

*FINAL REPORT*

**HYDROLOGIC STUDY OF  
PARK PLACE BASIN**

Prepared for:

**CLACKAMAS COUNTY  
COMMUNITY DEVELOPMENT DIVISION**  
and  
**CITY OF OREGON CITY**

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PLANNING  
ENGINEERING  
SURVEYING



**KAMPE ASSOCIATES INC.**

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## INTRODUCTION

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### Background and Authorization

The City of Oregon City (City) and Clackamas County (County) are currently planning for future development within a drainage basin located east of the Interstate-205 / Highway 213 Interchange, herein referred to as the Park Place Drainage Basin (see **Exhibit 1** for project location). This study focuses specifically on the easterly portion of the Park Place basin, a 156-acre area, bounded on the north by Forsythe Road, on the east by Swan Avenue, on the south by Holcomb Road, and on the west by South Apperson Boulevard.

This portion of the basin is a historic neighborhood of primarily single-family residential housing, having larger lots on the easterly hill and smaller lots in the westerly basin. The South Fork Water District filtration plant is located at the highest point of the basin, near its northeast corner. Park Place Elementary School is situated on a bench at the northwest corner of the basin. The Housing Authority of Clackamas County operates a housing development in the southwest corner of the basin.

The defined natural drainage feature starts in the northeast corner of the basin, west of Swan Avenue, and continues southwesterly to where it passes under Hunter Avenue. This drainageway then turns westerly to Front Street and northwesterly into a culvert located near the corner of Cleveland Street and Harley Avenue. Stormwater then flows from the culvert into an open ditch, north along Harley Avenue (approximately 230 feet), where it turns west and then northwest in an open field to near the corner of Larae Street and Apperson Boulevard. From this corner, water flows within a culvert under Apperson Boulevard to a ditch that extends westerly to South Clackamas River Road. Stormwater then flows south below the Oregon City By-Pass and Abernethy Road to Abernethy Creek. This principal drainage has culvert and piped crossings at the following locations, in the upper portion of the basin:

- Cleveland Street
- Hunter Avenue
- Hiram Avenue
- Front Avenue
- S. Cleveland Street & Harley Avenue
- Apperson Boulevard

A Street and Storm Drainage Project is in the construction phase for Front Avenue, between S. Holcomb Road and Larae Street. Improvements to Park Place Park, near the center of the basin, are currently under construction.

**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 flowrate 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. The 1988 Master Plan generally described the basins and the expected flowrates under current (1988) and ultimate (build out) conditions. As a result of the study, the Park Place 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 objectives of this study are:

- To analyze the existing drainage system, verifying the modeled flowrates from the 1988 study and adjusting for recent construction.
- To 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.

In this study, three strategies are proposed to convey stormwater in the Park Place Drainage Basin. These methods, in order of desirability, are:

- Preservation of natural drainage systems
- Construction of open channel drainage systems
- Construction of new, or upgrading of existing, piped systems.

## STUDY AREA CHARACTERISTICS

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### Geography and Topography

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. The main drainage running through the Park Place Basin is one such natural channel that has formed over the years.

The upper end of the Park Place drainage is relatively steep, flowing in a steep walled "V" shaped drainage. This portion of the stream has a well-defined alignment and does not pose a flooding threat to surrounding structures.

The central portion of the drainage is across a relatively flat basin, having a shallow low-flow channel, which have been realigned in places, by property owners, to follow lot lines. Undersized culvert pipes have been installed in some roadside ditches. The gradually sloping basin surrounding this low flow channel acts as a flood plain during major storm events, during which the surrounding properties are subject to flooding.

The lowest portion of this basin (between Harley Avenue and Apperson Boulevard) is in a well-defined channel, having side slopes, longitudinal slope and bottom width, which have provided drainage out of the basin without flooding adjacent structures. A portion of this section has been piped in 24-, 27-, and 30-inch diameter culverts.

### 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

Based on discussions with area residents, one area which has experienced storm drainage problems is at the intersection of Cleveland Street and Harley Street. According to residents, the roadside ditches are inadequate to handle existing storm runoff during some storm events each year, causing stormwater to spread across adjoining properties. Another area experiencing drainage problems are properties along the west side of Hiram Avenue, between Cleveland and Gain Streets. No stormwater collection system exists in this area, nor are roadside ditches well defined. Stormwater from the hillside to the east flows in sheets and shallow flow across yards and driveways. The section of 24-inch culvert pipe, in the main stream channel west of Harley Street, has an inadequate inlet which is subject to blockage, causing flooding of yards during peak storm events.

### 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 purpose 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 that during this 100-year flood event, extensive overbank flooding will occur along the lower section of Abernethy Creek. The 100-year flood plain elevation is approximately 45 feet for this entire section of the creek. Abernethy Creek enters the Willamette River near its confluence with the Clackamas River. This area of flooding, therefore, is primarily due to backwater effects from basins covering an extensive portion of Northwest Oregon. Any stormwater flow from the Park Place basin has an insignificant impact on the floodplain during this event.

### Soils Characteristics

Classification of soils in the study area have been made by the Soil Conservation Service. 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 inches/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 to 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 steep slopes. Drainage characteristics for these soils vary from good to poor. Table 1 summarizes the various soils found and their hydrologic grouping. (See **Exhibit 2** for a map of the soil types in the study area.)

TABLE 1 HYDROLOGIC GROUPINGS OF SOILS		
Soil Legends	Soil Name	Hydrologic Soil Group
3	Amity Silt Loam	D
13C	Cascade Silt Loam 8-15% slopes	C
17	Clackamas Silt Loam	D
36C	Hardscrable Silt Loam 7-20% slopes	D
37C	Helvetia Silt Loam 8-15% slopes	C
76B	Salem Silt Loam 0-7% slopes	B
91A	Woodburn Silt Loam 0-3% slopes	C
91B	Woodburn Silt Loam 3-8% slopes	C
92F	Xerochrepts & Haploxerous	C

Source: Soil Survey of Clackamas County, Oregon (U.S. - SCS)

### Existing Drainage Facilities

The existing storm drainage facilities consist primarily of roadside ditches, culverts and open channels, with the exception of the southwest area containing storm drains constructed with the Housing Authority project, and the recent Front Avenue street improvement project. Lengths of 12-inch diameter concrete and corrugated metal pipe have been placed in ditches and covered at several locations throughout the basin. A map showing existing facilities is included as **Exhibit 3**.

### 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

The Park Place Drainage Basin has no jurisdictional wetland areas of record at this time, nor any areas identified by City staff as having wetland value, as a part of their inventory.

## MODELING AND DESIGN METHODOLOGY

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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.** 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 and the urban growth boundary within the Park Place Drainage Basin. Wetlands information was obtained from METRO and the State of Oregon Division of State Lands (DSL). Design drawings of the Park Place Park and the Front Avenue improvement 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. This composite map is included herein as **Exhibit 4**.

### 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 measurements of actual impervious percentages in sample areas. Land use designations are based on current zoning designations in Oregon City (revised 6/95). **Exhibit 5** shows the land use designations used for modeling. The area modeled as one-acre residential assumes this density at ultimate development.

### Watershed Model

The Park Place Drainage Basin is composed of approximately 323 acres, located in the City of Oregon City. The upper portion of Park Place Drainage Basin (approximately 156 acres) was divided into 8 subbasins for this analysis. Subbasins originally designated as P-10 through P-40 in the 1988 drainage study have been renumbered as P10 through P80, in order to perform a more detailed analysis and to reflect current stormwater flow patterns (see **Exhibit 6**).

**Subbasin P-10** flows to a catch basin at the intersection of Larae Street and Front Avenue, where flow is conveyed in Larae Street through 12-inch and 15-inch pipes to a point near the 30-inch basin outlet pipe.

**Subbasin P-20**, south of P-20, flows to a 12-inch culvert pipe crossing Front Avenue, through an open channel in the P-60 subbasin.

**Subbasin P-30** flows are captured in Cleveland Street roadside ditches, and discharge into catch basins installed as a part of the Front Avenue Improvements.

**Subbasin P-40**, the largest subbasin, flows in an open channel with culvert crossings at Cleveland, Hunter, Hiram, and Front Avenues.

**Subbasin P-50**, consisting primarily of the Park Place School site, discharges its runoff into the roadside ditch on the east side of Apperson Boulevard. Based on our initial observations, P-50 appeared to be a part of the Park Place Subbasin. After computer modeling and further site observations, it was found to not contribute stormwater flow to the 30-inch basin outlet pipe. The sheet flows southerly and westerly to the roadside ditch along the north side of south LaRae Street, then northerly along South Apperson Boulevard.

**Subbasin P-60** receives concentrated flow from P-20, and collects sheet flows in the easterly roadside ditch on Harley Street.

**Subbasin P-70**, the southwesterly portion of the basin and the flattest subbasin, flows though 12-inch pipes in the Housing Authority site (which also contains an off-channel detention pond) then northerly in a 12-inch pipe in Harley Street to the intersection of Harley Street and S. Cleveland Avenue.

**Subbasin P-80**, bounded on the north by Larae Street, on the east by Harley Street, and on the south by South Cleveland Street, receives drainage from P-10, P-60, and P-70, respectively. These flows are combined and discharge to the west through the 30-inch culvert under South Apperson Road.

#### ***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 exceeding this level 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 the hydrologic analysis of the Park Place 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 PARK PLACE DRAINAGE BASIN**

Land Use Description	Curve Numbers for Hydrologic Soil Group			
	A	B	C	D
Park	N/A	61	74	80
1 Ac. Residential	N/A	79	84	84
1/4 Ac. Residential	N/A	83	87	90

An area-weighted average curve number was calculated by the computer program for each subbasin, based on the area percentage of each soil group in the subbasin.

#### ***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, or III Rainfall Hyetograph and that 1.4 to 2.1 inches of rain has fallen within this 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 below.

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								
	P-10	P-20	P-30	P-40	P-50	P-60	P-70	P-80
Area (acres)	25.4	12.8	10.5	41.1	7.9	9.0	40.0	8.8
EXISTING DEVELOPMENT CONDITION								
Weighted CN No.	84	82	85	85	77	88	88	88
Time of Concentration, TC (min.)	36	26	14	21	16	24	28	26
Impervious Fraction (%)	15	15	15	25	15	25	40	35
25-Year Storm Peak Discharge, Q (cfs)	10.6	5.5	6.2	22.5	3.2	5.3	23.2	5.1
FULL DEVELOPMENT CONDITION								
Weighted CN No.	84	82	85	85	77	88	88	88
Time of Concentration, TC (min.)	36	26	14	21	16	24	28	26
Impervious Fraction (%)	21	21	21	38	40	40	40	40
25-Year Storm Peak Discharge, Q (cfs)	11.0	5.7	6.4	24.0	4.1	5.5	23.2	5.2

### *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 Park Place 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 Park Place 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 7**.

#### *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 flowrate. (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 often lack funding for the maintenance required to keep them functioning 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, have submitted a Permit Application as a group. The final NPDES stormwater permit is expected to be issued shortly after completion of this report. 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 Park Place 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. Park Place 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 Park Place Creek and adjoining storm drainage improvements.

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 have specific topography and soils suited to this method. In this case, systems should be designed to the specifications listed above.

## PROPOSED IMPROVEMENTS

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The proposed improvements (see **Exhibit 8**) were developed to retain open channels where practical, for both their water quality and aesthetic value. The area between Harley Avenue and Hiram Avenue, however, is subject to flooding, erosion, and sedimentation during peak flows, and has limited room for open channels due to existing development. In considering a proposed storm drainage system for this area, the following constraints were considered:

- Existing development makes acquiring the necessary easement widths and straight alignments for open channel flow impractical.
- This area lacks well defined natural channels for any flows larger than the 2-year storm. Conversations with local residents have revealed that during large storm events, shallow channel flow from Subbasins P-10 through P-40 is dispersed into sheet flow at Hiram, Front, and Harley Avenues.
- The outflow from the newly constructed storm drainage system in Front Avenue requires peak flow capacity which would be difficult to contain in a roadside ditch, due to the number of driveway culverts and shallow downstream drainage structures.
- Outflow from Subbasin P-40 from Front Avenue to Cleveland St. is through a combination of owner-installed pipes and open channels, which are under capacity for the 25-year design storm.

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 basins offer the advantage of a lower level of monitoring and maintenance effort, due to the decreased total number of basins. Maintenance costs can be spread across a group of benefitting property owners, through stormwater utility fees or taxes. When regional detention basins are owned and operated by the City, maintenance can be done on a scheduled basis, ensuring that the basins will function as planned during design storm events. In addition, regional detention basins can be situated to take advantage of natural landforms, decreasing construction cost. They can also be incorporated into Parks or Open spaces, or Wetlands, thus distributing the cost of property acquisition through multiple use.

