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MASTER DRAINAGE REPORT

WINDMILL GULCH DRAINAGE BASIN

October 1971

MASTER DRAINAGE STUDY

for

The Drainage Basin Of

WINDMILL GULCH

Prepared for:

The City of Colorado Springs, Colorado

by

UNITED WESTERN ENGINEERS
4525 Northpark Drive
Colorado Springs, Colorado

October, 1971

UNITED WESTERN ENGINEERS

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Colorado Springs, Colo. 80907

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Mr. DeWitt Miller
City Hall
P.O. Box 1575
Colorado Springs, Colorado

Subject: Drainage Report, Windmill Gulch Basin

Dear Deke:

We are pleased to submit herewith our master drainage study of that portion of the Windmill Gulch drainage basin lying between Peterson Field and the Town of Security in El Paso County, Colorado.

The report includes a study of the rainfall-runoff characteristics of the basin and investigates two alternatives of handling the runoff. Substantial information in the way of hydrographs and other computations are included for reference, as well as our preliminary cost estimates, and our recommendations for acceptance and drainage fee rates within the basin.

We are also transmitting a copy of the report to the Colorado State Engineer for his investigation of the alternative pertaining to 'staged' flows so that he may comment as to the applicability of State Laws regarding dams.

We remain available to answer any questions or supply additional information on the report at your request.

Respectfully Submitted,

UNITED WESTERN ENGINEERS

Oliver E. Watts

Oliver E. Watts
PE-LS 9853
Engineering Director

Enclosure

/cel

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Mr. Frederick W. Paddock
Department of Dams
Colorado State Engineer
540 South Pierce Street
Denver, Colorado 80226

Dear Mr. Paddock:

Transmitted herewith for your review is a copy of the engineering report on the Windmill Gulch Drainage Basin which this firm has prepared for the City of Colorado Springs. I discussed this report with you on September 7, 1971, when you requested this review.

Your review on what is termed the 'staged' alternative in this report is requested as to the applicability of state laws and regulations concerning dams. Should the recommendations of this report violate any laws or regulations your advise concerning necessary corrective measures is requested.

Two types of techniques are utilized in this report to 'stage' the storm runoff and lower the resulting outflow. One involves storage in reservoirs located in the bottom of natural isolated basins or 'buffalo wallows' which do not naturally contribute to runoff of the total basin, The other involves normal roadway culvert installations which create storage for head on these culverts, resulting in a 'staged' outflow.

Please do not hesitate to call me if I may be of assistance in providing any further information or explanation.

Sincerely yours,

UNITED WESTERN ENGINEERS

Oliver E. Watts

Oliver E. Watts, PE-LS
Engineering Director

Enclosure

/cel

WINDMILL GULCH

DRAINAGE BASIN

ENGINEERING REPORT

TABLE OF CONTENTS:

I. Basin Description

The Windmill Gulch Drainage Basin lies immediately Northeast of the community of Security in El Paso County, Colorado. Included in the basin are all or portions of the following sections.

Sections	Township & Range
29, 30, 31, 32	T 14 S, R 65 W
36	T 14 S, R 66 W
5, 6, 7	T 15 S, R 65 W
1, 12	T 15 S, R 66 W

The limits of this basin shown on Plat A, comprises a total area of 2810 acres.

The basin is bounded on the North by the Peterson Field Drainage Basin, on the East by the Jimmy Camp Creek Drainage Basin, to the Northwest is the East Fork of Sand Creek; the Southern limits bound against the Town of Security.

The basin is presently undeveloped in its entirety, with the exception of a few minor structures incidental to Peterson Field. Immediate future development of the Northern portion is anticipated in the Chandelle Airpark Center, for which a drainage report was completed in December, 1970.

The basin is traversed from West to East by Drennan and Bradley Roads and by Canal Number 4. Access trails traverse the basin at various locations. Culverts incidental to the roads and canal comprise the only drainage structures within the basin above the Town of Security. An existing concrete-lined trapezoidal ditch has been installed in the major streambed through Security, which is analyzed in a later section of this report.

The topography of the basin is comprised of rolling hills of moderate steepness. Soils are mostly of the sandy type having above average infiltration rates after thorough wetting. Soil cover is comprised of native grasses and shrubs and no evidence of prior farming is noted. The basin has served for many years as grazing land and the range averages from poor to fair condition, previous over grazings being evident in certain areas. No other vegitative cover is predominant, although minor patches of willow, Russian olive, oak, and small cottonwood lie in the bottom of the major stream course.

Several isolated natural sump or "buffalo wallows" lie within the drainage basin. These are isolated minor pockets for storm runoff where no outflow exists. The sandy nature of the soil in these basins allow immediate percolation and rainfall is not sufficient for any of these areas to show evidence of prolonged ponding of water. These sumps range in size from a few to several hundred acres, and they lie along the Northern edge of the basin, North of Drennan Road. The area isolated by these sumps comprises a total of 1110 acres of the total basin of

2810 acres. In other words, only 1700 acres of the total basin will drain naturally.

Approximately 640 acres of the basin now lies within the city limits of Colorado Springs, said land being a part of Peterson Field.

A. <u>References</u>

1. U.S. Department of Agriculture - Soil Conservation Services: Various papers published for computation of storm runoff.
2. U.S. Department of the Interior - Bureau of Reclamation: "Design of Small Dams", 1965
3. Linsley, Kohler and Pavlus: "Hydrology for Engineers", McGraw - Hill, 1958.
4. Linsley and Franzini: "Water - Resources Engineering" McGraw - Hill, 1964.
5. Los Angeles County Flood Control District: "Hydrology and Hydraulic Design Manual", 1964.
6. Denver Regional Council of Governments - "Urban Storm Drainage Criteria Manuals, Vol's I & II", 1969.
7. American Iron and Steel Institute: "Handbook of Steel Drainage and Highway Construction Products", 1967.
8. Albertson, Barton and Simons: "Fluid Mechanics for Engineers", Prentice - Hall, 1960.
9. U.S. Department of the Interior - Bureau of Reclamation: "Design Standards - Number 3 - Canals and Related Structures", December, 1967.
10. U.S. Department of the Interior - Bureau of Reclamation: "Hydraulic and Excavation Tables", 11th Ed., 1957.
11. State of California, Department of Public Works, Division of Highways: "California Culvert Practice", 2nd Edition.
12. State of Colorado, Department of Highways: "Roadway Design Manual", 1968, as revised.
13. "Pikes Peak Regional Land Use Plan - 1990", The Pikes Peak Area Council of Governments, 1970.

II. Method of Analysis

B. Hydrology

The method of hydrologic analysis of this drainage basin is that accepted and prescribed by the City of Colorado Springs and is commonly known as the Soil Conservation Service (SCS) method. This method is applicable to the intermountain and plains areas of Colorado where maximum runoff results from summer storms, with reoccurrence intervals of from two to one hundred years. The City of Colorado Springs has designated the design runoffs as that from a storm of two inches per hour intensity having a duration of one hour for the 50 year storm, and a 3 1/2 inch intensity of duration one hour for the 100 year design storm.

The following is a summary of the SCS method of analysis.

1. The drainage basin is split up into major and minor drainage basins, being chosen on the basis of location with respect to required structures or desired points of analysis.

2. Individual basins are measured for area in square miles (A), and the length (L) in feet and difference in elevation (H) in feet of the drainage course from the most remote point in the basin to the point of outflow.

3. The design runoff is computed for each minor basin from the formula

$$q_p = \frac{484\,AQ}{T_{PO}}$$

where:

q_p = design runoff
A = Area - square miles
Q = Direct runoff in inches
Tpo = Time to peak

(a) The time to peak (Tpo) is computed from the formula

$$Tpo = D/2 + 0.6\ Tc$$

where:

D = Rainfall excess time. Since it is assumed that soils are thoroughly wet at the time of the design storm of duration one hour, then D = 1.0. Tc = Time of concentration for the storm, computed from the formula

$$Tc = \left(\frac{11.9\,L^3}{H}\right)^{0.385}$$ for over land flov

where:

L = Length of drainage course - miles
H = Difference in elevation - feet

Where the flow is not overland; that is concentrated into structures or natural, definate stream beds; the time of concentration is calculated from the velocity of flow in the structures provided. Basins which have structures in the lower reaches only (a common occurrence) should be split at the upper limit of the structures and analyzed as two basins, the upper one by overland flow and the lower one by flow in structures.

(b) The direct runoff is computed from the rainfall intensity and the soil cover complex number. The Soil Conservation Service has designated a soil cover complex number for the variety of commonly encountered soils and soil covers. In the majority of the Colorado Springs area and in this drainage basin, the soils are of Type 'B' and soil cover complex numbers are commonly utilized as tabulated below. Using an SCS chart, entering with the basic data of the rainfall intensity (2 inches 50 year, 3.5 inches 100 year) the below listed direct runoffs are obtained.

Type of Cover	Soil Cover Complex No.	Direct Runoff-in. Q50	Q100
Good to fair range land, Native State	74	0.36	1.25
Parks & Greenbelt Areas	50	0.02	0.20
Average Subdivision	94	1.42	2.89
Apartment - Small Business Areas with average parking	95	1.50	2.97
Commercial & School Sites & Road Rights-of-Way	97	1.70	3.20
Fully paved areas of Substantial Slope	100	2.00	3.50

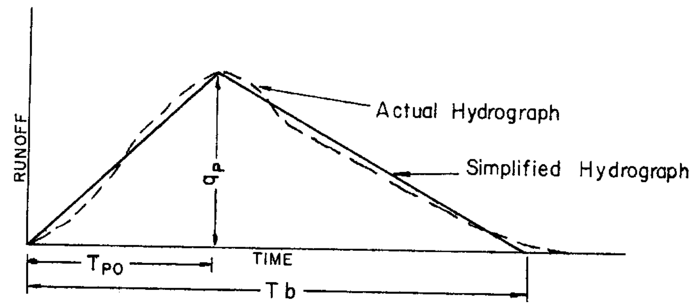
The standard practice is to perform hydrologic analysis on the 50-year runoff and convert where necessary to the 100-year runoff by multiplying by the Q100/Q50 runoff factor. An altogether too common practice is to apply the rainfall factor of 3.50/2.00 = 1.75, which is applicable only to fully paved areas and is, therefore, inaccurate in all but extremely few cases.

Many minor basis analyzed will overlap areas with varying Soil Cover Complex Numbers, and a composite curve must be developed which applies to the basin as a whole. The following is a sample calculation of this analysis.

	Area-Acres	Portion of Total Area	Curve Number	PxC
	10	0.23	50	11.5
	15	0.35	94	32.9
	3	0.07	100	7.0
	8	0.19	95	18.0
	7	0.16	97	15.5
TOTALS	43	1.00		84.9

This basin would then be analyzed as a whole, with a curve number of 85 and a resulting Q50 of 0.78, Q100 of 2.03, and $q_p 100/q_p 50$ of 2.60.

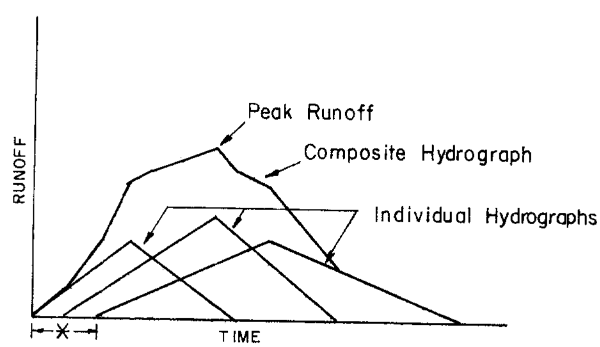
4. The simplified hydrograph is developed for individual basins as follows.



where: $Tb = 2.67\ Tpo$

This hydrograph is applicable to the point of discharge from the individual basin in question.

5. Hydrographs are compiled for the various points of interest in the basin, utilizing hydrographs of individual basins and compiling them as follows:



The composite hydrograph is a simple numerical summation of the individual hydrographs as rectified to the particular point of analysis. This rectification is done by calculating the travel time of runoff from the point of original analysis to the location of the composite hydrograph and offsetting the individual hydrograph by that amount. This is the time it takes for water to flow along the drainage course calculating for velocity of overland flow or velocity of flow in the type of structures provided. The total resulting flow must be assumed to calculate the required structures and resultant travel time and these assumptions must be verified by the flow time resulting in the final design. This results in a trial and error method, however, experienced hydrologists can usually verify a travel time within 0.01 hour on the initial assumption.

The summation of individual hydrographs to the composite hydrograph may be done graphically in most cases. Where reservoirs are utilized, however, the inflow characteristics are needed more precisely with respect to time. The individual hydrographs should then be interpreted analytically, and time intervals on the abcissa should be taken to correspond to ordinate zeros and peaks on the individual hydrographs.

C. Reservoir Staging

An alternative in many drainage studies is to provide reservoirs for flood control purposes from which an outlet works of some nature is provided to limit the flow to an allowable quantity. In addition, roadway culverts designed by criteria other than that of the City of Colorado Springs will require a similar analysis. The Colorado State Highway Department, for instance, designs their culverts to pass a 10-year storm flowing full under no head, and to pass a 50-year storm flowing under the full head allowable by the height of the road fill. Since the major greenbelts within the City of Colorado Springs are normally designed to pass a 100-year storm with no storage allowed, it is obvious that the 100-year storm run-off must be "staged" through culverts designed under an alternative criteria.

The following is a description of the analysis of this reservoir staging. It is applicable to the above two instances, as well as to spillway designs. In designing dams under the State Engineers criteria, the spillway must normally be designed to pass the "maximum probable" flood, and in those instances the outlet works is usually not considered, as the runoff is substantially higher and the plugging of the outlet works is probably due to the high sediment loading.

1. A reservoir storage curve is first developed by planimetering individual contour lines within the reservoir and calculating the acre-feet of storage.

2. An outflow conduit (or spillway) capacity curve is then developed for depth of water versus outflow in CFS. In the case of conduits, the curve is developed considering flows under partially full conditions and flow under pressure. Inlet, friction, elbow, transition and outlet losses must be considered. In the case of spillways the shape of the spillway crest, drawdown, transition losses and other factors must be considered. (See Section III E).

3. The resulting outflow hydrograph is obtained by a trial and error method. The outflow is first assumed for each increment of the inflow hydrograph and the resulting storage is calculated. The water level under this storage is compared with the water level giving the assumed outflow. The outflow is adjusted until the two water levels agree. By this

method the outflow hydrograph is developed and is utilized for all downstream hydrograph developments.

