City of Woodland
Storm Drainage Facilities Master Plan Update and Preliminary Engineering

Draft

Appendices
Volume 2 of 3

February 2006

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GEOTECHNICAL INVESTIGATION REPORT
CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

DRAFT

October 8, 2002

KLEINFELDER
An employee owned company

October 8, 2002
File No.: 23-485068-001

Mr. Fran Borcalli, PE
Wood Rodgers
3301 C Street, Building 100-B
Sacramento, California 95816

Subject: **Geotechnical Investigation Report**
City of Woodland
Outfall Levee Certification
Yolo County, California

Dear Mr. Borcalli:

Kleinfelder is pleased to present the attached geotechnical investigation report describing the results of our geotechnical investigation of the existing City of Woodland outfall levee located between River Road (a.k.a., County Road 22) and the Cache Creek Settling Basin Levee in Yolo County, California. The purpose of our investigation was to evaluate the condition and stability of the existing levees in accordance with requirements as set forth by the Federal Emergency Management Agency (FEMA) for levees to provide protection from a 100-year water stage event.

In general, the soils encountered within the existing levee and underlying near-surface foundation consist of moderate to high plasticity, medium stiff to hard clays and silts with some railroad embankment concrete rubble. These fine-grained soils generally continued to the maximum depth explored along approximately the eastern half of the levee alignment. Below approximately the western half of the levee alignment, loose to very dense poorly and well graded sands and gravels, and silty/clayey sands and gravels were encountered between depths of about 18½ and 52½ feet below the existing levee crown. These granular materials represent a potential conduit for under seepage beneath the western portion of the levee. Based on the data gathered, it is our professional opinion that the subject levee embankment meets FEMA guidelines for levee configuration, erosion, stability, through seepage, and settlement. However, under seepage gradients beneath the western portion of the levee are greater than COE guidelines. Detailed discussions, conclusions and recommendations addressing these issues are included in the attached report.

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We appreciate the opportunity of providing our services for this project. If you have questions regarding this report or if we may be of further assistance, please contact the undersigned.

Sincerely,

KLEINFELDER, INC.

DRAFT

Kenneth G. Sorensen, PE, GE
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Project Manager

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Senior Geologist

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GEOTECHNICAL INVESTIGATION REPORT
CITY OF WOODLAND OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

1. INTRODUCTION

1.1 GENERAL

In this report we present the results of our geotechnical investigation for FEMA certification of the existing outfall levee located between River Road and the Cache Creek Settling Basin Levee in Yolo County, California.

This report includes our conclusions and recommendations related to the geotechnical aspects of the project levees and are based on the subsurface conditions encountered at the locations of our explorations and the provisions and requirements outlined in the Limitations section of this report. Recommendations presented herein should not be extrapolated to other areas or used for other projects without our prior review.

1.2 PROJECT DESCRIPTION

The project involves evaluation of the existing levee embankment located along the southern extent of the City of Woodland outfall channel. The alignment is approximately 2 miles long, trending west to east between the eastern city limit and the western edge of the Yolo Bypass. The levee alignment relative to existing streets and topographic features is shown on Plate 1.

1.3 PURPOSE AND SCOPE OF SERVICES

The purpose of our investigation was to explore and evaluate the subsurface conditions at various locations along the existing levee alignment in order to evaluate the condition of the levee in accordance with Federal Emergency Management Agency (FEMA) requirements of Section 65.10 (b) Parts (3), (4), and (5) of the National Flood Insurance Program (NFIP).

The scope of our services was outlined in our proposal dated February 6, 2001 (File No. 23-YP6792) and our letter dated June 26, 2002 (File No. 23-485068-001), and included the following:

- A visual site reconnaissance to perform an initial evaluation of the existing levee and surface conditions;
- Engineering geologic evaluation, including research of existing, regional geologic literature and maps, review of available aerial photographs, geologic

interpretation of subsurface earth units based on boring findings, and review of groundwater conditions based on boring results;

- A field investigation consisting of drilling 11 borings through the top of the existing levee to explore the subsurface conditions;

- Laboratory testing of representative samples obtained during the field investigation to evaluate relevant physical and engineering parameters of the subsurface soils;

- A review of selected literature regarding the geology and seismicity of the project area;

- Evaluation of the data obtained and an engineering analyses to develop our geotechnical conclusions and recommendations;

- Preparation of this report which includes:

  A description of the proposed project;

  A description of the surface and subsurface site conditions encountered during our field investigation;

  A description of the geologic, seismic, and groundwater setting of the project area;

  A description of potential geologic hazards or other geologic conditions that may significantly influence the project site;

  Conclusions from our engineering evaluation concerning levee:

  - Embankment Protection [NFIP Section 65.10 (b)(3)];

  - Embankment and Foundation Stability [NFIP Section 65.10 (b)(4)];

  - Liquefaction [NFIP Section 65.10 (b)(4)];

  - Seepage [NFIP Section 65.10 (b)(4)];

  - Settlement [NFIP Section 65.10 (b)(5)];

  Recommendations (if any) for additional exploration/analyses to restore the levee to FEMA criteria;

An appendix, which includes a summary of our field investigation and laboratory testing programs.

1.4 BACKGROUND HISTORY AND SITE CONDITIONS

Our review of available documents indicates the subject outfall levee was initially constructed over 20 years ago. This levee historically served as the southern boundary of the Cache Creek Settling Basin. A new, engineered Cache Creek Settling Basin Levee was constructed in the 1990's and is located approximately 300 feet north and parallel to the outfall levee. The crown of the new Settling Basin Levee is approximately 15 feet higher in elevation than that of the current outfall levee.

The bottom of the subject outfall channel varies between approximately 13 and 19 feet below the outfall levee crown. The waterside toe of the levee embankment is approximately 5 to 7 feet below the levee crown, as it rests on a relatively wide bench area between the low flow channel and the levee toe. The top of the levee ranges from about 10 to 16 feet in width. Levee side slopes ranged from about 3 to 5(h):1(v) in most areas.

The south side of the levee includes a railroad embankment, which according to available historical aerial photographs, predates the construction of the levee. The top of the railroad embankment is approximately 3 to 4 feet below the levee crown. The levee appears to have been built on the north slope of the railroad embankment's. Large pieces of concrete rubble, rock and cast-over ballast material are present on the majority of the railroad embankment south slope. A roadside ditch (a linear depression), part of which was filled with water at the time of our field investigation, lies between the railroad embankment and River Road. The outfall levee crown is approximately 6 to 8 feet above the River Road street grade to the south.

At the time of our field investigation, the levee embankment was covered with a moderate growth of native grasses and brush. A few trees are present along the outfall channel banks. The materials exposed on the levee crown consisted of embankment soils, scattered vegetation, and areas of sand and gravel. Shrinkage cracks (from desiccation of plastic clays) were noted throughout the project area, with depths ranging from nominal to about 6 inches. The majority of cracking was observed on the waterside levee slope. No significant areas of erosion were observed on the levee.

1.5 FIELD INVESTIGATION

The subsurface conditions along the existing levee alignment were explored between June 21 and July 9, 2002, by drilling 11 borings at spacings of about 1,000 feet. The borings were drilled to maximum depths of about 41½ and 56½ feet below the existing top of the levee. Borings were drilled using a CME-85 truck-mounted drill rig equipped with 8-inch-diameter hollow-stem auger. The approximate locations of borings drilled for this investigation are shown on Plate 2. Our field engineer maintained a log of the borings, visually classified soils encountered according to the Unified Soil Classification System (see Plate A-1), and obtained relatively undisturbed and bulk samples of the subsurface materials. A key to the Logs of Borings is presented on Plate A-2, and Logs of Borings are presented on Plates A-3 through A-13 of Appendix A.

At each boring location, relatively undisturbed soil samples were obtained using a California, Modified California or Standard Penetration Sampler driven 18 inches (unless otherwise noted) into undisturbed soil using a 30-inch drop of a 140-pound hammer. Blow counts were recorded at 6-inch intervals for each sample attempt and are reported on the logs in terms of blows-per-foot for the last foot of penetration. Soil samples obtained from the borings were packaged and sealed in the field to reduce moisture loss and disturbance and returned to our Sacramento laboratory for further testing. After borings were completed, they were backfilled with cement grout.

1.6 LABORATORY ANALYSES

Laboratory tests were performed on selected samples to aid in soil classification and to evaluate physical properties of the soils, which affect the geotechnical aspects of the project levee. The laboratory test program was developed with emphasis on the evaluation of natural moisture content, density, gradation, plasticity, moisture-density relationships, consolidation, and shear strength of the soils encountered. A detailed description of the laboratory-testing program is presented in Appendix B. In addition, a summary of all laboratory tests performed is presented on the Summary of Laboratory Tests, Plate B-1.

2. GEOLOGY AND SEISMICITY

2.1 REGIONAL GEOLOGIC SETTING

The site is situated near Woodland, California within the southern portion of the Sacramento Valley. The Sacramento Valley represents the northern portion of the Great Valley geomorphic province of California. The foothills of the Sierra Nevada geomorphic province occur east of the Great Valley and the Coast Ranges geomorphic province occurs to the west. The Great Valley is an asymmetrical trough, approximately 400 miles long and 40 miles wide forming the broad valley along the axis of California. Erosion of the Coast Ranges to the west and Sierra Nevada mountain range to the east has generated alluvial, over bank, and localized lacustrine sediments up to 50,000 feet thick. Subsequent deformation has folded these sediments into an asymmetrical syncline with its axis off center toward the western Coast Ranges. Along the boundaries of the valley basin, these alluvial deposits pinch out to the east and lap onto older, alluvial and channel deposits associated with previous alignments of the American and Cosumnes Rivers and, at greater depth, metamorphic terrain and crystalline basement rock of the Sierra Nevada.

Tectonically, the proposed alignment is situated relatively distant from any major fault systems. As a result, this area has relatively low to moderate levels of historic seismicity. Major faults that primarily control the regions seismicity include the San Andreas and other Bay Area faults located 68 to 122 km (42-76 mi) to the west, the Coast Range-Central Valley geomorphic block boundary about 32 km (20 mi) west, and the Sierra Nevada frontal fault system located more than 162 km east. Although its potential as a source of historic earthquake activity remains controversial, the Foothills Faults System is located at least 54 km east of the alignment.

2.2 EARTH UNITS

The generalized distribution of geologic earth units is mapped by Helley and Harwood (1985), included as Plate 3, Site Geologic Map. Helley maps surface deposits within the project area as "Qb", or Holocene basin deposits. These deposits are generally relatively fine-grained, floodplain deposits resulting from over bank deposition from the Sacramento River to the east. In order to interpret the subsurface stratigraphy that may be present beneath the site, surficial geology of this and other fluvial geomorphology is necessary. High energy fluvial sediments deposited along the active river channel are generally confined within the current levee system. Outside of these levees, pre-levee alluvial deposits are mapped as "Qa". Basin deposits ("Qb") as mapped in the general vicinity of this project site represent floodplain deposits that have been deposited by over bank deposition from the Sacramento River prior to construction of man-made levees. Several outliers of Modesto Formation ("Qml") are mapped near the site. These outcrops of older alluvial deposits represent remnant windows of fluvial deposits relating to an earlier (Modesto age; 25,000-75,000 years BP) alignment of the American and Sacramento

Rivers. The texture and density of these deposits tend to coincide with their proximity to the source of deposition and their age, respectively. Accordingly, active stream channel "Qsc" deposits are typically sand and gravel and very loose. Older alluvium "Qa" deposits are still quite young but deposited in a much broader, stream-braided channel and tend to be somewhat finer-grained, but still loose. Basin deposits "Qb", as mapped onsite, are typically finer-grained than older alluvium consisting of relatively discontinuous lenses and layers of silt and sand with minor gravel zones and loose/soft to slightly dense/stiff. Modesto Formation deposits are texturally similar to the present day Qa analog, but due to their age have increased clay content from pedogenic processes and are denser/stiffer. Color of Modesto sediments may be more reddish brown-brown due to moderate pedogenic clay development. The estimated thickness of the basin deposits at this site is approximately 10 to 15 feet, based entirely on distance from outcrops and typical basin deposit thickness.

This interpretation based upon Helley's 1985 mapping was compared to soil conservation service mapping in which shallow (i.e. 6 ½ foot deep) hand borings were performed (see Figure 1). In this vicinity, soils are quite different north and south of the project alignment.

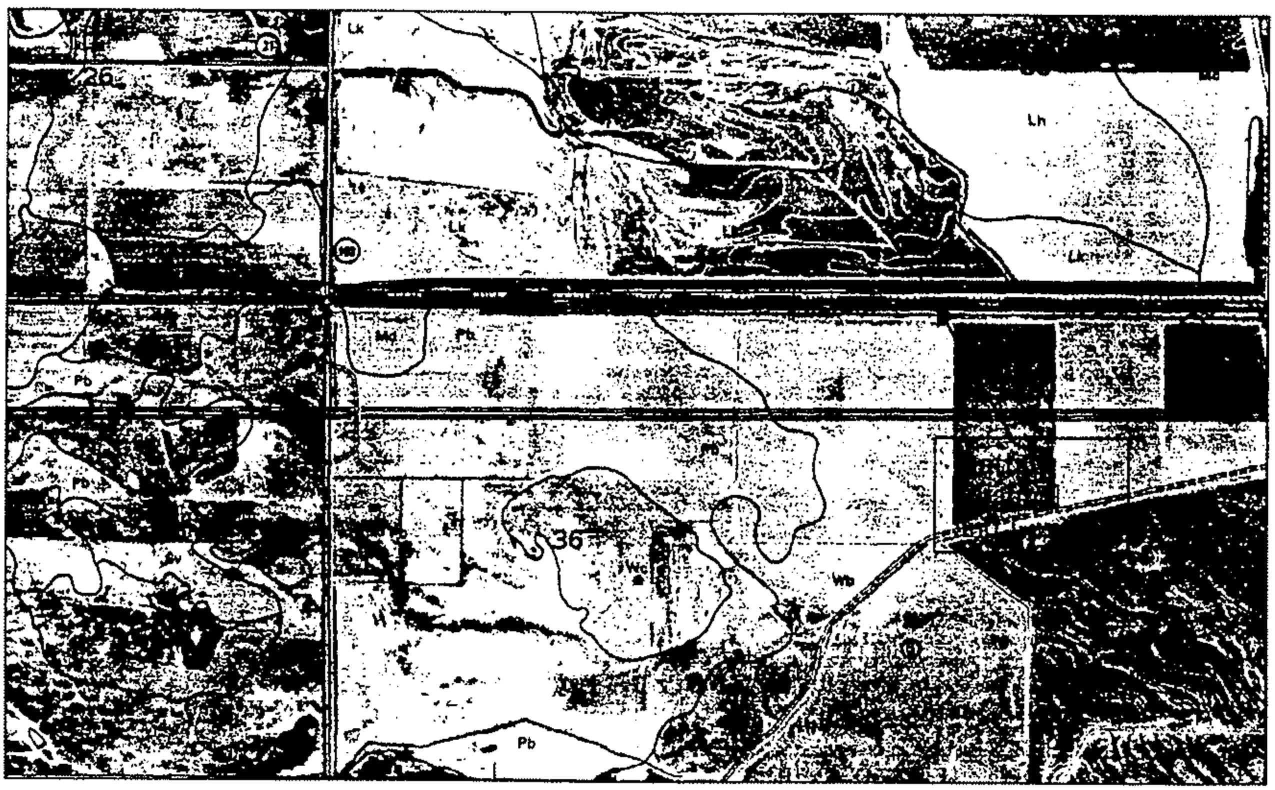


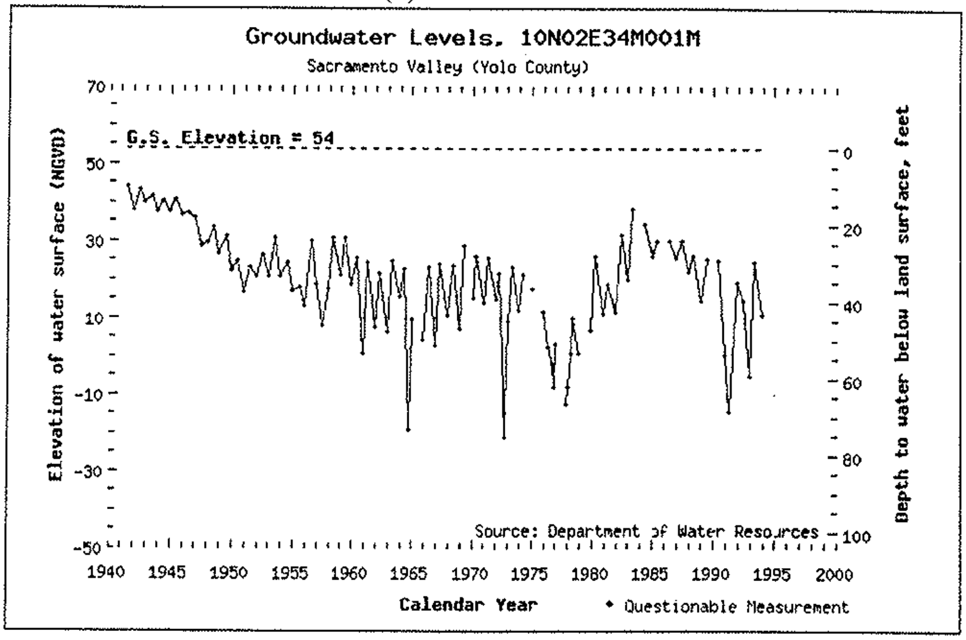
Figure 1. Soil Conservation Service (SCS) mapping of near-surface deposits (USDA, 1990; Aerial Photograph circa 1964).

On the north, very fine sandy loam of the Laugenour and Maria series are mapped and silty clay and clay of the Pescadero and Willows clay series are mapped to the south. Sandy soils north of the project are likely the result of settlement within the Cache Creek Settling Basin. Finer-grained soils south of the project are more representative of Helley's Qb basin deposits. Of particular importance is the reference to saline-alkali content of the Pescadero soil series south of the western portion of the alignment.

2.3 REGIONAL GROUNDWATER

Regional groundwater levels were reviewed based upon California Department of Water Resources (DWR) well information available at their map interface website. Two wells with substantial data and considered to be representative of the hydrogeologic setting were reviewed, including Well No. 10N02E34M001M located approximately 1 to 1.5 miles southwest of the project and Well No. 10N02E34Q001M just northwest of the site.

(a)



(b)

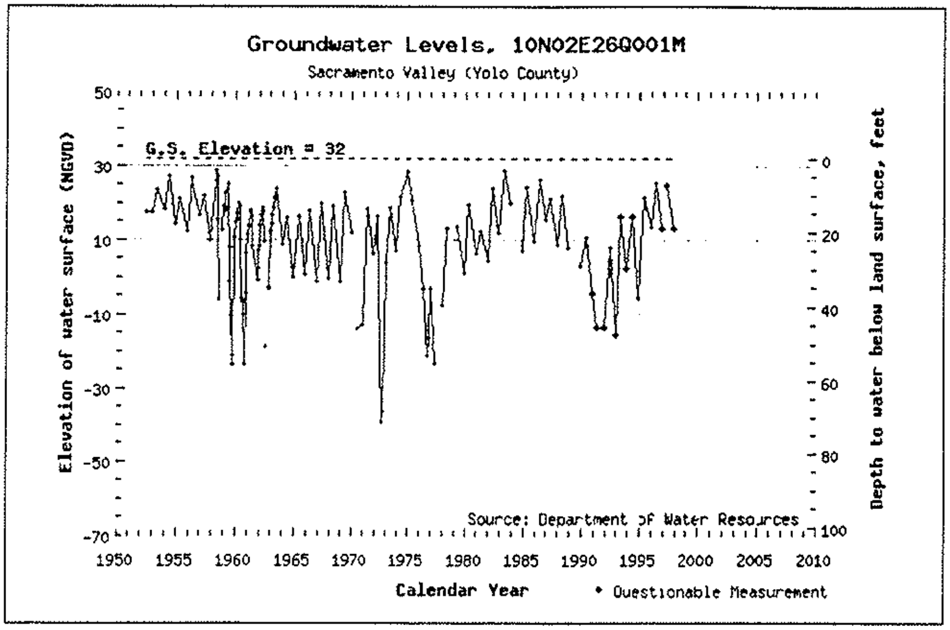


Figure 2. DWR (2002) groundwater well information for nearby Well Nos. 10N02E34M001M (a) and 10N02E34Q001M (b).

The historic hydrograph data for these wells indicates minimum groundwater levels vary severely with seasonal and annual rainfall variations (see Figure 3). However, minimum (i.e. shallowest) groundwater levels in the area were on the order of 3 to 5 feet below ground surface (bgs) (or Elevation 27 to 29 feet) north of the project and 10 to 18 feet bgs (or Elevation 36 to 44 feet) south of the project. Most recent minimum groundwater levels at both locations were recorded in 1983. On the basis of this information, we estimate future potential groundwater elevations may be as shallow as 3 feet bgs (or elevation 29 feet). Groundwater levels below the outfall levee are influenced by stage and duration of stage of retained water in the outfall channel. These groundwater levels will increase locally due to increases in stage within the outfall channel.

2.4 FAULTING

The project area is located within an area influenced by several major faults to the west and east. During the life of the proposed improvements it is probable that at least one moderate to severe earthquake will cause strong ground shaking in the project vicinity. There is no evidence of recent (Holocene) faulting within the site area and no faults are mapped to cut valley alluvium at or near the proposed alignment. Active earthquake fault zones are not indicated by Hart and Bryant (1997) in Special Publication 42, as defined by the Alquist-Priolo Earthquake Zoning Act of 1972.

The closest faults to the site are the Coast Ranges-Sierran Block Boundary zone about 32 km west of the site, the Dunnigan Hills fault about 18 km to the northwest, and the west branch of the Bear Mountains Fault zone (western splay of the Foothills Fault system) 54 km east of the site. If the Dunnigan Hills Fault were to exist further to the southeast, its projection would be about 6.5 km west of the site. The Willows fault is mapped by Harwood and Helley (1987) within 17 km (east) of the site. This fault is defined as potentially capable of generating infrequent and moderate magnitude earthquakes along it's northern extent north of the Sutter Buttes, and is mapped on the basis of offset, deep (i.e. 1500 feet) bedrock strata and associated groundwater elevation anomalies in that region.

2.5 HISTORIC SEISMICITY

Historic earthquakes in California during the period from 1815-2000 are summarized by Toppozada et al (2000). This map further confirms the general absence of large earthquake epicenters in the Sacramento region with the most significant events within 100 km of the site represented by:

- Moment magnitude 5.6 on April 30, 1892 located 32 km west-southwest
- Moment magnitude 6.4 on April 21, 1892 located 28 km west
- Moment magnitude 6.6 on April 19, 1892 located 41 km west
- Moment magnitude 6.0 on May 19, 1889 located 65 km south-southwest
- Moment magnitude 5.9 on October 12, 1891 located 75 km southwest
- Moment magnitude 6.1 on August 1, 1975 (Oroville) located 86 km north
- Moment magnitude 6.4 on May 31, 1898 located 89 km southwest

No other large magnitude events are recorded closer to the site.

2.6 ESTIMATED GROUND MOTIONS

Future seismicity in the proposed project area can be estimated by existing probabilistic maps prepared by the California Division of Mines and Geology (CDMG, 1996) (now the California Geological Survey) and Mualchin (1996) deterministic maps used widely for California transportation projects. Both of these models estimate peak ground accelerations (PGA) at the site of between 10% and 20% g are anticipated. For purposes of seismic design and liquefaction analyses, a value of 20% (0.2) g is generally accepted.

3. FINDINGS

3.1 SUBSURFACE CONDITIONS ENCOUNTERED

3.1.1 Subsurface Soil Conditions

Based on our findings, the earth fill that composes the levee consists predominantly of moderate to high plasticity, medium stiff to very stiff clay to depths of about 12 to 13 feet below the existing levee crown. Beneath this fill material, similar clays with gravel/cobbles and some concrete rubble (perhaps part of the older, adjacent railroad embankment) were encountered in the majority of the borings at depths of about 15 to 20 feet below the levee crown. This layer was most apparent in the eastern two-thirds of the levee alignment. In Boring B-9 this older embankment material was encountered as deep as about 30 feet below the levee crown. Below these fill layers; native soils varied significantly in gradation from one half of the alignment to the other.

Based on soils encountered in Borings B-1 through B-6, roughly the western half of the levee alignment fills are generally underlain by moderate plasticity, stiff to very stiff clays, sandy clays, and sandy silts at depths ranging from approximately 18½ to 25½ feet below the levee crown. Under these fine-grained soil layers, loose to very dense poorly and well-graded sands and gravels, and silty/clayey sands and gravels were encountered to depths of about 40½ to 52½ feet below the levee crown. Below these sands and gravels, low to moderate plasticity, stiff to hard clays, silty clays, and silts were generally encountered to depths of 56½ feet below the levee crown (the maximum depth of exploration).

Below the levee and railroad embankment fills encountered in Borings B-7 through B-11 (roughly the eastern half of the alignment), the native soils consisted of low to moderate plasticity, stiff to hard clays, sandy clays, and silty clays to depths of approximately 38 to 43 feet below the levee crown. Below these upper native clay layers, soils encountered in these five borings generally consisted of low plasticity, stiff to hard silts, sandy silts, clays, and silty clays to depths of 56½ feet below the levee crown (the maximum depth of exploration). One exception among these borings was in Boring B-7, where medium dense silty and poorly graded sands were encountered between depths of about 48 to 53 feet below the levee crown.

3.1.2 Groundwater

Groundwater was encountered in our borings as shallow as 15± feet below the levee crown along the west end of the levee embankment and as deep as 30± feet at the east end. These depths to groundwater are consistent with recently recorded levels in DWR Well No. 10N02E34Q001M.

3.1.3 Geologic Description

Based on our findings, soil conditions encountered in our eleven borings along the levee alignment consisted of lean to high plasticity clay soils and some plastic silts. The near-surface levee soils on the western portion of the site were underlain by a 10-15± foot thick layer of sandy, gravelly channel deposits at depths ranging from about 18½ to 25½ feet below the existing levee crown. A soil profile (i.e fence diagram) was prepared to correlate soils encountered in our borings and is included as Plate 6.

The channel deposits encountered at depth represent high-energy deposition that would be expected along the axis of an active river channel. These channel deposits are abruptly truncated to the east between Borings B-7 and B-8 where a zone of silt and clayey silt was encountered. Near-surface clays are interpreted to be Helley's (1985) "Qb" basin deposits, as mapped. The deeper channel deposits are relatively dense and thus may be older, representing a primary fluvial deposit of Modesto-age alluvium and perhaps a former alignment of the Sacramento River.

Detailed descriptions of the subsurface conditions encountered during our field investigation are presented on the Logs of Borings, Plates A-3 through A-13 of the appendix.

4. ENGINEERING ANALYSES

4.1 GENERAL

The following sections refer to the engineering analyses required in Section 65.10 of the NFIP and related requirements detailed in the U.S. Army Corps of Engineers (USACE) Manual EM 1110-2-1913, "Design and Construction of Levees," dated April 30, 2000, and EM1110-2-1601 "Hydraulic Design of Flood Control Channels," dated July 1, 1991.

4.2 ANALYSIS CROSS SECTIONS

Two generalized cross sections were modeled and analyzed for levee stability through seepage and under seepage. The cross sections were developed based on the subsurface data obtained from our field investigation, water surface and topographic survey information provided by Wood Rodgers, and from the Department of Water Resources (DWR) report ("Water Surface Profile Analysis for Cache Creek Settling Basin, City of Woodland Drainage Canal", DWR, July 7, 1992).

We understand the design maximum water surface elevation (WSE) is about Elevation 32.4 feet based on the DWR report (NGVD29 datum). This water surface elevation is based on the 100-year event flood stage with least 3 feet of freeboard. Following a section survey of the existing levee and landside slopes by Wood Rodgers in September 2002, it was determined the elevations surveyed in the DWR report were lower than the present survey elevations by an average of about 2.5 feet due to datum differences. The topographic survey by USACE and section surveys by Wood Rodgers used for the design of this project used the NAVD88 datum. Therefore, our analysis cross sections were converted to elevations based on the NAVD88 datum. A maximum WSE of 33.5 feet and a normal WSE of 27.5 feet was used in our analyses.

The analysis sections developed are labeled Section A and Section B. Analysis Section A represents the middle portion of the study area near Boring B-7. This section is similar to Analysis Section B with the primary differences being the slope of the bottom of the channel up to the levee and the presence of sand and gravel deposits beneath the levee and upper native clay soils. Analysis Section B represents the eastern (most downstream) end of the study area near Boring B-11. The profile in this area is characterized by having the steepest and most abrupt channel cross section and essentially cohesive clay and silt soils throughout the cross section.

4.3 EMBANKMENT PROTECTION

Evaluation of embankment protection was performed in accordance with Federal Emergency Management Agency (FEMA) requirements of Section 65.10 (b) Part (3) of the National Flood Insurance Program (NFIP).

We understand the existing outfall levee was constructed using local soils. Accordingly, the levee fill and underlying undisturbed native soils exhibit similar physical characteristics consisting primarily of moderate to high plasticity clays. The outfall channel is essentially straight with flow tangential to the levee embankment. The channel and adjacent levee embankments are presently covered with a moderate to dense growth of grasses, a few shrubs, and several small trees. Visual evidence of past surface erosion or sloughing on the levee faces are lacking. Moderate desiccation cracking in the exposed clay soils on the levee and foundation was observed.

Throughout a majority of the year, water depths within the channel are expected to remain relatively shallow (about 3 to 5 feet deep). Flow velocities are currently unknown but anticipated to be less than about 6 feet per second. During a 100 year stage event, the natural channel embankment and levees will contain for a short time about 13 to 16 feet of water. Flow velocities are anticipated to by in the range of 6 feet per second or less. Based on published guidelines, flow velocities of about 5 feet per second or less are permissible for unlined channels composed of plastic silts and clays with established vegetative cover. With the present vegetative cover and flow velocities of 5 feet per second or less, erosion within the channel due to either flow or wave action should be very slow, requiring only periodic maintenance to restore the levee to its original condition. Areas with higher flow velocities or turbulence should be provided with slope protection consisting of pavement or rip-rap. Erosion due to ice loading or impact of debris is anticipated to be negligible.

Given their relatively high plasticity, the native and fill clays may exhibit significant shrinking and swelling due to seasonal moisture fluctuations. Although this condition should not reduce the gross stability of the levees, shrinkage cracks will likely develop within the levee embankments during months of low precipitation. During and/or following rainfall, these cracks tend to become filled with water, leading to the development of hydrostatic pressures, softening of the surficial soils and subsequently accelerated sloughing or erosion of the embankments. Accordingly, the levee embankments will need to be inspected and maintained periodically to prevent progressive sloughing/erosion.

Maintenance of the levee slopes can be reduced by either overlying the moderately to highly plastic clays with a 12 to 18 inch thick layer of low plasticity soil to reduce shrinkage and swelling of the exposed soils, or by reducing the plasticity of the clays by treating the surficial soils with a hydrating agent such as lime. If requested, Kleinfelder can present design criteria for either of these alternatives.

4.4 EMBANKMENT AND FOUNDATION STABILITY

4.4.1 General

Evaluation of embankment and foundation stability was performed in accordance Federal Emergency Management Agency (FEMA) requirements of Section 65.10 (b) Part (4) of the National Flood Insurance Program (NFIP).

4.4.2 Embankment Geometry

The existing levee embankment geometry was compared with the guidelines set forth in the UASCE manual. In general, the embankment geometry conforms to the guidelines presented therein. Specially, this includes an embankment water side slope no greater than 3(h):1(v), a landslide slope no greater than 2(h):1(v), and a crest width of at least 10 feet.

4.4.3 Slope Stability Analyses Methods

Stability analyses were performed on levee and native embankment cross-sections at selected study sites chosen to represent both typical levee conditions and potentially weaker areas. The only portion of the project with moderate or steeper topography is the levee itself. Slope stability analyses were performed to evaluate the stability of levee fill materials and potential failure surfaces extending into the underlying, near-surface clayey soils.

Circular arc failures were analyzed using Spencer's method. Spencer's method is a two-dimensional, limit-equilibrium method that satisfies force equilibrium of slices and overall moment equilibrium of the potential sliding mass. The inclination of side forces between vertical slices is assumed to be the same for all slices and is calculated along with the factor of safety. This method utilizes the levee slope configuration, unit weight and shear strength properties of levee and foundation materials, and boundary and internal distribution forces due to water pressures. After a potential failure surface has been assumed, the soil mass located above the failure surface is divided into a series of vertical slices. Forces acting on each slice include the slice weight, the pore pressure, the effective normal force on the base, the mobilized shear force (including both cohesion and friction), and the horizontal side forces due to earth pressures.

Searches for critical failure surfaces were performed by specifying lines that the circumference of the circle is tangent to and a grid of points representing the circle centers. Separate searches for the critical failure surface were performed using tangent lines parallel to the levee and railroad embankment slope.

In the case of the steady-state seepage loading condition, the groundwater conditions were modeled by importing the groundwater pressure data from the results of the finite element seepage analyses, presented in the Seepage Analysis section of this report. As such, the pressures resulting from seepage forces are taken into account in this model.

The factor of safety against slope failure is calculated by determining the ratio of the resisting force (cohesion and friction along the failure surface) to the driving forces about the center of the assumed circular failure surface arc. The computer program Slope/W version 4.21 developed by Geo-Slope International, LTD was used to perform automatic searches of different potential failure surfaces and to compute a critical failure surface having the lowest factor of safety for a particular analysis condition. Printouts from the computer analyses are included in Appendix C.

4.4.4 Soil Parameters Used in Analysis

The determination of forces used in the stability analysis was based on the findings of field explorations, laboratory test results, and previous experience. For total stress analysis (i.e., sudden drawdown), it was conservatively assumed the design 100-year flood stage will be sufficiently prolonged such that the soils within the levees become saturated. Our estimates indicate that water would need to remain at flood levels for at least 20 days for this condition to develop, well in excess of anticipated flood durations. For effective stress analysis (i.e., steady-state seepage from full flood stage and intermediate river stage conditions, it was again conservatively assumed that any water stage which develops within the channel would extend horizontally through the levee embankment, with soils below the phreatic (free water) surface in a saturated condition. For earthquake or pseudo-static stability analyses, a horizontal seismic coefficient of 0.13 was used corresponding to 2/3 the peak ground acceleration determined in our ground shaking evaluation. Soil parameters used in the analyses were selected based on an evaluation of material type and density, laboratory index properties, consistency or relative density of the soils based on field penetration tests, and the results of laboratory strength tests. A summary of the soil properties used in our analyses is presented below:

Table 4.1
Soil Parameters Used in Slope Stability Analysis

Soil Classification	**Unit Weight (pcf)**	**Drained Strengths**	
		ϕ'	**c' (psf)**
Clay & clayey Silt (CL/CH/CL-ML)	110	15	300
Sand (SW/SP)	120	30	0
Gravel (GW/GP/GM/GC)	125	34	0

4.4.5 Conditions Requiring Analysis

The proposed levee slope configurations were analyzed for several different slope stability conditions as required in the USACE EM1110-2-1913 manual. These conditions are summarized below:

Table 4.2
Analysis Conditions

Design Condition	Slope Analyzed	Minimum Factor of Safety
Sudden Drawdown	Waterside & Landside	1.0
Steady Seepage from Full Flood Stage	Waterside & Landside	1.4
Earthquake	Waterside & Landside	1.0

The following cases were analyzed:

CASE A1: Section A - Channel Rapid Draw Down. This case represents the stability condition for the interior levee slopes under rapid draw down.

CASE A2: Section A - Channel Full. This case represents the stability condition for the interior levee slopes under steady-state seepage conditions with the channel at the maximum water surface elevation.

CASE A3: Section A - Channel Full. This case represents the stability condition for the exterior levee slopes under steady-state seepage conditions with the channel at the maximum water surface elevation.

CASE A4: Section A - Earthquake, Channel at Normal WSE. This case represents the stability condition for the interior channel levee slopes during an earthquake, with the channel at the normal water surface elevation.

CASE A5: Section A- Earthquake, Channel at Normal WSE. This case represents the stability condition for the exterior levee slopes during an earthquake, with the channel at normal water surface elevation.

CASE B1: Section B - Channel Rapid Draw Down. This case represents the stability condition for the interior levee slopes under rapid draw down.

CASE B2: Section B - Channel Full. This case represents the stability condition for the interior levee slopes under steady-state seepage conditions with the channel at the maximum water surface elevation.

CASE B3: Section B - Channel Full. This case represents the stability condition for the exterior levee slopes under steady-state seepage conditions with the channel at the maximum water surface elevation.

CASE B4: Section B - Earthquake, Channel at Normal WSE. This case represents the stability condition for the interior levee slopes during an earthquake, with the channel at the normal water surface elevation.

CASE B5: Section B - Earthquake, Channel at Normal WSE. This case represents the stability condition for the exterior levee slopes during an earthquake, with the channel at normal water surface elevation.

4.4.6 Stabilty Analysis Results

The results of the Slope/W slope stability computer program analyses for the proposed slope configurations are summarized on the table below for the profiles studied. The results shown in Table 4.3 below are based on the minimum factors of safety prescribed by the USACE EM1110-2-1913 manual.

Table 4.3
Calculated Factors of Safety for Slope Stability

Profile No.	Calculated Factor of Safety	Required Minimum Factor of Safety
Section A		
Case A1, Rapid Draw Down	2.8	1.0
Case A2, Steady State Full	5.3	1.4
Case A3, Steady State Full	2.1	1.0
Case A4, Earthquake	1.8	1.4
Case A5, Earthquake	1.5	1.0
Section B		
Case B1, Rapid Draw Down	2.7	1.0
Case B2, Steady State Full	5.4	1.4
Case B3, Steady State Full	2.3	1.0
Case B4, Earthquake	1.6	1.4
Case B5, Earthquake	1.4	1.0

The computer printouts of our slope stability analysis are presented in Appendix C. As shown, the most critical condition, as defined by a lower factor of safety, for all the levee and native soil embankments appears to be the exterior slopes under long-term steady-state seepage and design flood stage condition. However, the factor of safety for this condition, as well as the remainder of the conditions, well exceeds the minimum requirements as defined by the USACE EM1110-2-1913 manual. These relatively high factor of safety values are likely due to the relatively low levee embankment heights, as well as the strength of the soils that compose the levee embankments and native soil foundation layer.

4.4.7 Liquefaction

The term liquefaction describes a condition in which saturated soil loses shear strength and deforms as a result of increased pore water pressure induced by strong ground shaking during an earthquake. Embankments constructed either upon or with potentially liquefiable soil may become unstable and slump, flow, or spread laterally. The factors known to influence liquefaction potential include soil type, grain size, relative density, confining pressure, depth to groundwater, and the intensity and duration of ground shaking. Soils most susceptible to liquefaction are saturated, loose sandy soils generally at depths less than about 50 feet from the ground surface.

The referenced USACE EM1110-2-1913 manual under the discussion of "Earthquakes", describes the necessity for evaluation of liquefaction potential when addressing important levees. Although USACE does not normally consider liquefaction with full flood stage conditions due to the low probability of an earthquake coinciding with periods of high water, an evaluation of liquefaction is provided herein for consideration by FEMA.

4.4.7.1 Liquefaction Assessment

Evaluation of the potential for soil liquefaction was based on the subsurface conditions encountered in the borings, laboratory testing of soil samples recovered from the borings, and estimated ground motions from the design basis earthquake (DBE) having a 10 percent probability of being exceeded in 50 years. Based on published data, we estimate the DBE to consist of a 6.5 moment magnitude earthquake generating a peak horizontal ground acceleration of 0.20g.

Engineering analysis of liquefaction potential was based on the methods developed by the National Center for Earthquake Engineering and Research (Youd ET. Al. 2001). The groundwater level was taken at the ground surface. The results of this analysis indicate soil layers having the potential for liquefaction (factor of safety of less than one for the DBE) were encountered in Borings B-1 and B-5 at depths of about 19 and 25 feet below the levee crown. These layers consist of loose, well-graded and silty sands were encountered in isolated areas and ranged from about 2 to 4 feet in thickness. Other soils encountered on the site are characterized as having low liquefaction potential.

4.4.7.2 Seismically Induced Settlement Assessment

Seismically induced settlements were estimated based on the procedures outlined by Tokumatsu and Seed (1987). We estimate a 6.5 moment magnitude earthquake generating a peak horizontal ground acceleration of 0.20g would induce seismic ground surface settlement ranging from about 1- to 2½ inches along the western portion of the levee (near Borings B-1 and B-5) under normal water surface conditions in the outfall channel (WSE of about 25 feet). Based on the materials encountered in the borings, our estimates indicate liquefaction settlement would be negligible along the eastern portion of the levee (near Borings B-7 through B-11).

Settlement estimates due to liquefaction are considered highly approximate at this site due to the variation and discontinuity of potentially liquefiable soil layers. The methods used in our analysis are based on case history information gathered from earthquakes that have occurred throughout the world that may or may not accurately represent the expected seismic performance on this site. Therefore, we have evaluated the data gathered to approximate the level of risk associated with liquefaction settlement.

4.4.7.3 Lateral Spreading Assessment

An assessment of the lateral spreading potential beneath the levee embankment was performed based on the empirical relationships reported by Bartlett and Youd (1996). Based on the surface topography, the locations of liquefiable layers identified in Borings B-1 through B-5, and the soil conditions encountered elsewhere on the site, we estimate the risk of earthquake-induced lateral spreading to be low.

4.5 SEEPAGE

4.5.1 General

Levee through seepage and under seepage was evaluated in accordance with Federal Emergency Management Agency (FEMA) requirements of Section 65.10 (b) Part (4) of the National Flood Insurance Program (NFIP).

4.5.2 Analysis Methods

A seepage analysis was analyzed using steady-state analysis procedures of the finite element program SEEP/W. This software was developed by Geo-Slope International (1998) and can analyze two-dimensional planar or axi-symmetrical problems with isoparametric and higher-order finite elements. The program is able to work with multiple soil types having anisotropic hydraulic conductivity characteristics. Boundary conditions, in steady-state analyses can be modeled as constant head, no-flow, constant flow, or variable based on head condition. Infinite elements can also be included in the profile to model an infinite half-space at the edge of the model.

4.5.3 Soil Parameters Used in Analysis

The coefficients of hydraulic conductivity (permeability) for the various soils in the cross sections were selected using published empirical relationships between the soil type and the coefficient of permeability, such as those presented by Terzaghi and Peck (1967). Correlation relationships based on grain size distribution, as described in EM-1110-2-1913 (USACE, 2000) and in NAVFAC DM-7.01 (NAVFAC, 1986), were also utilized. Conservative values from the ranges provided by Terzaghi and Peck (1967) were assigned to the various zones, as shown in Table 4.4 below. Furthermore, a conservative ratio of horizontal to vertical permeability of 4 to 1 was assumed.

Table 4.4
Horizontal Hydraulic Conductivity for Various Soil Types

Soil Type	Range of Coefficients of Horizontal Hydraulic Conductivity (cm/sec)	Selected Values of Horizontal Hydraulic Conductivity		Anisotropy Ratio (k_v/k_h)
	Terzaghi and Peck (1967)	cm/sec	ft/day	
CL/CH/CL-ML	10^{-7} to 10^{-3}	10^{-5}	0.028	0.25
SW/SP	10^{-4} to 10^{-3}	$5x10^{-3}$	14	0.25
GW/GP	10^{-3} to 10^{-2}	10^{-2}	28	0.25

4.5.4 Analysis Results

The US Army Corps of Engineers describes a maximum allowable vertical exit gradient of 0.3 for new levee construction or existing levees that have not experienced the design maximum water surface elevation. This assumes an average soil unit weight of 115 pcf. For existing levees that have experienced the design maximum water surface elevation, the maximum allowable vertical gradient is 0.5. Due to the lack of information regarding past channel stage, it is our opinion a maximum vertical exit gradient of 0.3 is appropriate for this project. The existing slope configurations were modeled to evaluate the steady-state seepage conditions under the normal water surface in the channel and at proposed flood stage.

The factor of safety was calculated by checking the critical hydraulic gradient with the actual soil unit weight. The total unit weight used in determining the critical gradients was based on the laboratory moisture-unit weight relationships. A total soil unit weight of 110 pcf represented a critical gradient of 0.76. The critical gradient was then divided by the vertical exit gradient to obtain the factor of safety.

Results of the analyses are presented in Table 4.5 below. The graphical results of the calculated total head contours and vertical gradients from the SEEP/W computer program are shown in Appendix C.

Table 4.5
Calculated Vertical Exit Gradients, Internal Gradients, and Factors of Safety
For Existing Conditions

Section	Water Surface Condition	Exit Gradient at Levee Toe	Vertical Gradient in Upper Layer	Factor of Safety (γ_T=110 pcf)
A	Normal	0.3	0.3	2.5
B	Normal	0.1	0.1	7.6
A	Flood Stage	0.4	0.4*	1.9
B	Flood Stage	0.2	0.2	3.8
Note: * gradient exceeds 0.3 requirement				

The results of our analysis indicate the steady-state seepage phreatic surface during normal water conditions in the channel does not exit above the toe of the landside embankment. However, the steady-state seepage phreatic surface during prolonged flood stage in the channel exits above the toe of the landside embankment. The presence of standing water in the area between the River Road and the landside embankment near Boring B-6 suggests the potential for under seepage at normal water surface as well as flood stage conditions. Accordingly, the potential for uncontrolled seepage emerging on the landside levee slope is judged to be moderate.

4.6 SETTLEMENT

Levee settlement was evaluated in accordance with Federal Emergency Management Agency (FEMA) requirements of Section 65.10 (b) Part (5) of the National Flood Insurance Program (NFIP). Based on our field data and the results of laboratory tests, the existing levee fill and native soils exhibit a moderate potential to consolidate or settle with increases in stress. However, since the subject levees were constructed at least 20 years previous, settlement within the levees and foundation soils should be essentially complete. Accordingly, we estimate the potential for future loss of freeboard as a result of levee settlement is very low.

5. CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSIONS

On the basis of the results of our field explorations, laboratory tests, and engineering analysis, we have formed the following conclusions regarding the condition of the subject levee:

- Based on the topographic survey data provided, the levee geometry generally conforms to the guidelines presented in the USACE EM1110-2-1913 manual.

- Erosion potential of levee slopes within the outfall channel due to either flow or wave action should be low considering the existing vegetative cover provided the channel velocities are less than 5 feet per second (USACE EM1110-2-1601). Periodic maintenance may be required to maintain the levee in its original condition/configuration. Erosion protection should be maintained on the levee slopes. Erosion due to ice loading or impact of debris is anticipated to be negligible. Channel velocities in excess of 5 feet per second may necessitate the use of rip-rap or similar slope protection measures.

- The moderate to high plasticity clays encountered in the area of the existing levee may not meet US Army Corps of Engineers specifications for levee fill due to their plasticity. We recommend a borrow site investigation be performed if raising and/or widening the levee will be necessary. The moderate to high plasticity clays encountered within the levee and foundation areas may exhibit shrinking and swelling due to seasonal moisture fluctuations. Although this condition in itself should not reduce the gross stability of the levee, tension cracks will likely develop within the levee embankments during the dryer months. During and/or following rainfall, these cracks tend to become filled with water, leading to the development of hydrostatic pressures within the levee, a softening of the surficial soils, and subsequently accelerated sloughing or erosion of the embankments. Accordingly, the levee embankments will need to be inspected and maintained periodically to prevent progressive sloughing/erosion.

- Maintenance of the levees can be reduced by either overlying the high plasticity clays with a 12 to 18 inch layer of low plasticity soils to reduce desiccation cracking within the embankment. The plasticity of the clays could be reduced by treating the surficial soils with a hydrating agent such as lime. If requested, Kleinfelder would be pleased to present criteria for either of these alternatives.

- It is our opinion the levee embankments should be grossly stable against failures that could breach the levees and cause flooding during the 100-year water surface stage event.

- The risk of seismically induced liquefaction and resulting levee failure is low. Seismic settlement estimates due to liquefaction of soil layers at depth beneath the levee embankment are on the order of 1 to 2½ inches. The potential for seismically induced lateral spreading of the levee embankment and foundation soils is expected to be low.

- Estimates of levee through seepage are currently within acceptable limits. Estimates of levee under seepage through the foundation soils are in excess of acceptable limits along the western portion of the levee. The potential for uncontrolled under seepage, piping, and/or boiling is judged to be moderate under current conditions. Changes to the channel geometry will affect estimates of levee under seepage. If channel widening or other modifications are proposed, additional seepage evaluation will be necessary to complete the certification of the levee.

- The potential for future loss of freeboard as a result of levee settlement is estimated to be very low.

5.2 RECOMMENDATIONS

5.2.1 Underseepage Mitigation Alterantives

Excessive levee under seepage is anticipated in the area between approximately Borings B-1 and B-7. This condition can be mitigated by one of the following alternatives:

1. Reduce the maximum flood stage elevation from 33.5 to 30.5 feet (NAVD88 datum). This would reduce the maximum vertical exit gradient at the land side toe of the levee within acceptable limits (i.e., 0.3 or lower).

2. Fill the drainage ditch between the land side levee toe and River Road with at least 3 feet of compacted, native, clay or approved import soil. The final surface elevation of the fill should be at least 25 feet (NAVD88 datum). Recommendations for site grading are presented in the Site Preparation and Grading Section of this report.