The lower portion of the Park Place Basin was analyzed to determine the need for regional detention in the Upper Park Place Basin. The alignment of the lower portion of the Park Place stream channel has been extensively modified during the last 25 years. The United States Geological Survey (USGS) "Oregon City" quadrangle map, photo revised in 1970, shows this area to be a large swampy region, having a low flow channel along the toe of the Park Place hillside. The construction of a landfill (now closed), Clackamas River Drive improvements, Highway 213 construction, and the Abernethy Drive/Holcomb Road intersection, have formed the channel into a series of five open channel sections and five culvert crossings. Although no hydraulic analysis was done for this lower stream area during field inspection and map preparation, it appears that private property would not be at risk from flooding due to the predicted 25-year modeled peak flow rate.

In addition, the Park Place basin is located at the lowest extent of the Abernethy Creek drainage. This means that a large portion of its storm runoff is contributed during the early stage of a typical storm, not during the Abernethy basin peak. Detaining stormwater would therefore be a counter-productive measure in attempting to lower the peak flow in Abernethy Creek downstream of the Park Place basin outfall. In conclusion, regional detention in the upper Park Place Basin is not recommended.

Improvements are proposed in phases, as follows, based on the estimated significance of existing storm system failure:

**Phase 1** improvements include: a 24-inch storm drain located in an easement between Front Avenue and Cleveland Street; a 15-inch storm drain and a 30-inch storm drain in Cleveland Street between Front Avenue and Harley Avenue; and a 36-inch storm line in Harvey Avenue.

**Phase 2** improvements include: a 12-inch storm line in Hiram Avenue; a 24-inch storm line in Hiram Avenue; a 24-inch line between Hiram Avenue and Front Avenue in Clear Street; and a 30-inch line in Front Avenue.

**Phase 3** improvements include channel improvements. Ideally, the stream would remain in a natural state for maximum water quality and aesthetic benefits. In practice, however, urban streams should be managed as storm drainage conveyance facilities for surrounding areas with impervious surfaces and pollutant contamination. Additionally, improvements should be designed and constructed with long term maintenance of the channel as a primary consideration. These channels, typically constructed where drainage crosses private property, may be initiated as a part of a private site development, or may be part of a Capital Improvement Project (CIP). In some cases, it may be necessary to create piped or culverted sections in this area of primarily open channel. A detail showing two open channel sections and one piped section has been included as **Exhibit 9**.

**Phase 4** improvements include a 24-inch line Harley Avenue between Cleveland Street and Gain Street. This replaces the existing 12-inch line and open ditch in this street.

## PRELIMINARY CONSTRUCTION COST ESTIMATES

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The following phased improvements are proposed, in order of priority:

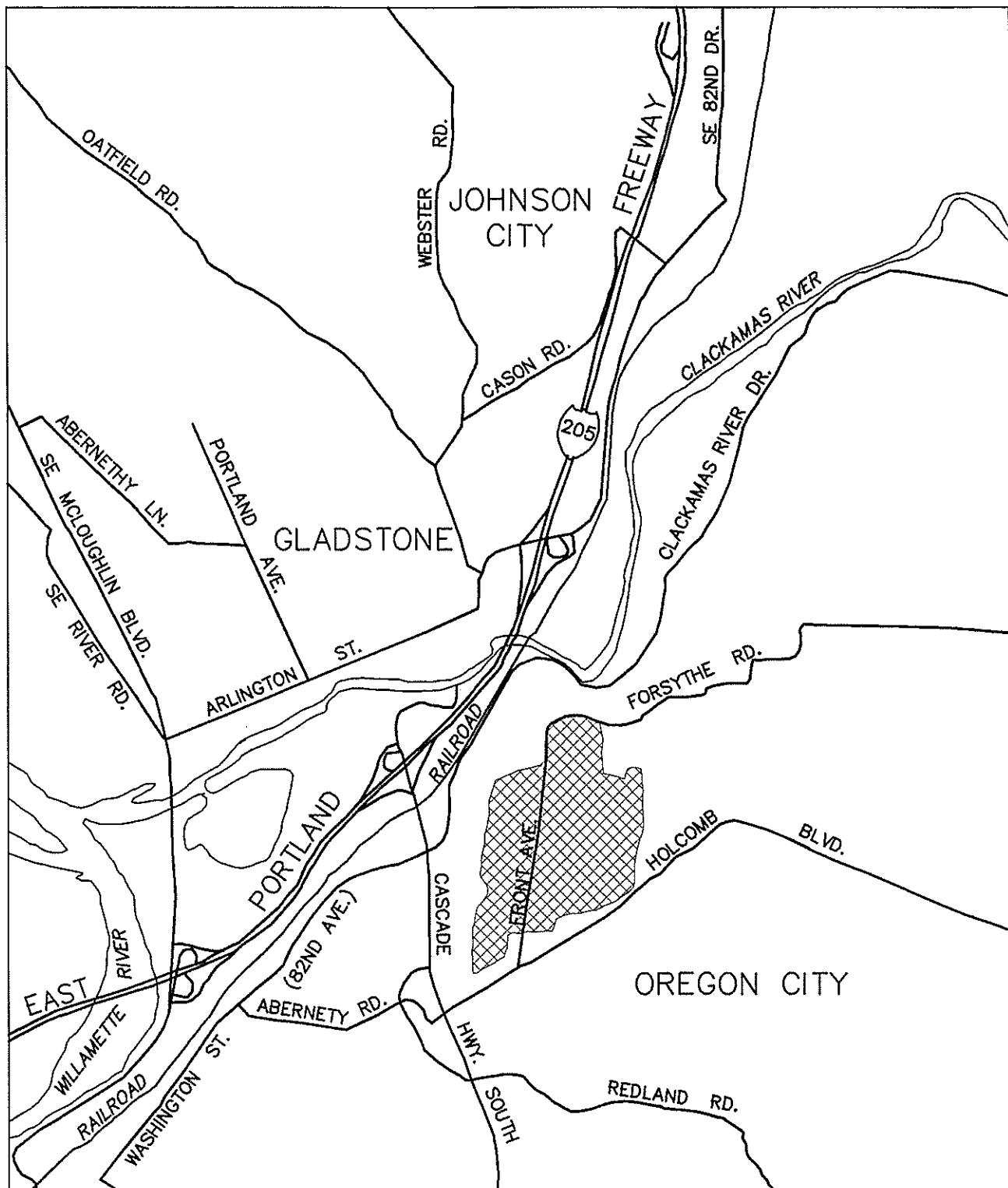
Phase	DESCRIPTION	COST (1995 dollars)
1	Pipeline Improvements from Harley Avenue, 200 ft. North of Cleveland, to the West side of Front Avenue.	\$123,000
2	Pipeline Improvements from the East Side of Front Avenue to and Including Hiram Avenue.	\$85,000
3	Channel Improvements and Easement Acquisition from Apperson Boulevard to Harley Avenue	\$70,000
4	Channel Improvements and Easement Acquisition from Hiram Avenue to Swan Avenue.	\$72,000
<b>TOTAL</b>		<b>\$350,000</b>

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**EXHIBIT 1**

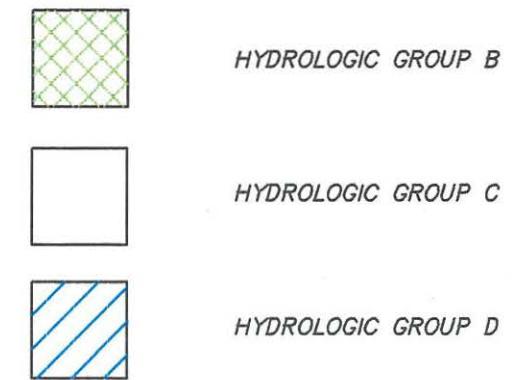
**VICINITY MAP**

PREPARED FOR:  
**CITY OF OREGON CITY**  
320 WARNER MILNE ROAD  
OREGON CITY, OREGON 97045-4000

08/11/95

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LAND SURVING  
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KAMPE ASSOCIATES

## STORM DRAINAGE PLAN PARK PLACE BASIN



## LEGEND

Type	Description	Group
3	Amity silt loam	D
13C	Cascade silt loam 8-15% slopes	C
17	Clackamas silt loam	D
36C	Hardscrable silt loam 7-20% slopes	D
37C	Helvetia silt loam 8-15% slopes	C
76B	Salem silt loam 0-7% slopes	B
91A	Woodburn silt loam 0-3% slopes	C
91B	Woodburn silt loam 3-8% slopes	C
92F	Xerocherpts & Haploxerous	C

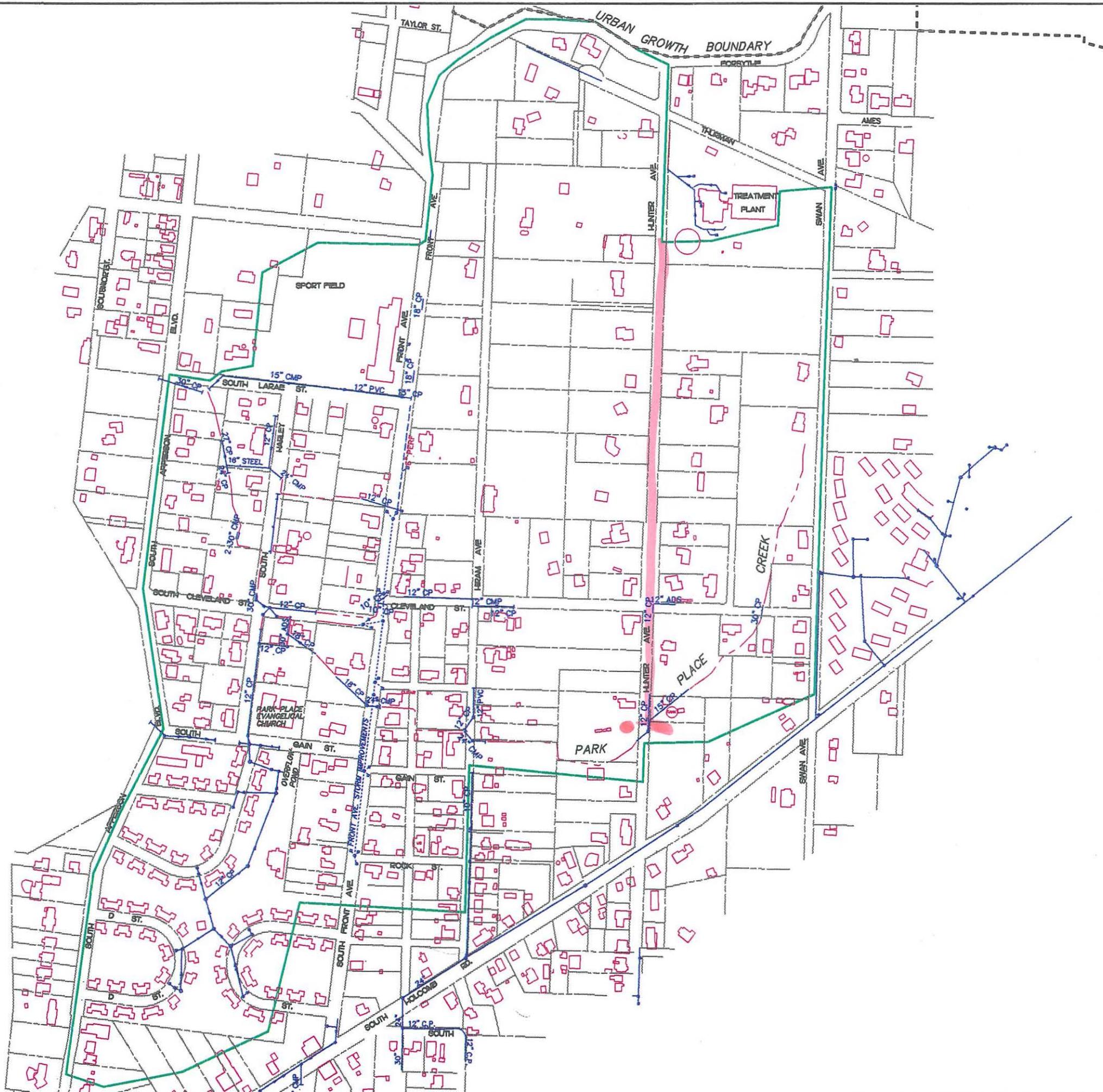
~ SOIL BOUNDARY DESIGNATION  
~ DRAINAGE BASIN BOUNDARY

**EXHIBIT 2**

PREPARED FOR:  
**CITY OF OREGON CITY**  
320 WARNER MILNE ROAD  
OREGON CITY, OREGON 97045-4000  
08/11

Scale: 1" = 400'