D. <u>Hydraulics</u>

Mannings Formula is the general basis for all hydraulic analysis utilized in this report, with the exception of spillway crest flows, discussed later. This formula comes in two general forms as follows:

$$= \frac{1.486}{n} AR^{2/3} S^{1/2} \text{ for channels}$$

$$= \frac{0.463}{14} D^{8/3} S^{1/2} \text{ for pipes}$$

Where: = Flow of water in cubic feet per second.

n = A constant, depending upon the roughness characteristics of the conduit, assumed for purposes of this investigation to be as follows.

n = 0.013 for concrete pipe or formed concrete structures.
n = 0.015 for concrete lined channels, other than slipformed
n = 0.018 for guited or shot-creted channels
n = 0.024 for corrugated metal pipe, standard uncoated 2 2/3" corrugations
n = 0.035 for standard well graded rip-rap, 18" max.

A = The area of the water cross-section in square feet.
R = The hydraulic radius of the conduit, being the area divided by the wetted perimeter.
S = The slope of the hydraulic gradient, expressed as a decimal.
D = The diameter of the circular conduit, when flowing full, usable only when the hydraulic gradient equals the slope of the conduit, or when minor losses are ignored.

1. Open channel designs. For most purposes in this report a shortcut method is utilized and the optimum shape of trapezoidal channel is assumed; that being where the bottom width (b) is equal to the depth of water (d) and where the side slope is one horizontal (Z) to one vertical. This permits a constant to be used in the design, avoiding the necessary trial and

error solution. This constant is as follows:

$$1.93 = \frac{q_p n}{b^{8/3} S^{1/2}}$$

For the given flow and slope, and assuming the necessary 'n' valve, the bottom width is then solved for. The area of the section is then 2b and a standard channel is specified to provide the necessary structure, plus freeboard.

Freeboard is taken as 6-inches for minor channels within the collection system and one foot for major channels within the outfall or greenbelt channels. For detailed final design the freeboard should be taken as a function of the velocity and the Froude number, considering curve radii in accordance with good engineering practice.

In certain cases, a standard bottom width is assumed to allow for maintenance, a minimum of eight feet being provided. A brief trial and error analysis is made to verify freeboard, the depth being assumed and varied until the constant AR common to each channel reach is had.

The velocity of flow is then calculated, V = /A and the travel time to subsequent hydrograph points is calculated and verified against the original assumptions. An error in travel time of 0.01 hours is considered allowable before modification of the hydrographs is required.

2. Conduit Designs. For conduits flowing full or partially full under no pressure, the formulas above are utilized, and sufficient freeboard on the entrance is provided to allow submergence of the entrance to the extent of the entrance head loss, this being:

hi = 0.022 V for C.M.P.
hi = 0.017 V for concrete pipe, box culverts, concrete arches, and corrugated arch plate culverts

More detailed analysis in the final design will be required for transition losses and possibly more efficient resulting structures.

For conduits flowing full under pressure, the following formula is applicable where the length is short with respect to the conduit diameter.

H = 1.5

Where: H = gross head, the difference between the reservoir surface and the crown of the conduit outlet or outlet water surface.
L = the length of the conduit
g = 32.2

The resulting flows are obtained easiest by the chart on Page 375 of the "Small Dams" book referenced. The use of this formula assumes free discharge characteristics and no elbow or transition losses which is verified in the design.

Where the length of the conduit is great with respect to the diameter 'minor' losses are ignored and the simplified hydraulic gradient is utilized in the Manning formula.

Culvert entrance characteristics vary slightly within the report but, in general, the culvert is buried below original ground and the inverts taken to coincide with inlet channel inverts where applicable. In the case of inlet channels this will permit the culvert to flow full before storage is experienced in the reservoir, increasing the efficiency of the installation. In other cases, the culvert must flow partially full during storage.

In the final design, refinments in grade will be required, based on a detailed survey of proposed channel centerlines. The preliminary designs shown in this report are based on the topography shown on plates A and B, and further refinment is considered unwarranted due to the inherent innacurracy of this topography.

III. Computations

A. Description of Alternatives and Criteria

The enclosed plates show the proposed development of the entire basin, and sets forth zoning requirements which are in accordance with the Pikes Peak Regional Land Use Plan referenced. This zoning is an integral part of the analysis of this report, and is the basis upon which all calculations are made. Utilizing this general guidline, the planners of this firm have proposed the shown subdivision layouts, upon which the drainage structures are provided. This layout is an assumption and provides the necessary basis for this report. The Chandelle Airpark Subdivision is shown in accordance with the previously approved preliminary plan, and an independant analysis of this area is made.

1. Criteria. The following criteria have been given to this firm by the City of Colorado Springs as a basis for the report.

a. The collection system is designed for a 50-year storm.

b. The major channels within greenbelt areas are designed for a 100-year storm.

c. Complete drainage of the entire basin is provided and no storage of a permanent or sustained period is allowed.

d. All proposed or resulting reservoir staging is on the basis of a 100-year storm.

2. Staged Alternative. This alternative uses reservoir staging techniques to limit the total outflow of the basin to a quantity which may be carried by existing drainage facilities downstream of the basin and the structures are shown on plate A. Two types of reservoir staging are experienced.

Advantage is taken of the natural sump areas or 'buffalo wallows' in the Northern portion of the basin, and a certain amount of flooding is permitted to occur under the design storm, in these cases the 100-year storm. Since these basins are of relatively flat topography, they are improved by construction of reservoir areas to limit the area of flooding, permitting maximum development. As these basins are topographically isolated and must be drained by the outlet conduits provided, they are not considered to fall under the State Engineer's juristiction. It may be seen that certain minor modifications are necessary within the proposed layout of the Chandelle Airpark in the vicinity of these reservoirs.

Certain road crossings along the major greenbelt areas are designed in accordance with standard roadway practice, except that the Colorado Highway Department Criteria is exceeded in the design. Instead of the highway 50-year design storm, these crossings are designed so that the roadway is not overtopped under the 100-year storm. In addition, a minimum of four feet of freeboard is specified as a safety factor.

The cost of the road fills, and the cost of the land lost to development in the flooded areas is attributed to the cost of development of this alternative. The purpose of this is twofold; to allow for a reasonable comparison of costs and to make construction of these road fills mandatory under future development of the basin.

The resulting outflows are handled in such a way as to fall within the capacity of the existing channel in the Town of Security, thereby eliminating the legal requirement to significantly improve the downstream reaches of the basin due to the increased runoff incurred under basin development. Included in this alternative, however, is the necessary replacement of the Alpine Avenue and Grand Boulevard culverts within the Town of Security, whose capacities are considerably less than the capacity of the channel.

Another investigation is made pertaining to this alternative which investigates the installation of a flood control dam, the location for which is shown on Plate A. This dam would clearly fall within the juristiction of the State Engineer and would require installation of a spillway capable of handling the maximum probable flood. The cost of this dam and spillway is prohibitive and, although substantiating information of this fact is included in this report, this subalternative is not considered in detail.

3. Unstaged Alternative. This alternative handles the design runoff in the standard method employed by the city over the past years, the structures for which are shown on Plate B.

Facilities are constructed which will permit discharge of the peak design runoffs and no flooding is permitted within the basin. The natural buffalo wallows are drained by conduits with submerged inlets so that they will handle the 100-year design storm flowing full without flooding occurring.

This alternative will result in flows out of the basin which will exceed the capacity of downstream facilities. It has been decided, therefore, that the city will incur a legal responsibility to improve or replace these facilities to the point of additional flows created. Since improvement is impractical the existing facilities are proposed to be removed and replaced with new facilities, and additional structures are provided to discharge these flows to Fountain Creek. The cost of these new facilities are included in this alternative and are considered applicable to the proposed drainage fee within the Windmill Gulch Basin.

Additional storm runoff from areas below the basin limits must, of course, be taken by the downstream facilities which will be provided. The cost of the additional size of these structures, however, must be born by the downstream residents. For the purpose of this report, the structures shown are sufficient to handle the flows of only the Windmill Gulch basin and costs are calculated accordingly.

B. Hydrology - Undeveloped Basin

The following are the hydrologic calculations and hydrographs pertaining to the design runoff from the Windmill Gulch drainage basin in its existing state. This analysis is provided to establish the present adequacy of the existing drainage structures downstream. It may be seen that the runoff from the 100-year design storm is 4547 CFS. From the hydraulic analysis of the existing facilities, included in Section III E4, it may be established that the channel through Security is not sufficient to accomodate this runoff, and the culverts on this channel are considerably undersized. For this reason, the city may wish to obtain a cost share from the county for replacement of these facilities under the various alternatives, although this report does not consider this in the estimate.

It should be noted that a large portion of the community of Security and Widefield lies below the end of the existing drainage facilities. It is readily apparant that a number of homes and structures are inadequately protected from storm runoff in the existing basins. These endangered structures are shown in detail on Plate B.

UNDEVELOPED FLOWS

Curve # = 74

MAJOR BASIN	SUB BASIN	AREA Planim. Read	AREA MILE	BASIN LENGTH	BASIN HEIGHT	Tc	DITCH LENGTH	DITCH SLOPE	V	TPO	FLOW Q	FLOW qp	Tb
I	A	33.97	0.1097	2800	90	0.205				0.62	0.36	74.0	1.66
II	A	25.91	0.0836	3000	100	0.213				0.63		55.0	1.67
	B	40.67	0.1313	4450	170	0.280				0.67		82.6	1.78
III	A	8.65	0.0279	4050	160	0.121				0.57		20.6	1.53
	B	Isolated				0						-0-	
	C	62.10	0.2005	5700	160	0.388				0.73		113.5	1.96
IV	A	38.41	0.1240	4050	160	0.250				0.65		79.1	1.74
	B	54.00	0.1743	4250	120	0.290				0.67		108.4	1.80
	C	75.25	0.2429	5500	160	0.360				0.72		141.0	1.91
	D	19.18	0.0619	2200	100	0.151				0.59		43.0	1.58
V	A	33.78	0.1091	4000	110	0.290				0.67		67.1	1.80
	B	51.40	0.1659	4500	100	0.321				0.69		99.8	1.85
	C	24.32	0.0785	3300	100	0.231				0.64		51.6	1.71
	D	33.69	0.1088	3650	130	0.240				0.64		70.5	1.72
	E	10.32	0.0333	1300	30	0.135				0.58	0.36	24.1	1.52

HYDROLOGIC COMPUTATION — BASIC DATA

PROJ: Windmill Gulch

By: OE Watts

Date 8-20-71

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Undeveloped

MAJOR BASIN	SUB BASIN	AREA Planim. Read	AREA MILE	BASIN LENGTH	BASIN HEIGHT	Tc	DITCH LENGTH	DITCH SLOPE	V	TPO	FLOW Q	FLOW qp	Tb
VI	A	21.76	0.0702	3100	90	0.230				0.64	0.36	46.4	1.70
	B	31.46	0.1016	4250	130	0.290				0.67		61.9	1.80
	C	30.20	0.0975	2200	80	0.165				0.60		67.1	1.60
	D	81.80	0.2834	4150	123	0.290				0.37		175.4	1.80
	E	Isolated										-0-	
VII	A	74.03	0.2390	5900	170	0.380				0.73		154.8	1.94
	B	34.29	0.1107	4200	140	0.280				0.67		68.8	1.78
	C	31.70	0.1023	4400	110	0.320				0.69	0.36	62.0	1.85
VIII	A	Isolated										-0-	
	B												
	C												
	D												
	E												
	F											-0-	

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MAJOR BASIN	SUB BASIN	AREA Planim. Read	AREA MILE	BASIN LENGTH	BASIN HEIGHT	Tc	DITCH LENGTH	DITCH SLOPE	V	TPO	FLOW Q	FLOW qp	Tb
VIII	G	Isolated										-0-	
IX	A	Isolated										-0-	
	B												
	C												
	D												
	E												
	F										0.36		
	G												
X	A												
	B												
	C												
	D											-0-	

Total area 1700 ac 2.6564 SM = 60.5% total basin

Total area isolated 1110 Ac 1.7350

HYDROLOGIC COMPUTATION — BASIC DATA

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Windmill Gulch - Undeveloped

LINE	FROM	TO	BASE qp	BASE Tp	DITCH L	DITCH S	DITCH TIME	Tp at POINT	Tp of NEXT	DIFF	qp	STREET CPY	Orig. Tb	REMARKS New Tb
I	A	1		0.62	0	--	0	0.62					1.66	1.66
II	A			0.63	0	--	0	0.63					1.67	1.67
	B			0.67	1920	1.3	0.60	1.27					1.78	2.38
III	A			0.57	1920	1.3	0.60	1.17					1.53	2.13
	C			0.73	3150	1.6	0.80	1.53					1.96	2.76
IV	A			0.65	3150	1.6	0.80	1.45					1.74	2.54
	B			0.67	5670	2.1	0.94	1.61					1.80	2.74
	C			0.72	5670	2.1	0.94	1.66					1.91	2.85
	D			0.59	4260	1.6	0.88	1.47					1.58	2.46
V	A			0.67	5640	1.6	0.98	1.65					1.80	2.78
	B			0.69	7680	1.4	1.16	1.85					1.85	3.01
	C			0.64	7290	1.4	1.15	1.79					1.71	2.86
	D			0.64	5640	1.6	0.98	1.62					1.72	2.70
	E			0.58	12090	1.7	1.33	1.91					1.52	2.85
VI	A			0.64	8910	1.3	1.25	1.89					1.70	2.95

HYDROLOGIC COMPUTATION —— ROUTING
SHEET 1 OF 2

U·W·E·
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LINE	FROM	TO	BASE qp	BASE Tp	DITCH L	DITCH S	DITCH TIME	Tp at POINT	Tp of NEXT	DIFF	qp	STREET CPY	Orig. Tb	REMARKS New Tb
VI	B			0.67	8910	1.3	1.25	1.92					1.80	3.05
	C			0.60	11460	1.5	1.32	1.82					1.60	2.92
	D			0.67	11460	1.5	1.32	1.89					1.80	3.12
VII	A			0.73	8910	1.3	1.25	1.98					1.94	3.19
	B			0.67	8910	1.3	1.25	1.92					1.78	3.03
	C			0.69	10980	1.6	1.27	1.96					1.85	3.12

