HYDROLOGIC STUDY OF CAUFIELD BASIN

CAUFIELD BASIN MASTER PLAN

ADOPTED NOVEMBER 1997
(By Ordinance 97-1029)

Prepared for:

City of Oregon City
and
Clackamas County
Community Development Division

Prepared by:

Kampe Associates, Inc.
Portland, OR

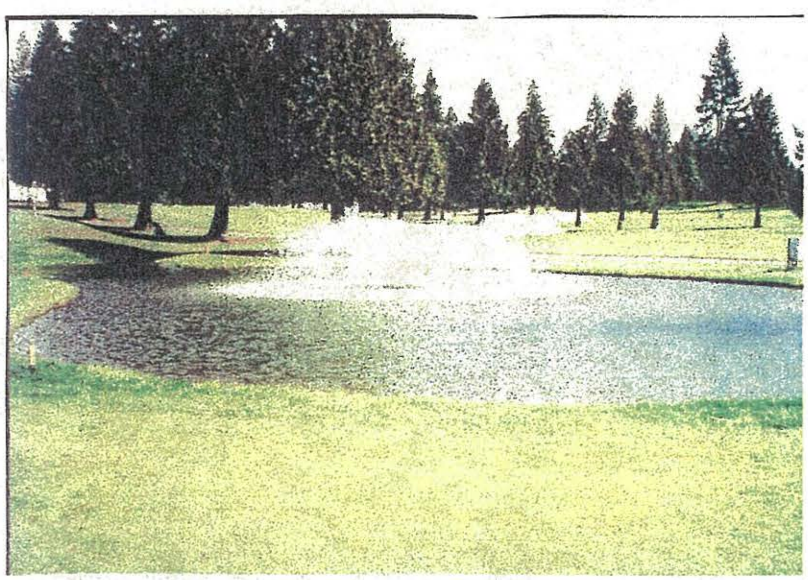


TABLE OF CONTENTS–CAUFIELD DRAINAGE BASIN

INTRODUCTION

Background and Authorization

The City of Oregon City (City) and Clackamas County (County) are currently planning for future development within a 936-acre drainage basin located primarily south and west of Beavercreek Road, along Highway 213, herein referred to as the Caufield Drainage Basin. This study focuses specifically on the easterly portion of the Caufield Basin (1988 Master Plan subbasins CA10 through CA80), a 551 acre area centered on Glen Oak Road, and extending easterly across Beavercreek Road.

This portion of the basin has experienced significant single-family residential development since sanitary sewer has become available. The northerly section of this basin includes a portion of the Clackamas Community College campus, and the Moss School site. The easterly section includes a portion of the Oregon City Golf Course. The Southeasterly section is mostly developed as single family residential housing. The Westerly, downstream section (west of Highway 213) is mostly developed as single- and multi-family housing. The central section of the basin, along Glen Oak Road, is mostly undeveloped.

Kampe Associates, Inc. has been retained to perform the following professional services:

1. Contact public agencies to determine agency requirements and any problems known to the agency.
2. Review existing conditions and available documents pertinent to the project.
3. Prepare a Master Storm Drainage Plan for the basin, based upon the above information.
4. Conduct a public involvement process, which includes, at a minimum, presentation of the final plans to the City Commission at a work session, and presentation of the plans for discussion and approval by the City Planning Commission.
5. Prepare and print thirty copies of the plan and provide them to the City.

Purpose and Objectives

In order for the City of Oregon City to provide storm drainage facilities that will meet the need of future development, a plan must be prepared to identify and model the basin-wide drainage system, considering both the existing facilities and future build-out of storm drainage facilities. Urbanization of a watershed changes its response to precipitation. Development typically increases the amount of impervious area, increasing both the peak runoff flow rate and total runoff volume. As development occurs, this increased runoff may result in flooding, water quality degradation, erosion and sedimentation. This drainage plan has been developed in order to address both the short and long term stormwater management needs of the basin.

In 1988, a storm drainage master plan was developed for all of Oregon City, including some areas within unincorporated Clackamas County. This Master Plan generally described the basins and the expected flow rates under current (1988) and ultimate (buildout) conditions. As a result of this study, the Upper Caufield basin has been identified by the City and County for further study. It is our understanding that it has been selected for study due to periodic flooding problems resulting from inadequate conveyance facilities, and because significant development is anticipated in the future.

The primary objectives of this study are:

- Analyze the existing drainage system, verifying the modeled flow rates from the 1988 study and adjusting for recent construction.
- Determine a layout for the "backbone" drainage system. This layout is to be used as a guide for future development, ensuring that development proposals incorporate these recommended drainage facilities. In addition, the plan may be used to schedule capital improvements in areas not expected to develop or redevelop.

STUDY AREA CHARACTERISTICS

Geography and Topography

The major drainage feature within this drainage basin is a drainageway that starts near the intersection of Beavercreek Road and Henrici Road. Stormwater is conveyed within the ditch along Beavercreek Road to a point approximately 850 feet northwest of Timberski Way, near the entrance to the Oregon City Golf Course. Stormwater is then conveyed in a natural swale from Beavercreek Road to Glen Oak Road at a point approximately one-half mile from the corner of Glen Oak Road and Beavercreek Road. At this point stormwater travels west within shallow ditches along both sides of Glen Oak Road, switching from the north to the south side of the road periodically through culverts. Stormwater continues along Glen Oak Road to a point approximately 450 feet east of Mollala Avenue. At this point the water turns north along side an existing home, then westerly through a culvert below Mollala Avenue to a pond located near the base of an electrical transmission tower. From this pond, stormwater travels west to the lower reach of Caufield Creek. A second drainage channel, parallel to, and north of Glen Oak Road, conveys storm water from east of Beavercreek Road westerly across a broad, relatively flat swale south of Clackamas Community College, and enters Caufield Creek near the east end of its culvert crossing under Highway 213.

Climate/Rainfall Pattern

Climatological data from the National Oceanic and Atmospheric Administration (NOAA) was reviewed for the Oregon City reporting station. The City of Oregon City has mild, wet winters and warm, relatively dry summers. Average minimum winter temperatures are in the mid-thirties, with extremes seldom dropping below zero degrees Fahrenheit. Average maximum summer temperatures are in the low eighties, with extremes seldom exceeding one hundred degrees Fahrenheit. The average annual precipitation is approximately 47 inches, with much of the precipitation occurring from October to May. Snowfall constitutes less than two percent of the annual precipitation.

Drainage Problems

1. Currently, stormwater is generally conveyed in open ditches along Beavercreek Road and Glen Oak Road, except for street crossings. In most cases these ditches are relatively shallow and are subject to flooding. Consideration should be given to how water should be routed through this area either within pipelines or open channels.
2. Where the ditch turns north, approximately 450 feet east of the corner of Mollala Avenue on Glen Oak Road, stormwater flows along side an existing home. The ditch in this area appears relatively shallow and subject to flooding. This study will look at possible rerouting of all or a portion of the stormwater away from this home.
3. The roadside ditch, along Glen Oak Road, qualifies as a perennial stream, per the State of Oregon Division of State Lands (DSL). It therefore is regulated under state and federal programs as discussed under the **Wetlands** section below. The existing stream channel has been modified along Glen Oak Road to flow in roadside ditches and culverts. It has flooded over the road at three culvert crossings (CA50.42, CA 50.50, CA60.60) during peak storm events in each of the last two years.

FEMA Flood Data

As noted in the 1988 Master Plan, the most recent Flood Insurance Study (FIS) was published by the Federal Emergency Management Agency (FEMA) in 1977. For the purposed of both insurance and regulation of development within the floodplain, FEMA established the 100-year flood as the base, or regulatory, flood. The 100-year flood event, by definition, has a one percent chance of occurrence in any given year. The FIS maps show no flooding hazard along Glen Oak Road during this 100-year flood event. Since flooding problems are known to exist, it is assumed that the 1977 FEMA study made no analysis of this (then) largely rural area. It is recommended that the City delineate the 100-year flood plain elevations for the Glen Oak Road region of Caufield Creek, incorporating these areas into the next Land Use Plan Update, prohibiting construction in these areas.

Soils Characteristics

Classification of soils in the study area have been made by the Soil Conservation Service. See **Exhibit 1** for a map of the soil types in the study area. Soils are categorized into *Hydrologic Soil Groups*, based on an estimate of the amount of runoff resulting from precipitation. These groupings assume that the soils are saturated and receive precipitation from long-duration storms. This rainfall to runoff relationship is complex and includes the *drainage* and *permeability* characteristics of the soil.

Drainage is the removal of excess surface and subsurface water from the soil. How easily and effectively the soil is drained depends on the depth to bedrock, to a cemented pan, or to other layers that affect the rate of water movement; permeability; depth to a high water table or depth of standing water if the soil is subject to ponding; slope; susceptibility to flooding; subsidence of organic layers; and potential frost action. Excavating and grading and the stability of ditchbanks are affected by depth to bedrock or to a cemented pan, large stones, slope, and the hazard of cutbanks caving.

Permeability refers to the ability of a soil to transmit water or air. The estimates indicate the rate of downward movement of water when the soil is saturated. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Permeability is considered in the design of soil drainage systems, septic tank absorption fields, and construction where the rate of water movement under saturated conditions affects behavior. Typical soil permeabilities vary from low values between 0.2-0.6 in./hour to moderate values between 0.6-2.0 inches/hour to high values between 2.0-6.0 inches/hour.

The four hydrologic soil groups are:
Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained t excessively drained sands or gravelly sands. These soils have a high rate of water transmission.
Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Soils in the study area are predominately silt loams on level to moderate slopes. Drainage characteristics for these soils is moderate. **Table 1** summarizes the various soils found and their hydrologic grouping.

TABLE 1 HYDROLOGIC GROUPINGS OF SOILS		
Soil Legend	**Soil Name**	**Soil Group**
8B	Bornstedt Silt Loam, 0-8% slopes	C
8C	Bornstedt Silt Loam, 8-15% slopes	C
24B	Cotrell Silty Clay Loam, 2-8% slopes	C
45B	Jory Silty Clay Loam, 2-8% slopes	C
45C	Jory Silty Clay Loam, 8-15% slopes	C
45D	Jory Silty Clay Loam, 15-30% slopes	C
Source: Soil Survey of Clackamas County, Oregon (U.S. - SCS)		

All soil types within the Upper Caufield Basin are within hydrologic soil group C.

Existing Drainage Facilities

The existing storm drainage facilities consist primarily of roadside ditches, culverts and open channels, with the following exceptions:

- Subbasin CA-30 contains storm drains constructed with the Fairway Downs and Osprey Glen subdivisions
- 1200 lineal feet of 30-inch concrete pipe and catch basins in Glen Oak Road
- 30-inch storm line crossing Mollala Avenue from Brendon Estates (see **Exhibit 2**)

Pond West of Highway 213

The State of Oregon, Department of Water Resources, Dam Safety Section maintains a database of all ponds being greater that 10 feet in height, or greater than 9.2 acre feet in volume. This unnamed pond in the Caufield Basin is listed in this database (ID No. OR03397) as being 10 ft in height and containing 4 ac.-feet of normal storage. Although the pond is in private ownership, it functions as a part of the City's storm drainage system, and ultimately should be maintained by the City for its storm drainage function. In conversation with the current owner of the pond, it was The earth dam which created this pond is of unknown origin, and further research and testing will be necessary to determine its condition. Regional detention relative to this pond is discussed further under "Storage Routing."

Glen Oak Road

The present low flow channel of Caufield Creek crosses Glen Oak Road three times, having its low flow channel in three sections of roadside ditch. Local residents report that these ditch sections are not adequate to handle even annual storm events without erosion, siltation, and over street flooding. The eventual future widening of Glen Oak Road will require relocation of the stream channel on both sides of the road, and will require flow control at the downstream end to prevent continued erosion, siltation, and structural damage. These roadside ditches will become increasingly problematic as upstream areas develop.

Land Use

The transition of a drainage basin from rural to urban land uses can greatly alter its hydrological response to rainfall. Urban land development is usually characterized by a rapid conversion from farmland and natural vegetative cover to rooftops and pavement. This increase in impervious land surfaces can dramatically alter the quantity and quality of storm runoff. As urban development occurs, the amount of rainfall converted to surface runoff is increased and the amount of rainfall contributed to groundwater recharge is decreased. If urban development is accompanied by an efficient drainage system, the time needed for surface runoff to reach a stream is substantially decreased. This results in a concentration of stormwater runoff that generally increases peak flow. Greater peak flows can create flooding problems, depending on the capacity of the drainage system and the downstream conditions.

Wetlands

All developers and agencies must consider wetlands issues from the outset of a project and determine whether sites considered for construction contain a jurisdictional wetland. A "jurisdictional" wetland has been defined under section 404 of the Clean Water Act as "Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." Wetlands falling within this definition are subject to regulation under the Clean Water Act. The "Federal Manual for Identifying and Delineating Jurisdictional Wetlands" provides identification procedures based on the presence of hydrophytic vegetation, hydric soils, and wetland hydrology. In Oregon, an application for authorization to alter a wetland under the respective state and federal programs requires a joint filing submitted to the Oregon Division of State Lands (ODSL) and the U.S. Army Corps of Engineers (COE). A permit is required for any activity that proposes to remove, fill or alter more than 50 cubic yards of material within the bed or banks of "waters of the State of Oregon." These agencies determine if the proposed project meets regulations, and require mitigation of impacts (typically creation of a new or enhancement of an existing wetland), so that the area has no net loss in wetland values. A "Nationwide Permit" program issues permits for projects falling under general categories having minimal impact, such as a maintenance activities, pipeline crossings, and outfall structures.

Failure to comply with state or federal wetland regulatory requirements can be a costly decision. The federal government, for example, has the authority to impose fines of up to $25,000 per day for a violation of the terms of a permit.

In addition to COE and DSL requirements, the Oregon Department of Environmental Quality (DEQ) has the responsibility, under section 401 of the Clean Water Act, to insure that all permitted activities meet state water quality standards. Finally, local jurisdiction in Oregon are required, under Oregon's Land Use Planning Goals, to implement programs to meet specific goals. Goal 5, Open Spaces, Scenic and Historic Areas, and Natural Resources, is "to conserve open space and protect natural and scenic resources." Wetlands are one of the natural resource types identified in the goal. Local jurisdictions in Oregon are in various stages of compliance with Goal 5.

In 1993, Oregon City conducted a wetland inventory, as a first step in meeting this goal. Three areas within the Upper Caufield basin were identified in this inventory as having resource value (see **Exhibit 3**):

- Caufield creek channel along Glen Oak Road
- Caufield Pond, immediately west of Highway 213, on Caufield Creek
- Logged area under the BPA power line corridor, South of Clackamas Community College

Of these three, however, only the pond west of Highway 213 is currently listed and mapped in the National Wetlands Inventory (NWI) database, as having been identified as a jurisdictional wetland. The City of Oregon City, in implementing Goal 5, has adopted into the Municipal Code a Water Resources (WR) Overlay District, intended to protect water resource areas, both ponds and water courses. A "transition area" extending 50 feet from the boundary of the water area or water course, is included in the managed area of each water resource area. Since these requirements apply only to those water resources identified in the water resource inventory of the city and county, the agencies should evaluate this inventory, based on the areas identified in this report as proposed to remain as open channel drainage courses.

MODELING AND DESIGN METHODOLOGY

A computer program was used to create a hydrologic model to analyze the existing drainage subbasins. The computer program used in the analysis was the Watershed Modeling program developed by the Eagle Point Corporation. The Watershed Modeling program has the capability to perform multiple watershed modeling tasks, such as rainfall hyetograph synthesis, flood hydrograph synthesis, flood routing analysis and storage routing, using a variety of computational modeling methods. The methods utilized in this study are described below.

Data Collection

In cooperation with the City and County, **Kampe Associates, Inc. (KAI)** collected available data relative to the drainage characteristics of the study area. Data included mapping and review of record drawings for existing drainage facilities, published rainfall information, soil types, existing and proposed land use, and wetlands. Existing information was verified, wherever possible, by field visits to the site. For the preparation of the base map, digital topographic information, created from aerial photogrammetry, using orthophoto base maps (created in 1987 by Spencer B. Gross Engineering), was obtained for the study area. This topographic information is plotted with two-foot contour intervals and includes spot elevations.

For this study, record drawings were obtained from the City of Oregon City for existing drainage facilities, and field investigations were made to verify, and add to, the record information. Geographic Information System (GIS) survey information was obtained from the Metropolitan Service District (METRO) Planning Department, including soil types, parcel boundaries, wetlands, and the urban growth boundary within the Caufield Drainage Basin. Design drawings of the Fairway Downs and Osprey Glen Subdivisions were obtained from the design engineers. This information was added to the topographic base information to create a composite base map for report exhibits and for use in performing the hydrologic analysis.

Land Use Model

Land use coverages are especially important in hydrology. For existing and ultimately planned development conditions, the 1988 Drainage Master Plan was used to determine impervious area percentages, with modifications based on specific anticipated "Ultimate" buildout conditions. Land use designations are based on current zoning designations in Oregon City and Clackamas County areas.

Exhibit 4 shows the land use designations used for modeling. Areas designated Moderate Density Residential (MDR), Low Density Residential (LDR), and Industrial (IND) are based on existing and future zoning maps. The campuses of Clackamas Community College and Moss School are designated as School (SCH). The Oregon City Golf Course is designated as Open Space (OPN).

Watershed Model

This easterly portion of the Caufield Drainage Basin was divided into 10 subbasins for this analysis. Subbasins originally designated as CA-50 and CA-80 in the 1988 drainage study have been renumbered as CA-50 and CA-55, and CA-80 and CA-85, respectively, in order to perform a more detailed analysis, and to reflect current stormwater flow patterns (see **Exhibit 3**).

Subbasin CA-10 drains the golf course and a small residential area, located east of Beavercreek Road. It drains northerly to a 21-inch culvert at the subbasin outlet.

Subbasin CA-20 is an undeveloped tract north of CA-10 and east of Beavercreek Road, draining to the roadside ditch and across the road in a 12-inch culvert.

Subbasin CA-30, where Caufield Creek first flows in a defined natural channel along Glen Oak Road, is currently being developed with single-family housing.

Subbasin CA-40 is mostly undeveloped tract on the North side of Glen Oak Road, across from CA-30.

Subbasins CA-50, CA-55 and CA-60 are minor swales lying West of CA-40 and CA-30.