3. Install a slurry cutoff wall extending through the underlying permeable soils and into a less permeable clay layer (aquitard) encountered at depths ranging from about 41 to 54 feet below the levee crown. The cutoff wall should penetrate at least 5 feet into the aquitard to provide the required seepage mitigation. The cutoff wall could be installed within the levee section or slightly beyond the water side toe. Detailed recommendations for cutoff wall construction can be provided as necessary for final design.

5.2.2 Slope Protection

The exposed waterside and landside levee embankments should be protected to reduce erosion and gullying from either flow in the channel or surface flows due to precipitation. As minimum, all exposed embankments should be planted with deep-rooted vegetation (i.e., grass) suited to the area. Vegetated channel slopes are considered appropriate for velocities of 5 feet per second or less (USACE EM1110-2-1601). Areas where turbulence or high velocity flows are anticipated should be protected by pavement or riprap. The slopes should be inspected periodically for erosion and vegetative cover, and should be repaired immediately if adverse conditions are detected.

5.2.3 Site Preparation and Grading

The following recommendations are applicable to engineered fill placement on and near the subject levee and outfall channel.

Prior to general site grading, existing vegetation, organic topsoil, and any debris should be stripped and disposed of outside the construction limits. We estimate the depth of stripping to be approximately 1 to 3 inches over a majority of the site. Deeper stripping or grubbing may be required where concentrations of organic soils or tree roots are encountered during site grading, or where demolition of existing structures and/or facilities is required. Stripped topsoil (less any debris) may be stockpiled and reused for landscape purposes, however, this material should not be incorporated into any engineered fill.

Following site stripping and any required grubbing and/or over-excavation, we recommend that all areas to receive engineered fill or to be used for the future support of structures or concrete slabs supported-on-grade be scarified to a depth of 8 inches, uniformly moisture-conditioned to between 2 and 5 percent above the optimum moisture content, and compacted to at least 90 percent of the maximum dry density as determined by ASTM (American Society for Testing and Materials) Test Method D 1557[1].

Should site grading be performed during or subsequent to wet weather, near-surface site soils may be significantly above optimum moisture content. Perched groundwater may also develop above less permeable on -site soils, saturating the near-surface materials. These conditions could hamper equipment maneuverability and efforts to compact site soils to the recommended compaction criteria. Disking to aerate, chemical treatment, replacement with drier material, or other methods may be required to reduce excessive soil moisture and facilitate earthwork operations.

5.2.3.1 Engineered Fill Materials

All engineered fill soils should be nearly free of organic or other deleterious debris, essentially non-plastic, and less than 3 inches in maximum dimension. In general, well-graded mixtures of gravel, sand, non-plastic silt, and small quantities of cobbles, rock fragments, and/or clay are acceptable for use as engineered fill. Specific requirements for engineered fill, as well as applicable test procedures to verify material suitability are provided below.

[1] *This test procedure should be used wherever relative compaction, maximum dry density, or optimum moisture content is referenced within this report.*

Table 5.1
Engineered Fill Requirements

Fill Requirement		Test Procedures	
		ASTM[1]	Caltrans[2]
Gradation			
Sieve Size	**Percent Passing**		
3 inch	100	C 136	202
¾ inch	70-100	C 136	202
No. 200	20-85	C 136	202
Plasticity			
Liquid Limit	**Plasticity Index**		
<50	>5 and <25	D 4318	204
Organic Content			
Less than 3%		D2974	---

[1]American Society For Testing and Materials Standards (Latest Edition)
[2]State of California, Department of Transportation, Standard Test Methods (latest edition)

In general, near-surface, on-site clay soils similar to those encountered in our borings may or may not meet the requirements indicated above. All imported fill materials to be used for engineered fill should be sampled and tested by the project Geotechnical Engineer prior to being transported to the site.

5.2.3.2 Compaction Criteria

Soils used for engineered fill should be uniformly moisture-conditioned to between 2 and 5 percent above the optimum moisture content, placed in horizontal lifts less than 8 inches in loose thickness, and compacted to at least 90 percent relative compaction. Disking, cross ripping, and/or blending may be required to uniformly moisture-condition soils used for engineered fill.

6. LIMITATIONS

The conclusions and recommendations contained in this report are based on our field observations and subsurface explorations, limited laboratory tests, and our present knowledge of the levee conditions. It is possible that soil conditions could vary between or beyond the points explored. If soil conditions are encountered which differ from those described herein, we should be notified immediately in order that a review may be made and any supplemental recommendations provided. If further improvements are proposed to the existing levees from that described in this report, our recommendations should also be reviewed.

We have prepared this report in substantial accordance with the generally accepted geotechnical engineering practice as it exists in the site area at the time of our study. No warranty is expressed or implied. The recommendations provided in this report are based on the assumption that an adequate program of tests and observations will be conducted by Kleinfelder during the construction phase in order to evaluate compliance with our recommendations.

This report may be used only by the client and only for the purposes stated, within a reasonable time from its issuance. Land use, site conditions (both on site and off site) or other factors may change over time, and additional work may be required with the passage of time. Any party other than the client who wishes to use this report shall notify Kleinfelder of such intended use. Based on the intended use of the report, Kleinfelder may require that additional work be performed and that an updated report be issued. Non-compliance with any of these requirements by the client or anyone else will release Kleinfelder from any liability resulting from the use of this report by any unauthorized party.

7. REFERENCES

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APPENDIX A

LOGS OF BORINGS

LIST OF ATTACHMENTS

The following plates are attached and complete this appendix.

Plate A-1	Unified Soil Classification System
Plate A-2	Log Key
Plate A-3	Log of Boring B-1
Plate A-4	Log of Boring B-2
Plate A-5	Log of Boring B-3
Plate A-6	Log of Boring B-4
Plate A-7	Log of Boring B-5
Plate A-8	Log of Boring B-6
Plate A-9	Log of Boring B-7
Plate A-10	Log of Boring B-8
Plate A-11	Log of Boring B-9
Plate A-12	Log of Boring B-10
Plate A-13	Log of Boring B-11

APPENDIX B

LABORATORY TESTING

General

Laboratory tests were performed on selected samples to aid in soil classification and to evaluate physical properties of the soils, which may affect the geotechnical aspects of project design and construction. A description of the laboratory testing program is presented below; a summary of all laboratory tests performed is presented on the Summary of Laboratory Tests, Plate B-1.

Moisture Content and Dry Unit Weight

Moisture content and dry unit weight tests were performed to evaluate moisture-conditioning requirements during possible site preparation and earthwork grading; soil overburden, and active and passive earth pressures; and relative soil strength and compressibility. Moisture content was evaluated in general accordance with ASTM Test Method D 2216; dry unit weight was evaluated using procedures similar to ASTM Test Method D 2937. Results of these tests are presented on the logs and are summarized on the Summary of Laboratory Tests.

Atterberg Limits

Atterberg Limits tests were performed to aid in soil classification and to evaluate the plasticity characteristics of the material. Additionally, test results were correlated to published data to evaluate the shrink/swell potential of near-surface site soils. Tests were performed in general accordance with ASTM Test Method D 4318. Results of these tests are presented on the logs and Plate B-2 and are summarized on the Summary of Laboratory Tests.

Sieve Analysis

Sieve analyses were performed to evaluate the gradational characteristics of the material and to aid in soil classification. Tests were performed in general accordance with ASTM Test Method C 136. Results of these tests are presented on the logs and are summarized on the Summary of Laboratory Tests. Also, particle size distributions for some of the samples tested are plotted on Plate B-3.

Organic Content

Total organic content tests were performed on a few soil samples suspected of containing significant quantities of organic material. Tests were performed in general accordance with ASTM D 2974. Results of these tests are presented on the logs and are summarized on the Summary of Laboratory Tests.

Consolidation

Consolidation tests were performed on two relatively undisturbed soil samples obtained in and below the levee fill to evaluate potential settlements under possible additional earth fill loads. Test procedures were in general accordance with ASTM Test Method D 2435. Results of these tests are presented on Plates B-4 and B-5.

Compaction

Two compaction tests were performed on near-surface bulk soil samples to evaluate maximum dry density and optimum moisture content. Test procedures were in general accordance with ASTM Test Method D 1557. Results of these tests are presented on Plates B-6 and B-7.

Triaxial Compression

Unconsolidated-undrained (UU) and Consolidated-undrained (CU) triaxial compression tests were performed on relatively undisturbed samples to evaluate the undrained and drained shear strength of the site soils. Tests were performed in general accordance with the Department of the Army Engineering Manual EM-1110-2-1906, Appendix X. Results of these tests are presented on Plates B-8 through B-13.

LIST OF ATTACHMENTS

The following plates are attached and complete this appendix.

APPENDIX C

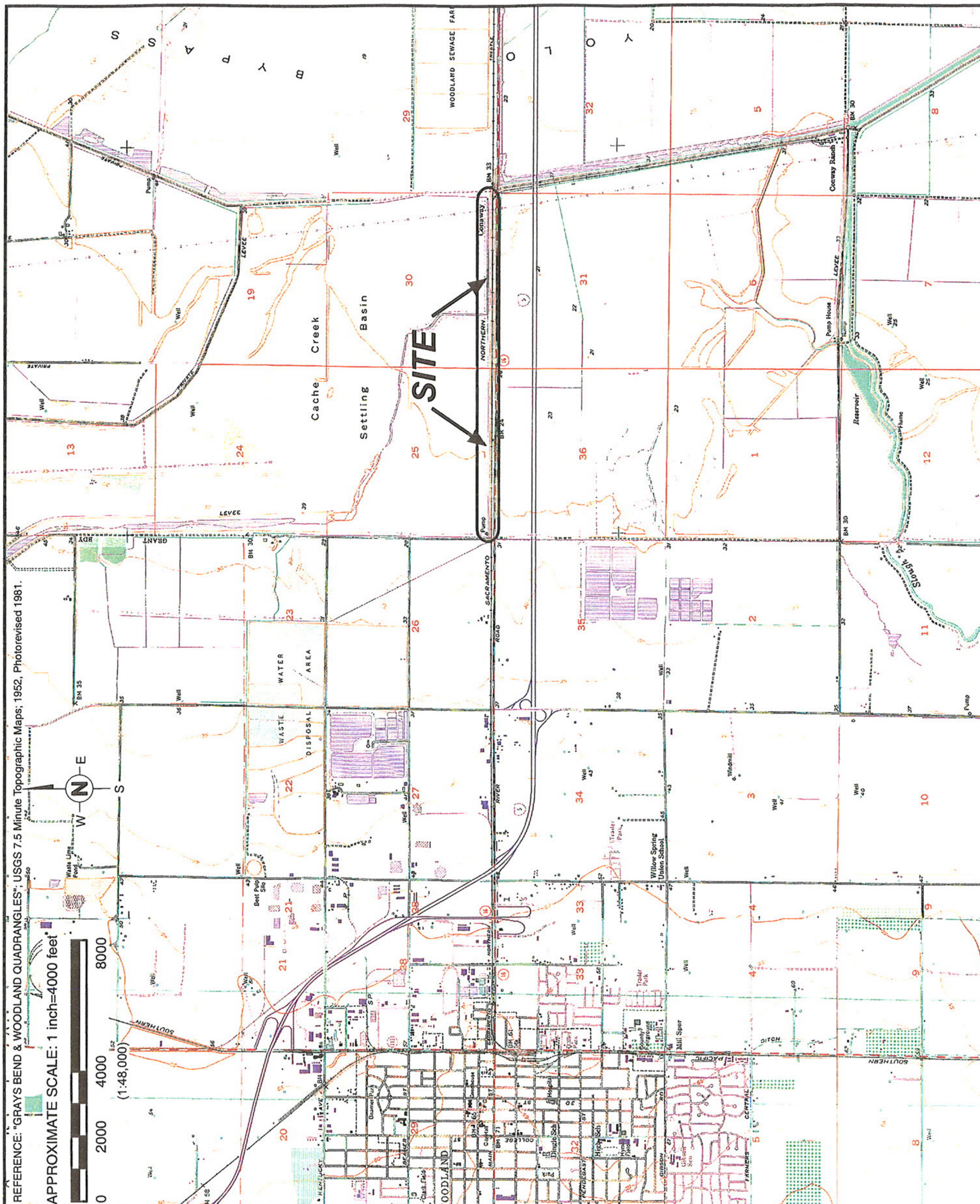
SLOPE STABILITY AND SEEPAGE ANALYSIS RESULTS - COMPUTER PRINTOUTS

The following computer printouts provide the input and output data for slope stability and seepage analyses performed for the Woodland Outfall Levee Certification. Descriptions of the levee configurations, parameter selections, and computer analyses as well as a summary of the computed factors of safety are included earlier in this report.

LIST OF ATTACHMENTS

The following plates are attached and complete this appendix.

APPENDIX A



KLEINFELDER

Graphic By: D. Anderson Project No. 23-485068-001	Date: 9/10/02 Filename: ofall_site.FH10	**SITE LOCATION MAP** CITY OF WOODLAND OUTFALL LEVEE CERTIFICATION YOLO COUNTY, CALIFORNIA

PLATE

1

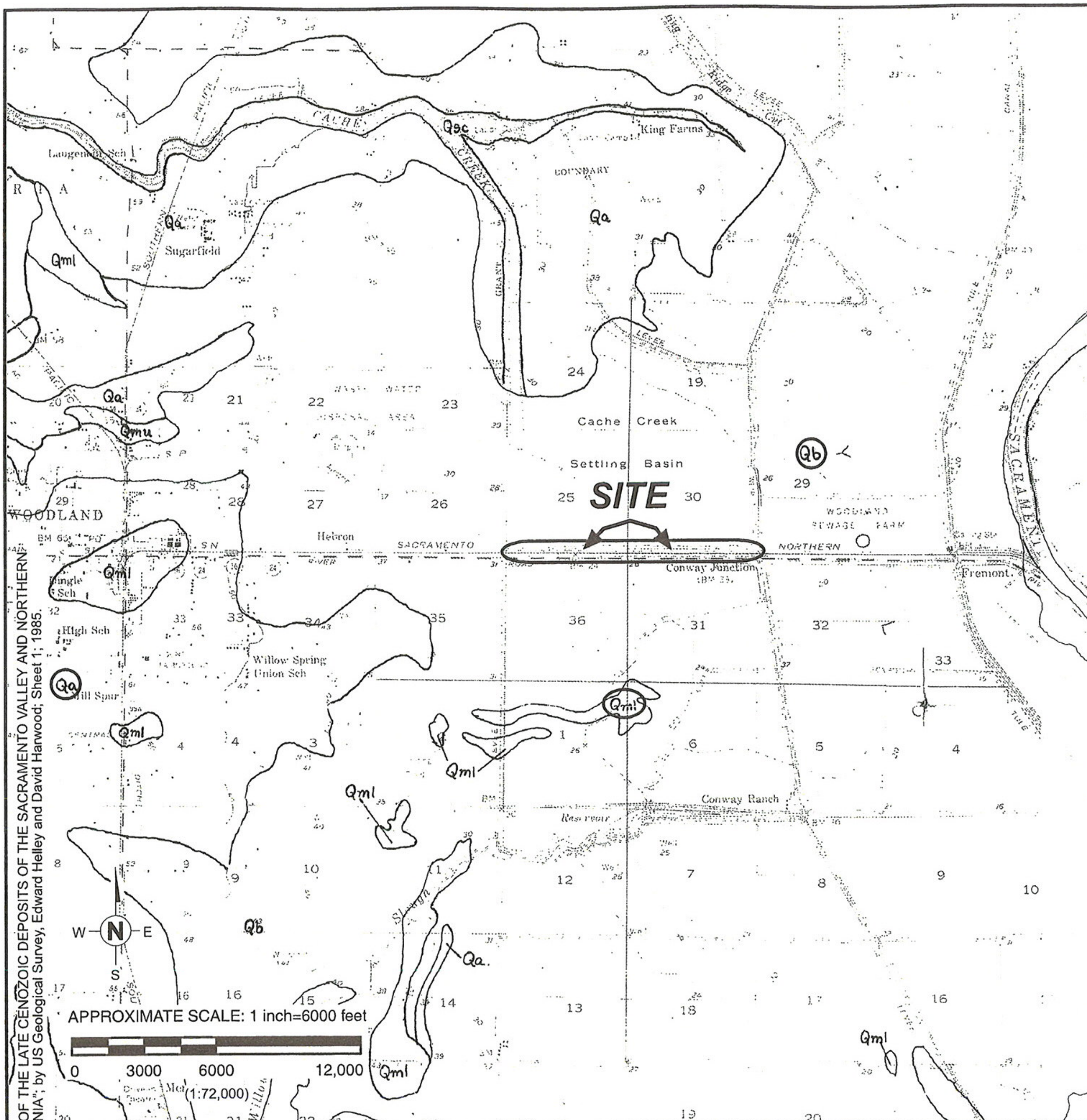
Reference: U.S. Army Corps of Engineers Topographic Survey, Andregg, 1999-2000, elevation datum NAVD88.

LEGEND

B-11 BORING LOCATION

800 0 400 800 1600

APPROXIMATE SCALE: 1 inch = 800 FT.



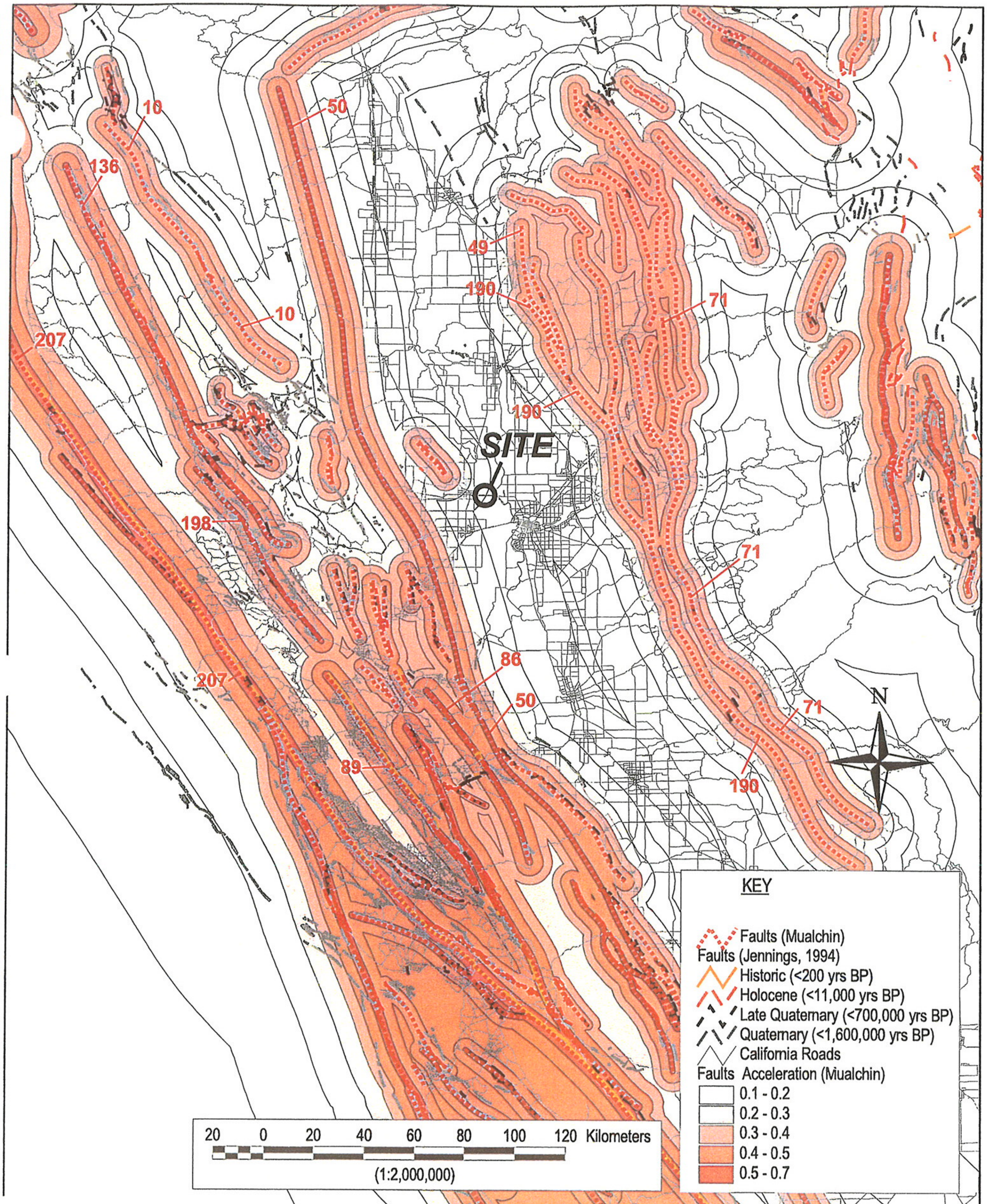
EXPLANATION

Qa - Alluvial Deposits (Holocene) - Unweathered gravel, sand, and silt deposited by present-day streams and river systems that drain the Coast Ranges, Klamath Mountains, and Sierra Nevada.

Qml - Older Alluvial Deposits (Pleistocene) - Modesto Formation - Lower Member - Unconsolidated, slightly weathered gravel, sand, silt, and clay.

Qb - Alluvial Deposits - Basin Deposits, Undivided (Holocene) - Fine grained silt and clay derived from the same sources as modern alluvium.

KLEINFELDER		SITE GEOLOGIC MAP CITY OF WOODLAND OUTFALL LEVEE CERTIFICATION YOLO COUNTY, CALIFORNIA	PLATE 3
Graphic By: D. Anderson Project No. 23-485068	Date: 9/9/02 Filename: ofall_geo.fh10		



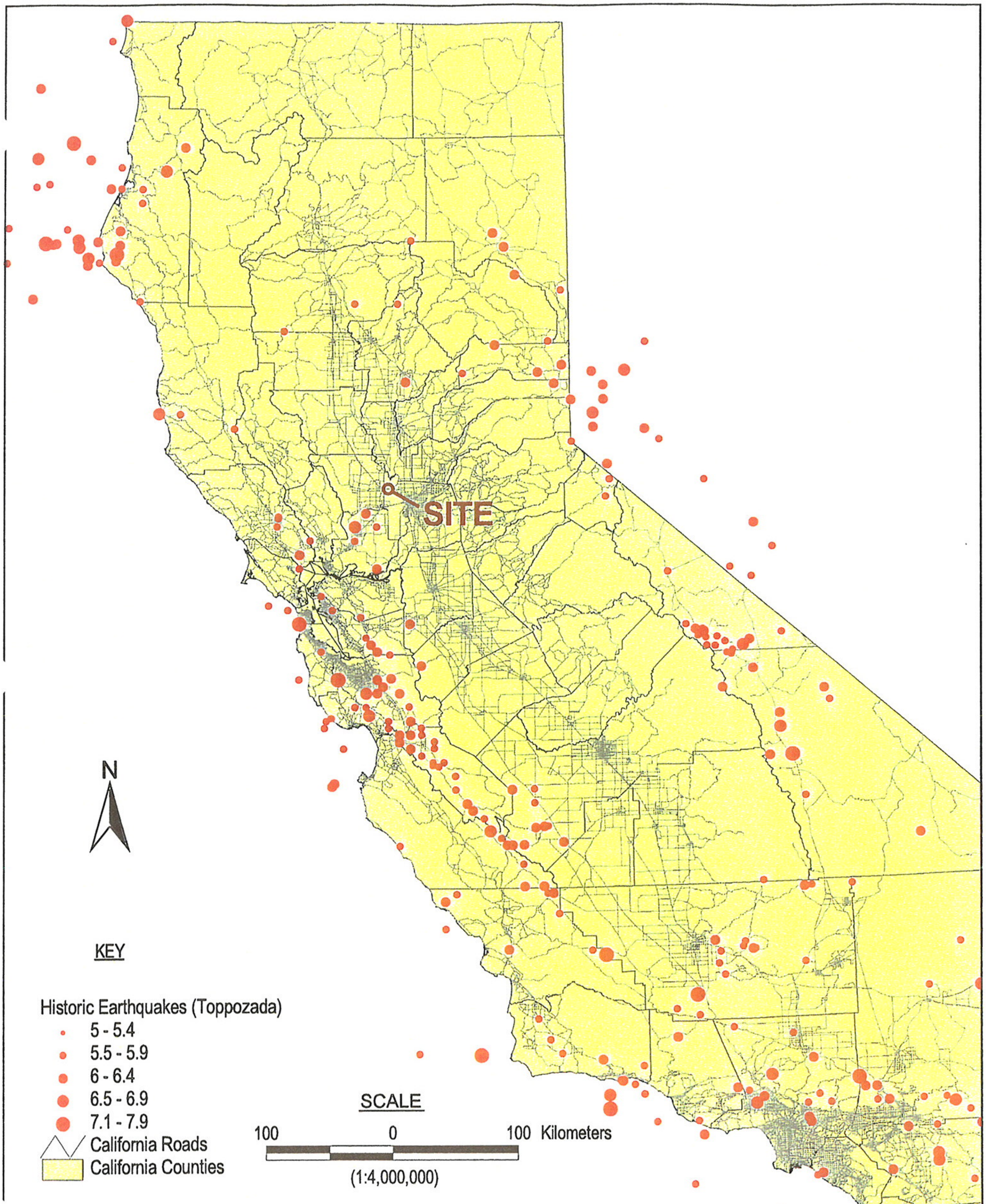
KLEINFELDER

Project No.: 23-485068-001
Graphic By: Dennis Anderson

Date: 9/10/02
File Name:

FAULTS AND SEISMIC GROUND MOTIONS
CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

Plate
4



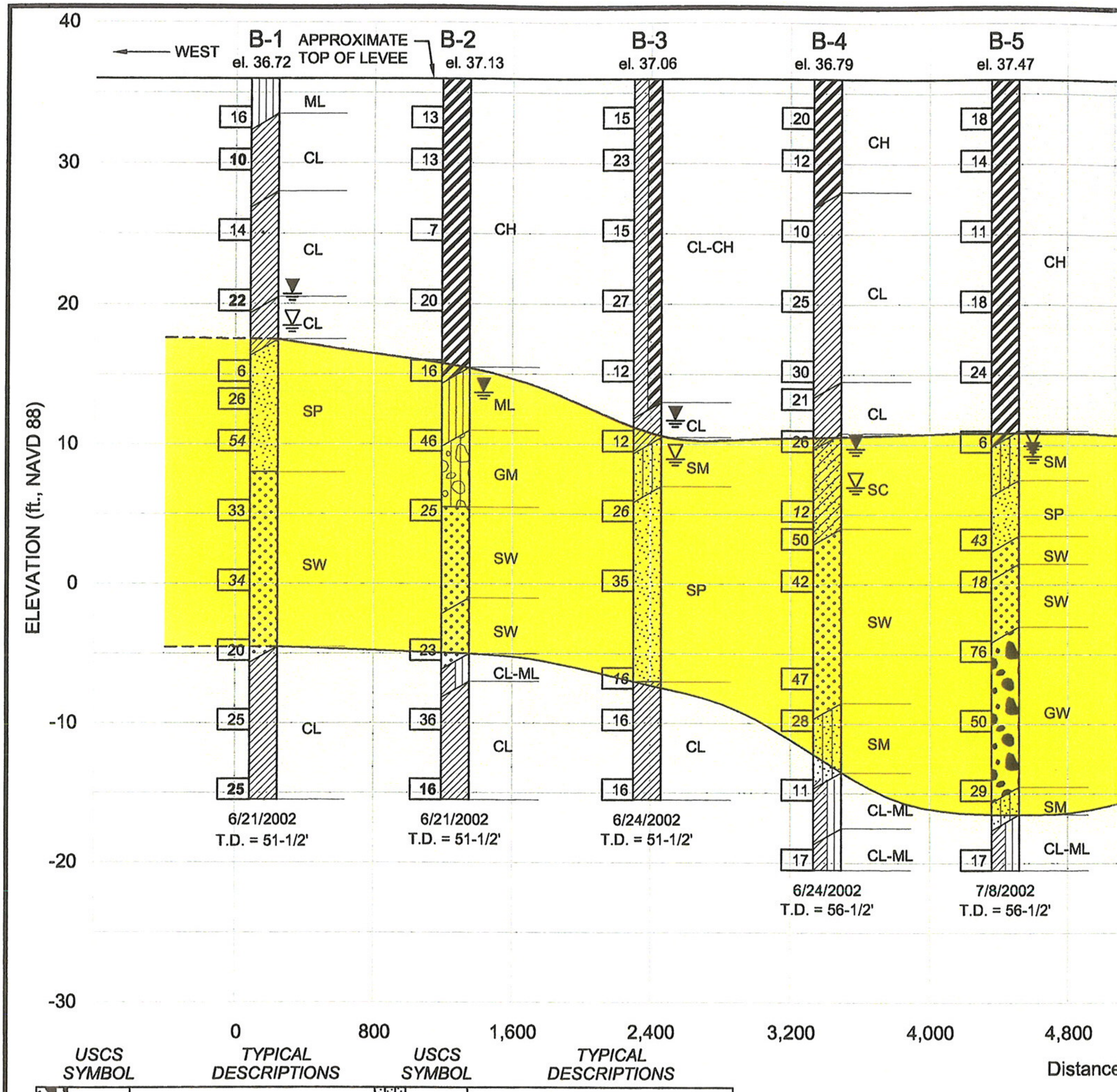
KLEINFELDER

Project No.: 23-485068-001
Graphic By: Dennis Anderson
Date: 9/10/02
File Name:

HISTORIC EARTHQUAKES MAP
CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

Plate
5

KA_ltr_port_std



USCS SYMBOL	TYPICAL DESCRIPTIONS	USCS SYMBOL	TYPICAL DESCRIPTIONS
GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES	SM	SILTY SANDS, SAND-GRAVEL-SILT MIXTURES
GM	SILTY GRAVELS, GRAVEL-SILT-SAND MIXTURES	SC	CLAYEY SANDS, SAND-GRAVEL-CLAY MIXTURES
GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	ML	INORGANIC SILTS & VERY FINE SANDS, SILTY OR CLAYEY FINE SANDS, CLAYEY SILTS WITH SLIGHT PLASTICITY
SW	WELL-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE OR NO FINES	CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
SP	POORLY-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE OR NO FINES	CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS

SAMPLER BLOW COUNT LEGEND

16 — Blows per foot with the California Sampler (3 inch O.D.)

10 — Blows per foot with the Modified California Sampler (2-1/2 inch O.D.)

54 — Blows per foot with the Standard Penetrometer (2 inch O.D.)

(All three samplers advanced using a 140 pound automatic trip hammer with a 30 inch drop)

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			USCS SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS (More than half of material is larger than the #200 sieve)	GRAVELS (More than half of coarse fraction is larger than the #4 sieve)	CLEAN GRAVELS WITH LITTLE OR NO FINES	GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
			GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
		GRAVELS WITH OVER 12% FINES	GM	SILTY GRAVELS, GRAVEL-SILT-SAND MIXTURES
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SANDS (More than half of coarse fraction is smaller than the #4 sieve)	CLEAN SANDS WITH LITTLE OR NO FINES	SW	WELL-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE OR NO FINES
			SP	POORLY-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE OR NO FINES
		SANDS WITH OVER 12% FINES	SM	SILTY SANDS, SAND-GRAVEL-SILT MIXTURES
			SC	CLAYEY SANDS, SAND-GRAVEL-CLAY MIXTURES
FINE GRAINED SOILS (More than half of material is smaller than the #200 sieve)	SILTS AND CLAYS (Liquid limit less than 50)		ML	INORGANIC SILTS & VERY FINE SANDS, SILTY OR CLAYEY FINE SANDS, CLAYEY SILTS WITH SLIGHT PLASTICITY
			CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
			OL	ORGANIC SILTS & ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS (Liquid limit greater than 50)		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILT
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
			OH	ORGANIC CLAYS & ORGANIC SILTS OF MEDIUM-TO-HIGH PLASTICITY
LOAMS				UNDER USDA SOIL CLASSIFICATION SYSTEM, SOIL OF APPROXIMATELY EQUAL SAND/SILT/CLAY

KA-USCS 23485068.GPJ 9/12/02

KLEINFELDER

Drafted By: D. Shelhart
Date: 9/12/2002
Project No.: 23-485068-001
File Number: 23485068

UNIFIED SOIL CLASSIFICATION SYSTEM

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

A-1

LOG SYMBOLS

BULK / BAG SAMPLE	-4	PERCENT FINER THAN THE NO. 4 SIEVE (ASTM Test Method C 136)
MODIFIED CALIFORNIA SAMPLER (2-1/2 inch outside diameter)	-200	PERCENT FINER THAN THE NO. 200 SIEVE (ASTM Test Method C 117)
CALIFORNIA SAMPLER (3 inch outside diameter)	LL	LIQUID LIMIT (ASTM Test Method D 4318)
STANDARD PENETRATION SPLIT SPOON SAMPLER (2 inch outside diameter)	PI	PLASTICITY INDEX (ASTM Test Method D 4318)
CONTINUOUS CORE	TXCU	CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION (EM 1110-1-1906)
SHELBY TUBE	EI	EXPANSION INDEX (UBC STANDARD 18-2)
ROCK CORE	COL	COLLAPSE POTENTIAL
WATER LEVEL (level where first encountered)	UC	UNCONFINED COMPRESSION (ASTM Test Method D 2166)
WATER LEVEL (level after completion)		
SEEPAGE	MC	MOISTURE CONTENT (ASTM Test Method D 2216)

GENERAL NOTES

1. *Lines separating strata on the logs represent approximate boundaries only. Actual transitions may be gradual.*
2. *No warranty is provided as to the continuity of soil conditions between individual sample locations.*
3. *Logs represent general soil conditions observed at the point of exploration on the date indicated.*
4. *In general, Unified Soil Classification System designations presented on the logs were evaluated by visual methods only. Therefore, actual designations (based on laboratory tests) may vary.*

KA-LOG_KEY 23485068.GPJ 9/12/02

KLEINFELDER	LOG KEY CITY OF WOODLAND OUTFALL LEVEE CERTIFICATION YOLO COUNTY, CALIFORNIA	PLATE A-2
Drafted By: D. Shelhart Project No.: 23-485068-001 Date: 9/12/2002 File Number: 23485068		

Surface Conditions:	Gravelly soil on levee crown, some narrow surface cracks, low grasses	Date Completed:	6/21/2002
Groundwater:	Groundwater initally enountered at a depth of approximately 16-1/2 feet below existing site grade and finally at a depth of 15 feet.	Logged By:	D. Stevens
		Total Depth:	51-1/2 feet
Method:	Hollow-Stem Auger	Boring Diameter:	8-inches
Equipment:	CME 85		

Depth (feet)	Elevation (ft., msl)	FIELD: Sample No.	FIELD: Blows/ft	FIELD: Pocket Penetrometer (tsf)	LABORATORY: Dry Density (pcf)	LABORATORY: Moisture Content (%)	LABORATORY: Liquid Limit	LABORATORY: Plasticity Index	LABORATORY: Passing #4 Sieve (%)	LABORATORY: Passing #200 Sieve (%)	LABORATORY: Other Tests	DESCRIPTION (Approximate Elevation 36.72 feet (msl))
	35											**SILT with sand** (ML): Olive-brown, dry, stiff to very stiff, fine sand, low plasticity, trace coarse sand and fine gravel, some clay
		1b	16							74		**Lean CLAY** (CL): Dark brown, moist, very stiff, moderate plasticity, trace organics, trace fine sand
		2b		3.75	91	18						
5	30	2c	10									poor recovery, trace fine gravel, stiff
												Lean CLAY (CL): Dark brown, moist, stiff, trace coarse sand, moderate to high plasticity
10		3b	14	2.5	88	20						olive-brown to dark brown, moderate plasticity
	25	3c					46	26			Atterberg; see Plate B-2	moderate to high plasticity
15		4b	22	3.5								some medium to coase sand
	20	4c										**Gravelly Lean CLAY with sand** (CL): Olive-brown, moist to wet, very stiff, moderate plasticity, fine to coarse gravel to 1-inch diameter, fine to coarse sand
												Poorly Graded SAND with gravel (SP): Gray to gray-brown, wet, loose, fine to coarse sand, fine to coarse gravel to 1-1/2 inch diameter, trace clay, some clay seams
20		None	6									NO RECOVERY
	15											(with sand-catcher in cal. sampler)
		5b	26						92	6	Sieve; see Plate B-3	medium dense
		5c			120	8						
25	10	Bag 6	54						80	5	Sieve; see Plate B-3	very dense, gravel to 2-inch diameter, trace clay seams

KLEINFELDER

Drafted By: D. Shelhart Project No.: 23-485068-001
Date: 10/7/2002 File Number: 23485068

LOG OF BORING B- 1

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE 1 of 2

A-3

SAC 2002 23485068.GPJ 10/7/02

Depth (feet)	Elevation (ft., msl)	Sample Type	Sample No.	Blows/ft	Pocket Penetrometer (tsf)	Dry Density (pcf)	Moisture Content (%)	Liquid Limit	Plasticity Index	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Other Tests	Lithography	DESCRIPTION
														Well Graded SAND with gravel (SW): Gray to gray-brown, wet, medium dense, fine to coarse gravel to 1-1/2 inch diameter, fine to coarse sand, trace clay
30			8b 8c	33						61	0	Sieve; see Plate B-3		
	5													gravel to 2-inch diameter in cuttings
35			Bag 9	34										dense
	0													
40			Bag 10a Bag 10b Bag 10c	20	2.5									with clay
														Lean CLAY (CL): Gray-brown, moist, very stiff, low plasticity, trace fine to medium sand, some moderately cemented silt pieces, mottled
	-5													
45			11c	25	1.75						85			trace fine to medium sand seams
	-10													
50			12b 12c	25	1.25									some fine sand
														low to moderate plasticity
	-15													Boring completed at a depth of approximately 51-1/2 feet below existing site grade.
55														
	-20													
60														

KLEINFELDER

Drafted By: D. Shelhart
Date: 10/7/2002

Project No.: 23-485068-001
File Number: 23485068

LOG OF BORING B-1

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
2 of 2
A-3

SAC 2002 23485068.GPJ 10/7/02

Surface Conditions:	Gravelly soil on levee crown, some narrow surface cracks, low grasses	Date Completed:	6/21/2002
Groundwater:	Groundwater encountered at a depth of approximately 22 feet below existing site grade.	Logged By:	D. Stevens
		Total Depth:	51-1/2 feet
Method:	Hollow-Stem Auger	Boring Diameter:	8-inches
Equipment:	CME 85		

Depth (feet)	Elevation (ft., msl)	Sample No.	Blows/ft	Pocket Penetrometer (tsf)	Dry Density (pcf)	Moisture Content (%)	Liquid Limit	Plasticity Index	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Other Tests	DESCRIPTION (Approximate Elevation 37.13 feet (msl))
0												**Fat CLAY** (CH): Olive-brown to dark brown, dry, stiff, low plasticity, trace organics
	35	1b 1c	13	4.5	104	21				85		with a 2 to 4-inch thick sand and fine gravel layer, moist, moderate plasticity
5		2b 2c	13	3.25			51	35			Atterberg; see Plate B-2 Triaxial UU; see Plate B-8	gray-brown, mottled, low plasticity
	30											
10		3b 3c	7	2.0 0.75	102	25						dark brown, moderate plasticity, medium stiff gray-brown, mottled, trace fine to medium sand, low plasticity
	25											
15		4b 4c	20	2.5						86		olive-brown, very stiff, trace fine sand, low to moderate plasticity, mottled
	20											
20		5b 5c	16	2.0 0.5	101	25						**Sandy SILT** (ML): Olive, moist to wet, stiff to very stiff, low plasticity, fine sand, some clay
	15											
25		6b 6c	46						45	7	Sieve; see Plate B-3	**Silty GRAVEL with sand** (GM): Gray-brown, wet, dense, fine to coarse gravel to 1-inch diameter, fine to coarse sand, approximately 15% fines
	10											

KLEINFELDER

Drafted By: D. Shelhart Project No.: 23-485068-001
Date: 10/7/2002 File Number: 23485068

LOG OF BORING B-2

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
1 of 2
A-4

SAC 2002 23485068.GPJ 10/7/02

Depth (feet)	Elevation (ft., msl)	Sample Type	Sample No.	Blows/ft	Pocket Penetrometer (tsf)	Dry Density (pcf)	Moisture Content (%)	Liquid Limit	Plasticity Index	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Other Tests	DESCRIPTION
		FIELD				LABORATORY							
30													decreasing clay, increasing sand
			Bag 7a Bag 7b	25						94	0	Sieve; see Plate B-3	**Well Graded SAND** (SW): Gray, wet, medium dense, fine to medium sand, some coarse sand, trace fine gravel, trace silt
	5												
35													2-feet of heaving sand in auger, no sample taken
	0												
													Well Graded SAND with gravel (SW): Gray, wet, medium dense, fine to coarse sand, fine to coarse gravel to 2-1/2 inch diameter, trace silt, some clay seams
40													
			8b 8c	23						54	4	Sieve; see Plate B-3	**Gravelly SILTY CLAY with sand** (CL-ML): Gray-brown, wet, very stiff, fine to coarse gravel to 2-inch diameter, fine to coarse sand, low plasticity
	-5												
													Lean CLAY (CL): Gray-brown, moist, very stiff to hard, low to moderate plasticity, mottled
45													
			9b 9c	36	2.25						97		trace moderately cemented silt pieces
	-10												
50													
			10b 10c	16	3.0								trace fine gravel
	-15												Boring completed at a depth of approximately 51-1/2 feet below existing site grade.
55													
	-20												
60													

Lithography

KLEINFELDER

Drafted By: D. Shelhart
Date: 10/7/2002

Project No.: 23-485068-001
File Number: 23485068

LOG OF BORING B-2

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

A-4

SAC 2002 23485068.GPJ 10/7/02

Surface Conditions:	Gravelly soil on levee crown, some narrow surface cracks, low grasses	Date Completed:	6/24/2002
Groundwater:	Groundwater initally enountered at a depth of approximately 26 feet below existing site grade and finally at a depth of 24 feet.	Logged By:	D. Stevens
		Total Depth:	51-1/2 feet
Method:	Hollow-Stem Auger	Boring Diameter:	8-inches
Equipment:	CME 85		

Depth (feet)	Elevation (ft., msl)	Sample No.	FIELD Blows/ft	FIELD Pocket Penetrometer (tsf)	LABORATORY Dry Density (pcf)	LABORATORY Moisture Content (%)	LABORATORY Liquid Limit	LABORATORY Plasticity Index	LABORATORY Passing #4 Sieve (%)	LABORATORY Passing #200 Sieve (%)	LABORATORY Other Tests	DESCRIPTION (Approximate Elevation 37.06 feet (msl))
												Lean/Fat CLAY (CL/CH): Olive-brown, dry, stiff, moderate plasticity, trace organics, mottled
	35	1b	15	>4.5							Organic Content=3.7%	dry to moist, some blocky structure
		1c					50	29			Atterberg; see Plate B-2	
5		2b	23	>4.5								very stiff, moist
	30	2c								83		dark brown, trace fine sand, trace organics
10		3b	15	3.0								olive-brown, decreasing sand
	25	3c		4.5	97	21						dark brown to gray-brown, increasing sand, trace slightly cemented silt pieces
15		4b	27	2.25								gray to gray-brown, mottled, decreasing sand
	20	4c									Triaxial CU; see Plate B-11	
20		5b	12	3.5								dark brown, trace fine gravel, stiff
	15	5c		2.5								gray-brown, mottled, low plasticity, some strongly cemented silt pieces, increasing moisture
												Sandy Lean CLAY (CL): Gray-brown, mottled, moist to wet, stiff, fine sand, low plasticity
25		6b	12									**Silty SAND** (SM): Gray-brown, wet, loose, mottled, fine grained, some clay, high fines content
	10	6c								25		

KLEINFELDER

Drafted By: D. Shelhart Project No.: 23-485068-001
Date: 10/7/2002 File Number: 23485068

LOG OF BORING B-3

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

A-5

SAC 2002 23485068.GPJ 10/7/02

Depth (feet)	Elevation (ft., msl)	Sample Type	Sample No.	Blows/ft	Pocket Penetrometer (tsf)	Dry Density (pcf)	Moisture Content (%)	Liquid Limit	Plasticity Index	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Other Tests	Lithography	DESCRIPTION
30			Bag 7	26						59	6	Sieve; see Plate B-3		**Poorly Graded SAND with gravel** (SP): Gray to gray-brown, wet, medium dense, fine to coarse gravel to 1-1/2 inch diameter, some clay stringers
	5													
35			8b	35										increasing sand, increasing clay
			8c			124	9							
	0													
40														2-feet of heaving sand, no sample taken
	-5		Bag 9a	16						62	5	Sieve; see Plate B-3		
			Bag 9b											**Lean CLAY** (CL): Gray-brown, moist, stiff to very stiff, moderate plasticity, mottled
45				16										
			10c								78			
	-10													
50			11b	16										
			11c		1.5	94	32							
	-15													Boring completed at a depth of approximately 51-1/2 feet below existing site grade.
55														
	-20													
60														

KLEINFELDER

Drafted By: D. Shelhart
Date: 10/7/2002

Project No.: 23-485068-001
File Number: 23485068

LOG OF BORING B-3

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

A-5

SAC 2002 23485068.GPJ 10/7/02

Surface Conditions:	Gravel road on levee crown, sparse grasses, some narrow surface cracks	Date Completed:	6/24/2002
Groundwater:	Groundwater initally encountered at a depth of approximately 28 feet below existing site grade and finally at a depth of 26 feet.	Logged By:	D. Stevens
		Total Depth:	56-1/2 feet
Method:	Hollow-Stem Auger	Boring Diameter:	8-inches
Equipment:	CME 85		

Depth (feet)	Elevation (ft., msl)	Sample No. (FIELD)	Blows/ft (FIELD)	Pocket Penetrometer (tsf) (FIELD)	Dry Density (pcf) (LABORATORY)	Moisture Content (%) (LABORATORY)	Liquid Limit (LABORATORY)	Plasticity Index (LABORATORY)	Passing #4 Sieve (%) (LABORATORY)	Passing #200 Sieve (%) (LABORATORY)	Other Tests (LABORATORY)	DESCRIPTION — Approximate Elevation 36.79 feet (msl)
												Fat CLAY (CH): Olive-brown, dry to moist, very stiff, moderate to high plasticity, trace fine sand
	35											
		1b	20		98	17						
		1c					54	36			Atterberg; see Plate B-2	dark brown, some blocky structure, moist
5												
		2b	12	4.0						87		
	30	2c			99	23						dark brown to gray-brown, mottled, stiff
												Lean CLAY (CL): Dark brown, moist, stiff, moderate plasticity, trace coarse sand and fine gravel
10												
		3b	10	1.25								increasing moisture
	25	3c										gray-brown to dark brown, mottled, trace moderately cemented silt pieces, low to moderate plasticity auger chatter from 12-foot to 13-foot depth, possible concrete rubble, some seepage
15												
		4b	25	2.25						72		trace organics, some fine sand, very stiff, moderate plasticity
	20	4c										
20												
			30									olive-brown, some gravel to 1-inch diameter, some large voids possibly left by concrete rubble, slight lime/cement odor, poor recovery
		5c										
	15											**Lean CLAY** (CL): Light gray with brown mottling, moist, stiff, low plasticity, trace fine sand
		6b	21	1.25								
		6c			111	22						stiff to very stiff
25												
		7b	26									some gravel to 2-inch diameter, slight lime/cement odor
	10	7c							74	23	Sieve; see Plate B-3	**Clayey SAND with gravel** (SC): Gray to gray-brown, wet, medium dense, fine to coarse gravel to 1-inch diameter, fine to coarse sand some interbedded silty clay, increasing sand, decreasing clay

KLEINFELDER

Drafted By: D. Shelhart Project No.: 23-485068-001
Date: 10/7/2002 File Number: 23485068

LOG OF BORING B-4

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE 1 of 2

A-6

SAC 2002 23485068.GPJ 10/7/02

Depth (feet)	Elevation (ft., msl)	Sample Type	Sample No.	Blows/ft	Pocket Penetrometer (tsf)	Dry Density (pcf)	Moisture Content (%)	Liquid Limit	Plasticity Index	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Other Tests	Lithography	DESCRIPTION
			FIELD			LABORATORY								
30	5		None	12										no recovery
			8b 8c	50										**Well Graded SAND with gravel** (SW): Gray to gray-brown, wet, dense, fine to coarse gravel to 2-inch diameter, fine to coarse sand, trace clay
35	0		Bag 9b 9c	42						61	5	Sieve; see Plate B-3		
40	-5													2-feet of heaving sand, no sample taken
			Bag 10b	47										gravel to 2-1/2 inch diameter
45	-10		11b 11c	28		104	24				51			**Silty SAND** (SM): Gray-brown, wet, medium dense, fine grained
														some silt seams
														trace fine gravel
50	-15		12b 12c	11	1.5						92			**Silty CLAY** (CL): Gray-brown, moist, stiff, low plasticity, mottled, trace fine sand
														Silty CLAY with sand (CL/ML): Gray-brown, moist, mottled, stiff to very stiff, low plasticity, fine sand
55	-20		13b 13c	17	1.25									increasing silt
														Boring completed at a depth of approximately 56-1/2 feet below existing site grade.
60	-25													

KLEINFELDER

Drafted By: D. Shelhart Project No.: 23-485068-001
Date: 10/7/2002 File Number: 23485068

LOG OF BORING B-4

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
2 of 2
A-6

SAC 2002 23485068.GPJ 10/7/02

Surface Conditions:	Sand and gravel road on levee crown, some cracking on crown and North-slope surfaces	Date Completed:	7/8/2002
Groundwater:	Groundwater initally enountered at a depth of approximately 25 feet below existing site grade and finally at a depth of 26-1/2 feet.	Logged By:	D. Stevens
		Total Depth:	56-1/2 feet
Method:	Hollow-Stem Auger	Boring Diameter:	8-inches
Equipment:	CME 85		