# STORM DRAINAGE PLAN PARK PLACE BASIN



## LEGEND

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

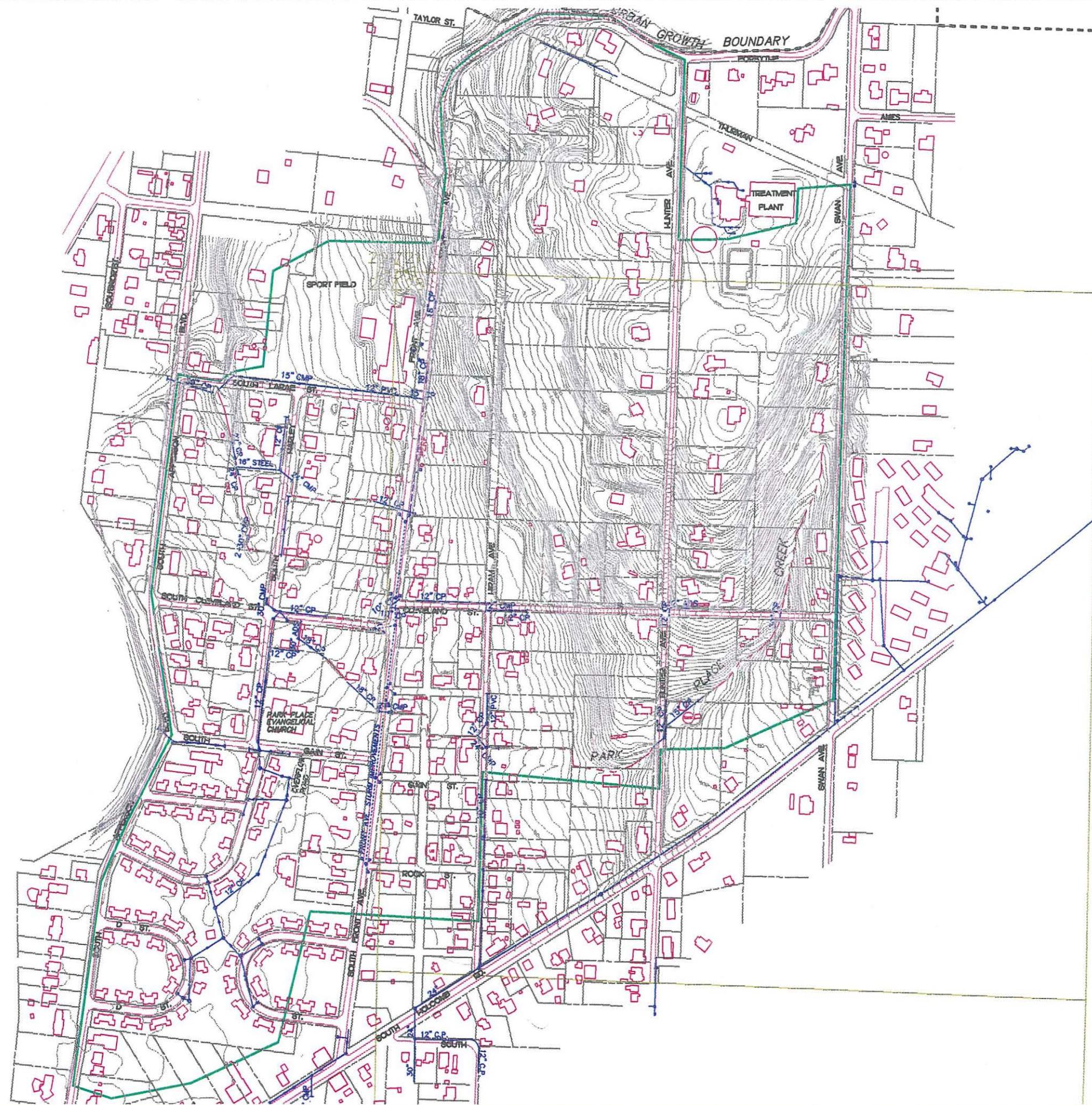
### **EXHIBIT 3**

## EXISTING DRAINAGE FACILITIES

**PREPARED FOR:  
CITY OF OREGON CITY  
320 WARNER MILNE ROAD  
OREGON CITY, OREGON 97045-4000**

Scale: 1" = 400'

## STORM DRAINAGE PLAN PARK PLACE BASIN



LEGEND

—	STORM LINE
—	EDGE OF PAVEMENT
—	DITCH/CREEK
—	PROPERTY LINE
	CULVERT
— X —	FENCE
	DRAINAGE BASIN BOUNDARY

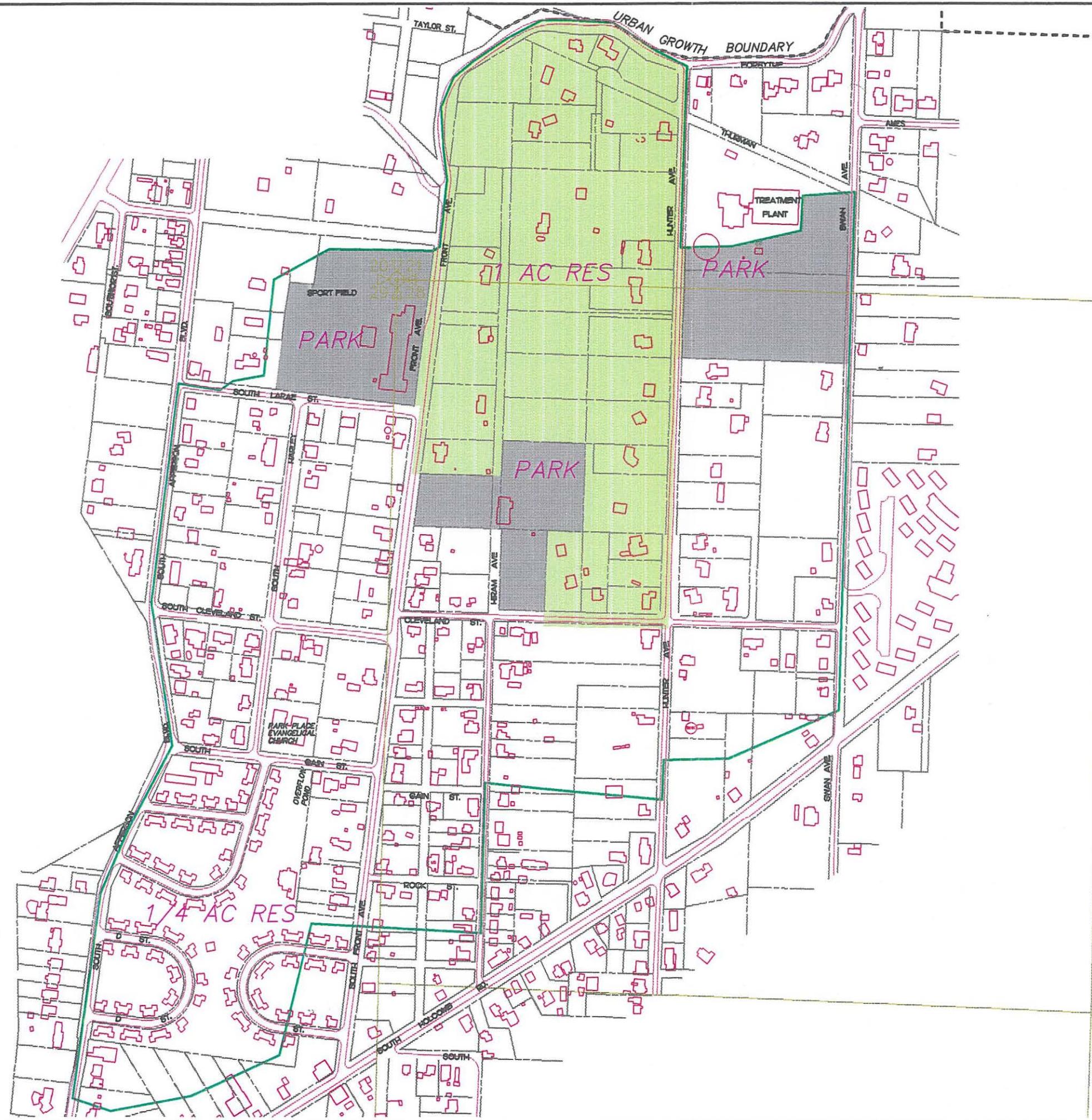
**EXHIBIT 4**  
**BASE MAP**

PREPARED FOR:  
**CITY OF OREGON CITY**  
320 WARNER MILNE ROAD  
OREGON CITY, OREGON 97045-4000  
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Scale: 1"=400'

STORM DRAINAGE PLAN  
PARK PLACE BASIN



**LEGEND**

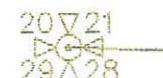
PROPERTY LINE



EXISTING STRUCTURE



EXISTING EDGE OF PAVING



QUARTER SECTION LINE



DRAINAGE BASIN BOUNDARY



1/4 ACRE RESIDENTIAL



1 ACRE RESIDENTIAL



PARK

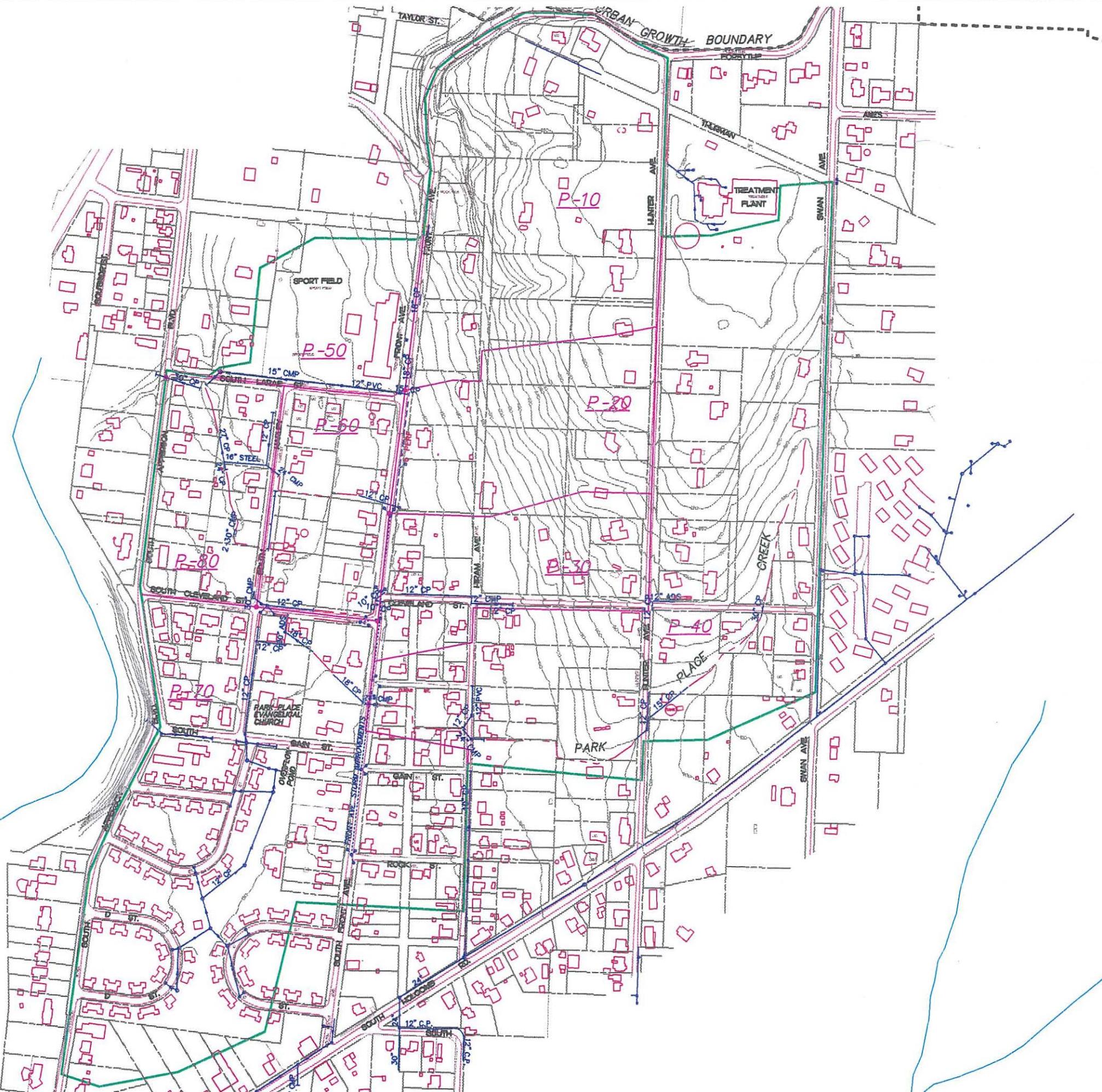
**EXHIBIT 5**  
LAND USE MAP

PREPARED FOR:  
**CITY OF OREGON CITY**  
320 WARNER MILNE ROAD  
OREGON CITY, OREGON 97045-4000  
08/11/08

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Scale: 1"=400'