Subbasin CA-70 is a large, relatively flat wide swale along the South side to Clackamas Community College. It receives drainage from CA-20, and does not impact the Glen Oak Road drainage.

Subbasin CA-80 lies West of Highway 213, but its outfall is piped across the highway, and enters Caufield Creek at the outfall of CA-55.

Subbasin CA-85, also West of Highway 213, surrounds, and drains directly into the existing pond.

Storm Recurrence Interval

In designing storm drainage facilities, it is common practice to size culverts, pipes and ditches for larger flows in areas that cannot tolerate flooding, such as major highways, and to size for smaller flows in less traveled areas, such as local collector streets, which can tolerate a greater amount of flooding. This is a matter of economics relating to the storm recurrence interval. If hydraulic facilities are designed for a 100-year storm recurrence interval, the probability that the design flow will be exceeded in any given year is quite low (i.e., one percent probability), so the level of protection against flooding would be very high. If the design was based on a 2-year storm recurrence interval, the probability of exceedance would be very high (i.e., fifty percent probability in any given year), so the level of protection would be quite low. The obvious trade-off in the planning and design of drainage facilities is the cost of the facility. The 25-year storm recurrence interval was chosen as the maximum storm event to consider for "Minor" drainage structures, and the 100-year storm recurrence interval was chosen as the design storm event for the major channel analysis of the Upper Caufield Drainage Basin.

Rainfall

The volume of runoff from rainfall is determined primarily by the amount of precipitation and by infiltration characteristics related to soil type, antecedent moisture, type of vegetal cover, impervious surface, and surface retention. Once the storm recurrence interval or design frequency has been established, the rainfall intensity can be determined. This study uses the Intensity-Duration-Frequency (IDF) curve prepared for the Oregon City region in Metro's 1980 "Storm Water Management Design Manual." The original IDF curve and interpolated data points used for modeling are included in Appendix B.

For purposes of hydrologic analysis and design, the rainfall distribution with respect to time, or hyetograph, is required. A hyetograph can be synthesized, if a series of rainfall distribution values are known. The United States Soil Conservation Service (SCS) developed dimensionless rainfall distributions, based on the generalized rainfall-duration-frequency relationships established by the U.S. Weather Bureau. The SCS Type 1A rainfall distribution was used in this study. The 1A rainfall distribution was found by the SCS to be applicable to the storm patterns observed in the portion of Oregon and Washington located west of the Cascades. Appendix B presents the SCS rainfall distribution regions for the Pacific states and a graph of the Type 1A rainfall distribution.

Using the SCS rainfall distribution charts, the total precipitation for the 2-year, 25-year, and 100-year storm recurrence intervals were estimated to be as follows:

2-Year, 24-Hour Storm	2.6 Inches
25-Year, 24-Hour Storm	4.0 Inches

100-Year, 24-Hour Storm 4.5 Inches

The total precipitation values listed above were input into the Watershed Modeling program to synthesize the rainfall hyetographs. From the hyetographs, storm runoff hydrographs (time distributions of storm runoff) were created by the program. From the hydrograph, peak runoff values and total volumes over time were found.

SCS Curve Number Method

The Watershed Computer Model offers the user many options to transform rainfall input into rainfall excess. (Rainfall excess is the portion of rainfall that does not infiltrate into the soil-cover complex and is, therefore, available for runoff.) The SCS's Curve Number method was selected for use in this study. In this method, the combination of hydrologic soil group and land use is used to determine the hydrologic soil-cover complex. The effect of the hydrologic soil-cover complex on the amount of rainfall that runs off is represented by a runoff curve number, referred to as CN. The curve numbers that were assigned to each of the hydrologic soil groups throughout the study area are shown in **Table 2.**

TABLE 2
CURVE NUMBERS USED FOR HYDROLOGIC SOIL GROUPS WITHIN THE UPPER CAUFIELD DRAINAGE BASIN

Land Use Description	Curve Numbers for Hydrologic Soil Group			
	A	B	C	D
Low Density Residential (LDR)	N/A	N/A	82	N/A
Moderate Density Residential (MDR)	N/A	N/A	90	N/A
Open Space and Parks (OPN)	N/A	N/A	74	N/A
Industrial (IND)	N/A	N/A	82	N/A
Schools (SCH)	N/A	N/A	79	N/A

Runoff Analysis

In 1965, the SCS developed the TR-20 model for hydrologic evaluation of flood events, for use in analysis of water resource projects. It computes direct runoff resulting from synthetic or natural rainstorms. Flood hydrographs are developed, as well as routing for channels and reservoirs. The TR-20 model was originally intended for large, rural watersheds. The Watershed Modeling computer program incorporates a methodology similar to that used in the TR-20 model to compute and route hydrographs.

Multiple runs of the SCS TR-20 model were used to develop the TR-55 model. The TR-55 model was developed in 1975 and is used for smaller urban areas ranging in area from 1 to 2,000 acres. The TR-55 assumes a twenty-four-hour Type I, IA, II, and III Rainfall Hyetograph and that 1.4 to 2.1 inches of rain has fallen within the basin prior to the design storm. TR-55 determines each individual hydrograph and routes them to an outlet point. The results of our Watershed Modeling are summarized in **Table 3.** This table summarizes the modeling parameters and resultant peak flow rates for each subbasin, under existing conditions and under full development conditions.

TABLE 3 SUMMARY OF HYDROLOGIC DATA									
	CA-10	CA-20	CA-30	CA-40	CA-50	CA-55	CA-60	CA-70	CA-80
Area (acres)	73.8	92.2	153.6	49.7	42.6	25.5	30.2	174.0	27.9
EXISTING DEVELOPMENT CONDITION									
SCS Curve Number	74	74	82	74	74	82	86	74	82
Time of Concentration, TC (min.)	92.6	151.9	63.3	83.3	129.8	58.3	93.0	128.3	23.6
Impervious Fraction (%)	5.0	2.0	14.0	9.0	4.0	2.6	3.6	2.0	25.0
25-Year Storm Peak Discharge, Q (cfs)	10.9	10.3	45.6	8.3	5.3	7.1	8.3	20.9	13.6
FULL DEVELOPMENT CONDITION									
Weighted CN No.	74	85	87	87	87	87	87	87	87
Time of Concentration, TC (min.)	22.2	32.8	22.0	23.1	35.6	10.9	12.7	22.1	8.0
Impervious Fraction (%)	25	15	20	20	32	32	25	28	25
25-Year Storm Peak Discharge, Q (cfs)	27.3	20.5	63.4	16.4	21.4	17.9	20.2	99.2	19.9

Flood Routing

Flood routing refers to the process of calculating the passage of a flood hydrograph through a drainage system. Channel Routing (through a piped or open channel system) and Storage Routing (through a reservoir) accounts for the amount of water stored in the stream or reservoir when calculating downstream peak flows.

Channel Routing

For the Caufield basin, the Modified Att-Kin (MAK) method was used to determine the effect of channel storage when routing and combining subbasin flows. This method used channel cross-section geometry and longitudinal slope to determine the affect of storage and time coefficients. The continuity equation and the manning equation (or field flow tests) are used to calculate a downstream hydrography in which the peak flow is both lower in quantity and later in time than that which would result from a simple addition of hydrographs.

The Modified Att-Kin method of modeling determines a downstream output hydrography based on the velocity and the cross section of a stream channel. By using these two factors, the stream channel acts as reservoir thereby storing water within the basin and releasing it at some lower rate (i.e. reducing the expected peak flowrate). As the size of the drainage areas and channel sizes increase, or where the confluence of large streams are being considered, channel processes must be considered to maintain a reasonable level of model accuracy. For designs in small watersheds there may be small cross sectional areas and high velocities that would result in little or no storage capacity within the channel. In terms of the hydrologic cycle within the Caufield Basin, the channel processes that are used by the Modified Att-Kin method may not significantly lower the peak flowrates. Therefore, it is our opinion that the individual peak flowrates can simply be added at their combination nodes. The individual subbasin and the combined peak flowrates for the 25-year 24-hour storm are shown on **Exhibit 5**.

Storage Routing (Stormwater Detention)

The concept of detention is to store the excess upstream stormwater that would otherwise cause downstream flooding, and release it at a slower, predetermined rate. The design rate of release from the detention pond may be based on the capacity of a downstream drainage structure, or, in a drainage basin where development or other land use changes are occurring, the rate of release may be limited to the current peak flow rate. (In this case, a detention pond would be sized to store excess runoff anticipated with future development and to release no more than peak flows associated with present development.) This is desirable where land use changes may cause flows that overload portions of an existing downstream conveyance system.

There are essentially two types of detention methods: on-site detention and regional detention. On-site detention is defined as runoff detention installed with each development to reduce the peak runoff to a certain mandated value. A policy of requiring on-site detention results in numerous small detention basins throughout the community. These basins are difficult to monitor when they become numerous and, thus, often lack funding for the maintenance required for them to function properly.

Water Quality

On November 16, 1990, the Environmental Protection Agency (EPA) published regulations requiring stormwater discharge permits, as a part of its National Pollution Discharge Elimination System (NPDES). Listed in Section 40 of the Code of Federal Regulations (40CFR) parts 122, 123 and 124, these rules implement Sections 401 and 402(p) of the 1972 Clean Water Act, and became effective December 17, 1990. The regulations apply to cities and unincorporated urbanized areas having populations greater than 100,000. Regulated agencies in the local region include Multnomah and Washington Counties, including some cities and agencies within these counties, and the City of Portland. These regulations cover industrial stormwater dischargers under individual or group permits. Cities and counties must prepare detailed management plans that include water quality testing, pollutant source identification, and a plan to reduce pollution using appropriate management practices. Although Clackamas County and Oregon City are not listed as regulated agencies in the 40CFR NPDES stormwater regulations, Clackamas County and nine co-applicants, including Oregon City, submitted a Permit Application as a group. The final NPDES stormwater permit has been issued. Compliance with NPDES requirements will certainly be a learning process, and the related water quality considerations should form the foundation of a stormwater management plan, including an update of stormwater design standards.

Natural Drainage System Concepts

The traditional stormwater control method for Upper Caufield Creek would require, at ultimate build out, a continuous network of pipes, from the street catch basins to the outfall in an open channel at the downstream end of the basin. Experience developed over the last 30 years has revealed significant problems with past stormwater control practices. Recently, planners and developers have used the concepts of "Natural Drainage" and "Major-Minor" systems. Details of these concepts, summarized below, are provided in References 1 to 3.

In a natural drainage system, the drainage course, over time, sizes itself to respond to the varying amounts of runoff. Low-flow channels form which accommodate storms of about 2-year recurrence intervals or less, and flood plains form for the major storm events. Caufield Creek is one such natural channel that has formed over the years. Constructing a drainage system patterned after this natural system offers the following advantages over piped systems:

- Increased potential for infiltration
- Water quality improvement
- Aesthetic appeal
- Potential cost savings

This type of system utilizes the existing natural drainage system to the fullest extent possible, minimizing the use of underground storm sewers. Where drainage channels need to be constructed, wide, shallow swales lined with grass or native vegetation are used instead of cutting deep narrow ditches.

The Major-Minor concept was developed to eliminate flooding while minimizing the cost of the storm drainage system. The minor system, consisting of underground pipes and culverts, and/or swales, is designed to transport more frequent storms, while minimizing inconvenience to the public. The major system consists primarily of surface grading, shallow swales, and natural channels. This system is designed to accept some inconvenience, but to eliminate significant flood damage during large storms.

Typical guidelines for this design concept are as follows:

- Site grading and building location should be done so that in a complete failure of the minor storm system, no buildings will be flooded by the design storm flow.
- Where channels cross a roadway, the low point should be located directly over the culvert.
- Use the 10-year storm to design the minor drainage system.
- Perform more detailed analysis of problem areas such as sump areas, relatively flat areas, and structures located lower than streets or parking lots.
- Use the 100-year storm to design the major drainage system.

This is the conceptual framework for the proposed improvements to Caufield Creek and adjoining storm drainage improvements along Glen Oak Road.

In addition, the following considerations should be given when designing natural drainage systems:

- Wetland mitigation areas, water quality ponds, and the construction or reconstruction of open channels should be designed and landscaped with the goal of stream maximizing stream health, utilizing sedimentation and biological uptake as mechanisms of pollutant removal.
- Existing wetland areas, whether designated as jurisdictional wetlands or not, should be improved or rehabilitated to maximize their usefulness for water quality enhancement.

Infiltration

The use of dry wells for roof drainage was considered as a measure to reduce surface runoff by recharging stormwater into the ground. Other potential advantages of this type of on-site infiltration include decreasing the cost of a conventional drainage system, improving water quality, and increasing dry-weather stream flows. Disadvantages of these systems include practical difficulties in keeping sediment out of the structure during construction, the need for careful construction of the structures, and the risk of groundwater contamination.

Soil permeability and depth to bedrock are the primary limitations to the widespread use of infiltration structures. Soil permeability requirements vary, but 0.6 inches/hour is normally required at a minimum. This permeability should be measured on site by percolation tests typically used to design septic tank systems. The "perc" test should be run on the soil horizon with the minimum permeability. The minimum depth to bedrock should be 5 feet Infiltration structures should be designed to allow bypassing of runoff during extreme storms or when the facility clogs. Infiltration systems are typically designed for the control of storms less than a 10-year design frequency.

Since the soils in this drainage basin are generally not suited for infiltration, widespread use of dry wells for on-site disposal of stormwater is not recommended. However, individual sites may be have specific topography and soils suited to this method. In this case, systems should be designed to the specifications listed above.

PROPOSED IMPROVEMENTS (Revised November 1997)

General

The following five strategies are proposed for stormwater conveyance in the Caufield Drainage Basin:

- Preservation of natural drainage systems;
- Construction of open channel drainage systems;
- Construction of new, or upgrading or existing, piped systems;
- Establishment of existing pond areas as regional detention opportunities; and
- Construction of on-site detention ponds designed to: 1) control peak release rates for the 2-year and 25-year design storms, and 2) enhance water quality.

Drainage improvements within the Caufield Basin that result from these strategies shall be initiated as part of a private site development, or may be part of a Capital Improvement Project (CIP).

Ideally, Caufield Creek and other un-named drainageways in the basin would remain in a natural state for maximum water quality, water resource preservation, and aesthetic benefits. However, urban streams must be managed to accommodate: 1) increased water volumes from increased impervious areas that result from developing previously vacant lands; 2) potential water quality degradation from pollutants introduced through urban land use; and 3) long-term maintenance. In some cases, it may be necessary to create piped or culverted sections.

The Caufield Basin was analyzed to determine the need for regional detention. Regional detention is defined as a storage facility that receives runoff from a large area and is sized to attenuate the peak in that runoff. Regional detention facilities can be situated to take advantage of natural landforms, thereby decreasing construction cost. They can also incorporate parks, trails, open spaces, or wetlands, thus distributing the cost of property acquisition through multiple use. Regional detention facilities offer the advantage of a lower level of monitoring and maintenance effort than on-site detention, due to the decreased total number of facilities. When regional detention facilities are owned and operated by the City, maintenance can be done on a scheduled basis, ensuring that the facilities will function as planned during design storm events. Coordination is required between cooperating developments and/or the City to ensure design adequacy and ability to meet multi-purpose land use goals and to develop construction and maintenance financing strategies.

Detention Facilities

On-Site Detention

The current practice of on-site detention, as described in the City's 1988 Drainage Master Plan, is as follows: "Each detention facility shall be designed to reduce the 25-year recurrence interval peak flow based on after development on-site conditions to that peak flow that would have occurred during a 10-year recurrence interval event based on before-development on-site conditions."

The above detention requirements shall be replaced with the following stormwater detention criteria for on-site detention ponds:

1. *For surface water leaving a development site, the following criteria shall be met:*
   - A. *The peak release rate for the 2-year design storm after development shall not exceed the pre-developed 2-year design storm peak runoff rate.*
   - B. *The peak release rate for the 25-year design storm after development shall not*

exceed the pre-developed 25-year design storm peak runoff rate.

2. *The procedure for determining the detention quantities is set forth in Chapter 4.4 Retention/Detention Facility Analysis and Design, King County, Washington. Surface Water Design Manual (ibid) (revised November 1995) except subchapters 4.4.5 Tanks, 4.4.6 Vaults and Figure 4.4.4G Permanent Surface Water Control Pond Design. This reference shall be used for procedure only.*
3. *A landscaping plan shall be submitted for City approval and landscaping shall be planted prior to plat approval.*
4. *Water quality enhancement shall be considered in configuring the pond and selecting landscape materials.*
5. *A long-term maintenance plan that defines public and/or private responsibility, including financial implications, shall be established for the pond and landscaping.*
6. *Off-site drainage shall not pass through an on-site detention facility without being incorporated into the detention calculations. Provisions for the off-site flows shall be made in the pond's overflow system.*

Regional Detention

For purposes of calculating regional detention requirements, the flow attenuation of upstream on-site detention was ignored, assuming a scenario where these impoundments were filled prior to the modeled 25-year and greater storm event. This is based on research and modeling done in King County, Washington (see Reference 12). This study demonstrated that current "single event" design methodologies do not simulate actual performance of detention ponds. Field calibration of a continuous simulation model of on-site detention ponds led to the following conclusion:

> "The generally poor performance is the result of the ponds filling and overtopping at a frequency greater that the design storm. The reason for this is the inherent assumption in any event-based design that the pond is empty when an event begins. Because pre-developed runoff rates in the Puget Sound area are low, relative to post-developed rates, the ponds drain slowly and contain water for many consecutive days during the winter. Thus, when a large event occurs, the full pond volume is not available and the pond overtops. When a detention pond is full, pond inflows are not detained, and the outflow nearly equals the inflow, increasing the potential for downstream flooding and erosion."

In addition to the on-site detention now required during development, three sub-regional detention facilities located along the Caufield Creek main channel have been identified to attenuate the ultimate 25-year flow rate for the entire basin and control downstream flooding from the 100-year storm event. The facilities have been sized to maximize the detention available without significant alteration of the existing topography, and to consider the location of existing structures and roadways. The land area required for a regional detention facility that is over and above water resource setbacks shall be acquired by the City by dedication or fair compensation. The regional detention facility area within the water resource setbacks shall be dedicated to the City.

These detention facilities should be constructed with consideration to their aesthetic appeal, utilizing curved shorelines and landscaping. During the design phase of these facilities, the design team shall seek to incorporate multiple use features that allow the detention area to function as a public amenity in addition to a detention facility for surface water. Amenities include wetland enhancement, stream channel improvement, trails, parks, and open space. Stormwater detention overflow facilities shall be designed to pass storms between the 25-year and 100-year design storms directly into the major drainage system channel without overtopping.