Depth (feet)	Elevation (ft., msl)	FIELD: Sample Type	FIELD: Sample No.	FIELD: Blows/ft	FIELD: Pocket Penetrometer (tsf)	LABORATORY: Dry Density (pcf)	LABORATORY: Moisture Content (%)	LABORATORY: Liquid Limit	LABORATORY: Plasticity Index	LABORATORY: Passing #4 Sieve (%)	LABORATORY: Passing #200 Sieve (%)	LABORATORY: Other Tests	Lithography	DESCRIPTION — Approximate Elevation 37.47 feet (msl)
			Bulk 1									Compaction; see Plate B-6		**Fat CLAY** (CH): Olive-brown, dry, very stiff, moderate plasticity, trace fine sand
	35		1b 1c	18	>4.5	103	16				80			moist, some blocky structure
5			2b 2c	14	3.5									some dry, cracked areas in samples dark brown to dark gray, increasing sand, slight organic odor, stiff
	30													
10			3b 3c	11	3.25			55	40			Atterberg; see Plate B-2 Consolidation; see Plate B-4		dark brown, decreasing sand, mottled, more uniform structure, low to moderate plasticity
	25													
15			4b 4c	18	2.25						84			brown to gray, mottled, low plasticity, very stiff trace organics
	20													
20			5b 5c	24	2.75	110	21							dark brown to dark gray, mottled, trace fine gravel, moderate plasticity brown to gray, mottled
	15													
25														olive-brown
			Bag 6	6							42	Sieve; see Plate B-3		**Silty SAND** (SM): Olive-brown, wet, loose, fine grained
	10													**Poorly Graded SAND** (SP): Gray-brown, wet,

Depth (feet)	Elevation (ft., msl)	Sample No.	Blows/ft	Pocket Penetrometer (tsf)	Dry Density (pcf)	Moisture Content (%)	Liquid Limit	Plasticity Index	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Other Tests	DESCRIPTION
30												medium dense, fine to medium grained, trace silt
												2-1/2 feet of heaving sand, no sample taken
	5	Bag 7a Bag 7b	43							20		
												Well Graded SAND with gravel (SW): Gray-brown, wet, dense, fine to coarse sand, gravel to 3/4-inch diameter, trace silt, trace clay seams
35												**Well Graded SAND with gravel** (SW): Gray-brown, wet, medium dense, fine to coarse gravel to 1-1/2 inch diameter, fine to coarse sand, trace silt
		Bag 8	18						63	4	Sieve; see Plate B-3	
	0											
40												**Well Graded GRAVEL with sand** (GW): Gray-brown, wet, very dense, gravel to 3-inch diameter, some cobbles to 4-inch diameter
		Bag 9	76									some clay seams, poor recovery
	-5											
45												gravel to 1-1/2 inch diameter, trace clay seams, dense
		Bag 10b Bag 10c	50						45	4	Sieve; see Plate B-3	
	-10											stiffened up
50												**Silty SAND** (SM): Olive-brown, wet, medium dense, fine grained
		11b 11c	29							44		
	-15											**Silty CLAY** (CL-ML): Yellow-brown to light gray, mottled, moist, stiff, low plasticity, trace fine sand
55												some fine sand lenses, trace fine gravel
		12b 12c	17	1.5								
	-20											Boring completed at a depth of approximately 56-1/2 feet below existing site grade.
60												
	-25											

KLEINFELDER

Drafted By: D. Shelhart
Date: 10/7/2002

Project No.: 23-485068-001
File Number: 23485068

LOG OF BORING B- 5

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

A-7

SAC 2002 23485068.GPJ 10/7/02

Surface Conditions:	Sand and gravel road on levee crown, some surface cracks on N. slope	Date Completed:	7/8/2002
Groundwater:	Groundwater initally encountered at a depth of approximately 26 feet below existing site grade and finally at a depth of 25-1/2 feet.	Logged By:	D. Stevens
		Total Depth:	56-1/2 feet
Method:	Hollow-Stem Auger	Boring Diameter:	8-inches
Equipment:	CME 85		

Depth (feet)	Elevation (ft., msl)	Sample Type	FIELD: Sample No.	FIELD: Blows/ft	FIELD: Pocket Penetrometer (tsf)	LABORATORY: Dry Density (pcf)	LABORATORY: Moisture Content (%)	LABORATORY: Liquid Limit	LABORATORY: Plasticity Index	LABORATORY: Passing #4 Sieve (%)	LABORATORY: Passing #200 Sieve (%)	LABORATORY: Other Tests	Lithography	DESCRIPTION Approximate Elevation 37.34 feet (msl)
														Gravelly Lean CLAY with sand (CL): Olive-brown, dry, very stiff, fine to coarse sand, fine to coarse gravel to 1-1/4 inch diameter, moderate plasticity
	35		1b 1c	24	>4.5									**Lean CLAY** (CL): Dark brown, moist, very stiff, trace strongly cemented pieces, trace fine sand, moderate plasticity, some blocky structure
5			2b 2c	20	2.75						97			some interbedded fine gravel trace organics, blocky structure continued
	30													
10			3b 3c	10	4.0 1.75	98	26							stiff, some cracks in samples more uniform structure, olive-brown, low to moderate plasticity, mottled auger chatter from 12 to 13-1/2 foot depth, possibly on gravel or concrete rubble
	25													
15			4c	19										poor recovery, very stiff, moderate plasticity, dark brown, large angular void possibly from concrete rubble, trace pieces of concrete
	20													**Lean CLAY** (CL): Olive-brown, mottled, moist, very stiff, moderate to high plasticity, trace fine sand
20			5b 5c	27	2.75			47	33			Atterberg; see Plate B-2 Triaxial CU; see Plate B-12		trace fine gravel to 3/4-inch diameter gray-brown to brown, mottled
	15													
25			6b 6c	18	1.5						44			some fine to medium sand and fine gravel, olive-brown **Clayey SAND** (SC): Gray-brown, wet, medium dense, fine to medium grained, some fine gravel
	10													

SAC 2002 23485068.GPJ 10/7/02

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Drafted By: D. Shelhart Project No.: 23-485068-001
Date: 10/7/2002 File Number: 23485068

LOG OF BORING B- 6

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
1 of 2
A-8

Depth (feet)	Elevation (ft., msl)	Sample Type	Sample No.	Blows/ft	Pocket Penetrometer (tsf)	Dry Density (pcf)	Moisture Content (%)	Liquid Limit	Plasticity Index	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Other Tests	DESCRIPTION
30													**Poorly Graded SAND** (SP): Gray, wet, medium dense, medium to coarse grained, trace clay seams
			7b 7c	29						63	4	Sieve; see Plate B-3	**Well Graded SAND with gravel** (SW): Gray-brown, wet, medium dense, fine to coarse gravel to 1-1/2 inch diameter, fine to coarse sand
	5												
35			Bag 8	58									very dense, decreasing clay, gravel to 1-inch diameter
	0												
40			9c	20		122	8						gravel to 1-1/2 inch diameter, medium dense increasing clay
	-5												**Well Graded GRAVEL with sand** (GW): Gray-brown, wet, dense, fine to coarse gravel, fine to coarse sand
45			10c	53						48	3	Sieve; see Plate B-3	dense, decreasing clay
	-10												
50			11b 11c	14	1.0						85		**SILT** (ML): Brown to gray-brown, moist, stiff, mottled, low plasticity, some clay, some fine sand decreasing sand
	-15												**Lean CLAY** (CL): Brown to light gray, moist, hard, mottled, low plasticity, trace fine sand
55			12b 12c	34	2.5 3.0								yellow-brown, mottled Boring completed at a depth of approximately 56-1/2 feet below existing site grade.
	-20												
60													
	-25												

KLEINFELDER

LOG OF BORING B-6

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

A-8

Drafted By: D. Shelhart
Date: 10/7/2002
Project No.: 23-485068-001
File Number: 23485068

SAC 2002 23485068.GPJ 10/7/02

Surface Conditions:	Gravel road on levee crown, scattered grasses, slight cracking on crown and north slope	Date Completed:	6/25/2002
Groundwater:	Groundwater encountered at a depth of approximately 26 feet below existing site grade.	Logged By:	D. Stevens
Method:	Hollow-Stem Auger	Total Depth:	56-1/2 feet
Equipment:	CME 85	Boring Diameter:	8-inches

Depth (feet)	Elevation (ft., msl)	FIELD: Sample Type	FIELD: Sample No.	FIELD: Blows/ft	FIELD: Pocket Penetrometer (tsf)	LABORATORY: Dry Density (pcf)	LABORATORY: Moisture Content (%)	LABORATORY: Liquid Limit	LABORATORY: Plasticity Index	LABORATORY: Passing #4 Sieve (%)	LABORATORY: Passing #200 Sieve (%)	Other Tests	Lithography	DESCRIPTION — Approximate Elevation 37.21 feet (msl)
														Lean/Fat CLAY (CL/CH): Dark brown, dry to moist, stiff, moderate to high plasticity, trace fine sand
	35		1b 1c	13	>4.5	91	18				94			moist, some blocky structure olive-brown, moderate plasticity, increasing sand, trace moderately cemented silt pieces
5			2b 2c	13	3.0									dry to moist, trace gravel to 1-inch diameter, blocky structure continued olive-brown to dark brown, moist, moderate to high plasticity
	30													**Lean CLAY** (CL): Gray-brown, mottled, moist, stiff, low to moderate plasticity, trace fine sand, trace strongly cemented silt pieces
10			3b 3c	12	2.5 1.0							Triaxial CU; see Plate B-13		dark brown, uniform structure olive-brown increasing moisture, dark brown, moderate plasticity
	25													
15			4b 4c	17	2.25						88	Sieve; see Plate B-3 Organic Content=3.2%		trace fine gravel, very stiff dark gray, trace organics
	20													
20			5b 5c	24	2.75	110	21							gray-brown to olive brown, mottled
	15													
25			6b 6c	11								▼		gray-brown, low plasticity, stiff, sampler was wet on the outside
	10													

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Drafted By: D. Shelhart Project No.: 23-485068-001
Date: 10/7/2002 File Number: 23485068

LOG OF BORING B- 7

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

Depth (feet)	Elevation (ft., msl)	Sample No.	Blows/ft	Pocket Penetrometer (tsf)	Dry Density (pcf)	Moisture Content (%)	Liquid Limit	Plasticity Index	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Other Tests	Description
30		7b 7c	32	2.0						94	Consolidation; see Plate B-5	low to moderate plasticity, very stiff to hard, trace moderately cemented silt pieces some fine sand, with silt, mottled, trace coarse sand
	5											
35		8b 8c	31	2.5								interbedded fine sand lenses, trace coarse sand, trace strongly cemented silt pieces **Silty CLAY** (CL/ML): Light gray with brown mottling, moist, very stiff to hard, low plasticity, trace fine sand, some strongly cemented silt pieces
	0											
40		9b 9c	17	1.5 2.0	101	26						stiff to very stiff, increasing silt, some interbedded fine sand lenses **CLAY with sand** (CL): Light gray-brown, mottled, moist, very stiff, low plasticity, fine sand
	-5											
45		10b 10c	22	3.0			36	14		83	Atterberg; see Plate B-2	gray-brown, some moderately cemented silt pieces, decreasing sand increasing sand
	-10											**Silty SAND** (SM): Olive-brown, wet, medium dense, fine grained, trace clay seams, trace strongly cemented silt pieces
50		11b 11c	35							25		**Poorly Graded SAND** (SP): Olive-brown, wet, medium dense, fine grained, trace silt
	-15											**Lean CLAY** (CL): Gray-brown to brown, mottled, moist, very stiff, low plasticity, trace fine sand
55		12b 12c	20	2.5								Boring completed at a depth of approximately 56-1/2 feet below existing site grade.
	-20											
60												
	-25											

SAC 2002 23485068.GPJ 10/7/02

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Drafted By: D. Shelhart Project No.: 23-485068-001
Date: 10/7/2002 File Number: 23485068

LOG OF BORING B-7

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
2 of 2
A-9

Surface Conditions:	Sand and gravel road on levee crown, some surface cracks, sparse vegetation	Date Completed:	7/9/2002
Groundwater:	Groundwater initally enountered at a depth of approximately 38 feet below existing site grade and finally at a depth of 27 feet.	Logged By:	D. Stevens
Method:	Hollow-Stem Auger	Total Depth:	51-1/2 feet
Equipment:	CME 85	Boring Diameter:	8-inches

Depth (feet)	Elevation (ft., msl)	Sample Type	FIELD: Sample No.	FIELD: Blows/ft	FIELD: Pocket Penetrometer (tsf)	LABORATORY: Dry Density (pcf)	LABORATORY: Moisture Content (%)	LABORATORY: Liquid Limit	LABORATORY: Plasticity Index	LABORATORY: Passing #4 Sieve (%)	LABORATORY: Passing #200 Sieve (%)	LABORATORY: Other Tests	Lithography	DESCRIPTION — Approximate Elevation 36.55 feet (msl)
	35													**Lean CLAY** (CL): Dark brown, dry, stiff, moderate plasticity, trace fine sand
			1b 1c	15				48	29			Atterberg; see Plate B-2		moist, trace fine gravel, blocky structure, mottled
5	30		2b 2c	17		83	20							very stiff, blocky structure continued
10	25		3b 3c	11	>4.5 1.75						92			stiff, olive-brown, mottled dark brown, mottled, more uniform structure a little auger chatter at 12-foot depth
15	20		4b 4c	13	2.0									dark gray mottled trace fine to medium sand and fine to coarse gravel lenses
20	15		Bag 5	20										gray-brown, mottled, low to medium plasticity, very stiff
25	10		6b 6c	22	3.0									olive-brown, motled, moderate plasticity
												▼		**Sandy Lean CLAY** (CL): Brown, mottled, moist, very stiff, fine sand, low plasticity

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Drafted By: D. Shelhart
Date: 10/7/2002
Project No.: 23-485068-001
File Number: 23485068

LOG OF BORING B- 8

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
1 of 2
A-10

Depth (feet)	Elevation (ft., msl)	Sample Type	Sample No.	Blows/ft	Pocket Penetrometer (tsf)	Dry Density (pcf)	Moisture Content (%)	Liquid Limit	Plasticity Index	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Other Tests	Lithography	DESCRIPTION
30	5	■	Bag 7	23							70			increasing moisture
														Silty CLAY (CL-ML): Brown to gray-brown, mottled, moist, stiff to very stiff, fine sand, low plasticity
35	0	■	8b 8c	19	1.5	97	27							some strongly cemented silt pieces
												▽		
														Lean CLAY with sand (CL): Brown to gray-brown, mottled, moist, very stiff, low plasticity, fine sand, trace coarse gravel to 2-1/2 inch diameter
40	-5	■	9b 9c	19	2.25									
														SILT with sand (ML): Brown to gray-brown, mottled, moist to wet, very stiff, low plasticity, interbedded fine sand lenses
45	-10	■	10b 10c	18	1.75						15			trace moderately cemented pieces
														increasing fine sand lenses
50	-15	■	11b 11c	19	2.0									**SILT** (ML): Gray-brown to brown, mottled, moist, very stiff, low plasticity, trace fine sand, some clay
														Boring completed at a depth of approximately 51-1/2 feet below existing site grade.
55	-20													
60														

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LOG OF BORING B- 8

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
2 of 2
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Drafted By: D. Shelhart
Date: 10/7/2002
Project No.: 23-485068-001
File Number: 23485068

SAC 2002 23485068.GPJ 10/7/02

Surface Conditions:	Gravel road on levee crown, sparse grasses, some narrow surface cracks, larger cracks on north levee slope	Date Completed:	6/25/2002
Groundwater:	Groundwater initally enountered at a depth of approximately 28 feet below existing site grade and finally at a depth of 18-1/2 feet.	Logged By:	D. Stevens
		Total Depth:	41-1/2 feet
Method:	Hollow-Stem Auger	Boring Diameter:	8-inches
Equipment:	CME 85		

Depth (feet)	Elevation (ft., msl)	Sample Type	Sample No. (FIELD)	Blows/ft (FIELD)	Pocket Penetrometer (tsf) (FIELD)	Dry Density (pcf) (LABORATORY)	Moisture Content (%)	Liquid Limit	Plasticity Index	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Other Tests	Lithography	DESCRIPTION Approximate Elevation 36.58 feet (msl)
	35		Bulk 1									Compaction; see Plate B-7		**Lean CLAY** (CL): Olive-brown, dry, stiff, moderate to high plasticity, trace fine sand, trace gravel
			2b 2c	10		87	15	44	18			Atterberg; see Plate B-2		moist, some blocky structure, dark brown
5	30		3b 3c	19	3.5									continued blocky structure, very stiff
10	25		4b 4c	16	>4.5							Triaxial UU; see Plate B-9		more uniform structure, trace moderately cemented silt pieces olive-brown to dark brown auger chatter from 12-foot to 14-foot depth, very difficult drilling with cobbles and concrete rubble, 5-inch diameter cobble lodged in bit as observed when pulled augers to change bit teeth
15	20		5c	22										poor recovery, slight lime/cement odor, large angular void on bottom of sample possibly from concrete rubble
20	15		Bag 6b 6c	25	4.0						62			olive-brown, some concrete rubble pieces and associated voids from sampling
25	10		Bag 7	41										poor recovery, hard, some concrete rubble pieces

SAC 2002 23485068.GPJ 10/7/02

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Drafted By: D. Shelhart
Date: 10/7/2002

Project No.: 23-485068-001
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LOG OF BORING B-9

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
1 of 2
A-11

Depth (feet)	Elevation (ft., msl)	Sample Type	Sample No.	Blows/ft	Pocket Penetrometer (tsf)	Dry Density (pcf)	Moisture Content (%)	Liquid Limit	Plasticity Index	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Other Tests	Lithography	DESCRIPTION
	5		Bag 8	37										poor recovery, some free water on sampler
			9b 9c	19	2.0									**Lean CLAY** (CL): Gray-brown, mottled, moist, very stiff, low plasticity, trace fine sand, trace interbedded fine sand lenses, trace cemented silt pieces
35	0		10b 10c	30	2.5	138	26				86			low to moderate plasticity
40	-5		11b 11c	30	2.5									
														Boring completed at a depth of approximately 41-1/2 feet below existing site grade.

Depth scale: 30, 35, 40, 45, 50, 55, 60. Elevation scale: 5, 0, -5, -10, -15, -20.

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Drafted By: D. Shelhart
Date: 10/7/2002
Project No.: 23-485068-001
File Number: 23485068

LOG OF BORING B- 9

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

A-11

SAC 2002 23485068.GPJ 10/7/02

Surface Conditions:	Sand and gravel road on levee crown, some surface cracks, sparse vegetation	Date Completed:	7/9/2002
Groundwater:	Groundwater initally enountered at a depth of approximately 43 feet below existing site grade and finally at a depth of 30 feet.	Logged By:	D. Stevens
Method:	Hollow-Stem Auger	Total Depth:	51-1/2 feet
Equipment:	CME 85	Boring Diameter:	8-inches

Depth (feet)	Elevation (ft., msl)	Sample Type	Sample No. (FIELD)	Blows/ft (FIELD)	Pocket Penetrometer (tsf) (FIELD)	Dry Density (pcf) (LABORATORY)	Moisture Content (%)	Liquid Limit	Plasticity Index	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Other Tests	Lithography	DESCRIPTION — Approximate Elevation 36.64 feet (msl)
	35													**Lean/Fat CLAY** (CL/CH): Olive-brown to dark brown, dry, stiff, moderate plasticity, trace fine sand, trace organics
			1b 1c	10							95			dry to moist blocky structure, moist
5	30		2b 2c	16				50	32			Atterberg; see Plate B-2		very stiff, blocky structure continued, mottled
10	25		3b 3c	11	2.0	81	32							stiff, more uniform structure, trace rootlets some auger chatter between 12 and 13-foot depth
15	20		4b 4c	16	2.5							Organic Content=2.9%		very stiff, dark brown to dark gray some organics
20	15		5b 5c	20	2.5	101	21				79			gray-brown to olive-brown, mottled
25	10		6b 6c	21	3.75									brown to olive-brown, mottled

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Drafted By: D. Shelhart Project No.: 23-485068-001
Date: 10/7/2002 File Number: 23485068

LOG OF BORING B-10

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

A-12

Depth (feet)	Elevation (ft., msl)	Sample No.	Blows/ft	Pocket Penetrometer (tsf)	Dry Density (pcf)	Moisture Content (%)	Liquid Limit	Plasticity Index	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Other Tests	Description
30	5	7b 7c	30	>4.5								brown, mottled, trace fine sand; trace strongly cemented silt pieces
35	0	8b 8c	33	4.5								hard
												SILT (ML): Brown to light gray, mottled, moist, stiff to very stiff, trace fine sand, low plasticity, some clay
40	-5	9b 9c	19	1.0	102	22				61		some interbedded fine sand, increasing moisture
45	-10	10b 10c	12	1.25								stiff, water on sampler
												Silty CLAY (CL-ML): Brown to light gray, mottled, moist, stiff, low plasticity
50	-15	11b 11c	28	1.25 2.5								very stiff
												Boring completed at a depth of approximately 51-1/2 feet below existing site grade.
55	-20											
60												

KLEINFELDER

Drafted By: D. Shelhart
Date: 10/7/2002
Project No.: 23-485068-001
File Number: 23485068

LOG OF BORING B-10

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
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A-12

SAC 2002 23485068.GPJ 10/7/02

Surface Conditions:	Gravel road on levee crown, scattered grasses, some cracking on north slope	Date Completed:	6/25/2002
Groundwater:	Groundwater initally enountered at a depth of approximately 29-1/2 feet below existing site grade and finally at a depth of 26 feet.	Logged By:	D. Stevens
Method:	Hollow-Stem Auger	Total Depth:	51-1/2 feet
Equipment:	CME 85	Boring Diameter:	8-inches

Depth (feet)	Elevation (ft., msl)	Sample Type	FIELD: Sample No.	FIELD: Blows/ft	FIELD: Pocket Penetrometer (tsf)	LABORATORY: Dry Density (pcf)	LABORATORY: Moisture Content (%)	LABORATORY: Liquid Limit	LABORATORY: Plasticity Index	LABORATORY: Passing #4 Sieve (%) Passing #200 Sieve (%)	LABORATORY: Other Tests	Lithography	DESCRIPTION Approximate Elevation 36.38 feet (msl)
	35												**Lean CLAY** (CL): Olive-brown, dry, stiff, moderate plasticity, trace fine sand
			1b 1c	11	3.5	89	24						moist, mottled, some blocky structure, dark brown
5	30		2b 2c	10	2.0					93	Sieve; see Plate B-3		trace fine gravel, continued blocky structure
10	25		3b 3c	11	2.5						Triaxial UU; see Plate B-10		more uniform structure olive-brown
													slight auger chatter, possible concrete rubble
15	20		4b 4c	11	1.0					99			trace fine sand seams gray, low to moderate plasticity, trace organics
20	15		5b 5c	19	2.0								very stiff, moderate plasticity, trace cemented silt pieces
25	10		6b 6c	24	2.5	106	20				▼		gray-brown, mottled increasing moisture

Depth (feet)	Elevation (ft., msl)	Sample Type	Sample No.	Blows/ft	Pocket Penetrometer (tsf)	Dry Density (pcf)	Moisture Content (%)	Liquid Limit	Plasticity Index	Passing #4 Sieve (%)	Passing #200 Sieve (%)	Other Tests	Description
30													
	5		7b 7c	19	3.0								brown to gray-brown, mottled, some silt, low plasticity some interbedded clayey fine sand
													Lean CLAY with sand (CL): Gray-brown with brown mottling, moist, very stiff, fine sand, low plasticity
35	0		8b 8c	24	1.75								trace fine gravel
40	-5		9b 9c	19	 1.75						56		with silt, light gray to brown, some interbedded fine sand seams, trace cemented silt pieces
													Silty CLAY (CL/ML): Light gray with brown mottling, moist, stiff, low plasticity, trace fine sand
45	-10		Bag 10b Bag 10c	8									trace strongly cemented silt pieces with a 4-inch thick silty fine sand layer
													Lean CLAY (CL): Gray-brown, mottled, moist, hard, low plasticity, trace fine sand
50	-15		11b 11c	40	4.0								
													Boring completed at a depth of approximately 51-1/2 feet below existing site grade.
55	-20												
60													

KLEINFELDER

Drafted By: D. Shelhart Project No.: 23-485068-001
Date: 10/7/2002 File Number: 23485068

LOG OF BORING B-11

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

A-13

SAC 2002 23485068.GPJ 10/7/02

APPENDIX B

BORING NO.	SAMPLE DEPTH (ft)	DRY UNIT WEIGHT (pcf)	MOISTURE CONTENT (% of dry weight)	PARTICLE SIZE SIEVE SIZE (percent passing)						ATTERBERG LIMITS		OTHER TESTS
				3"	3/4"	#4	#10	#40	#200	L.L.	P.I.	
B- 1	2.5								74			
B- 1	3.0	91	18									
B- 1	10.5	88	20									
B- 1	11.0									46	26	Atterberg; see Plate B-2
B- 1	22.5				97	92	80	22	6			Sieve; see Plate B-3
B- 1	23.0	120	8									
B- 1	25.0				97	80	55	16	5			Sieve; see Plate B-3
B- 1	31.0				100	61	31	5	0			Sieve; see Plate B-3
B- 1	46.0								85			
B- 2	2.5	104	21									
B- 2	3.0								85			
B- 2	5.5									51	35	Atterberg; see Plate B-2
B- 2	6.0											Triaxial UU; see Plate B-8
B- 2	10.5	102	25									
B- 2	15.5								86			
B- 2	21.0	101	25									
B- 2	26.0				95	45	31	16	7			Sieve; see Plate B-3
B- 2	30.5				100	94	88	33	0			Sieve; see Plate B-3
B- 2	40.5				84	54	37	19	4			Sieve; see Plate B-3
B- 2	45.5								97			
B- 3	2.5											Organic Content=3.7%
B- 3	3.0									50	29	Atterberg; see Plate B-2
B- 3	6.0								83			
B- 3	11.0	97	21									
B- 3	16.0											Triaxial CU; see Plate B-11
B- 3	26.0								25			
B- 3	30.0				98	59	35	15	6			Sieve; see Plate B-3
B- 3	36.0	124	9									
B- 3	42.0				100	62	38	20	5			Sieve; see Plate B-3
B- 3	46.0								78			
B- 3	51.0	94	32									
B- 4	2.5	98	17									
B- 4	3.0									54	36	Atterberg; see Plate B-2
B- 4	5.5								87			
B- 4	6.0	99	23									
B- 4	15.5								72			
B- 4	23.0	111	22									
B- 4	26.0				99	74	66	46	23			Sieve; see Plate B-3
B- 4	36.0				91	61	42	15	5			Sieve; see Plate B-3
B- 4	45.5								51			
B- 4	46.0	104	24									

KLEINFELDER

Drafted By: D. Shelhart
Date: 9/12/2002

Project No.: 23-485068-001
File Number: 23485068

SUMMARY OF LABORATORY TESTS

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
1 of 3
B-1

KA-LABSUM 23485068.GPJ 9/12/02

BORING NO.	SAMPLE DEPTH (ft)	DRY UNIT WEIGHT (pcf)	MOISTURE CONTENT (% of dry weight)	PARTICLE SIZE SIEVE SIZE (percent passing)						ATTERBERG LIMITS		OTHER TESTS
				3"	3/4"	#4	#10	#40	#200	L.L.	P.I.	
B- 4	51.0								92			
B- 5	0.0											Compaction; see Plate B-6
B- 5	2.5								80			
B- 5	3.0	103	16									
B- 5	10.5									55	40	Atterberg; see Plate B-2
B- 5	11.0											Consolidation; see Plate B-4
B- 5	15.5								84			
B- 5	21.0	110	21									
B- 5	26.0						100	100	42			Sieve; see Plate B-3
B- 5	32.0								20			
B- 5	35.5				94	63	37	10	4			Sieve; see Plate B-3
B- 5	46.0				86	45	30	12	4			Sieve; see Plate B-3
B- 5	51.0								44			
B- 6	6.0								97			
B- 6	11.0	98	26									
B- 6	20.5									47	33	Atterberg; see Plate B-2
B- 6	21.0											Triaxial CU; see Plate B-12
B- 6	26.0								44			
B- 6	31.0				96	63	34	19	4			Sieve; see Plate B-3
B- 6	41.0	122	8									
B- 6	46.0				97	48	28	12	3			Sieve; see Plate B-3
B- 6	51.0								85			
B- 7	2.5								94			
B- 7	3.0	91	18									
B- 7	11.0											Triaxial CU; see Plate B-13
B- 7	15.5						100	99	88			Sieve; see Plate B-3
B- 7	16.0											Organic Content=3.2%
B- 7	21.0	110	21									
B- 7	31.0								94			Consolidation; see Plate B-5
B- 7	40.5	101	26									
B- 7	45.5									36	14	Atterberg; see Plate B-2
B- 7	46.0								83			
B- 7	50.5								25			
B- 8	2.5									48	29	Atterberg; see Plate B-2
B- 8	6.0	83	20									
B- 8	10.5								92			
B- 8	30.5								70			
B- 8	36.0	97	27									
B- 8	46.0								15			
B- 9	0.0											Compaction; see Plate B-7
B- 9	2.5									44	18	Atterberg; see Plate B-2

KA-LABSUM 23485068.GPJ 9/12/02

KLEINFELDER

Drafted By: D. Shelhart
Date: 9/12/2002

Project No.: 23-485068-001
File Number: 23485068

SUMMARY OF LABORATORY TESTS

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

B-1

BORING NO.	SAMPLE DEPTH (ft)	DRY UNIT WEIGHT (pcf)	MOISTURE CONTENT (% of dry weight)	PARTICLE SIZE SIEVE SIZE (percent passing)						ATTERBERG LIMITS		OTHER TESTS
				3"	3/4"	#4	#10	#40	#200	L.L.	P.I.	
B- 9	3.0	87	15									
B- 9	11.0											Triaxial UU; see Plate B-9
B- 9	20.5								62			
B- 9	35.5								86			
B- 9	36.0	138	26									
B-10	2.5								95			
B-10	5.5									50	32	Atterberg; see Plate B-2
B-10	11.0	81	32									
B-10	16.0											Organic Content=2.9%
B-10	20.5								79			
B-10	21.0	101	21									
B-10	40.5	102	22									
B-10	41.0								61			
B-11	3.0	89	24									
B-11	5.5						98	96	93			Sieve; see Plate B-3
B-11	11.0											Triaxial UU; see Plate B-10
B-11	16.0								99			
B-11	26.0	106	20									
B-11	40.5								56			

KLEINFELDER

Drafted By: D. Shelhart
Date: 9/12/2002

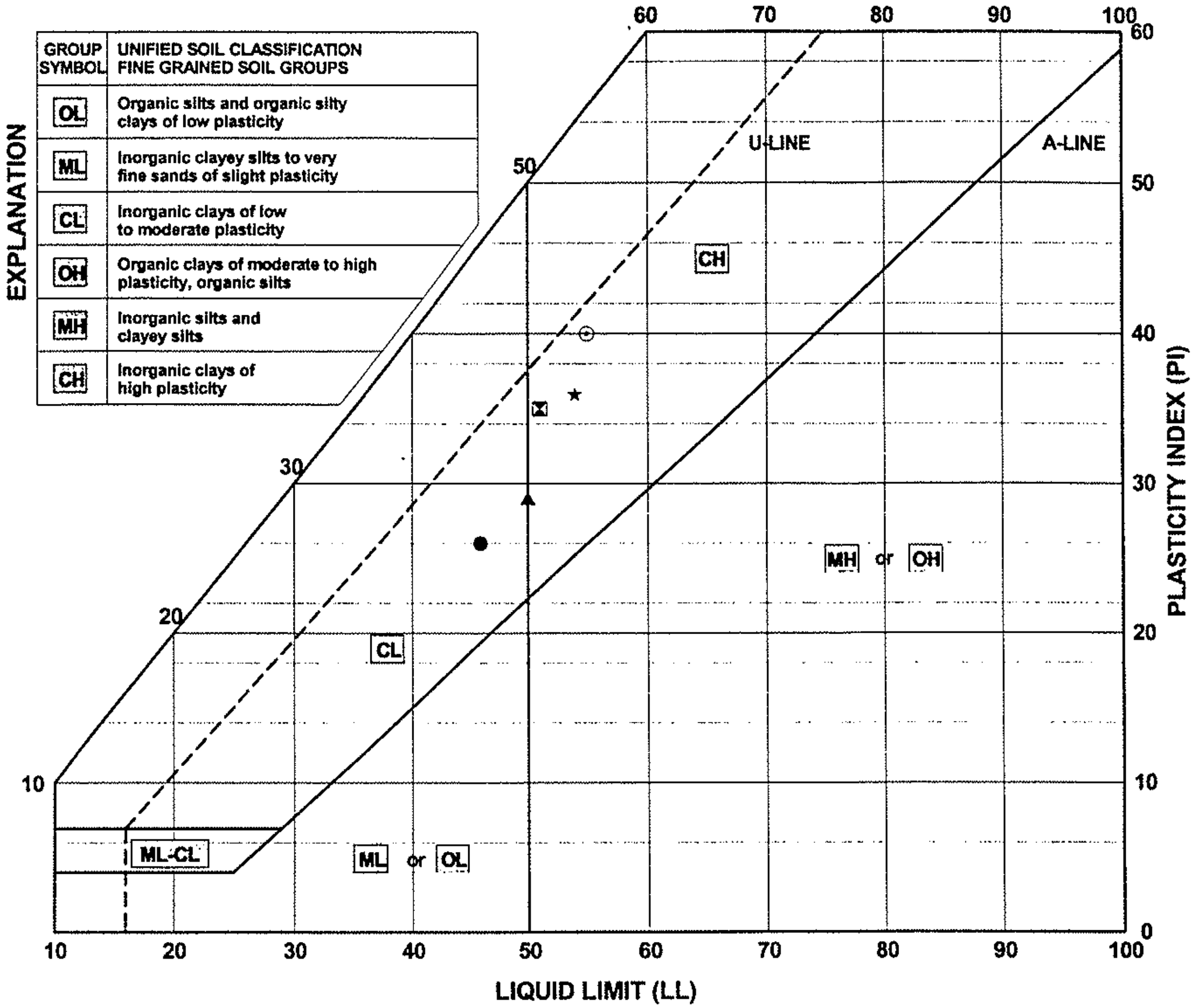
Project No.: 23-485068-001
File Number: 23485068

SUMMARY OF LABORATORY TESTS

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
3 of 3
B-1

KA-LABSUM 23485068.GPJ 9/12/02



LEGEND:	SOURCE	DEPTH	LL	PL	PI	DESCRIPTION
●	B- 1	11.0	46	20	26	Olive-Brown to Dark Brown Lean CLAY
⊠	B- 2	5.5	51	16	35	Olive-Brown to Dark Brown Fat CLAY
▲	B- 3	3.0	50	21	29	Olive-Brown Lean/Fat CLAY
★	B- 4	3.0	54	18	36	Dark Brown Fat CLAY
⊙	B- 5	10.5	55	15	40	Dark Brown Fat CLAY

KA_ATTERBERG 23485068.GPJ 9/12/02

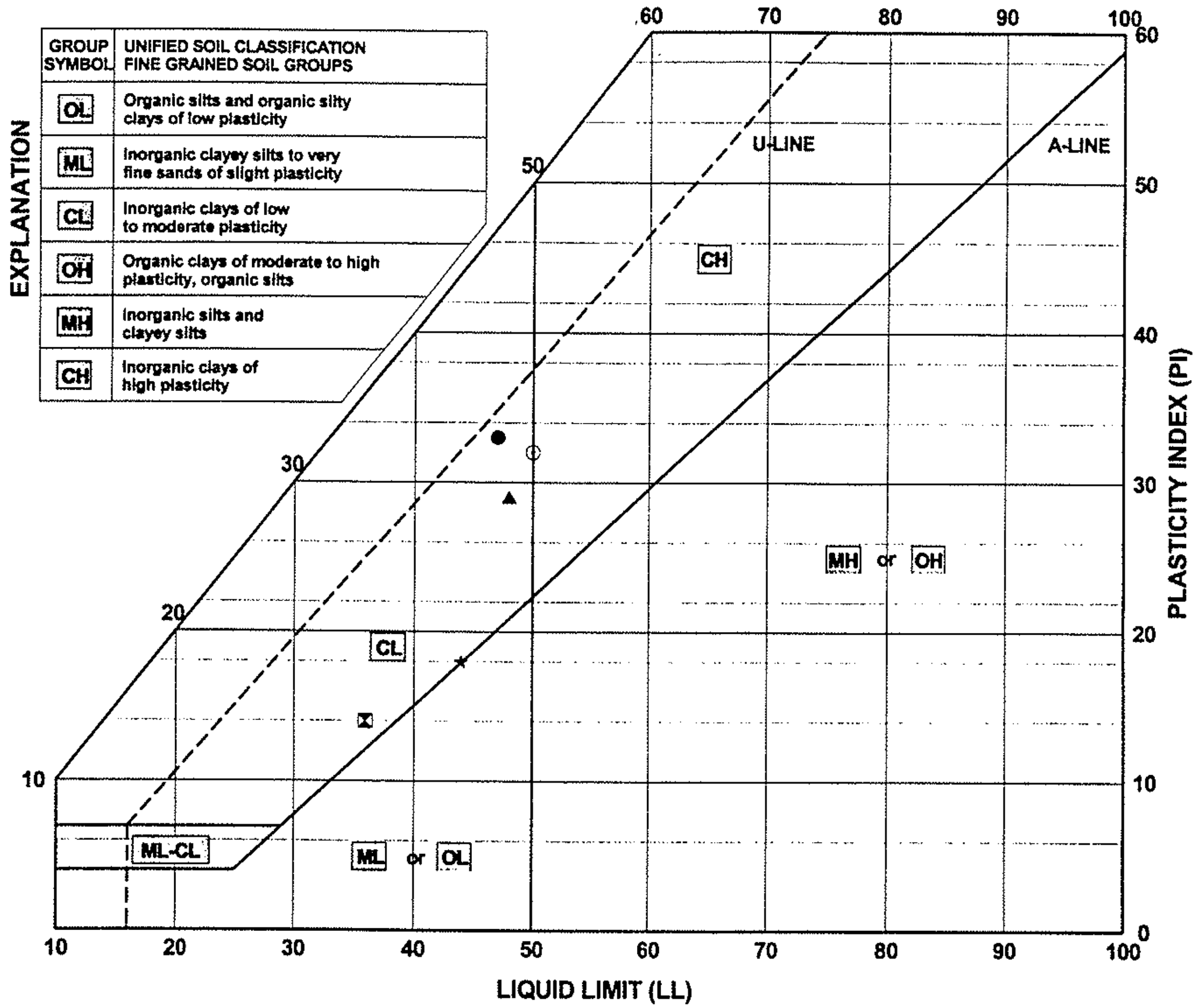
KLEINFELDER

Drafted By: D. Shelhart
Date: 9/12/2002
Project No.: 23-485068-001
File Number: 23485068

PLASTICITY CHART

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
1 of 2
B-2



LEGEND:	SOURCE	DEPTH	LL	PL	PI	DESCRIPTION
●	B- 6	20.5	47	14	33	Olive-Brown Lean CLAY
⊠	B- 7	45.5	36	22	14	Gray-Brown CLAY with sand
▲	B- 8	2.5	48	19	29	Dark Brown Lean CLAY
★	B- 9	2.5	44	26	18	Olive Brown Lean CLAY
⊙	B-10	5.5	50	18	32	Olive-Brown Lean/Fat CLAY

KA_ATTERBERG 23485068.GPJ 9/12/02

KLEINFELDER

Drafted By: D. Shelhart
Date: 9/12/2002

Project No.: 23-485068-001
File Number: 23485068

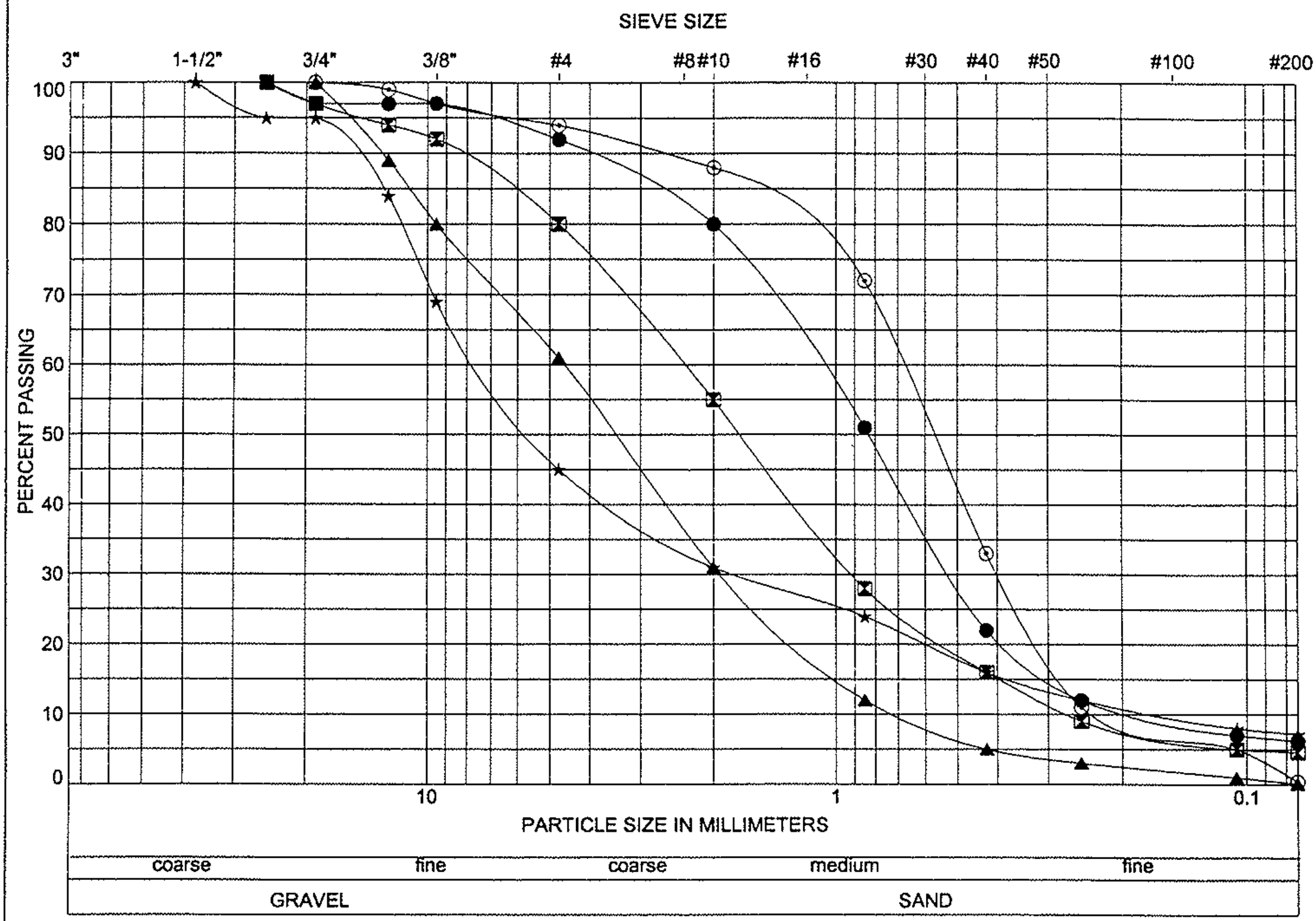
PLASTICITY CHART

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

2 of 2

B-2



LEGEND:	SOURCE	DEPTH (ft)	GRAVEL (%)	SAND (%)	FINES (%)	D60 (mm)	D30 (mm)	D10 (mm)	DESCRIPTION
●	B- 1	22.5	8	86	6	1.11	0.51	0.177	Gray to Gray-Brown Poorly Graded SAND with gravel
⊠	B- 1	25.0	20	75	5	2.38	0.91	0.27	Gray to Gray-Brown Poorly Graded SAND with gravel
▲	B- 1	31.0	39	61	0	4.61	1.91	0.697	Gray to Gray-Brown Well Graded SAND with gravel
★	B- 2	26.0	55	38	7	7.33	1.77	0.163	Gray-Brown Silty GRAVEL with sand
⊙	B- 2	30.5	6	94	0	0.69	0.4	0.217	Gray Well Graded SAND

KA_SIEVE 23485068.GPJ 9/12/02

KLEINFELDER

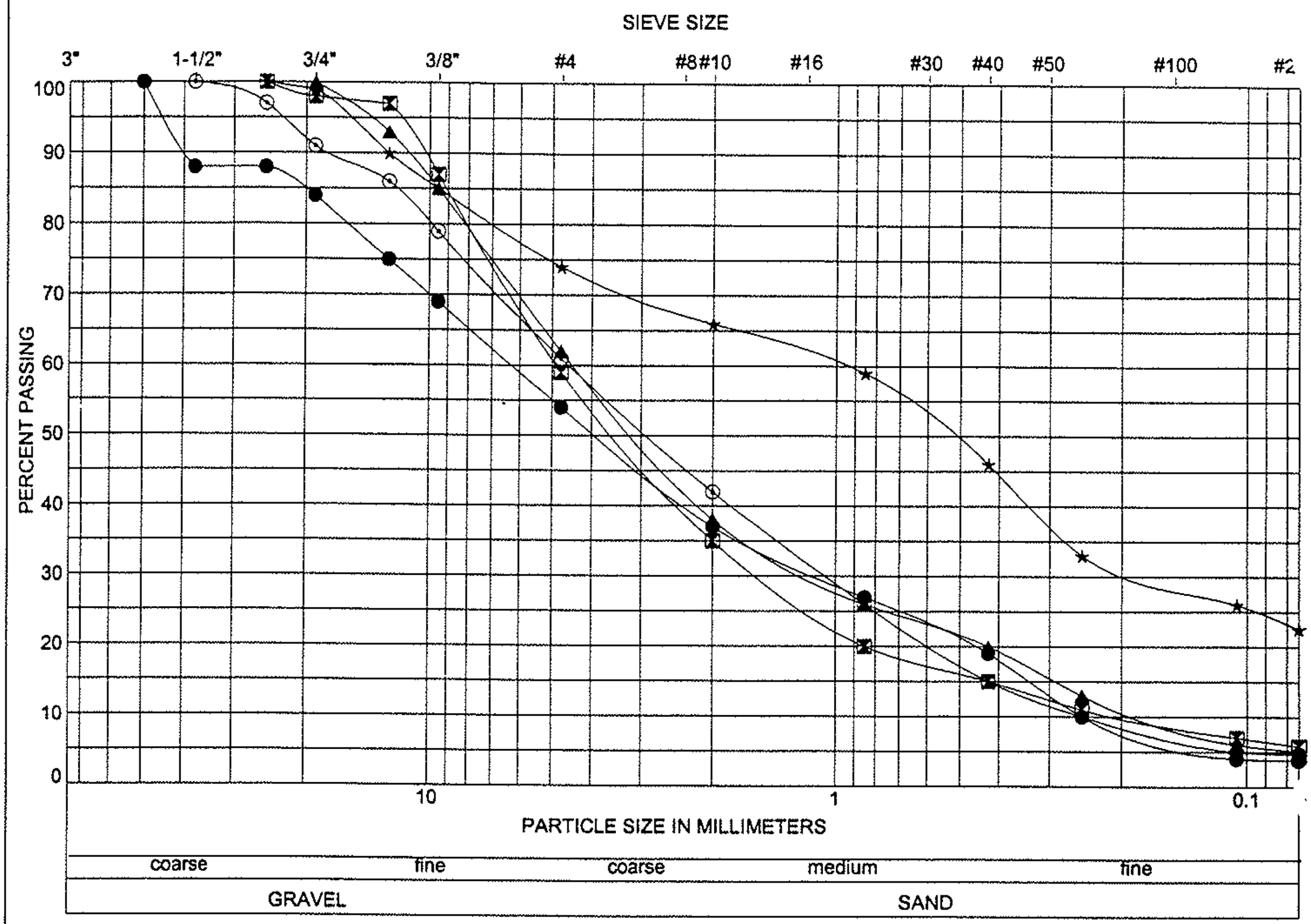
Drafted By: D. Shelhart
Date: 7/1/2002

Project No.: 23-485068-001
File Number: 23485068

SIEVE ANALYSIS

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
1 of 4
B-3



LEGEND:	SOURCE	DEPTH (ft)	GRAVEL (%)	SAND (%)	FINES (%)	D60 (mm)	D30 (mm)	D10 (mm)	DESCRIPTION
●	B- 2	40.5	46	50	4	6.27	1.1	0.25	Gray Well Graded SAND with gravel
⊠	B- 3	30.0	41	53	6	4.87	1.5	0.202	Gray to Gray-Brown Poorly Graded SAND with gravel
▲	B- 3	42.0	38	57	5	4.42	1.13	0.173	Gray to Gray-Brown Poorly Graded SAND with gravel
★	B- 4	26.0	26	51	23	0.96	0.17		Gray to Gray-Brown Clayey SAND with gravel
⊙	B- 4	36.0	39	56	5	4.54	1.05	0.25	Gray to Gray-Brown Well Graded SAND with gravel

KA_SIEVE 23485068.GPJ 9/12/02

KLEINFELDER

Drafted By: D. Shelhart
Date: 7/1/2002
Project No.: 23-485068-001
File Number: 23485068