STORM DRAINAGE PLAN  
PARK PLACE BASIN



**EXHIBIT 6**  
**DRAINAGE SUB-BASINS**

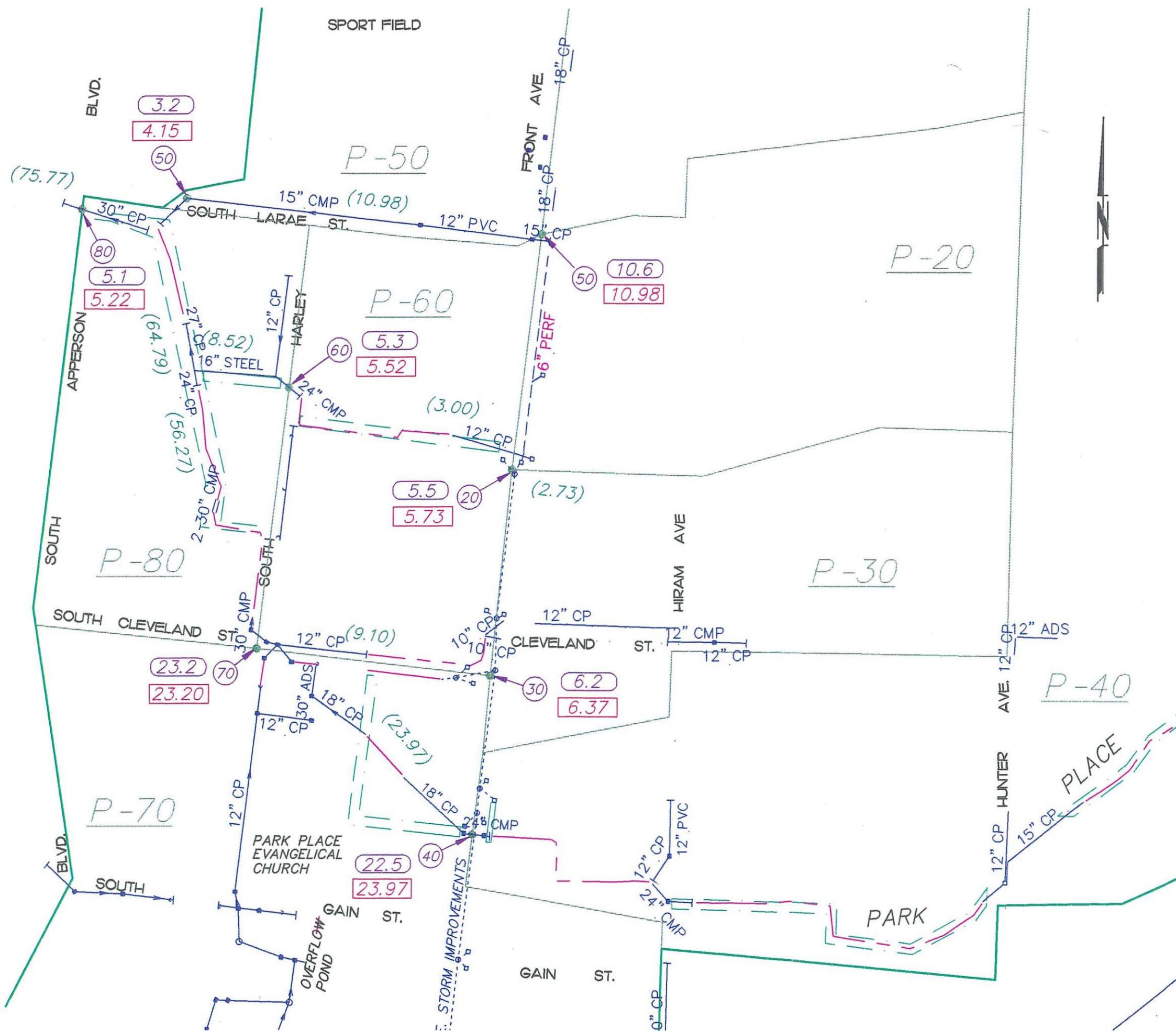
PREPARED FOR:  
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OREGON CITY, OREGON 97045-4000

08/24/85

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Scale: 1"=400'

STORM DRAINAGE PLAN  
PARK PLACE BASIN



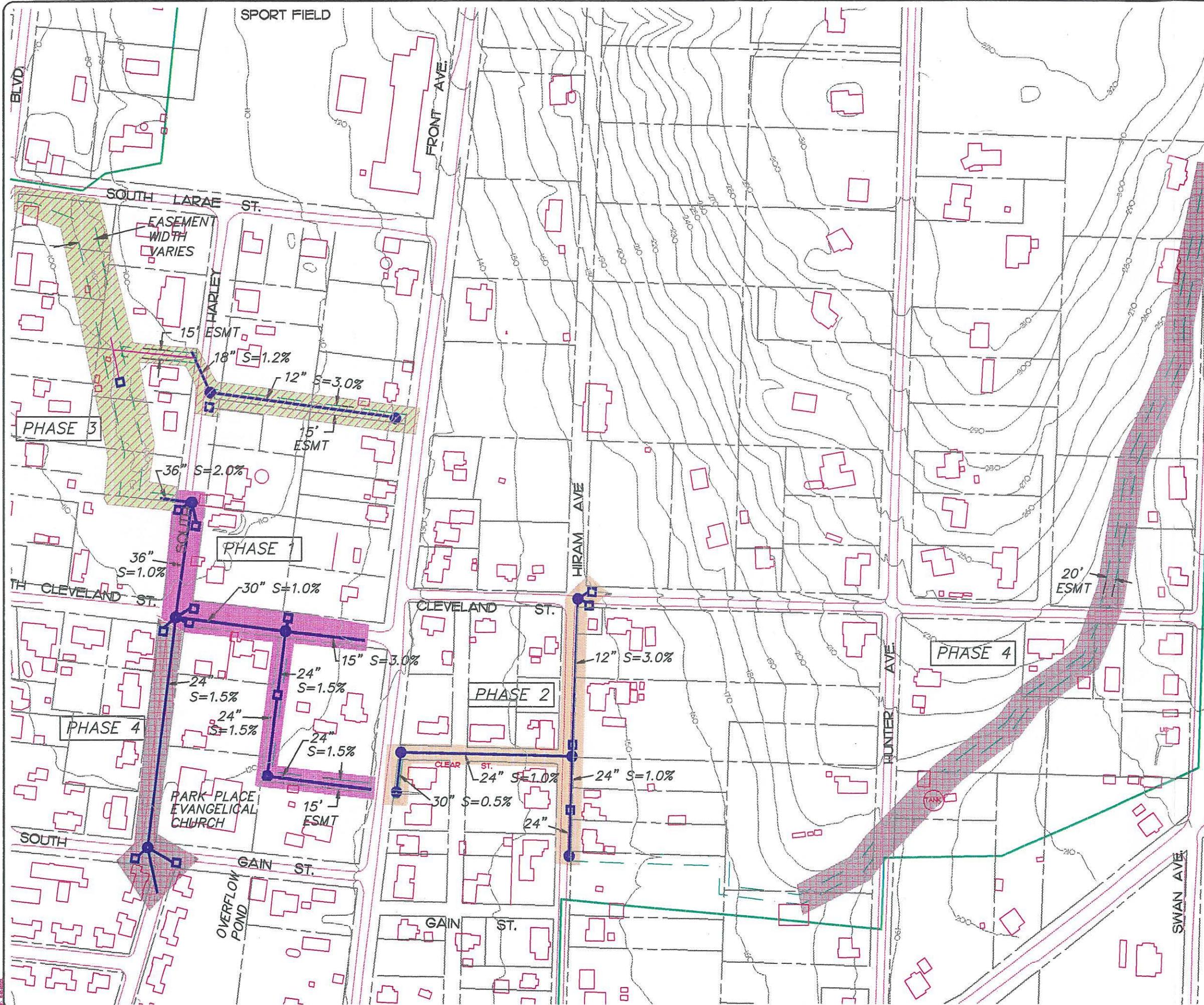
PREPARED FOR:  
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320 WARNER MILNE ROAD  
OREGON CITY, OREGON 97045-4000  
02/06/06

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Scale: 1"=200'

## STORM DRAINAGE PLAN PARK PLACE BASIN

### LEGEND



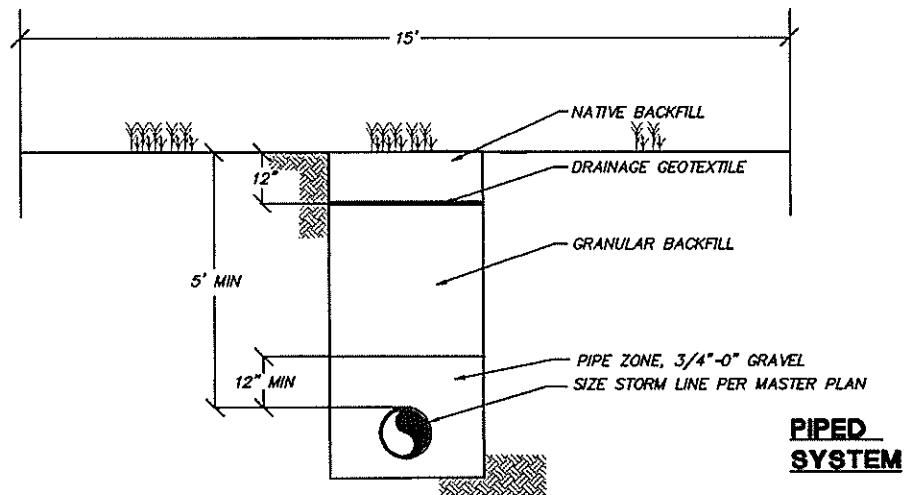
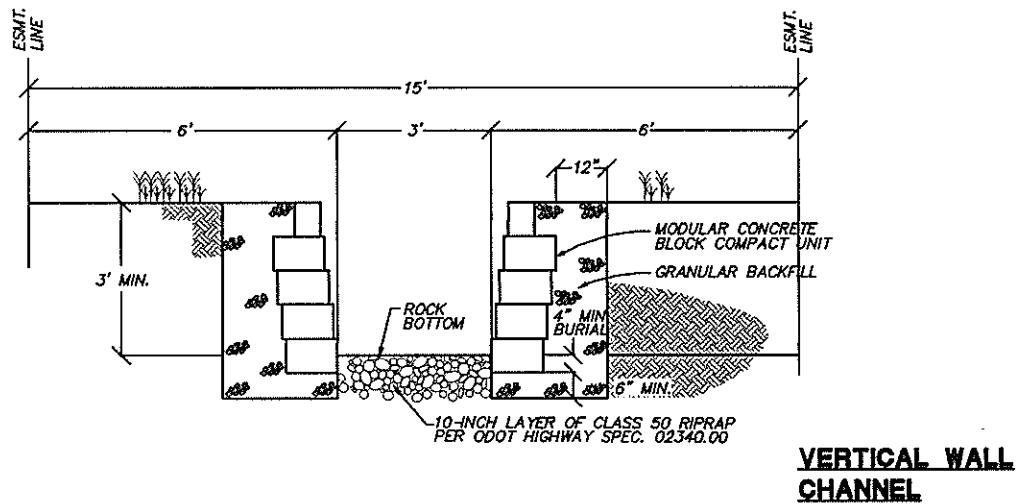
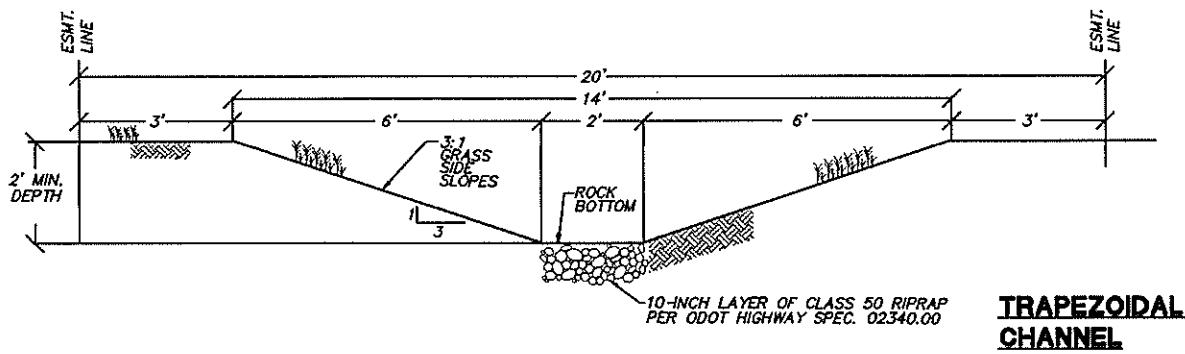
**EXHIBIT 8**

## PROPOSED DRAINAGE FACILITIES

**PREPARED FOR:  
CITY OF OREGON CITY  
320 WARNER MILNE ROAD  
OREGON CITY, OREGON 97045-4000**

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Scale: 1"=100'



**EXHIBIT 9**  
**PROPOSED CHANNEL DETAILS**

PREPARED FOR:  
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OREGON CITY, OREGON 97045-4000

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08/20/05

## 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***

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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 gravelly 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	
	Based on actual mean section:	0.035 - 0.050
		0.035 - 0.040
Channels not maintained, weeds and brush uncut:	Jagged and irregular	
	Dense weeds, high as flow depth	
	Clean bottom, brush on sides	
	Clean bottom, brush on sides, highest stage of flow	
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	

Eagle Point

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 Transportation, 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.