Drainage Channel Easements

Existing Caufield Creek drainage channels shall be retained as open channel drainage swales when properties develop. As parcels develop, easements shall be dedicated along Caufield Creek's existing open channels. The easements are to be used to reconstruct the Caufield Creek channel with the intent of: 1) accommodating the widening of Glen Oak Road; 2) preserving an open channel for Caufield Creek; 3) providing water quality enhancement; and 4) providing access for maintenance vehicles and equipment. The easements shall range from 15 to 30 feet wide, depending on their configuration and intended use (e.g., a narrower easement may be appropriate for low design flows or if nearby maintenance access is available). Private property owners shall maintain the easements, unless the drainage channel is located within the right-of-way.

Where existing drainage channels are located on parcels that are not being developed, the existing property owners will be requested to protect the drainage channels from erosion, filling, or reconfiguration. This request is intended to preserve historic and/or natural drainage routes and enhance water quality. If channel conditions are found to compromise public safety, the City will consider acquiring easements where needed. The easement would provide the City with the ability to improve and maintain the drainage channels.

Proposed Phased Improvements

The improvements presented below are separated into five phases. The improvements are illustrated on **Exhibits 6 and 7**. Timing of easement and right-of-way acquisition and/or improvement design and construction should coincide with land development within the basin; in a manner that most benefits the City; when agreement is reached between the City and the property owner; or when public safety is considered at risk, as determined by the City Engineering Manager.

Phase 1
Reconstruct 2,100 lineal feet of open channel along Glen Oak Road, including the following:
1. Acquire 30-foot wide easements along Glen Oak Road as shown on **Exhibit 6**.
2. Acquire 80,000-square foot detention area in either Option 1 or Option 2 location.
3. Reconstruct Caufield Creek channel in new easement area, allowing for pavement widening and wetland enhancement.
4. Construct sub-regional detention Pond No. 1, Option 1 or 2.
5. Replace existing 48-inch corrugated metal culvert pipe (Node CA 50.42) with 60 lineal feet of 48-inch concrete culvert pipe, slope=1.0%, including field inlet.

Future vertical and horizontal alignment of Glen Oak Road in the 2,100-linear foot area should be considered prior to easement acquisition and design and construction of roadside stream channel.

Phase 2
Stream channel improvements between Glen Oak Road and Highway 213.
1. Acquire an approximately 30-foot wide by 570-foot long easement along existing creek alignment (near power lines).
2. Acquire 80,000 square foot detention area.
3. Construct sub-regional detention Pond No. 2.

Phase 3
Replace 700 lineal feet of existing 30-inch diameter storm drain pipe in Glen Oak Road. If this portion of the road is lowered to improve site distance, the storm drain improvement could be incorporated into the road reconstruction project.

Phase 4

1. Acquire an approximately 15-foot wide by 1,600-foot long easement along the north side of Glen Oak Road, from Beavercreek Road to the west.
2. Construct 1,600 lineal feet of roadside ditch.
3. Construct field inlet and manhole connection at upstream and downstream ends, respectively of existing 21-inch concrete culvert crossing Beavercreek Road at the golf course entrance.
4. Replace existing 12-inch concrete culvert, crossing Beavercreek Road at the outlet of Sub-basin CA-20, with 80 lineal feet of 18-inch culvert.

Phase 5

1. Acquire 90,000-square foot easement at pond west of Highway 213.
2. Reconstruct existing dam, creating sub-regional detention Pond No. 3.

PRELIMINARY CONSTRUCTION COST ESTIMATES

The following phased improvements are proposed, in order of priority (see also **Exhibits 6 & 7**):

PHASE	DESCRIPTION	COST *(1995 dollars)*
1	2100 Lineal Feet of Channel Reconstruction on Lower Glen Oaks Road, 48-inch Culvert Replacement, New Sub-Regional Detention Facility #1, Option 1 or 2.	$624,000
2	New Sub-Regional Detention Facility #2, Acquire CA-70 Easement.	$408,000
3	600 Lineal Feet of 30-inch Pipe Replacement on Central Glen Oaks Road.	$65,000
4	Channel Improvements on Upper Glen Oaks Road, Two Culvert Replacements.	$77,000
5	Purchase and Reconstruct Dam on Existing Pond West of Highway 213 as Sub-Regional Detention Facility #3.	$223,000
	TOTAL	**$1,397,000**

REFERENCES

1. Juncja, N., and J. Veltman, "National Drainage in the Woodland", Wallace, McHarg, Roberts and Todd, Philadelphia, PA, 1977.

2. Diniz, E.V., and W. Espey, Jr., "Maximum Utilization of Water Resources in a Planned Community", Espey, Huston and Associates, Inc., Austin TX, 1976.

3. "Public Facilities Manual", Vol. 2, Fairfax County VA, 1980.

4. Corbitt, R., "Standard Handbook of Environmental Engineering", McGraw-Hill, Inc., New York, N.Y., 1990.

5. Stahre, P. and B. Urbonas, "Stormwater Detention for Drainage, Water Quality, and CSO Management", Prentice-Hall, Inc., Englewood Cliffs, NJ, 1990.

6. DeGroot, W., "Stormwater Detention Facilities", American Society of Civil Engineers, New York, NY, 1982.

7. "Stormwater Management Design Manual", Portland, OR and Vancouver WA Metropolitan Area Service District (METRO), 1980.

8. McCuen, R., "A Guide to Hydrologic Analysis Using SCS Methods", Prentice-Hall, Inc., Englewood Cliffs, NJ, 1982.

9. Schueler, T., "Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs", Metropolitan Washington Council of Governments, Washington, D.C., 1987.

10. "Practices in Detention of Urban Stormwater Runoff", Special Report No. 43, American Public Works Association, Bolingbrook, IL, 1974.

11. Fishman, P., S. Pfeiffer, and S. Schell, "Key Issues in Wetland Regulation in Oregon", National Business Institute, Inc., Eau Claire, WI, 1995.

12. Barker, B., R. Nelson, and M. Wigmosta, "Performance of Detention Ponds Designed According to Current Standards", Stormwater Management Manual for the Puget Sound Basin, 1992.

13. "Soil Survey of Clackamas County, Oregon", United States Department of Agriculture, Soil Conservation Service, 1985.

STORM DRAINAGE PLAN
CAUFIELD BASIN

- SOIL TYPE 8C
- SOIL TYPE 24B
- SOIL TYPE 45C
- SOIL TYPE 45D

LEGEND

Type	Description	Group
8B	Bornstedt silt loam 0-8% slopes	C
8B	Bornstedt silt loam 8-15% slopes	C
24B	Cottrell silty clay loam 2-8% slopes	C
45B	Jory silty clay loam 2-8% slopes	C
45C	Jory silty clay loam 8-15% slopes	C
45D	Jory silty clay loam 15-30% slopes	C

- SOIL BOUNDARY DESIGNATION
- DRAINAGE BASIN BOUNDARY

SCALE: 1" = 800'

EXHIBIT 1

SOIL MAP

PREPARED FOR:
CLACKAMAS COUNTY
COMMUNITY DEVELOPMENT
DIVISION and the
CITY OF OREGON CITY
320 WARNER MILNE ROAD
OREGON CITY, OREGON 97045-4000
2/19/96

PLANNING
CIVIL ENGINEERING
LAND SURVEYING
KAMPE ASSOCIATES

STORM DRAINAGE PLAN
CAUFIELD BASIN

LEGEND

- EXISTING STREAM/DITCH
- EXISTING STORM LINE
- PROPERTY LINE
- DRAINAGE BASIN BOUNDARY

N

SCALE: 1" = 800'

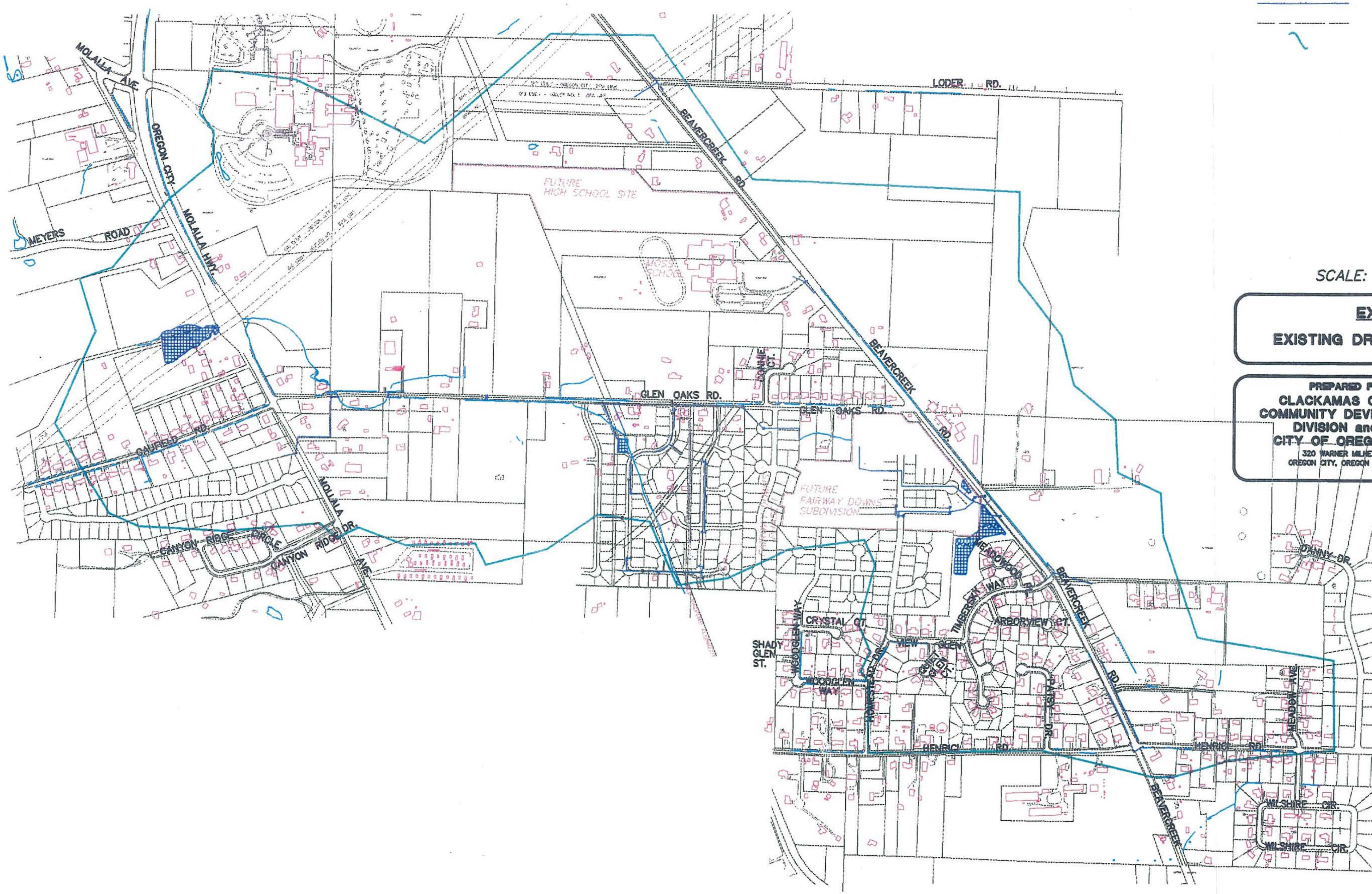


EXHIBIT 2

EXISTING DRAINAGE FACILITIES

PREPARED FOR:
CLACKAMAS COUNTY
COMMUNITY DEVELOPMENT
DIVISION and the
CITY OF OREGON CITY
320 WARNER MILNE ROAD
OREGON CITY, OREGON 97045-4000
2/19/96

PLANNING
CIVIL ENGINEERING
LAND SURVEYING
KAMPE ASSOCIATES

STORM DRAINAGE PLAN
CAUFIELD BASIN

DRAINAGE BASIN BOUNDARY

WETLAND PONDS

WETLAND STREAMS

EXISTING STEAMS

CA-20 SUB-BASIN NUMBER

EXHIBIT 3

DRAINAGE SUB-BASINS & WETLANDS

PREPARED FOR:
CLACKAMAS COUNTY COMMUNITY DEVELOPMENT DIVISION and the CITY OF OREGON CITY
320 WARNER MILNE ROAD
OREGON CITY, OREGON 97045-4000
2/10/96

PLANNING
CIVIL ENGINEERING
LAND SURVEYING
KAMPE ASSOCIATES

Scale: 1"=800'

STORM DRAINAGE PLAN
CAUFIELD BASIN

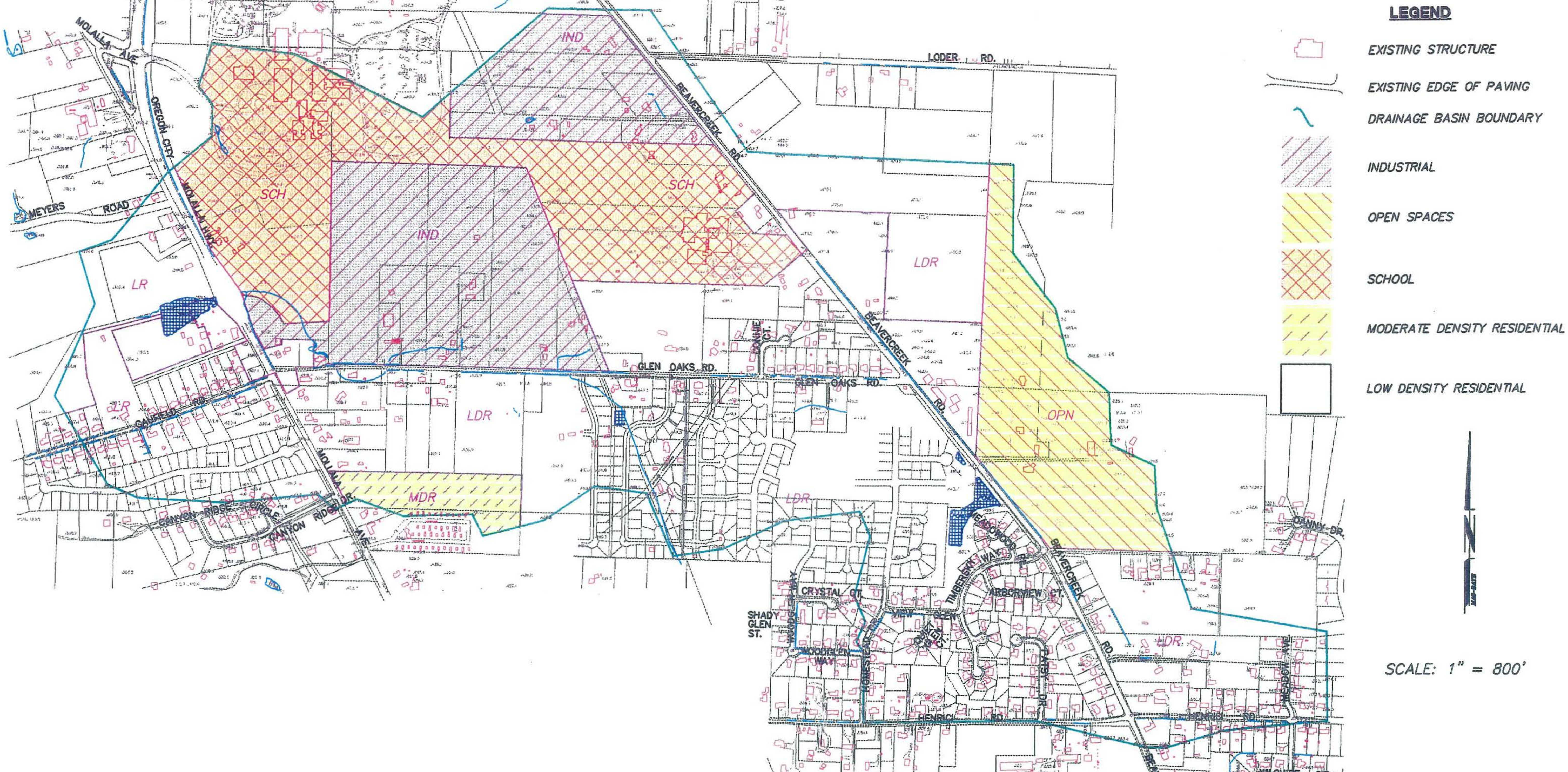


EXHIBIT 4

LAND USE MAP

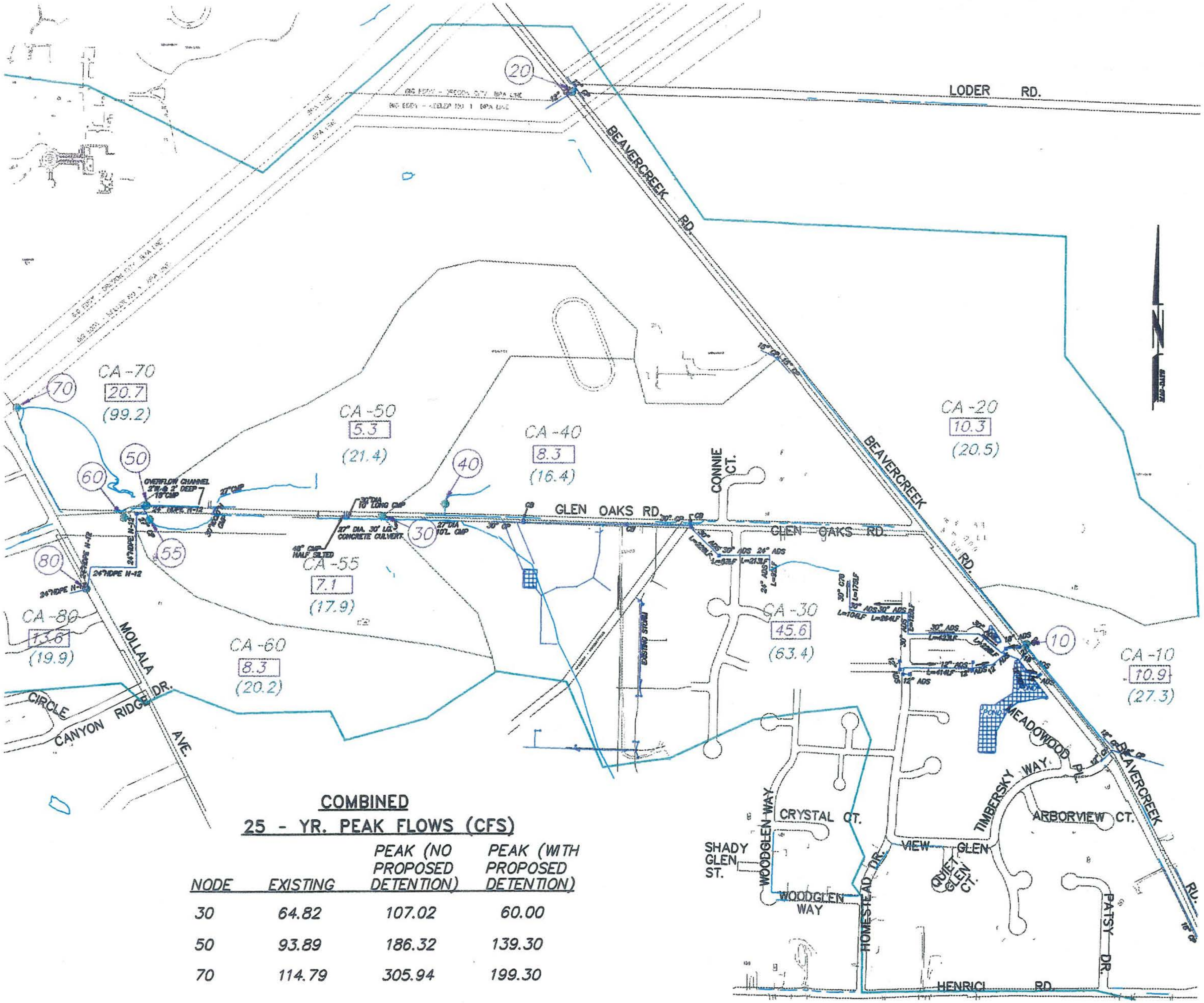
PREPARED FOR:
CLACKAMAS COUNTY
COMMUNITY DEVELOPMENT
DIVISION and the
CITY OF OREGON CITY
320 WARNER MILNE ROAD
OREGON CITY, OREGON 97045-4000
2/16/99