HYDROLOGIC COMPUTATION —— ROUTING
SHEET 2 OF 2

UWE

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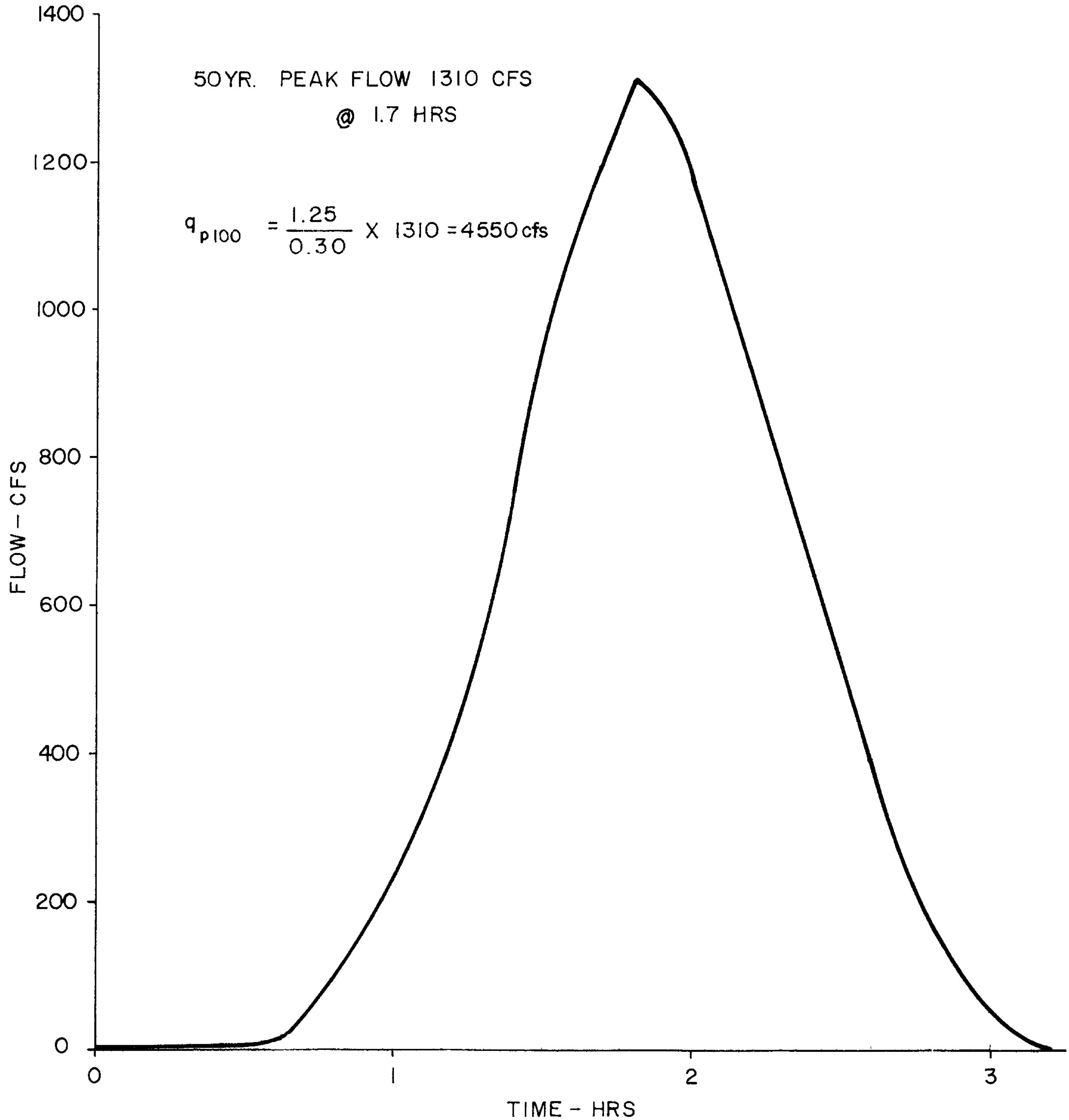

WINDMILL GULCH BASIN
POINT NO. 1 - HYDROGRAPH
EXISTING CONDITIONS
FIG. 1

III.

C. Hydrology - Fully Developed Basin

The following are the hydrologic calculations for the fully developed Windmill Gulch Basin in accordance with the zoning and proposed subdivision layouts shown on Plates A and B. The calculations are for the 50-year design storm, and factors are applied to obtain the 100-year design storm where required, as described in Sections II B.

Composite curve numbers are applied for individual basins as previously described, however, within the naturally isolated basins North of Drennan Road, different curve numbers are utilized on the 50 and 100-year storms. These basins contain soils of a greater than average percolation, and all present runoff in these areas is rapidly absorbed into the ground. This is accounted for in a curve number lower than normally applied under full subdivision development for the 100-year storm. For the 50-year storm, however, we apply a higher runoff factor to obtain an additional safety factor in the collection system design, accomodating an anticipated sealing of the pervious soils due to sediment loads.

Hydrographs, storage curves and other data are included in Section III E of this report, under the respective alternatives.

1" = 300'   Developed Area $Tpo = 0.5 + 0.6\ Tc$ $qp = \frac{484\ AQ}{Tpo}$ $Tb = 2.67\ Tpo$

MAJOR BASIN	SUB BASIN	AREA Planim. Read	AREA MILE	BASIN LENGTH	BASIN HEIGHT	Tc	DITCH LENGTH	DITCH SLOPE	V	TPO	FLOW Q	FLOW qp	Tb
I	A	33.97	.1097	1750	90	0.122	880	3.86	18.9	0.586	1.42	128.7	1.57
II	A	25.91	.0836	1100	50	0.090	700	3.43	13.4	0.568		101.2	1.52
	B	40.67	.1313	2050	75	0.171	1650	4.91	20.1	0.626		144.2	1.67
III	A	8.65	.0279	400	20	0.042	830	3.04	18.0	0.544		35.2	1.45
	B	29.26	.0945	1350	35	0.130				0.578		112.4	1.54
	C	62.10	.2005	3350	70	0.28	1400 550	1.43% 8.18%	13.9 26.8	0.701	1.09	150.9	1.87
IV	A	38.41	.1240	1600	65	0.125	1750	4.29%	19.9	0.599	0.80	80.2	1.60
	B	54.00	.1743	3400	70	0.27	1000	5.00%	23.3	0.674	0.80	100.1	1.80
	C	75.25	.2429	4000	95	0.31	1900	3.68%	21.9	.706	1.24	2065	1.89
	D	19.18	.0619	2200	100	.151				.591	0.42	21.3	1.58
V	A	33.78	.1091	4000	110	.290				.674	1.09	85.4	1.80
	B	51.40	.1659	4500	100	.321				.693	1.09	126.3	1.85
	C	24.32	.0785	3300	100	.231				.639	0.21	12.5	1.71
	D	33.69	.1088	3650	130	.240				.644	0.35	28.6	1.72
	E	10.32	.0333	1300	30	.135				.581	1.42	39.4	1.52

HYDROLOGIC COMPUTATION — BASIC DATA

PROJ: Windmill Gulch   By: OE Watts   Date: 8-16-71

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1" = 300'

MAJOR BASIN	SUB BASIN	AREA Planim. Read		BASIN LENGTH		Tc	DITCH LENGTH		V	TPO	FLOW Q		Tb
		Planim. Read	MILE	LENGTH	HEIGHT		LENGTH	SLOPE			Q	qp	
VI	A	21.76	.0702	950	50	0.076	2500	2.00%	34.8	0.566	1.09	65.4	1.51
	B	31.46	.1016	1500	110	0.093	2500	2.00%	34.8	0.655	1.25	93.8	1.75 1.80
	C	30.20	.0975	2200	80	.165				.599	1.42	111.9	1.60
	D	87.80	.2834	4150	123	.290				.674		289.0	1.80
	E	17.10	.0552	1600	20	.200				.620		61.2	1.66
VII	A	74.03	.2390	5900	170	.380				.728	0.23	36.5	1.94
	B	34.29	.1107	4200	140	.280				.668	0.02	1.6	1.78
	C	31.70	.1023	4400	110	.320				.692	1.09	78.0	1.85
VIII	A	33.07	.1068	2800	50	.260				.656	1.50	118.2	1.75
	B	12.37	.0399	1100	32	.108				.565	1.50	51.2	1.51
	C	22.40	.0723	1850	75	.132				.579	1.42	85.8	1.55
	D	30.38	.0981	1950	63	.160				.596		113.1	1.59
	E	37.87	.1223	2200	24	.265				.659		127.5	1.76
	F	16.80	.0542	1750	30	.190				.614	1.10	47.0	1.64

HYDROLOGIC COMPUTATION — BASIC DATA

PROJ: Windmill Gulch

By: OE Watts

Date: 8-16-71

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MAJOR BASIN	SUB BASIN	AREA Planim. Read		BASIN		Tc	DITCH		V	TPO	FLOW		Tb
			MILE	LENGTH	HEIGHT		LENGTH	SLOPE			Q	qp	
VIII	G	11.95	.0386	1000	35	.092				.555	1.42	47.8	1.48
IX	A	49.71	.1590	3000	60	.262				.657	1.20	140.5	1.75
	B	37.39	.1196	3350	90	.250				.650	1.42	126.5	1.74
	C	36.53	.1168	2600	78	.200				.620	1.50	136.8	1.66
	D	13.28	.0424	1800	60	.150				.590	1.42	49.4	1.58
	E	28.68	.0917	2600	56	.228				.637		98.9	1.70
	F	17.13	.0548	2400	46	.225				.635		59.3	1.70
	G	22.42	.0717	1500	40	.140				.584		84.4	1.56
X	A	36.52	.1168	3000	60	.262				.657		122.2	1.75
	B	11.75	.0376	1500	4	0.36				0.716		36.1	1.91
	C	25.50	.0816	1500	20	.185				.611		91.8	1.63
	D	50.37	.1611	3000	55	.275				.665		166.5	1.78
TOTAL	2810.5 acres		4.3914										

HYDROLOGIC COMPUTATION – BASIC DATA

PROJ: Windmill Gulch

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III.

D. Hydrology - Maximum Probable Flood at Damsite.

The following are the calculations and the hydrograph pertaining to the maximum probable flood at the damsite, considered as an alternative within the staged flow alternative of this report. This is the flow upon which the design of the spillway of the dam must be based.

The method utilized is the Soil Conservation Service Method for maximum probable flood in a "high-hazard" dam where significant loss of life and property will occur on dam failure. This method is outlined in the "small dams" book referenced.

Point #2 and Dam

Dam is actually 780' above point #2 to upstream toe-assumed to include drainage areas III C and IV A.

Maximum Probable Flood Calculations

Soil Cover Complex (Type B Soil)

Basin	Area SM	% Total Area	Curve #	% x Curve #
III C	0.2005	0.0520	90	4.7
IV A	0.1240	0.0322	86	2.8
B	0.1743	0.0452	85	3.8
C	0.2329	0.0630	92	5.8
D	0.0619	0.0161	77	1.2
V A	0.1091	0.0283	90	2.5
B	0.1659	0.0431	90	3.9
C	0.0785	0.0204	69	1.4
D	0.1088	0.0282	74	2.1
E	0.0333	0.0086	94	0.8
VI A	0.0702	0.0182	90	1.6
B	0.1016	0.0264	92	2.4
C	0.0975	0.0253	94	2.4
D	0.2834	0.0736	94	6.9
E	0.0552	0.0143	94	1.3
VII A	0.2390	0.0620	70	4.3
B	0.1107	0.0287	50	1.4
C	0.1023	0.0266	90	2.4
VIII A	0.1068	0.0277	95	2.6
B	0.0399	0.0136	95	1.3

Basin	Area SM	% Total Area	Curve #	% x Curve #
VIII C	0.0723	0.0189	94	1.8
D	0.0981	0.0255	94	2.4
E	0.1223	0.0317	94	3.0
F	0.0542	0.0141	91	1.3
G	0.0386	0.0100	94	0.9
IX A	0.1590	0.0413	91	3.8
B	0.1196	0.0310	94	2.9
C	0.1168	0.0303	95	2.9
D	0.0424	0.0110	94	1.0
E	0.0548	0.0142	94	1.3
G	0.0717	0.0186	94	1.7
X A	0.1168	0.0303	94	2.8
B	0.0376	0.0098	94	0.9
C	0.0816	0.0212	94	2.0
D	0.1611	0.0418	94	3.9
TOTALS	2466 acres 3.8527	1.00	----	88.2 Use 88

Dam - Cont

Time of Concentration: Travel time from most remote point (area # IX A)

Location	Time-Hrs.
IX A	Tc=0.26
	0.03
Point 10	
	0.08
Point 11	
	0.05
Point 6	
	0.03
Point 4	
	0.04
Point 3	

Point 3 - Dam

$Q = 515$ CFS +

$S = \frac{5856 - 5820}{1940} = 0.0186$

$b\ 8/3 = \frac{515 \times 0.015}{1.93 \times 0.1362} = 29.39$

$b = 3.55$

$v = \frac{515}{25.20} = 20.4$ FPS

$\text{Time} = \frac{1940}{3600\ V} = 0.03$ hrs.

Subtotal 0.49 hrs.

Total Tc = 0.52 hrs.

Check Remote Area X D

X D	Tc = 0.28
	0.40
Point 12	
	0.03
Point 11	
	0.15
Dam	

E = 0.58 hrs. ← Use

Tc < 3 hrs Use 1/2 hr. increments, adjust on 6, 4, 3, 1, 2, 5 order
Figure 1 6-hr. 10 SM precip = 22.8 in., Zone 4 East of 105°
Figure 2 Max, Prob. Precip. Ignore runoff after 24 hrs.

