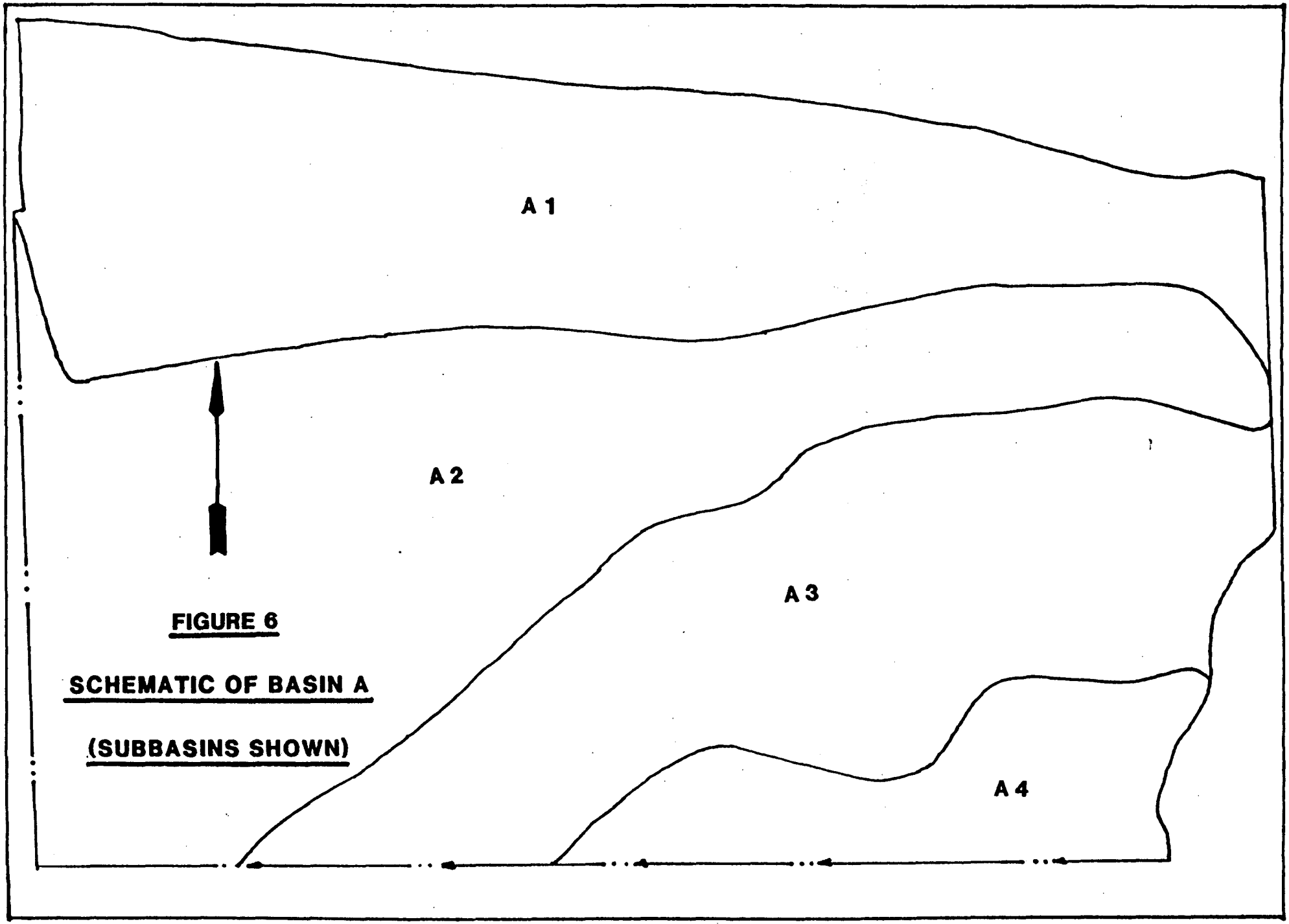


FIGURE 6

SCHEMATIC OF BASIN A

(SUBBASINS SHOWN)