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 conservation tillage	Poor	62	73	81	84
	Contoured and terraces	Good	60	2	80	83
	Contoured and terraces	Poor	61	72	79	82
	Contoured and terraces	Good	59	70	78	81
	Contoured and terraces and conservation tillage	Poor	60	71	78	81
	Contoured and terraces and conservation tillage	Good	58	69	77	80
Close-seeded legumes or ro- tation 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	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads	—	—	59	74	82	86
Forest-range Herbaceous	—	Poor	—	79	86	—
		Fair	—	71	80	—
		Good	—	61	74	—
Oak - aspen	—	Poor	—	65	74	—
		Fair	—	47	57	—
		Good	—	30	41	—
Juniper - grass	—	Poor	—	72	83	—
		Fair	—	58	73	—
		Good	—	41	61	—
Sage - grass	—	Poor	—	67	80	—
		Fair	—	50	63	—
		Good	—	35	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**

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# Appendix C: Default Layers

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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 following 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 (tc)***

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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:

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

The basin lag is then estimated using:

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

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:

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

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

## 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:

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

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 than 300 ft

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

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

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:

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

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:

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

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:

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

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 ( $\text{ft}^2$ )

$P$  = 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:

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

Where:

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

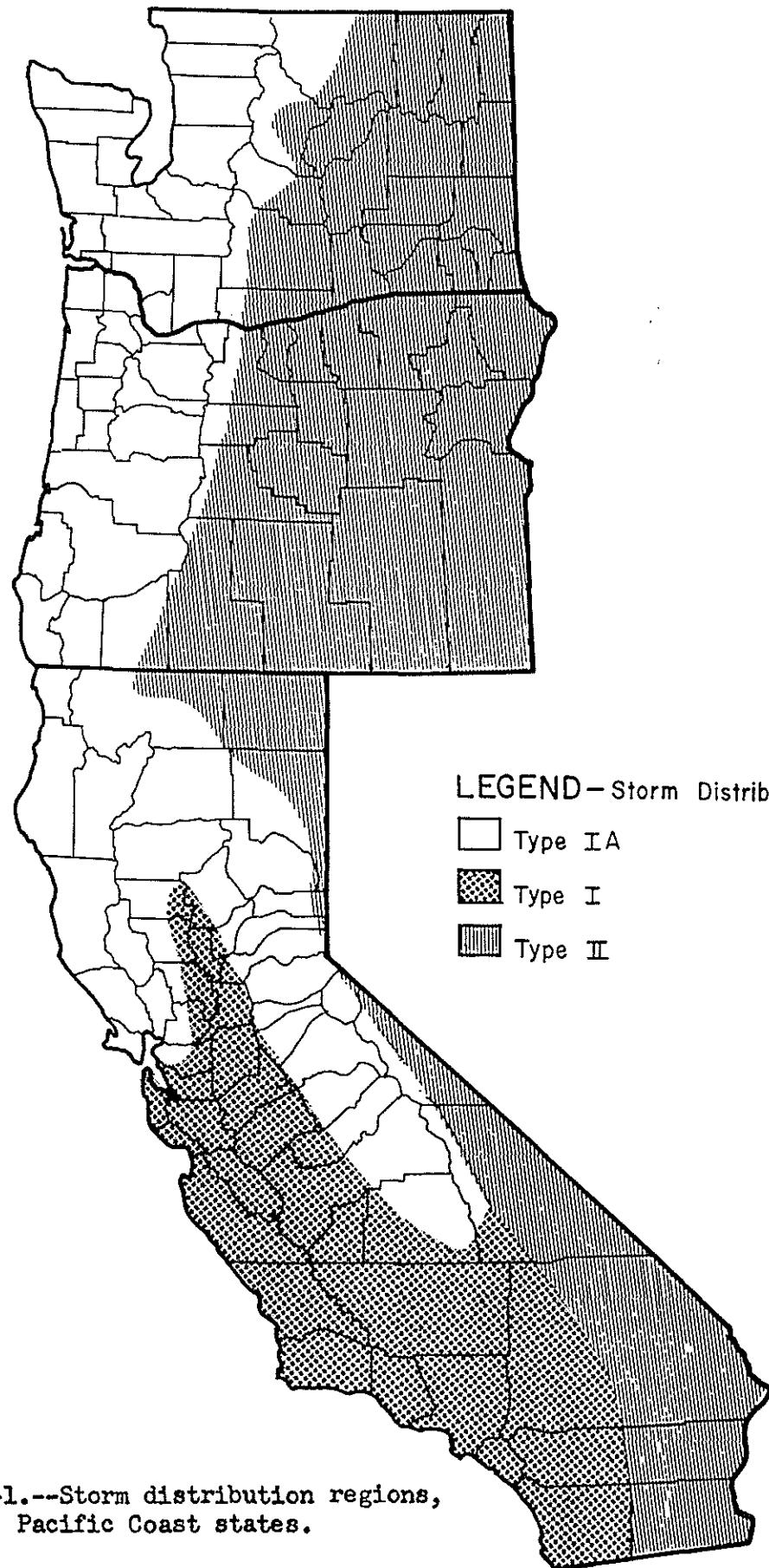
$V$  = average flow velocity, in ft/sec

$L$  = 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**



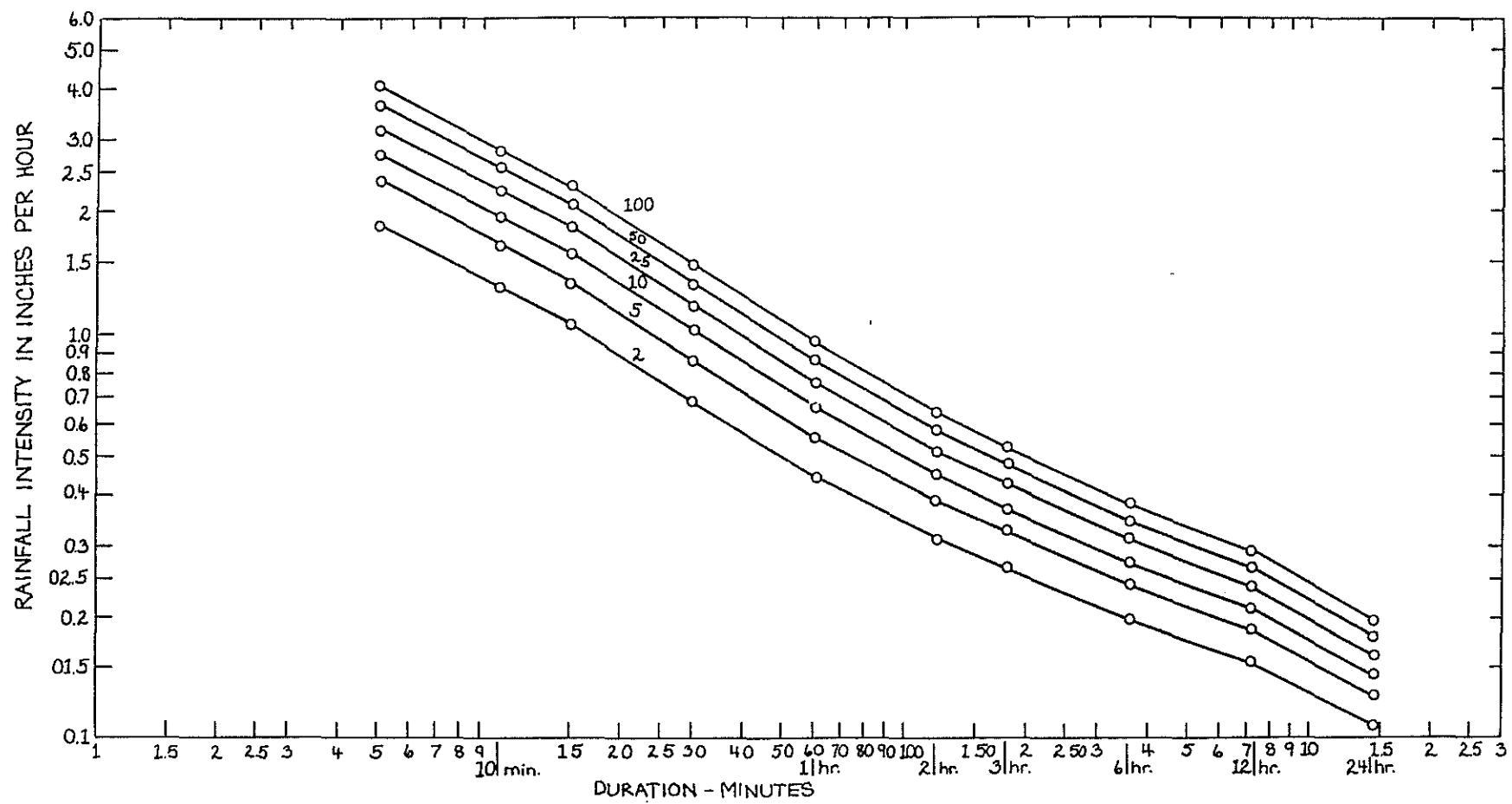


Figure D-3. Intensity-Duration-Frequency/Oregon City

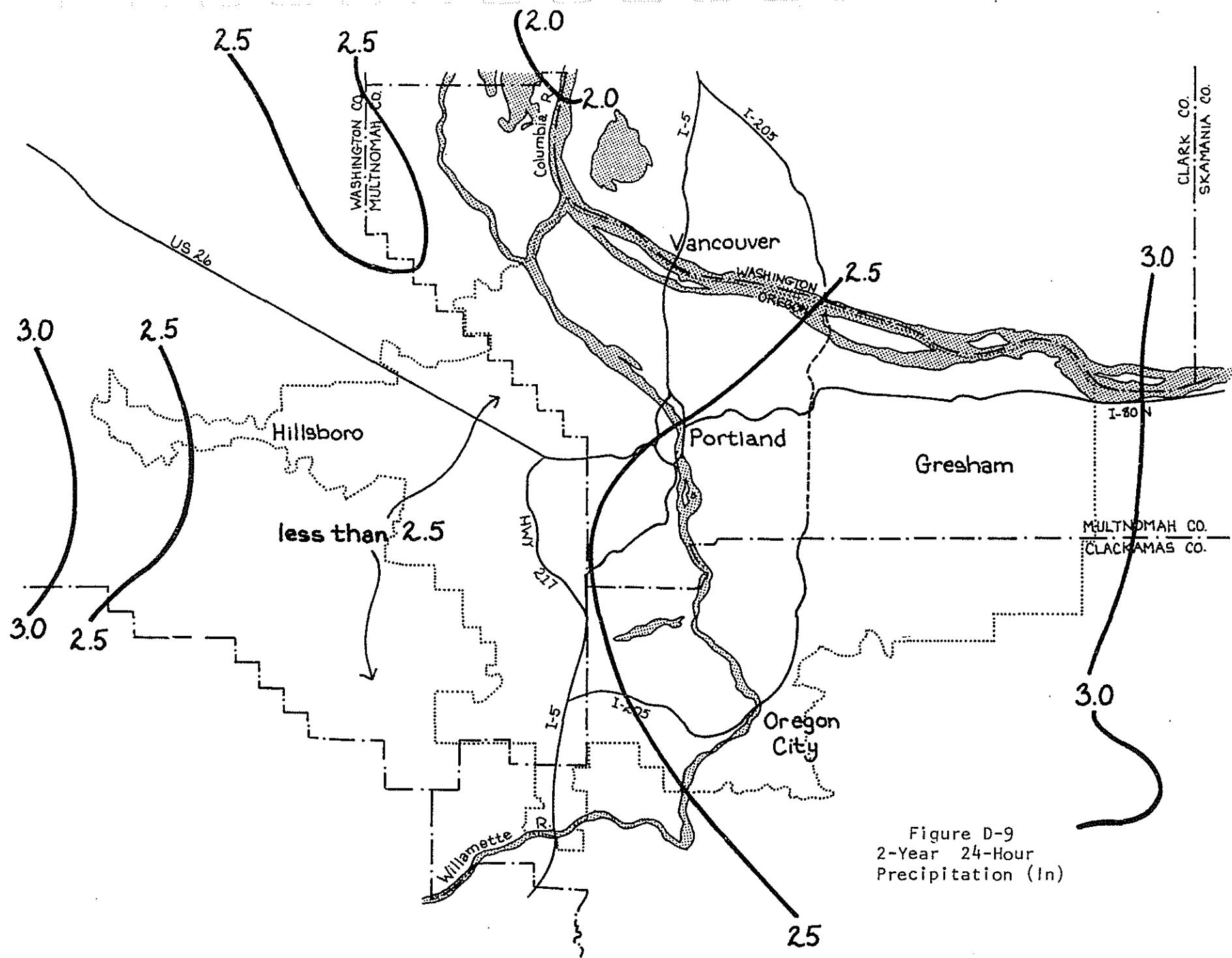


Figure D-9  
2-Year 24-Hour  
Precipitation (In)