Duration - Hrs.	% 10 SM 6 hr.	Total Rain-in.
0-6	100	22.8
0-12	111	25.3
0-24	117	26.7

Use Zone C

Time - Hrs.	Figure 4 % 6 hr.	Accum. Rain - In.	Inc. Rain	Adjusted Inc. Rain	Adjusted Accum. Rain
0	0	0			0
1/2	36	8.2	8.2	0.9	0.9
1	49	11.2	3.0	0.9	1.8
1 1/2	57	13.0	1.8	1.1	2.9
2	64	14.6	1.6	1.0	3.9
2 1/2	70	16.0	1.4	1.4	5.3
3	75	17.1	1.1	1.1	6.4
3 1/2	80	18.2	1.1	8.2	14.6
4	84	19.2	1.0	3.0	17.6
4 1/2	88	20.1	0.9	1.8	19.4
5	92	21.0	0.9	1.6	21.0

Time - Hrs.	Figure 4 % 6 hr.	Accum. Rain - In.	Inc. Rain	Adjusted Inc. Rain	Adjusted Accum. Rain
5 1/2	96	21.9			21.9
			0.9	0.9	
6	100	22.8			22.8
			2.5	2.5	
12	---	25.3			25.3
			1.4	1.4	
24	---	26.7			26.7

Direct Runoff From Fig A-4, Curve #88

Time - Hrs.	Inc. Rain	Accum. Rain	Runoff		Inc. Loss
			Accum.	Inc. (Q)	
0		0	0		
	0.90			0.01	0.89
1/2		0.90	0.01		
	0.90			0.81	0.09
1		1.80	0.82		
	1.10			0.96	0.14
1 1/2		2.90	1.78		
	1.00			0.90	0.10
2		3.90	2.68		
	1.40			1.32	0.08
2 1/2		5.30	4.00		
	1.10			1.07	0.03
3		6.40	5.07		
	8.20			8.18	0.025 (1)
3 1/2		14.60			
	3.00			2.98	Abandon Curve
4		17.60			
	1.80			1.77	0.025
4 1/2		19.40			
	1.60			1.58	0.025
5		21.00			
	0.90			0.88	0.025
5 1/2		21.90			
	0.90			0.88	0.025
6		22.80			
	2.50			2.20	0.30
12		25.30			
	1.40			0.80	0.60
24		26.70			

(1) Use 0.05 in/hr loss min = 0.025"/1/2 hr, round even
= 0.30"/6 hr
= 0.60"/12 hr

where Tc=0.58 hrs
$Tp = D/2 + 0.35$
where A=3.85 SM
$qp = 1863.4 \frac{Q}{Tp}$

Tp=0.60 for D=0.50
Tp=3.35 for D=6.00

Incremental Hydrographs

$Tp = D/2 + 0.6\ Tc$
$Tb = 2.67\ Tp$
$qp = \frac{484\ AQ}{Tp}$

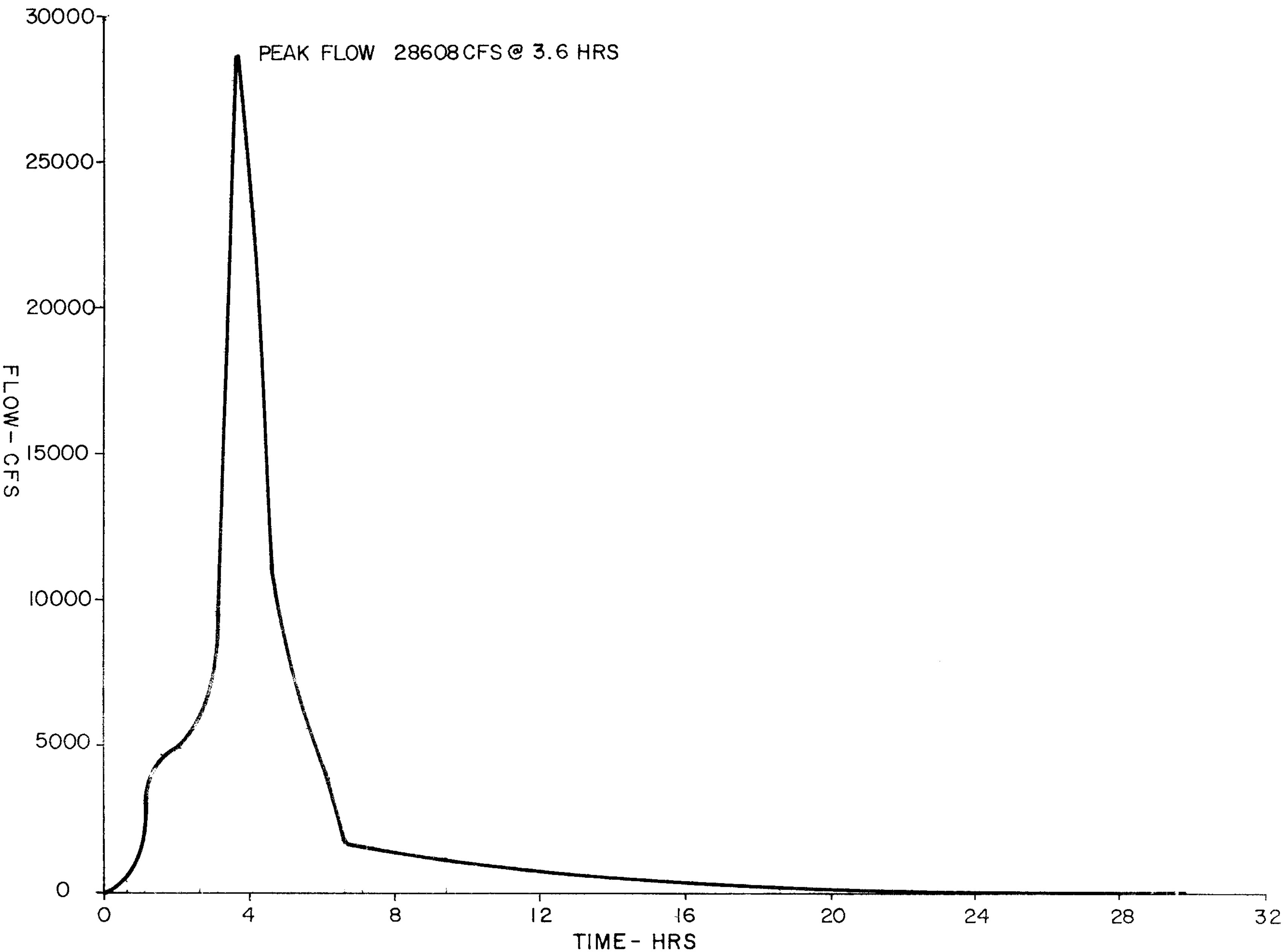
Time - Hrs	D	Q	To	Tp	Tb	Qp
0						
1/2	0.50	0.01	0	0.60	1.6	31
1		0.81	0.50	1.1	2.1	2515
1 1/2		0.96	1.00	1.6	2.6	2981
2		0.90	1.50	2.1	3.1	2796
2 1/2		1.32	2.00	2.6	3.6	4099
3		1.07	2.50	3.1	4.1	3323
3 1/2		8.18	3.00	3.6	4.6	25404
4		2.98	3.50	4.1	5.1	9255
4 1/2		1.77	4.00	4.6	5.6	5497
5		1.58	4.50	5.1	6.1	4907
5 1/2		0.88	5.00	5.6	6.6	2733
6	0.50	0.88	5.50	6.1	7.1	2733
12	6.00	2.20	6.00	9.35	14.94	1224
24	12.00	0.80	12.00	18.65	29.76	224

Tp=6.65 for D=12.00

Tb=1.60 for D=0.50

Tb=8.94 for D=6.00

Tb=17.76 for D=12.00



WINDMILL GULCH BASIN
MAX. PROBABLE FLOOD AT ALTERNATE
DAM SITE
HYDROGRAPH
FIG. 2

III.

E. Hydraulics

The following are the hydraulic computations for the various facilities within the Windmill Gulch Drainage Basin. The computations for the collection system are based on the 50-year storm, and the outfall system is based on the 100-year storm. The collection system is common to both alternatives. These computations are performed in accordance with the procedures outlined in Section II. Included in the appendix are the hydrographs for the various points of analysis, which are shown on Plates A and B and further substantiating data such as storage capacity curves, outlet conduit capacity curves, inflow and outflow hydrographs and storage curves are presented for the staged flow alternative.

III.

E. 1. Collection System

Area	Location & Distance	Elev & S	S 1/2	Q50	b 8/3	b	SF Area	Use Ditch	Culverts etc.
IA	0+00	5792							curb out-let
	670	0.0343	0.1853	129	5.415	1.89	7.14	3x2	
	6+70	5769							
IIA	0+00	5798							curb out-let
	530	0.0321	0.1791	101	4.388	1.74	6.06	3x2	
	5+30	5781							
IIB	0+00	5900							
	780	0.0385	0.1961	100	3.96	1.68	5.64	2x2	
	7+80	5870							
	140	0.021	------	120					42" RCP
	9+20	5867							
	350	0.0486	0.2204	120	4.234	1.72	5.92	3x2	
	12+70	5850							
	1010	0.0505	0.2247	144	4.98	1.83	6.70	3x2	
	22+80	5799							
									Add 240' 2x2
IIIA	10+00	5820							
	100	0.02	------	148					42" RCP
	11+00	5818							
	480	0.0333	0.1826	148	630	2.00	8.00	3x2	
	15+80	5802							
IIIB	0+00	5830							curb out-let, 2-36" x 40' RCP's
	1000	0.0100	0.1000	112	8.705	2.25	10.12	3x3	

Area	Location & Distance	Elev & S	S 1/2	Q50	b 8/3	b	SF Area	Use Ditch	Culverts, etc.
III C	0+00	5894							
	430	0.0116	0.1078	60	4.33	1.73	5.99	3x2	Curb Outlet
	4+30	5889							
	40	0.05	------	70					Curb Outlet
	4+70	5887							30" RCP
	390	0.0159	0.0240	70	4.39	1.74	6.06	3x2	
	8+60	5881							
	40	0.025	------	75					Curb Outlet
	9+00	5880							36" RCP
	260	0.0077	0.0877	75	6.65	2.04	8.32	3x3	
	11+60	5878							
	40	0.025	------	100					
	12+00	5877							36" RCP
	440	0.0023	0.0477	100	16.29	2.85	16.24	4x3	Curb Outlet
	16+40	5876							
	40	0.025	------	151					
	16+80	5875							42" RCP
	920	0.0391	0.1978	151	5.93	1.95	7.60	3x3	Curb Outlet
	26+00	5839							
IV A	0+00	5894							
	250	0.1480	0.3847	80	1.62	1.20	2.88	2x2	Curb Outlet
	2+50	5857							
	120	0.033	------	80					
	3+70	5853							30" RCP
	640	0.0438	0.2092	80	2.97	1.51	4.56	2x2	
	10+10	5825							
IV B	0+00	5900							
	400	0.0550	0.2345	100	3.31	1.57	4.93	2x2	Curb Outlet
	4+00	5878							
IV C	0+00	5995							
	650	0.0231		50					
	6+50	5980							Street Flow
	750	0.0067		65					
	14+00	5975							Street Flow
	300	0.0167		90					2-16'CB's
	17+00	5970							42" RCP
									Curb Outlet

Area	Location & Distance	Elev & S	S 1/2	Q50	b 8/3	b	SF Area	Use Ditch	Culverts, etc.
IV C	1300 30+00	0.0238 5939	0.1544	100	5.03	1.83	6.70	3x2	
	1300 43+00	0.0354 5893	0.1881	206	8.51	2.24	10.04	3x3	
	80 43+80	0.0500 5889		206	----				42" RCP
	320 47+00	0.0344 5878	0.1854	206	8.64	2.25	10.12	3x3	
IV D	350 50+50	0.04 5864	0.2000	307	11.93	2.54	12.90	3x3	
	150 52+00	0.0267 5866		328	-----				60" RCP
	660 58+60	0.0424 5832	0.2060	328	12.37	2.57	13.21	4x3	
V A	490	0.0694		85.4	2.52	1.42	4.03	2x2	1 Curb Out-let
V B	2100	0.0348		126.3	5.27	1.86	6.91	3x2	1 CO, 1-36" RCP x 40'
V C	790	0.0468		12.5	0.389	0.70	0.98	2x2	18"RCPx120' 18"RCPx40'
V D	1000	0.0590		28.6	0.915	0.97	1.88	2x2	18"RCPx120' 24"RCPx40'
VI A	0+00 400 4+00	5921 0.07 4993	0.2646	65	1.91	1.28	3.28	2x2	1 Curb Out-let
VI B	0+00 120 1+20	5006 0.067 4998	0.2582	94	2.83	1.48	4.38	2x2	42"x120'RCP

Area	Location & Distance	Elev & S	S 1/2	Q50	b 8/3	b	SF Area	Use Ditch	Culverts, etc.
VI D	0+00	6053							
Line 1	1100	0.0064	0.0798	49	4.77	1.80	6.48	3x2	Curb Outlet 200'30'RCP
	11+00	6046							
	650	0.0323	------	73					30" RCP
	17+50	6025							
	460	0.0109	------	73					
	22+10	6020							36" RCP 2-8'CB's & 36" hd wall
	870	0.0287	0.1695	88	4.04	1.69	5.71	3x2	
	30+80	5995							
	810	0.0111	0.1054	98	7.23	2.10	8.82	3x3	2-4'CB's 280 2x2 Ditch
	38+90	5986							
	350	0.0228	0.1512	147	7.56	2.14	9.16	3x3	2-8'CB's & 36" Hd Wall& 100'36"RCP
	42+40	5978							
	1110	0.0207	0.1439	197	10.64	2.43	10.81	3x3	48"RCPx40'& 2-48" hdwl
	53+50	5955							
	430	0.0116	0.1078	197	19.20	2.71	14.69	3x3	
	57+80	5950							
Line 2	0+00	5998							66"x120'RCP Curb Inlets & 12'CB
	430	0.0046	------	58					30"RCP
	4+30	5996							
	500	0.0920	0.3033	93	2.38	1.38	3.81	2x2	30" Hd Wall
	9+30	5950							
VII C	3+50	6000							
	350	0.02	------	78					2-12'CB's 36" RCP

Area	Location & Distance	Elev & S	S 1/2	Q50	b 8/3	b	SF Area	Use Ditch	Culverts, etc.
VII C	0+00	5993							2-4' CB's
	90	0.022	------	78					36" RCP
	0+90	599							36" Hd Wall
	580	0.0586	0.2421	78	2.50	1.41	3.98	2x2	
	6+70	5857							
VII A	0+00	5912							18"x40" RCP
	380	0.0316	0.1778	20	0.87	0.95	1.80	2x2	
	3+80	5900							
	60	0.0333	------	20					18"RCP & hdwl
	4+40	5898							Curb Outlet
	460	0.0130	0.1142	25	1.70	1.22	2.98	2x2	
	9+00	5892							
	80	0.025	------	25					21"RCP & hdwl
	9+80	5890							Curb Outlet
	260	0.0154	0.1240	30	1.88	1.77	3.23	2x2	
	12+40	5886							
	40	0.050	------	30					21"RCP & hdwl
	12+80	5884							Curb Outlet
	1750	0.0366	0.1912	36	1.46	1.15	2.64	2x2	
	30+30	5820							
IX A	0+00			Q 100=					
	1400		0.0447	422	73.3	5.00		6x5H	66" RCP
	14+00								
	770		0.1871	422	17.53	2.93		4x3	
	21+70								
	310		0.1378	422	23.80	3.28		4x4	
	24+80								

Area	Location & Distance	Elev & S	S 1/2	Q50	b 8/3	b	SF Area	Use Ditch	Culverts, etc.
X C	Beg Dit	6105							
	260	0.0094	0.0971	91.8	7.35	2.11	8.90	5x2'-6"	
	Beg Cul	1							
	50			91.8					42" RCP
	End Cul								
	530		0.0971	91.8	7.35	2.11	8.90	3x2'-6"	
	End Dit	6100							
X D	Curb Out-let	6120							1 Curb Out-let
		0.0293	0.1711	50	2.27	1.36	3.70	2x2	
	4+10	6108							
		0.0070	0.0838	80	7.42	2.12	8.99	3'x2'-6"	Add 300' 2x2 2 Curb Out-lets
	10+20 8.6								
			------	100					
	10+60 EC								48" RCP
	11+00 PI		0.0838	166	15.40	2.79	15.57	4x3	
	15+50 End	6100	0.0838	166.5	15.44	2.79	15.57	4x3	

III. E.

2. Outfall System - Staged Alternative and Existing Security Channel

a. Outfall channel calculations - 100-year storm.