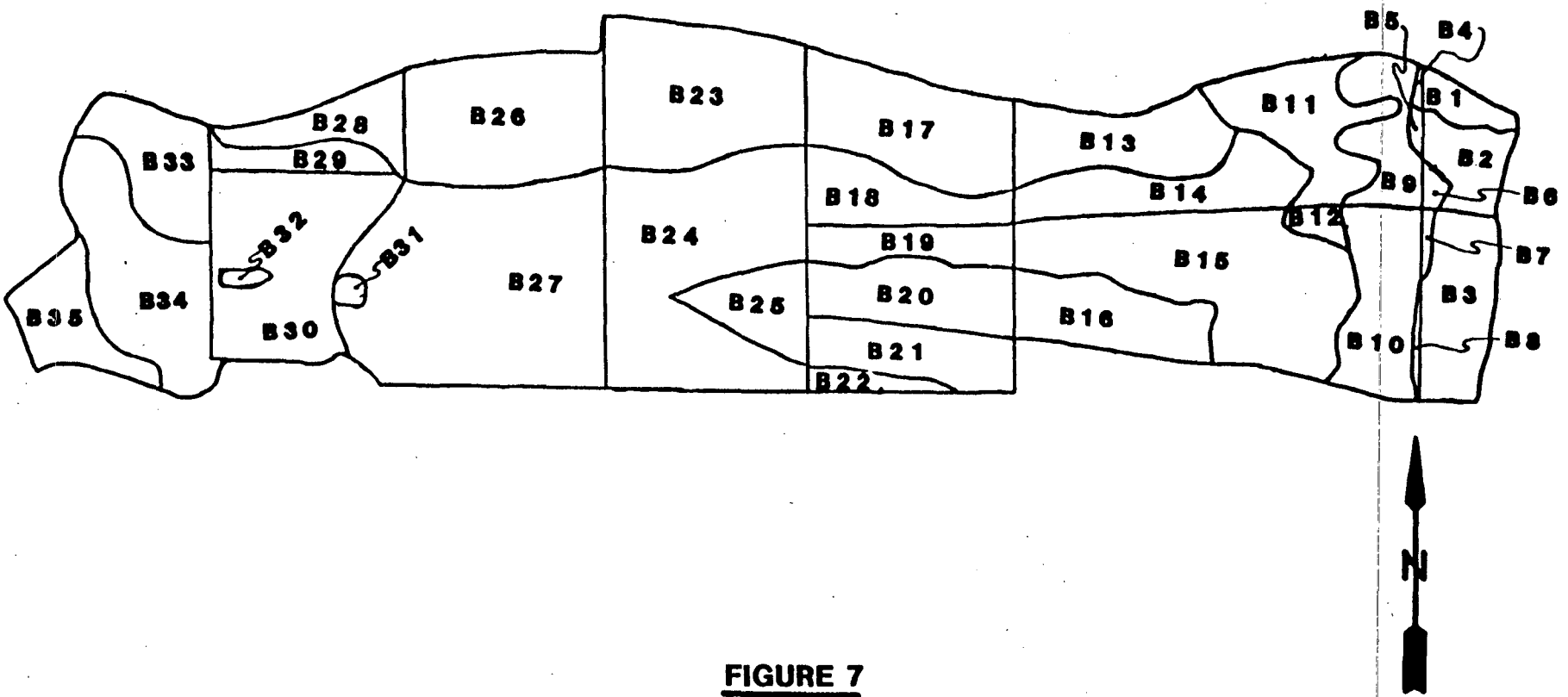


FIGURE 7

SCHEMATIC OF BASIN B

(SUBBASINS SHOWN)

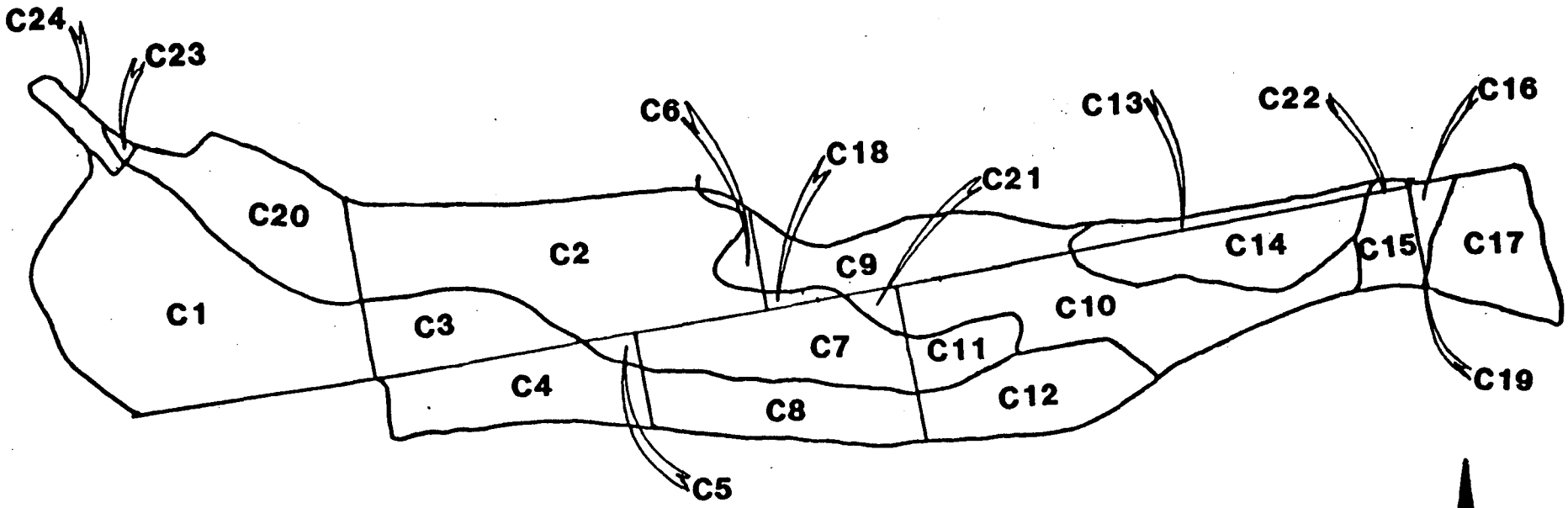


FIGURE 8

SCHEMATIC OF BASIN C

(SUBBASINS SHOWN)