KAMPE ASSOCIATES

STORM DRAINAGE PLAN
CAUFIELD BASIN

CAUFIELD PLACE SCHEMATIC - 25 YR

[10.27]	EXISTING SUBBASIN FLOWS
(99.15)	PEAK SUBBASIN FLOWS - NO DETENTION
(50)	NODE NUMBER
CA-20	SUBBASIN NUMBER



NODE	SUB-BASINS
10	CA10
20	CA20
30	CA10+CA30+CA40
40	CA40
50	CA10+CA30+CA40+CA50+CA55 +CA60+CA80
55	CA55
60	CA60
70	CA10+CA20+CA30+CA40+CA50 +CA55+CA60+CA70+CA80
80	CA80

COMBINED
25 - YR. PEAK FLOWS (CFS)

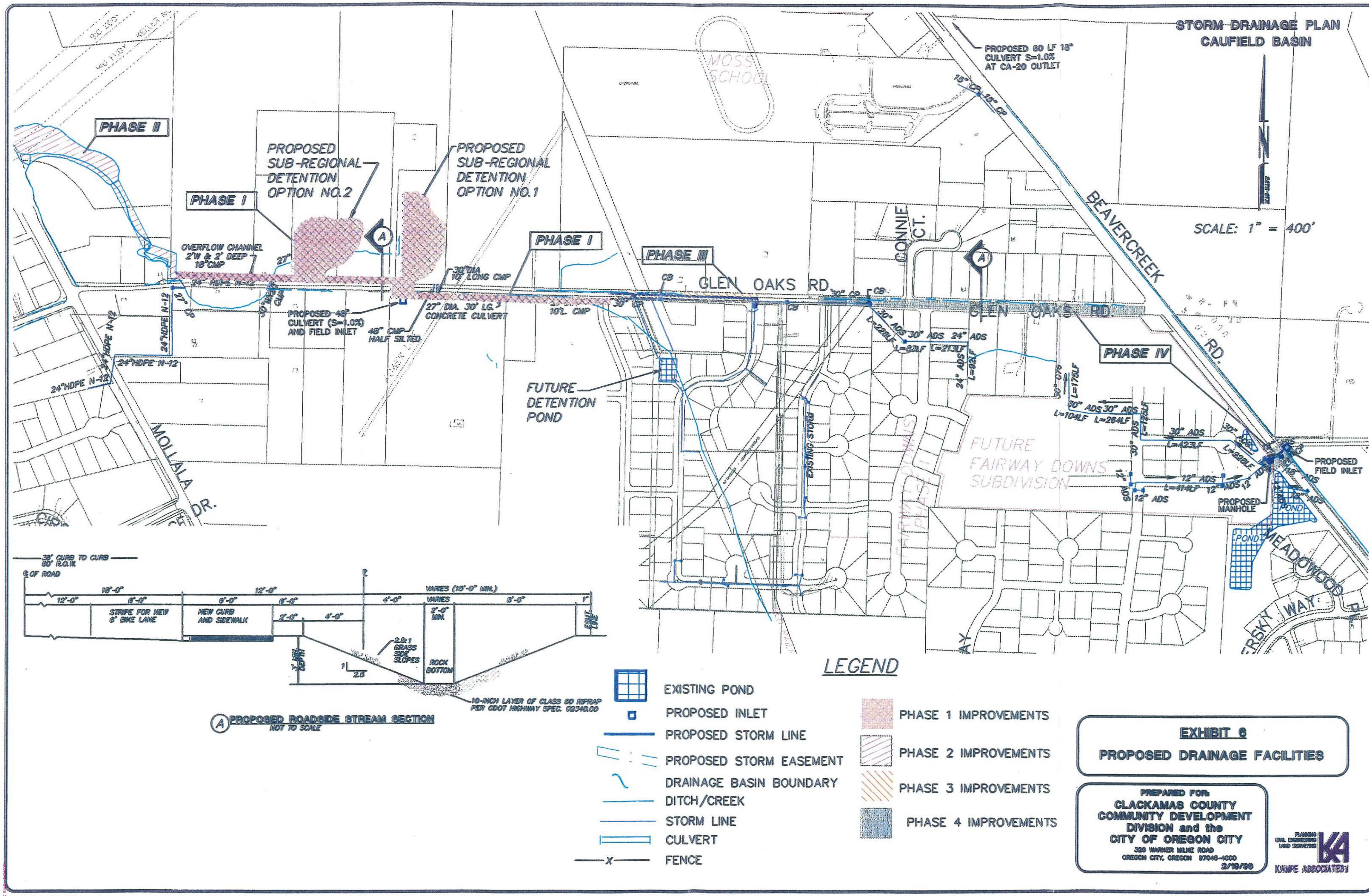
NODE	EXISTING	PEAK (NO PROPOSED DETENTION)	PEAK (WITH PROPOSED DETENTION)
30	64.82	107.02	60.00
50	93.89	186.32	139.30
70	114.79	305.94	199.30

EXHIBIT 5
SUB-BASIN ANALYSIS
25 YEAR EXISTING FLOWS

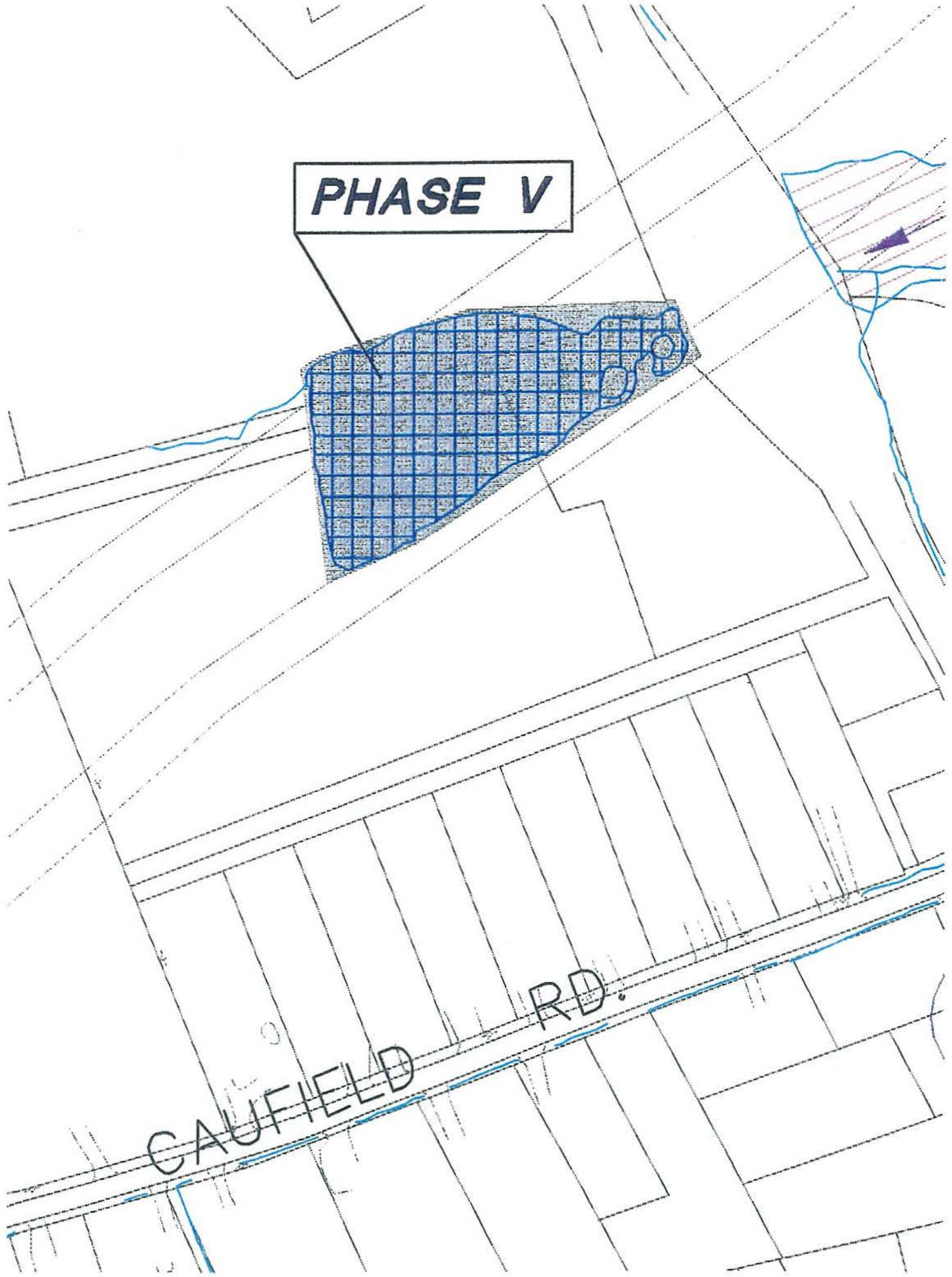
PREPARED FOR:
CLACKAMAS COUNTY
COMMUNITY DEVELOPMENT
DIVISION and the
CITY OF OREGON CITY
320 WARNER MILNE ROAD
OREGON CITY, OREGON 97045-4000
2/19/96

KAMPE ASSOCIATES

SCALE: 1" = 600'


STORM DRAINAGE PLAN
CAUFIELD BASIN
SCALE: 1" = 400'
PROPOSED 60 LF 18" CULVERT S=1.0% AT CA-20 OUTLET
MOSS SCHOOL
PHASE II
PHASE I
PHASE III
PHASE IV
PROPOSED SUB-REGIONAL DETENTION OPTION NO.2
PROPOSED SUB-REGIONAL DETENTION OPTION NO.1
OVERFLOW CHANNEL 2'W & 2' DEEP 18"CMP
24" HDPE N-12
24"HDPE N-12
30"DIA 10' LONG CMP
PROPOSED 48" CULVERT (S=1.0%) AND FIELD INLET
48" CMP HALF SILTED
27" DIA. 30' LG. CONCRETE CULVERT
GLEN OAKS RD
CONNIE CT.
BEAVERCREEK RD.
FUTURE DETENTION POND
EXISTING STORM
FUTURE FAIRWAY DOWNS SUBDIVISION
PROPOSED FIELD INLET
PROPOSED MANHOLE
POND
MEADOWOOD
MOLLALA DR.
PROPOSED ROADSIDE STREAM SECTION
NOT TO SCALE
STRIPE FOR NEW 6' BIKE LANE
NEW CURB AND SIDEWALK
2.5:1 GRASS SIDE SLOPES
ROCK BOTTOM
18-INCH LAYER OF CLASS 50 RIPRAP PER ODOT HIGHWAY SPEC. 02340.00
LEGEND
EXISTING POND
PROPOSED INLET
PROPOSED STORM LINE
PROPOSED STORM EASEMENT
DRAINAGE BASIN BOUNDARY
DITCH/CREEK
STORM LINE
CULVERT
FENCE
PHASE 1 IMPROVEMENTS
PHASE 2 IMPROVEMENTS
PHASE 3 IMPROVEMENTS
PHASE 4 IMPROVEMENTS
EXHIBIT 6
PROPOSED DRAINAGE FACILITIES
PREPARED FOR:
CLACKAMAS COUNTY COMMUNITY DEVELOPMENT DIVISION and the CITY OF OREGON CITY
2/19/96
KAMPE ASSOCIATES

STORM DRAINAGE PLAN
CAUFIELD BASIN



N

SCALE: 1" = 200'

LEGEND

- DITCH/CREEK
- NEW DETENTION POND PHASE 5
- PHASE 2 IMPROVEMENTS
- EXISTING POND

EXHIBIT 7

PROPOSED DRAINAGE FACILITIES

PREPARED FOR:
CLACKAMAS COUNTY
COMMUNITY DEVELOPMENT
DIVISION and the
CITY OF OREGON CITY
320 WARNER MILNE ROAD
OREGON CITY, OREGON 97045-4000
2/19/96

KAMPE ASSOCIATES I

APPENDIX A

REFERENCE TABLES

The following **Reference Tables** are from The ***Eagle Point*** *"Watershed Modeling"* documentation. Runoff Coefficients, Manning's Flow Coefficients, Runoff Curve Numbers, and Structure Coefficients from these tables were used in modeling for this basin. Watershed modeling methods and parameters used in this study are summarized in **Appendix C.**

Appendix A: Reference Tables

The following tables are included for your convenience

- Runoff Coefficients
- Manning's Roughness Coefficients for Sheet Flows
- Manning's Roughness Coefficients for Channel Flows
- Constants for Inlet Control Design Equations
- Manning's n Values for Selected Conduits
- Entrance Loss Coefficients (k_e)
- Runoff Curve Numbers
- K Coefficient for Estimating Travel Time for Shallow Flow in TR-55 Method

Runoff Coefficients

Description of Area		Coefficient
Business	Central Business	0.70 - 0.95
	District and Local	0.50 - 0.70
Residential	Single Family	0.35 - 0.45
	Multi-units	0.40 - 0.75
	1/2 acre lots or larger	0.25 - 0.40
Industrial:	Light	0.50 - 0.80
	Heavy	0.60 - 0.90
	Parks, cemeteries	0.10 - 0.25
	Playgrounds	0.20 - 0.35
	Railroad yards	0.20 - 0.40
	Unimproved	0.10 - 0.30

For Impervious Surfaces

Description of Surface	Coefficient
Asphalt	0.70 - 0.95
Concrete	0.80 - 0.95
Roofs	0.75 -0.95

For Pervious Surfaces

Slope	SCS Soils			
	A	B	C	D
Flat (0-2%)	0.04	0.07	0.11	0.15
Average (2 - 6%)	0.09	0.12	0.16	0.20
Steep (Over 6%)	0.13	0.18	0.23	0.28

Manning's Roughness Coefficients for Sheet Flow

Surface	Manning's n Value
Smooth concrete	0.012
Ordinary concrete lining	0.013
Good wood	0.014
Vitrified clay	0.015
Brick with cement mortar	0.014
Cast iron	0.015
Corrugated metal pipes	0.023
Cement rubble surface	0.024
Short grass	0.015
Dense grass	0.024
Bermuda grass	0.041
Light underbrush woods	0.40
Dense underbrush woods	0.80
Rangeland	0.13

SOURCE: *Hydraulic Analysis and Design*, Richard H. McCuen, 1989.