The following are the major greenbelt channel calculations for the staged flow alternative.

Culverts & Channel Calculations - Staged Alternative

Greenbelt Channel $b^{8/3} = \frac{q_{pn}}{1.93 S^{1/2}}$

Line	Location & Distance	Elev & S	S 1/2	Q 100	b 8/3	b	SF Area	Use Ditch	Culverts, etc.
12-4	Point 12	6088							
	2000	0.015	--	32.6					24" RCP H
	End Cul.	6058							
	230	0.0168	0.1295	184	11.04	2.46	12.10	3x3	
	Top Cul.	6054							
	100	0.0168	--	184					48" RCP & Hws
	Bot Cul	6052							
	1100	0.0168	0.1295	185	11.10	247	12.20	3x3	
	PT 9 Cul	6034							2750 LF 48" RCP H
	980	0.0110	0.1048	311	23.06	3.25	21.12	4x3'-6"	
	PT 11								
	1570	0.0110	0.1048	311	23.06	3.25	21.12	4x3'-6"	
	PT 7 Cul	6005							550 LF 24"RCP
	1090	0.010		431					72" RCP H
	PT 6	5995							1050 LF 24"RCP
	650	0.0569	0.2386	431	14.04	269	14.47	4x3	
	VII C	5958							
	1250	0.0328	0.1811	547	23.47	3.27	21.39	4x3'-6"	
	VII A	5917							
	1020	0.0265	0.1627	709	33.87	3.75	28.12	5x4	
	4 A	5890							
	400	------	------	293					54" RCP
	End Cul	5877							
	370	0.0081	0.0900	293	25.30	3.36	22.58	4x4	
	4	5874							
5-4	5	5932							
	220	----	------	598					72" RCP
	End Cul	5922							
	1700	0.0188	0.1372	827	46.85	4.23	35.79	5x5	
	4 B	5890							
	100	-------	------	708					78" RCP
	End Cul	5886							

Line	Location & Distance	Elev & S	S 1/2	Q 100	b 8/3	b	SF Area	Use Ditch	Culverts, etc.
	990	0.0121	0.1101	708	49.98	4.34	37.67	5x5	
	4	5874							
4-3	4	5874							
	460	0.0058	0.0764	995	101.2	5.65	63.84	8x6	
	V B	5871							
	420			1120	113.9	5.90	69.62	8x6	
	V C	5869							
	935			1161	118.1	5.99	71.76	8x7	
	V D	5864							
	435			1237	125.8	6.13	75.15	8x7	
	V A	5861							
	150			1321	134.4	6.28	78.88	8x7	
	PT 3	5860							
3-2	200	0.02	-------	654					
	End Cul	5856							72" RCP
	260	0.0186	0.1362	654	37.32	3.89	30.26	5x5	
	Beg Cul	5851							
	100			654					
	End Cul	5849							78" RCP
	560			654	37.32	3.89	30.26	5x5	
	III C	5839							
	360			827	47.19	4.25	36.12	5x5	
	IV D	5832							
	400			1594	90.96	5.43	58.97	8x6	
	IV A	5825							
	260			1806	103.1	5.69	64.75	8x6	
	Dam	5820							
	780	0.0128	0.1132	1806	124.0	6.10	74.42	8x7	
	2	5810							
2-1	170	0.0176		1380					2-60" RCP's
	End Cul	5807							
	330	0.0155	0.1244	1380	86.21	5.32	56.60	8x6	

Line	Location & Distance	Elev & S	S 1/2	Q 100	b 8/3	b	SF Area	Use Ditch	Culverts, etc.
	III A	5802							
	220			1620	101.2	5.65	63.84	8x6	
	II B	5799							
	1180			1854	115.8	5.94	70.57	8x7	
	II A	5781							
	780			2018	126.1	6.13	75.15	8x7	
	I A	5769							
	190			2228	139.2	6.37	81.15	8x7	
	1	5765							
		170		1355					2-60"RCP's
	End Cul	5761							

III.

E.2

b. The following are the calculations pertaining to the existing facilities through the Town of Security. It may be seen that the channel is filled to capacity under this alternative, resulting in six inches of freeboard on tangent and no freeboard on the minimum radius of curvature.

The channel through Security was contracted in 1968 by the El Paso County Engineering Department as a result of severe flooding in the 1965 flood which caused one house in Security to be floated off its foundations. It is known as the Aspen Ditch. The culverts on Aspen Avenue and Grand Boulevard were in at the time of construction and were not changed. The as-built channel section varies from that initially designed in both shape and gradient, and it is considerably smaller than that originally designed.

The channel configuration shown in the calculations is the result of a survey conducted by this firm. The as-built channel varies considerably in wall height, grade and alignment and the conservative result of this survey is used in the calculations. Hydraulic efficiency and safety is sacrificed by the mentioned variations, the alignment being constructed in short segments of tangent as opposed to more efficient curve radii. No lip was provided to protect against overtopping and inflows at the top of the lining, however, the bottom is thickened to provide for maintenance within the channel. The concrete finish is considered poor, but within design assumption limits. A maintenance road parallels the channel for its entire length. A channel cross-section is provided for reference in Section IV of this report.

Several items should be stressed regarding the hydraulics of the as-built facilities. Although the channel section will accomodate the 1355 CFS design flow under this alternative, an analysis of the existing culverts show that the flow is governed by entrance losses and their capacity is only about 225 CFS. For this reason their replacement by adequately sized arch plate structures is recommended, the costs for which are included in this report. The existing channel, as previously mentioned, terminates in an area which will result in substantial possible flood damage to downstream residents. As discussed in section III B, this danger exists at present runoff rates. Since proposed upstream development under this alternative will not exceed the capacity of the existing channel, its extension is not considered binding upon the city and is not recommended.

Culverts & Channel Calculations - Staged Alternative

Existing Security Channel

Area	Location & Distance	Elev & S	S 1/2	Q50	b 8/3	b	SF Area	Existing Ditch & Culv's	Culverts, etc. to be replaced
1-End	End Cul								
	357	0.0128	0.1131	1355	9.00	4.50	60.75	9x5	
	Top Alpine 44							7x4 RCB	12'x6'-2 1/2" Arch
	Bot Alpine 1982						60.75	9x5	
	Top Grand 44							7x4 RCB	12'x6'-2 1/2" Arch
	Bot Grand 125	0.0128					60.75	9x5	
	End Ditch								

Min R = 280'

$$d_2 - d = \frac{V^2 B}{gR}$$

B = 18.00

$$V = \frac{1355}{60.75} = 22.30$$

$$d_2 - d = \frac{22.30^2 \times 18.00}{32.2 \times 280} = 0.99 < 1.00$$

III.
E. 2
C. Curves presented in the appendix represent a summary of calculations pertaining to the staging techniques at the various reservoirs and road crossings in this alternative. Included are inflow and outflow hydrographs, storage capacity curves, outlet conduit capacity curves and storage-time curves for each location. Detailed calculations are not included in this report but will be made available upon request to interested parties.

It is stressed that these calculations are of a preliminary nature only. Although they are performed in detail, no area within the basin is considered to be topographically represented to an accuracy which would warrent a final design of any of the proposed structures. The feasibility of this alternative is substantially demonstrated, however, the design is considered critical enough to warrant similar analysis of each crossing on the final design which was based on accurate field surveys.

3. Outfall System - Unstaged Alternative The following are the calculations pertaining to the outfall system design of the unstaged flow alternative, shown on Plate B of the appendix. Hydrographs for each point are enclosed in the appendix. It may be seen that the design discharge at the lower end of the basin (point number one) is 3946 CFS, or considerably more than the 1355 CFS capacity of existing facilities through the Town of Security. For this reason the design considers replacement of these facilities and extension of them to discharge into Fountain Creek.

The extension of the facilities are designed for the discharge quantity of the basin. It is realized that additional inflow downstream of the basin must be accomodated, however, the cost of the additional structure will have to be borne by downstream governmental agencies. In addition, the city may wish to acquire a cost share for facilities required for the peak discharge of 4547 CFS of the existing basin.

Culverts & Channel Calculations - Unstaged Alternative

Area	Location & Distance	Elev & S	S 1/2	Q100	b 8/3	b	SF Area	Use Ditch	Culverts etc.	Time Hrs.
Pt 12	0+00	6088						5x5x1260'		
	1000	0.0109	0.1044	499	37.15	3.88	30.11	5x5 H		0.017
	10+00									
	150	0.0109	------						78" RCP H	
	11+50									
	1600		0.1044	683	50.85	4.36	38.02	5x5		0.047
	27+50	6058								
	1450(-100)							5x5 -100' of 84" RCP		
from #9	42+00	6034								
								620'4x3	150LF66' RCP & Hw's	
	See Pt 10			422				310'4x4		0.03
Pt 10		6044						2010 6x5H		
	2750	0.004	------	856			56.65		2.84" RCP H	0.07
		6034								
Join Ditch										
Join	0+00	6034								
Dit	1050	0.0181	0.1345	1371	79.20	5.16	53.25	6x5		0.011
Pt 11	10+50	6015								
	1450	0.013	0.1145	1443	97.92	5.58	62.27	6x5		0.017
Join ACP	25+00	5996								
Pt 8	0+00	6050								
	1020	0.6%	------	304					H72"RCP & Hw	0.029
Outlet		6044								
	860	1.4%	------	304					60" RCP	0.020
		6032								
	700	3.1%	------	304					54" RCP	0.010
		6010								
	950	0.0123	0.1113	752	52.50	4.42	39.07	5x5		0.013
Pt 7										

Culverts & Channel Calculations - Unstaged Alternative

H indicates deep exc

Area	Location & Distance	Elev & S	S 1/2	Q100	b 8/3	b	SF Area	Use Ditch	Culverts etc.	Time Hrs.
	180	0.0123	------	752					2-66" RCP & Hw (2)H	
Join Dit		5996								
Join Dit	1100	5996 0.01	0.1000	2228	173.1	786	123.56	8x8 H	2-84"x 100'RCP	0.017
Pt 6	-100	5985								
13	1050	6006 0.020	------	178					48"RCP & Hw	
6		5985								
6-4	Pt 6 2470	5985 0.0364	0.1909	2340	95.24	5.52	60.94	8x5		0.022
	Pt 4A 520	5895 0.0096	0.0981	2340	185.3	7.09	100.5	8x8		0.008
	Culvert 400	5890 0.0075	------	2340			106.9		20'x7'4" Arch	0.006
	End Cul 370	5877 0.0081	0.0900	2340	202.0	7.31	106.9	8x8		0.006 =0.04
	Pt 4	5874								
5-4	Pt 5 220	5932 0.0455	------	802			76.97		2-84"RCP	0.006
	End Cul 1700	5922 0.0188	0.1372	1212	68.64	4.88	47.63	8x5		0.017
	Pt 4B 990	5890 0.0172	0.1313	1212	71.72	4.97	49.40	8x5	100',2- 84"RCP	0.006 =0.03
	Pt 4	5880								
4-3	Pt 4 460	0.0058	0.0764	3552	361.2	9.10	165.6	12x9		0.004

Culverts & Channel Calculations - Unstaged Alternative

Area	Location & Distance	Elev & S	S 1/2	Q100	b 8/3	b	SF Area	Use Ditch	Culverts etc.	Time Hrs.
	V B 420			3703	376.6	9.25	171.1	12x9		0.005
	V C 935			3753	3817	9.29	172.6	12x9		0.012
	V D 435			3845	391.0	9.38	176.0	12x10		0.006
	V A 150			3946	401.3	9.47	179.4	12x10		0.002
	Pt 3						Used	0.04		0.029
3-2	Pt 3 170	0.0176	------	3946			179.4		21'x10'-10" Arch	0.002
(Use 820')	End Cul 920-100	0.0186	0.1362	3946	225.1	7.63	116.4	12x7	20'x7'4" Arch	0.008
	III C 360			4115	234.8	7.74	119.8	12x8		0.003
	IV D 400			4865	277.5	8.25	136.1	12x8		0.003
	IV A 260			5073	289.4	8.38	140.4	12x9		0.002
	PVT 780	0.0128	0.1131	5073	348.5	8.98	161.3	12x9		0.007
	2								S=	0.025
									Used	0.020
2-	2 170			5073			161.3		20'x10'-4" Arch	0.002
	End Culv. 330	0.0155	0.1244	5073	316.9	8.67	150.34	12x9		0.003

Culverts & Channel Calculations - Unstaged Alternative

Area	Location & Distance	Elev & S	S 1/2	Q 100	b 8/3	b	SF Area	Use Ditch	Culverts etc.	Time Hrs.
	III A 220			5333	333.1	8.83	155.94	12x9		0.002
	II B 1180			5588	349.0	8.99	161.6	12x9		0.009
	II A 780			5767	360.2	9.10	165.6	12x9		0.006
	I A 190			5994	374.4	9.23	170.4	12x9		0.002
	Pt #1 170			5994			182.8		21'x10' 10"Arch	0.002 0.024 Used 0.03
	End Culv 349	0.0128	0.1131	5994	411.8	9.56	182.8	12x10 H		
	Top Alpine 60								21x10'-10" Arch	
	Bot Alpine 1966								12x10H= 2432'	
	Top Grand 60								21x10'-10"Arch	
	Bot Grand 117									
	End Security 1300	5729 0.0146	0.1209		385.3	9.33	174.1	12x10		
	Beg Arch 350	5710 0.0071							21'x10'-5 1/2" Arch	
	End Arch 350	0.0071	0.0845		551.3	10.67	227.7	12x11		
	GB	5705								

Culverts & Channel Calculations - Unstaged Alternative

Area	Location & Distance	Elev & S	S 1/2	Q 100	b 8/3	b	SF Area	Use Ditch	Culverts etc.	Time Hrs.
	250	0.0091	0.0953		488.8	10.20	208.1	12x11		
	Beg Cul									
	70	0.0091	------						23'x11'-6" Arch H	
	End Cul									
	230	0.0091	0.0953		488.8	10.20	208.1	12x11		
	GB	5700								
	100	0.20	0.4472		104.2	5.71	65.2	12x6		
	GB	5680								
	110	0.1818	0.4264		109.3	5.81	67.5	12x6		
	End	5660							Energy Dissipator	

III.