5. Procedures for calculation of model parameters in the Urban Drainage and Criteria Manual[16] were followed.

Determination of curve numbers was determined based on land use characteristics and on soil types within each subbasin. The SCS National Engineering Manual, Section 4[5] (which presents the curve number method) calls for the use of antecedent soil moisture III conditions (for wet soils) when the 5-day antecedent rainfall is greater than 2.1 inches. As shown in Table 1, the 5-day antecedent rainfall prior to June 3, 1989 was 1.61 inches. Therefore, the antecedent II condition which is indicative of average soil moisture conditions was used. It should be noted that this assumption does not significantly affect the magnitude of differences between the "historic" and June 3, 1989 modeled conditions.

Results of the hydrologic modeling are summarized in Table 7. Figure 9 presents the hydrographs for the "historic" versus June 3, 1989 conditions. Table 7 and Figure 9 pertain to the downstream most point of each basin and show the effects of the City's activities on characteristics of the flood.

Modeling results were checked with the following flood flow estimates for reasonableness and consistency:

1. Estimates contained in the Outfall System Planning - Gunbarrel Area study[2],

2. Measurements of June 3, 1989 flood flows by Boulder County personnel[28], and

3. Further Evaluations of flood flows in the January 19, 1990 memorandum to Jim Crain[6].

TABLE 7
SUMMARY OF HYDROLOGIC MODELING OF JUNE 3 1989 FLOOD FOR THREE BASINS STUDIED[1]

Basin[2]	"Historic" Condition		Conditions on June 3, 1989	
	Peak Flow[3] (cfs)	Total Volume (AF)	Peak Flow[3] (cfs)	Total Volume (AF)
A	130	15	130	15
B	500	67	510	68
C	220	25	190	22

[1] Based on modeling using HEC-1 as discussed in text.

[2] Basins shown on Figure 2 and described in Tables 4 and 5.

[3] Peak flow rounded from Figure 9.