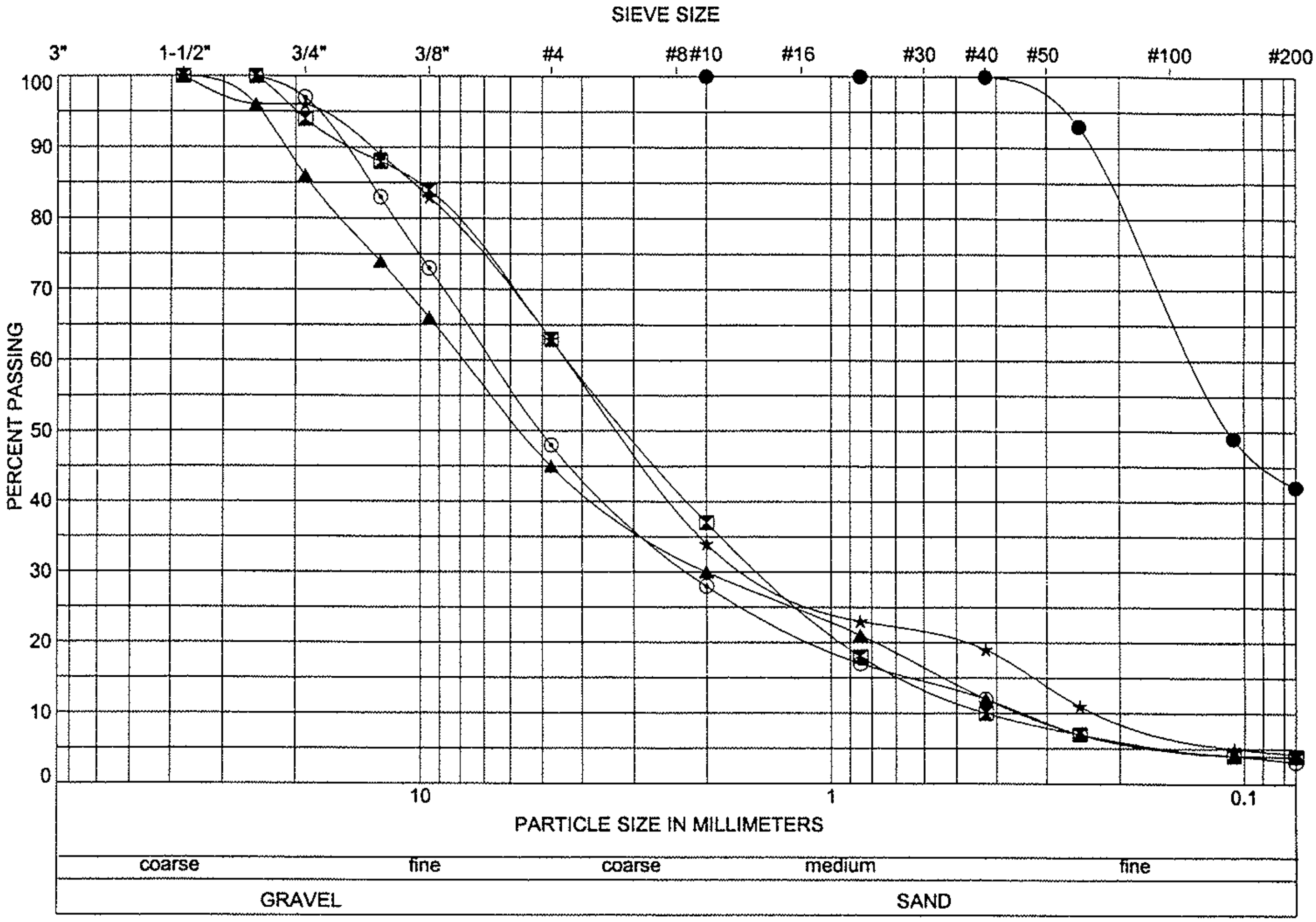
SIEVE ANALYSIS

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

2 of 4

B-3



LEGEND:	SOURCE	DEPTH (ft)	GRAVEL (%)	SAND (%)	FINES (%)	D60 (mm)	D30 (mm)	D10 (mm)	DESCRIPTION
●	B- 5	26.0	0	58	42	0.13			Olive-Brown Silty SAND
⧗	B- 5	35.5	37	59	4	4.3	1.46	0.425	Gray-Brown Well Graded SAND with gravel
▲	B- 5	46.0	55	41	4	7.79	2	0.344	Gray-Brown Well Graded GRAVEL with sand
★	B- 6	31.0	37	59	4	4.34	1.47	0.217	Gray-Brown Well Graded SAND with gravel
⊙	B- 6	46.0	52	45	3	6.63	2.18	0.344	Gray-Brown Well Graded GRAVEL with clay and sand

KA_SIEVE 23485068.GPJ 9/12/02

KLEINFELDER

Drafted By: D. Shelhart
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Project No.: 23-485068-001
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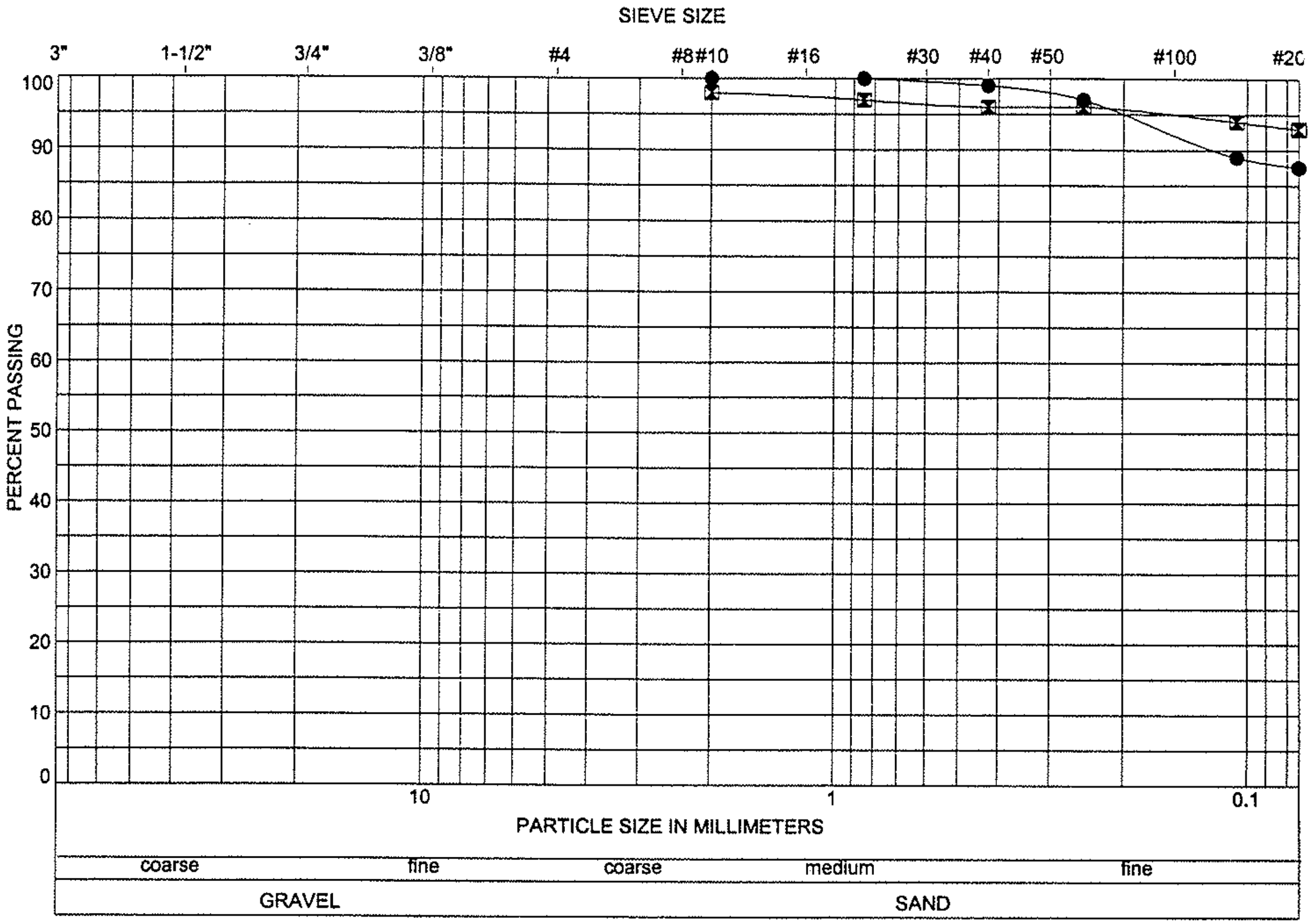
SIEVE ANALYSIS

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
3 of 4
B-3



LEGEND:	SOURCE	DEPTH (ft)	GRAVEL (%)	SAND (%)	FINES (%)	D60 (mm)	D30 (mm)	D10 (mm)	DESCRIPTION
●	B- 7	15.5	0	12	88				Olive-Brown Lean CLAY
⊠	B-11	5.5	0	5	93				Olive-Brown Lean CLAY

KA_SIEVE 23485068.GPJ 9/12/02

KLEINFELDER

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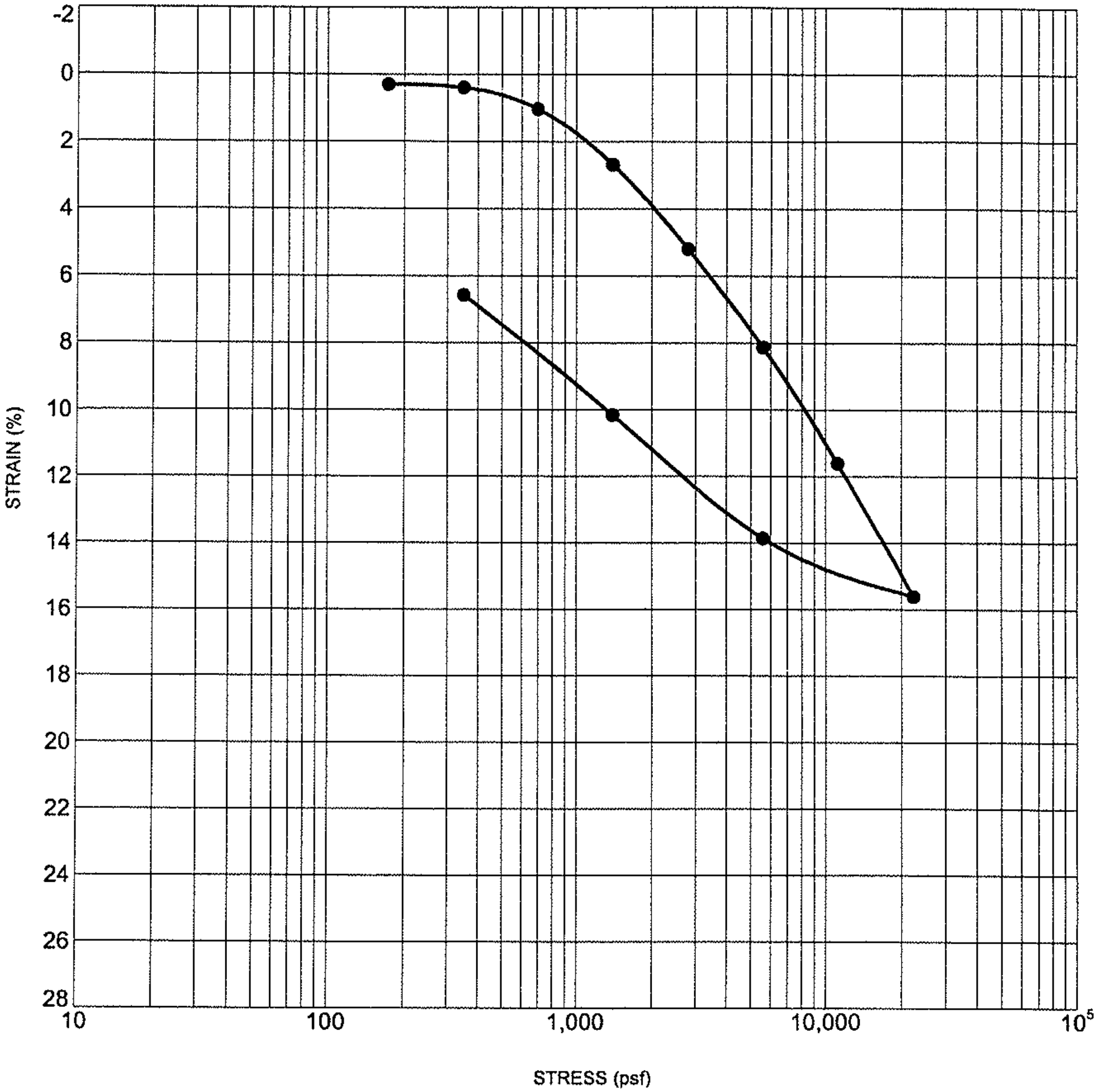
Project No.: 23-485068-001
File Number: 23485068

SIEVE ANALYSIS

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
4 of 4
B-3



		Before	After
BORING: B- 5	Wet Unit Weight (pcf) =	124.8	137.3
At a depth of approximately 11.0 feet	Moisture Content (%) =	25.0	24.0
	Dry Unit Weight (pcf) =	99.8	110.7

KA_CONSOL_STRAIN 23485068.GPJ 9/12/02

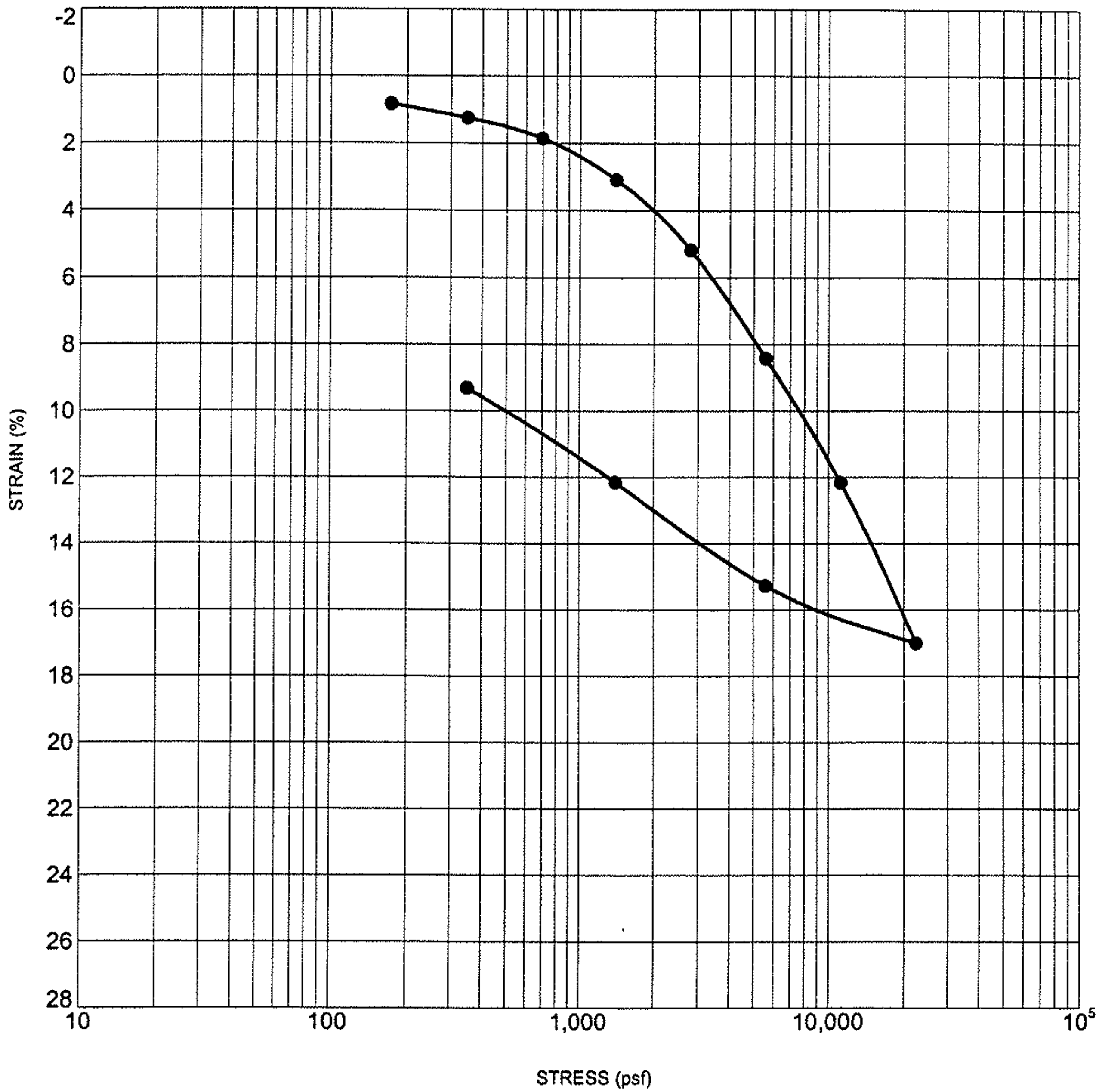
KLEINFELDER

Drafted By: D. Shelhart
Date: 9/12/2002
Project No.: 23-485068-001
File Number: 23485068

CONSOLIDATION TEST

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
B-4



		Before	After
BORING: B- 7	Wet Unit Weight (pcf) =	126.9	190.5
At a depth of approximately 31.0 feet	Moisture Content (%) =	25.5	24.6
	Dry Unit Weight (pcf) =	101.1	152.9

KA_CONSOL_STRAIN 23485068.GPJ 9/12/02

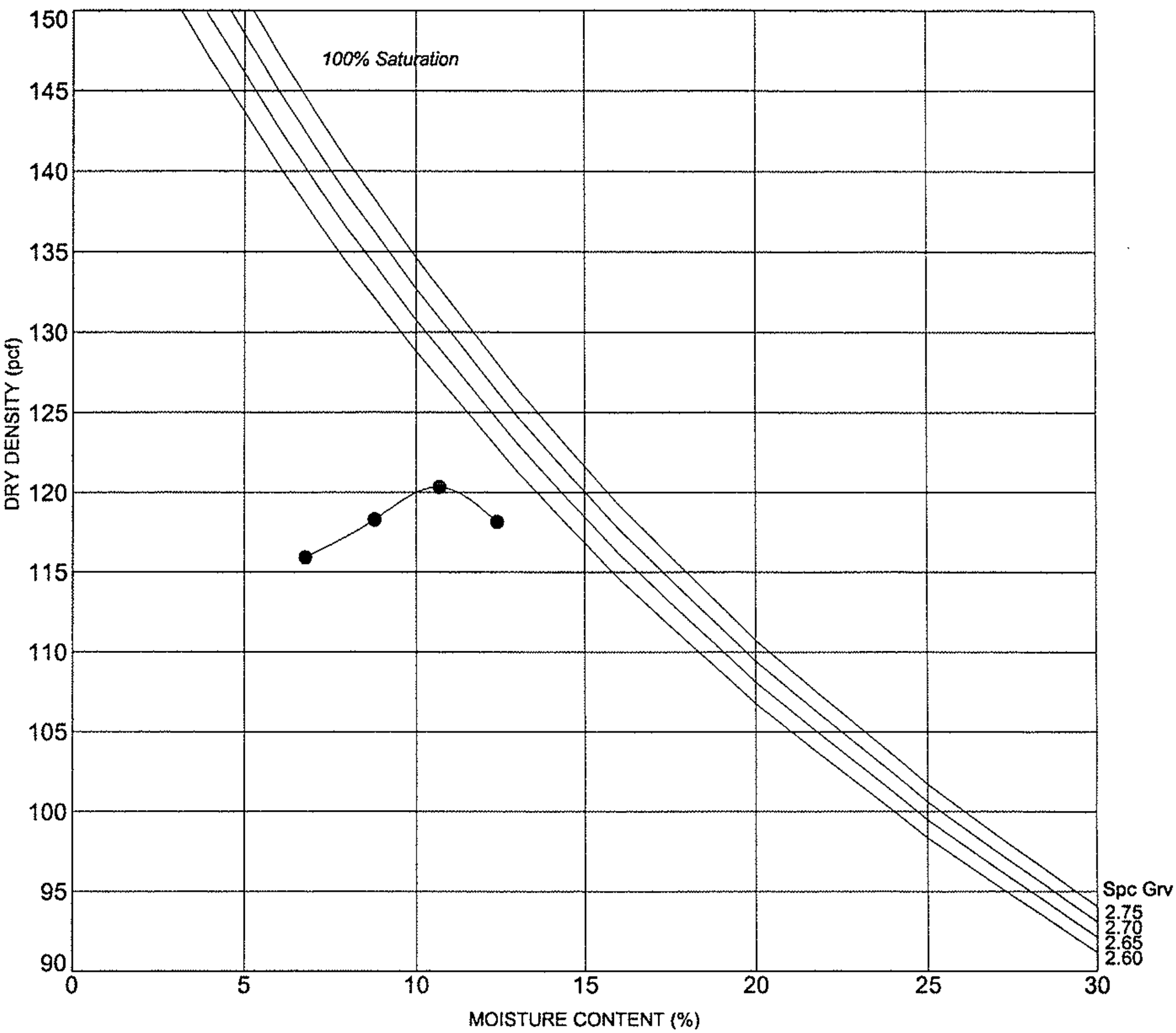
KLEINFELDER

Drafted By: D. Shelhart　Project No.: 23-485068-001
Date: 9/12/2002　File Number: 23485068

CONSOLIDATION TEST

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
B-5



LEGEND:	SOURCE	DEPTH (ft)	OPTIMUM MOISTURE (%)	MAXIMUM DRY DENSITY (pcf)	TEST METHOD	DESCRIPTION
●	B- 5	0.0	11.0	120.5	ASTM D1557 Method A	Olive-Brown Lean CLAY

KA-COMPACTION 23485068.GPJ 9/12/02

KLEINFELDER

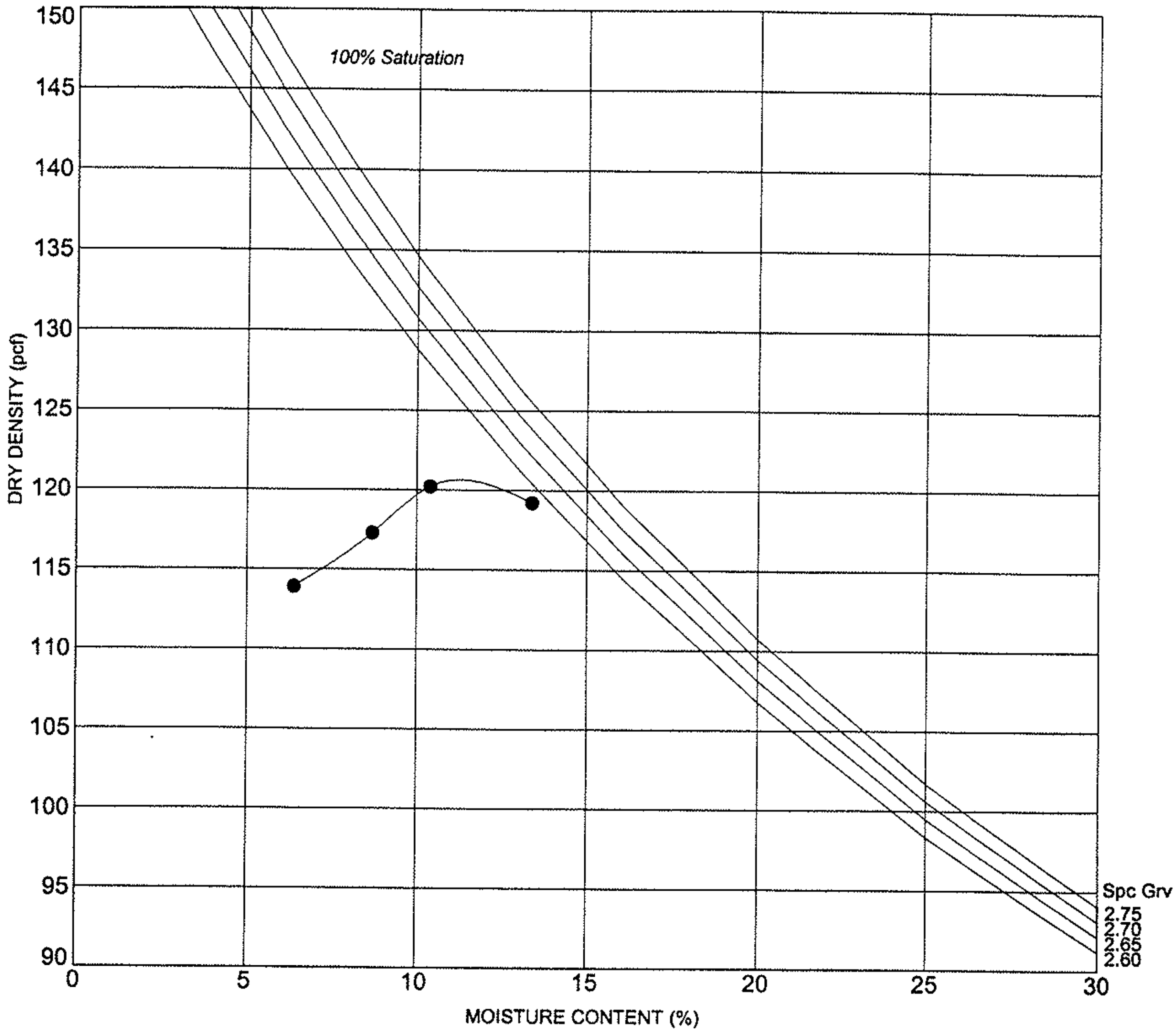
Drafted By: D. Shelhart
Date: 9/12/2002

Project No.: 23-485068-001
File Number: 23485068

COMPACTION CURVE

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
B-6



LEGEND:	SOURCE	DEPTH (ft)	OPTIMUM MOISTURE (%)	MAXIMUM DRY DENSITY (pcf)	TEST METHOD	DESCRIPTION
●	B- 9	0.0	11.5	121.0	ASTM D1557 Method A	Olive-Brown Lean/Fat CLAY

KA-COMPACTION 23485068.GPJ 9/12/02

KLEINFELDER

COMPACTION CURVE

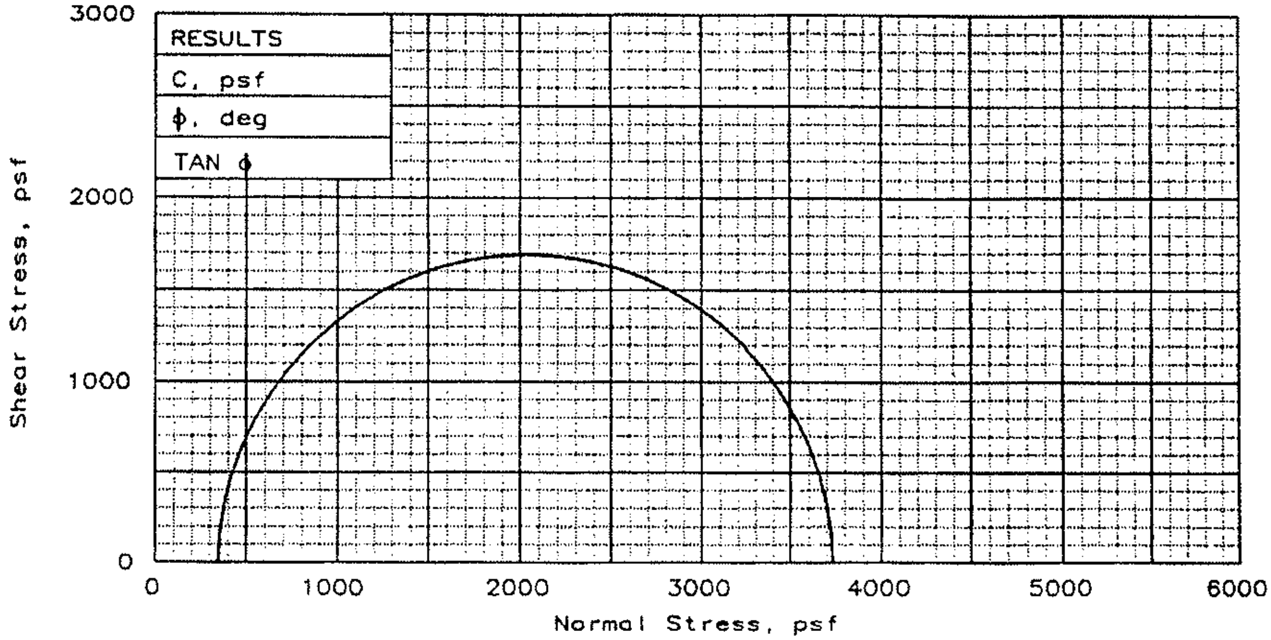
CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

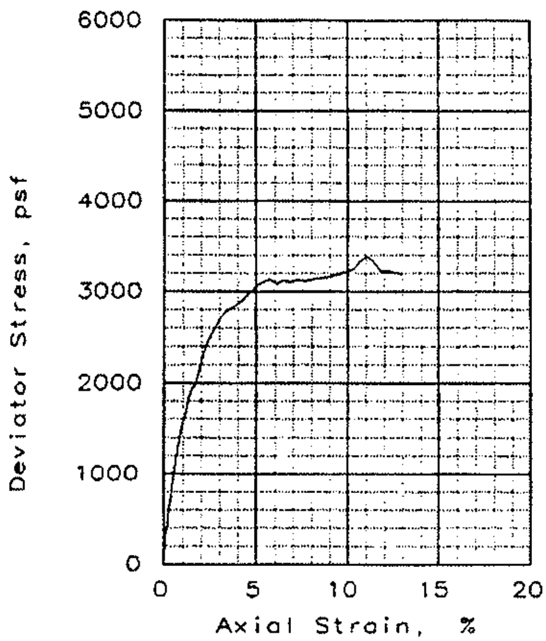
PLATE

B-7

Drafted By: D. Shelhart
Date: 9/12/2002

Project No.: 23-485068-001
File Number: 23485068





SAMPLE NO.:		1
INITIAL	WATER CONTENT, %	21.0
	DRY DENSITY, pcf	98.3
	SATURATION, %	79.3
	VOID RATIO	0.714
	DIAMETER, in	2.40
	HEIGHT, in	5.23
AT TEST	WATER CONTENT, %	21.0
	DRY DENSITY, pcf	98.3
	SATURATION, %	79.3
	VOID RATIO	0.714
	DIAMETER, in	2.40
	HEIGHT, in	5.23
Strain rate, %/min		0.30
BACK PRESSURE, psf		0
CELL PRESSURE, psf		350
FAIL. STRESS, psf		3385
ULT. STRESS, psf		
σ_1 FAILURE, psf		3735
σ_3 FAILURE, psf		350

TYPE OF TEST:
Unconsolidated Undrained
SAMPLE TYPE: Undisturbed
DESCRIPTION: Pending

SPECIFIC GRAVITY= 2.7
REMARKS: C23 485068/001

Fig. No.: ______

CLIENT: Kleinfelder

PROJECT: City Outfall Levee Study

SAMPLE LOCATION: B2-C2 @ 6.0'

PROJ. NO.: 02-239 DATE: 7-19-02

TRIAXIAL SHEAR TEST REPORT

SIERRA TESTING LABORATORIES, INC.

KLEINFELDER

Drawn By: D. Shelhart
Project No. 23-485068-001

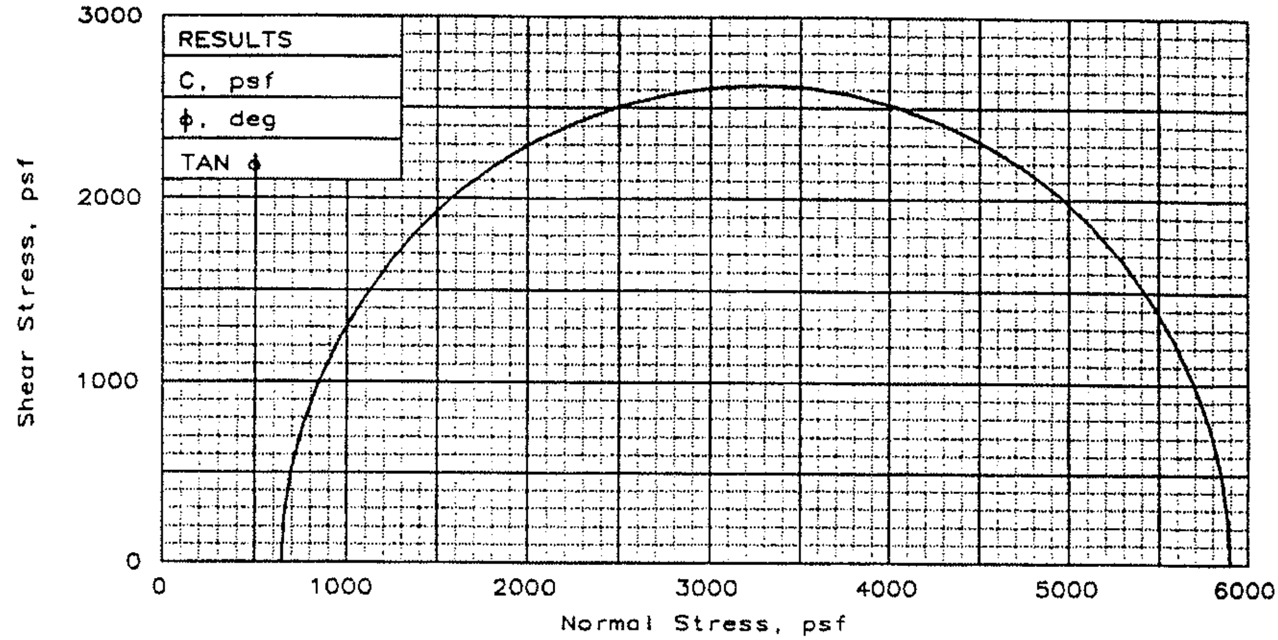
Date: 8-16-2002
Filename: 2673b.fh10

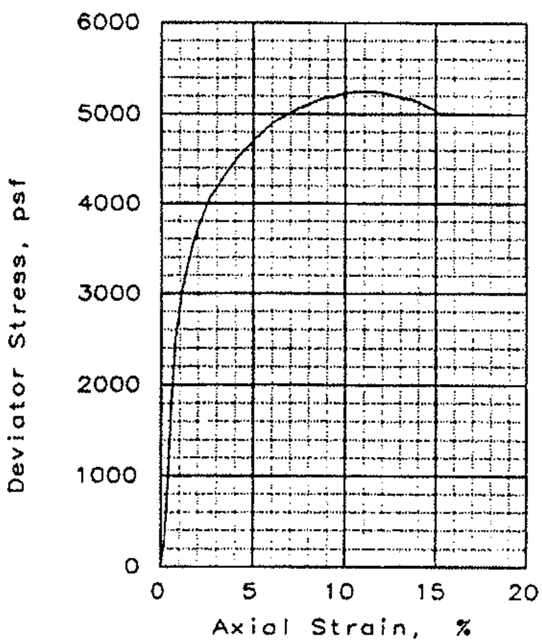
TRIAXIAL UU TEST

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

B-8





SAMPLE NO.:		1
INITIAL	WATER CONTENT, %	21.2
	DRY DENSITY, pcf	104.3
	SATURATION, %	93.0
	VOID RATIO	0.616
	DIAMETER, in	2.40
	HEIGHT, in	5.11
AT TEST	WATER CONTENT, %	21.2
	DRY DENSITY, pcf	104.3
	SATURATION, %	93.0
	VOID RATIO	0.616
	DIAMETER, in	2.40
	HEIGHT, in	5.11
Strain rate, %/min		0.30
BACK PRESSURE, psf		0
CELL PRESSURE, psf		649
FAIL. STRESS, psf		5249
ULT. STRESS, psf		
σ_1 FAILURE, psf		5899
σ_3 FAILURE, psf		649

TYPE OF TEST:
Unconsolidated Undrained

SAMPLE TYPE: Undisturbed

DESCRIPTION: Pending

SPECIFIC GRAVITY= 2.7

REMARKS: C23 485068/001

Fig. No.: ______

CLIENT: Kleinfelder

PROJECT: City Outfall Levee Study

SAMPLE LOCATION: B9-4C @ 11.0'

PROJ. NO.: 02-239 DATE: 7-25-02

TRIAXIAL SHEAR TEST REPORT

SIERRA TESTING LABORATORIES, INC.

KLEINFELDER

Drawn By: D. Shelhart | Date: 8-16-2002

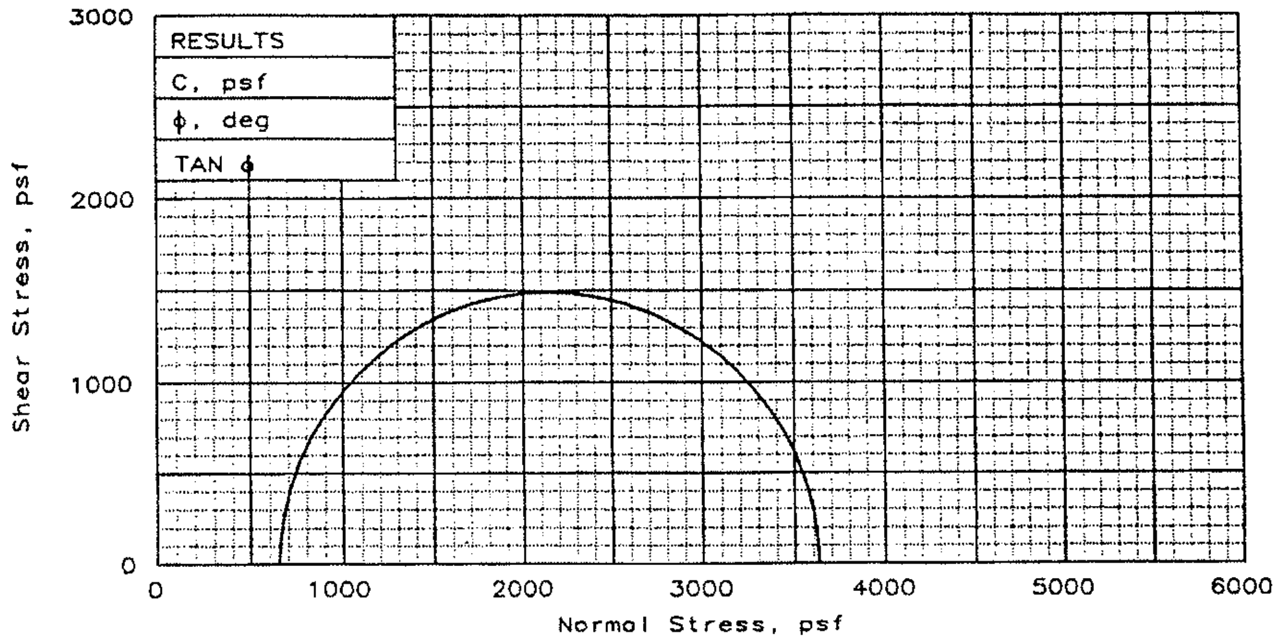
Project No. 23-485068-001 | Filename: 2673c.fh10

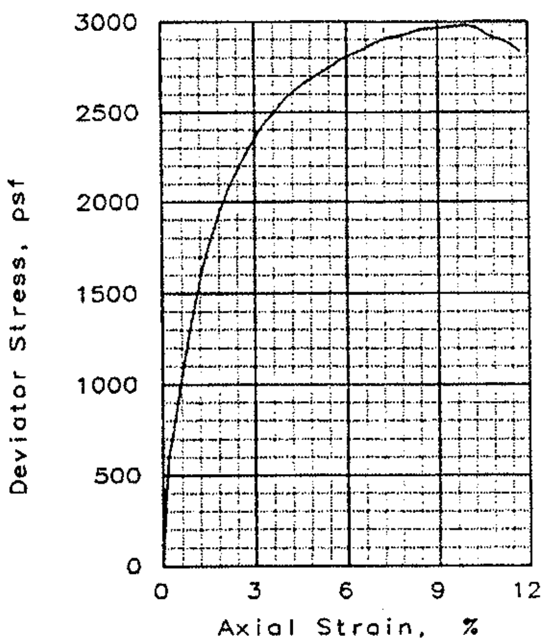
TRIAXIAL UU TEST

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

B-9





SAMPLE NO.:		1
INITIAL	WATER CONTENT, %	33.9
	DRY DENSITY, pcf	87.5
	SATURATION, %	98.7
	VOID RATIO	0.927
	DIAMETER, in	2.41
	HEIGHT, in	5.45
AT TEST	WATER CONTENT, %	33.9
	DRY DENSITY, pcf	87.5
	SATURATION, %	98.7
	VOID RATIO	0.927
	DIAMETER, in	2.41
	HEIGHT, in	5.45
Strain rate, %/min		0.30
BACK PRESSURE, psf		0
CELL PRESSURE, psf		654
FAIL. STRESS, psf		2980
ULT. STRESS, psf		
σ_1 FAILURE, psf		3634
σ_3 FAILURE, psf		654

TYPE OF TEST:
Unconsolidated Undrained
SAMPLE TYPE: Undisturbed
DESCRIPTION: Pending

SPECIFIC GRAVITY= 2.7
REMARKS: C23 485068/001

Fig. No.: ______

CLIENT: Kleinfelder

PROJECT: City Outfall Levee Study

SAMPLE LOCATION: B11-3C @ 11.0'

PROJ. NO.: 02-239 DATE: 7-25-02

TRIAXIAL SHEAR TEST REPORT

SIERRA TESTING LABORATORIES, INC.

KLEINFELDER

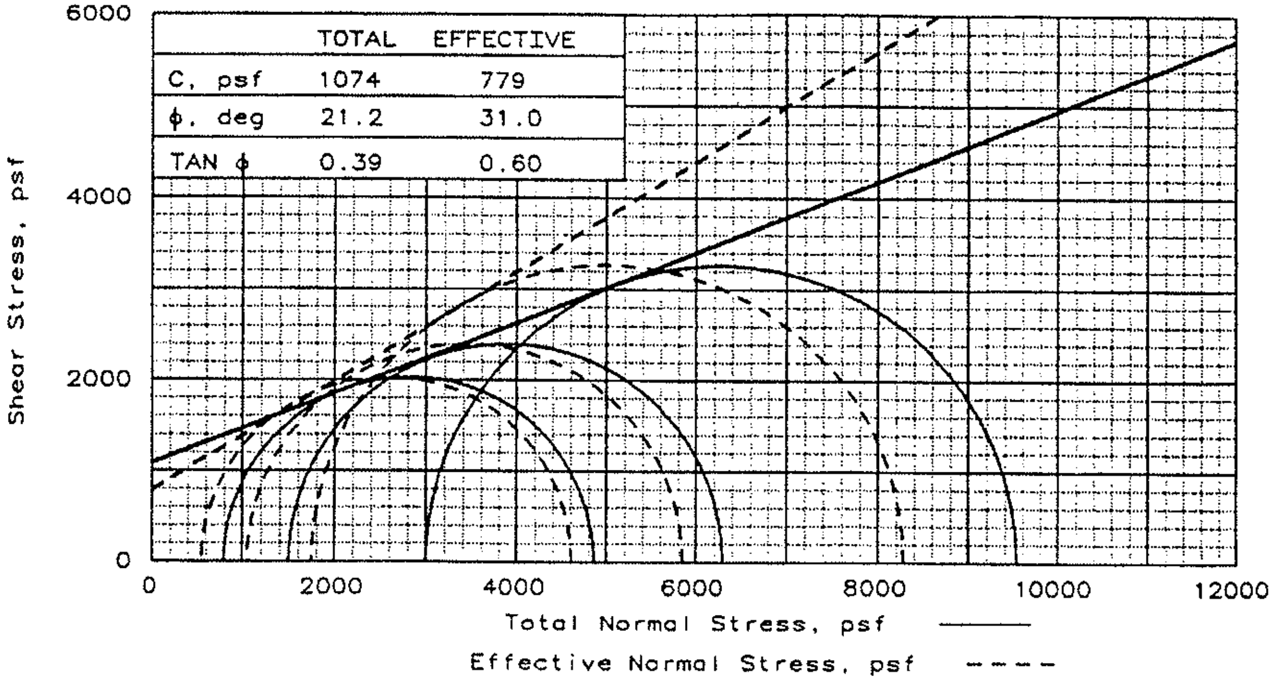
Drawn By: D. Shelhart
Project No. 23-485068-001

Date: 8-16-2002
Filename: 2673d.fh10

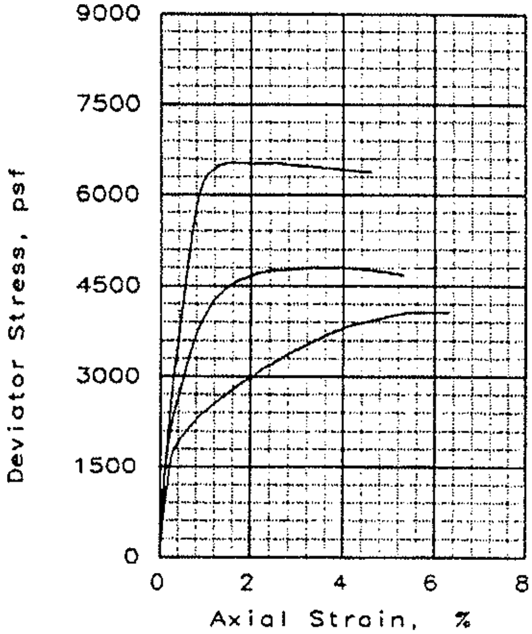
TRIAXIAL UU TEST

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
B-10



	TOTAL	EFFECTIVE
C, psf	1074	779
φ, deg	21.2	31.0
TAN φ	0.39	0.60



	SAMPLE NO.:	1	2	3
INITIAL	WATER CONTENT, %	19.9	19.9	19.9
	DRY DENSITY, pcf	109.4	109.4	109.4
	SATURATION, %	99.4	99.4	99.4
	VOID RATIO	0.541	0.541	0.541
	DIAMETER, in	2.42	2.42	2.42
	HEIGHT, in	5.60	5.60	5.60
AT TEST	WATER CONTENT, %	18.2	17.6	16.7
	DRY DENSITY, pcf	113.0	114.2	116.2
	SATURATION, %	100.0	100.0	100.0
	VOID RATIO	0.492	0.476	0.451
	DIAMETER, in	2.39	2.46	2.52
	HEIGHT, in	5.54	5.17	4.87
	Strain rate, %/min	0.03	0.03	0.03
	BACK PRESSURE, psf	8078	8006	7992
	CELL PRESSURE, psf	8879	9507	10992
	FAIL. STRESS, psf	4065	4800	6540
	TOTAL PORE PR., psf	8323	8453	9245
	ULT. STRESS, psf			
	TOTAL PORE PR., psf			
	$\bar{\sigma}_1$ FAILURE, psf	4620	5854	8287
	$\bar{\sigma}_3$ FAILURE, psf	556	1054	1747

TYPE OF TEST:
CU with Pore Pressures
SAMPLE TYPE: Undisturbed
DESCRIPTION: Pending

SPECIFIC GRAVITY= 2.7
REMARKS: C23 485068/001

Fig. No.: ______

CLIENT: Kleinfelder

PROJECT: City Outfall Levee Study

SAMPLE LOCATION: B3-4C @ 16.0'

PROJ. NO.: 02-239 DATE: 7-30-02

TRIAXIAL SHEAR TEST REPORT

SIERRA TESTING LABORATORIES, INC.