E. 4. Subalternative Dam As mentioned previously a detailed design of the alternative dam is not included, however, preliminary design has been accomplished, the details for which are shown in the appendix.

One major problem in the dam alternative is its inefficiency due to location. It may be seen that the 100-year storm runoff from areas below the dam is 1008 CFS at a time of 0.66 hours. This means that the outlet works may contribute only 347 CFS at this time period to avoid exceeding the capacity of the downstream channel. This will require a 48-inch diameter conduit with considerable storage head available behind the dam.

The major drawback to the dam alternative is the spillway requirement. The spillway floor elevation must be above the maximum water surface of the 100-year staged flow so as not to effect the hydraulics of the outlet works. For the maximum probable flood, the spillway section selected was a 100 foot wide ogee crest with free discharge characteristics and 16 foot high side walls. This creates the necessity for eighteen feet of fill in addition to that necessary for the design storm, and costs become prohibitive.

IV Preliminary Cost Estimate

The following are the preliminary cost estimates for the various alternatives The collection system, based on the 50-year design storm is common to each alternative. The bases for the cost estimate are prices currently encountered under contracts by the City in projects of a similar nature. Prices of specific items are as shown in the estimate; prices of structures involving several items of work not normally lumped together are based on the following item prices:

Item	Unit Price
Excavation - Minor Structures	$3.00/CY
Excavation - Major Conduits	2.00/CY
Mass Excavation and Compaction (Normal)	0.50/CY
Concrete Lining - Minor Ditches	10.00/SY
Concrete Lining - Major Structures	7.00/SY
Concrete in Minor Structures	250.00/CY
Concrete in Major Structures	125.00/CY
Mass Concrete	60.00/CY
Concrete Removal	1.00/SY

Certain of the facilities shown on the plates and in the estimate are marked 'H' to designate a difficult installation, meaning excessive excavation and backfill, or particular conflicts with existing features. The unit prices are correspondingly higher in these cases.

A. Collection System

The following is the cost estimate for the 50-year design collection system, shown on both Plates A and B.

Collection System - Estimate

Item	Type	Quantity	Unit Price	Total Cost
Ditch	2x2	9,620 LF	11.62	$ 111,784.00
	3x2	8,990	12.95	116,420.00
Ditch	3x2 1/2	1,400	14.94	20,916.00
	3x3	6,810	16.98	115,634.00
	4x3	1,590	18.42	29,288.00
RCP	18"	380	12.00	4,560.00
	21"	120	16.00	1,920.00
	24"	40	18.00	720.00
	30"	1,440	20.00	28,800.00
	36"	1,240	21.00	26,040.00
	42"	830	23.00	19,090.00
	48"	80	25.00	2,000.00
	60"	150	40.00	6,000.00
	66"	120	45.00	5,400.00
Headwalls	18"	10	110.00	1,110.00
	21"	4	132.00	528.00
	24"	2	177.00	354.00
	30"	8	269.00	2,152.00
	36"	13	315.00	4,095.00
	42"	13	416.00	5,408.00
	48"	4	518 00	2.072.00
	60"	2	875.00	1,750.00
	66"	2	1,053.00	2,106.00
Curb Outlets	Std	25	300.00	7,500.00
Catch Basin	4'	4	350.00	1,400.00
	8'	4	450.00	1,800.00
	12'	3	700.00	2,100.00
	16'	2	775.00	1,550.00

TOTAL------------------$522,497.00

B. Staged Alternative

1. As Proposed The following is the cost estimate and proposed drainage fees for the staged flow alternative.

Outfall System - Staged Alternative - Estimate

Structure	Type	Quantity	Unit Price	Cost
Ditch	3x3	1330 LF	16.98	$ 22,583.00
	4x3	1270	18.42	23,393.00
	4x3 1/2	3800	20.59	78,242.00
	5x4	1020	16.91	17,248.00
	5x5	3870	20.14	77,942.00
	6x5 H	1400	29.07	40,698.00
	8x6	2090	27.20	56,848.00
	8x7	4450	30.96	137,772.00
RCP	24	3600	18.00	64,800.00
	24 H	3020	30.00	90,600.00
	48	100	25.00	2,500.00
	48 H	2750	37.00	101,750.00
	54	400	35.00	14,000.00
	60	680	40.00	27,200.00
	66	150	47.00	7,050.00
	72	420	55.00	23,100.00
	72 H	1090	75.00	81,750.00
	78	200	60.00	12,000.00
Headwall	24	9	177.00	1,593.00
	48	4	518.00	2,072.00
	54	2	696.00	1,392.00
	60 Dol	4	1350.00	5,400.00
	66	2	1053.00	2,106.00
	72	6	1231.00	7,386.00
	78	2	1410.00	2,820.00
Arch Plate	12'x6'-2 1/2	88	150.00	13,200.00
Culvert Rem	LS	LS	LS	2,000.00
Req'd Fill	Res	1,093,574	0.50	546,787.00
Right of Way	Res	63.50	3000.00	190,500.00

TOTAL-------------------$1,654,732.00

+ Collection System 522,497.00

Subtotal-----------------$2,177,229.00

15% Engineering & Minor Structures

TOTAL-------------------$2,503,813.00

÷ 2810.5 acres $890.88/acre-Staged

2. Alternative Dam The following is the preliminary estimate on the alternative dam shown on Plate A and figures 72 and 73.

ESTIMATE

Earthwork & Sitework		
Clearing & Grubbing	Lump Sum @ $10.00	$ 10,000.00
Stripping	33,900 CY @ $0.50	16,950.00
Exc for cutoff trench	1,900 CY @ $2.00	3,800.00
Borrow exc	239,500 CY @ $0.80	191,600.00
Dam emb	206,473 CY @ $0.50	103,236.00
Riprap	18,815 CY @ $10.00	188,150.00
Emb seeding	8.82 Ac @ $75.00	661.00
Relocate Irrigation Ditch	Lump Sum @ $10,000.00	10,000.00
	Subtotal-------------	$524,397.00
Spillway		
Mass concrete	2944 CY @ $60.00	$176,640.00
Structural concrete	1815.2 CY @ $125.00	226,900.00
Compacted Backfill	3000 CY @ $4.00	1,200.00
Riprap	1000 CY @ $10.00	10,000.00
	Subtotal-------------	$414,740.00
Outlet Works		
72" RCP	300 LF @ $75.00	$ 22,500.00
Structural concrete	129.1 CY @ $125.00	16,138.00
Structure exc	1074 CY @ $3.00	3,222.00
Structure BF	1040 CY @ $4.00	4,160.00
	Subtotal-------------	$ 46,020.00
	TOTAL CONST WORK------------	$985,157.00
Misc Costs		
20% Engineering, legal & Contingency		$195,031.00
Right-of-way: 25 acres @ $3,000.00		75,000.00
	Subtotal-------------	$270,031.00
	GRAND TOTAL-------------	$1,255,188.00

B. Staged Alternative

The following is the preliminary cost estimate and proposed drainage fee for the staged flow alternative.

UNSTAGED FLOW ALTERNATIVE

Item	Type	Quantity	Unit Price	Cost
Ditch	4x3	620	18.42	$ 11420
	4x4	310	18.95	5874
	5x5	5160	20.14	103922
	5x5 H	1000	27.55	27550
	6x5	2500	21.29	53225
	6x5 H	2010	29.07	58431
	8x5	5160	23.59	121724
	8x8	890	34.86	31025
	8x8 H	1100	45.60	50160
	12x9	5955	44.69	248253
	12x10	1885	49.19	92723
	12x10 H	2432	51.36	124908
	12x11	830	53.83	44679
	12x6	210	32.09	6739
RCP	48	1050	25.00	26250
	54	700	35.00	24500
	60	860	40.00	34400
	66	150	47.00	7050
	66 H	360	60.00	21600
	72 H	2040	75.00	153000
	78 H	150	95.00	14250
	84	1040	80.00	83200
	84 H	5500	100.00	550000
Arch	20'x7'-4"	500	200.00	100000
	20'x10'-4"	170	230.00	39100
	21'x10'-10"	460	230.00	105800
	21'x10'-5 1/2"	350	230.00	80500
	23'x11'-6"	70	250.00	17500
Headwalls	48	2	518.00	1036
	66	2	1054.00	2106
	Dbl66	2	2106.00	4212
	72	1	1231.00	1231
	78	2	1410.00	2820
	84	0	1588.00	-0-
	2-84	4	3176.00	12704
	3-84	2	4500.00	9000
Inlet Exc	Chandelle	324	3.00	972
Inlets	Chandelle	254.6	7.00	1782
Culv Rem	Security	LS	LS	2000
Dissipator	Fountain	LS	LS	50000
ROW	Security	3.168 Ac	4000.00	12672

TOTAL----------------$2,338,318

UNSTAGED - TOTAL COST

Collection System	$ 522,497.00
Outfall System	2,338,318.00
Subtotal	2,860,815.00
15% Engr & Minor Structures	
TOTAL------------------------------	$3,289,937.00
÷ 2810.5------------------------------	$1170.59/Acre - Unstaged

V. Conclusions and Recommendations

A. Comparison of Alternatives

Item	Staged Alternative	Unstaged Alternative
Total Cost	$ 2,177,229.00	$ 3,289,937.00
Drainage Fee	890.88/Acre	1170.59/Acre
Maximum Runoff CFS:		
Point #1	1355	5994
2	1380	5073
3	654	3946
4	995	3552
4A	293	2340
4B	708	1212
5	598	802
6	431	2228
7	28	750
8	30	304
9	126	856
10	126	856
11	311	1443
12	33	499
13	36	178
Cost of Improving Downstream Facilities	$15,200.00	$347,098.00

B. Conclusions

1. This drainage basin contains a total of 2810 acres, 1110 acres of which comprise natural buffalo wallows which do not presently contribute to the runoff.

2. The 100-year runoff from the existing basin is 4547 CFS.

3. Drainage facilities have been constructed through a portion of the Town of Security downstream of this basin. The existing channel will accomodate 1355 CFS, while existing culverts on Aspen Avenue and Grand Boulevard will accomodate only 225 CFS. An area downstream of these drainage facilities is not protected from any significant runoff of the existing basin. Substantial downstream damage will result from a storm in the existing basin of the magnitude for which the City currently designs or for which existing facilities were designed.

4. By designing storm drainage facilities in accordance with standard practice in the City of Colorado Springs, the basin will develope a total runoff of 5994 CFS under full development. The City will incur a legal liability to protect downstream residents from this substantially increased flow. The total estimated cost of improvements under this, the unstaged alternative, is $3,289,937.00 of which $347,098.00 applies to improvement of downstream facilities. This results in a drainage fee of $1,170.59 per acre chargable to land developers within the basin.

5. The zoning shown on Plates A and B is an integral part of this report.

6. By using staging techniques, in which peak storm runoffs are temporarily stored in a series of reservoirs and behind road fills, the developed basin will discharge 1355 CFS into the Town of Security. The existing channel will accomodate this discharge and the insufficiently designed culverts on Aspen Avenue and Grand Boulevard will require replacement. The cost of the total improvements under this alternative is $2,177,229, of which $15,200 is attributed to replacement of existing culverts. This will result in a drainage fee of $890.88 per acre to be paid by future developers within the basin.

7. The existing facilities are undersized under existing runoff conditions. Under the staged flow alternative, as shown on Plate A, we conclude that El Paso County has a legal obligation to share in the costs for improving the culverts and that the City has no obligation to extend the facilities. Under the unstaged alternative, we feel the County has an obligation to share in the costs of the replacement of existing facilities and the extension of these facilities to the discharge point at Fountain Creek as shown on Plate A.

8. Only 640 acres of the 2810 acres comprising this drainage basin lie within the City limits of Colorado Springs. Implementation of the drainage facilities

project recommended in this report will be possible only if the entire basin is within the City limits or the entire basin or participates in the drainage facility construction on an equal basis. No means are presently available to implement construction recommended in this report which falls within El Paso County juristiction - those areas downstream of the basin - which will require drainage improvements.

9. The staged flow alternative will require the review of the State Engineer to assure the City that no violation of Colorado Law concerning dams will result in its implementation.

B. Recommendations We recommend that the City of Colorado Springs take the following action on this report.

1. Consider as alternatives

(a) Extend the City limits to encompass the limits of the drainage basin so that structures may be installed under the administration of the City as recommended in this report.

(b) Form a drainage district in coorporation with the Town of Security and El Paso County to properly administer construction of facilities as recommended in this report.

2. Accept and make implementation of the staged flow alternative outlined in this report after assurance by the State Engineer that no apparent violation of State Law will result in its implementation.

3. Assess a drainage fee of $900.00 per acre upon all development within this basin.

4. Take the necessary steps to obtain El Paso County cooperation and cost sharing of facilities recommended by this report which fall within their area of juristiction or for which they have a legal obligation to protect residents within their governmental juristiction.