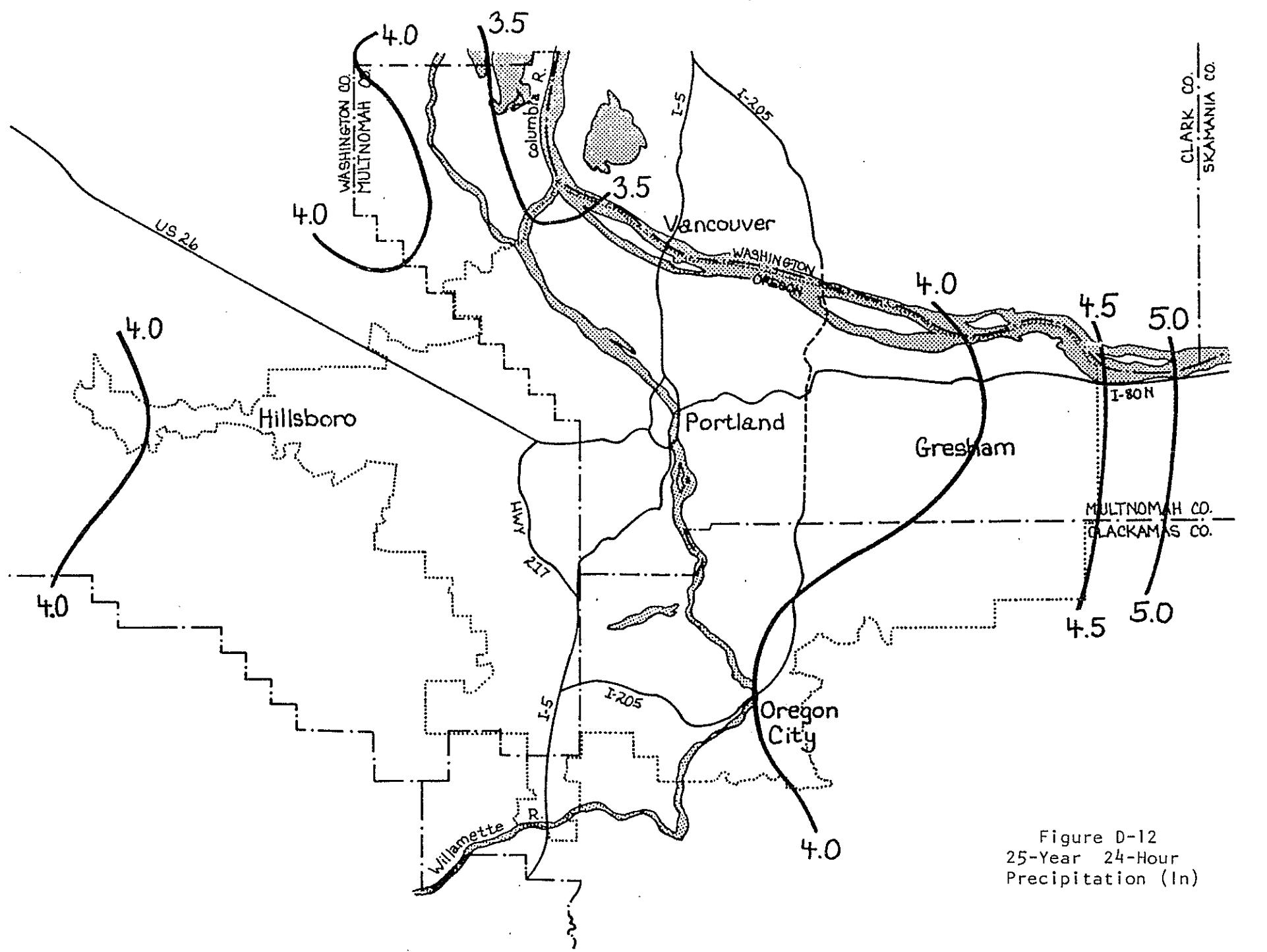


Figure D-12  
25-Year 24-Hour  
Precipitation (In)

## **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 : 4  
 TYPE : SANTA BARBARA  
 DESCRIPTION : P10-25-EXISTING

## [HYDROGRAPH INFORMATION]

Peak Discharge.....	=	10.59 (cfs)
Volume.....	=	5.47 (acft)
Time Interval.....	=	10.00 (min)
Time to Peak.....	=	490.00 (min)
Time of Base.....	=	1790.00 (min)
Multiplication factor.....	=	1.00

## [BASIN DESCRIPTION]

Watershed Area.....	=	25.41 (ac)
Curve Number.....	=	84

## [TIME CONCENTRATION -- TR-55]

## SHEET FLOW

Manning's Roughness Coef. (n).....	=	0.20000
Flow Length (L).....	=	350.00 (ft)
2-yr 24-hr Rainfall (R).....	=	2.60 (in)
Land Slope (S).....	=	0.03000
Travel Time of Sheet Flow.....	=	31.70 (min)

## SHALLOW FLOW

K_Coeff (surface description) (K).....	=	0.70000
Watercourse Slope (S).....	=	0.20000
Velocity (V).....	=	3.13 (ft/s)
Flow Length (L).....	=	550.00 (ft)
Travel Time of Shallow Flow.....	=	2.93 (min)

## CHANNEL FLOW

Hydraulic Radius (R).....	=	0.71 (ft)
Channel Slope (S).....	=	0.06000
Manning's Roughness Coef. (n).....	=	0.02000
Channel Velocity (V).....	=	14.52 (ft/s)
Flow Length (L).....	=	800.00 (ft)
Travel Time of Shallow Flow.....	=	0.92 (min)

## TIME OF CONCENTRATION

Time of Concentration.....	=	35.54 (min)
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## [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 : 5  
 TYPE : SANTA BARBARA  
 DESCRIPTION : P20-25-EXISTING

## [HYDROGRAPH INFORMATION]

Peak Discharge.....	=	5.48 (cfs)
Volume.....	=	2.61 (acft)
Time Interval.....	=	10.00 (min)
Time to Peak.....	=	490.00 (min)
Time of Base.....	=	1680.00 (min)
Multiplication factor.....	=	1.00

## [BASIN DESCRIPTION]

Watershed Area.....	=	12.82 (ac)
Curve Number.....	=	82

## [TIME CONCENTRATION -- TR-55]

## SHEET FLOW

Manning's Roughness Coef. (n).....	=	0.20000
Flow Length (L).....	=	250.00 (ft)
2-yr 24-hr Rainfall (R).....	=	2.60 (in)
Land Slope (S).....	=	0.04000
Travel Time of Sheet Flow.....	=	21.58 (min)

## SHALLOW FLOW

K_Coeff (surface description) (K).....	=	0.70000
Watercourse Slope (S).....	=	0.22500
Velocity (V).....	=	3.32 (ft/s)
Flow Length (L).....	=	800.00 (ft)
Travel Time of Shallow Flow.....	=	4.02 (min)

## CHANNEL FLOW

Hydraulic Radius (R).....	=	0.70 (ft)
Channel Slope (S).....	=	0.01000
Manning's Roughness Coef. (n).....	=	0.02000
Channel Velocity (V).....	=	5.87 (ft/s)
Flow Length (L).....	=	270.00 (ft)
Travel Time of Shallow Flow.....	=	0.77 (min)

## TIME OF CONCENTRATION

Time of Concentration.....	=	26.36 (min)
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## [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 : 6  
 TYPE : SANTA BARBARA  
 DESCRIPTION : P30-25-EXISTING

## [HYDROGRAPH INFORMATION]

Peak Discharge.....	=	6.18 (cfs)
Volume.....	=	2.33 (acft)
Time Interval.....	=	5.00 (min)
Time to Peak.....	=	480.00 (min)
Time of Base.....	=	1560.00 (min)
Multiplication factor.....	=	1.00

## [BASIN DESCRIPTION]

Watershed Area.....	=	10.52 (ac)
Curve Number.....	=	85

## [TIME CONCENTRATION -- TR-55]

## SHEET FLOW

Manning's Roughness Coef. (n).....	=	0.20000
Flow Length (L).....	=	200.00 (ft)
2-yr 24-hr Rainfall (R).....	=	2.60 (in)
Land Slope (S).....	=	0.17500
Travel Time of Sheet Flow.....	=	10.00 (min)

## SHALLOW FLOW

K_Coeff (surface description) (K).....	=	0.70000
Watercourse Slope (S).....	=	0.16000
Velocity (V).....	=	2.80 (ft/s)
Flow Length (L).....	=	550.00 (ft)
Travel Time of Shallow Flow.....	=	3.27 (min)

## CHANNEL FLOW

Hydraulic Radius (R).....	=	0.50 (ft)
Channel Slope (S).....	=	0.06000
Manning's Roughness Coef. (n).....	=	0.01300
Channel Velocity (V).....	=	17.69 (ft/s)
Flow Length (L).....	=	350.00 (ft)
Travel Time of Shallow Flow.....	=	0.33 (min)

## TIME OF CONCENTRATION

Time of Concentration.....	=	13.61 (min)
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## [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 : 7  
 TYPE : SANTA BARBARA  
 DESCRIPTION : P40-25-EXISTING

## [HYDROGRAPH INFORMATION]

Peak Discharge.....	=	22.52 (cfs)
Volume.....	=	9.54 (acft)
Time Interval.....	=	5.00 (min)
Time to Peak.....	=	485.00 (min)
Time of Base.....	=	1660.00 (min)
Multiplication factor.....	=	1.00

## [BASIN DESCRIPTION]

Watershed Area.....	=	41.07 (ac)
Curve Number.....	=	85

## [TIME CONCENTRATION -- TR-55]

## SHEET FLOW

Manning's Roughness Coef. (n).....	=	0.05000
Flow Length (L).....	=	400.00 (ft)
2-yr 24-hr Rainfall (R).....	=	2.60 (in)
Land Slope (S).....	=	0.02500
Travel Time of Sheet Flow.....	=	12.51 (min)

## SHALLOW FLOW

K_Coeff (surface description) (K).....	=	0.70000
Watercourse Slope (S).....	=	0.11000
Velocity (V).....	=	2.32 (ft/s)
Flow Length (L).....	=	450.00 (ft)
Travel Time of Shallow Flow.....	=	3.23 (min)

## CHANNEL FLOW

Hydraulic Radius (R).....	=	0.90 (ft)
Channel Slope (S).....	=	0.05200
Manning's Roughness Coef. (n).....	=	0.05000
Channel Velocity (V).....	=	6.33 (ft/s)
Flow Length (L).....	=	2100.00 (ft)
Travel Time of Shallow Flow.....	=	5.53 (min)

## TIME OF CONCENTRATION

Time of Concentration.....	=	21.27 (min)
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## [RAINFALL DESCRIPTION]

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

Impervious Fraction.....	=	0.25000
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## HYDROGRAPH REPORT

RECORD NUMBER : 8  
 TYPE : SANTA BARBARA  
 DESCRIPTION : P50-25-EXISTING

## [HYDROGRAPH INFORMATION]

Peak Discharge.....	=	3.20 (cfs)
Volume.....	=	1.39 (acft)
Time Interval.....	=	5.00 (min)
Time to Peak.....	=	480.00 (min)
Time of Base.....	=	1580.00 (min)
Multiplication factor.....	=	1.00

## [BASIN DESCRIPTION]

Watershed Area.....	=	7.92 (ac)
Curve Number.....	=	77

## [TIME CONCENTRATION -- TR-55]

## SHEET FLOW

Manning's Roughness Coef. (n).....	=	0.10000
Flow Length (L).....	=	430.00 (ft)
2-yr 24-hr Rainfall (R).....	=	2.60 (in)
Land Slope (S).....	=	0.09300
Travel Time of Sheet Flow.....	=	13.65 (min)

## SHALLOW FLOW

K_Coef (surface description) (K).....	=	1.50000
Watercourse Slope (S).....	=	0.06700
Velocity (V).....	=	3.88 (ft/s)
Flow Length (L).....	=	300.00 (ft)
Travel Time of Shallow Flow.....	=	1.29 (min)