Manning's Roughness Coefficients for Channel Flow

Description of Area		Manning's n Range
Unlined Open Channels		
Earth, Uniform Section	Clean, recently completed	0.016 - 0.018
	Clean, after weathering	0.018 - 0.020
	With short grass, few weeds	0.022 - 0.027
	In gravely soil, uniform section, clean	0.022 - 0.025
Earth, fairly uniform section	No vegetation	0.022 - 0.025
	Grass, some weeds	.025 - 0.030
	Dense weeds or aquatic plants in deep channels	0.030 - 0.035
	Sides, clean, gravel bottom	0.025 - 0.030
	Sides, clean, cobble bottom	0.030 - 0.040
Dragline excavated or dredged	No vegetation	0.028 - 0.033
	Light brush on banks	0.035 - 0.050
Rock	Based on design section	0.035 - 0.050
	Based on actual mean section: Smooth and uniform	0.035 - 0.040
	Based on actual mean section: Jagged and irregular	0.040 - 0.045
Channels not maintained, weeds and brush uncut:	Dense weeds, high as flow depth	0.080 - 0.120
	Clean bottom, brush on sides	0.050 - 0.080
	Clean bottom, brush on sides, highest stage of flow	0.070 - 0.110
	Dense brush, high stage	0.100 - 0.140

Manning's Coefficient for Channel Flow, continued

Description of Area			Manning's n Range
Roadside channels and swales with maintained vegetation (Values shown are for velocities of 2 and 6 ft/sec)			
Depth of flow up to 0.7 ft	Bermuda grass, Kentucky bluegrass, buffalo grass	Mowed to 2 in.	0.045 - 0.070
		Length 4 to 6 in.	0.050 - 0.090
	Good stand, any grass	Length about 12 in.	0.090 - 0.180
		Length about 24 in.	0.150 - 0.300
	Fair stand, any grass	Length about 12 in.	0.080 - 0.140
		Length about 24 in.	0.130 - 0.250
Depth of flow 0.7 - 1.5 ft	Bermuda grass, Kentucky bluegrass, buffalo grass	Mowed to 2 in.	0.035 - 0.050
		Length 4 to 6 in.	0.040 - 0.060
	Good stand, any grass	Length about 12 in.	0.070 - 0.120
		Length about 24 in.	0.100 - 0.200
	Fair stand, any grass	Length about 12 in.	0.060 - 0.100
		Length about 24 in.	0.090 - 0.170

Manning's Coefficient for Channel Flow, continued

Description of Area			Manning's n Range
Natural Stream Channels			
Minor Streams (surface width at flood stage less than 100 ft.)	Fairly regular section	Some grass and weeds, little or no brush	0.030 - 0.035
		Dense growth of weeds, depth of flow materially greater than weed height	0.035 - 0.050
		Some weeds, light brush on banks	0.040 - 0.050
		Some weeds, heavy brush on banks	0.050 - 0.070
		Some weeds, dense willows on banks	0.060 - 0.080
	For trees within channel, with branches submerged at high stage, increase all above values by:		0.010 - 0.020
	Irregular sections, with pools, slight meander, increase value for fairly regular sections by about:		0.010 - 0.020
	Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stage	Bottom of gravel, cobbles and few boulders	0.040 - 0.050
		Bottom of cobbles, with large boulders	0.05 - 0.07

SOURCE: *Hydraulic Analysis and Design*, Richard H. McCuen, 1989

K Coefficient for Shallow Flow

Land Use	K
Forest with heavy ground litter, hay meadow	0.25
Trash fallow or minimum tillage cultivation; contour or strip cropped; woodland	0.50
Short grass pasture (outland flow)	0.70
Cultivated straight row (outland flow)	0.90
Nearly bare and untilled (overland flow)	1.00
Grassed waterway	1.50
Unpaved Area	1.60
Paved area (sheet flow); small upland gullies	2.00

SOURCE: *Hydraulic Analysis and Design*, Richard H. McCuen, 1989

Constants for Inlet Control Design Equations

Chart Number	Shape and Material	Nomograph Scale	Inlet Edge Description	Equation Form
1	Circular	1	Square edge w/headwall	1
	Concrete	2	Groove end w/headwall	
		3	Groove end projecting	
2	Circular	1	Headwall	1
	CMP	2	Mitered to slope	
		3	Projecting	

3	Circular	A	Beveled ring, 45° bevels	1
		B	Beveled ring, 33.7° bevels	
8	Rectangular	1	30° to 75° wingwall flares	
	Box	2	90° and 15° wingwall flares	1
		3	0° wingwall flares	
9	Rectangular	1	90° headwall w/ 3/4" camfers	2
	Box	2	18° to 33.7° wingwall flare, d = .083D	
10	Rectangular	1	90° headwall w/ 3/4" camfers	2
	Box	2	90° headwall w/45° bevels	
		3	90° headwall w/33.7° bevels	

Constants for Inlet Control Design, continued

Chart Number	Shape and Material	Nomograph Scale	Inlet Edge Description	Equation Form
11	Rectangular	1	3/4" chamfers; 45° skewed headwall	2
	Box	2	3/4" chamfers; 30° skewed headwall	
		3	3/4" chamfers; 15° skewed headwall	
			45° bevels; 10° - 45° skewed headwall	
12	Rectangular	1	45° non-offset wingwall flares	2
	Box	2	18.4° non-offset wingwall flares	
	3/4" chamfers	3	18.4° non-offset wingwall flares	
			30° skewed barrel	
13	Rectangular	1	45° wingwall flares—offset	2
	Box	2	33.7° wingwall flares—offset	
	Top Bevels	3	18.4° wingwall flares—offset	
16-19	C M Boxes	1	90° headwall	1
		2	Thick wall projecting	
		3	Thin wall projecting	

Constants for Inlet Control Design, continued

Chart Number	Unsubmerged		Submerged	
	K	M	c	Y
1	.0098	2.0	.0398	0.67
	.0078	2.0	.0292	0.74
	.0045	2.0	.0317	0.69
2	.0078	2.0	.0379	0.69
	.0210	1.33	.0463	0.75
	.0340	1.5	.0553	0.54
3	.0018	2.5	.0300	0.74
	.0018	2.5	.0243	0.83
8	.026	1.0	.0385	0.81
	.061	0.75	.0400	0.80
	.061	0.75	.0423	0.82
9	.510	0.667	.0309	0.80
	.486	0.667	.0249	0.83
10	.515	0.667	.0375	0.79
	.495	0.667	.0314	0.82
	.486	0.667	.0252	0.865

Constants for Inlet Control Design, continued

Chart Number	Unsubmerged		Submerged	
	K	M	c	Y
11	.522	0.667	.0402	0.73
	.533	0.667	.0425	0.705
	.545	0.667	.04505	[0.68]
	.498	0.667	.0327	0.75
12	.497	0.667	.0339	0.803
	0.493	0.667	0.0361	0.806
	0.495	0.667	0.0386	0.71
13	0.497	0.667	0.0302	0.835
	0.495	0.667	0.0252	0.881
	0.493	0.667	0.0227	0.887
16-19	0.0083	2.0	0.0379	0.69
	0.0145	1.75	0.0419	0.64
	0.0340	1.5	0.0496	0.57

SOURCE: *Hydraulic Design of Highway Culverts, Hydraulic Design Series, No.5.* U.S. Department of Transporation, 1985.

Roughness Coefficients (Manning's n Values) for Selected Conduits

Surface	Manning's n Value
Reinforced concrete pipe	0.013
Reinforced concrete box	0.013
Vitrified clay pipe	0.013
Coated cast iron pipe	0.011
Uncoated cast iron pipe	0.012
Commercial wrought-iron, black pipe	0.013
Commercial wrought-iron, galvanized pipe	0.014
Smooth lockbar and welded "OD" pipe	0.011
Riveted and spiral steel	0.015
Corrugated metal pipe	0.0225
Corrugated aluminum pipe	0.0225
Corrugated metal pipe (paved invert)	0.020
Corrugated metal multi-plate pipe	0.035
Polyvinyl chloride (PVC) pipe	0.010

Entrance Loss Coefficients k_e

Box Culverts

Type of Structure and Design of Entrance	Coefficient
Headwall Parallel to Embankment (no wingwalls):	—
Square-edged on three edges	0.50
Three edges rounded to radius of 1/12 barrel dimension	0.20
Wingwalls at 15 to 45 degrees to Barrel:	—
Square-edged top corner	0.40
Top corner rounded to radius of 1/2 barrel dimension	0.20

Pipe Culverts

Type of Structure and Design of Entrance	Coefficient
Concrete Pipe Projecting from Fill (no headwall):	—
Socket end of pipe	0.20
Square cut end of pipe	0.50
Concrete Pipe with Headwall or Headwall and Wingwalls:	—
Socket end of pipe	0.20
Square cut end of pipe	0.50
Rounded entrance, with rounding radius = 1/12 of diameter	0.20
Corrugated Metal Pipe:	—
Projecting from fill (no headwall)	0.90
With headwall or headwall and wingwalls, square edge	0.50

SOURCE: *Hydraulic Design of Highway Culverts, Hydraulic Design Series, No. 5.* U.S. Department of Transportation, 1985.

Runoff Curve Numbers (Ave. Watershed Condition $I_a = 0.2S$

SCS developed a soil classification system consisting of four groups, identified by the letters A, B, C and D. Soil characteristics associated with each group are:

- Group A: deep sand, deep loess, aggregated silts
- Group B: shallow loess; sandy loam
- Group C: clay loams; shallow sandy loams; soils low in organic content; soils
- Group D: soils that swell significantly when wet; heavy plactic clays; certain saline soils

Land Use Description	Average (%) impervious	Curve Numbers for Hydrologic Soil Group			
		A	B	C	D
Fully developed urban areas (vegetation established)					
Lawns, open spaces, parks, golf courses, cemeteries, etc.					
Good condition; grass cover on 75% or more of the area		39	61	74	80
Fair condition; grass cover on 50% to 75% of the area		49	69	79	84
Poor condition; grass cover on 50% or less of the area	—	68	79	86	89
Paved parking lots, roof, driveways, etc.	—	98	98	98	98
Streets and Roads					
Paved with curbs and storm sewers		98	98	98	98
Gravel	—	76	85	89	91
Dirt		72	82	87	89
Paved with open ditches		83	89	92	93
Commercial and business areas	85	89	92	94	95
Industrial districts	72	81	88	91	93
Row houses, town houses and residential with lot sizes 1/8 acre or less	65	77	85	90	92

Cover			Curve Numbers for Hydrologic Soil Group			
Land Use	**Treatment of Practice**	**Hydrologic Conditions**	**A**	**B**	**C**	**D**
Residential: average lot size						
1/4 acre	38	61	75	83	87	
1/3 acre	30	57	72	81	86	
1/2 acre	25	54	70	80	85	
1 acre	20	51	68	79	84	
2 acre	12	46	65	77	82	
Developing urban areas c (no vegetation established Newly graded area	—	77	86	91	94	
Cultivated agricultural land						
Fallow	Straight row		77	86	91	94
	Conservation tillage	Poor	76	85	90	93
	Conservation tillage	Good	74	83	88	90
Row Crops	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Conservation tillage	Poor	70	80	87	90
	Conservation tillage	Good	64	75	82	85
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Contoured and	Poor	69	78	83	87
	conservation tillage	Good	64	74	81	85
	Contoured and terraces	Poor	66	74	80	82
	Contoured and terraces	Good	62	71	78	81
	Contoured and terraces	Poor	65	73	79	81
	and conservation tillage	Good	61	70	77	80

Cover			Curve Numbers for Hydrologic Soil Group			
Land Use	**Treatment of Practice**	**Hydrologic Conditions**	**A**	**B**	**C**	**D**
Small grain	Straight row	Poor	65	76	84	88
	Straight row	Good	63	75	83	87
	Conservation tillage	Poor	64	75	83	86
	Conservation tillage	Good	60	72	80	84
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	3	81	84
	Contoured and	Poor	62	73	81	84
	conservation tillage	Good	60	2	80	83
	Contoured and terraces	Poor	61	72	79	82
	Contoured and terraces	Good	59	70	78	81
	Contoured and terraces	Poor	60	71	78	81
	and conservation tillage	Good	58	69	77	80
Close-seeded legumes or rotation meadow	Straight row	Poor	66	77	85	89
	Straight row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
	Contoured and terraces	Poor	63	73	80	83
	Contoured and terraces	Good	51	67	76	80
Noncultivated agricultural land						
Pasture or range	No mechanical treatment	Poor	68	79	86	89
	No mechanical treatment	Fair	49	69	79	84
	No mechanical treatment	Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	6	35	70	79
Meadow	—	—	30	58	71	78
Forestland - grass or orchards - evergreen or deciduous	—	Poor	55	73	82	86
		Fair	44	65	76	82
		Good	32	8	72	79
Brush	—	Poor	48	67	77	83
		Good	20	48	65	73

Cover			Curve Numbers for Hydrologic Soil Group			
Land Use	**Treatment of Practice**	**Hydrologic Conditions**	**A**	**B**	**C**	**D**
Woods	—	Poor Fair Good	45 36 25	66 60 55	77 73 70	83 79 77
Farmsteads	—	—	59	74	82	86
Forest-range Herbaceous	—	Poor Fair Good	—	79 71 61	86 80 74	—
Oak - aspen	—	Poor Fair Good	—	65 47 30	74 57 41	—
Juniper - grass	—	Poor Fair Good	—	72 58 41	83 73 61	—
Sage - grass	—	Poor Fair Good	—	67 50 35	80 63 46	—

aFor land uses with impervious areas, curve numbers are computed assuming that 100% of runoff from impervious areas are directly connected to the drainage system. Pervious areas (lawn) are considered to be equivalent to lawns in good condition and the impervious areas have a CN of 98.

bIncludes paved streets.

cUse for the design of temporary measures during grading and construction. Impervious area percent for urban areas under development vary considerably.

dFor conservation tillage poor hydrologic condition, 5 to 20% of the surface is covered with residue (less than 750-lb/acre row crops or 300-lb/acre small grain).

eClose-drilled or broadcast.
For noncultivated agricultural land:
Poor hydrologic condition has less than 25% ground cover density.
Fair hydrologic condition has between 25 and 50% ground cover density.

Good hydrologic condition has more than 50% ground cover density.
For forest-range:
Poor hydrologic condition has less than 30% ground cover density.
Fair hydrologic condition has between 30 and 70% ground cover density.
Good hydrologic condition has more than 70% ground cover density.

SOURCE: *Hydraulic Analysis and Design*, Richard H. McCuen,1989.

Appendix B: References

American Public Works Association Research Foundation, *Urban Stormwater Management*. 1st edition. Chicago, American Public Works Association, 1981.

Black, Peter E., *Watershed Hydrology*. 1st edition. Englewood Cliffs, NJ, Prentice Hall, 1991.

Bediet, Philip B., and Huber, Wayne C., *Hydrology and Floodplain Analysis*. 1st Edition. Reading, MA, Addison-Wesley, 1992.

Brater, Ernest F. and King, Horace W., *Handbook of Hydraulics*. 6th edition. New York, McGraw-Hill, 1976.

Chow, V., Maidment, D., and Mays, L., *Applied Hydrology*. 2nd edition. New York, McGraw-Hill, 1988.

City of Austin, *Drainage Manual*. City of Austin, TX, 1989.

City of Los Angeles, *Bureau of Engineering Manual, Part G: Storm Drain Design*. City of Los Angeles Public Works Department, 1973.

DeGroot, William, *Stormwater Detention Facilities*. 1st edition. New York, American Society of Civil Engineers, 1982.

Grant, Douglas M., *Isco Open Channel Flow Measurement Handbook*. 3rd edition. Lincoln, NE, Isco, 1978.

Hromadka, T.; McCuen R.; Yen, C.; *Computational Hydrology in Flood Control and Planning*. 1st edition. Mission Viejo, CA, Lighthouse Publications, 1987.

Illinois Department of Transportation, *Drainage Manual*. Illinois DOT Bureau of Bridges and Structures, 1989.

Kibler, David F., *Urban Stormwater Hydrology, Manual 7*. 1st edition. Washington, D.C., American Geophysical Union, 1982.

King County, Washington, *Surface Water Design Manual*. rev. ed. King County Washington, Department of Public Works, 1990.

Linsley, R.; Kohler, M.; and Paulhus, J.; *Hydrology for Engineers*. 3rd edition. New York, McGraw-Hill, 1982.

Linsley, Ray K., et al., *Water-Resources Engineering*. 4th edition. New York, McGraw-Hill, 1992.

Linsley, R.; Kohler, M.; and Paulhus, J.; *Water Resources and Environmental Engineering*. 2nd edition. New York, McGraw-Hill, 1975.

McCuen, Richard H., *Hydraulic Analysis and Design*. 2nd edition. Englewood Cliffs, NJ, Prentice-Hall, 1989.

Scheaffer, John R. et al., *Urban Storm Drainage Management*. 2nd edition. Washington, D.C., Marcel Decker, 1982.

Singh, Vijay P., *Elementary Hydrology*. 1st edition. Englewood, NJ, Prentice-Hall, 1992.

Soil Conservation Service. *Computer Program for Project Formulation Hydrology TR-20*. US Department of Agriculture, Lanham, MD, 1982.

Soil Conservation Service. *Urban Hydrology for Small Watersheds, TR-55*. 2nd edition. US Department of Agriculture, Lanham, MD, 1986.

U.S. Army Corps of Engineers, *Flood Hydrograph Package, HEC-1*. 4th edition. Davis, CA, Hydrologic Engineering Center, 1990.

U.S. Department of Transportation, *Hydraulic Design of Highway Culverts, Hydraulic Design Series, No. 5*. rev. ed. McLean VA, Federal Highway Administration, 1985.

U.S. Department of Transportation, *Hydrology, Hydraulic Engineering Circular No. 19*. rev. ed. McLean VA, Federal Highway Administration, 1985.

Viessman, Warren Jr. et al, *Introduction to Hydrology*. 2nd edition. New York, IEP, 1977.

Virginia Department of Transportation, *Drainage Manual*. Virginia DOT, 1989.

Wanielista, Martin, *Hydrology and Water Quantity Control*. 1st edition. New York, John Wiley and Sons, Inc., 1990.

Appendix C: Default Layers

The following table contains a list of layers associated with each ***Watershed Modeling*** drawing.

Layer Name	Description
HYDRO 00X	Hydrograph Block and Description (#, Rp, Qp, Tp)
LU_XXXXXX	Land Use Library Layer
WB_XXXXXX	Watershed Library Layer

Graphical Default Layers

The follwing table contains a list of layers associated with each ***Watershed Modeling*** graphic.

Layer Name	Description
Basis	Graph title, outline rectangle, scale line, number
Coords	Coordinate X,Y value
Curvex	Hydrograph, unit hydrograph, structure curve line
Grid	Grid Line
Legend	Legend box, legend description

Appendix D: Time of Concentration (t_C)

Time of concentration, t_c, for a drainage area is defined as the time a drop of water takes to drain from the hydraulically most remote point in the watershed. It affects the shape and the peak discharge of the unit hydrograph and flood hydrograph. In general, higher and faster peak discharge is associated with smaller t_c.

Different methods are available for computing t_c for a drainage area. ***Watershed Modeling*** has two methods built into its programming structure to compute t_c, in addition to the user-defined option. These are the SCS Lag method and the TR-55 tabular method. A brief theory on each of these methods follow:

SCS Lag Method

Proposed by the Soil Conservation Services (SCS), this method uses the basin lag time based on the average land slope, curve number (CN) and the hydraulic length. From the known CN, the available storage, S, is computed using:

$$S = \frac{1000}{CN} - 10 \qquad \text{(D-1)}$$

The basin lag is then estimated using:

$$Lag = \frac{L^{0.8} * (S+1)^{0.7}}{1900 * (s * 100)^{0.5}} \; hours \qquad \text{(D-2)}$$

Where:

Lag = basin lag in hours
L = hydraulic length in feet
S = available storage
s = average slope of the drainage area in ft/ft

The time of concentration, t_c, for the drainage basin is then computed using:

$$t_c = 1.67 * Lag \quad (hours) \qquad \text{(D-3)}$$

$$= (1.67 * Lag) * 60 \quad (minutes) \qquad \text{(D-4)}$$

TR-55 Method

The TR-55 tabular method of computing t_c divides it into travel times for three different segments; namely sheet flow, shallow concentrated flow and channel flow. Travel times for each segment are computed and summed to arrive at the time of concentration for the drainage basin. For example:

$$t_c = t_{sf} + t_{scf} + t_{cf} \qquad \text{(D-5)}$$

Where:
t_c =time of concentration for the drainage basin
t_{sf} =time of travel for sheet flow
t_{scf} =travel time for shallow concentrated flow
t_{cf} =travel time for channel flow

The units of t_c are the same as that of t_{sf}, t_{scf} and t_{cf}.