FIGURE 9A
HYDROGRAPH FOR JUNE 3, 1989 CONDITION
BASIN A

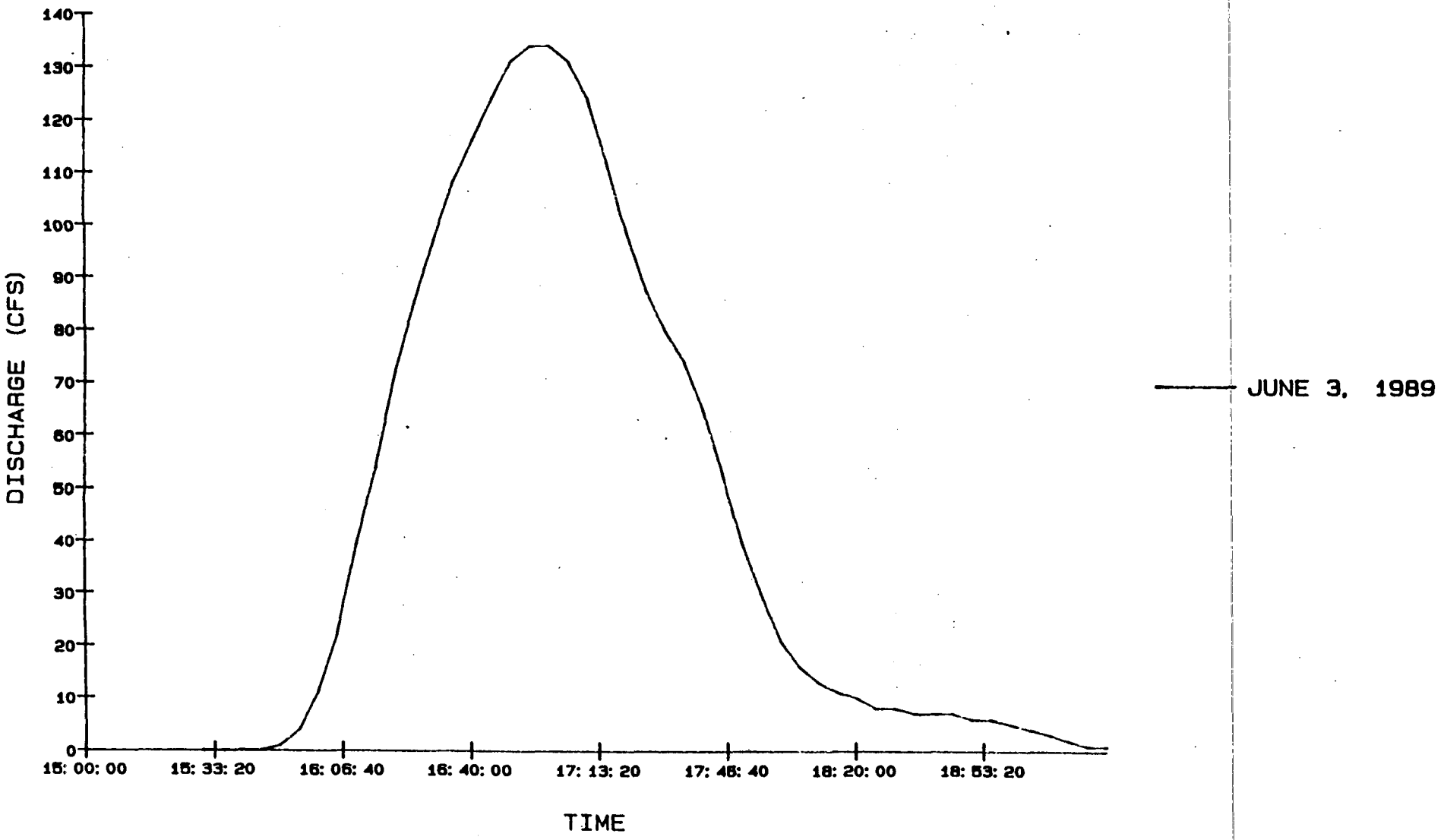


FIGURE 9B
HYDROGRAPH FOR JUNE 3, 1989 CONDITION
BASIN B

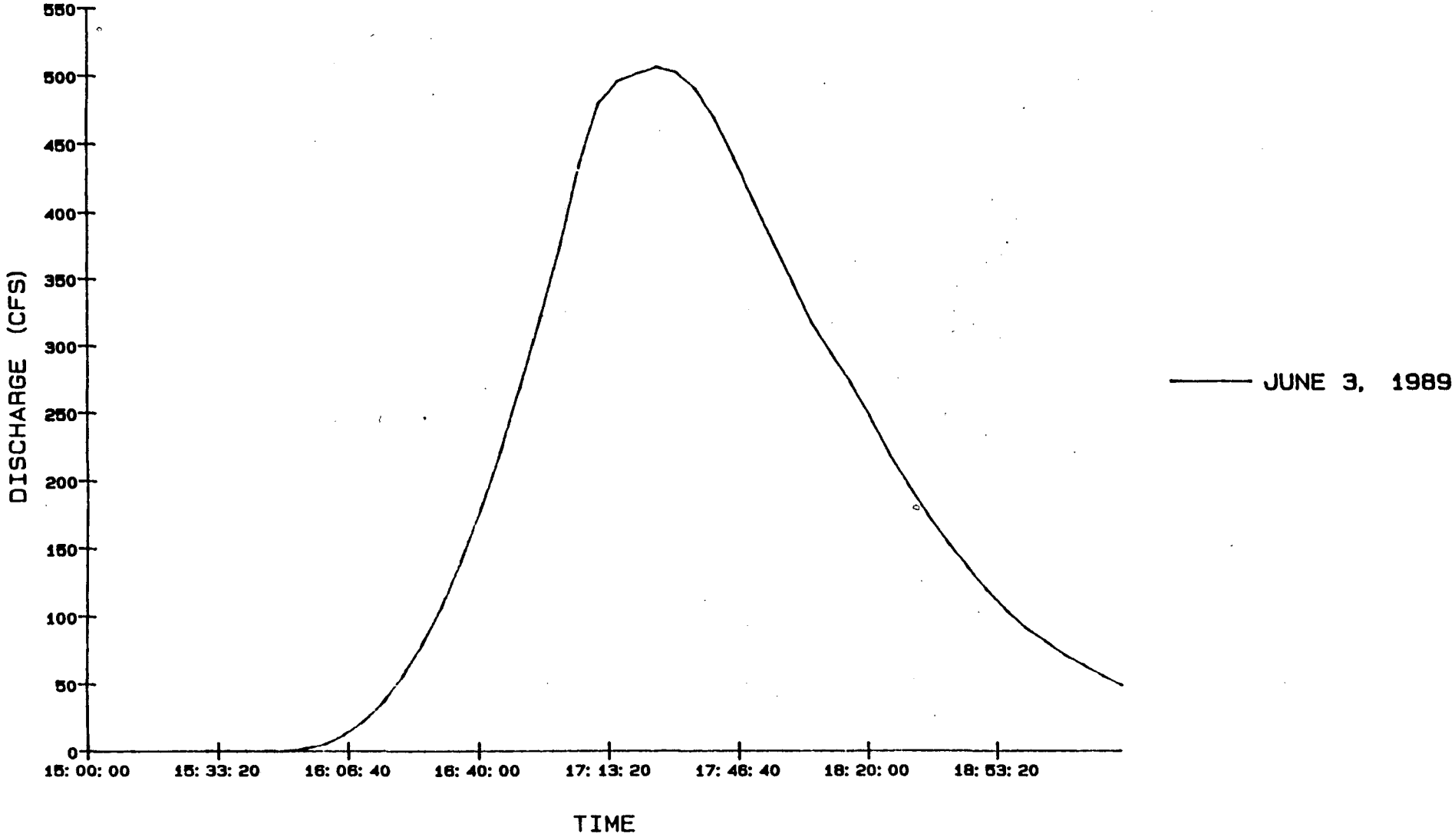
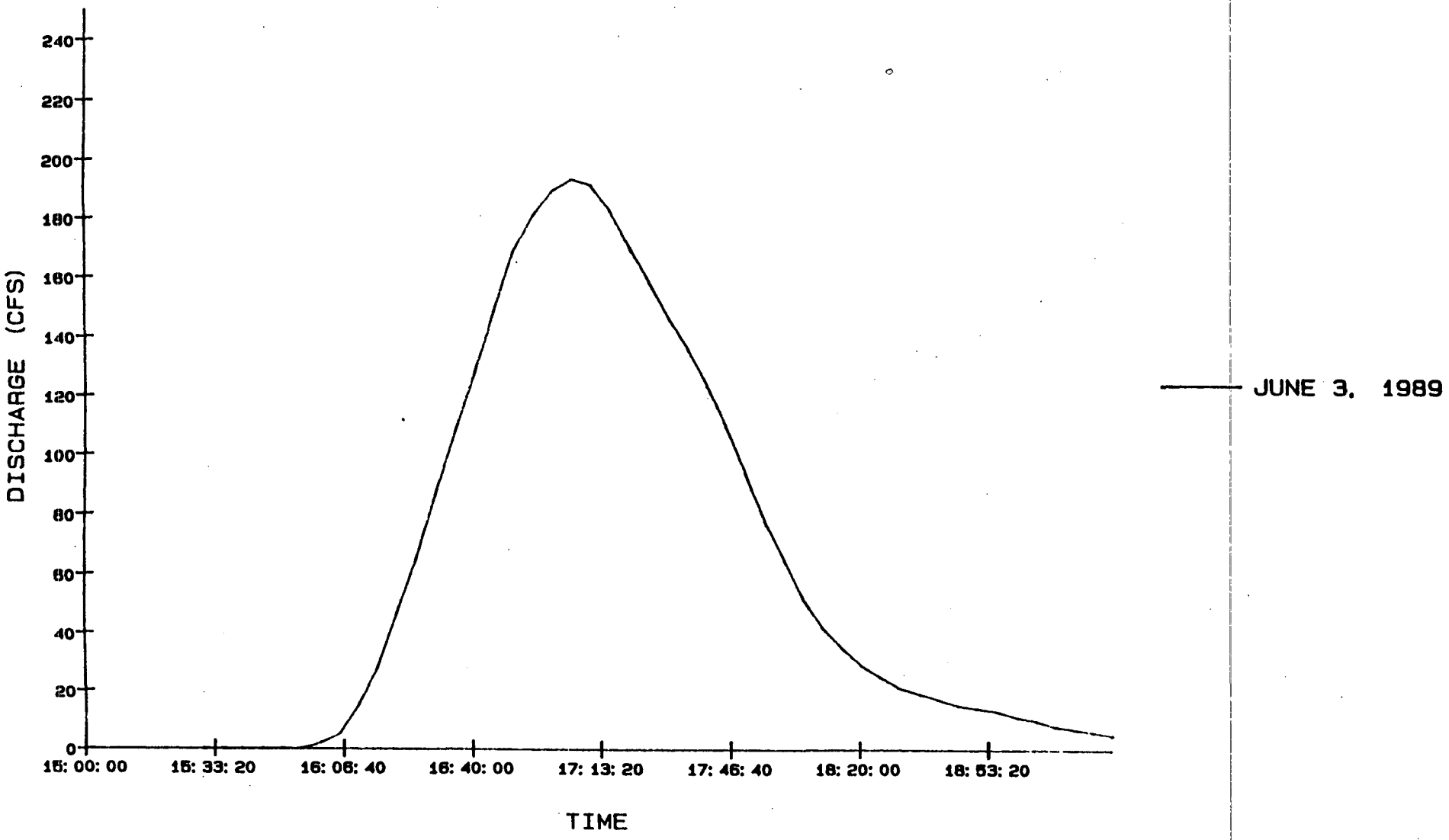


FIGURE 9C
HYDROGRAPH FOR JUNE 3, 1989 CONDITION
BASIN C



We have also relied upon our previous experience with flood events in the Boulder and Front Range area in reviewing the modeling results. In conclusion, the flood flows predicted by the modeling presented in Table 7 are reasonable and consistent with the data and documents reviewed.

As shown in Table 7 and Figure 9, the activities of the City did not result in significant increases in peak runoff rate or storm volume in Basins A and B, and, in our opinion, the increases would not have increased damages to the claimants' properties. Therefore, the activities of the City in Basins A and B did not contribute to any of the alleged flood damages in the basins.

In Basin C, the activities of the City caused a slight decrease in the peak runoff rate and storm volume. This is due to the establishment of pasture with good to excellent cover on the Richardson parcel (Figure 2). Had the pasture not been established, the land would have been in wheat strips. The runoff generation potential from the pasture is significantly less than from wheat strips.