5. Apply the following guidelines in implementing the recommended design alternative.

a. Require respective developers to, in general, limit the flows at respective hydrology points to those figures shown in this report, and to limit the outflow of the basin to 1350 CFS.

b. Require detailed hydraulic calculations on all staging techniques to be submitted for approval, based on fully detailed field surveys.

c. Implement this plan, based on the actual development order of the basin, to assure that the maximum basin discharge from the basin does not exceed 1350 CFS and that no serious erosion hazard will result. This will require departure from existing procedures to allow for construction of facilities outside development areas as these facilities become required.

6. Make copies of this report available to El Paso County and the Pikes Peak Area Council of Governments for their information.

VI. Definition of Terms and Abreviations

Term	Abbreviation	Definition
Abcissa	--	The horizontal datum line for any curve.
Area	A	Area in square miles of a portion of land or, in square feet of a conduit structure.
Base Time	T_B	The time, in hours, for the runoff of a particular storm to decrease until it ceases.
Basin	--	A topographical area of land that will discharge all storm runoff along some particular line of flow or at some particular point.
Bottom Width	b	The width, in feet, of the bottom of a trapezoidal conduit.
Depth	d	The depth of water, in feet, in a conduit.
Developed	--	Installations of subdivisions and other facilities to fully occupy the land under the proposed zoning.
Diameter	D	Pertains to a circular conduit.
Duration	D	The length of time, in hours, of a particular rainstorm.
Freeboard	--	The clear distance between the top of the water surface and the top of the structure containing the water.
Froude Number	Fr	A number which assesses the nature of flow in conduits.
Gravity	g	The acceleration due to gravity on a falling object, being 32.2 ft/sec^2
Greenbelt	--	The area surrounding and including a structure provided for the discharge of storm water.
Head	H	For the purposes of this report, the amount of water, in feet, standing above the top of a culvert, or lip of a spillway.

Term	Abbreviation	Definition
Height	H	The difference of elevation, in feet, along the length of a particular drainage course.
Hydraulic Radius	R	The area of a conduit, divided by the conduits wetted perimeter.
Hydrograph	--	A curve of runoff in CFS versus time, in hours.
Hydrology	--	The science that relates to the water of the earth.
Infiltration	i	The ability of a particular soil to absorb portions of the total amount of water deposited under rainfall.
Intensity	I	The amount of water, in inches, deposited uniformly over a portion of the earth in a particular rainstorm.
Invert	--	The lowest point in a conduit.
Length	L	Length of a particular drainage course in feet.
Mannings Coefficient	n	A number assigned by experience to assess the roughness characteristics of a structure containing runoff.
Ordinate	--	The vertical datum line for any curve.
Outflow Capacity Curve	--	A curve representing the runoff or discharge with respect to head.
Peak Time	Tpo	The time, in hours, for the storm runoff to reach a peak, or maximum discharge.
Radius	R	The actual or effective radius upon which a circle is struck, representing the center of a conduit.
Recurrance Interval	--	A storm of recurrance interval of 100 years is likely to occur once each 100 years.
Runoff	q_p	The amount of water which flows openly as a result of a rainstorm, and is not, therefore, absorbed into the earth or lost to the atmosphere. Synonimous with discharge.

Term	Abbreviation	Definition
Runoff	Q	The amount of rainfall, in inches, which is not lost to the atmosphere or absorbed into the earth.
SCS	--	The Soil Conservation Service of the U.S. Department of Agriculture.
Sediment	--	The portions of the earth eroded under runoff and carried by that runoff, subject to being deposited at some point downstream.
Side Slope	Z	The slope of an excavation surface or finished structure, representing the horizontal distance with respect to a unit vertical distance.
Slope	S	A demensionless decimal representing the actual, or effective, fall of the water surface in a conduit with respect to the length of a conduit.
Soil Cover Complex	--	A number, assigned by experience, to a particular soil which considers infiltration, soil cover and topographical characteristics.
Storage	AF	The quantity of water in acre feet, (the amount of water covering one acre, one foot deep) contained by local topography.
Storage Curve	--	A curve representing the storage with respect to elevation or depth of water, in feet.
Time of Concentration	Tc	The time, in hours, it takes for water to flow from the most remote point in a drainage basin to the point of outflow of that basin.
Top Width	B	The distance across the top of the wetted surface of a conduit, in feet.

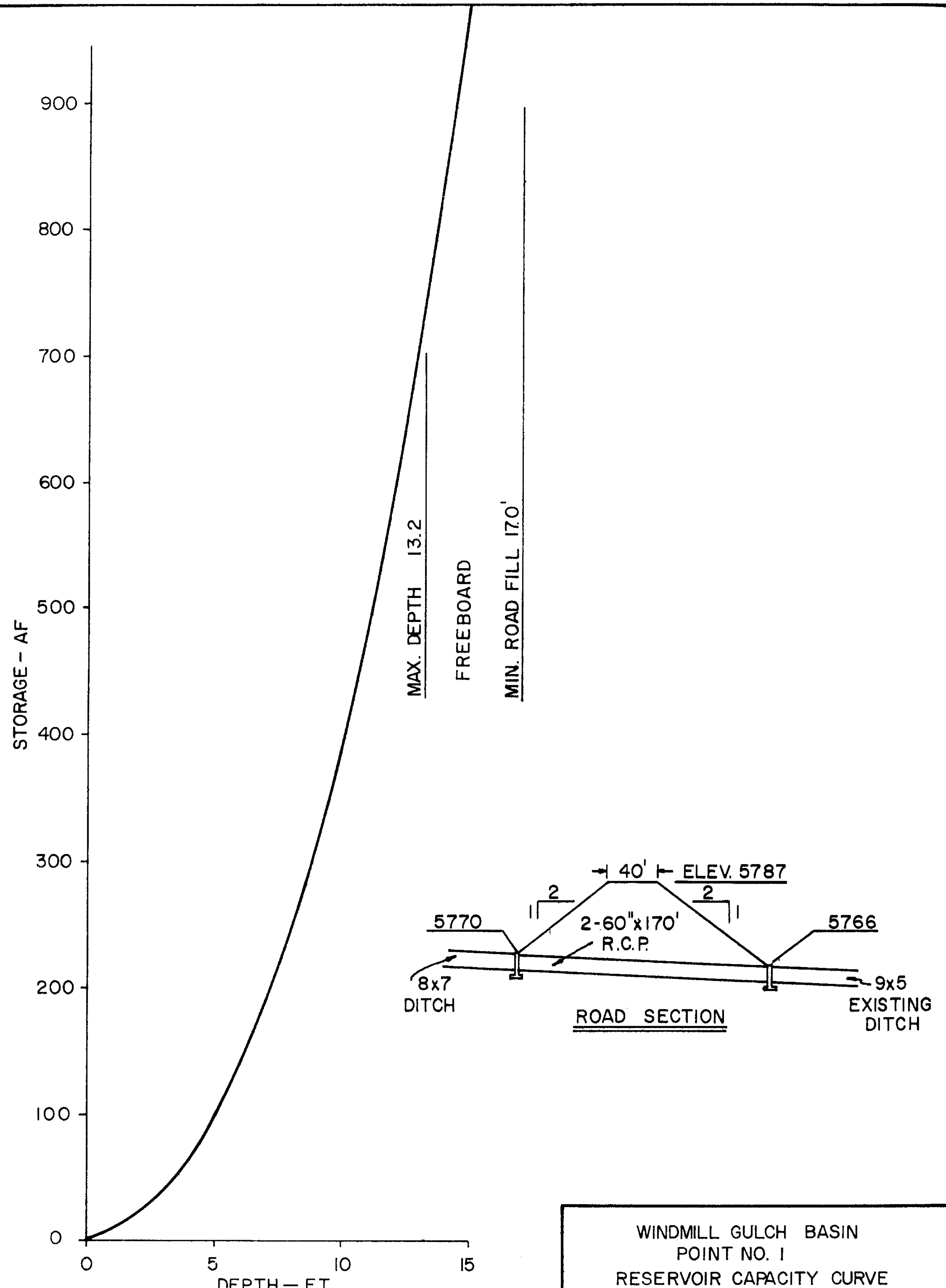
Term	Abbreviation	Definition
Topography	Topo	The physical characteristics of the earth which define the three dimentional shape of the land.
Undeveloped	--	The basin in its existing state.
Velocity	V, fps	The speed of runoff, in feet per second.