## CHANNEL FLOW

Hydraulic Radius (R).....	=	0.71 (ft)
Channel Slope (S).....	=	0.02000
Manning's Roughness Coef. (n).....	=	0.05000
Channel Velocity (V).....	=	3.35 (ft/s)
Flow Length (L).....	=	300.00 (ft)
Travel Time of Shallow Flow.....	=	1.49 (min)

## TIME OF CONCENTRATION

Time of Concentration.....	=	16.43 (min)
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## [RAINFALL DESCRIPTION]

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

Impervious Fraction.....	=	0.15000
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## HYDROGRAPH REPORT

RECORD NUMBER : 9  
 TYPE : SANTA BARBARA  
 DESCRIPTION : P60-25-EXISTING

## [HYDROGRAPH INFORMATION]

Peak Discharge.....	=	5.25 (cfs)
Volume.....	=	2.25 (acft)
Time Interval.....	=	5.00 (min)
Time to Peak.....	=	485.00 (min)
Time of Base.....	=	1650.00 (min)
Multiplication factor.....	=	1.00

## [BASIN DESCRIPTION]

Watershed Area.....	=	9.02 (ac)
Curve Number.....	=	88

## [TIME CONCENTRATION -- TR-55]

## SHEET FLOW

Manning's Roughness Coef. (n).....	=	0.20000
Flow Length (L).....	=	250.00 (ft)
2-yr 24-hr Rainfall (R).....	=	2.60 (in)
Land Slope (S).....	=	0.05600
Travel Time of Sheet Flow.....	=	18.87 (min)

## SHALLOW FLOW

K_Coeff (surface description) (K).....	=	0.70000
Watercourse Slope (S).....	=	0.02000
Velocity (V).....	=	0.99 (ft/s)
Flow Length (L).....	=	200.00 (ft)
Travel Time of Shallow Flow.....	=	3.37 (min)

## CHANNEL FLOW

Hydraulic Radius (R).....	=	0.71 (ft)
Channel Slope (S).....	=	0.02000
Manning's Roughness Coef. (n).....	=	0.05000
Channel Velocity (V).....	=	3.35 (ft/s)
Flow Length (L).....	=	320.00 (ft)
Travel Time of Shallow Flow.....	=	1.59 (min)

## TIME OF CONCENTRATION

Time of Concentration.....	=	23.82 (min)
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## [RAINFALL DESCRIPTION]

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

Impervious Fraction.....	=	0.25000
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## EDSC WATERSHED MODELING

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## HYDROGRAPH REPORT

RECORD NUMBER : 10  
 TYPE : SANTA BARBARA  
 DESCRIPTION : P70-25-EXISTING

## [HYDROGRAPH INFORMATION]

Peak Discharge.....	=	23.20 (cfs)
Volume.....	=	10.50 (acft)
Time Interval.....	=	5.00 (min)
Time to Peak.....	=	485.00 (min)
Time of Base.....	=	1730.00 (min)
Multiplication factor.....	=	1.00

## [BASIN DESCRIPTION]

Watershed Area.....	=	40.01 (ac)
Curve Number.....	=	88

## [TIME CONCENTRATION -- TR-55]

## SHEET FLOW

Manning's Roughness Coef. (n).....	=	0.05000
Flow Length (L).....	=	300.00 (ft)
2-yr 24-hr Rainfall (R).....	=	2.60 (in)
Land Slope (S).....	=	0.00500
Travel Time of Sheet Flow.....	=	18.93 (min)

## SHALLOW FLOW

K_Coeff (surface description) (K).....	=	2.00000
Watercourse Slope (S).....	=	0.01000
Velocity (V).....	=	2.00 (ft/s)
Flow Length (L).....	=	350.00 (ft)
Travel Time of Shallow Flow.....	=	2.92 (min)

## CHANNEL FLOW

Hydraulic Radius (R).....	=	0.25 (ft)
Channel Slope (S).....	=	0.01000
Manning's Roughness Coef. (n).....	=	0.01300
Channel Velocity (V).....	=	4.55 (ft/s)
Flow Length (L).....	=	1750.00 (ft)
Travel Time of Shallow Flow.....	=	6.41 (min)

## TIME OF CONCENTRATION

Time of Concentration.....	=	28.25 (min)
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## [RAINFALL DESCRIPTION]

Distribution Type.....	=	SCS IA
Total Precipitation.....	=	4.00 (in)
Return Period.....	=	25 (yr)
Storm Duration.....	=	24.00 (hr)
Impervious Fraction.....	=	0.40000

## HYDROGRAPH REPORT

RECORD NUMBER : 11  
 TYPE : SANTA BARBARA  
 DESCRIPTION : P80-25-EXISTING

## [HYDROGRAPH INFORMATION]

Peak Discharge.....	=	5.13 (cfs)
Volume.....	=	2.27 (acft)
Time Interval.....	=	5.00 (min)
Time to Peak.....	=	485.00 (min)
Time of Base.....	=	1670.00 (min)
Multiplication factor.....	=	1.00

## [BASIN DESCRIPTION]

Watershed Area.....	=	8.80 (ac)
Curve Number.....	=	88

## [TIME CONCENTRATION -- TR-55]

## SHEET FLOW

Manning's Roughness Coef. (n).....	=	0.20000
Flow Length (L).....	=	250.00 (ft)
2-yr 24-hr Rainfall (R).....	=	2.60 (in)
Land Slope (S).....	=	0.04000
Travel Time of Sheet Flow.....	=	21.58 (min)

## SHALLOW FLOW

K_Coef (surface description) (K).....	=	1.50000
Watercourse Slope (S).....	=	0.04000
Velocity (V).....	=	3.00 (ft/s)
Flow Length (L).....	=	180.00 (ft)
Travel Time of Shallow Flow.....	=	1.00 (min)

## CHANNEL FLOW

Hydraulic Radius (R).....	=	0.50 (ft)
Channel Slope (S).....	=	0.02000
Manning's Roughness Coef. (n).....	=	0.05000
Channel Velocity (V).....	=	2.65 (ft/s)
Flow Length (L).....	=	600.00 (ft)
Travel Time of Shallow Flow.....	=	3.77 (min)

## TIME OF CONCENTRATION

Time of Concentration.....	=	26.35 (min)
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## [RAINFALL DESCRIPTION]

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

Impervious Fraction.....	=	0.35000
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## HYDROGRAPH REPORT

RECORD NUMBER : 12  
 TYPE : SANTA BARBARA  
 DESCRIPTION : P10-25-ULTIMATE

## [HYDROGRAPH INFORMATION]

Peak Discharge.....	=	10.98 (cfs)
Volume.....	=	5.65 (acft)
Time Interval.....	=	10.00 (min)
Time to Peak.....	=	490.00 (min)
Time of Base.....	=	1790.00 (min)
Multiplication factor.....	=	1.00

## [BASIN DESCRIPTION]

Watershed Area.....	=	25.41 (ac)
Curve Number.....	=	84

## [TIME CONCENTRATION -- TR-55]

## SHEET FLOW

Manning's Roughness Coef. (n).....	=	0.20000
Flow Length (L).....	=	350.00 (ft)
2-yr 24-hr Rainfall (R).....	=	2.60 (in)
Land Slope (S).....	=	0.03000
Travel Time of Sheet Flow.....	=	31.70 (min)

## SHALLOW FLOW

K_Coef (surface description) (K).....	=	0.70000
Watercourse Slope (S).....	=	0.20000
Velocity (V).....	=	3.13 (ft/s)
Flow Length (L).....	=	550.00 (ft)
Travel Time of Shallow Flow.....	=	2.93 (min)

## CHANNEL FLOW

Hydraulic Radius (R).....	=	0.71 (ft)
Channel Slope (S).....	=	0.06000
Manning's Roughness Coef. (n).....	=	0.02000
Channel Velocity (V).....	=	14.52 (ft/s)
Flow Length (L).....	=	800.00 (ft)
Travel Time of Shallow Flow.....	=	0.92 (min)

## TIME OF CONCENTRATION

Time of Concentration.....	=	35.54 (min)
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## [RAINFALL DESCRIPTION]

Distribution Type.....	=	SCS IA
Total Precipitation.....	=	4.00 (in)
Return Period.....	=	25 (yr)
Storm Duration.....	=	24.00 (hr)
Impervious Fraction.....	=	0.21000

## EDSC WATERSHED MODELING

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## HYDROGRAPH REPORT

RECORD NUMBER : 15  
 TYPE : SANTA BARBARA  
 DESCRIPTION : P40-25-ULTIMATE

## [HYDROGRAPH INFORMATION]

Peak Discharge.....	=	23.97 (cfs)
Volume.....	=	10.13 (acft)
Time Interval.....	=	5.00 (min)
Time to Peak.....	=	485.00 (min)
Time of Base.....	=	1660.00 (min)
Multiplication factor.....	=	1.00

## [BASIN DESCRIPTION]

Watershed Area.....	=	41.07 (ac)
Curve Number.....	=	85

## [TIME CONCENTRATION -- TR-55]

## SHEET FLOW

Manning's Roughness Coef. (n).....	=	0.05000
Flow Length (L).....	=	400.00 (ft)
2-yr 24-hr Rainfall (R).....	=	2.60 (in)
Land Slope (S).....	=	0.02500
Travel Time of Sheet Flow.....	=	12.51 (min)

## SHALLOW FLOW

K_Coeff (surface description) (K).....	=	0.70000
Watercourse Slope (S).....	=	0.11000
Velocity (V).....	=	2.32 (ft/s)
Flow Length (L).....	=	450.00 (ft)
Travel Time of Shallow Flow.....	=	3.23 (min)

## CHANNEL FLOW

Hydraulic Radius (R).....	=	0.90 (ft)
Channel Slope (S).....	=	0.05200
Manning's Roughness Coef. (n).....	=	0.05000
Channel Velocity (V).....	=	6.33 (ft/s)
Flow Length (L).....	=	2100.00 (ft)
Travel Time of Shallow Flow.....	=	5.53 (min)

## TIME OF CONCENTRATION

Time of Concentration.....	=	21.27 (min)
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## [RAINFALL DESCRIPTION]

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

Impervious Fraction.....	=	0.38000
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## HYDROGRAPH REPORT

RECORD NUMBER : 16  
 TYPE : SANTA BARBARA  
 DESCRIPTION : P50-25-ULTIMATE

## [HYDROGRAPH INFORMATION]

Peak Discharge.....	=	4.15 (cfs)
Volume.....	=	1.71 (acft)
Time Interval.....	=	5.00 (min)
Time to Peak.....	=	480.00 (min)
Time of Base.....	=	1580.00 (min)
Multiplication factor.....	=	1.00

## [BASIN DESCRIPTION]

Watershed Area.....	=	7.92 (ac)
Curve Number.....	=	77

## [TIME CONCENTRATION -- TR-55]

## SHEET FLOW

Manning's Roughness Coef. (n).....	=	0.10000
Flow Length (L).....	=	430.00 (ft)
2-yr 24-hr Rainfall (R).....	=	2.60 (in)
Land Slope (S).....	=	0.09300
Travel Time of Sheet Flow.....	=	13.65 (min)

## SHALLOW FLOW

K_Coef (surface description) (K).....	=	1.50000
Watercourse Slope (S).....	=	0.06700
Velocity (V).....	=	3.88 (ft/s)
Flow Length (L).....	=	300.00 (ft)
Travel Time of Shallow Flow.....	=	1.29 (min)

## CHANNEL FLOW

Hydraulic Radius (R).....	=	0.71 (ft)
Channel Slope (S).....	=	0.02000
Manning's Roughness Coef. (n).....	=	0.05000
Channel Velocity (V).....	=	3.35 (ft/s)
Flow Length (L).....	=	300.00 (ft)
Travel Time of Shallow Flow.....	=	1.49 (min)

## TIME OF CONCENTRATION

Time of Concentration.....	=	16.43 (min)
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## [RAINFALL DESCRIPTION]

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

Impervious Fraction.....	=	0.40000
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## HYDROGRAPH REPORT

RECORD NUMBER : 17  
 TYPE : SANTA BARBARA  
 DESCRIPTION : P60-25-ULTIMATE

## [HYDROGRAPH INFORMATION]

Peak Discharge.....	=	5.52 (cfs)
Volume.....	=	2.37 (acft)
Time Interval.....	=	5.00 (min)
Time to Peak.....	=	485.00 (min)
Time of Base.....	=	1650.00 (min)
Multiplication factor.....	=	1.00

## [BASIN DESCRIPTION]

Watershed Area.....	=	9.02 (ac)
Curve Number.....	=	88

## [TIME CONCENTRATION -- TR-55]

## SHEET FLOW

Manning's Roughness Coef. (n).....	=	0.20000
Flow Length (L).....	=	250.00 (ft)
2-yr 24-hr Rainfall (R).....	=	2.60 (in)
Land Slope (S).....	=	0.05600
Travel Time of Sheet Flow.....	=	18.87 (min)