The results in Table 7 are explained in Table 5 and the accompanying discussion in the "Land Use" section of this document. As is indicated in this section and in Table 7, the City's treatments were done on agricultural areas. These areas historically had relatively low plant cover and a significant amount of fallow ground, and consequently, a relatively high runoff generation potential. This is consistent with the record of previous flooding in the area. In addition, the cultivation for weed control and activities related to the conversion process implemented by the City did not result in large changes to the soil surface.

Evaluation of Specific Issues in Basin A

This section addresses the following specific issues which various claimants in Basin A have cited in allegations concerning damages to their properties:

1. The alleged increase in sediment produced by the storm due to the City's activities;

2. November 1988 grading of a "ditch" next to the fence along the southern border of Basin A;

3. Cutting of ten swales into the area being converted to native vegetation in Basin A;

4. The use of hay bales in Basin A where the swales meet with the alleged drainage ditch; and,

5. The alleged hay bale dam which was reportedly located at the southwestern corner of Basin A, across from the St. Mary Magdalene Episcopal Church on Cambridge Street.

Each of these issues are addressed in the following discussions.

Sediment Yield

Five claimants in Basin A allege that activities of the City degraded runoff quality and increased sediment yield from the flood, thus causing damages to their properties. In response to these allegations, the sediment yield in Basin A from the June 3, 1989 storm and the effects of the City of Boulder's activities were evaluated using two independent methods: (1) the Modified Universal Soil Loss Equation (MUSLE) developed by the SCS, and (2) the Universal Soil Loss Equation routed with sediment delivery ratios (USLE/SDR). In both methods, predictions were made of the amount of sediment released in the June 3, 1989 storm by each subbasin, and that amount of sediment was routed to the model outlet. A review of available sediment yield models indicated that these methods are most appropriate because:

1. The USLE and MUSLE were derived from studies on agricultural lands similar to the lands being studied;

2. Both methods will predict the effects of changes in land condition (such as changes which occurred in Basin A) on potential sediment yield;

3. Both methods have been widely used and have been subjected to extensive verification and review; and,

4. The MUSLE is still considered to be the state-of-the-art modeling method in regards to evaluation of soil erosion. MUSLE is utilized in many current computer models to predict soil loss (e.g., CREAMS).

As was done with the hydrologic modeling, sediment yield from "historic" conditions (conditions that would have existed had the City not treated the lands) was compared to the yield from land treated by the City. Comparisons of land use for Basin A are shown in Table 5.

Table 8 summarizes the results of the sediment yield study and shows that results from the two methods used are comparable.

Table 8 indicates that Basin A sediment was increased by 4.3-10.7 percent due to the City's activities. Because the soils in the basins are generally composed of clays and silts, most of the sediment produced is fine in texture, and not susceptible to deposition. This means that, relatively speaking, sediment will tend to be transported out of the basin and will only be deposited in areas of slow water or behind erosion control structures.

During a field inspection, Wright Water Engineers observed sediment deposited at one of the hay bale structures. According to City personnel (Dick Antonio) the amount of mud deposited on Cambridge Street was less than that from a reported storm in 1988.

TABLE 8

SUMMARY OF SEDIMENT YIELD FROM BASIN A

Sediment Yield	"Historic"[1]		June 3, 1989		Percent Change in June 3 vs. "Historic"	
	MUSLE[2]	USLE/SDR[3]	MUSLE[2]	USLE/SDR[3]	MUSLE[2]	USLE/SDR[3]
Tons/acre	5.00	5.04	5.53	5.26		
Tons	459	463	508	483	+10.7%	+4.3%

[1] "Historic" represents strip-cropping as has been conducted in the past.

[2] Soil loss predicted by the "Modified Universal Soil Loss" equation.

[3] Soil loss predicted by "Universal Soil Loss Equation" with sediment delivery ratios.

In conclusion, the relative increase in sediment in Basin A is small and would not be perceptible. The increase would not be the cause of structure failure and did not contribute to the alleged damages. That is, the claimants' properties would have incurred equivalent damages under "historic" conditions.

Activities to Ditch in Basin A. Wright Water Engineers interviewed Boulder Open Space staff[25] regarding the "historic" condition of the alleged "ditch" along the southern boundary of Basin A, and the alleged activities of the City in November 1988 on the ditch. In addition, Wright Water Engineers inspected the area on September 9, 1989 and March 21, 1990.

The alleged ditch is located entirely on City land. The exact origin of the alleged ditch is not known. The ditch is not continuous and was not designed according to engineering standards or approved for drainage control. The developer placed fill to the south of the ditch and landowners to the south along the ditch built fences, berms, retaining walls and other structures to divert runoff. Some of these structures were built on City land without notice or approval. Adjacent landowners have also dumped cut grass, leaves, and other debris in the area of the reported ditch.

The overall effect of these activities was to direct historically south/southwest-flowing runoff and sediment from Gunbarrel Hill in a westerly direction towards Cambridge Street.