APPENDIX

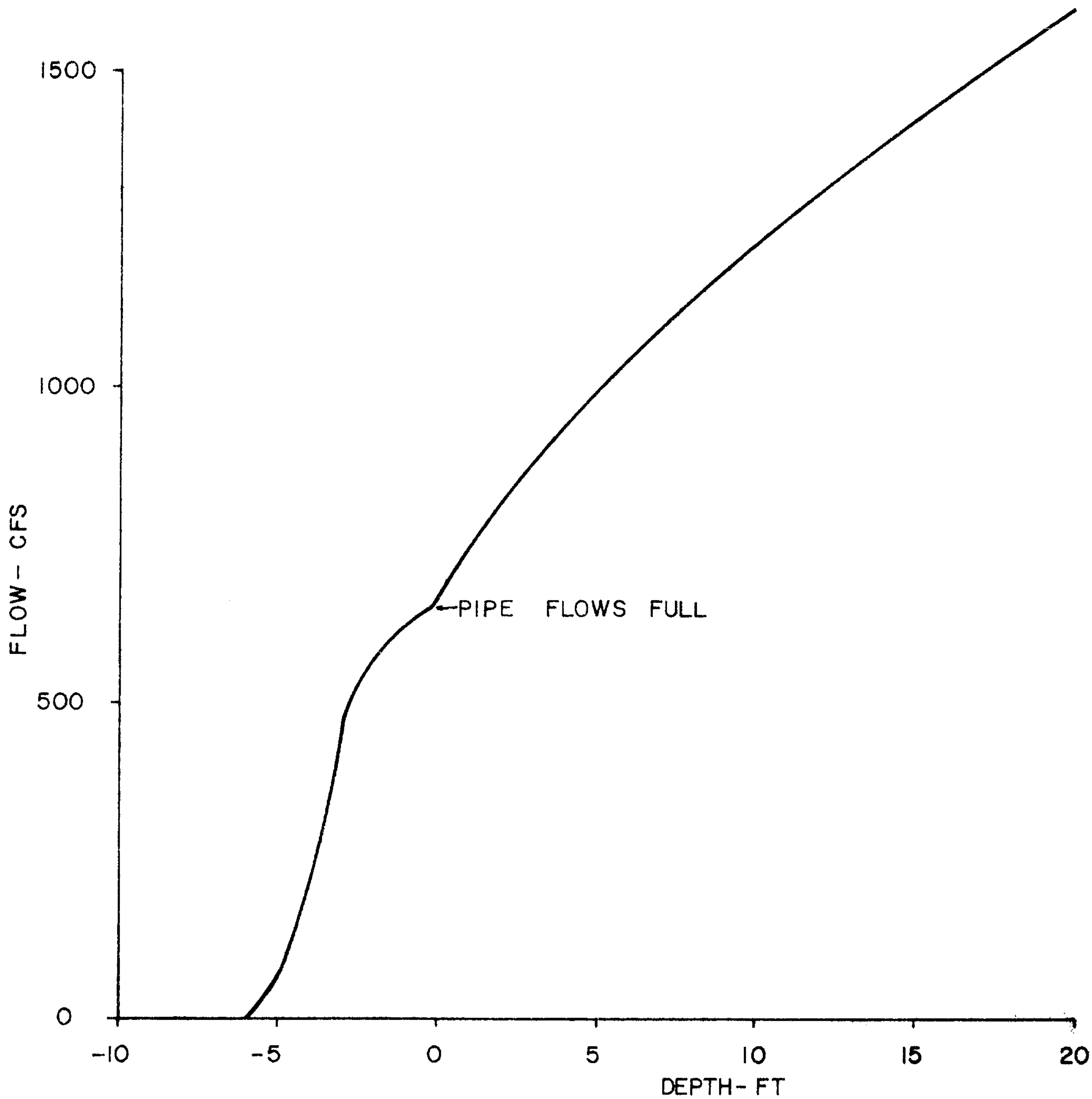
WINDMILL GULCH

DRAINAGE BASIN

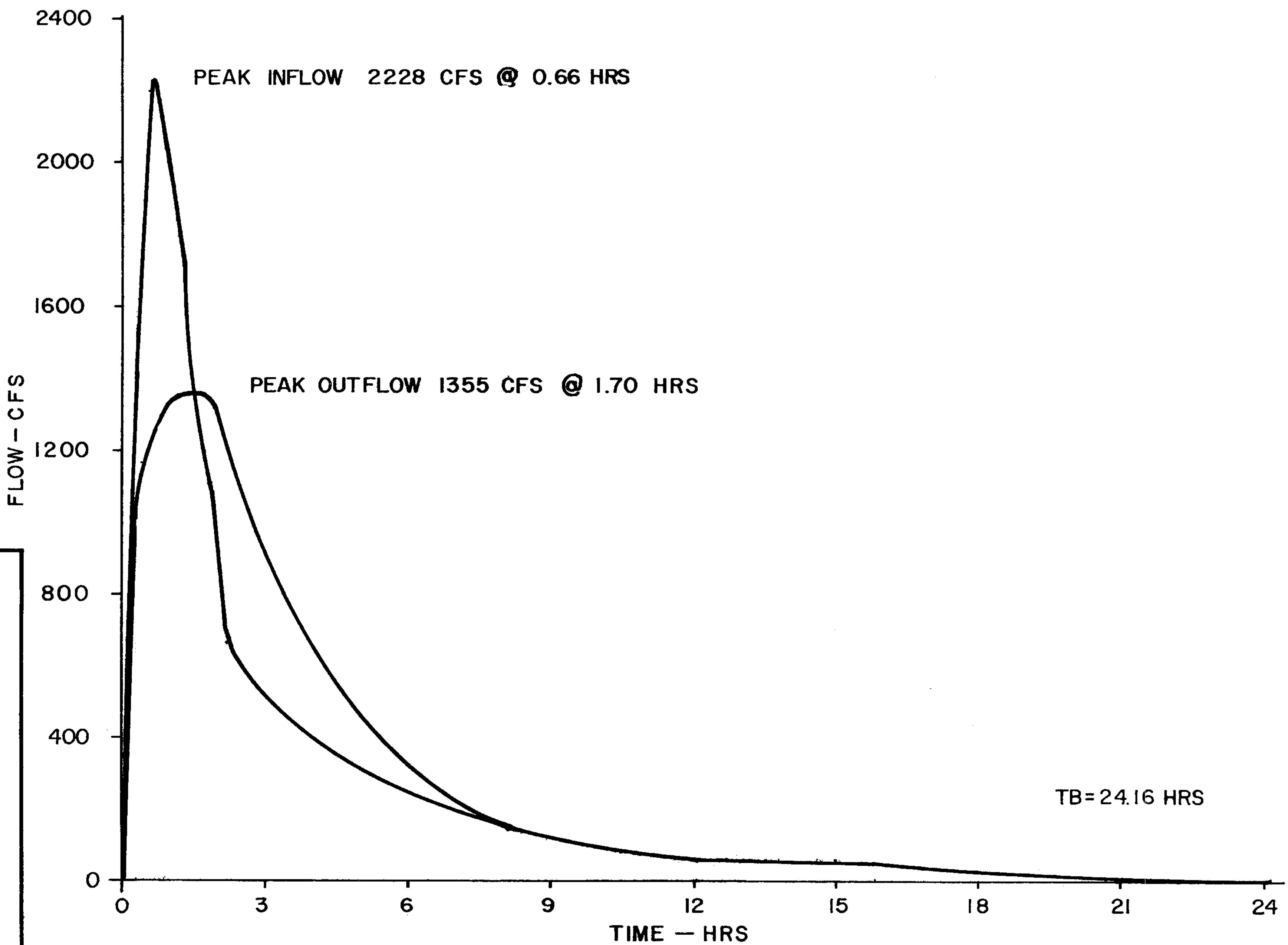
ENGINEERING REPORT



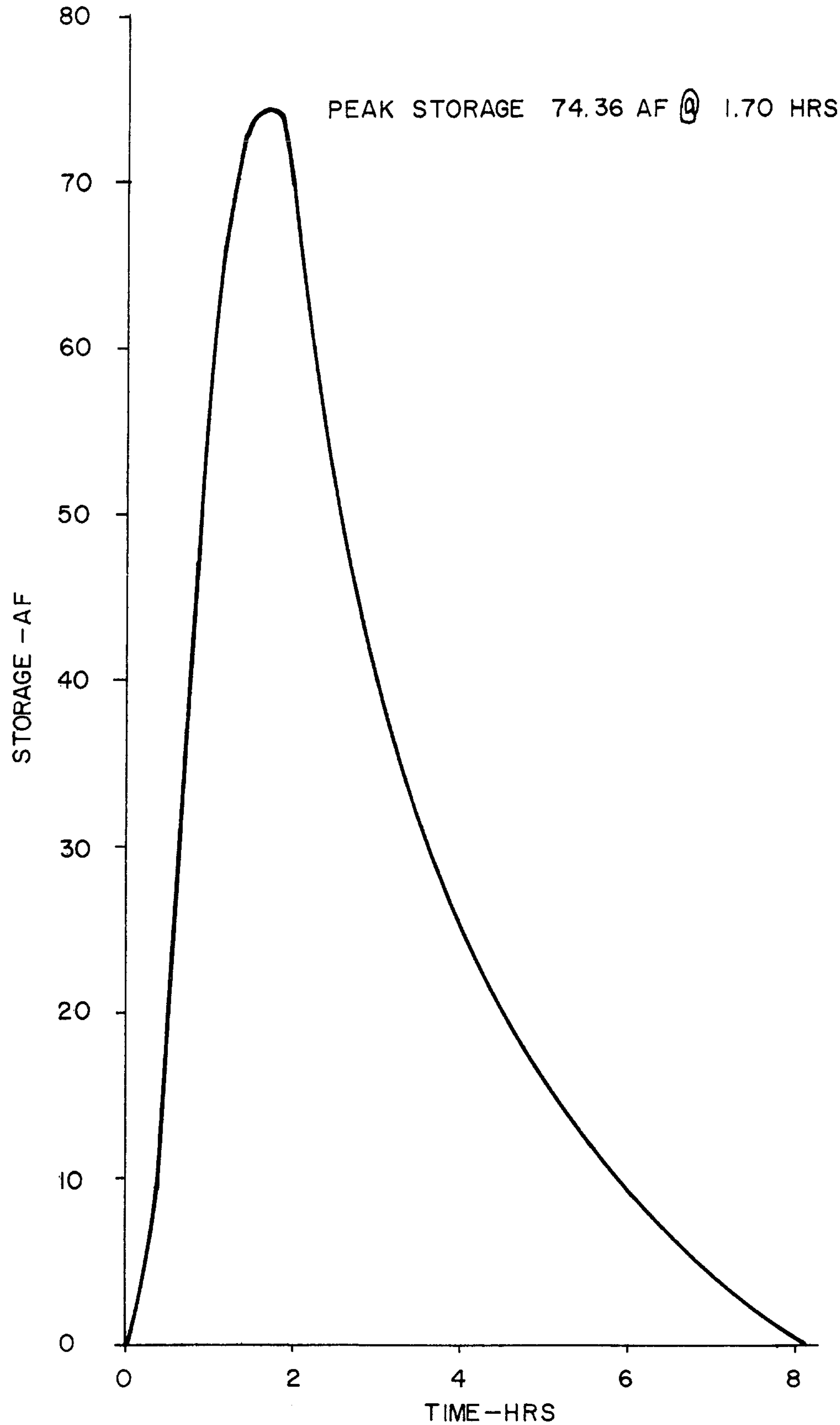
WINDMILL GULCH BASIN
POINT NO. 1
RESERVOIR CAPACITY CURVE
FIG. 3



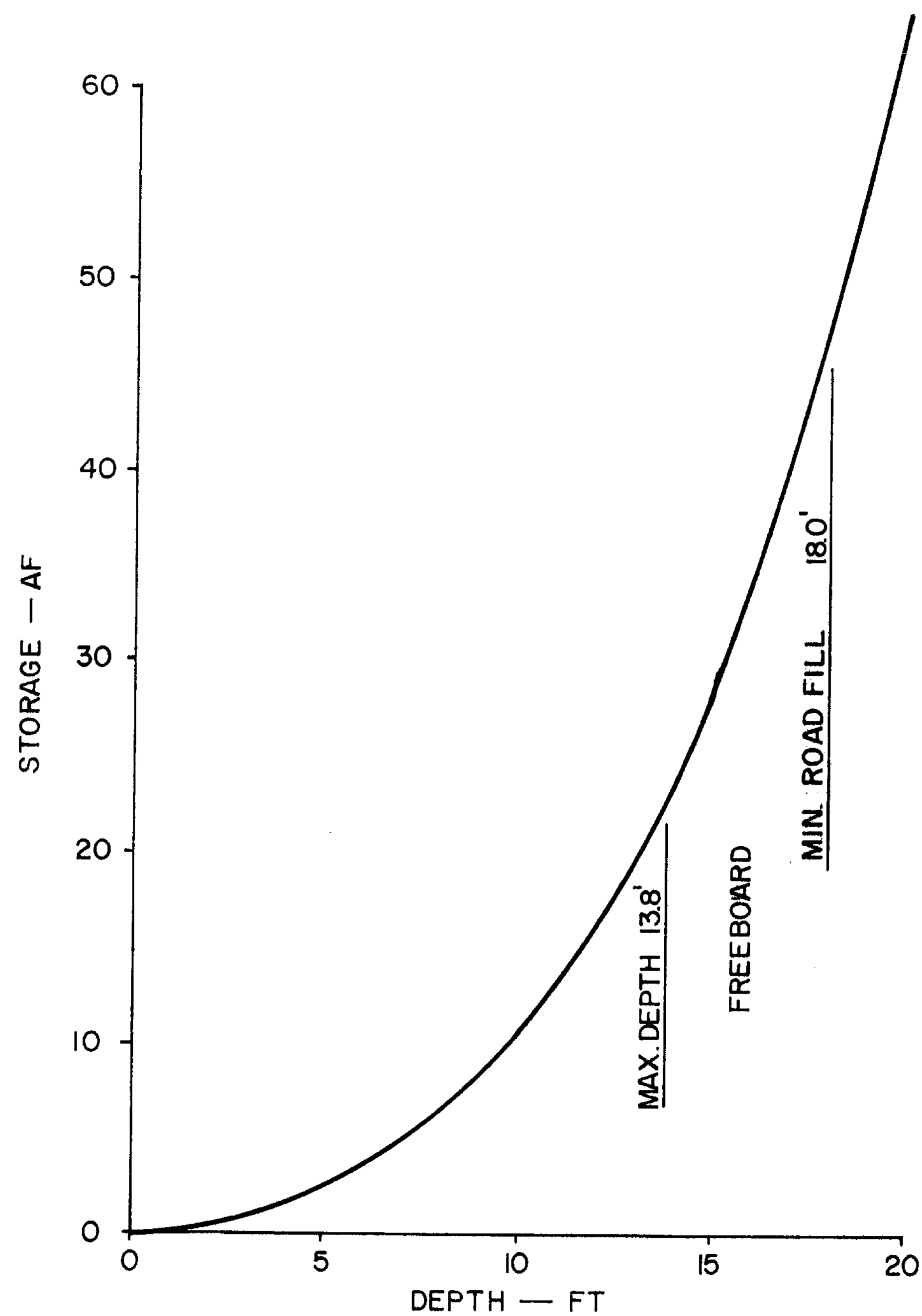
WINDMILL GULCH BASIN
POINT NO. 1
OUTLET CONDUIT CAPACITY CURVE
2-60" DIA x 170'
FIG. 4

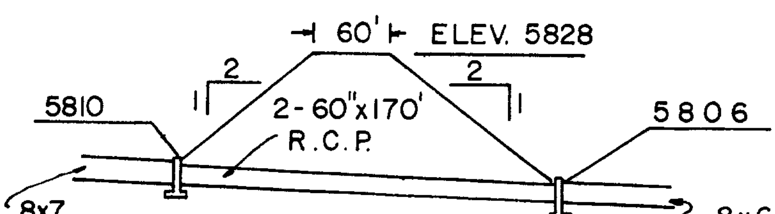


WINDMILL GULCH BASIN
POINT NO. 1
HYDROGRAPH
FIG. 5



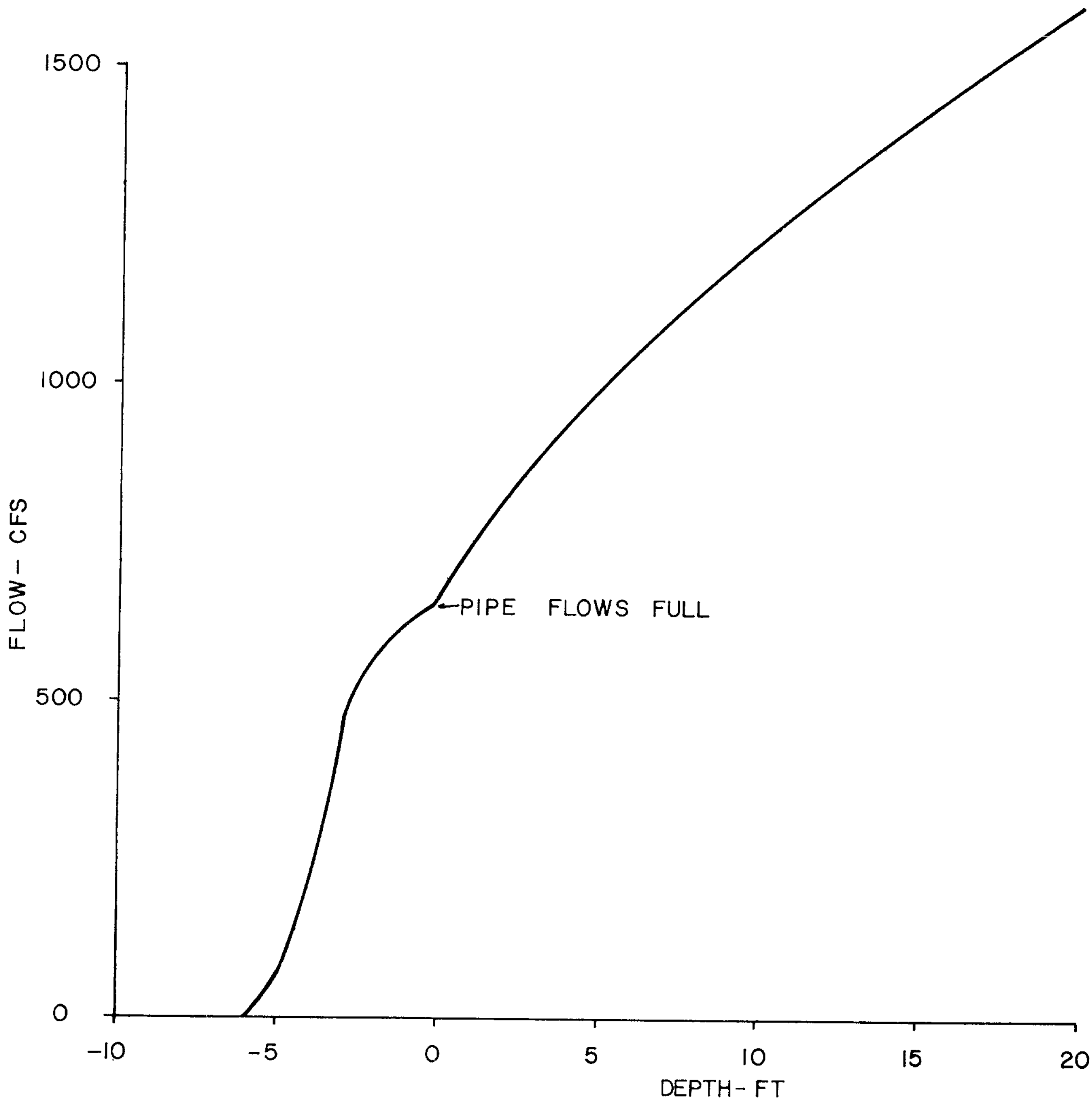
WINDMILL GULCH BASIN
POINT NO. I
STORAGE CURVE
FIG. 6





ROAD SECTION

WINDMILL GULCH BASIN
POINT NO. 2
RESERVOIR CAPACITY CURVE
FIG. 7



WINDMILL GULCH BASIN
POINT NO. 2
OUTLET CONDUIT CAPACITY CURVE
2-60" DIA x 170'
FIG. 8