KLEINFELDER

Drawn By: D. Shelhart
Project No. 23-485068-001

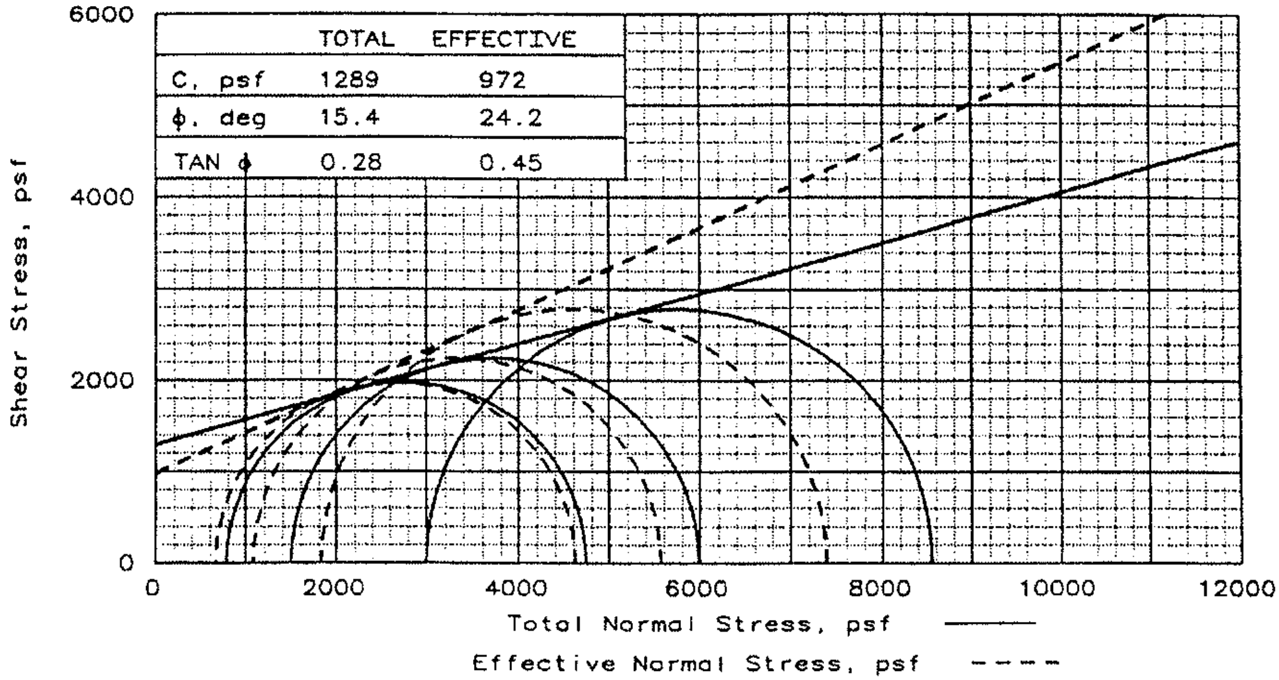
Date: 8-16-2002
Filename: 2673e.fh10

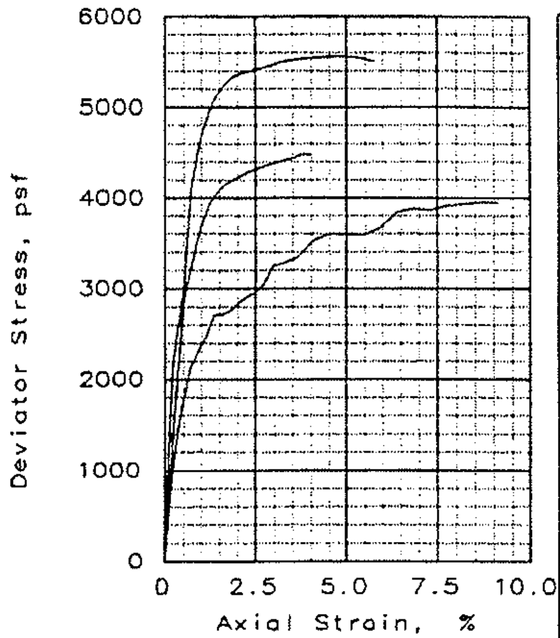
TRIAXIAL CU TEST

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

B-11





SAMPLE NO.:		1	2	3
INITIAL	WATER CONTENT, %	19.7	19.7	19.7
	DRY DENSITY, pcf	109.7	109.7	115.6
	SATURATION, %	99.2	99.2	116.0
	VOID RATIO	0.536	0.536	0.458
	DIAMETER, in	2.34	2.34	2.28
	HEIGHT, in	5.50	5.50	5.50
AT TEST	WATER CONTENT, %	19.2	18.6	16.1
	DRY DENSITY, pcf	111.0	112.2	117.6
	SATURATION, %	100.0	100.0	100.0
	VOID RATIO	0.519	0.502	0.433
	DIAMETER, in	2.33	2.44	2.43
	HEIGHT, in	5.48	4.96	4.77
Strain rate, %/min		0.03	0.03	0.03
BACK PRESSURE, psf		7857	8064	8050
CELL PRESSURE, psf		8649	9564	11049
FAIL. STRESS, psf		3952	4486	5559
TOTAL PORE PR., psf		7978	8482	9216
ULT. STRESS, psf				
TOTAL PORE PR., psf				
$\bar{\sigma}_1$ FAILURE, psf		4623	5569	7392
$\bar{\sigma}_3$ FAILURE, psf		671	1083	1833

TYPE OF TEST:
CU with Pore Pressures
SAMPLE TYPE: Undisturbed
DESCRIPTION: Pending

SPECIFIC GRAVITY= 2.7
REMARKS: C23 485068/001

Fig. No.: ______

CLIENT: Kleinfelder

PROJECT: City Outfall Levee Study

SAMPLE LOCATION: B6-5C @ 21.0'

PROJ. NO.: 02-239 DATE: 7-30-02

TRIAXIAL SHEAR TEST REPORT

SIERRA TESTING LABORATORIES, INC.

KLEINFELDER

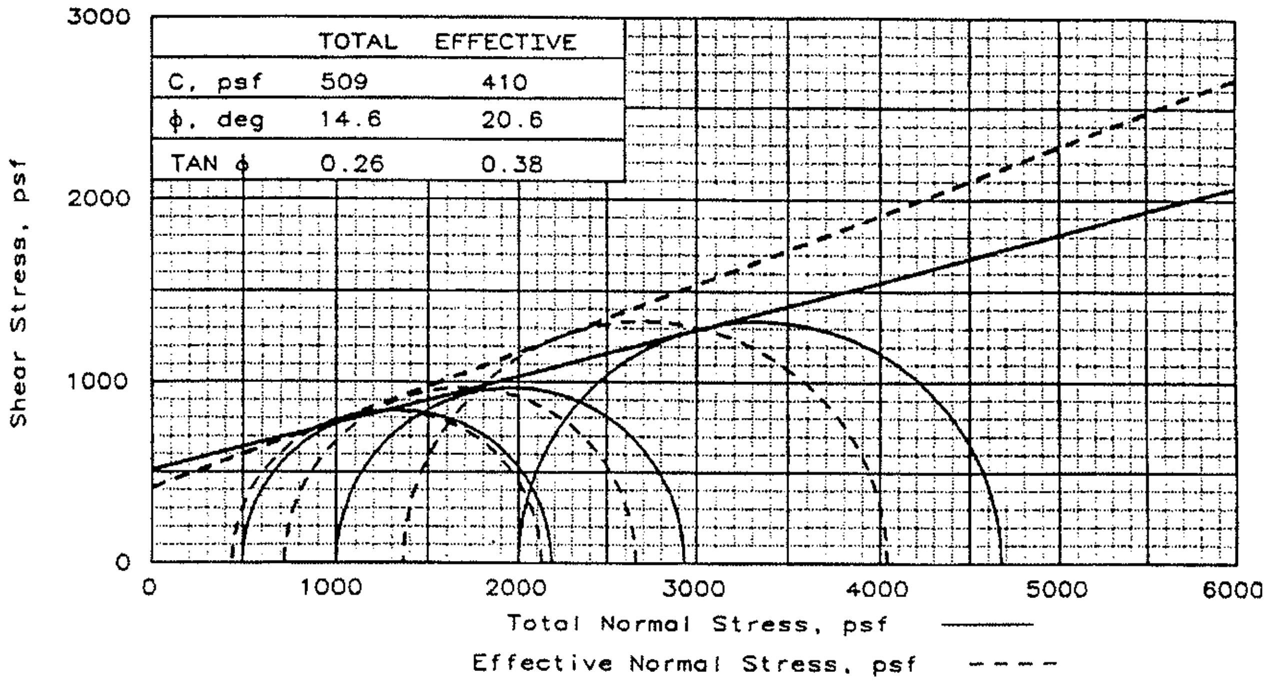
Drawn By: D. Shelhart
Project No. 23-485068-001

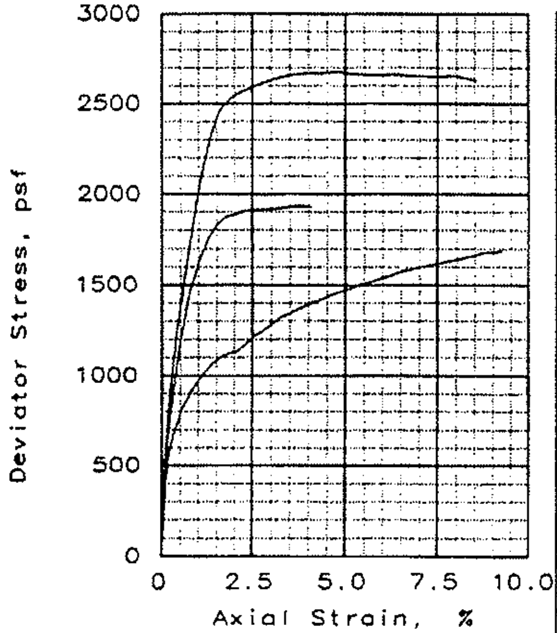
Date: 8-16-2002
Filename: 2673f.fh10

TRIAXIAL CU TEST

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
B-12





SAMPLE NO.:		1	2	3
INITIAL	WATER CONTENT, %	24.0	24.2	24.2
	DRY DENSITY, pcf	102.2	102.2	102.2
	SATURATION, %	99.6	100.4	100.4
	VOID RATIO	0.649	0.649	0.649
	DIAMETER, in	2.41	2.41	2.41
	HEIGHT, in	5.46	5.46	5.46
AT TEST	WATER CONTENT, %	22.7	22.0	21.4
	DRY DENSITY, pcf	104.5	105.7	106.9
	SATURATION, %	100.0	100.0	100.0
	VOID RATIO	0.613	0.595	0.577
	DIAMETER, in	2.39	2.50	2.54
	HEIGHT, in	5.42	4.90	4.68
Strain rate, %/min		0.03	0.03	0.03
BACK PRESSURE, psf		9749	9706	9720
CELL PRESSURE, psf		10248	10705	11720
FAIL. STRESS, psf		1687	1936	2675
TOTAL PORE PR., psf		9806	9979	10354
ULT. STRESS, psf				
TOTAL PORE PR., psf				
$\bar{\sigma}_1$ FAILURE, psf		2129	2661	4041
$\bar{\sigma}_3$ FAILURE, psf		442	726	1367

TYPE OF TEST:
CU with Pore Pressures
SAMPLE TYPE: Undisturbed
DESCRIPTION: Pending

SPECIFIC GRAVITY= 2.7
REMARKS: C23 485068/001

Fig. No.: ______

CLIENT: Kleinfelder

PROJECT: City Outfall Levee Study

SAMPLE LOCATION: B7-3C @ 11.0'

PROJ. NO.: 02-239 DATE: 7-30-02

TRIAXIAL SHEAR TEST REPORT

SIERRA TESTING LABORATORIES, INC.

KLEINFELDER

Drawn By: D. Shelhart | Date: 8-16-2002
Project No. 23-485068-001 | Filename: 2673g.fh10

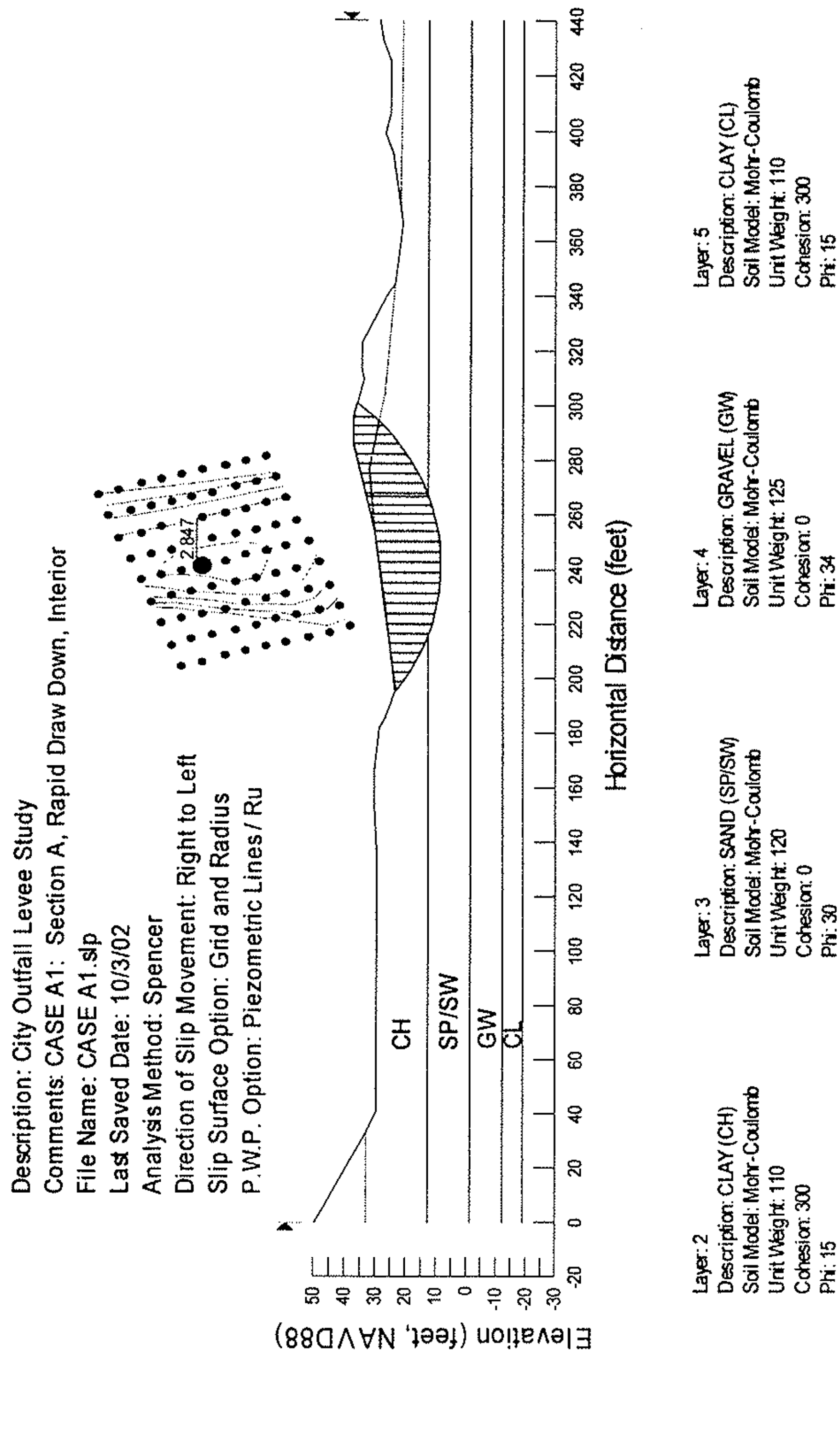
TRIAXIAL CU TEST

CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

B-13

APPENDIX C



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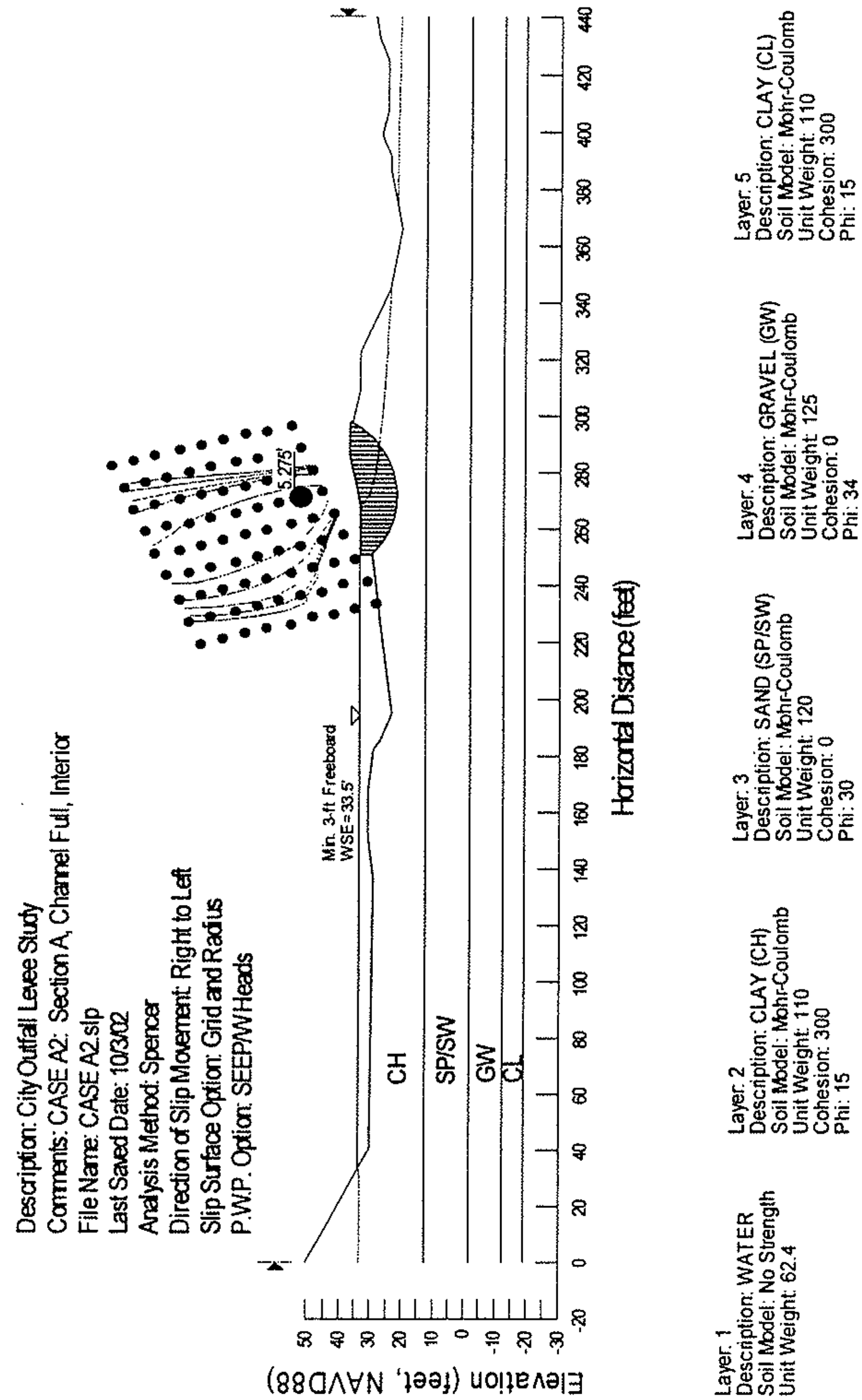
Graphic By: K. Sorensen	Date: 10-7-02		
Project No. C234845068	Filename: City Outfall.doc		



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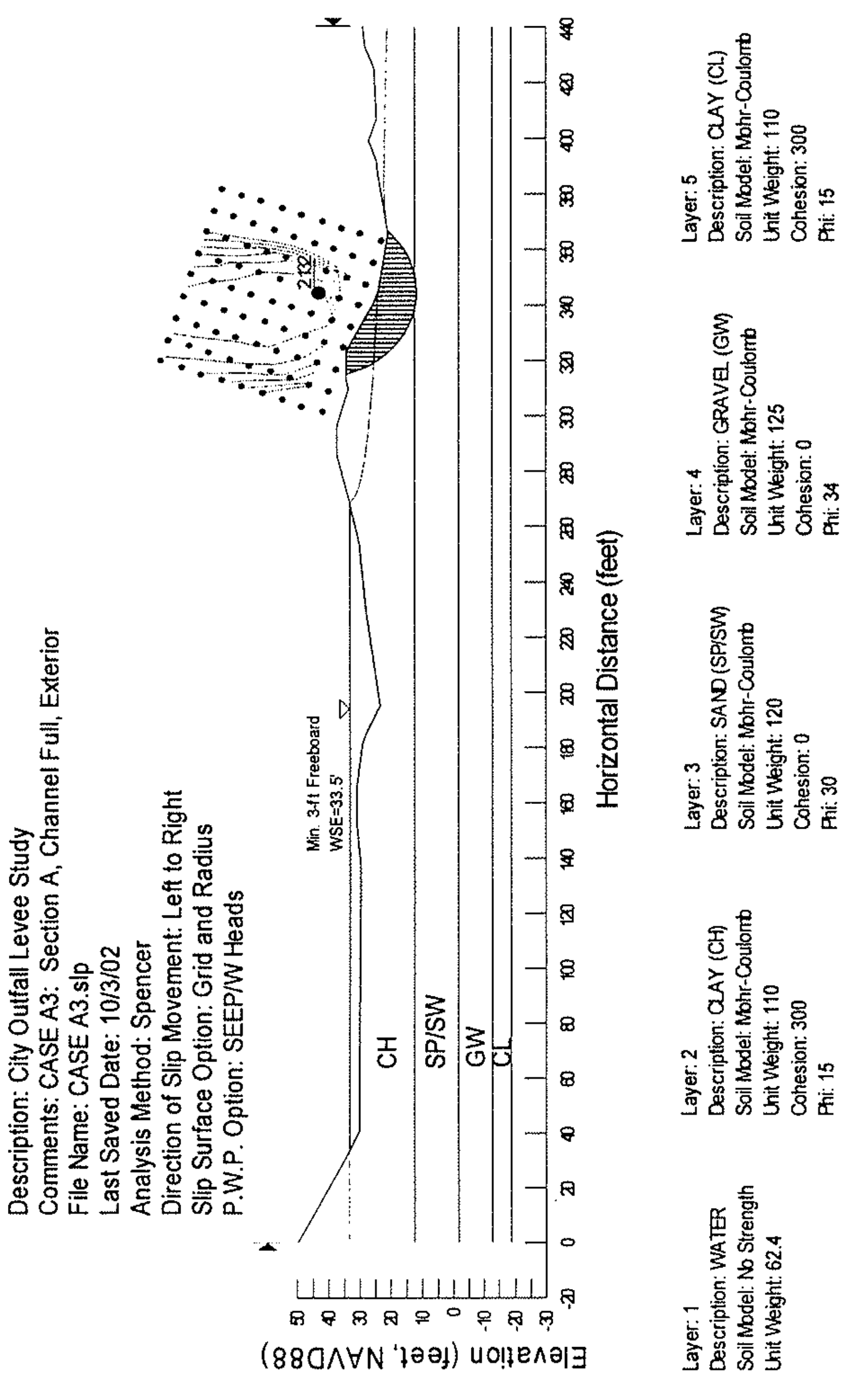
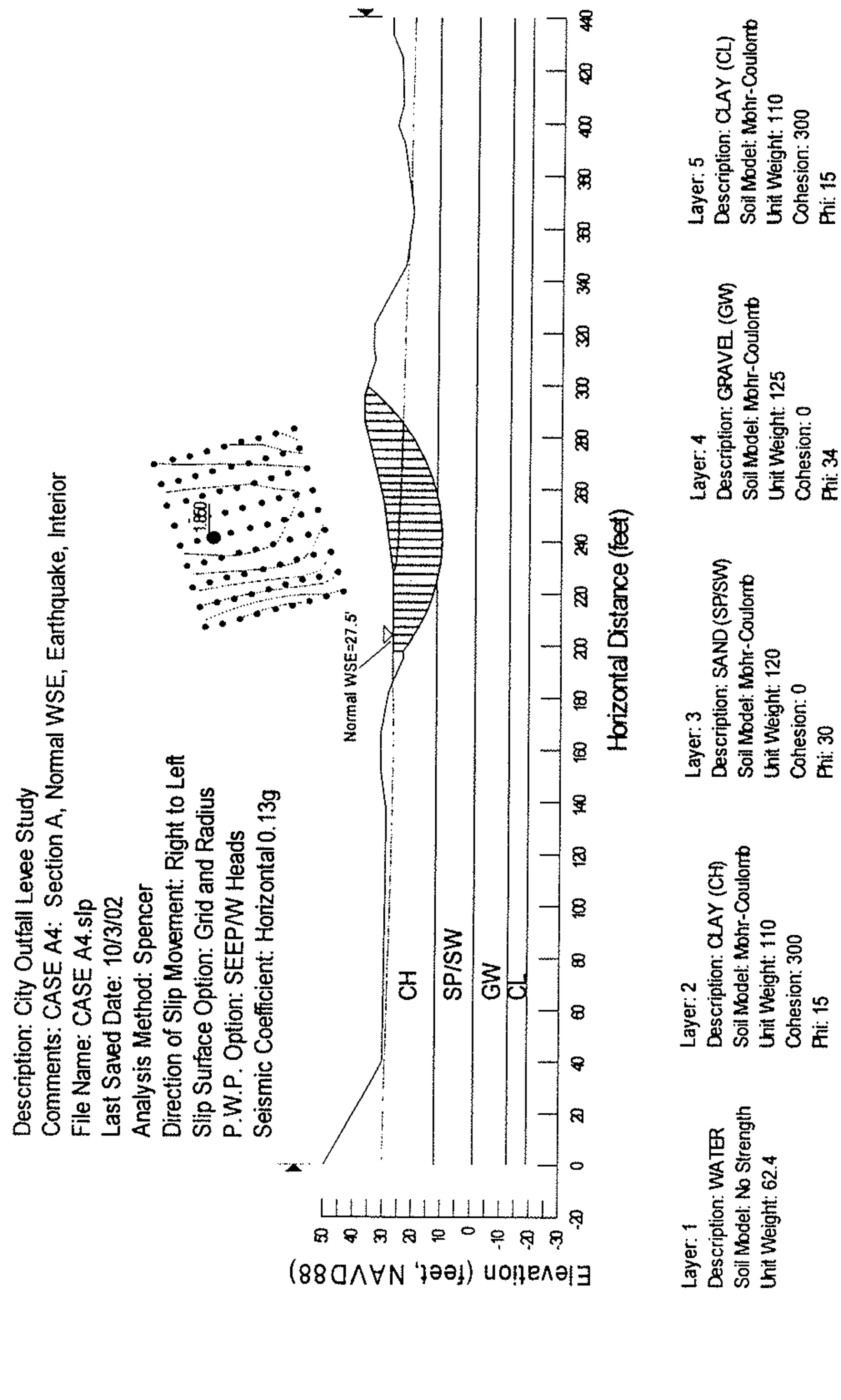
Graphic By: K. Sorensen	Date: 10-7-02		
Project No. C234845068	Filename: City Outfall.doc		



KLEINFELDER

Graphic By: K. Sorensen	Date: 10-7-02	Slope Stability Analysis Results Section A CITY OF WOODLAND OUTFALL LEVEE CERTIFICATION YOLO COUNTY, CALIFORNIA	PLATE C-3
Project No. C234845068	Filename: City Outfall.doc		



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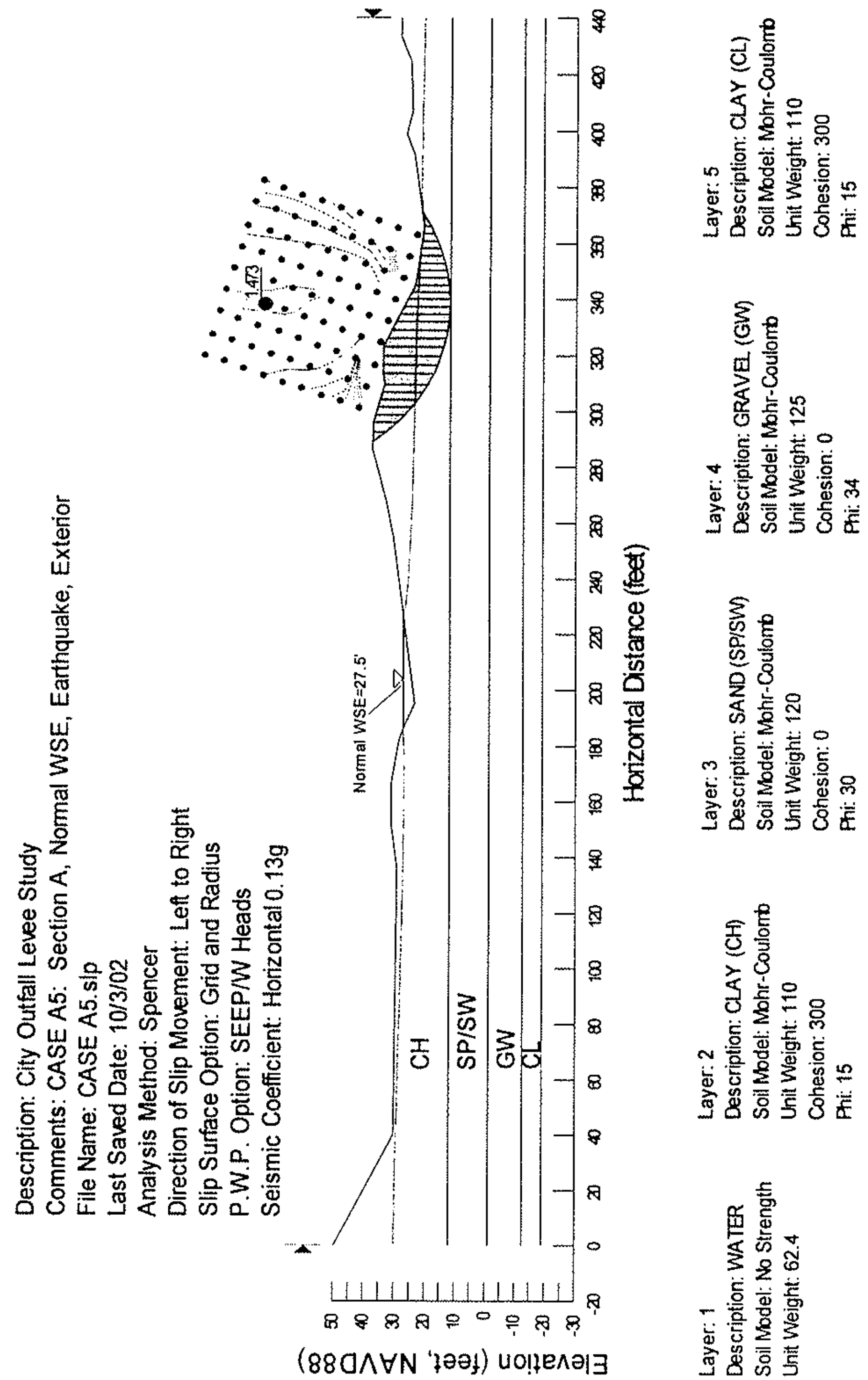

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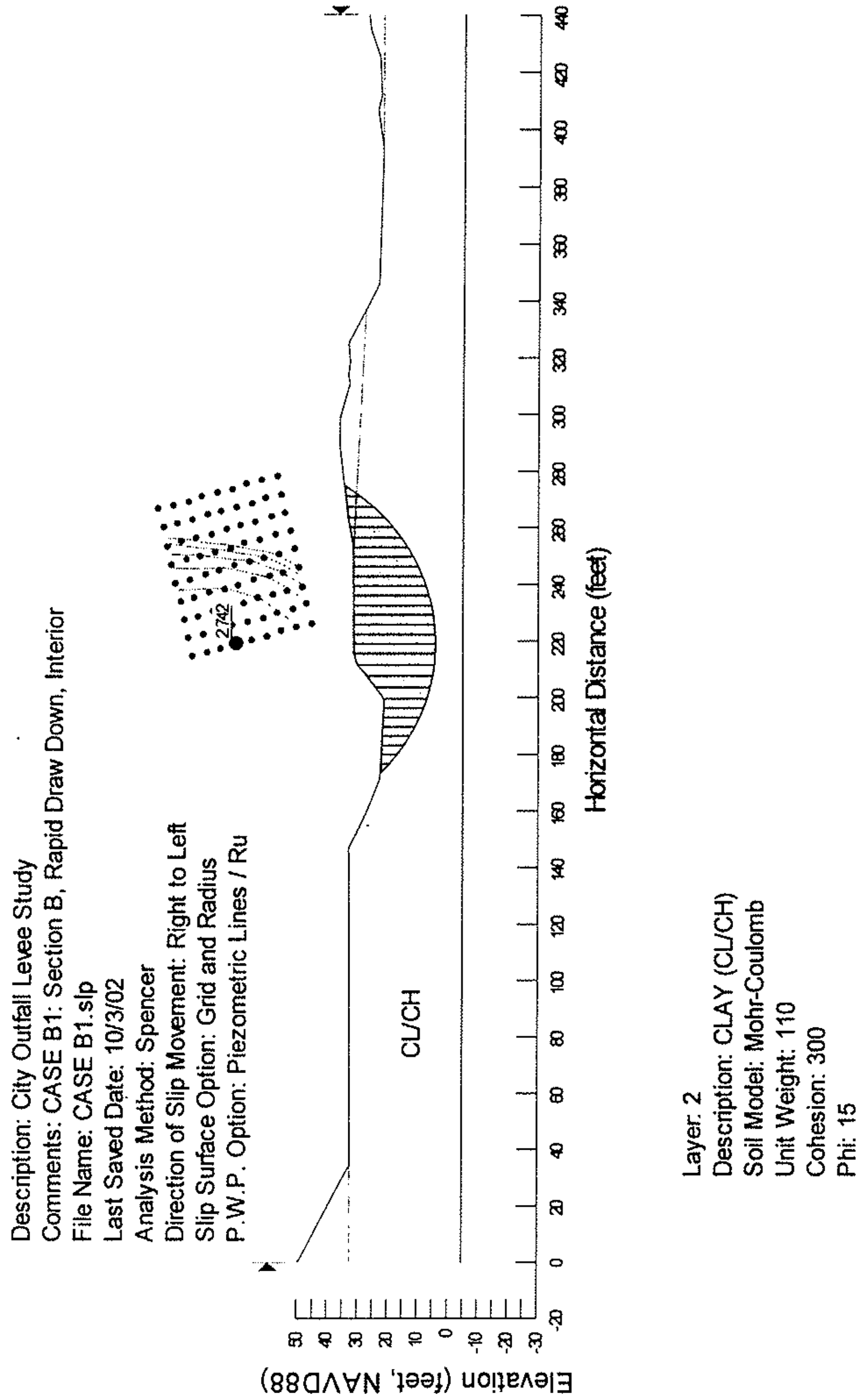
Graphic By: K. Sorensen	Date: 10-7-02
Project No. C234845068	Filename: City Outfall.doc

Slope Stability Analysis Results
Section A
CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE
C-5



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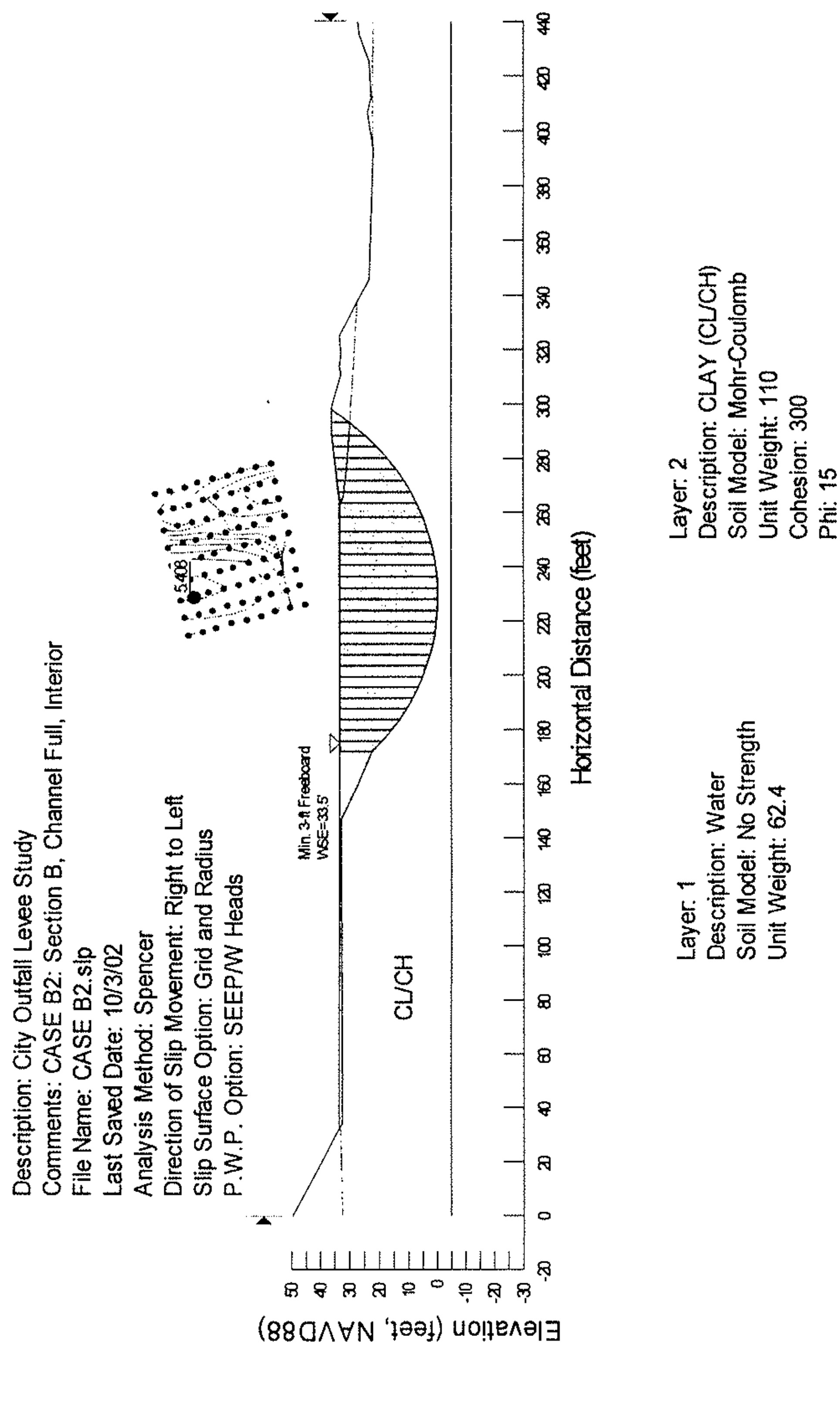

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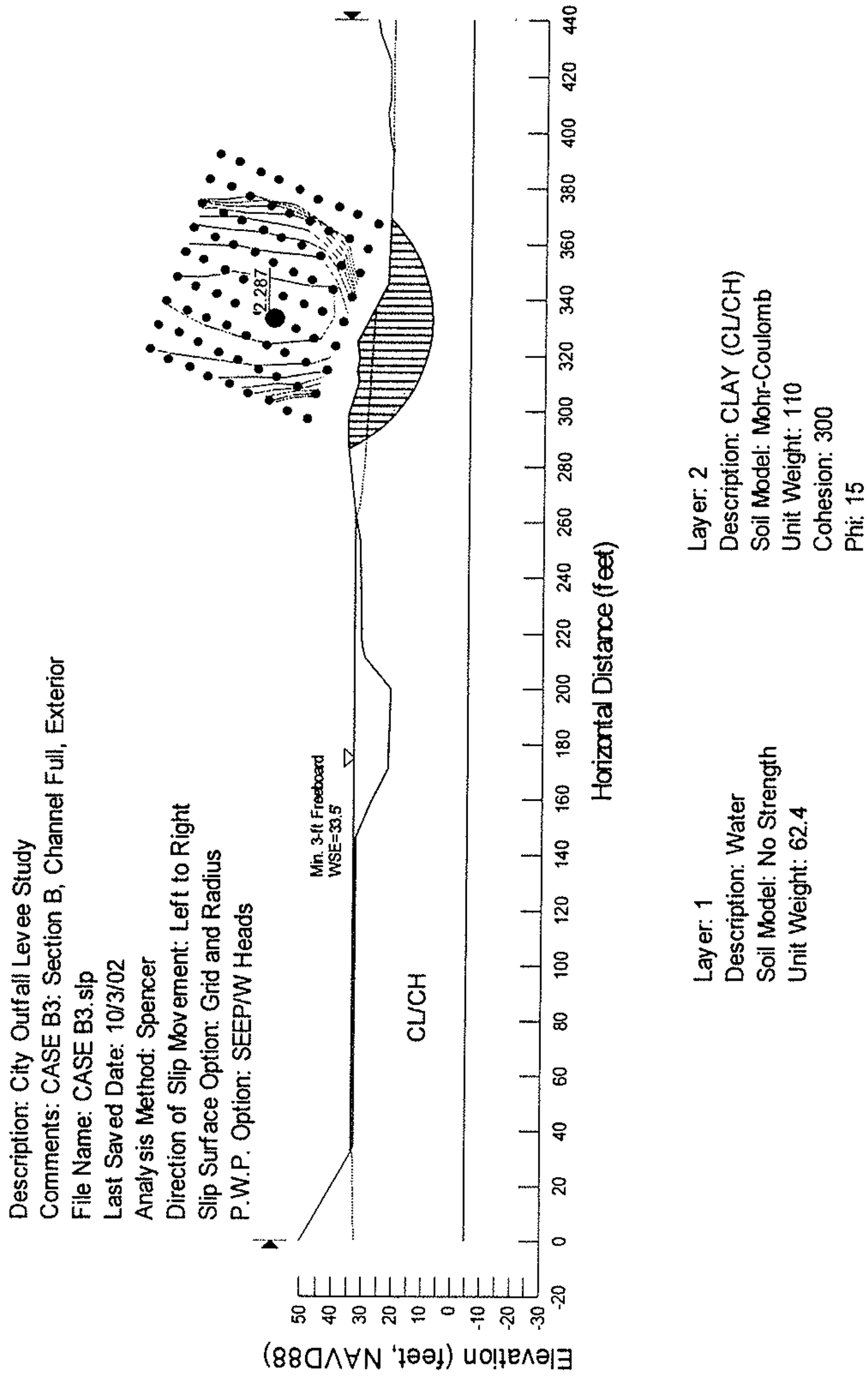
Project No. C234845068	Filename: City Outfall.doc		



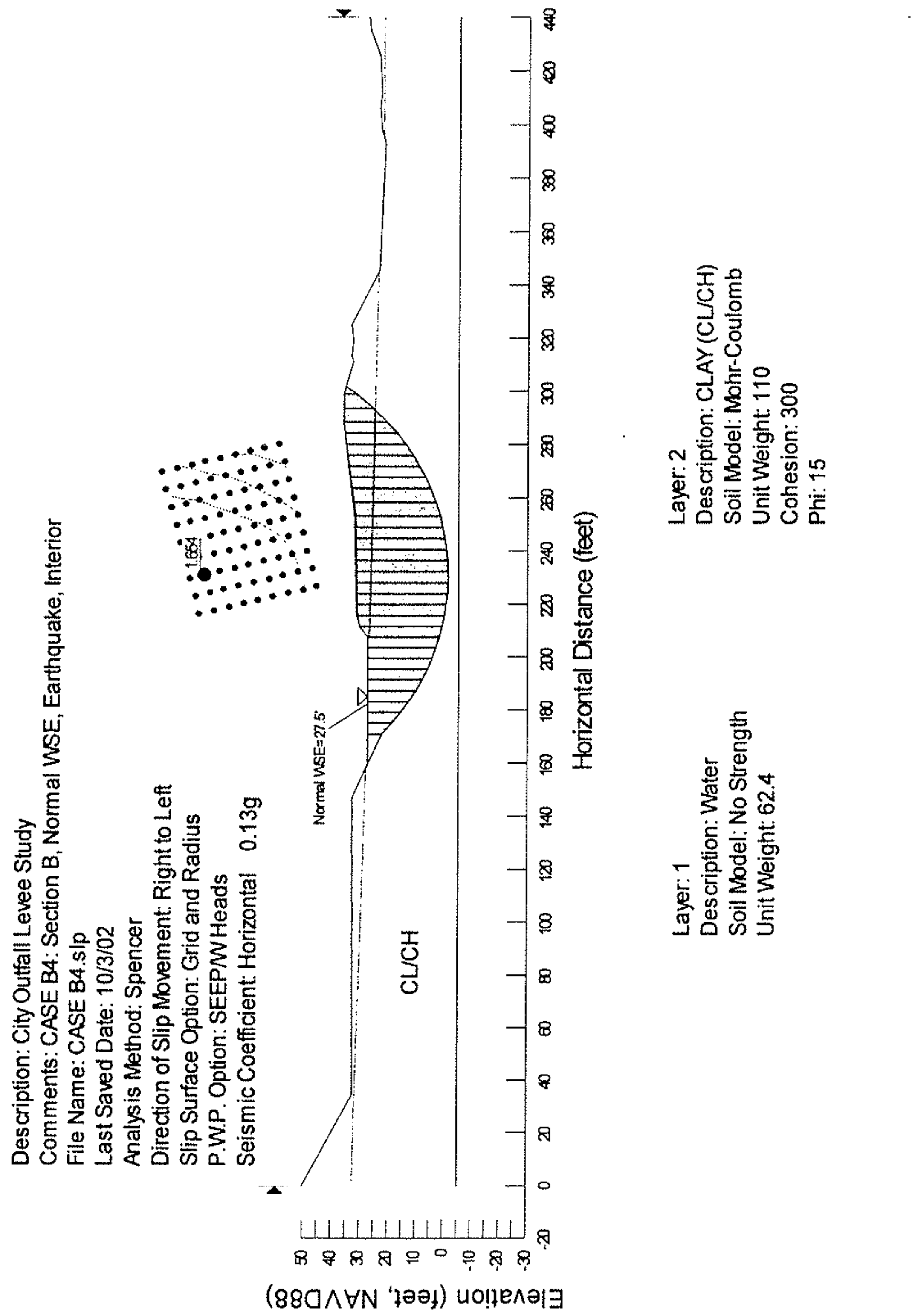
KLEINFELDER

Graphic By: K. Sorensen	Date: 10-7-02
Project No. C234845068	Filename: City Outfall.doc

Slope Stability Analysis Results
Section B
CITY OF WOODLAND
OUTFALL LEVEE CERTIFICATION
YOLO COUNTY, CALIFORNIA

PLATE

C-8



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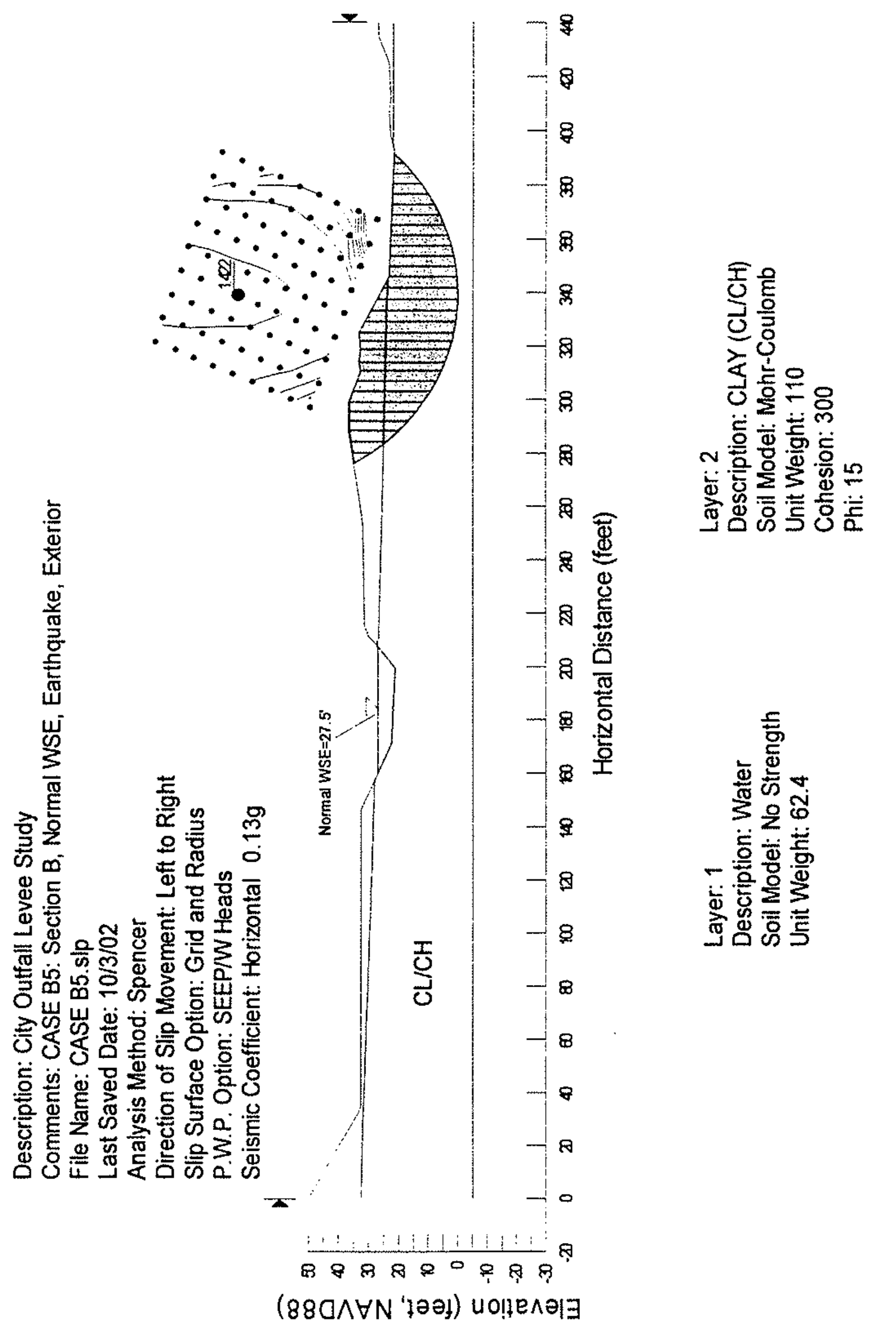
Graphic By: K. Sorensen / Date: 10-7-02		
Project No. C234845068 / Filename: City Outfall.doc		