## SHALLOW FLOW

K_Coef (surface description) (K).....	=	0.70000
Watercourse Slope (S).....	=	0.02000
Velocity (V).....	=	0.99 (ft/s)
Flow Length (L).....	=	200.00 (ft)
Travel Time of Shallow Flow.....	=	3.37 (min)

## CHANNEL FLOW

Hydraulic Radius (R).....	=	0.71 (ft)
Channel Slope (S).....	=	0.02000
Manning's Roughness Coef. (n).....	=	0.05000
Channel Velocity (V).....	=	3.35 (ft/s)
Flow Length (L).....	=	320.00 (ft)
Travel Time of Shallow Flow.....	=	1.59 (min)

## TIME OF CONCENTRATION

Time of Concentration.....	=	23.82 (min)
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## [RAINFALL DESCRIPTION]

Distribution Type.....	=	SCS IA
Total Precipitation.....	=	4.00 (in)Re
Storm Duration.....	=	24.00 (hr)
Impervious Fraction.....	=	0.40000

## EDSC WATERSHED MODELING

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## HYDROGRAPH REPORT

RECORD NUMBER : 18  
 TYPE : SANTA BARBARA  
 DESCRIPTION : P70-25-ULTIMATE

## [HYDROGRAPH INFORMATION]

Peak Discharge.....	=	23.20 (cfs)
Volume.....	=	10.50 (acft)
Time Interval.....	=	5.00 (min)
Time to Peak.....	=	485.00 (min)
Time of Base.....	=	1730.00 (min)
Multiplication factor.....	=	1.00

## [BASIN DESCRIPTION]

Watershed Area.....	=	40.01 (ac)
Curve Number.....	=	88

## [TIME CONCENTRATION -- TR-55]

## SHEET FLOW

Manning's Roughness Coef. (n).....	=	0.05000
Flow Length (L).....	=	300.00 (ft)
2-yr 24-hr Rainfall (R).....	=	2.60 (in)
Land Slope (S).....	=	0.00500
Travel Time of Sheet Flow.....	=	18.93 (min)

## SHALLOW FLOW

K_Coef (surface description) (K).....	=	2.00000
Watercourse Slope (S).....	=	0.01000
Velocity (V).....	=	2.00 (ft/s)
Flow Length (L).....	=	350.00 (ft)
Travel Time of Shallow Flow.....	=	2.92 (min)

## CHANNEL FLOW

Hydraulic Radius (R).....	=	0.25 (ft)
Channel Slope (S).....	=	0.01000
Manning's Roughness Coef. (n).....	=	0.01300
Channel Velocity (V).....	=	4.55 (ft/s)
Flow Length (L).....	=	1750.00 (ft)
Travel Time of Shallow Flow.....	=	6.41 (min)

## TIME OF CONCENTRATION

Time of Concentration.....	=	28.25 (min)
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## [RAINFALL DESCRIPTION]

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

Impervious Fraction.....	=	0.40000
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## HYDROGRAPH REPORT

RECORD NUMBER : 19  
 TYPE : SANTA BARBARA  
 DESCRIPTION : P80-25-ULTIMATE

## [HYDROGRAPH INFORMATION]

Peak Discharge.....	=	5.22 (cfs)
Volume.....	=	2.31 (acft)
Time Interval.....	=	5.00 (min)
Time to Peak.....	=	485.00 (min)
Time of Base.....	=	1670.00 (min)
Multiplication factor.....	=	1.00

## [BASIN DESCRIPTION]

Watershed Area.....	=	8.80 (ac)
Curve Number.....	=	88

## [TIME CONCENTRATION -- TR-55]

## SHEET FLOW

Manning's Roughness Coef. (n).....	=	0.20000
Flow Length (L).....	=	250.00 (ft)
2-yr 24-hr Rainfall (R).....	=	2.60 (in)
Land Slope (S).....	=	0.04000
Travel Time of Sheet Flow.....	=	21.58 (min)

## SHALLOW FLOW

K_Coeff (surface description) (K).....	=	1.50000
Watercourse Slope (S).....	=	0.04000
Velocity (V).....	=	3.00 (ft/s)
Flow Length (L).....	=	180.00 (ft)
Travel Time of Shallow Flow.....	=	1.00 (min)

## CHANNEL FLOW

Hydraulic Radius (R).....	=	0.50 (ft)
Channel Slope (S).....	=	0.02000
Manning's Roughness Coef. (n).....	=	0.05000
Channel Velocity (V).....	=	2.65 (ft/s)
Flow Length (L).....	=	600.00 (ft)
Travel Time of Shallow Flow.....	=	3.77 (min)

## TIME OF CONCENTRATION

Time of Concentration.....	=	26.35 (min)
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## [RAINFALL DESCRIPTION]

Distribution Type.....	=	SCS IA
Total Precipitation.....	=	4.00 (in)
Return Period.....	=	25 (yr)
Storm Duration.....	=	24.00 (hr)
Impervious Fraction.....	=	0.40000

## **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**

<b>ITEM NO.</b>	<b>DESCRIPTION</b>	<b>ESTIMATED QUANTITY</b>	<b>UNIT</b>	<b>UNIT COST</b>	<b>TOTAL COST</b>
<b>UPPER PARK PLACE BASIN</b>					
<b>Phase 1</b>					
1	Phase 1 Easement	10,000	SF	\$ 0.50	\$ 5,000.00
	Acquisition Fees	1	Parcel	\$ 1,000.00	\$ 1,000.00
	Total Phase 1 Esmt Cost				\$ 6,000.00
2	12' Dia. Storm Drain Pipe	180	LF	\$ 24.00	\$ 4,320.00
3	15' Dia. Storm Drain Pipe	170	LF	\$ 27.00	\$ 4,590.00
4	18' Dia. Storm Drain Pipe	0	LF	\$ 38.00	\$ 0.00
5	24' Dia. Storm Drain Pipe	535	LF	\$ 44.00	\$ 23,540.00
6	30' Dia. Storm Drain Pipe	230	LF	\$ 60.00	\$ 13,800.00
7	36' Dia. Storm Drain Pipe	320	LF	\$ 66.00	\$ 21,120.00
8	48" Manhole	1	EA	\$ 1,400.00	\$ 1,400.00
9	60" Manhole	3	EA	\$ 2,200.00	\$ 6,600.00
10	Connect to Exist. Storm Line	0	EA	\$ 500.00	\$ 0.00
11	Catch Basin (Std.)	6	EA	\$ 650.00	\$ 3,900.00
12	Catch Bsin (O.S.)	1	EA	\$ 800.00	\$ 800.00
13	Field Inlet	0	EA	\$ 600.00	\$ 0.00
14	Junction Vault	0	EA	\$ 3,100.00	\$ 0.00
15	A.C. Sawcut	800	LF	\$ 1.50	\$ 1,200.00
16	A.C. Repair	240	SY	\$ 15.75	\$ 3,780.00
<b>Total Phase 1</b>					<b>\$ 91,050.00</b>
<b>Phase 2</b>					
1	Phase 2 Easement	2,800	SF	\$ 0.50	\$ 1,400.00
	Acquisition Fees	8	Parcel	\$ 1,000.00	\$ 8,000.00
	Total Phase 2 Esmt Cost				\$ 9,400.00
2	12' Dia. Storm Drain Pipe	290	LF	\$ 24.00	\$ 6,960.00
3	15' Dia. Storm Drain Pipe	0	LF	\$ 27.00	\$ 0.00
4	18' Dia. Storm Drain Pipe	0	LF	\$ 38.00	\$ 0.00
5	24' Dia. Storm Drain Pipe	570	LF	\$ 44.00	\$ 25,080.00
6	30' Dia. Storm Drain Pipe	90	LF	\$ 60.00	\$ 5,400.00
7	36' Dia. Storm Drain Pipe	0	LF	\$ 66.00	\$ 0.00
8	48" Manhole	2	EA	\$ 1,400.00	\$ 2,800.00
9	60" Manhole	1	EA	\$ 2,200.00	\$ 2,200.00
10	Connect to Exist. Storm Line	0	EA	\$ 500.00	\$ 0.00
11	Catch Basin (Std.)	2	EA	\$ 650.00	\$ 1,300.00
12	Catch Bsin (O.S.)	2	EA	\$ 800.00	\$ 1,600.00
13	Field Inlet	2	EA	\$ 600.00	\$ 1,200.00
14	Junction Vault	2	EA	\$ 3,100.00	\$ 6,200.00
15	A.C. Sawcut	140	LF	\$ 1.50	\$ 210.00
16	A.C. Repair	32	SY	\$ 15.75	\$ 504.00
<b>Total Phase 2</b>					<b>\$ 62,854.00</b>

**OREGON CITY DRAINAGE MASTER PLAN**  
**PRELIMINARY ENGINEER'S OPINION OF CONSTRUCTION COSTS**

<u>ITEM NO.</u>	<u>DESCRIPTION</u>	<u>ESTIMATED QUANTITY</u>	<u>UNIT</u>	<u>UNIT COST</u>	<u>TOTAL COST</u>
<b>Phase 3</b>					
1	Phase 3 Easement	40,000	SF	\$ 0.50	\$ 20,000.00
	Acquisition Fees	12	Parcel	\$ 1,000.00	\$ 12,000.00
	Total Phase 3 Esmt Cost				\$ 32,000.00
2	12' Dia. Storm Drain Pipe	430	LF	\$ 24.00	\$ 10,320.00
3	15' Dia. Storm Drain Pipe	0	LF	\$ 27.00	\$ 0.00
4	18' Dia. Storm Drain Pipe	100	LF	\$ 38.00	\$ 3,800.00
5	24' Dia. Storm Drain Pipe	0	LF	\$ 44.00	\$ 0.00
6	30' Dia. Storm Drain Pipe	0	LF	\$ 60.00	\$ 0.00
7	36' Dia. Storm Drain Pipe	0	LF	\$ 66.00	\$ 0.00
8	48" Manhole	3	EA	\$ 1,400.00	\$ 4,200.00
9	60" Manhole	0	EA	\$ 2,200.00	\$ 0.00
10	Connect to Exist. Storm Line	2	EA	\$ 500.00	\$ 1,000.00
11	Catch Basin (Std.)	1	EA	\$ 650.00	\$ 650.00
12	Catch Bsin (O.S.)	0	EA	\$ 800.00	\$ 0.00
13	Field Inlet	1	EA	\$ 600.00	\$ 600.00
14	Junction Vault	0	EA	\$ 3,100.00	\$ 0.00
15	A.C. Sawcut	60	LF	\$ 1.50	\$ 90.00
16	A.C. Repair	15	SY	\$ 15.75	\$ 236.25
<b>Total Phase 3</b>					\$ 52,896.25
<b>Phase 4</b>					
1	Phase 4 Easement	40,000	SF	\$ 0.50	\$ 20,000.00
	Acquisition Fees	15	Parcel	\$ 1,000.00	\$ 15,000.00
	Total Phase 4 Esmt Cost				\$ 15,000.00
2	12' Dia. Storm Drain Pipe	95	LF	\$ 24.00	\$ 2,280.00
3	15' Dia. Storm Drain Pipe	0	LF	\$ 27.00	\$ 0.00
4	18' Dia. Storm Drain Pipe	0	LF	\$ 38.00	\$ 0.00
5	24' Dia. Storm Drain Pipe	590	LF	\$ 44.00	\$ 25,960.00
6	30' Dia. Storm Drain Pipe	0	LF	\$ 60.00	\$ 0.00
7	36' Dia. Storm Drain Pipe	0	LF	\$ 66.00	\$ 0.00
8	48" Manhole	0	EA	\$ 1,400.00	\$ 0.00
9	60" Manhole	1	EA	\$ 2,200.00	\$ 2,200.00
10	Connect to Exist. Storm Line	0	EA	\$ 500.00	\$ 0.00
11	Catch Basin (Std.)	2	EA	\$ 650.00	\$ 1,300.00
12	Catch Bsin (O.S.)	0	EA	\$ 800.00	\$ 0.00
13	Field Inlet	0	EA	\$ 600.00	\$ 0.00
14	Junction Vault	0	EA	\$ 3,100.00	\$ 0.00
15	A.C. Sawcut	1,170	LF	\$ 1.50	\$ 1,755.00
16	A.C. Repair	260	SY	\$ 15.75	\$ 4,095.00
<b>Total Phase 4</b>					\$ 52,590.00

**TOTAL CONSTRUCTION COST:** \$ 259,390.25  
 Additional Const. Costs (Traffic Control, Mobilization, Clearing, Contingency)(20%) \$ 51,878.05  
 Engineering Design and Contract Administration (15%) \$ 38,908.54

**TOTAL PROJECT COST:** \$ 350,176.84

KAMPE ASSOCIATES, INC.  
 Planning/Civil Engineering/Land Surveying