The only activity of the City related to the alleged ditch in Basin A was to remove trash from the ditch in November of 1988. Trash removal was necessary due to dumping by adjacent landowners into the ditch and to the growth of weeds in the ditch. Specifically, the following activities were performed on the alleged ditch in November 1988:

1. A single pass with a grader was used to push trash and litter from the area;

2. The trash was graded into a windrow;

3. Large objects were handpicked by City staff from the windrow; and,

4. The remaining trash, mainly plant litter and debris, was reincorporated into the immediate area.

These activities did not materially affect the cross sectional area or the conveyance capacity of the alleged ditch in regards to the June 3 flood. Cleaning of the ditch would have a general effect of decreasing surface roughness and increasing the potential conveyance capacity of the ditch.

The alleged ditch has not been an officially recognized drainage feature in any drainage plans for the area. There is no right-of-way or easement for the ditch, and there is no entity responsible for maintenance of and improvements to the ditch. In summary, the activities of the City in November 1988 would have increased the capacity of the ditch by decreasing surface roughness.

Drainage Swales in Basin A. The "swales" in Basin A to which several claimants referred are shallow "water bars" which were purposefully constructed in Basin A to control sediment and runoff from the steeper portions of this basin. Ten water bars were built specifically to:

1. Slow surface runoff velocities to prevent or reduce soil erosion,

2. Trap sediment,

3. Reduce sediment losses from the basin, and

4. Help stabilize the basin until vegetation was established.

The water bars were constructed in a manner consistent with the CRP contract the City had for this land. The contract necessitates that adequate erosion control measures be implemented throughout the life of the project. Water bars are a frequently used and generally accepted erosion control technique in the Boulder area and along the Front Range.

Ten water bars were created using a grader. It was determined from surveying the water bars with a level that the bars were generally constructed to drain to the northwest. away from property owners to the south[25]. The water bars were constructed to function during 3- to 5-year flood events.

It is our opinion that construction of the water bars was consistent with accepted erosion control measures and did not increase flows or sediment along the southern boundary of Basin A. Furthermore, the water bars did not contribute to flood damages to the claimants' properties for the following reasons:

1. The water bars were constructed so that they generally sloped to the northwest and conveyed runoff away from properties to the south. This means that the flow path of the runoff was increased, thus increasing losses and decreasing the flood peak;

2. The water bars trapped sediment and generally performed as they were supposed to; and,

3. Inspection of the water bars on September 9, 1989 indicated that no significant degradation of the bars had taken place.

Use of Hay Bales for Erosion Control. Various claimants have alleged that hay bales used by the City contributed to their flood damages in Basin A.

Hay bales were installed along the alleged "ditch" in Basin A by the City specifically to disperse runoff and control the sediment which historically has come off this area. The bales were arranged along the southern basin

boundary to deflect flows and to trap sediment which otherwise could have flowed onto adjacent properties. Hay bales are commonly used by developers, cities, and others to control erosion from construction sites and disturbed sites. Hay bales are recommended in erosion criteria manual's and ordinances along the Front Range, and erosion plans which employ hay bales are frequently approved.

It is generally recommended that hay bales be staked into the ground to prevent them from being washed away during a flood. However, due to the relatively brief time period for which the bales were needed the City did not stake them into the ground. (Erosion control measures are typically designed to last throughout an entire project life which may be for up to a year or more; protective measures are required for approximately a one to two month period during the City vegetation process prior to establishment of native vegetation or a cover crop.)

Alleged Hay Bale Dam Failure. Several of the claimants have alleged that the hay bales which were placed on Gunbarrel Hill in Basin A were washed down to the southwest corner of the basin where they stacked up against the fence corner, and effectively creating a small dam. The hay bales allegedly ponded water back up into Basin A along its southern boundary and caused damages to several properties. Also, when the hay bale dam failed, a wave of water and sediment was sent downstream and damaged other properties, including the church on Cambridge Street.

Wright Water Engineers conducted an evaluation of the alleged hay bale dam in order to determine:

1. Whether significant water could have been ponded behind such a dam to cause damages to claimants' properties along Grasmere Drive; and

2. The effect on flood flows and sediment yield of the reported dam failure.

A field evaluation of the alleged hay bale dam site (Figure 2) was conducted by WWE on September 20, 1989. This included survey measurements. The goal of the evaluation was to determine: (1) whether sufficient water could have been stored to cause a flood wave if a dam failure did occur; and, (2) the magnitude of any flood wave from a dam failure.

The following assumptions were used to model the hay bale dam; it should be noted that these assumptions, in our opinion, are very conservative, and are not likely to have occurred:

- The hay bales formed a continuous and effective dam approximately 3 feet high in the fence corner;
- The dam extended 20 feet east along the fence line and 50 feet north along the other fence line;
- the dam existed long enough to fill with water; and,
- The dam failure occurred over a short period of time.