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Graphic By: K. Sorensen	Date: 10-7-02		
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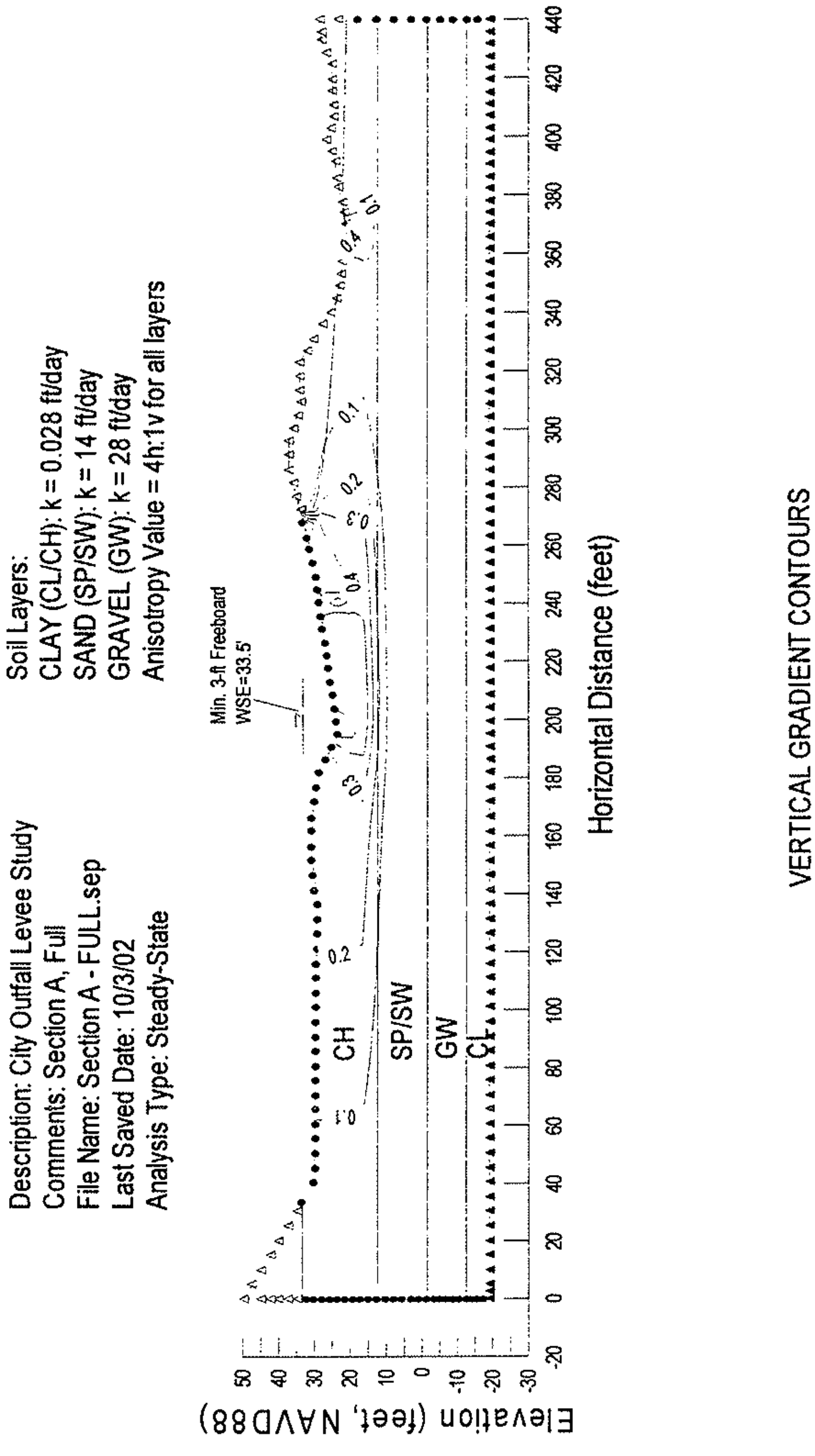

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Graphic By: B. Money	Date: 9-10-02		
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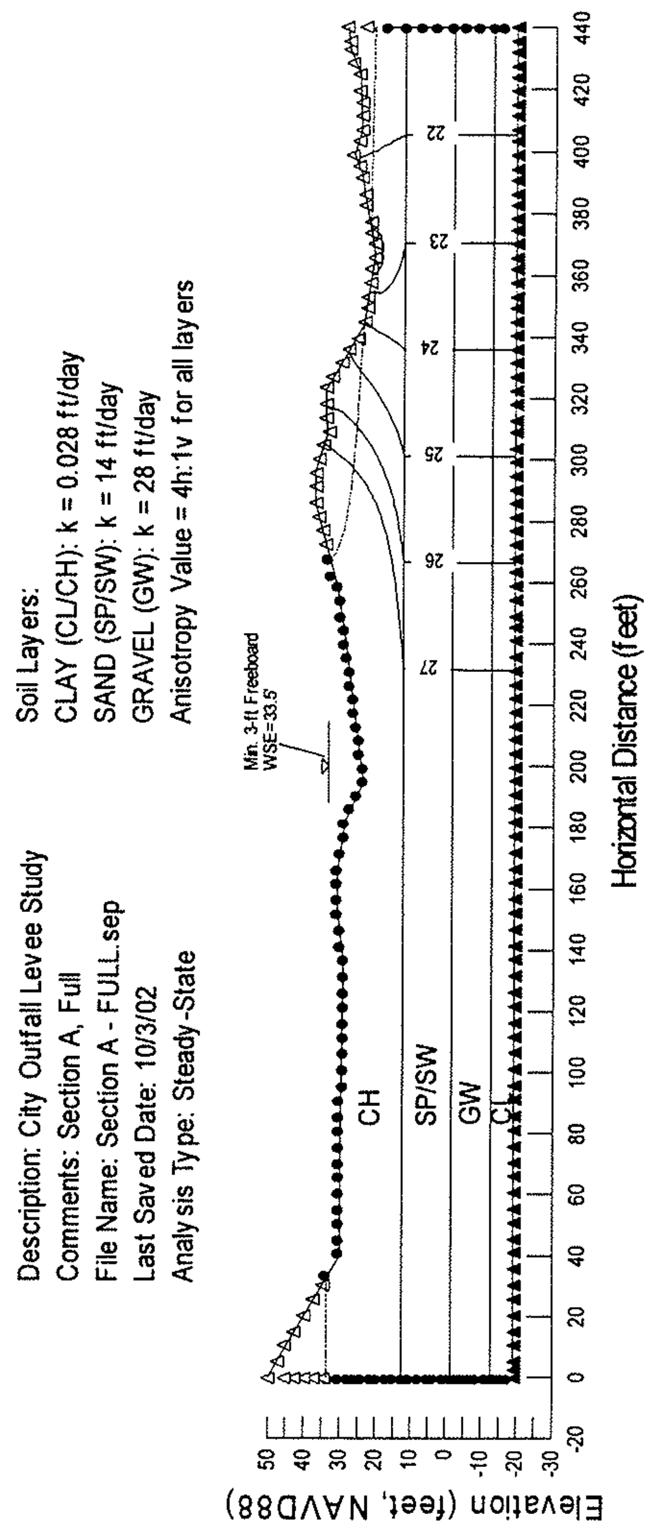

TOTAL HEAD CONTOURS

KLEINFELDER		Seepage Analysis Results Section A CITY OF WOODLAND OUTFALL LEVEE CERTIFICATION YOLO COUNTY, CALIFORNIA	PLATE C-12
Graphic By: B. Money	Date: 9-10-02		
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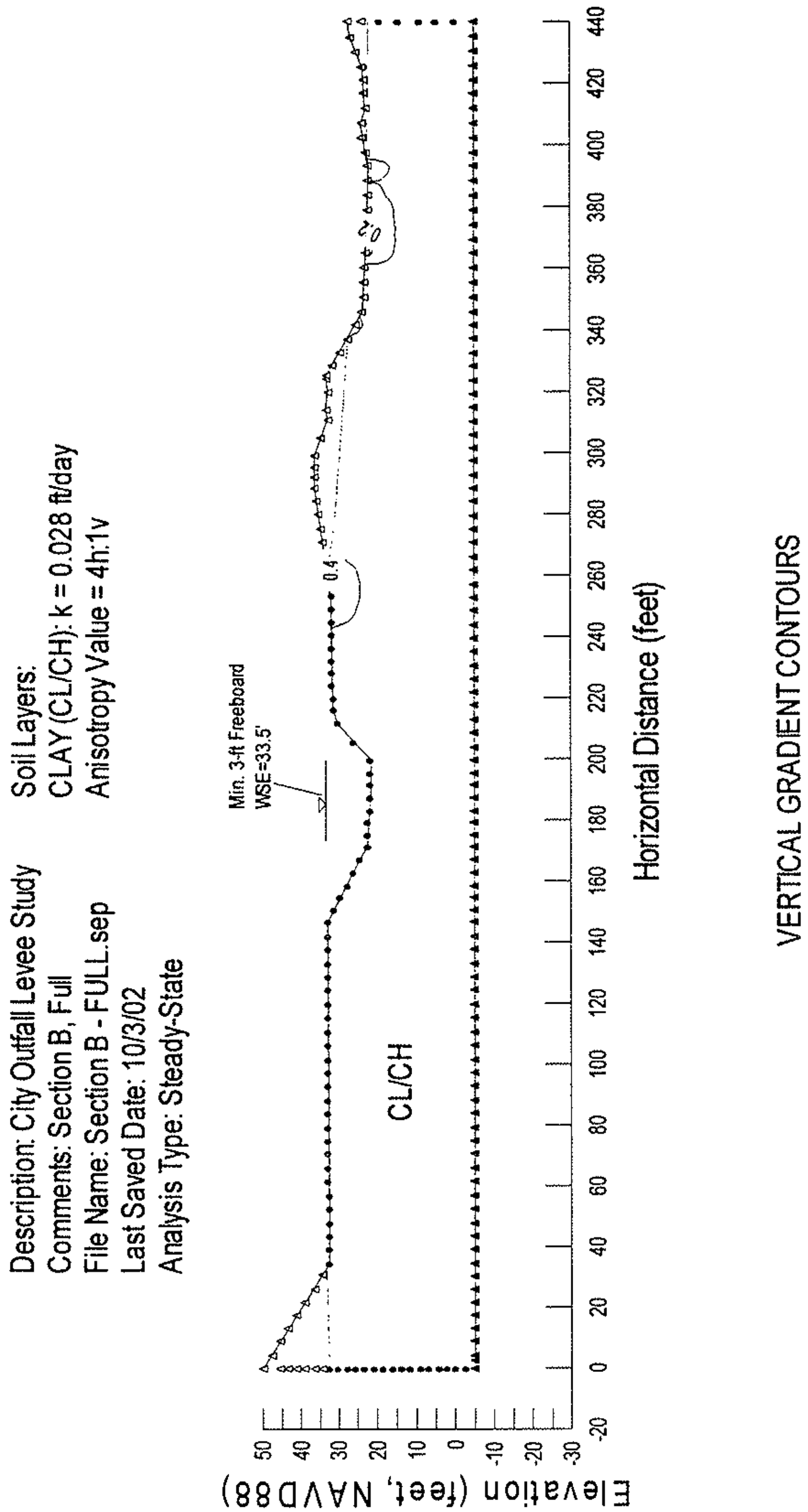

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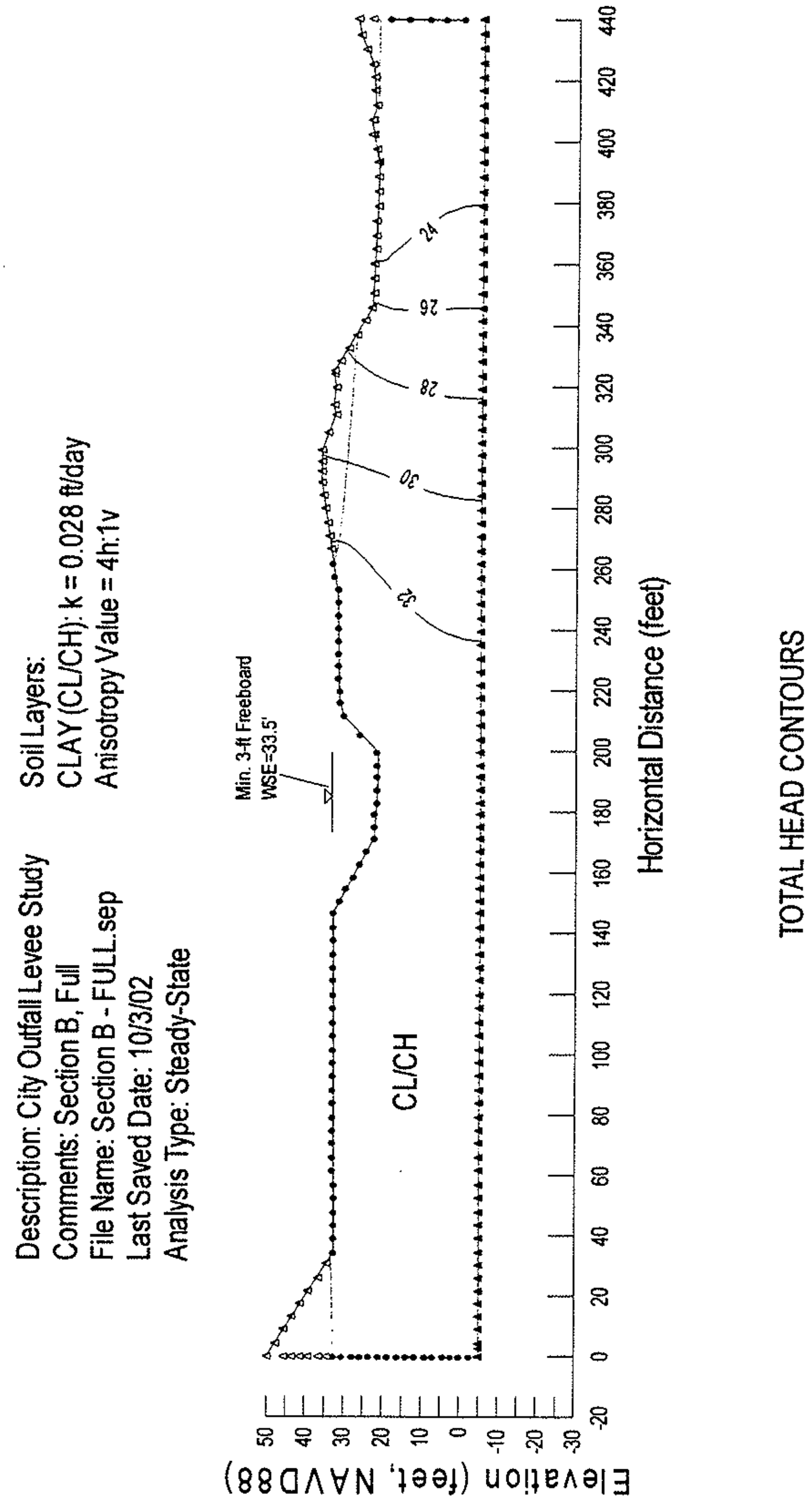

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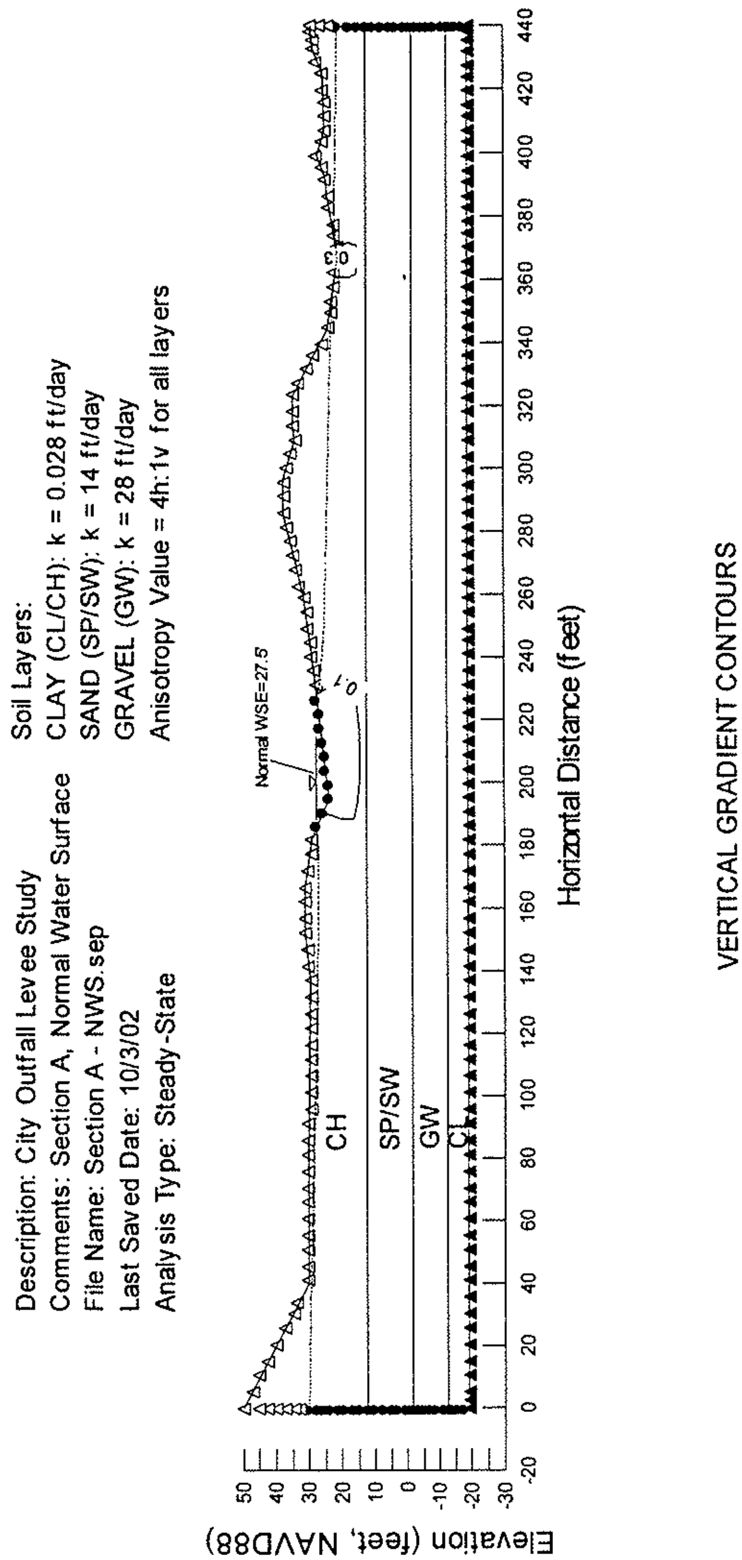

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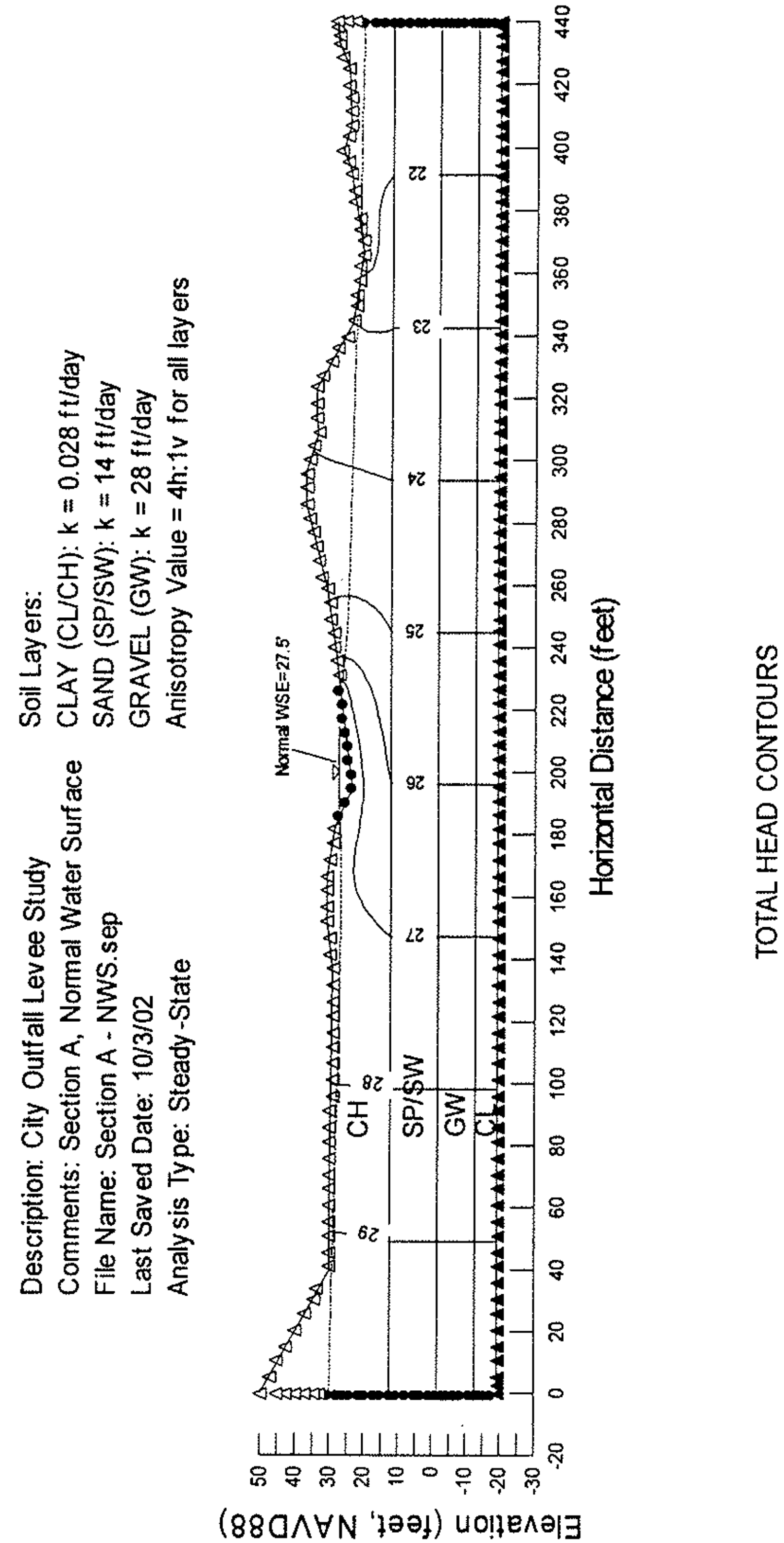
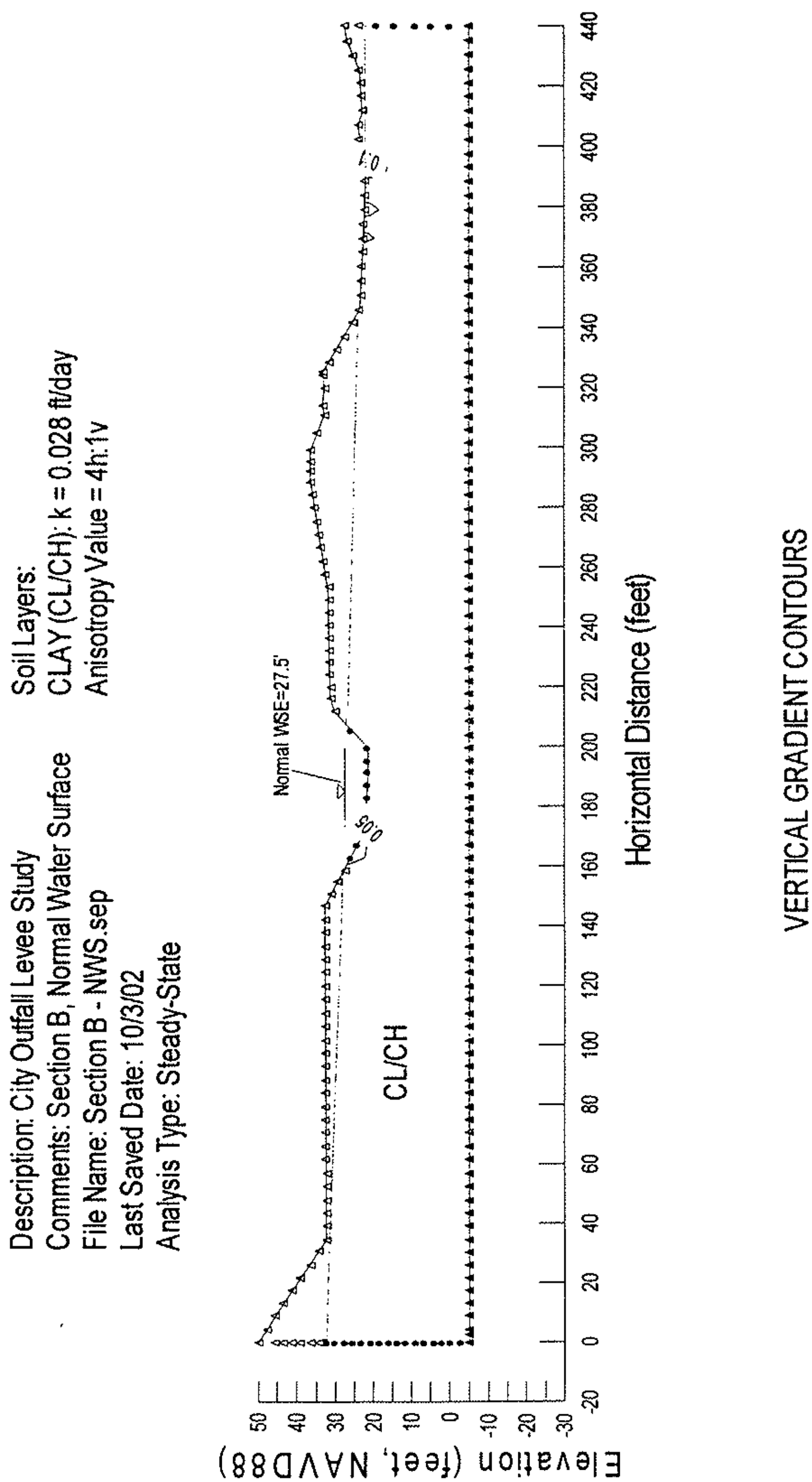


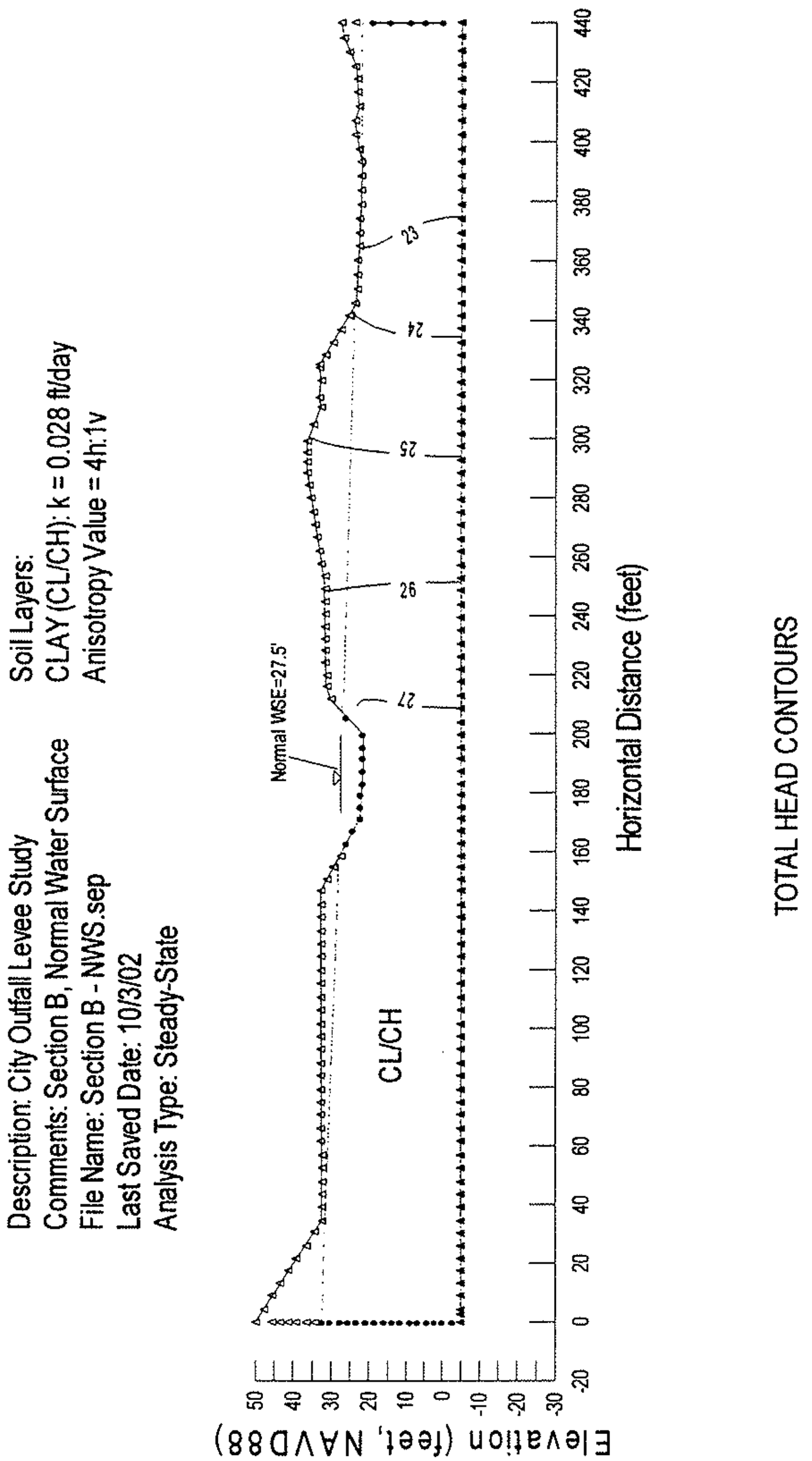
KLEINFELDER

Graphic By: B. Money	Date: 9-10-02	Seepage Analysis Results Section A CITY OF WOODLAND OUTFALL LEVEE CERTIFICATION YOLO COUNTY, CALIFORNIA	PLATE C-16
Project No. C23485068-1	Filename: City Outfall.doc		



KLEINFELDER

Graphic By: B. Money	Date: 9-10-02	Seepage Analysis Results Section B CITY OF WOODLAND OUTFALL LEVEE CERTIFICATION YOLO COUNTY, CALIFORNIA	PLATE C-17
Project No. C23485068-1	Filename: City Outfall.doc		



KLEINFELDER		Seepage Analysis Results Section B CITY OF WOODLAND OUTFALL LEVEE CERTIFICATION YOLO COUNTY, CALIFORNIA	PLATE C-18
Graphic By: B. Money	Date: 9-10-02		
Project No. C23485068-1	Filename: City Outfall.doc		

Draft
Storm Drainage Facilities Master Plan – Update and Preliminary Engineering

Environmental Permit Strategies

Prepared for:

Wood Rodgers Inc.

Prepared by:

EIP Associates

September 8, 2003

INTRODUCTION

Implementation of the major elements of the City of Woodland's Storm drainage Facilities Master Plan (SDFMP) could require federal, state, and local level resource permitting. The severity of ground disturbing activities and whether these activities impact listed plant and/or wildlife species, sensitive habitats, or affect federally or state protected waters of the U.S., including wetlands, will determine exactly which permits could be required.

The following is a brief summary of the regulatory context under which biological resources are managed at the federal, State, and local level. Agencies with responsibility for protection of biological resources in the SDFMP area include:

- U.S. Army Corps of Engineers (wetlands and other waters of the United States);
- U.S. Fish and Wildlife Service (endangered species and migratory birds);
- California Department Fish and Game (waters of the State, endangered species, and other protected plants and wildlife); and
- City of Woodland (General Plan Conservation Element Goals and Policies).

A number of federal, state, and local statutes provide a regulatory structure that guides the protection of biological resources. The following discussion provides a summary of those laws that are most relevant to biological resources in the vicinity of the SDFMP area.

Federal

U.S. Army Corps of Engineers

Under Section 404 of the Clean Water Act, the U.S. Army Corps of Engineers (Corps) has authority to regulate activity that could discharge fill or dredge material or otherwise adversely modify wetlands or other waters of the United States. Wetlands are defined by the federal government as "...those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." This definition was developed for the purpose of identifying wetlands subject to regulation under Section 404 of the Clean Water Act. Perennial and intermittent creeks are considered waters of the United States and are also within the regulatory jurisdiction of the Corps.

The Corps implements the federal policy embodied in Executive Order 11990 (May 1977), which, when implemented, is intended to result in no net loss of wetlands values or acres. In achieving the goals of the Clean Water Act, the Corps seeks to avoid adverse impacts and to offset unavoidable adverse impacts on existing aquatic resources. Any fill or adverse modification of wetlands may require a permit from the Corps prior to the start of work. Typically, permits issued by the Corps are a condition of a project as mitigation to offset unavoidable impacts on wetlands and other waters of the U.S. in a manner that achieves the goal of no net loss of wetland acres or values.

Implementation of the SDFMP could require a permit from the Army Corps of Engineers. One of three possible permit applications, Nationwide Permit (NWP), Individual Permit or Regional

General Permit. Authorization under a Nationwide Permit is designed to regulate with minimal delay or paperwork, certain activities having minimal (less than 0.5 acres or r 500 linear feet) impacts. Nationwide Permits applicable to the SDFMP include:

- NWP #2 - Structures in Artificial Canals
- NWP #3 – Maintenance
- NWP #7 – Outfall Structures
- NWP #13 – Bank Stabilization
- NWP#18 – Minor Discharges
- NWP # 32 – Temporary Construction
- NWP#34 – Maintenance Dredging of Existing Basins

If a project cannot conform to the terms and conditions of an NWP, then an "Individual Permit" may be required. An Individual Permit is granted on a case-by-case basis for specific projects impacting greater than 0.5 acres or 500 linear feet of waters of the U.S.

A "Regional General Permit" is issued for a category or categories of activities within a region, when those activities are similar in nature and cause minimal damage, and avoid duplication of regulatory control, whereas regulatory control comes from another federal agency.

An application for an "Individual Permit" from the Corps would be the most appropriate for implementation of the SDFMP, unless impacts can be limited to less than 0.5 acre, or less than 500 linear feet of waters of the U.S. If this is possible, the project could qualify for authorization under a NWP Permit.

U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service (USFWS) implements the Migratory Bird Treaty Act (16 USC Section 703-711), and the Federal Endangered Species Act (FESA; 16 USC ' 153 *et seq).* Projects that would result in "take" of any federally listed threatened or endangered species are required to obtain permits from the USFWS through either Section 7 (interagency consultation) or Section 10(a) (incidental take permit) of FESA, depending on the involvement by the federal government in permitting or funding the project. The permitting process is used to determine if a project would jeopardize the continued existence of a listed species and what mitigation measures would be required to avoid jeopardizing the species.

"Take" under federal definition means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct with regards to species listed by the federal government. Candidate species do not have the full protection of FESA; however, the USFWS advises project applicants that candidate species could be elevated to listed status at any time. For this reason, federal candidate species are addressed in this SEIR. The Federal regulations only apply to species that are listed by the federal government and not to species that are only listed by the state.

Implementation of the SDFMP could require a permit from the USFWS if the proposed project results in "take" of any federally listed threatened or endangered species. If the project has any federal connection/nexus (i.e., uses federal money or subject to Army Corps permitting), the project proponent can enter into a FESA Section 7 consultation process in order to obtain an incidental take permit. If there is no federal connection/nexus, then the project proponent must enter into FESA Section 10(a) consultation with the Fish and Wildlife Service. Therefore, if there is no federal connection/nexus, the application for a FESA Section 10 (A) incidental take permit would be the most appropriate permit for the project. The Section 10(A) process will could require preparation of a Habitat Conservation Plan (HCP). Currently, the Section 10(A) permit process is taking up to two years to complete.

State

California Department of Fish and Game

The California Department of Fish and Game (CDFG) derives its authority from the Fish and Game Code of California. Species listed under the California Endangered Species Act (Fish and Game Code Section 2050 et seq) cannot be "taken" without adequate mitigation and compensation. At present, "take" means to hunt, pursue, catch, capture, or kill, or to attempt to do so. It should be noted that at this time, based on the opinion of the California Attorney General's Office, "take" does not prohibit indirect harm by way of habitat modification. CDFG may implement endangered species protection by entering "management agreements" with project proponents.

California Fish and Game Code Sections 3503, 3503.5, and 3511 describe unlawful take, possession, or needless destruction of birds, nests, and eggs. Fully protected birds (Section 3511) may not be taken or possessed except under specific permit. Section 3503.5 of the Code protects all birds-of prey and their eggs and nests against take, possession, or destruction of nests or eggs.

Species of Special concern (CSC) is a category conferred by CDFG for those species, which are considered to be indicators of regional habitat changes, or are considered to be potential future protected species. Species of Special Concern do not have any special legal status, but are intended by CDGF for use as a management tool to take these species into special consideration when decision are made concerning the future of any land parcel.

The CDFG receives its authority to designate and protect rare plants under the California Native Plant Protection Act of 1977 (CDFG Code Section 1900 et seq). California Environmental Quality Act (CEQA) Guidelines Section 15380, defines "rare" in a broader sense than the definitions of threatened, endangered or species of special concern. Guidelines issued by the director of CDFG state that plants in CNPS 1B fulfill the criteria of "rare" under Section 15380 of the CEQA Guidelines, and should be included in environmental impact reports and mitigation. CDFG guidelines do not carry the obligations of law or regulation, but CDFG views this policy as a means to avoid project delays in addressing species issues of which the applicant was not formerly notified. CDFG can request additional consideration of species not otherwise protected under this definition.

CDFG Sections 1601 through 1603.3 of the CDFG Code prohibit alterations of any streams, including intermittent and seasonal channels and many artificial channels, without the consent of CDFG. The limit of CDFG jurisdiction is, subject to the judgment of the Department, up to the 100-year flood level. This would apply to any channel modifications that would be required to meet drainage, transportation or flood-control objects of the project. It is important to note that, in order to complete the Streambed Alteration Agreement with CDFG, there must be an approved CEQA document for the project.

The California Endangered Species Act (CESA) is similar to the FESA, but pertains to state-listed endangered and threatened plant and wildlife species. CESA requires state agencies to consult with CDFG when preparing CEQA documents in order to ensure that lead agency actions do not jeopardize listed species. It directs agencies to consult with CDFG on projects or actions that could affect listed species, directs CDFG to determine whether jeopardy would occur, and allows CDFG to identify "reasonable and prudent alternatives" to a project consistent with conserving the species. A lead agency can approve a project that affects a listed species if it is determined that there are "overriding considerations;" however, agencies are prohibited from approving projects that would cause the extinction of a listed species.

If implementation of the SDFMP results in any changes to the flow, bed channel, or bank of any river, stream, or lake (could include drainage channels, if they support substantial natural habitat components) then the project proponent is required to enter into a Streambed Alteration Agreement (Fish and Game code 1601) with CDFG.

If implementation of the SDFMP results in direct "take" of a state listed species it must conform to the California Endangered Species Act (CESA). State agencies will not approve private or public projects under their jurisdiction that would jeopardize threatened or endangered species if reasonable and prudent alternatives are available.

CESA requires that all State lead agencies (as defined under CEQA) conduct an endangered species consultation with CDFG if their actions could affect a State listed species. The State lead agency and/or project applicants must provide information to CDFG on the project and its likely impacts. CDFG must then prepare written findings on whether the proposed action would jeopardize a listed species or would result in the direct take of a listed species. Because CESA does not have a provision for "harm" (see discussion of FESA, above), CDFG considerations pursuant to CESA are limited to those actions that would result in the direct take of a listed species.

If CDFG determines that a proposed project could impact a State listed threatened or endangered species, CDFG will provide recommendations for "reasonable and prudent" project alternatives. The CEQA lead agency can only approve a project if these alternatives are implemented, unless it finds that the project's benefits clearly outweigh the costs, reasonable mitigation measures are adopted, there has been no "irreversible or irretrievable" commitment of resources made in the interim, and the resulting project would not result in the extinction of the species. In addition, if there would be threatened or endangered species impacts, the lead agency typically requires project applicants to demonstrate that they have acquired "incidental take" permits from CDFG and/or USFWS (if it is a Federal listed species) prior to allowing/permitting impacts to such species.

If implementation of the SDFMP projects results in impacts to a state listed species, an "incidental take" permit pursuant to §2081 of the Fish and Game Code would be necessary (versus a Federal incidental take permit for Federal listed species). CDFG will issue an incidental take permit only if-

1) The authorized take is incidental to an otherwise lawful activity;
2) the impacts of the authorized take are minimized and fully mitigated;
3) the measures required to minimize and fully mitigate the impacts of the authorized take:
    a) are roughly proportional in extent to the impact of the taking on the species;
    b) maintain the project applicant's objectives to the greatest extent possible; and,
    c) capable of successful implementation; and,
4) adequate funding is provided to implement the required minimization and mitigation measures and to monitor compliance with, and the effectiveness of, the measures.

State and Federal incidental take permits are issued on a discretionary basis, and are typically only authorized if applicants are able to demonstrate that impacts to the listed species in question are unavoidable, and can be mitigated to an extent that the reviewing agency can conclude that the proposed impacts would not jeopardize the continued existence of the listed species under review. Typically, if there would be impacts to a listed species, mitigation that includes habitat avoidance, preservation, and creation of endangered species habitat is necessary to demonstrate that projects would not threaten the continued existence of a species. In addition, management endowment fees are usually collected as part of the agreement for the incidental take permit(s).

The endowment is used to manage any lands set-aside to protect listed species, and for biological mitigation monitoring of these lands over (typically) a five-year period.

California Environmental Quality Act (CEQA)

Under the California Public Resources Code section 15380 of the CEQA Guidelines defines "rare" in a broad sense that includes species other than those listed as State or federally threatened or endangered. On this basis, animals or plants which may not be formally listed, but for which evidence exists that they could meet the standards for listing, could be considered rare for the purposes of impact assessment.

If implementation of the SDFMP results in significant impacts or potentially significant impacts on "rare" species the project proponent shall prepare a CEQA document that will disclose to the public the environmental impacts. The severity or magnitude of impacts or potential impacts will determine what type of environmental document would be prepared. If an Initial Study is prepared and no significant impacts are identified, then a negative declaration can be prepared. The Negative Declaration must show that there is no substantial evidence that the project or any aspects may cause a significant effect on the environment. If the initial study identifies potentially minor impacts that can feasibly mitigated then a Mitigated Negative Declaration can be prepared that identifies mitigation measures that reduce the impact to less than significant. If the project, or any aspects of the project, has impacts that would cause a significant effect on the environment then an Environmental Impact Report would be prepared.

Local

Yolo County Habitat/Natural Community Conservation Plan

The Yolo County Habitat Conservation Plan is a multispecies regional Habitat Conservation Plan (HCP) for Yolo County that mitigates planned development within the spheres of influence of the incorporated cities in the county. The HCP provides a conservation strategy to mitigate for the loss of approximately 12,000 acres of urban development in a largely agricultural region. A Steering Committee for the project is comprised of representatives from the cities of Davis, West Sacramento, Winters, and Woodland. In addition, the California Department of Fish and Game (CDGF), the U.S. Fish and Wildlife Service (USFWS), UC Davis, the Yolo County Farm Bureau, Sierra Club, and representatives from the development and business community are working to achieve a balanced solution to the preservation of habitat for 29 species. When complete, the final HCP will serve as the basis for joint permitting for a CDFG Section 2081 Management Agreement and a USFWS Section 10(a) incidental take permit.

Final approval of the HCP has been on hold since the fall of 1998. Recently, the California Department of Fish and Game has requested that Yolo County also incorporate the policies and guidelines of a Natural Community Conservation Plan (NCCP); therefore the HCP process has been re-designed as the Yolo County Habitat/Natural Community Conservation Plan. Generally, NCCP plans take a broad-based ecosystem approach to planning for the protection and perpetuation of biological diversity. An NCCP identifies and provides for the regional or area wide protection of plants, animals, and their habitats, while allowing compatible and appropriate economic activity.

The Yolo County Habitat/Natural Community Conservation Plan is in the preliminary stages of development. The Plan is overseen and directed by the Yolo County Joint Powers Agency (JPA) with an appointed director.

Implementation of the SDFMP could result in impacts to the environment; if the impacts cannot be avoided then mitigation could be required to offset the impacts. If the Yolo County Habitat/Natural Community Conservation Plan is approved and functioning, it could provide the necessary mitigation requirements for implementation of the SDFMP.

City of Woodland Tree Ordinance

The unincorporated areas of Yolo County do not have a tree ordinance or tree protection policies; however the incorporated areas of the City of Woodland is subject to a tree protection ordinance.

The following descriptions and requirements are from Chapter 20A of the City of Woodland Ordinances, which is intended to protect valuable tree resources in the City.

"Heritage tree" means any valley oak tree with a trunk diameter of thirty-three inches or more at breast height (at fifty-four inches from the ground), which is of good quality in terms of health, vigor, growth, and conformity to generally accepted horticultural standards of shape for its species.

"Landmark tree" means a tree or stand of trees which is of historical or public significance as designated by the city council upon the recommendation of both the tree commission and the historical preservation commission.

Sec. 20A-1-90. Development Projects-Tree plan.

An application for a development project shall be accompanied by a tree plan containing the following information:

(1) Contour map showing the location, size, species, and condition of all existing trees which are located upon the proposed property for development;

(2) Identification of those tree which the applicant proposes to preserve and those which are proposed to be removed and the reason for such removal;

(3) A program for the preservation of street trees, heritage, specimen, landmark trees and trees with aesthetic value (trees with a nine inch diameter or larger, measured at breast height, in healthy condition) during and after completion of the development project, as required in the city standard specifications, engineering design standards, Section 8, grading and erosion control;

(4) A program for the replacement of any trees proposed to be removed, as required by Section 20A-1-100;

(5) Any change in the trees to be saved and/or removed as designated on the approved development plan shall only be permitted upon the written approval of the director. (Ord. No. 1230, 4 (part); Ord. No. 1300, 4 (part)).

Sec. 20A-1-100. Tree Replacement Program.

A person owning or controlling a development project shall be required to replace street trees other than heritage, specimen or landmark trees, approved for removal as part of the approval of the project in accordance with subsection (1). Each heritage, specimen and/or landmark tree approved for removal shall be replaced in accordance with subsection (2).

(1) For each six inches or fraction thereof of the diameter of a tree which was approved for removal, two trees of an approved species, each of a minimum of fifteen-gallon container size shall be planted on the project site. However, an increased number of smaller size trees may be planted if approved by the director, or a fewer number of such trees of a larger size if approved by the director.

(2) For each six inches or fraction thereof of the diameter of a tree, which was approved for removal, four trees of an approved species, each of a minimum fifteen-gallon container size, shall be planted on the project site. However, an increased number of smaller size trees may be planted if approved by the director, or a fewer number of such trees of a larger size if approved by the director.

(3) If the development site is inadequate in size to accommodate the replacement trees, the trees shall be planted on pubic property with the approval of the director. Upon the request of the developer and the approval of the director, the city may accept an in-lieu payment of the current retail price per fifteen-gallon replacement tree on condition that all such payments shall be used for tree-related educational projects and/or planting programs for the city.

If implementation of the SDFMP, in incorporated areas of the City of Woodland, affects trees under the regulatory authority of the City's tree ordinance, a permit and mitigation could be required. If trees are affected in the unincorporated areas of the county there are currently no protection afforded to these trees. However, the Yolo County Tree Commission is drafting a revision of the City's current Tree Ordinance. The revision has been a lengthy process, but the county is expecting to have it in place in the next couple of months. Therefore, any trees in the unincorporated areas of the county would be afforded protection in the near future.

City Of Woodland

General Plan Goals and Policies

Chapter 7 of the *City of Woodland's General Plan Policy Document* (February 1996) contains goals, policies and implementation programs that establish the framework for the protection of valuable environmental resources in the Woodland area. The goals and policies fall under the following categories, which relate to Woodland's environmental resources.

- Water resources, to protect and enhance the natural quantity and qualities of the Woodland area's rivers, creeks, sloughs, and groundwater.
- Fish and Wildlife Habitat, to protect, restore and enhance habitats that support fish and wildlife species so as to maintain populations at viable levels.
- Vegetation, to preserve and protect the valuable vegetation resources of the Woodland Area.
- Open Space for the Preservation of Natural Resources, to preserve and enhance open space lands to maintain the natural resources of the Woodland Area.

Implementation of the SDFMP that affects the City of Woodland's valuable environmental resources shall abide by the specific goals and policies of the City's General Plan. See Appendix A for the specific goals and policies of the City's General Plan.

APPENDICES

Appendix A

City Of Woodland General Plan Policies For Natural Resources

WATER RESOURCES

The availability, quantity, and quality of water is vital to natural processes and human activities. Water is essential to the development of housing, commerce, industry, and agriculture, to recreation, and to the maintenance of high quality fish and wildlife habitats.

The Yolo Bypass and Sacramento River lie two miles east of Woodland, Willow Slough is located south of the Planning Area boundary, and Cache Creek is one mile north of the city. A groundwater aquifer underlies Woodland and serves as the City's municipal water supply. Most of these resources are regional in nature and require a cooperative effort to ensure protection of water quality in these bodies. Policies in this section seek to protect these use. Water supplies are also discussed in Chapter 4, Section 4.C., "Water Supply and Delivery."

GOAL 7.A

To protect and enhance the natural quantity and qualities of the Woodland area's rivers, creeks, sloughs, and groundwater.

POLICIES

7.A.1. The City shall cooperate with Yolo County in the conservation of Cache Creek for the protection of its water resources and its open space qualities. To this end, the City shall oppose the introduction of new potential sources of pollutants to Cache Creek.

7.A.2. The City shall monitor any activities that may degrade the aquifers of Cache Creek as it impacts City water supply and shall support the maintenance of high water quality in Cache Creek.

7.A.3. The City shall cooperate with other jurisdictions in jointly studying the potential for using surface water sources to balance the groundwater supply so as to protect against aquifer overdrafts and water quality degradation.

7.A.4. The City shall help protect groundwater resources from overdraft by promoting water conservation and groundwater recharge efforts.

7.A.5. The City shall continue to require the use of feasible and practical best management practices (BMPs) to protect receiving waters from the adverse effects of construction activities and urban runoff.

7.A.6. The City shall encourage the protection of floodplain lands and where appropriate, acquire public easements for purposes of flood protection, public safety, wildlife preservation, groundwater recharge, access and recreation.