Sheet Flow

The flow over plane surfaces, which have depths of about 0.1 feet, are lumped into the sheet flow category. Using assumptions of:

- shallow, steady, uniform flow
- constant intensity rainfall excess
- 24-hour storm duration
- negligible effect of infiltration
- flow lengths less that 300 ft

TR-55 uses the kinematic solution to the Manning's equation to calculate t_{sf} as:

$$t_{sf} = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,(s)^{0.4}} \qquad \text{(D-6)}$$

Where:
t_{sf} =sheet flow travel time, in hours
n =Manning's roughness coefficient for sheet flow (see *Appendix A—Reference Tables*)
L =sheet flow length (ft.)
P_2 =2 year, 24 hour rainfall (in.)
s =Slope of hydraulic grade line which is approximated as the land slope in ft/ft.

Shallow Concentrated Flow

TR-55 method assumes that the sheet flow becomes shallow concentrated flow after a maximum of 300 feet. The average velocity is taken as a function of water course slope and land use. The relationship is expressed as:

$$V = k\,(100s)^{0.5} \qquad \textbf{(D-7)}$$

Where:

V =average velocity in ft/sec

k =parameter, which is a function of land use (see *Appendix A—Reference Tables*)

s =average land slope (ft/ft)

The travel time for shallow concentrated flow is then computed as:

$$t_{scf} = \frac{L}{(3600V)} \qquad \textbf{(D-8)}$$

Where:

t_{scf} =time of travel for shallow concentrated flow, in hours

L =flow length (ft)

V =average velocity from equation E-7 in ft/sec

Channel Flow

TR-55 uses Manning's equation to determine the average velocity through channels. The Manning's equation is:

$$V = \frac{1.49}{n} R_h^{2/3} * s^{1/2} \qquad \textbf{(D-9)}$$

Where:

V =average channel velocity in ft/sec

n =Manning roughness coefficient for channel material (see *Appendix A—Reference Tables*)

R_h =hydraulic radius (ft.)

A =flow area (ft^2)

P =wetted perimeter of the channel (ft)

s =slope of the hydraulic grade line, assumed to be the channel slope in ft/ft

The travel time for channel flow, t_{cf}, is then computed as:

$$t_{cf} = \frac{L}{3600V} \qquad \text{(D-10)}$$

Where:

t_{cf} =time of travel for channel flow, in hours

V =average flow velocity, in ft/sec

L =flow length, in feet

Equations E-6, E-7 and E-10 can now be used in equation E-5 to compute time of concentration in hours.

APPENDIX B

SCS RAINFALL DISTRIBUTIONS

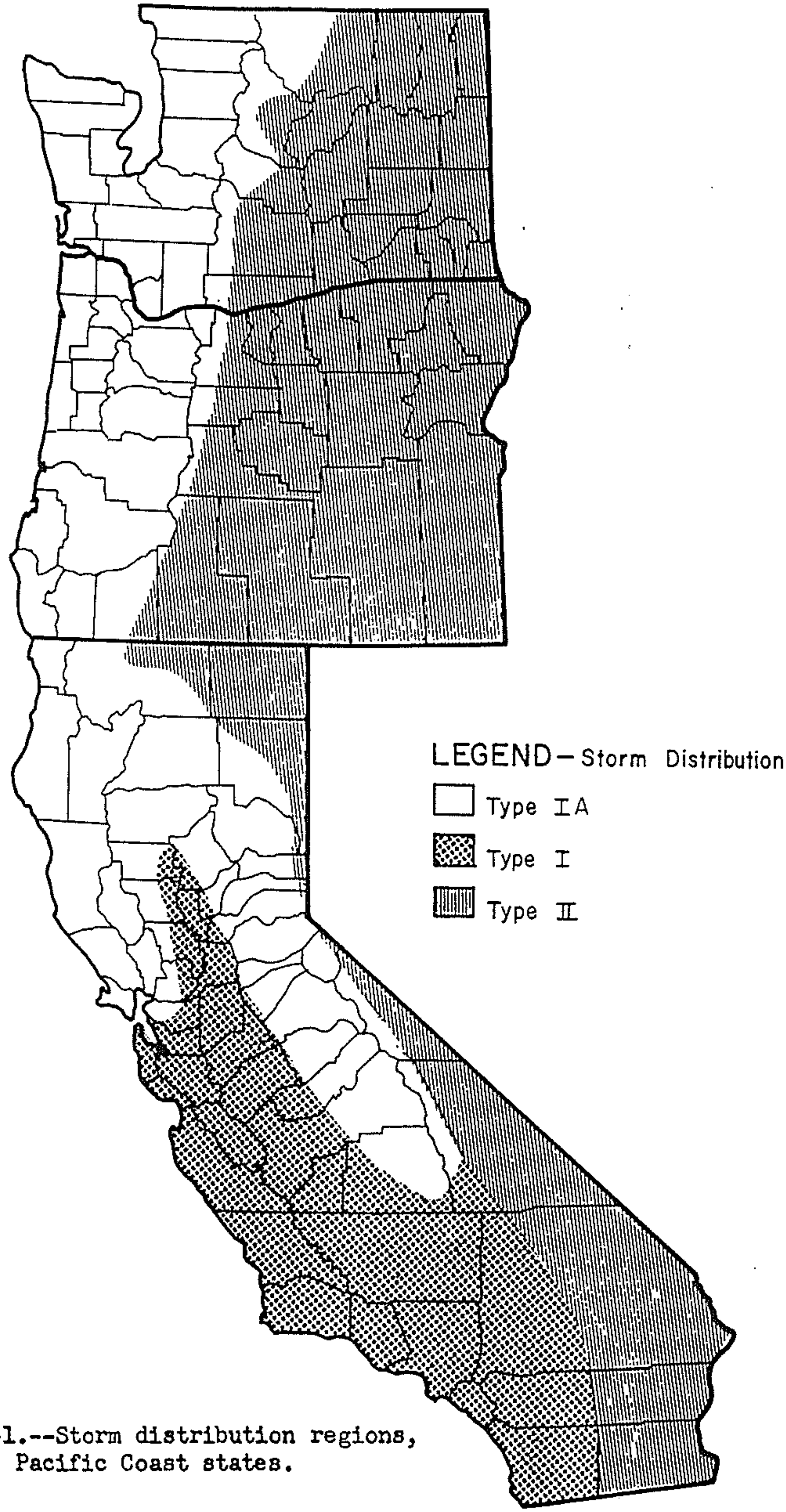


Figure D-1.--Storm distribution regions,
Pacific Coast states.

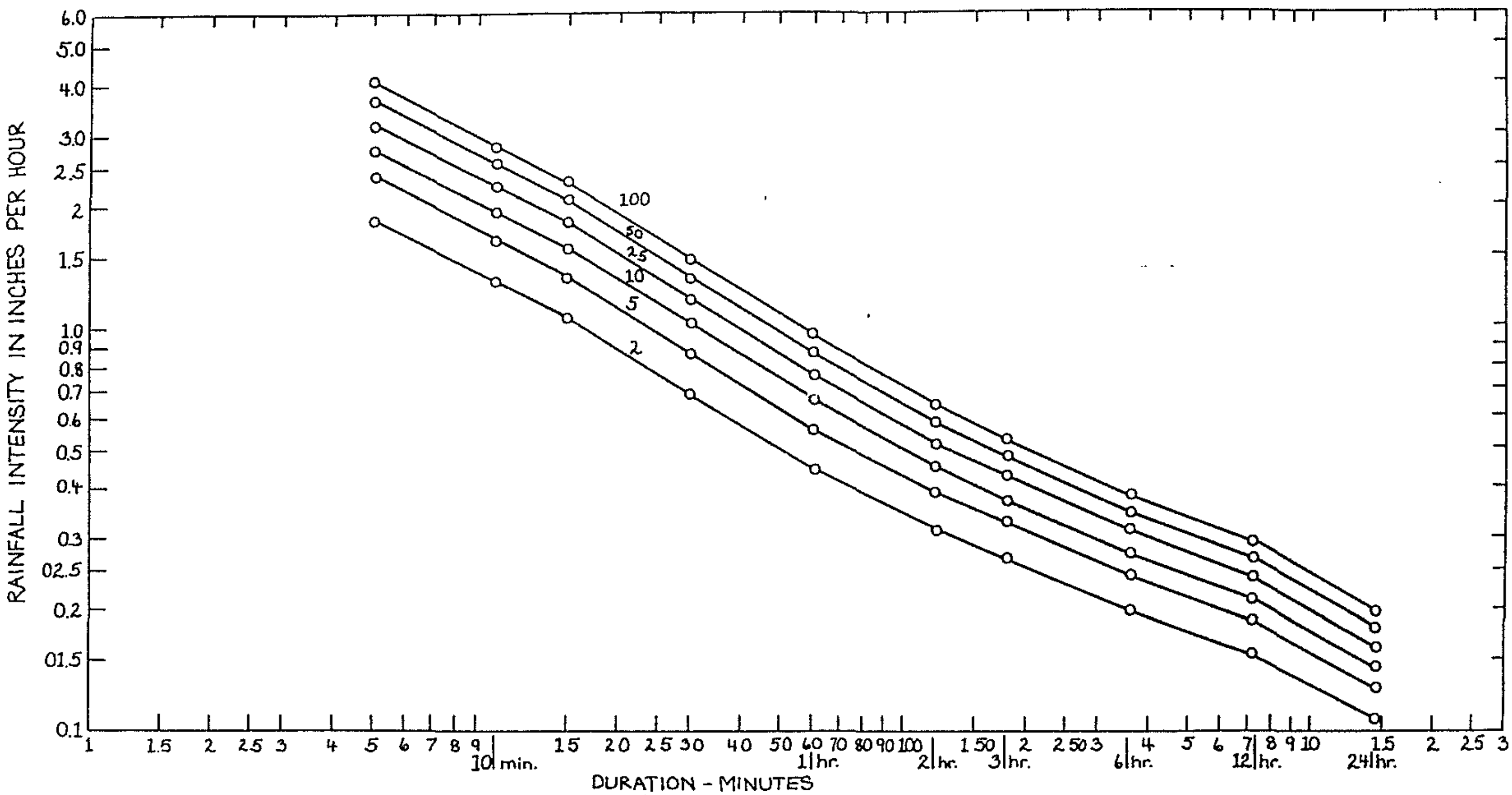


Figure D-3. Intensity-Duration-Frequency/Oregon City

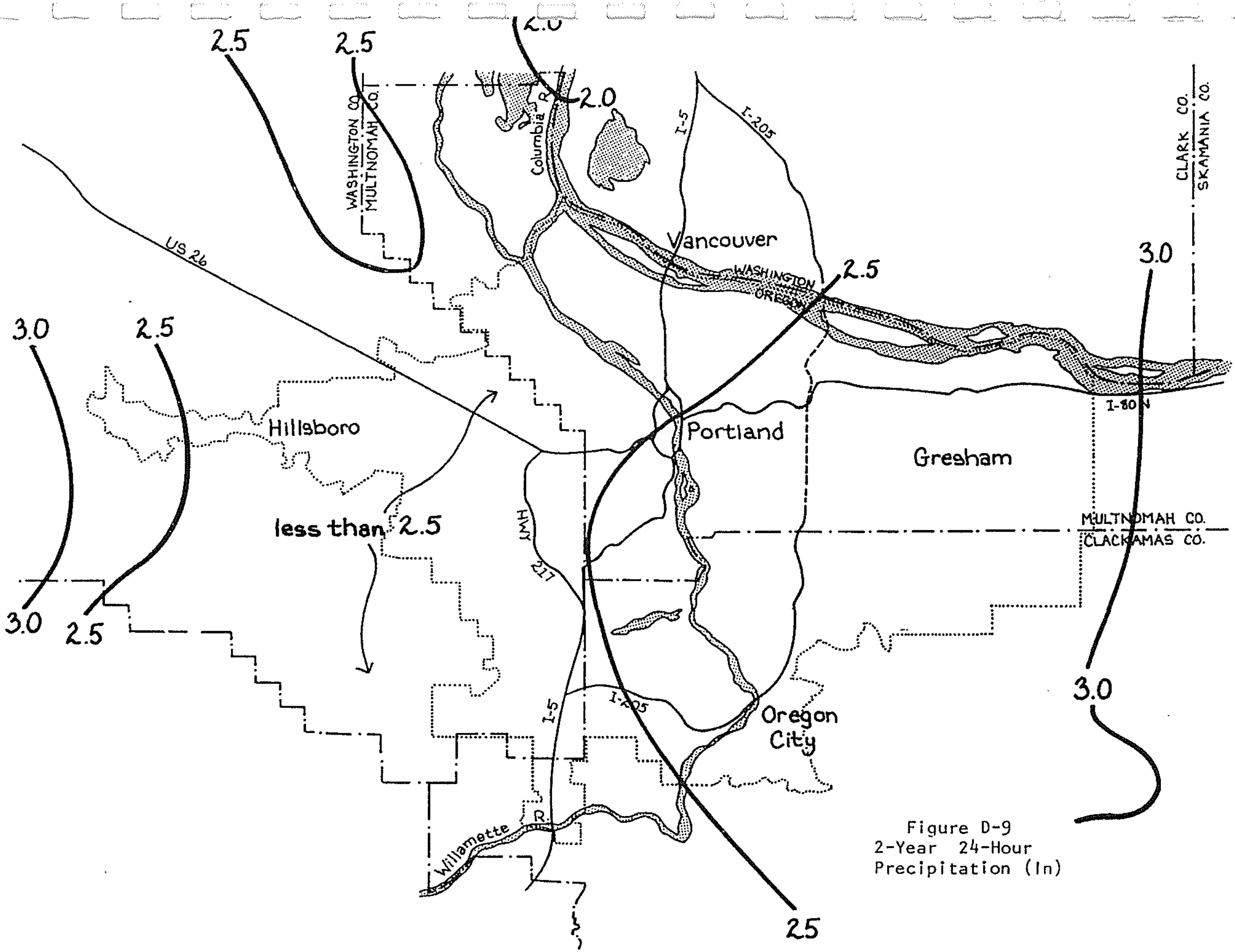


Figure D-9
2-Year 24-Hour
Precipitation (In)

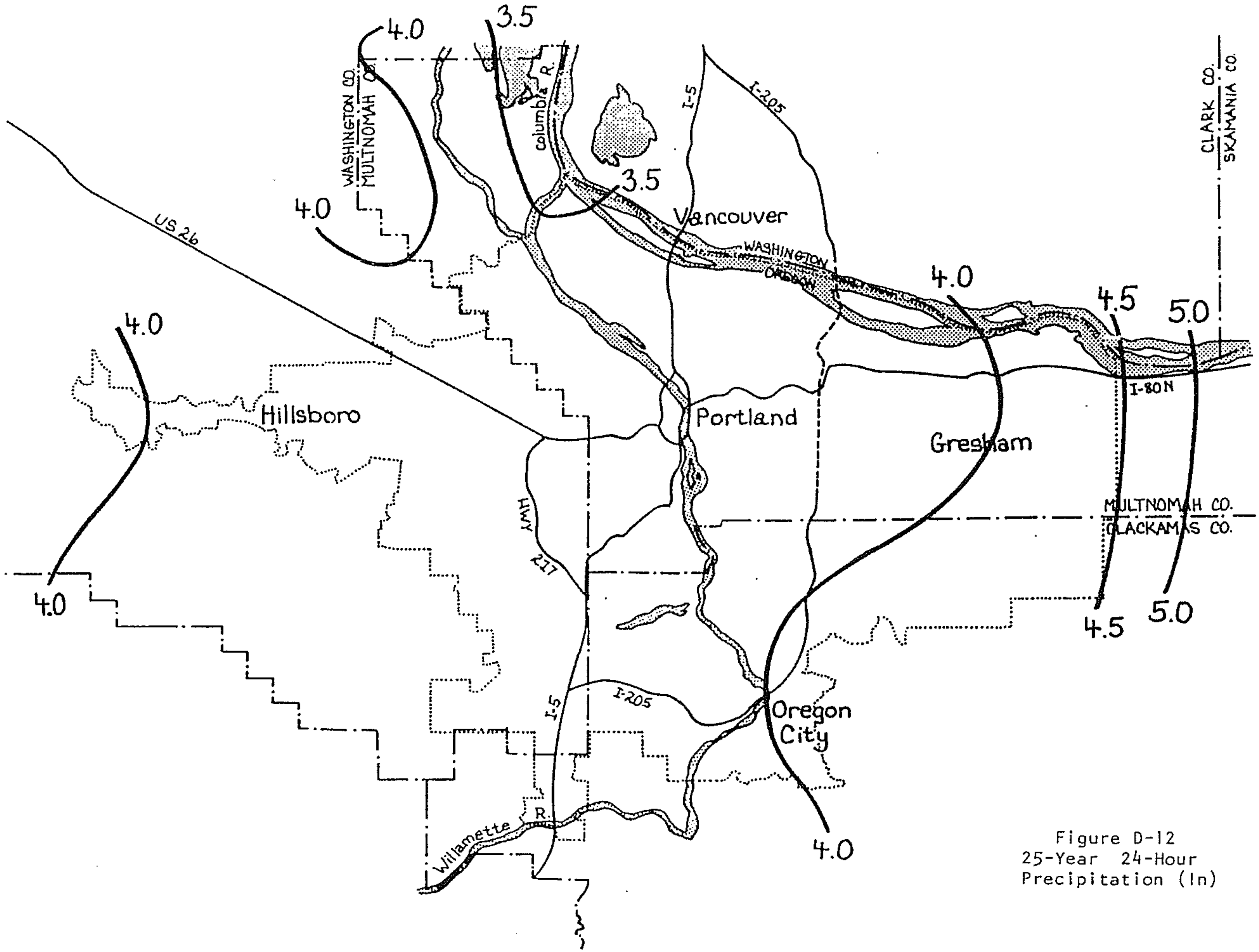


Figure D-12
25-Year 24-Hour
Precipitation (In)

APPENDIX C

FLOOD HYDROGRAPH SUMMARIES & GRAPHS

The following Flood Hydrograph Summaries provide a synopsis of the modeling assumptions and resultant calculated flowrates for each of the modeled subbasins, as well as combined hydrograph data and storage routing results, if applicable.