Based on these assumptions, our analysis shows that:

1. The maximum potential volume of water which could be stored behind the dam studied is approximately 50 cubic-feet. This represents a relatively small amount of water. That more water was not stored is due to the topography of the area which would allow for storage only in a limited area immediately adjacent to the fence. That is, the slope drops off steeply within approximately 20 feet of the fence, and water would exit to Cambridge Street 50 feet north of the fence corner as there is no boundary on the south to contain water.

2. Had the dam failed, the amount of water in storage would have caused an imperceptible increase in the flood flow rate. It is logical that the dam would have failed around the time of the peak flow (130 cfs). Had the dam failed over a short time period, flows would have been dispersed over a large area (that is, there is no defined channel into which it would have flowed).

Therefore, it is concluded that, had worst case conditions existed (a water-tight dam 3 feet high by 20 feet by 50 feet), only a small amount of water could have been stored behind a dam due to the topography. The failure of such a dam would not have caused a significant increase in the flood flow.

In regards to the potential of backwater effects, as discussed in this section, the topography of the hay bale dam area limits the potential for water to be stored and for any backwater effects. The channels from the east and northeast have abrupt breaks in slope which prevent backwater. The channel to the north along the fence would spill to Cambridge Street and could not result in backwater.

(BOS.3)

FOOTNOTES

1. Boulder County – Storm Drainage Criteria Manual, Boulder County, Colorado, June 1984.

2. Outfall System Planning Study – Gunbarrel Area, Urban Drainage & Flood Control District et al., December 1987.

3. Flood Insurance Rate Map – Boulder County, Colorado, Panels 130 and 140 of 225, Federal Emergency Management Agency, July 15, 1988.

4. Soil Survey of Boulder County Area, Colorado, Soil Conservation Service, U.S. Department of Agriculture, January 1975.

5. National Engineering Handbook (Section 4 - Hydrology), Soil Conservation Service, U.S. Department of Agriculture.

6. Memorandum to Jim Crain from Bruce Johnson, P.E., and Timothy Feehan regarding Gunbarrel Estates Detention Project, dated December 20, 1989, City of Boulder files.

7. Personal communication with Mr. Timothy Feehan, Water Resources Engineer for Boulder County, January 17, 1990.

8. "Drought Breaking Rain Leaves Mud," Longmont Times, July 26, 1977.

9. "Sun Cakes Gunbarrel Mud," Longmont Times, July 26, 1977.

10. Memorandum on file with Boulder County from A.J. Sariniello dated July 27, 1977 concerning flooding on June 15, 1977 in Gunbarrel Estates.

11. Memorandum in Boulder County files dated November 14, 1977 to Ann Raisch, from D.J. Galloway regarding a proposed drainage ditch along 73rd Street.

12. Copies of plat maps on file with Boulder County that showed location of flood damages.

13. Memorandum on file with Boulder County dated June 6, 1978 regarding Conway property drainage problems on Simmons Drive.

14. "Rains Cause Flooding, Gunbarrel Owners have to Bail Out Basements," Boulder Daily Camera, June 4, 1989.

15. "Heatherwood Wants Drainage Fixed, Flooding Sparks Complaints," Boulder Daily Camera, June 4, 1989.

16. Urban Storm Drainage Criteria Manual (Vols. 1 and 2), Denver Regional Council of Governments, March 1969 (most current version).

17. Boulder County Subdivision Regulations Article 12, adopted by Boulder County.

FOOTNOTES
(Continued)

18. Informal Report of the Evaluation of Alternatives for Outfall Systems – Boulder Gunbarrel Area, Urban Drainage & Flood Control District et al., February 1986.

19. Personal communication with Allan Taylor, Boulder Public Works, February 13, 1990.

20. HKA/UDFCD F2P2 Quantitative Precipitation Forecast, Date: 06/03/89, Henz Kelly & Associates, Flooding Potential Forecast, issued at 11:30 a.m., June 3, 1989.

21. Henz Kelly & Associates/Internal Alert Status Report, Date: 6/3/89, Henz Kelly & Associates, issued 12:30 p.m., June 3, 1989.

22. Climatological Data — Colorado, May 1989, Volume 94, No. 5, and Climatological Data — Colorado, June 1989, Volume 94, No. 6, National Oceanic and Atmospheric Administration, Asheville, NC, 1989.

23. Rain gage data obtained by personal communication with five Gunbarrel residents, footnoted in Table 2 of this report.

24. Personal communication with Dick Antonio, Boulder Open Space, September 9, 1989.

25. Personal communication with Chris Wilson, Boulder Open Space, February 15, 1990.

26. Memorandum to Wright Water Engineers from Delwin L. Andrew, farm operator, dated February 9, 1990.

27. HEC-1 Flood Hydrograph Package, U.S. Army Corps of Engineers, October 1970 (most current version used).

28. Personal communication with Tim Feehan, Water Resources Engineer for Boulder County, February 12, 1990.

29. Conservation plan - schedule of operations for City of Boulder, Form OMB No. 0579-0013, SCS, U.S. Department of Agriculture.

30. Appendix to Form CRP-1, Conservation Reserve Contract for City of Boulder, Form OMB No. 0560-0125, SCS, U.S. Department of Agriculture.