IMPLEMENTATION PROGRAMS

7.1. The City shall monitor any activities that may degrade the aquifers of Cache Creek as it affects City water supplies.

Responsibility: Public Works Department

Time Frame: Ongoing

FISH AND WILDLIFE HABITAT

Fish and wildlife resources in the Woodland area occur in both natural and altered habitats. Habitats altered either by agricultural cultivation or urban development make up most of the Planning Area. Although altered by human activities, these areas may still be valuable for wildlife. Natural habitats in and around Woodland include Willow Slough, some riparian areas, alkali sinks, and some natural oaks.

Yolo County and the cities in the county are undertaking a comprehensive countywide Habitat Conservation Plan (HCP) to address the effects of growth throughout the county on biological resources. The primary goal of the HCP is the conservation of 29 state- and federally-listed rare, threatened, and endangered species, and species of special concern.

Policies in this section encourage the protection of important habitats and commit the City to continued participation in the HCP as a means of addressing the effects of growth on these habitats.

GOAL 7.B

To protect, restore, and enhance habitats that support fish and wildlife species so as to maintain populations at viable levels.

POLICIES

7.B.1. The City shall participate in the *countywide Habitat Conservation Plan* to mitigate the impacts of growth projected under the General Plan on wildlife habitats in the Woodland area.

7.B.2. Until the countywide *Habitat Conservation Plan* is adopted, prior to approval of discretionary development permits involving parcels within a significant ecological resource area, the City shall require, as part of the environmental review process, a biotic resources evaluation of the site by a wildlife biologist. The evaluation shall be based upon field reconnaissance performed at the appropriate time of year to determine the presence or absence of federally- or state-listed rare, threatened, or endangered species of plants or animals. Such evaluation will consider the potential for significant impact on these resources, and will identify feasible measures to mitigate such impacts or indicate why mitigation is not feasible. In approving any such discretionary development permit, the City shall determine the feasibility of the identified mitigation measures.

Significant ecological resource areas shall, at a minimum, include the following:

a. Any habitat for federally- or state-listed rare, threatened or endangered animals or plants.

b. Large areas of non-fragmented natural habitat
c. Identifiable wildlife movement zones, including but not limited to, non-fragmented stream environment zones, avian and mammalian migratory routes, and known concentration areas of waterfowl within the Pacific Flyway.

7.B.3. In connection with the countywide Habitat Conservation Plan, the City shall identify and protect significant ecological resource areas and other unique wildlife habitats critical to protecting and sustaining wildlife populations.

7.B.4. The City shall require that development in areas known to have particular value for wildlife be carefully planned and, where possible, located so that the reasonable value of the habitat for wildlife is maintained.

7.B.5. The City shall encourage the control of residual pesticides to prevent potential damage to water quality, vegetation, and wildlife.

7.B.6. The City shall support preservation of the habitats of federally- or state-listed rare, threatened, endangered, and/or other special status species. Federal and state agencies, as well as other resource conservation organizations, shall be encouraged to acquire and manage endangered species' habitats.

7.B.7. The City shall cooperate with, encourage, and support the plans of other public agencies to acquire fee title or conservation easements to privately-owned lands in order to preserve important wildlife corridors and to provide habitat protection of California Species for Concern and state or federally-listed rare, threatened, or endangered plant and animal species.

7.B.8. The City shall support and cooperate with efforts of other local, state, and federal agencies and private entities engaged in the preservation and protection of significant biological resources from incompatible land uses and development. Significant biological resources include endangered, threatened, or rare species and their habitats, wetland habitats, wildlife migration corridors, and locally-important species/communities.

7.B.9. The City shall support the management efforts of the California Department of Fish and Game to maintain and enhance the productivity of important fish and game species by protecting identified critical habitat for these species from incompatible suburban, rural residential, or recreational development.

IMPLEMENTATION PROGRAMS

7.2 In conjunction with Yolo County and other cities in the county, the City shall adopt the countywide *Habitat Conservation Plan* to mitigate the impacts of projected growth on plant and wildlife habitats in the Woodland area.

Responsibility: Community Development Department
Planning Commission
City Council

Time Frame: FY 95-96

VEGETATION

Like fish and wildlife habitat, the diverse stands of vegetation in Woodland include both native and non-native species. Named because of the abundance of native oaks in the city, Woodland is still the "City of Trees," although most are now non-native varieties.

Policies of this section support the preservation of important plant species, and promote the use of native species where possible in new development and landscaping.

GOAL 7.C
To preserve and protect the valuable vegetation resources of the Woodland area.

POLICIES

7.C.1. The City shall participate in the countywide *Habitat Conservation Plan* to mitigate the impacts of growth projected under the General Plan on vegetation habitats in the Woodland area.

7.C.2. The City shall encourage landowners and developers to preserve natural vegetation in visually-sensitive areas and along important transportation corridors.

7.C.3. The City shall require developers to use native and compatible non-native species, especially drought- resistant species, to the extent possible in fulfilling landscaping requirements imposed as conditions of permits or for project mitigation.

7.C.4. The City shall support the preservation of outstanding areas of natural vegetation, including, but not limited to, oak woodlands, riparian areas, and vernal pools.

7.C.5. The City shall ensure that landmark trees and major groves of native trees are preserved and protected. In order to maintain these areas in perpetuity, protected areas shall also include younger vegetation with suitable space for growth and reproduction.

7.C.6. The City shall establish procedures for identifying and preserving rare, threatened, and endangered plant species that may be adversely affected by public or private development projects, including those identified by the countywide Habitat Conservation Plan.

7.C.7. The City shall encourage the conservation of sufficiently large, continuous expanses of native vegetation to provide suitable habitat for maintaining abundant and diverse wildlife.

7.C.8. The City shall support the management of wetland and riparian plant communities for passive recreation, groundwater recharge, nutrient catchment, and wildlife habitats. Such communities shall be restored or expanded, where possible and as appropriate.

7.C.9. The City shall require that new development preserve natural woodlands to the maximum extent possible.

7.C.10. The City shall encourage the planting of native trees, shrubs, and grasslands in order to preserve the visual integrity of the landscape, provide habitat conditions suitable for native wildlife, and ensure that a maximum number and variety of well-adapted plants are maintained.

7.C.11. The City shall require that new development avoid, as much as possible, ecologically-fragile areas (e.g., areas of rare or endangered species of plants, riparian areas, alkali sinks). Where feasible, these areas should be protected through public acquisition of fee title or conservation easements to ensure protection.

IMPLEMENTATION PROGRAMS

See Implementation Program 7.2

OPEN SPACE FOR THE PRESERVATION OF NATURAL RESOURCES

Part of the enjoyment of Woodland is its open space resources, both manmade and natural. Woodland's open space resources include parks, mature trees in the neighborhoods and along roadways, the agricultural lands surrounding Woodland, and surrounding elements of the natural environment. Other goals and policies related to open space can be found in the "Agriculture" and "Landscaping and Streetscaping" sections of Chapter 1.

GOAL 7.D

To preserve and enhance open space lands to maintain the natural resources of the Woodland area.

POLICIES

7.D.1. The City shall support the preservation and enhancement of natural land forms, natural vegetation, and natural resources as open space to the maximum extent feasible. The City shall, where appropriate, permanently protect as open space areas of natural resource value, including wetlands preserves, riparian corridors, woodlands, and floodplains.

7.D.2. The City shall require that new development be designed and constructed to preserve significant stands of vegetation and any areas of special ecological significance as open space to the maximum extent feasible.

7.D.3. The City shall support the maintenance of open space and natural areas that are interconnected and of sufficient size to protect biodiversity, accommodate wildlife movement, and sustain ecosystems.

7.D.4. Where it does not conflict with wastewater treatment requirements and public safety, the City shall consider allowing areas at the wastewater treatment plant site to function as plant and wildlife habitat and, where feasible, shall provide public access to these areas.

7.D.5. The City shall encourage the development of natural open space areas in regional, community, and neighborhood parks.

7.D.6. The City shall serve as the steward of public open space and ensure that the use and maintenance of the open space is carried out in an environmentally responsible manner.

7.D.7. The City shall plan and establish natural open space parkland as a part of the overall City park system.

7.D.8. The City shall manage, enhance, and improve the City's tree cover as a valuable community resource.

7.D.9. The City shall investigate the benefits of annexing to th Resource Conservation District.

Draft

Tule Canal and Railroad Trestle Erosion Control Methods

Prepared for:

Wood Rodgers, Inc.

Prepared by:

EIP Associates

September 10, 2003

Introduction

During the winter rainy season, water normally exits Woodland's storm-drainage canal along the north side of County Road 22, crosses under the road through culverts and flows eastward along the south side of the road. During high precipitation events, however, these canals reach their capacity and overflow, producing overland sheet-flows that travel eastward, across the Yolo Bypass, into the Tule Canal. At these times, erosion can occur around the base of the railroad trestle and along the west bank of the Tule Canal.

Soil movement associated with erosion can also impact water quality and fish habitat in the Yolo Bypass. Loss of topsoil can adversely affect growth of native vegetation and agricultural crops and can encourage the growth of non-native, invasive plants and weeds. The Yolo Bypass also provides important habitat and resources for large numbers of migrating and over-wintering waterfowl, as well as the federally-listed giant garter snake and state-listed Swainson's hawk.

Ground-stabilization measures and erosion control Best Management Practices (BMPs) can be implemented to minimize erosion, protect water quality, reduce further damage along the railroad trestle and west bank of the Tule Canal, and ultimately, to prevent catastrophic failure of either the railroad trestle or County Road 22.

Because the Yolo Bypass falls under the regulatory authority of the Army Corps of Engineers, resource permits may be required for some of the ground-disturbing activities associated with the erosion control BMPs and bank stabilization measures. It is likely that some mitigation will be required to offset any potential impacts to giant garter snake and Swainson's hawk habitat in these areas.

Timing of Work

In general, maintenance and construction activities that remove vegetative soil cover and/or will potentially release sediment into storm water will be conducted during the dry season (Approximately April through October).

Activities that are subject to permit requirements will be conducted during the period authorized by the permits.

Bare soil surfaces resulting from maintenance, implementation of BMPs, and/or construction activities shall be covered with suitable erosion controls (fabric, mulch, hydro seeding, etc.):

- No later than 3 days following the disturbance during the rainy season (approximately November through March)

- No later than seven days following the disturbance during the dry season (approximately April through October)

Every effort shall be made be made to immediately cover bare soil surfaces resulting from implementation of BMPs.

BMPs

Specific bank and levee stabilization measures that can be applied to prevent further erosion to the railroad trestle and west bank of the Tule Canal include:

- Asphalt Berms
- Live-staking
- Sandbags
- Diversion Berm
- Rip Rap
- Energy Dissipator

Below are brief description of these measures that could minimize further damage to the bank of the Tule canal and railroad trestle.

BMP:

ASPHALT BERM

DESCRIPTION

An asphalt berm is a ridge of asphalt concrete or "cutback" constructed at the top of a disturbed slope. The purpose of the BMP is direct stormwater runoff away from an unstable slope.

APPLICATIONS

This BMP may be used wherever stormwater runoff must be diverted away from a disturbed slope and toward a sediment containment facility or stable runoff.

LIMITATIONS

This BMP should not be used:

- ✓ to concentrate runoff onto unstable, eroded areas.

CONSTRUCTION GUIDELINES

- ✓ Construct asphalt berm to the minimum height and width needed to divert runoff without adding unnecessary weight.
- ✓ Asphalt berms may be striped or marked for traffic safety.
- ✓ Asphalt berms may be used to anchor temporary plastic sheeting.

BMP MAINTENANCE

- ✓ Periodic inspection should be conducted, and berms repaired as necessary.

BMP REMOVAL

- ✓ Asphalt berm removal may not be necessary, or may be conducted during permanent slope or streambank repair activities.
- ✓ Recycle or reuse asphalt berm material if applicable.
- ✓ Dispose of plastic sheeting if applicable.

BMP:
LIVE STAKING

DESCRIPTION

Live staking involves the insertion of live, vegetative cuttings into the ground in a manner that allows the cutting (stake) to take root and grow. This BMP is used to reduce the potential for soil to become water borne, to reduce water velocity/erosive forces, and to aid in habitat protection.

APPLICATIONS

This BMP may be used to repair small slips and slumps, to reinforce or enhance stream banks, and to anchor and enhance the effectiveness of wattles, fascines, straw logs and other erosion control materials. It may also be used in conjunction with approved rip rap installations (vegetated rip rap).

LIMITATIONS

This BMP should not be used:

- ✓ where vegetation growth will interfere with maintenance or facility access.
- ✓ where vegetation growth will create safety issues.
- ✓ for immediate soil stabilization results.

CONSTRUCTION GUIDELINES

Live staking must be implemented during the dormancy period of chosen plant species, late fall to early spring. If native willows or cottonwood are not found in the vicinity, live staking may not be a good option. Cuttings should generally be ¾ inch in diameter or larger depending on the species. Cuttings of small diameter (up to 1- ½ inches) shall be 18 inches long minimum. Poles should be 1.5-3.5 inches diameter and 6-8 feet long. The actual length of cuttings depends on the application but the cutting should be long enough to reach into moist soils in mid-summer or the capillary fringe.

Stakes must not be allowed to dry out. All cuttings should be soaked in water for a minimum of 24 hours. Soaking significantly increases the survival rate of the cuttings, however they must be planted the same day they are removed from water.

Use an iron stake or bar to make a pilot hole in firm soil. Plant the stakes butt-ends into the ground, with the leaf bud scars or emerging buds always pointing up. Be careful not to damage the buds, strip the bark or split the stake during installation. The stakes should not be planted in rows or at regular intervals, but at random in the most suitable places at a rate of 2-5 cuttings/square yard.

Set the stake as deep as possible into the soil, preferably with 80 percent of its length into the soil and in contact with mid-summer moist soils. The stake should protrude only to a maximum of one-quarter its length above the ground level to prevent it from drying. Stakes should be cut so that cutting extends above competing herbaceous vegetation. At least 2 buds and/or bud scars shall be above the ground after planting. It is essential to have good contact between the stake and soil for roots to sprout. Tamp the soil around the cutting. Do not fertilize.

BMP MAINTENANCE

- ✓ Periodic inspection, repair and maintenance will be done in accordance with permit requirements. If no permits are required, vegetation will be monitored for the first two years or until the vegetation is established.
- ✓ Staked area may need to be watered during summer months.

BMP REMOVAL

- ✓ BMP removal is not necessary.

BMP:
SANDBAG

DESCRIPTION

A sandbag is a pre-manufactured cloth or plastic bag filled with sand or gravel. Sandbags can be used to keep water away from work areas and unstable slopes, and to construct curb inlet sediment barriers. Sandbags are also used as protection against flooding, as ballast, and in the construction of cofferdams and clean water bypasses.

APPLICATIONS

This BMP may be used during emergencies to control the flow and level of water. it may be used during construction to form dewatered areas such as cofferdams and clean water bypasses.

LIMITATIONS

This BMP should not be used:

- ✓ where prohibited by permit conditions.
- ✓ as a permanent structure.

CONSTRUCTION GUIDELINES

- ✓ When used in water bodies, this BMP must be used in accordance with permit conditions.
- ✓ Secure ends of sandbags to ensure material does not scatter.
- ✓ When used as a barrier, stack bags tightly together and in alternative (brick-layer) fashion.

BMP MAINTENANCE

- ✓ During construction, inspect daily during the workweek. Schedule additional inspections during storm events. Make any required repairs.
- ✓ Replace damaged sandbags.
- ✓ Remove sediment when deposits reach ½ the height of the sandbag barrier.

BMP REMOVAL

- ✓ Evaluate site to determine when BMP is no longer needed.
- ✓ Remove sediment buildup in front of BMP.
- ✓ Remove BMP, recycle and/or re-use if applicable.
- ✓ Revegetate area disturbed by BMP removal.
- ✓ Material in sandbags may be spread on slopes and stable areas where allowed by permit conditions.

BMP:
DIVERSION BERM

DESCRIPTION

A diversion berm is a temporary ridge of compacted soil or aggregate base material, sandbags or continuous bag berm constructed at the top or base of a disturbed slope. The purpose of the BMP is direct stormwater runoff away from an unstable slope.

APPLICATIONS

This BMP may be used wherever stormwater runoff must be temporarily diverted away from a disturbed slope and toward a sediment containment facility or stable runoff.

LIMITATIONS

This BMP should not be used:

- ✓ in fast flowing water.
- ✓ as a replacement for failing roadway shoulders.
- ✓ as slide debris storage within 150' of any water body.

CONSTRUCTION GUIDELINES

- ✓ Berm material should be adequately compacted to prevent failure.
- ✓ Temporary seeding and mulch shall be applied to all surfaces of a soil diversion berm according to the "Timing of Work" BMP.

BMP MAINTENANCE

- ✓ Periodic inspection should be conducted, and berms repaired as necessary.

BMP REMOVAL

- ✓ Evaluate site to determine BMP is no longer needed (the area has stabilized – potential of sediment laden water exiting the area has passed).
- ✓ Remove sediment buildup.
- ✓ Remove BMP – recycle and/or re-use if applicable.
- ✓ Revegetate area disturbed by BMP removal if applicable.

BMP:
RIP RAP

DESCRIPTION

Rip rap is a structural method appropriate for supporting slopes and/or reducing erosion in areas where biotechnical methods are unsuitable and where engineered retaining structures are unnecessary.

APPLICATIONS

Rip rap may be used to stabilize steep slopes with seepage problems and/or unstable soils that need armoring to prevent sloughing. This BMP shall only be used as a last resort in locations where planting or other stabilizing methods are impracticable. Rip rap may also be used in combination with biotechnical BMPs.

Rip rapped areas should be evaluated for finishing with topsoil and revegetation to improve the drainage capacity of the fill and the stability of the rip rap matrix.

LIMITATIONS

- ✓ Rip rap shall not be used as a stand-alone method of streambank stabilization.
- ✓ Permits must be obtained prior to placing any rip rap below the mean high water line of any water body, or in other sensitive areas.

CONSTRUCTION GUIDELINES

- ✓ Perform live staking or pole planting during rip rap placement as appropriate.
- ✓ Place rip rap to its full thickness in one operation.
- ✓ The toe of the riprap slope should be keyed to a stable foundation at its base.
- ✓ Schedule topsoil and revegetation finish work at an appropriate time or year.

BMP MAINTENANCE

- ✓ Riprap should be inspected periodically for scour or dislodged stones and repairs made immediately.

BMP REMOVAL

- ✓ BMP removal should not be necessary.

BMP:

ENERGY DISSIPATER

DESCRIPTION

An energy dissipater is a structure designed to control erosion at the outlet of a channel or conduit by reducing the velocity of flow and dissipating the energy.

APPLICATIONS

This BMP is required at the outlet of any new or replacement drainage culvert. Existing culverts shall be evaluated and upgrades (energy dissipater installations) scheduled as appropriate.

The outlets of channels, conduits, and other structures are points of high erosion potential. To prevent scour and undermining, an outlet stabilization structure is needed to absorb the impact of the flow and reduce the velocity to non-erosive levels.

A riprap-lined apron is a commonly used practice for this purpose because of its relatively low cost and ease of installation. The riprap apron should be extended downstream until stable conditions are reached, even though this may exceed the length calculated for design velocity control. Down drains and flumes may also be used as energy dissipaters. Rock aprons may also be required below down drains and flumes depending on slope steepness and soil conditions.

LIMITATIONS

- ✓ This BMP shall not be used below the mean high water line of any water body unless permits have been obtained.
- ✓ Consider other energy dissipaters such as concrete impact basins or paved outlet structures where site conditions warrant.
- ✓ Rock/rip rap dissipaters may require containment in gabion baskets or mattresses to maintain their effectiveness.

CONSTRUCTION GUIDELINES

- ✓ Berm material should be adequately compacted to prevent failure.
- ✓ Temporary seeding and mulch shall be applied to all surfaces of a soil diversion berm according to the "Timing of Work" BMP.

BMP MAINTENANCE

- ✓ Inspect outlet structures after heavy rains to see if any erosion around the structures has taken place or if stones have been dislodged. Immediately make all needed repairs to prevent further damage.

- ✓ Clean flumes as necessary.

BMP REMOVAL

- ✓ BMP removal should not be necessary.

Draft

Environmental Opportunities and Constraints Analysis

for the

City of Woodland's Drainage Plan Update

September 2003

Prepared for:
Wood Rodgers, Inc.

Prepared by:
EIP
ASSOCIATES

Environmental Opportunities and Constraints Analyses for the City of Woodland's Drainage Plan Update and Implementation Plan

INTRODUCTION

This report provides the City of Woodland (City) with preliminary information regarding biological opportunities and constraints associated with drainage improvements to Woodland's storm water outfall channel (Project Site). Specifically, the report identifies areas suitable for drainage improvements and areas that could pose a constraint to drainage improvements.

The Project Site is a run-off channel or flood control conveyance channel, designed to accommodate stormwater and urban runoff from the City of Woodland. In order to prepare an update to the City of Woodland's Drainage Master Plan and an Implementation Plan, the City initially investigated the potential for the conjunctive use of the Project Site for flood control and natural areas and/or open space. The City quickly recognized the benefit of additional information on the biological opportunities and constraints of the project channel to the planning process. This report is, therefore, intended to provide such additional information as part of the City's decision-making process.

Habitats within the Project Site are characterized in terms of predominant vegetation associations or plant communities and wetlands. They are also discussed in terms of their potential to support resident and migratory wildlife and rare, threatened, or endangered species (special-status species). For consistency, on-site habitats are classified using the system developed for the Draft Yolo County Habitat Conservation Plan (Yolo HCP). A description of special-status plant and animal species and their habitat requirements is also provided, along with the potential for their occurrence at the Project Site.

EXISTING CONDITIONS

The Outfall Channel (Channel) begins at the East Main Pump Station at the intersection of Yolo County Road 103 and County Road 22, approximately 1/4 mile north of Interstate 5, on the eastern edge of the industrial zone of the City of Woodland. The East Main Pump Station is currently connected to the City of Woodland's North and South Drainage Canals. From the east side of the Pump Station, just north of the railroad tracks (parallel to County Road 22) and south of the Cache Creek Settling Basin levee, the Channel flows eastwards for approximately two miles, to the western levee of the Yolo Bypass.

The approximately 50-acre Project Site is within the U.S. Geological Survey (USGS) 7.5-minute series topographic map for Grays Bend, California (1953, photorevised 1968 and 1975). It is bounded by County Road 22 and the Yolo Short Line Railroad track to the south; Cache Creek Settling Basin to the north; and the west levee of the Yolo Bypass to the east. At an elevation of 20 to 25 feet above sea level, the Channel's topography is fairly level, with approximately 45 degree slopes on either bank. Agricultural lands, consisting mostly of row crops and rice fields, immediately surround the Project Site, which itself is a constructed channel that shows little evidence of recent disturbance.

METHODOLOGY

<u>Review of Existing Information</u>

Documented information pertinent to biological and wetland resources of the Project Site were compiled, reviewed, and analyzed prior to the field survey, including:

- U.S. Geological Survey Topographic Map (7.5-minute series) for Grays Bend, California. (1953, photorevised 1968 and 1975);
- Aerial Photograph of the Project Site (Aerial Photobank, flown July 2003), Digital Sky Aerial Imaging;
- *Preliminary Descriptions of the Terrestrial Natural Communities of California* (Holland 1986);

- *List of California Terrestrial Natural Communities Recognized by the California Natural Diversity Data Base.* California Department of Fish and Game, Wildlife and Habitat Date Analysis Branch;
- The Jepson Manual of Higher Plants of California (Jepson Manual 1993);
- Yolo County Soils List; and
- Hydric Soils List (USDA 1991).
- California Natural Diversity Data Base (CNDDB [Rare Find]) records for the Grays Bend, Sacramento West, Davis, and Taylor Monument USGS 7.5-minute Quadrangle topographic maps;
- *Draft Yolo County Habitat Conservation Plan.* EIP Associates, 2001;
- *Draft Supplemental Program Environmental Impact Report for the Cache Creek Resource Management Plan and Project-Level Environmental Impact Report for the Cache Creek Improvement Program.* Aspen Environmental Group, April 2002.
- *Final Biological Resources Assessment and Special Status Species Surveys – Spring Lake Drainage Park Plan Sites*, Yolo County, CA. Foothill Associates, July 2002.
- *Draft Preserve Management Plan for the Spring Lake Drainage Park, Yolo County*, Foothill Associates March 2003;
- *Stormwater Drainage Facilities Master Plan Technical Memorandum, Spring Lake Specific Plan*, Borcalli and Associates, November 16 2001; and
- *City of Woodland Treatment Wetland Feasibility Study*, CH_2M HILL, November 2002.
- *Storm Drainage Facilities Master Plan, City of Woodland*, Borcalli and Associates, December 1999.

The potential occurrence of special-status species was researched within an approximate 10-mile radius of the Project Site – a sufficient distance to accommodate regional habitat diversity and to overcome the limitations of the CNDDB, which contains only recorded occurrences, but does not constitute an exhaustive inventory of every resource.

Field Reconnaissance

Field surveys were conducted to identify suitable habitat for potentially-occurring special-status species or sensitive biological resources. EIP Staff biologists Ron Walker and Emily Keller conducted a reconnaissance-level foot survey of the Project Site on July 10, 2003, from 0930 to 1500 hours. Ambient temperature ranged from approximately 90 to 98 degrees Fahrenheit during the period, skies were clear and winds were mild, traveling from the north at 3-5 mph.

The objectives of the field reconnaissance were to: (1) inventory the flora and fauna of the Project Site; (2) determine the presence of any special status species or potential habitat; and (3) identify potentially jurisdictional resources (i.e. wetlands) that could occur occurring onsite.

Vegetation of the Project Site was mapped on a color aerial oblique photograph at a scale of 1 inch= 450 feet and classified using the system developed for the Draft Yolo County HCP. Plant species nomenclature follows Jepson (1993). Mapped data were then digitized into a geographic information system (GIS) for analysis and display.

During the reconnaissance survey, special attention was paid to those areas potentially-supporting sensitive biological resources, including species of plants or animals afforded special recognition by federal, state, or local resource agencies or organizations, as well as habitats that are unique, of relatively limited distribution, or of particular value to wildlife.

Based on the results of the literature review and record searches, a list of sensitive plants, animals, and habitats potentially occurring within the project vicinity was developed for verification in the field (see Table 1).

Survey Limitations

The field survey was conducted during the late summer, when migratory wildlife that could occur within the Project Site were no longer present. The late summer season was also outside the blooming period of many of the special status plant species that could occur on the Project Site. Focused surveys for special status species, according to USFWS or CDFG protocol, were not conducted.

SOILS

There are five mapped soil units in the Project Area (Soil Survey of Yolo County, California; USDA, 1972) see Figure A.

Laugenour very fine sandy loam, deep, flooded.

This soil type occurs on most of the northern portion of the Project Site. It is a poorly drained soil on alluvial fans and is subject to flooding.. Small areas of Lang sandy loam, deep, flooded, and Maria silt loam, flooded are included in this soil type. Permeability of this soil is moderately rapid permeability and it is subject to deposition. Uses include cultivation of sugar beets, grain, sorghum, and tomatoes, pasture, wildlife habitat, and recreation. A detailed soil profile of a soil in the Laugenour series indicated that this soil type could be alkaline. This soil type is included on the hydric soils list of the U.S.

Maria silt loam, flooded

This soil type occurs on most of the northern portion of the Project Site and is subject to flooding. Maria silt loam is a poorly-drained silt loam, formed on alluvial fans from sedimentary rocks and moderately alkaline throughout the soil profile. Laugenour very fine sandy loam, flooded, and Riverwash soil units can be inclusions in this soil type. Uses include cultivation (sugar beets, grain sorghum and tomatoes), dry farmed pasture, wildlife habitat and recreation. This soil type is included on the hydric soils list of the U.S.

Maria silt loam deep

This soil type is located on the southwestern portion of the Project Site. Permeability is moderate to slow and moderately alkaline throughout the soil profile. Small areas of deep, drained Merritt silty clay loam occur in this soil type. Uses include crops such as sugar beets, tomatoes, alfalfa and almonds, wildlife habitat, and recreation.

TABLE 1

SPECIAL STATUS SPECIES[1] POTENTIALLY OCCURRING WITHIN THE REGION OF WOODLANDS OUTFALL CHANNEL

Common Name	Scientific Name	Status[2] Fed/CA/other	Habitat and Seasonal Distribution in California	Likelihood of Occurrence Within the Site Vicinity[3]
Plants				
Heckard's Pepper Grass	*Lepidium latipes* var. *heckardii*	FSC/none/1B	Found in Valley and foothill grassland, vernal pools, endemic to Yolo County.	**Moderate.** Plant occurs on areas with alkaline soils and sometimes on the edges on vernal pools the outfall channel does support alkaline soils. Closest occurrence (CNDDB) to the Project Site is approximately three miles to the south.
Heartscale	*Atraplex cordulata*	FSC/none/1B	Chenopod scrub, valley and foothill grassland, meadows alkaline flats and scalds in the central valley, sandy soils.	**Low.** Plant occurs on areas with alkaline soils and has not been reported since 1955. The outfall channel does support this type of soil. Closest occurrence (CNDDB) to the Project Site is approximately five miles to the south.
San Joaquin Saltbush	*Atriplex joaquiniana*	FSC/none/1B	Chenopod scrub, alkali meadow, alkali wetlands or alkali sink scrub with *Distichlis spicata*.	**Low.** Plant occurs on areas with alkaline soils. The outfall channel does support alkaline soils. Closest occurrence (CNDDB) to the Project Site is two miles to the southwest.
Brittlescale	*Atriplex depressa*	FSC/none/1B	Chenopod scrub, meadows playas, vernal pools. Usually in alkali scalds or alkali clays in meadows or annual grassland, rarely associated with riparian habitat or vernal pools.	**None.** Plant occurs on areas with alkaline soils in meadows. The outfall channel does not support this type of habitat. Closest occurrence (CNDDB) to the Project Site is two miles to the northwest.
Alkali Milk Vetch	*Astragalus tener* var. *tener*	FSC/none/1B	Alkali playa, vernal pools, alkali flats and flooded lands.	**Moderate.** Plant occurs on areas with alkaline soils, and vernal pools. The outfall channel does support alkaline soils. Closest occurrence (CNDDB) to the Project Site is two miles to the southwest.
Rose Mallow	*Hibiscus lasiocarpus*	None/none/2	Marshes and Swamps (freshwater), moist freshwater soaked river banks and peat islands in sloughs.	**Low.** Moist banks of the Outfall Channel represent suitable habitat for this plant species.
Palmate-Bracted Bird's – Beak	*Cordylanthus palmatus*	E/E/1B	Chenopod scrub, valley and foothill grassland, usually on Pescadero Silty Clay wich is alkaline with *Distichlis frankenia*.	**Moderate.** Plant occurs on areas with alkaline soils, and vernal pools. The outfall channel does support alkaline soils. Closest occurrence (CNDDB) to the Project Site is one mile to the south.
Invertebrates				
California Linderiella	*Linderiella occidentalis*	FSC/none/none	Seasonal pools in grasslands with old alluvial soils underlain by hardpan or in sandstone depressions	**Low.** Small depressions that hold seasonal water could represent suitable habitat for this species. The Closest occurrence (CNDDB) to the Project Site is nine miles south.

TABLE 1

SPECIAL STATUS SPECIES[1] POTENTIALLY OCCURRING WITHIN THE REGION OF WOODLANDS OUTFALL CHANNEL

Common Name	Scientific Name	Status[2] Fed/CA/other	Habitat and Seasonal Distribution in California	Likelihood of Occurrence Within the Site Vicinity[3]
Valley Elderberry Longhorn Beetle	*Desmocerus californicus dimorphis*	T/none/none	Central valley of California, in association with elderberry shrubs (*Sambucus* sp.)	**None.** Field surveys did not reveal the presence of elderberry shrubs in the Outfall Channel. The Closest occurrence (CNDDB) to the Project Site is nine miles south.
Fish				
Sacramento Splittail	*Pogonichthys macrolepidotus*	T/none/none	Lake and rivers of Central Valley but now confined to the Delta, Suisun Bay and associated marshes, slow moving river sections	**None.** The Outfall Channel does not represent suitable habitat for this species. Species confined to Sacramento River approximately two miles to the east.
Sacramento Perch	*Archoplites interruptus*	FSC/none/none	Sloughs, slow moving rivers and lakes of the Central Valley, prefer warm water; aquatic vegetation is essential for young.	**Low.** The outfall channel represents suitable habitat for an introduced population.
Reptiles				
Giant Garter Snake	*Thamnophis gigas*	T/T/none	Prefers freshwater marsh and low gradient streams. Has adapted to drainage canals and irrigation ditches.	**Moderate to High.** The low flows of the outfall channel represent suitable habitat for this species. There are approximately 33-recorded occurrences (CNDDB) of GGS within 7 miles of the Outfall Channel.
Birds				
Great Egret	*Ardea alba*	None/CDFG Code/none	Nesting colonies or rookeries protected by CDFG Code. Colonial nester in large trees, rookery sites located near marshes, tidal flats, irrigated pastures and margins of rivers and lakes.	**Moderate/Observed.** Some of the larger trees within the Outfall Channel represent suitable nesting habitat for this species; however; no nests have been observed to date. Great egrets are commonly observed foraging within the Outfall Channel.
Snowy Egret	*Egretta thula*	FSC/CDFG Code/none	Nesting colonies or rookeries protected by CDFG Code. Colonial nester on ground or low shrubs or tules. Rookery sites located close to foraging areas such as marshes, tidal flats, wet meadows, irrigated pastures and margins of rivers and lakes.	**Moderate/Observed.** The outfall channel represents suitable nesting habitat for this species. However; no nests have been observed to date. Snowy egrets are commonly observed foraging within the Outfall Channel.

TABLE 1

SPECIAL STATUS SPECIES[1] POTENTIALLY OCCURRING WITHIN THE REGION OF WOODLANDS OUTFALL CHANNEL

Common Name	Scientific Name	Status[2] Fed/CA/other	Habitat and Seasonal Distribution in California	Likelihood of Occurrence Within the Site Vicinity[3]
Western Burrowing Owl	*Athene cunicularia hypugea*	FSC/CSC/none	Nests and forages throughout the state in open, dry, annual or perennial grasslands, deserts, and scrublands characterized by low-growing vegetation.	**Low.** The sides of the south levee to the Cache Creek settling Basin represents marginally suitable nesting habitat for this species, it is only lacking a ground squirrel population that would provide suitable nesting burrows. However, the site does represent suitable foraging habitat for this species during the winter months Closest occurrence (CNDDB) to the Project Site is three miles to the south, near Yolo County disposal site (land fill).
Black-Crowned Night Heron	*Nycticorax nycticorax*	None/CDFG Code/none	Nesting colonies or rookeries protected by CDFG Code. Colonial nester and resident around marshes and rivers. Nests in trees and dense tules. Mud-bordered bays.	**Low/Observed.** The Outfall Channel does not represent suitable nesting habitat for this species. However, black-crowned night herons are commonly observed foraging in the Outfall Channel.
White-faced Ibis	*Plegadis chihi*	FSC/none/none	Generally the rookery sites are in shallow fresh water marshes in dense tules interspersed with areas of shallow water for foraging.	**None.** The outfall channel does not represent suitable nesting or foraging habitat for this species.
White-Tailed Kite	*Elanus leucurus*	FSC/none/none	Open grasslands, marshes or meadows for foraging, dense topped trees for nesting and perching. Often next to deciduous woodlands.	**High/Observed.** The trees in the outfall Channel represent suitable nesting habitat for this species. White-tailed kites are commonly observed foraging in the Outfall Channel.
Swainson's Hawk	*Buteo swainsoni*	FSC/T/none	Oak savannahs and riparian areas, forages in agricultural areas with low-growth crops such as alfalfa, and tomatoes.	**High/Observed.** The outfall Channel supports one nesting pair of Swainson's hawk and there is a second nest only 200 feet away form the channel. Swainson's hawks are commonly seen in the spring and summer foraging in the Outfall Channel.
Western Snowy Plover	*Charadrius alexandrinus nivosus*	T/CSC/none	Sandy beaches, salt pond levees and shores of large alkali lakes, needs sandy, gravelly or friable soils for nesting	**None.** The Outfall Channel does not represent habitat for this species. Nearest recorded occurrence (CNDDB) is the Davis sewage treatment pond.
Mountain Plover	*Charadrius montanus*	PT/CSC/none	Short grasslands, freshly plowed fields, newly sprouting grain fields and sometimes sod farms. Flat topography, prefers grazed areas.	**None.** The Outfall Channel does not represent habitat for this species. Marginally represents foraging area during the winter months.

TABLE 1

SPECIAL STATUS SPECIES[1] POTENTIALLY OCCURRING WITHIN THE REGION OF WOODLANDS OUTFALL CHANNEL

Common Name	Scientific Name	Status[2] Fed/CA/other	Habitat and Seasonal Distribution in California	Likelihood of Occurrence Within the Site Vicinity[3]
Tricolored Blackbird	*Agelaius tricolori*	FSC/CSC/none	Highly colonial species, numerous in central valley and vicinity, requires open water, protected nesting substrate an foraging area with insect prey within a few KM on the colony	**Low.** The willow scrub habitat represents marginal nesting habitat for the tri-colored black bird..
California Department of Fish and Game Sensitive habitats				
Great Valley Cottonwood Forest	*NA*	None/sensitive/none	Mostly mature forests of cottonwood, ash, willow, and valley oak in strips of 100 to two hundred feet wide	**None.** The Outfall Channel does not support Great Valley Cottonwood Forest
Elderberry Forest	*NA*	None/sensitive/none	Scattered oaks and elderberry shrubs within floodplain areas	**None.** The outfall Channel does not support elderberry shrubs.

NOTES:

1 - Special Status Species: Animals that were included in this table have a ranking of CSC or higher. Special-status plants that were included in this table have a ranking of 1B or higher.

2 - Status:

Federal

- FE Federally listed as Endangered
- FT Federally listed as Threatened
- FC Federal Candidate Species
- FSC U.S. Fish and Wildlife Service designated "Species of Concern"

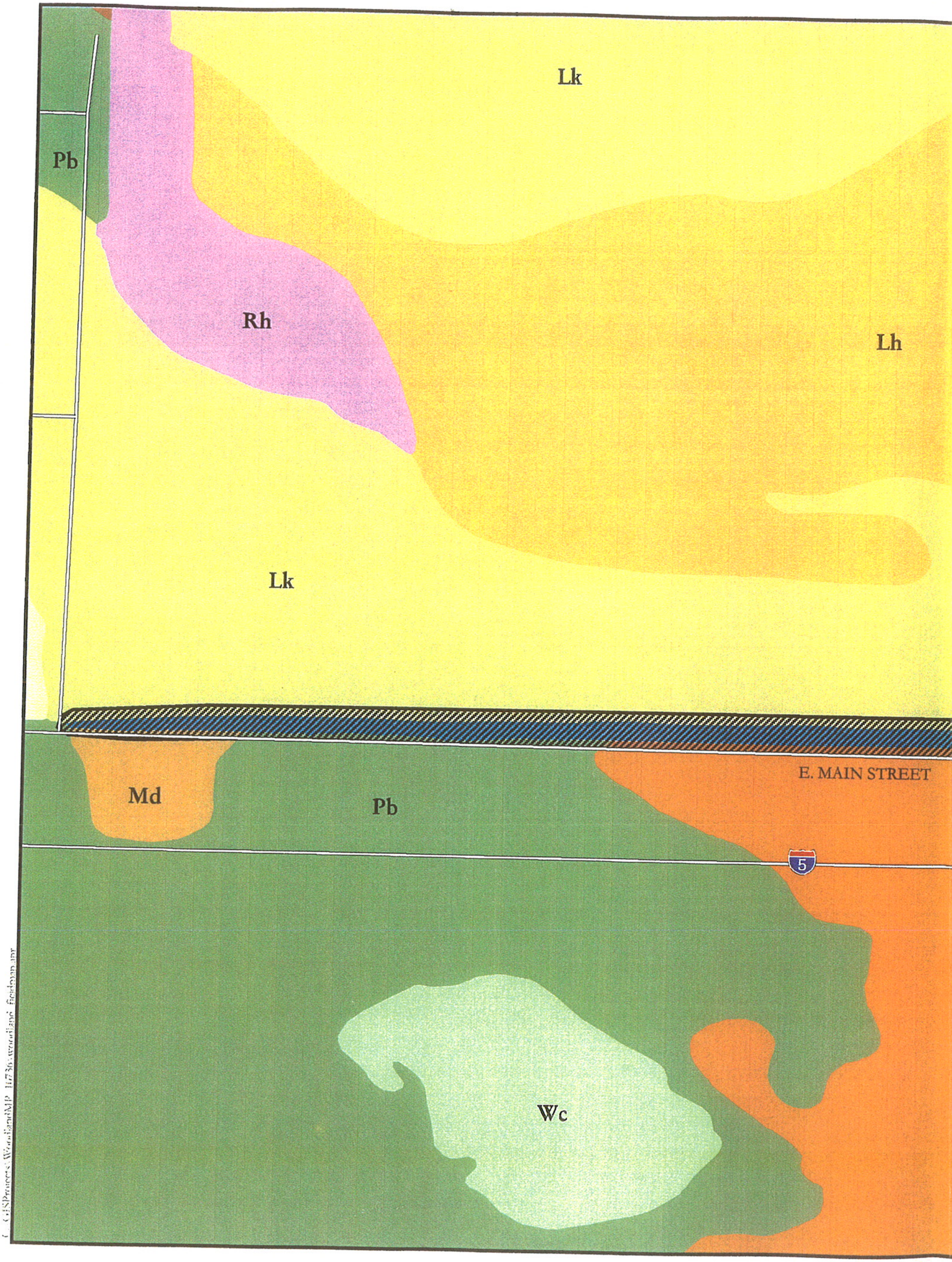
State

- SE State listed as Endangered
- ST State listed as Threatened
- CFP California Department of Fish and Game designated "Fully Protected" or "Protected" – Permit required for "take."
- CSC California Department of Fish and Game designated "Species of Special Concern"
- CDFG Code CDFG Code 3503, unlawful to destroy bird nests
- Sensitive CDFG classifies these habitats as sensitive

Other

- 1B California Native Plant Society (CNPS) Ranking. Defined as plants that are rare, threatened, or endangered in California and elsewhere.
- 2 Plants rare, threatened or endangered in California, but more common elsewhere

3 - Occurrence Sources/Site Vicinity: CDFG Natural Diversity Database (CNDDB). Site vicinity includes the Project Site, and lands within ten miles of the Project Site.


Lk
Pb
Rh
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Lk
E. MAIN STREET
Md
Pb
5
Wc

Pescadero silty clay, saline-alkali

This soil type is also located in the southern portion of the Project Site, in basins with slopes less than one percent. It consists of poorly-drained and slowly-permeable silty clays, formed in alluvium from sedimentary rocks. Areas of Capay silty clay, Marvin silty clay loam, Riz loam and Willows clay occur as inclusions in this mapped unit. This soil is mainly used for dryland pasture, but other uses include rice, sugar beets, wildlife habitat, and recreation.

Willows clay

This is another soil type occurring in basins with slopes of less than 1 percent in the southern portion of the Project Site. It has slow permeability, slow surface runoff, and contains alkali inclusions. Capay silty clay, Marvin silty clay loam, Pescadero silty clay, Riz loam and Sacramento clay Soil units occur as inclusions in this mapped unit. Uses include cultivation (rice and sugar beets) dry farmed safflower, irrigated pasture, wildlife habitat and recreation.

VEGETATATION (INCLUDING JURISDICTIONAL RESOURCES)

The Project Site is dominated by non-native, annual grassland, with freshwater marsh, emergent herbaceous wetland, and willow scrub riparian habitat interspersed (see Figures 1 through 3). A brief description of the composition, vegetative structure, and approximate distribution and extent of each community is described below.

Annual Grassland

Most of the Outfall Channel is dominated by annual grassland habitat, which is composed of non-native annual grasses, including wild oats (*Avena fatua*), ripgut brome (*Bromus diandris*), soft chess (*Bromus hordeaceous*), and barleys (*Hordeum* spp.). The variety of forbs interspersed among the grasses are nearly all exotic species, such as yellow star thistle (*Centaurea solstitialis*), black mustard (*Brassica nigra*), Common sowthistle (*Sonchus oleraceus*) and peppergrass (*Lepidium oblongum*). Though native plants are rare in this habitat type, grasslands are of moderate value to many native wildlife species for foraging or nesting.

Waters and Wetlands

Wetland habitats include naturally wet areas (whether rainfall or creek and stream -supported) and modified creeks, drainages, or artificial impoundments supplied with pumped or passive water. The Outfall Channel is an example of the latter. Wetlands are functionally defined as habitats that: (1) are seasonally subject to either ponding or soil saturation; (2) exhibit hydric soils; and (3) support hydrophytic vegetation.

The extent of potential U.S. Army Corps of Engineers (Corps) jurisdiction under Section 404 of the U.S. Clean Water Act and/or California Department of Fish and Game (CDFG) jurisdiction under Section 1601 of the Fish and Game Code is expected to be roughly coincident with the limits of willow scrub, freshwater marsh, and/or emergent herbaceous wetland habitat. While a general assessment of jurisdictional waters and wetlands was conducted as part of the reconnaissance-level survey of the Project Site, a formal jurisdictional wetlands delineation was not performed. A formal delineation should be conducted within one year of anticipated project construction activities and all wetlands-related issues should be considered in the environmental document and planning process.

Freshwater Marsh / Emergent Herbaceous Wetland

Seasonal and perennial wetlands, characterized by emergent herbaceous vegetation, generally occur in association with ponds and drainages within the Project Site and are typically supported by stormwater runoff, agricultural irrigation water, or naturally occurring creeks, sloughs, streams, and rivers. Vegetation varies in height, cover, and species composition, depending on water depth and frequency of inundation. These habitats occur mostly in deep water areas of the Outfall Channel, where water exists throughout most of the year.

Typical vegetation includes stands of cattails (*Typha* sp.) and tule (*Scirpus robustus*), with Baltic rush (*Juncus balticus*), barnyard grass (*Echinochloa crus-galli*), umbrella sedge (*Cyperus eragrostis*), and dallis grass (*Paspalum dilatatum*). Other wetland plant species typically found in this habitat include water smartweed (*Polygonum amphibium*), ditchgrass (*Paspalum distichum*), salt grass (*Distichlis spicata*), floating boxseed (*Ludwigia repens*), and South American vervain (*Verbena bonariensis).*

10736-00

FIGURE 1
Habitat Map

Source: Todd Quam - Digital Sky 2003, EIP Associates 2003

Woodland Drainage Master Pan

Not to Scale

EIP

FIGURE 2
Habitat Map

Source: Todd Quam - Digital Sky 2003, EIP Associates 2003

Not to Scale

EIP

10736-00

Woodland Drainage Master Pan

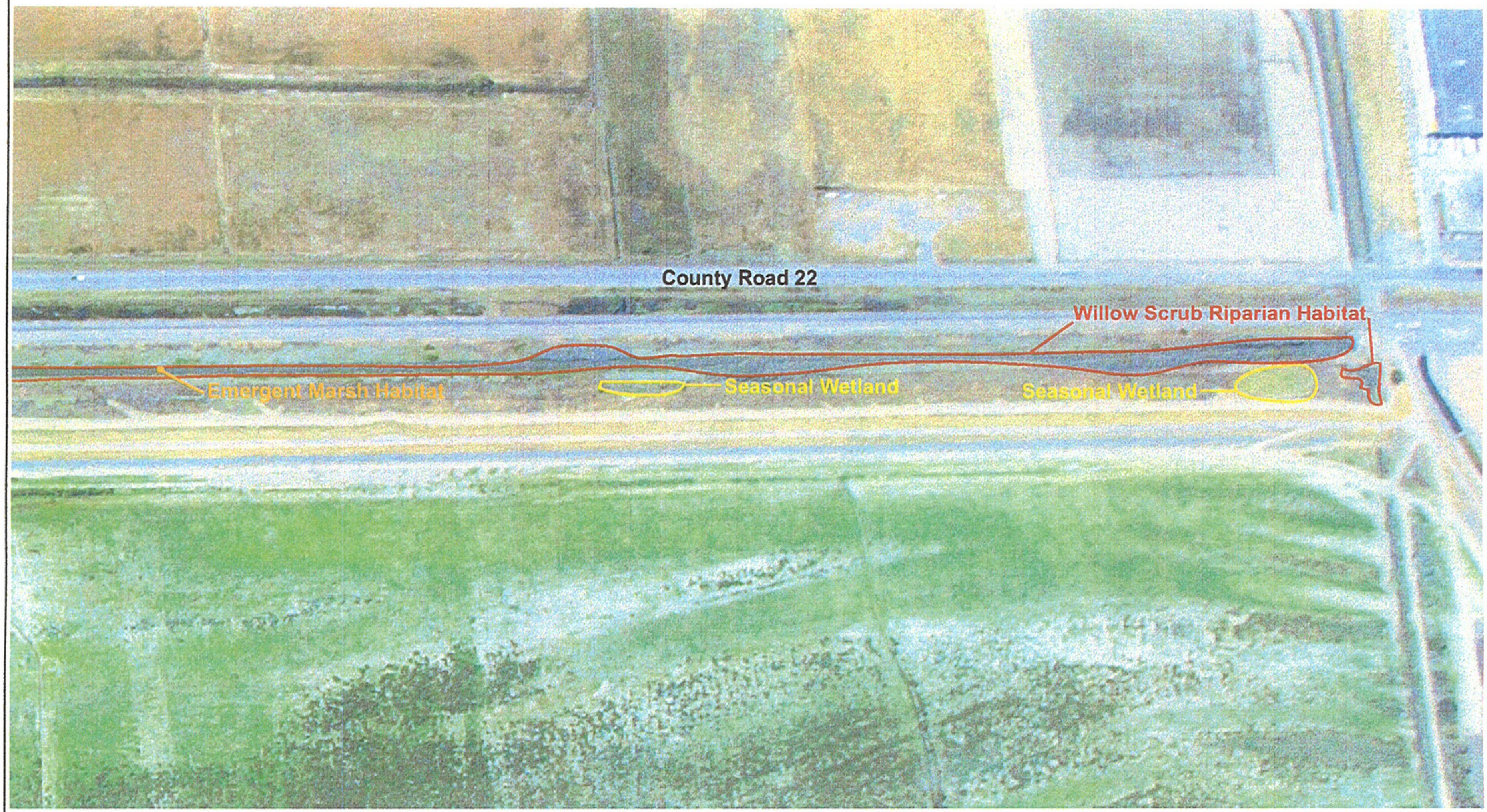

FIGURE 3
Habitat Map

Source: Todd Quam - Digital Sky 2003, EIP Associates 2003

10736-00

Not to Scale

EIP

Woodland Drainage Master Pan

Willow Scrub Riparian

The Willow Scrub Riparian habitat subtype is generally a closed-canopy stand of mixed, mature cottonwood (*Populus fremontii*), willow (*Salix* sp.), Oregon ash (*Fraxinus latifolia*), and valley oak (*Quercus lobata*) trees with a scattered-to-dense understory of smaller trees, shrubs, and vines. Onsite, this willow scrub riparian habitat is in a transitional state, with dense willow thickets that, if left undisturbed, will eventually develop into mature willow trees interspersed with ash and valley oak trees.