HYDROGRAPH REPORT
RECORD NUMBER: *1*
TYPE: *SANTA BARBARA*
DESCRIPTION: *EXISTING-CA10-25*

[HYDROGRAPH INFORMATION]

Peak Discharge	=	10.93 (cfs)
Volume	=	10.49 (acft)
Time Interval	=	10.00 (min)
Time to Peak	=	540.00 (min)
Time of Base.	=	2430.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	73.75 (ac)
Curve Number	=	74

TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.25000
Flow Length (L)	=	300.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.02000
Travel Time of Sheet Flow	=	39.39 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	0.70000
Watercourse Slope (S)	=	0.01000
Velocity (V)	=	0.70 (ft/s)
Flow Length (L)	=	1800.00 (ft)
Travel Time of Shallow Flow	=	42.86 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	1.90 (ft)
Channel Slope (S)	=	0.00500
Manning's Roughness Coef. (n)	=	0.10000
Channel Velocity (V)	=	1.62 (ft/s)
Flow Length (L)	=	1000.00 (ft)
Travel Time of Shallow Flow.	=	10.31 (min)

TIME OF CONCENTRATION

Time of Concentration	=	92.56 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction	=	0.05000

HYDROGRAPH REPORT
RECORD NUMBER: *2*
TYPE: *SANTA BARBARA*
DESCRIPTION: *EXISTING-CA20-25*

[HYDROGRAPH INFORMATION]

Peak Discharge	=	10.27 (cfs)
Volume	=	12.65 (acft)
Time Interval	=	10.00 (min)
Time to Peak	=	610.00 (min)
Time of Base	=	3110.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	92.42 (ac)
Curve Number	=	74

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.25000
Flow Length (L)	=	1000.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.03000
Travel Time of Sheet Flow	=	87.75 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	0.70000
Watercourse Slope (S)	=	0.01300
Velocity (V)	=	0.80 (ft/s)
Flow Length (L)	=	2800.00 (ft)
Travel Time of Shallow Flow.	=	58.47 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	1.90 (ft)
Channel Slope (S)	=	0.02000
Manning's Roughness Coef. (n)	=	0.10000
Channel Velocity (V)	=	3.23 (ft/s)
Flow Length (L)	=	1100.00 (ft)
Travel Time of Shallow Flow.	=	5.67 (min)

TIME OF CONCENTRATION

Time of Concentration....................	=	151.90 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction	=	0.02000

HYDROGRAPH REPORT
RECORD NUMBER: *3*
TYPE: *SANTA BARBARA*
DESCRIPTION: *EXISTING-CA30-25*

[HYDROGRAPH INFORMATION]

Peak Discharge	=	45.62 (cfs)
Volume	=	31.04 (acft)
Time Interval	=	10.00 (min)
Time to Peak	=	500.00 (min)
Time of Base	=	2170.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	153.60 (ac)
Curve Number	=	82

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.01300
Flow Length (L)	=	1700.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.01000
Travel Time of Sheet Flow	=	19.56 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	0.70000
Watercourse Slope (S)	=	0.02000
Velocity (V)	=	0.99 (ft/s)
Flow Length (L)	=	2400.00 (ft)
Travel Time of Shallow Flow	=	40.41 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	0.50 (ft)
Channel Slope (S)	=	0.02500
Manning's Roughness Coef. (n)	=	0.01300
Channel Velocity (V)	=	11.42 (ft/s)
Flow Length (L)	=	2300.00 (ft)
Travel Time of Shallow Flow.	=	3.36 (min)

TIME OF CONCENTRATION

Time of Concentration	=	63.32 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction	=	0.14000

HYDROGRAPH REPORT
RECORD NUMBER: 4
TYPE: SANTA BARBARA
DESCRIPTION: EXISTING-CA40-25

[HYDROGRAPH INFORMATION]

Peak Discharge	=	8.27 (cfs)
Volume	=	7.42 (acft)
Time Interval	=	10.00 (min)
Time to Peak	=	530.00 (min)
Time of Base	=	2300.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	49.65 (ac)
Curve Number	=	74

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.25000
Flow Length (L)	=	700.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.04000
Travel Time of Sheet Flow	=	58.80 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	0.70000
Watercourse Slope (S)	=	0.02000
Velocity (V)	=	0.99 (ft/s)
Flow Length (L)	=	1300.00 (ft)
Travel Time of Shallow Flow	=	21.89 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	1.90 (ft)
Channel Slope (S)	=	0.02000
Manning's Roughness Coef. (n)	=	0.10000
Channel Velocity (V)	=	3.23 (ft/s)
Flow Length (L)	=	500.00 (ft)
Travel Time of Shallow Flow	=	2.58 (min)

TIME OF CONCENTRATION

Time of Concentration	=	83.26 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction	=	0.09000

HYDROGRAPH REPORT
RECORD NUMBER: *5*
TYPE: *SANTA BARBARA*
DESCRIPTION: *EXISTING-CA50-25*

[HYDROGRAPH INFORMATION]

Peak Discharge	=	5.29 (cfs)
Volume	=	5.99 (acft)
Time Interval	=	10.00 (min)
Time to Peak	=	560.00 (min)
Time of Base	=	2770.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	42.63 (ac)
Curve Number	=	74

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.25000
Flow Length (L)	=	1200.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.03000
Travel Time of Sheet Flow	=	101.53 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	0.70000
Watercourse Slope (S)	=	0.01800
Velocity (V)	=	0.94 (ft/s)
Flow Length (L)	=	1100.00 (ft)
Travel Time of Shallow Flow	=	19.52 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	1.90 (ft)
Channel Slope (S)	=	0.01000
Manning's Roughness Coef. (n)	=	0.10000
Channel Velocity (V)	=	2.29 (ft/s)
Flow Length (L)	=	1200.00 (ft)
Travel Time of Shallow Flow	=	8.75 (min)

TIME OF CONCENTRATION

Time of Concentration	=	129.81 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction	=	0.04000

HYDROGRAPH REPORT
RECORD NUMBER: *7*
TYPE: *SANTA BARBARA*
DESCRIPTION: *EXISTING-CA60-25*

[HYDROGRAPH INFORMATION]

Peak Discharge	=	8.29 (cfs)
Volume	=	6.53 (acft)
Time Interval	=	10.00 (min)
Time to Peak	=	510.00 (min)
Time of Base	=	2370.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	30.21 (ac)
Curve Number	=	86

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.25000
Flow Length (L)	=	700.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.04000
Travel Time of Sheet Flow	=	58.80 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	0.70000
Watercourse Slope (S)	=	0.02000
Velocity (V)	=	0.99 (ft/s)
Flow Length (L)	=	2000.00 (ft)
Travel Time of Shallow Flow	=	33.67 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	1.90 (ft)
Channel Slope (S)	=	0.02000
Manning's Roughness Coef. (n)	=	0.10000
Channel Velocity (V)	=	3.23 (ft/s)
Flow Length (L)	=	100.00 (ft)
Travel Time of Shallow Flow	=	0.52 (min)

TIME OF CONCENTRATION

Time of Concentration	=	92.99 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction	=	0.03600

HYDROGRAPH REPORT
RECORD NUMBER: *8*
TYPE: *SANTA BARBARA*
DESCRIPTION: *EXISTING-CA70-25*

[HYDROGRAPH INFORMATION]

Peak Discharge	=	20.90 (cfs)
Volume	=	23.81 (acft)
Time Interval	=	10.00 (min)
Time to Peak	=	560.00 (min)
Time of Base	=	2930.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	174.01 (ac)
Curve Number	=	74

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.25000
Flow Length (L)	=	800.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.02300
Travel Time of Sheet Flow	=	81.64 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	0.70000
Watercourse Slope (S)	=	0.02100
Velocity (V)	=	1.01 (ft/s)
Flow Length (L)	=	2000.00 (ft)
Travel Time of Shallow Flow	=	32.86 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	1.90 (ft)
Channel Slope (S)	=	0.01900
Manning's Roughness Coef. (n)	=	0.10000
Channel Velocity (V)	=	3.15 (ft/s)
Flow Length (L)	=	2600.00 (ft)
Travel Time of Shallow Flow	=	13.75 (min)

TIME OF CONCENTRATION

Time of Concentration	=	128.25 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction	=	0.02000

HYDROGRAPH REPORT
RECORD NUMBER: *9*
TYPE: *SANTA BARBARA*
DESCRIPTION: *EXISTING-CA80-25*

[HYDROGRAPH INFORMATION]

Peak Discharge	=	13.64 (cfs)
Volume	=	6.04 (acft)
Time Interval	=	2.00 (min)
Time to Peak.	=	482.00 (min)
Time of Base	=	1672.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	27.93 (ac)
Curve Number	=	82

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.25000
Flow Length (L)	=	100.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.01500
Travel Time of Sheet Flow	=	18.35 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	0.70000
Watercourse Slope (S)	=	0.01500
Velocity (V)	=	0.86 (ft/s)
Flow Length (L)	=	200.00 (ft)
Travel Time of Shallow Flow	=	3.89 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	0.50 (ft)
Channel Slope (S)	=	0.01700
Manning's Roughness Coef. (n)	=	0.01300
Channel Velocity (V)	=	9.41 (ft/s)
Flow Length (L)	=	761.00 (ft)
Travel Time of Shallow Flow	=	1.35 (min)

TIME OF CONCENTRATION

Time of Concentration	=	23.59 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction.	=	0.25000

HYDROGRAPH REPORT
RECORD NUMBER: *10*
TYPE: *SANTA BARBARA*
DESCRIPTION: *ULTIMATE-CA10-25*

[HYDROGRAPH INFORMATION]

Peak Discharge	=	27.30 (cfs)
Volume	=	13.16 (acft)
Time Interval	=	10.00 (min)
Time to Peak	=	490.00 (min)
Time of Base	=	1670.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	73.75 (ac)
Curve Number	=	74

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.04000
Flow Length (L)	=	300.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.05000
Travel Time of Sheet Flow	=	6.30 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	1.50000
Watercourse Slope (S)	=	0.02000
Velocity (V)	=	2.12 (ft/s)
Flow Length (L)	=	1530.00 (ft)
Travel Time of Shallow Flow	=	12.02 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	0.50 (ft)
Channel Slope (S)	=	0.00000
Manning's Roughness Coef. (n)	=	0.01300
Channel Velocity (V)	=	8.23 (ft/s)
Flow Length (L)	=	0.00 (ft)
Travel Time of Shallow Flow	=	3.85 (min)

TIME OF CONCENTRATION

Time of Concentration	=	22.17 (min)

[RAINFALL DESCRIPTION]

Distribution Type........................	=	SCS IA
Total Precipitation......................	=	4.00 (in)
Return Period...........................	=	25 (yr)
Storm Duration..........................	=	24.00 (hr)
Impervious Fraction.....................	=	0.25000

HYDROGRAPH REPORT
RECORD NUMBER: *11*
TYPE: *SANTA BARBARA*
DESCRIPTION: *ULTIMATE-CA20-25*

[HYDROGRAPH INFORMATION]

Peak Discharge	=	20.47 (cfs)
Volume	=	20.47 (acft)
Time Interval	=	10.00 (min)
Time to Peak	=	540.00 (min)
Time of Base	=	3150.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	92.42 (ac)
Curve Number	=	85

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.04000
Flow Length (L)	=	1200.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.02000
Travel Time of Sheet Flow	=	27.56 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	1.50000
Watercourse Slope (S)	=	0.02000
Velocity (V)	=	2.12 (ft/s)
Flow Length (L)	=	100.00 (ft)
Travel Time of Shallow Flow	=	0.79 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	0.50 (ft)
Channel Slope (S)	=	0.02000
Manning's Roughness Coef. (n)	=	0.01300
Channel Velocity (V)	=	10.21 (ft/s)
Flow Length (L)	=	2700.00 (ft)
Travel Time of Shallow Flow	=	4.41 (min)

TIME OF CONCENTRATION

Time of Concentration	=	32.76 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction	=	0.15000

HYDROGRAPH REPORT
RECORD NUMBER: *12*
TYPE: *SANTA BARBARA*
DESCRIPTION: *ULTIMATE-CA30-25*

HYDROGRAPH INFORMATION]

Peak Discharge	=	63.37 (cfs)
Volume	=	40.51 (acft)
Time Interval	=	10.00 (min)
Time to Peak	=	500.00 (min)
Time of Base	=	2180.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	169.60 (ac)
Curve Number	=	87

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.04000
Flow Length (L)	=	600.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.05000
Travel Time of Sheet Flow	=	10.97 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	2.00000
Watercourse Slope (S)	=	0.02000
Velocity (V)	=	2.83 (ft/s)
Flow Length (L)	=	800.00 (ft)
Travel Time of Shallow Flow.	=	4.71 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	0.50 (ft)
Channel Slope (S)	=	0.02500
Manning's Roughness Coef. (n)	=	0.01300
Channel Velocity (V)	=	11.42 (ft/s)
Flow Length (L)	=	4300.00 (ft)
Travel Time of Shallow Flow	=	6.28 (min)

TIME OF CONCENTRATION

Time of Concentration	=	21.96 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction	=	0.20000

HYDROGRAPH REPORT
RECORD NUMBER: *13*
TYPE: *SANTA BARBARA*
DESCRIPTION: *ULTIMATE-CA40-25*

[HYDROGRAPH INFORMATION]

Peak Discharge	=	16.35 (cfs)
Volume	=	11.86 (acft)
Time Interval	=	10.00 (min)
Time to Peak	=	500.00 (min)
Time of Base	=	2320.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	49.65 (ac)
Curve Number	=	87

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.04000
Flow Length (L)	=	550.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.01800
Travel Time of Sheet Flow	=	15.40 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	1.50000
Watercourse Slope (S)	=	0.03500
Velocity (V)	=	2.81 (ft/s)
Flow Length (L)	=	450.00 (ft)
Travel Time of Shallow Flow	=	2.67 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	0.50 (ft)
Channel Slope (S)	=	0.02000
Manning's Roughness Coef. (n)	=	0.02000
Channel Velocity (V)	=	6.64 (ft/s)
Flow Length (L)	=	2000.00 (ft)
Travel Time of Shallow Flow	=	5.02 (min)

TIME OF CONCENTRATION

Time of Concentration	=	23.10 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction	=	0.20000

HYDROGRAPH REPORT
RECORD NUMBER: 14
TYPE: SANTA BARBARA
DESCRIPTION: ULTIMATE-CA50-25

[HYDROGRAPH INFORMATION]

Peak Discharge	=	21.35 (cfs)
Volume	=	10.66 (acft)
Time Interval	=	10.00 (min)
Time to Peak	=	490.00 (min)
Time of Base	=	1810.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	42.63 (ac)
Curve Number	=	87

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.04000
Flow Length (L)	=	800.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.03000
Travel Time of Sheet Flow	=	16.94 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	1.50000
Watercourse Slope (S)	=	0.03300
Velocity (V)	=	2.72 (ft/s)
Flow Length (L)	=	200.00 (ft)
Travel Time of Shallow Flow	=	1.22 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	0.50 (ft)
Channel Slope (S)	=	0.01400
Manning's Roughness Coef. (n)	=	0.04000
Channel Velocity (V)	=	2.78 (ft/s)
Flow Length (L)	=	2900.00 (ft)
Travel Time of Shallow Flow	=	17.41 (min)

TIME OF CONCENTRATION

Time of Concentration	=	35.58 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction	=	0.32000

HYDROGRAPH REPORT
RECORD NUMBER: *16*
TYPE: *SANTA BARBARA*
DESCRIPTION: *ULTIMATE-CA60-25*

[HYDROGRAPH INFORMATION]

Peak Discharge	=	20.16 (cfs)
Volume	=	7.36 (acft)
Time Interval	=	5.00 (min)
Time to Peak	=	480.00 (min)
Time of Base	=	1565.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	30.21 (ac)
Curve Number	=	87

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.04000
Flow Length (L)	=	200.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.02500
Travel Time of Sheet Flow	=	6.01 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	1.50000
Watercourse Slope (S)	=	0.03000
Velocity (V)	=	2.60 (ft/s)
Flow Length (L)	=	400.00 (ft)
Travel Time of Shallow Flow	=	2.57 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	0.50 (ft)
Channel Slope (S)	=	0.02000
Manning's Roughness Coef. (n)	=	0.01300
Channel Velocity (V)	=	10.21 (ft/s)
Flow Length (L)	=	2500.00 (ft)
Travel Time of Shallow Flow	=	4.08 (min)

TIME OF CONCENTRATION

Time of Concentration	=	12.66 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction	=	0.25000

HYDROGRAPH REPORT
RECORD NUMBER: *17*
TYPE: *SANTA BARBARA*
DESCRIPTION: *ULITMATE-CA70-25*

[HYDROGRAPH INFORMATION]

Peak Discharge	=	99.15 (cfs)
Volume	=	42.87 (acft)
Time Interval	=	10.00 (min)
Time to Peak	=	490.00 (min)
Time of Base	=	1700.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	174.01 (ac)
Curve Number	=	87

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.04000
Flow Length (L)	=	300.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.03000
Travel Time of Sheet Flow	=	7.73 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	1.50000
Watercourse Slope (S)		0.01500
Velocity (V)	=	1.84 (ft/s)
Flow Length (L)	=	800.00 (ft)
Travel Time of Shallow Flow	=	7.26 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	0.50 (ft)
Channel Slope (S)	=	0.01000
Manning's Roughness Coef. (n)	=	0.01300
Channel Velocity (V)	=	7.22 (ft/s)
Flow Length (L)	=	3100.00 (ft)
Travel Time of Shallow Flow	=	7.16 (min)

TIME OF CONCENTRATION

Time of Concentration	=	22.14 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction	=	0.28000

HYDROGRAPH REPORT
RECORD NUMBER: 18
TYPE: SANTA BARBARA
DESCRIPTION: ULTIMATE-CA80-25

[HYDROGRAPH INFORMATION]

Peak Discharge	=	19.85 (cfs)
Volume	=	6.80 (acft)
Time Interval	=	2.00 (min)
Time to Peak.	=	478.00 (min)
Time of Base	=	1522.00 (min)
Multiplication Factor	=	1.00

[BASIN DESCRIPTION]

Watershed Area	=	27.93 (ac)
Curve Number	=	87

[TIME CONCENTRATION -- TR-55]

SHEET FLOW

Manning's Roughness Coef. (n)	=	0.05000
Flow Length (L)	=	100.00 (ft)
2-yr 24-hr Rainfall (R)	=	2.60 (in)
Land Slope (S)	=	0.01500
Travel Time of Sheet Flow	=	5.06 (min)

SHALLOW FLOW

K_Coef (surface description) (K)	=	1.50000
Watercourse Slope (S)	=	0.01500
Velocity (V)	=	1.84 (ft/s)
Flow Length (L)	=	200.00 (ft)
Travel Time of Shallow Flow	=	1.81 (min)

CHANNEL FLOW

Hydraulic Radius (R)	=	0.50 (ft)
Channel Slope (S)	=	0.01700
Manning's Roughness Coef. (n)	=	0.01300
Channel Velocity (V)	=	9.41 (ft/s)
Flow Length (L)	=	800.00 (ft)
Travel Time of Shallow Flow	=	1.42 (min)

TIME OF CONCENTRATION

Time of Concentration	=	8.29 (min)

[RAINFALL DESCRIPTION]

Distribution Type	=	SCS IA
Total Precipitation	=	4.00 (in)
Return Period	=	25 (yr)
Storm Duration	=	24.00 (hr)
Impervious Fraction	=	0.25000

HYDROGRAPH REPORT
RECORD NUMBER: *23*
TYPE: *RESER MOD. PULS*
DESCRIPTION: *RESERVOIR #2 OUTFLOW*

[HYDROGRAPH INFORMATION]

Peak Discharge	=	154.04 (cfs)
Volume	=	159.25 (acft)
Time Interval	=	10.00 (min)
Time to Peak	=	580.00 (min)
Time of Base	=	4590.00 (min)
Peak Elevation	=	0.00 (ft)

[RESERVOIR STRUCTURE INFORMATION]

Reservoir #	=	2
Description	=	Reservoir #2
Storage Type	=	TRAP BASIN
Max. Storage	=	538666.67 Cuft
Discharge Type	=	COMP STAGE/DIS
Max Discharge	=	157.18 cfs

[RESERVOIR INFORMATION]

Reservoir #	=	2
Reservoir Description	=	Reservoir #2

[INFLOW HYDROGRAPH INFORMATION]

Hydrograph #	=	22
Hydrograph Description	=	Reservoir 2 Inflow

RESERVOIR REPORT
RECORD NUMBER: *1*
STORAGE TYPE: *TRAP BASIN*
DISCHARGE TYPE: *COMP STAGE/DIS*
DESCRIPTION: *RESERVOIR #1*

[RATING CURVE LIMIT]

Minimum Elevation	=	404.00 (ft)
Maximum Elevation	=	410.00 (ft)
Elevation Increment	=	0.25 (ft)

[STAGE STORAGE INFORMATION]

RESERVOIR DESCRIPTION:

Base Length	=	340.00 (ft)
Base Width	=	170.00 (ft)
Top Length	=	370.00 (ft)
Top Width.	=	200.00 (ft)

[STAGE DISCHARGE INFORMATION]

OUTLET STRUCTURE:
STR #: 1
TYPE: CIRCULAR ORIFICE
DESCRIPTION: RESERVOIR #1 OUTFLOW

RESERVOIR REPORT
RECORD NUMBER: *2*
STORAGE TYPE: *TRAP BASIN*
DISCHARGE TYPE: *COMP STAGE/DIS*
DESCRIPTION: *RESERVOIR #2*

[RATING CURVE LIMIT]

Minimum Elevation	=	372.00 (ft)
Maximum Elevation	=	380.00 (ft)
Elevation Increment	=	0.25 (ft)

[STAGE STORAGE INFORMATION]

RESERVOIR DESCRIPTION:

Base Length	=	540.00 (ft)
Base Width	=	100.00 (ft)
Top Length	=	580.00 (ft)
Top Width	=	140.00 (ft)

[STAGE DISCHARGE INFORMATION]

OUTLET STRUCTURE:
STR #: 3
TYPE: RECTANGULAR ORIFICE
DESCRIPTION: Reservoir #2 Outflow 1

OUTLET STRUCTURE REPORT

RECORD NUMBER : 3
TYPE : RECTANGULAR ORIFICE
DESCRIPTION : Reservoir #2 Outflow 1

[RATING CURVE LIMIT]

Minimum Elevation........................	=	372.00	(ft)
Maximum Elevation........................	=	380.00	(ft)
Elevation Increment......................	=	0.50	(ft)

[OUTLET STRUCTURE INFORMATION]

Width....................................	=	10.00	(ft)
Height...................................	=	1.20	(ft)
Coefficient Co...........................	=	0.60000	
Invert Elevation.........................	=	372.00	(ft)
# of Openings............................	=	1	

[RECTANGULAR ORIFICE EQUATION]

Q = Co*A*[2gh]/k]^0.5
A = Wetted area, (sqft)
K = 1

OUTLET STRUCTURE REPORT

RECORD NUMBER : 1
TYPE : CIRCULAR ORIFICE
DESCRIPTION : Reservoir #1 outflow

[RATING CURVE LIMIT]

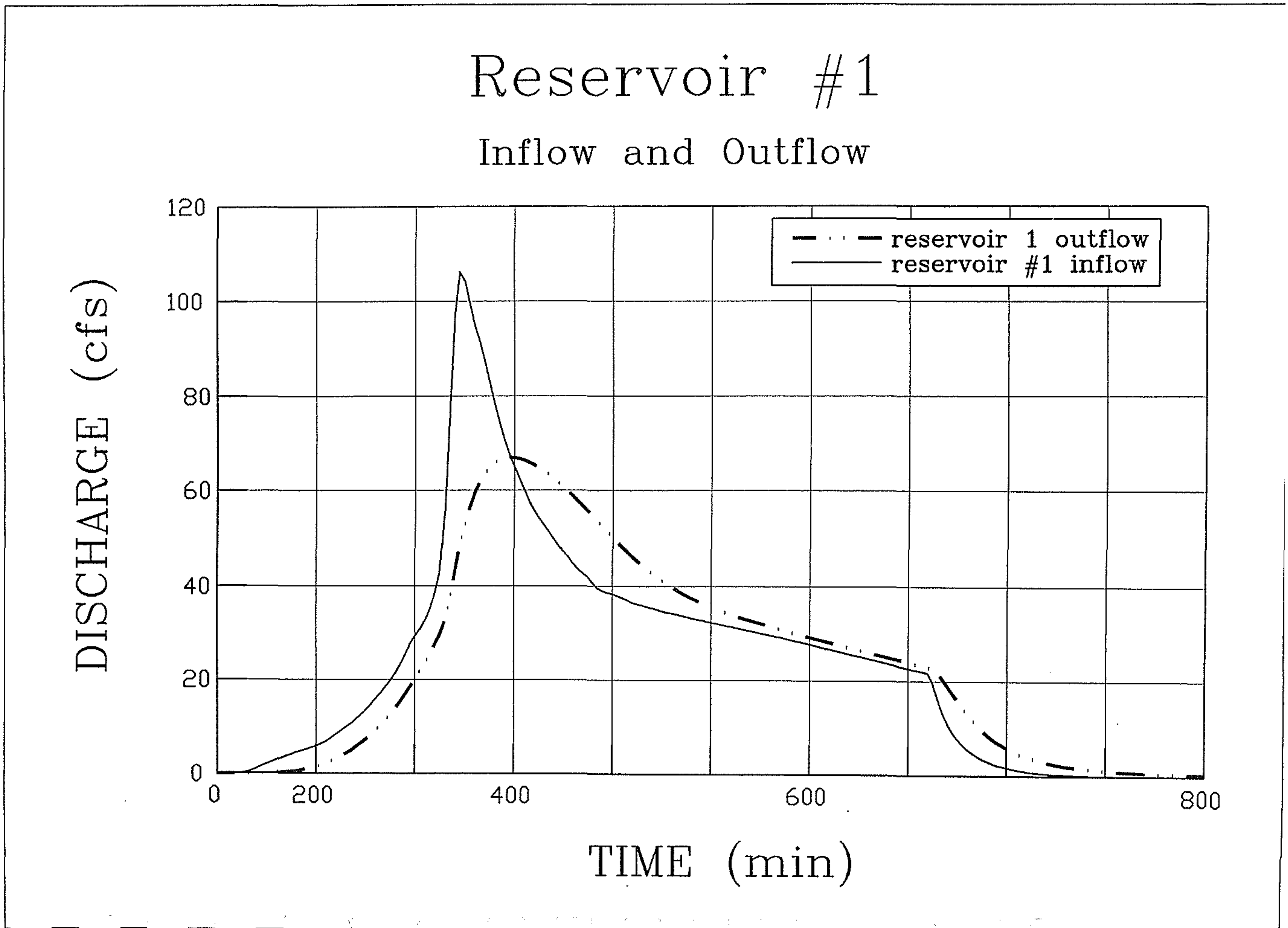
Minimum Elevation.........................	=	404.00 (ft)
Maximum Elevation.........................	=	409.00 (ft)
Elevation Increment.......................	=	0.50 (ft)

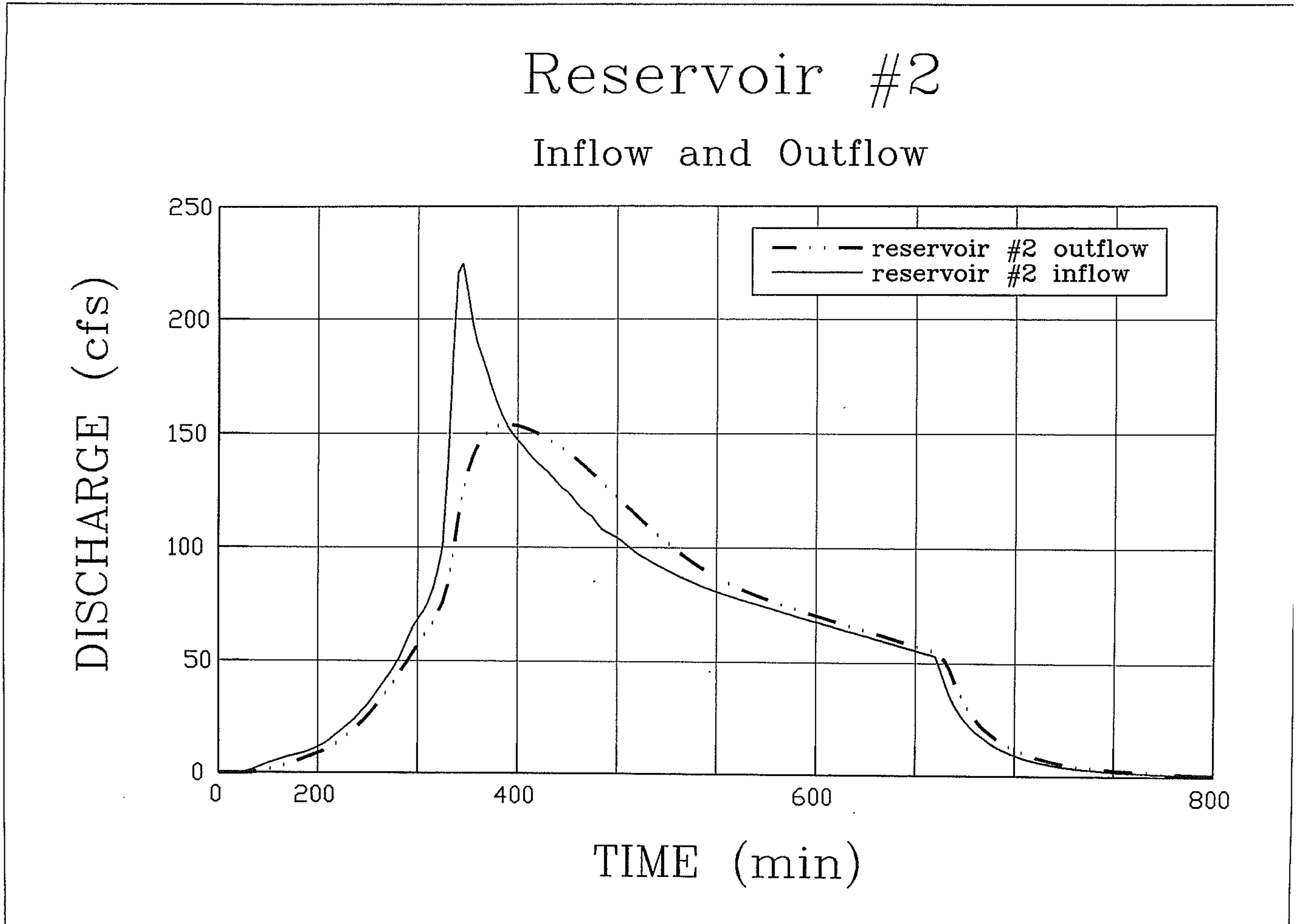
[OUTLET STRUCTURE INFORMATION]

Radius....................................	=	1.25 (ft)
Coefficient Co............................	=	0.80000
Invert Elevation..........................	=	404.00 (ft)
# of Openings.............................	=	1

[CIRCULAR ORIFICE EQUATION]

Q = Co*A*[2gh]/k]^0.5
A = Wetted area, (sqft)
K = 1


Reservoir #1
Inflow and Outflow
reservoir 1 outflow
reservoir #1 inflow
DISCHARGE (cfs)
120
100
80
60
40
20
0
0
200
400
600
800
TIME (min)



Reservoir #2
Inflow and Outflow
reservoir #2 outflow
reservoir #2 inflow
DISCHARGE (cfs)
250
200
150
100
50
0
0
200
400
600
800
TIME (min)

APPENDIX D

COST ESTIMATES WORKSHEETS

The following cost estimates are based on 1995 dollars, and reflect typical costs for projects of similar size and scope. No appraisals were done, nor were any property owners contacted regarding costs. Although these estimates are based on costs for completed projects, land and construction costs vary widely, so the estimated costs must be considered to be approximate only.

OREGON CITY DRAINAGE MASTER PLAN

PRELIMINARY ENGINEER'S OPINION OF CONSTRUCTION COSTS

ITEM NO.	DESCRIPTION	ESTIMATED QUANTITY	UNIT		UNIT COST		TOTAL COST
CAUFIELD BASIN							
	Phase 1 - Glen Oaks Road Stream Channel Reconstruction and Detention Facility #1						
1	Phase 1 Easement	80,000	SF	$	0.50	$	40,000.00
	Acquisition Fees	8	Parcel	$	1,000.00	$	8,000.00
	Detention Area Purchase	80,000	SF	$	4.00	$	320,000.00
	Total Phase 1 Esmt and Land Purchase Cost					$	368,000.00
2	Stream Channel Reconstruction	2,100	LF	$	15.00	$	31,500.00
3	2 Ac. Detention Pond Construction	1	LS	$	50,000.00	$	50,000.00
4	48" Culvert Pipe	60	LF	$	96.00	$	5,760.00
5	Field Inlet	2	EA	$	600.00	$	1,200.00
6	Outfall Structure	2	EA	$	2,500.00	$	5,000.00
7	A.C. Sawcut	80	LF	$	1.50	$	120.00
8	A.C. Repair	40	SY	$	16.00	$	640.00
	Total Phase 1					$	**462,220.00**
	Phase 2 - Detention Facility #2						
1	Phase 2 Easement	17,000	SF	$	0.50	$	8,500.00
	Acquisition Fees	4	Parcel	$	1,000.00	$	4,000.00
	Detention Area Purchase	80,000	SF	$	3.00	$	240,000.00
	Total Phase 2 Esmt and Land Purchase Cost					$	**252,500.00**
2	2 Acre Detention Pond Construction	1	EA	$	50,000.00	$	50,000.00
	Total Phase 2					$	**302,500.00**
	Phase 3 - Pipe Replacement, Glen Oaks Road						
1	12" Dia. Storm Drain Pipe	40	LF	$	24.00	$	960.00
2	30" Dia. Storm Drain Pipe	700	LF	$	60.00	$	42,000.00
3	Connect to Exist. Storm Line	2	EA	$	500.00	$	1,000.00
4	Field Inlet	2	EA	$	600.00	$	1,200.00
5	60" Manhole	1	EA	$	2,200.00	$	2,200.00
7	A.C. Sawcut	60	LF	$	1.50	$	90.00
8	A.C. Repair	20	SY	$	15.75	$	315.00
	Total Phase 3					$	**47,765.00**

OREGON CITY DRAINAGE MASTER PLAN

PRELIMINARY ENGINEER'S OPINION OF CONSTRUCTION COSTS

ITEM NO.	DESCRIPTION	ESTIMATED QUANTITY	UNIT		UNIT COST		TOTAL COST
	Phase 4 - Misc. Improvements						
1	Phase 4 Easement	24,000	SF	$	0.50	$	12,000.00
	Acquisition Fees	15	Parcel	$	1,000.00	$	15,000.00
	Total Phase 4 Esmt Cost					$	**27,000.00**
2	Drainage Ditch Reconstruction	1,600	LF	$	15.00	$	24,000.00
3	18" Dia. Storm Drain Pipe	80	LF	$	38.00	$	3,040.00
4	Field Inlet	2	EA	$	600.00	$	1,200.00
5	48" Manhole	1	EA	$	1,400.00	$	1,400.00
6	A.C. Sawcut	60	LF	$	1.50	$	90.00
7	A.C. Repair	20	SY	$	15.75	$	315.00
	Total Phase 4					$	**57,045.00**
	Phase 5 - Detention Pond Esmt. and Pond Dam Reconstruction						
1	Phase 5 Easement	90,000	SF	$	0.50	$	45,000.00
	Acquisition Fees	5	Parcel	$	1,000.00	$	5,000.00
	Total Phase 4 Esmt Cost					$	**50,000.00**
2	Dam Reconstruction	1	LS	$	65,000.00	$	65,000.00
	Total Phase 5					$	**165,000.00**

TOTAL CONSTRUCTION COST:	$	**1,034,530.00**
Additional Const. Costs (Traffic Control, Mobilization, Clearing, Contingency)(20%)	$	**206,906.00**
Engineering Design and Contract Administration (15%)	$	**155,179.50**
TOTAL PROJECT COST:	$	**1,396,615.50**

KAMPE ASSOCIATES, INC.

Planning/Civil Engineering/Land Surveying