Special Status Plants

Habitat was assessed for several special status plants that could potentially occur within the Project Site, including: rose mallow (*Hibiscus lasiocarpus*), palmate-bracted bird's beak (*Cordylanthus palmatus*), alkali milk vetch (*Astragalus tener* var. *tener*), San Joaquin saltbush, brittlescale (*Atraplex depressa*), Heckard's pepper grass (*Lepidium latipes* var. *heckardii*), and heartscale (*Atraplex cordulata*). Though no individuals of these species were observed during the field survey, alkaline soils and soils with alkaline inclusions within the Project Site do provide suitable habitat for six plants listed in Table 1..

Wildlife

The common wildlife species in Table 2, below, were observed during the field survey:

Though additional, common wildlife species may occur on the Project Site, they were not observed during the field survey. Because common species are not of primary concern with respect to potential impacts of development, a comprehensive list of such potentially-occurring species is not provided in this report. The focus of the field survey was to determine the presence of special status species or suitable habitat to support them. The results of these field observations are discussed below.

Special Status Wildlife

Swainson's Hawk

Swainson's hawk (*Buteo swansoni*) historically occurred in open grassland communities throughout lowland California, but due to agricultural conversion of native habitats, the breeding population of

TABLE 2

WILDLIFE SPECIES OBSERVED IN THE PROJECT AREA

Common Name	Scientific Name	Comments (Habitat Association)
Fish		
Mosquito Fish	Gambusia affinis	Marsh Emergent
Amphibians		
Bullfrog	Rana catesbeiana	Marsh Emergent
Pacfic tree frog	Hyla regina	Marsh Emergent
Reptiles		
Western fence lizard	*Sceloporus occidentalis*	Annual grassland
Birds		
red-tailed hawk	*Buteo jamaicensis*	Annual grassland
American kestrel	*Falco sparverious*	Annual grassland
great egret	*Ardea alba*	Marsh Emergent
Swainson's hawk	*Buteo swainsoni*	Annual grassland
great blue heron	*Ardea herodias*	Marsh Emergent
Mallard	*Anas platyrhynchos*	Marsh Emergent
black phoebe	*Sayornis nigricans*	Annual grassland
Western meadowlark	*Sturnella neglecta*	Annual grassland
mourning dove	*Zenaida macroura*	Annual grassland
rock dove	*Columba livia*	Annual grassland
American crow	*Corvus brachyrhynchos*	Annual grassland
California towhee	*Pipilo crissalis*	Annual grassland
lesser gold finch	*Carduelis psaltria*	Annual grassland
house finch	*Carpodacus mexicanus*	Annual grassland
song sparrow	*Melospiza melodia*	Annual grassland
Mammals		
Ground squirrel	*Spermophilus* sp.	Annual grassland
pocket gopher	*Thomomys bottae*	Annual grassland
Coyote	*Canis latrans*	Annual grassland
Raccoon	*Procyon lotor*	Annual grassland

this species declined by an estimated 91 percent by 1980. The Central Valley population of Swainson's hawk now occurs only where there are compatible agricultural crops that provide foraging habitat, and large trees, which provide secure nesting sites. Studies conducted under the supervision of DFG have demonstrated that field crops such as alfalfa, and row crops such as tomatoes and sugar beets, provide high value foraging habitat for this species. These crops have high prey availability for Swainson's hawk due to optimal combinations of prey population and reduced vegetative cover. It should be noted that foraging habitat for this species is the single most important parameter determining the current distribution of this species in the Central Valley.

Although trees that will support nest platforms are important, the hawks will not establish nest territories in areas that do not have sufficient foraging habitat and prey densities to support the adult pair and the young of the pair, regardless of whether appropriate nest trees are present. Crops such as those described above have essentially replaced native grasslands as this species' principal foraging habitat in the Central Valley of California. Accordingly, conversion of agricultural lands to urban uses or incompatible agricultural uses continues to restrict the range of this species even further. Northeastern Solano County and southern Yolo County now represent one of the last major strongholds of this species in California. The density of nesting Swainson's hawks in this area is attributable to the prevalence of compatible agricultural crops and harvesting techniques. Therefore, the annual grassland within the Channel and the adjacent suitable agricultural lands for foraging, make the Channel optimum nesting and foraging habitat for Swainson's hawks. Swainson's hawks have been observed nesting and foraging in the Channel.

To avoid potential violation of Fish and Game Code 2080 (i.e. killing of a listed species) project related disturbance at active Swainson's hawk nesting sites should be reduced or eliminated during critical phases of the nesting cycle (March 1-September 15 annually). Nest abandonment, loss of young, reduced health and vigor of eggs and/or nestlings (resulting in reduced survival rates), could ultimately result in the take (killing) of nestling or fledgling Swainson's hawks incidental to otherwise lawful activities. The taking of Swainson's hawks in this manner can be a violation of Section 2080 of the Fish and Game Code. To avoid potential violations of Fish and Game Code 2080, the

Department of Fish and Game recommends and encourages project sponsors to obtain 2081 Management Authorizations for their projects.[1]

Any changes to the vegetation (i.e., grassland and tree removal) within the channel or channel construction activities in close proximity to a nest during the breeding season would be considered a significant impact to the Swainson's hawk and in violation of Fish and game Code.

<u>Northern Harrier</u>

The northern harrier (*Circus cyaneus*) is a State species of special concern and protected by the Federal Migratory Bird Treaty Act and California State Fish and Game Codes. It is a slim-bodied raptor with long, narrow wings and an owl-like facial disc. Northern harriers breed between April and July and build their nests on the ground in shrubby vegetation. They hunt in annual grasslands, pastures, fresh emergent wetlands, and some croplands.

The northern harrier is a common year round species in Yolo County, which suggests nesting throughout the county where they inhabit marshes, agricultural fields, and grasslands. Therefore the grassland and emergent marsh wetlands provide suitable nesting and foraging habitat. Northern harriers are commonly observed foraging in the Outfall Channel.

<u>Giant Garter Snake</u>

The giant garter snake (*Thamnophis gigas*, GGS), a state and federal threatened species, generally inhabits marshlands supported by perennial fresh water and low gradient streams, but also inhabits temporary waters such as sloughs, irrigation canals, drainage ditches, and flooded rice fields. During their active season from April to October, the giant garter snake basks on sunny exposures to raise its body temperature. These basking sites may be in the form of piles of small boulders, mats of vegetation, trash debris (scrap plywood, wood planks, etc.), and streamside vegetation. This vegetation along with upland burrows of rodents and crayfish provides refuge from flooding and predation. By the first of November, most giant garter snakes are in winter retreats and will remain

1 Staff Report regarding Mitigation for Impacts to Swainson's hawk (*Buteo swainsoni*) in the Central Valley of California, CDFG 1994.

there until spring. The giant garter snake is a secretive snake, therefore, abundance and/or population information is not readily available. In Yolo County, there are several recorded occurrences of the giant garter snake along Putah Creek and near rice farms along the Willow Slough Bypass and Conaway Ranch.

Review of the CNDDB database occurrences links the observations of GGS with the presence of rice fields or irrigation canals in this region. All occurrences for giant garter snakes are documented east and south of the Project Site in association with rice fields and irrigation ditches. GGS occurrences have been recorded at the Conaway Ranch, southeast of the Project Site, at Willow Slough south of the Project Site, and in the Yolo Bypass east of the Project Site. Consequently, their occurrence in the Channel is very possible.

DISCUSSION

Constraints With Regard to Special Status Plant Communities and Species

There are significant constraints associated with any impacts on disturbance of the habitats found within the Outfall Channel. The majority of the Channel is classified as annual grassland habitat, which is a monocultural association supporting a very low diversity of native plants and predominance of non-native species. However; the grassland habitat occurs on areas of alkaline soils; thereby having the potential to support special-status plant species that require alkaline soils for survival (e.g. Palmate-bracted bird's-beak, alkali milk vetch, Heckard's pepper grass). Any impacts or ground disturbing activities have the potential to impact special-status plant species that could occur here.

A well-developed willow scrub riparian area, supporting willows and a few other wetland plant species, is found in a linear strip that travels the site along the northern and southern banks of the Channel (see Figures 1 through 3). Freshwater emergent wetlands are interspersed within this willow scrub riparian habitat. These habitats would be considered sensitive because of the habitat itself, its ability to support sensitive wildlife species, and the implications for permit processing for impacts to jurisdictional resources.

Opportunities With Regard to Special Status Plant Communities and Species

On-site opportunities would consist of preservation and enhancement of existing plant populations. A "No-Action" Alternative would maintain the Project Site in its current condition and preserve existing wetland and alkali upland/wetland habitat. Enhancement of existing vegetation along the Channel (i.e., by planting elderberry shrubs for the federally listed Valley elderberry longhorn beetle) could provide additional benefits to special-status species.

At present, the City of Woodland is proposing development of the Spring Lake Drainage Park Preserve and associated channels south of Woodland around the City of Woodland's wastewater treatment plant property.[2] The Preserve is in the currently-designated "Urban Preserve" lands approximately one mile south of the Channel. This project will involve construction of detention ponds and associated channels to collect stormwater from the Spring Lake Specific Plan Area. In addition, the Preserve will address mitigation for impacts from implementation of the Spring Lake Residential development to the west and could involve: (1) up to 250 acres of Palmate-Bracted Bird's-Beak (Alkali Upland) Preserve; (2) Alkali Wetland Preserve; and (3) mitigation lands for Swainson's hawk and burrowing owl foraging habitat. The Preserve Plan is in a draft stage and is being reviewed by the City, upon the City of Woodland's approval, there could be an opportunity to mitigate for any potential impacts to alkali plant species along the Channel by somehow participating in this Preserve. Participation could take the form of in-lieu mitigation fees, a conservation easement or some other contribution to the establishment or management of this Park Preserve.

Opportunities and Constraints With Regard to Sensitive Wildlife Species

As previously mentioned, the on-site opportunities would consist of preservation and enhancement of existing plant populations. A "No-Action" Alternative would maintain the Project Site in its current condition and preserve existing wetland and alkali upland/wetland habitat. Enhancement of existing vegetation along the Channel (i.e., by planting native grasses for small mammal forage, that in turn would provide a prey base for raptors) and providing a more perennial source of water could provide additional benefits to the giant garter snake.

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2 Preserve Management Plan, Spring Lake Preserves, Yolo County California. Prepared for City of Woodland, Spring Lake Planning Group, and California Department of Fish and Game, August 2003.

The City of Woodland has preliminary plans to develop a Preserve (Spring Lake Drainage Park) in the currently-designated "Urban Preserve" lands south of the Channel. This Preserve will address mitigation of impacts of the Spring Lake Residential development to the west and could involve: (1) up to 250 acres of Palmate-Bracted Bird's-Beak (Alkali Upland) Preserve; (2) Alkali Wetland Preserve; and (3) mitigation lands for Swainson's hawk and burrowing owl foraging.

The Preserve Plan is in a draft stage and is being reviewed by the City, upon the City of Woodland's approval, there could be an opportunity to mitigate for any potential impacts to Swainson's hawk nesting/ foraging habitat along the Channel by somehow participating in this Preserve. Participation could take the form of in-lieu mitigation fees, a conservation easement or some other contribution to the establishment or management of this Park Preserve.

CONCLUSION

The willow scrub riparian habitat should be considered the primary constraint to alterations or ground disturbing activities within the outfall Channel, due to its status as a sensitive habitat (jurisdictional wetlands), supports an active Swainson's hawk (state threatened species) nests, and potential habitat for giant garter snake, and its implications with regard to regulatory permit processing.

In addition, the Outfall Channel supports alkaline soils and therefore has the potential to support special-status plant species.

In terms of restoration or mitigation opportunities, the willow scrub riparian habitat also provides the greatest potential for habitat enhancement. Therefore, in summary, the willow scrub riparian habitat poses the greatest constraint to development and the greatest opportunity for preservation and enhancement. To the extent that the proposed alterations can consider, and incorporate, the willow scrub riparian habitat into the project design, the impacts with respect to biological resources will be reduced.

City of Woodland

Technical Guidance Manual
for
Stormwater Quality Control Measures

August 2003

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Appendices

SECTION 1
BACKGROUND AND GOALS

Background

In 1972, the Federal Water Pollution Control Act (also referred to as the Clean Water Act (CWA)) was amended to provide that the discharge of pollutants to waters of the United States from any point source be prohibited, unless the discharge is in compliance with a National Pollutant Discharge Elimination System (NPDES) permit. In 1987, further amendments to the CWA added Section 402(p), which established a framework for regulating municipal and industrial stormwater discharges under the NPDES program through a two-phase implementation plan. Phase 1 regulations, promulgated in 1990, require metropolitan areas with a population greater than one hundred thousand and specific categories of industrial facilities, to obtain an NPDES permit for stormwater discharges. Phase 2 regulations, promulgated in 1999, require designated communities or regions that operate municipal separate stormwater sewer systems (MS4s) and have populations less than one hundred thousand to obtain an NPDES permit for stormwater discharges. Such communities are defined as Small MS4s. The stomwater sewer system operated by the City of Woodland was designated by the State of California Water Resources Control Board (SWRCB) as a Small MS4 subject to Phase 2 stormwater regulations based on several criteria for designation including; the City's high population density, the discharge of stormwater to sensitive water bodies, and significant contributor of pollutants to waters of the United States.

In 2003 the City of Woodland received a Phase 2 municipal NPDES permit for stormwater discharges issued by the SWRCB under the statewide general permit program for Small MS4s. Under this permit, the City is required to develop, administer, implement, and enforce a Comprehensive Stormwater Management Program (CSWMP) to reduce pollutants in urban runoff to the maximum extent practicable (MEP). The CSWMP implemented by the City is a multi-faceted, dynamic program, which is designed to reduce stormwater pollution to the maximum extent practicable. The CSWMP emphasizes all aspects of pollution control including, but not limited to, public awareness and participation, source control, regulatory restrictions, water quality monitoring, and treatment control.

Controlling urban runoff pollution from new development during and after construction is critical to the success of the Comprehensive Stormwater Management Program. The New Development Management Program (NDMP) is an element of the Comprehensive Stormwater Management Program being implemented by the City to specifically control post-construction urban runoff pollutants from new development and redeveloped areas. The goal of the NDMP is to minimize runoff pollution typically caused by land development and protect the beneficial uses of receiving waters by employing a sensible combination of pollutant source control and site-specific treatment control measures. The NDMP envisions reducing stormwater pollutants from new development by employing on-site control measures for commercial, industrial, multi-family, and single-family residential land uses

"Source Control Measures" and "Treatment Control Measures", as used in this Manual, refer to best management practices (BMPs) and features incorporated in the design of a land development or redevelopment project that prevent and/or reduce pollutants in stormwater runoff from the project. Source Control Measures limit the exposure of materials and activities so that potential sources of pollutants are prevented from contacting storm runoff. Treatment Control Measures are reasonable, engineered systems that provide a reduction of pollutants in runoff to be consistent with the MEP standards imposed by the Federal Clean Water Act on the City. This Manual contains design guidance for on-site source and treatment controls for new development and redevelopment projects.

In addition to the City permit requirements, owners/developers of some of the sites in the City may also be subject to the State of California's general permit for stormwater discharge from industrial activities (Industrial General Permit) and general permit for stormwater from construction activities (Construction General Permit). The control measures provided in this Manual may assist the owner/developer in meeting the requirements of the State's permit. The City of Woodland stormwater management staff is available to provide assistance regarding State permit requirements.

Goals

This Manual has been prepared by the City of Woodland to accomplish the following goals:

- Ensure that new developments reduce urban runoff pollution to the "maximum extent practicable,"
- Ensure the implementation of measures in this Manual are consistent with NPDES permit and other State requirements.
- Provide guidance to developers, design engineers, agency engineers, and planners on the selection and implementation of appropriate stormwater treatment and source control measures, and
- Provide maintenance procedures to ensure that the selected control measures will be maintained to provide effective, long-term pollution control.

SECTION 2
OVERVIEW AND
USE OF THE MANUAL

Introduction

The control measures, often termed Best Management Practices or BMPs, described in this Manual were selected to optimize post-construction, on-site stormwater pollution control. On-site control measures, for the purposes of this Manual, apply to infill and new development project categories listed in the Woodland Storm Water Management Plan. Applicable New Development project categories are listed in Table 2-1 along with the categories of pollutants likely to be present in stormwater runoff from project areas.

Table 2-1. New Development Project Categories and Associated Pollutants of Concern

New Development Project Category	Pollutant Category of Concern						
	Sediment	Nutrients	Metals	Trash and Debris	Oxygen Demand	Toxic Organics	Bacteria
Commercial Developments (≥ 1acre)	X	X	X	X	X	X	X
Automotive Repair Shops	X		X	X	X	X	
Retail Gasoline Outlets	X		X	X	X	X	
Restaurants		X		X	X	X	X
Parking Lots (≥ 5,000 SF or 25 spaces)	X		X	X	X	X	
Home Subdivisions (≥ 10 units)	X	X	X	X	X	X	X

X = Pollutant likely to be present in stormwater runoff from project area

A design decision flowchart is presented in Figure 2-1 to aid the user of the Manual in determining what steps need to be completed in the design process to comply with stormwater control requirements. A key step in the process is project assessment to determine expected pollutants (see Table 2-1), receiving water quality and hydraulic conditions, and site conditions (e.g. soils, groundwater, topography), as all these conditions will influence the selection of appropriate control measures. The selection of appropriate control measures should be a collaborative effort between the project proponent and the City stormwater staff. It is recommended that discussions between project planners and engineers and City stormwater staff regarding selection of controls measures occur early in the design process.

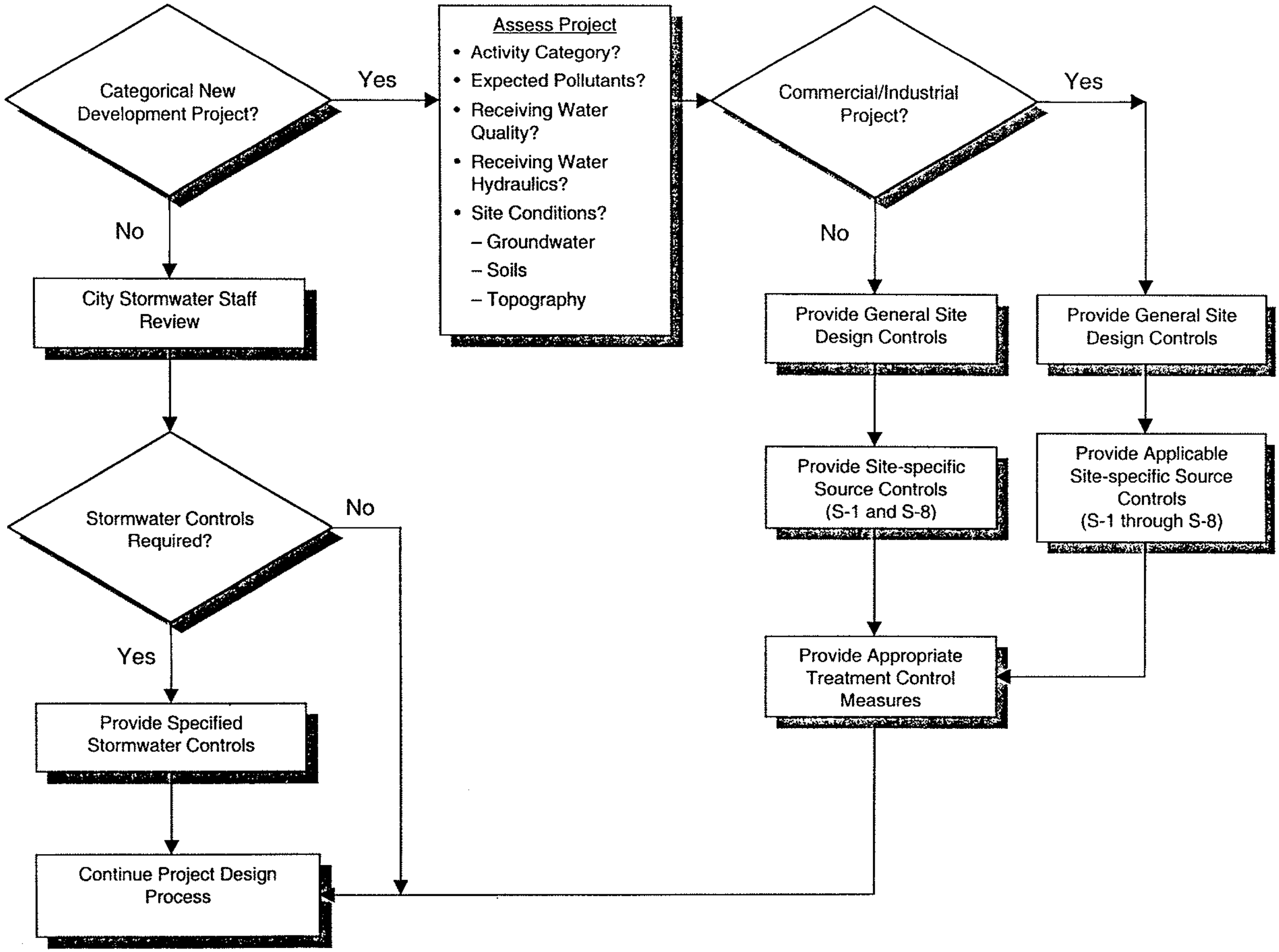


Figure 2-1. Stormwater Controls Design Decision Flowchart

If the project is determined by the City to be a Categorical New Development project (see Table 2-1), the project must be designed to include the control measures specified in this Manual. Projects that are not New Development category projects are still subject to City stormwater staff review. Stormwater controls may be required by the City for Non-Categorical New Development category projects, depending on the potential for discharge of pollutants in stormwater runoff.

Overview of Stormwater Pollution Control Measures

The categories of stormwater pollution controls measures specified in this Manual are summarized in Table 2-2 along with applicable projects and primary objectives of the control measures:

Table 2-2. Summary of Required Stormwater Pollution Controls Measures

Control Measure Category	Applicable Projects	Primary Objective
General Site Design Control Measures	All Categorical New Development projects	Minimize the volume and rate of stormwater runoff discharge from the project site.
Site-specific Source Control Measures	Specific outdoor activities and development features: • Outdoor storage area • Trash storage area • Loading/unloading dock area • Repair/maintenance bay • Vehicle/equipment/accessory wash area • Fueling area	Prevent potential pollutants from contacting rainwater or stormwater runoff or to prevent discharge of contaminated runoff to the storm drain system or receiving water.
Treatment Control Measures	All Categorical New Development projects – at least one approved treatment control measure required unless project discharges runoff to regional treatment facility.	Remove pollutants from stormwater runoff prior to discharge to the storm drain system or receiving water.

Site design and site-specific source controls are generally the most effective means to control urban runoff pollution because they minimize the need for treatment and are required for all applicable projects. Treatment controls are required in addition to source controls to meet the New Development requirement to minimize, to the maximum extent practicable, discharge of pollutants to the stormwater conveyance system. Treatment controls are required for all projects, except as noted below, and may be selected from a list of approved methods. Alternative or proprietary treatment controls not described in this Manual may be considered on a case-by-case basis provided the project proponent can demonstrate that treatment equivalent to approved methods is achievable. Alternative control measures are further discussed at the end of Section 5. New Development projects that discharge stormwater runoff to City-approved, regional stormwater treatment control facilities that comply with the design requirements of this Manual are not required to provide separate treatment controls. However, such projects are required to provide site design and site-specific source controls in accordance with this Manual. A matrix of New Development project categories and required stormwater pollution control measures is presented in Table 2-3 to aid the Manual user in determining what controls are required for various project categories. Detailed descriptions and design criteria and procedures for the three types of control measures are presented in fact sheet format in Sections 3, 4, and 5 of the Manual for General Site Design Controls, Site-specific Source Controls, and Treatment Controls, respectively.

Table 2-3. Control Measure Selection Matrix for New Development Project Categories

New Development Project Category	General Site Design Control Measures[a]					Site-Specific Source Control Measures[b]								Treatment Control Measures[c]
	Conserve Natural Areas (G-1)	Protect Slopes and Channels (G-2)	Control Peak Runoff Rates (G-3)	Minimize Impervious Area (G-4)	Minimize Effective Imperviousness (G-5) Turf Buffer (G-5.1) Grass-lined Channel (G-5.2)	Storm Drain Message and Signage (S-1)	Out door Storage Area Design (S-2)	Trash Storage Area Design (S-3)	Loading/unloading Dock Area Design (S-4)	Repair/maintenance Bay Design (S-5)	Vehicle/Equipment/ Accessory Washing Area Design (S-6)	Fueling Area Design (S-7)	Proof of Control Measure Maintenance (S-8)	Grass Strip Filter (T-1) Grass Swale Filter (T-2) Extended Detention Basin (T-3) Wet Detention Basin (T-4) Constructed Wetland (T-5) Detention Basin/Sand Filter (T-6) Porous Pavement Detention (T-7) Porous Landscape Detention (T-8) Infiltration Basin (T-9) Infiltration Trench (T-10) Media Filter (T-11) Proprietary Controls (T-12)[f]
Commercial Developments (≥ 1 acre)	R	R	R	R	R[e]	R	R[d]	R[d]	R[d]	R[d]	R[d]	R[d]	R	S
Automotive Repair Shops	R	R	R	R	R[e]	R	R[d]	R[d]	–	R[d]	R[d]	R[d]	R	S
Retail Gasoline Outlets	R	R	R	R	R[e]	R	R[d]	R[d]	–	R[d]	R[d]	R	R	S
Restaurants	R	R	R	R	R[e]	R	R[d]	R[d]	R[d]	–	R[d]	–	R	S
Parking Lots (≥ 5,000 SF or 25 spaces)	R	R	R	R	R[e]	R	R[d]	R[d]	–	–	–	–	R	S
Home Subdivisions (≥ 10 units)	R	R	R	R	R[e]	R	R[d]	–	–	–	–	–	R	S

R = Required if applicable to project
R[d] = Required if activity area is included in the project
R[e] = Required unless shown to be infeasible based on site conditions. Select one or more applicable control measures
S = Select one or more applicable treatment control measures from list above, unless project discharges runoff to regional treatment facility
(a) = Refer to Fact Sheets in Section 3 for detailed information and design criteria
(b) = Refer to Fact Sheets in Section 4 for detailed information and design criteria
(c) = Refer to Fact Sheets in Section 5 for detailed information and design criteria
(f) = Use only on a case-by-case basis with City staff approval or in combination with other applicable treatment control measures

SECTION 3
GENERAL SITE DESIGN
CONTROL MEASURES

Introduction

The principal objective of the General Site Design Control Measures specified in this Manual is to reduce stormwater runoff peak flows and volumes through appropriate site design. The benefits derived from this approach include:

- Reduced size of downstream treatment controls and conveyance systems;
- Reduced pollutant loading to treatment controls; and
- Reduced hydraulic impact on receiving streams.

General Site Design Control Measures include the following design features and considerations designated G-1 through G-5:

- G-1: Conserve Natural Areas
- G-2: Protect Slopes and Channels
- G-3: Control Peak Stormwater Runoff Discharge Rates
- G-4: Minimize Impervious Area
- G-5: Minimize Effective Imperviousness

The General Site Design Control Measures described in this Section are required for all Categorical New Development projects unless the project proponent demonstrates to the satisfaction of the City that the particular measures are not applicable to the proposed project, or the project site conditions make it infeasible to implement the design control measure in question.

Description

Detailed descriptions and design criteria for each of the General Site Design Control Measures are presented in this Section in fact sheet format.

Conserve Natural Areas

Purpose

Each project site possesses unique topographic, hydrologic and vegetative features, some of which are more suitable for development than others. Locating development on the least sensitive portion of a site and conserving naturally vegetated areas can minimize environmental impacts in general and stormwater runoff impacts in particular.

Design Criteria

If applicable and feasible for the given site conditions, the following site design features or elements are required and should be included in the project site layout, consistent with applicable General Plan and Local Area Plan policies:

1. Concentrate or cluster development on least-sensitive portions of a site, while leaving the remaining land in a natural undisturbed state;
2. Limit clearing and grading of native vegetation at a site to the minimum amount needed to build lots, allow access, and provide fire protection;
3. Maximize trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native and/or drought-tolerant plants;
4. Promote natural vegetation by using parking lot islands and other landscaped areas;
5. Preserve riparian areas and wetlands.

Protect Slopes and Channels

Purpose

Erosion of slopes and channels can be a major source of sediment and associated pollutants, such as nutrients, if not properly protected and stabilized.

Design Criteria

Slope Protection

Slope protection practices must conform to design requirements or standards set forth by local agency erosion and sediment control standards and design standards. The design criteria described in this fact sheet are intended to enhance and be consistent with these local standards.

1. Slopes must be protected from erosion by safely conveying runoff from the tops of slopes.
2. Slopes must be vegetated (full-cover) with first consideration given to use of native or drought-tolerant species.

Channel Protection

Control measure G-3 is intended to limit peak flow to avoid erosive conditions in unlined receiving streams. The following measures should be implemented to provide additional erosion protection of unlined receiving streams. Activities and structures must conform to applicable standards and specifications of agencies with jurisdiction (e.g. U.S. Army Corps of Engineers, California Department of Fish and Game).

1. Utilize natural drainage systems to the maximum extent practicable, but minimize runoff discharge rate and volume to the maximum extent practicable.
2. Stabilize permanent channel crossings.
3. In cases where beds and/or banks of receiving streams are fragile and particularly susceptible to erosion, special stabilization may be required.
    a. Small grade control structure (e.g. drop structure) may be used to reduce the slope of the channel.
    b. Severe bends or cut banks may need to be hardened by lining with grass or rock.
    c. Rock-lined, low-flow channels may be appropriate to protect fragile beds.
4. Install energy dissipaters, such as rock riprap, at the outlets of storm drains, culverts, conduits or channels that discharge into unlined channels.

Control Peak Stormwater Runoff Discharge Rates

Purpose

Unless controlled, peak stormwater runoff rates from developed areas are typically higher than those from previously undeveloped areas. Higher peak flows can change stream morphology and increase downstream erosion that can damage stream habitat and impact aesthetic value. In addition, higher flows convey larger pollutant loads to receiving waters. Control of peak stormwater discharge rates is thus required to protect stream habitat and aesthetic value by maintaining non-erosive hydraulic conditions in unlined receiving streams during stormwater runoff events.

Design Criteria

Categorical New Development projects that directly discharge to unlined receiving streams shall implement one of the following criteria:

1. 2-year, post-development discharge rates shall not exceed the pre-developed discharge rates for the 2-year frequency storm event.
2. Demonstrate to the satisfaction of the City that discharge of peak flow from the project site for the 2-year frequency storm event will:
   a. maintain or reduce predevelopment downstream erosion potential; and
   b. protect stream habitat.

Peak flows shall be determined using the procedures set forth in the latest version of the City of Woodland Storm Drainage Facilities Master Plan – Storm Drainage Guidance and Criteria.

Minimize Impervious Area

Purpose

The potential for discharge of pollutants in stormwater runoff from a project site increases as the percentage of impervious area within the project site increases. Impervious areas increase the volume and rate of runoff flow. Pollutants deposited on impervious areas tend to be easily mobilized and transported by runoff flow. Minimizing impervious area through site design is an important means of minimizing stormwater pollutants of concern. In addition to the environmental and aesthetic benefits, a highly pervious site may allow reduction in the size of downstream conveyance and treatment systems, yielding savings in development costs.

Design Criteria

Some aspects of site design are directed by local agency building and fire codes and ordinances. The design strategies suggested in this fact sheet are intended to enhance and be consistent with these local codes and ordinances. Maximizing perviousness at every possible opportunity requires integration of many small strategies. Suggested strategies for minimizing imperviousness through site design include the following:

1. Reduce the footprints of building and parking lots;
2. Cluster buildings and paved areas to maximize pervious area;
3. Use minimum allowable roadway and sidewalk cross-sections and parking stall widths;
4. Include landscape islands in cul-de-sacs (where approved);
5. Use pervious pavement materials where appropriate, such as modular paving blocks, turf blocks, porous concrete and asphalt, brick, and gravel or cobbles. (Ref. BASMAA, 1999 for descriptions of pervious pavements options.)
6. Use grass-lined channels or surface swales to convey runoff instead of paved gutters. (See Fact Sheet G-5.2)

Purpose

Stormwater runoff flows from impervious areas typically contains higher concentrations of pollutant and higher peak flows than flows from equally-sized pervious areas. The impacts of flow from impervious areas can be reduced by employing a design strategy termed "minimizing effective imperviousness". This approach involves routing runoff from impervious areas over grassy areas or other pervious areas prior to discharge to the storm drainage system or receiving water to reduce peak flows, reduce total runoff volume and provide some degree of pollutant removal. In addition to the environmental and aesthetic benefits, minimizing effective imperviousness may allow reduction in the size of downstream conveyance and treatment systems, yielding savings in development costs. Projects that employ the approaches described in this fact sheet in accordance with the specified design criteria will be allowed to reduce the value of the effective impervious ratio used later in this Manual to size treatment controls. Calculation of effective imperviousness is described later in this fact sheet.

Description and Design

Suggested design strategies to minimize effective imperviousness include G-5.1: Turf Buffer and G-5.2: Grass-lined Channel. Suggested uses of these design strategies are illustrated in Figure 3-1. These design control measures are described below along with associated design criteria. It is important to note that at least one of these control measures is required to be employed in the site design unless site conditions make it infeasible to do so. For this site design requirement to be waived, project proponents must demonstrate infeasibility to the satisfaction of the City stormwater review staff.

G-5.1: Turf Buffers

Description

Turf Buffers are uniformly graded and densely vegetated strips of turf grass. Runoff flow is distributed uniformly across the top width of the strip to achieve sheet flow down the length of the strip. Turf Buffers provide opportunity for infiltration, reduce peak flows from impervious areas and provide some degree of pollutant removal. Applications of Turf Buffers are illustrated in Figure 3-2. Turf Buffers differ from Grass-lined Channels, as they are designed to receive and maintain sheet flow as opposed to concentrated or channelized flow. Sheet flow application to the top of the Turf buffer may achieved by routing sheet flow from impervious areas, such as parking lots, directly to the top of the Turf Buffer or by redistributing concentrated flow across the top of the Turf Buffer by means of a level spreader. Turf Buffer strips, used for the purpose of minimizing effective imperviousness, are similar to Grass Strip Filters employed as a treatment control (see Section 5, Fact Sheet T-1), but differ in terms of the values used for the two principal design parameters – linear application rate (across the top width of the buffer) (cfs/ft width) and down-slope length.

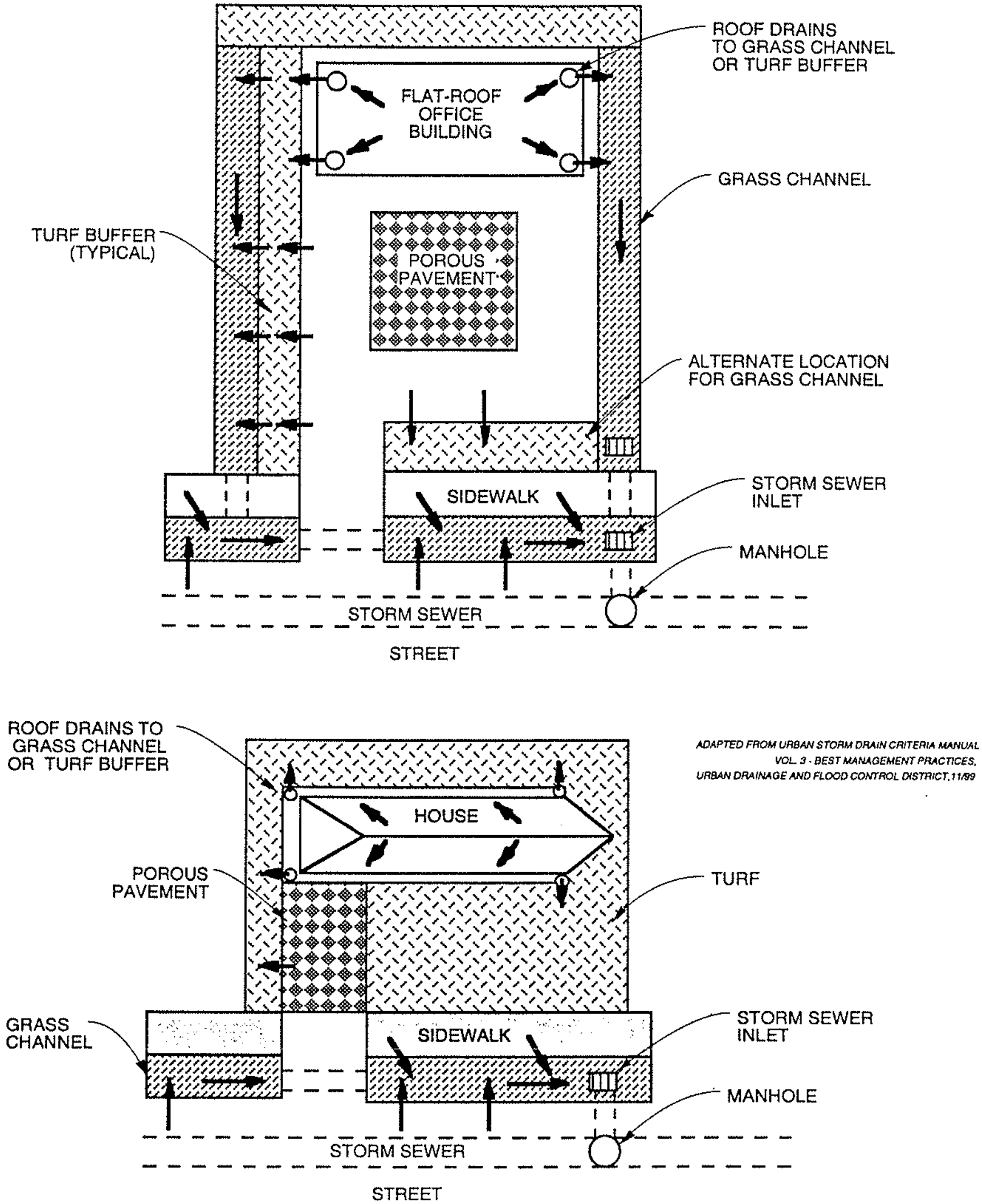


Figure 3-1 EXAMPLES OF MINIMIZING FLOWFROM IMPERVIOUS AREA

General Application and Design Considerations

Turf Buffers are appropriate for use in residential, commercial, industrial and institutional settings as illustrated in Figure 3-1. They are typically located adjacent to impervious areas to be mitigated. Their use should be incorporated into the site and master drainage planning and their design should be performed in close coordination with the landscape architect. The contributing flow from impervious areas that can be accommodated by the Turf Buffer will be limited according to the design criteria in this fact sheet. Tributary areas are typically less than 5 acres. Several Turf Buffers may be used on a single site, each sized according to the impervious area from which it receives flow. Irrigation and regular mowing are required to maintain the turf grass cover. Turf Buffers should be located away from, or protected from, excessive pedestrian or vehicular traffic that can damage the grass cover and adversely affect achievement of sheet flow over the surface. Although Turf Buffers provide some degree of pollutant removal, they do not qualify as treatment controls and must be followed by at least one of the approved treatment controls described in Section 5.

Design Criteria and Procedure

Principal design criteria for Turf Buffers are summarized in Table 3-1. See Figure 3-2 for dimensional relationships.

Table 3-1. Turf Buffer Design Criteria

Design Parameter	Unit	Design Criteria
Design Flow (SQDF)	cfs	0.20 in./h × C × Area
Maximum linear application rate (q_a)	cfs/ft width	0.05
Minimum width (normal to flow) (W_{TB})	ft	(SQDF) / (q_a)
Minimum length (flow direction) (L_{TB})	ft	8 (minimum)
Maximum slope (flow direction) (S_{TB})	%	10 (maximum)
Vegetation	–	Turf grass (irrigated)

Design procedure and application of design criteria are outlined in the following steps:

1. Design Flow — Determine Stormwater Quality Design Flow (SQDF) for impervious area to be mitigated.

   SQDF = 0.20 × C × Area (see Calculation Fact Sheet, Section 5)

2. Minimum Width — Calculate minimum width of the Turf Buffer (W_{TB}) normal to flow direction.

   W_{TB} = (SQDF) / (q_a)

   W_{TB} = (SQDF) / 0.05 cfs/ft (minimum)

3. Minimum Length — Length of the Turf Buffer (L_{GB}) in the direction of flow shall not be less than 8 feet.

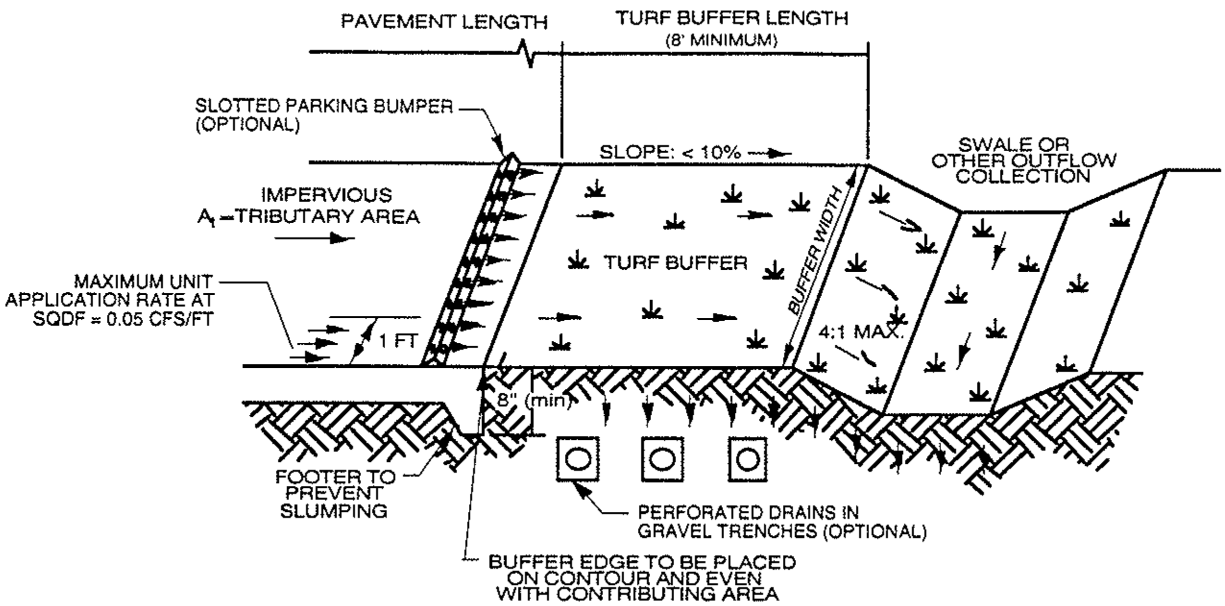
   L_{TB} = 8 feet (minimum)

4. Maximum Slope — Slope of the ground in the direction of flow shall not be greater than 10 percent.

5. Flow Distribution	Incorporate a device at the upstream end of the Turf Buffer to evenly distribute flows along the top width, such as slotted curbing, modular block porous pavement, or other spreader devices. Concentrated flow delivered to the Turf Buffer must be distributed evenly by means of a level spreader of similar concept.
6. Vegetation	Provide irrigated perennial turf grass to yield full, dense cover (See Appendix F for suitable grasses).
7. Outflow Collection	Provide a means for outflow collection and conveyance (e.g. grass channel/swale, storm drain, street gutter)

Design Example

A completed design form follows as a design example. Blank design forms are provided in Appendix G.



SHEET FLOW CONTROL

NOT TO SCALE

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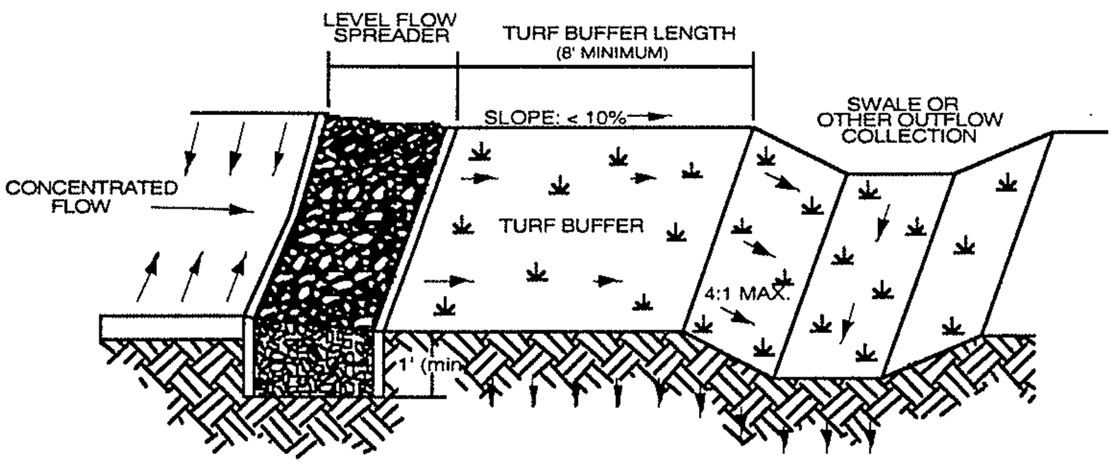


CONCENTRATED FLOW CONTROL

NOT TO SCALE

Figure 3-2 TURF BUFFER

Design Procedure Form for G-5.1: Turf Buffer

Designer: ______________________

Company: ______________________

Date: ______________________

Project: ______________________

Location: ______________________

1. Design Flow	SQDF = 1.0 cfs
2. Design Width W_{TB} = (SQDF) / 0.05 cfs/ft.	W_{TB} = 20.0 ft.
3. Design Length (8 ft minimum)	L_{TB} = 8.0 ft.
4. Design Slope (10% maximum)	S_{TB} = 3.0 %
5. Flow Distribution (Check type used or describe "Other")	X Slotted curbing ___ Modular block porous paving ___ Level spreader ___ Other ___
6. Vegetation (describe type)	Tall fescue
7. Outflow Collection (Check type used or describe "Other")	X Grass Channel/Swale ___ Street Gutter ___ Storm Sewer ___ Underdrain used ___ Other ___

Notes: ______________________

G-5.2: Grass-lined Channels

Description

Grass-lined Channels are densely vegetated drainageways with gentle sideslopes and gradual longitudinal slopes in the direction of flow that collect and slowly convey runoff to downstream points of discharge. Grass-lined Channels provide an opportunity for infiltration, reduce peak flows from impervious areas and provide some degree of pollutant removal. Applications of Grass-lined Channels are illustrated in Figure 3-3. Grass-lined Channels, used for the purpose of minimizing effective imperviousness, are similar to Grass Swale Filters employed as a treatment control (see Section 5, Fact Sheet T-1), but differ in terms of design depth of flow and minimum contact time.

General Application and Design Considerations

Grass-lined Channels are appropriate for use in residential, commercial, industrial and institutional settings as illustrated in Figure 3-1. They are typically used in conjunction with Turf Buffers and are located adjacent to impervious areas to be mitigated. Their use should be incorporated into the site and master drainage planning. The contributing flow from impervious areas that can be accommodated by the Grass-lined Channels will be limited according to the design criteria in this fact sheet. Tributary areas are typically less than 5 acres. Several Grass-lined Channels may be used on a single site, each sized according to the impervious area from which it receives flow. Irrigation and regular mowing are required to maintain the turf grass cover. Grass-lined Channels are not the same as Grass Swale Filters. Consequently, Grass-lined Channels do not qualify as treatment controls and must be followed by at least one of the approved treatment controls described in Section 5.

Design Criteria and Procedure

Principal design criteria for Grass-lined Channels are summarized in Table 3-2 (Ref. Figure 3-3).

Table 3-2 Grass-lined Channel Design Criteria

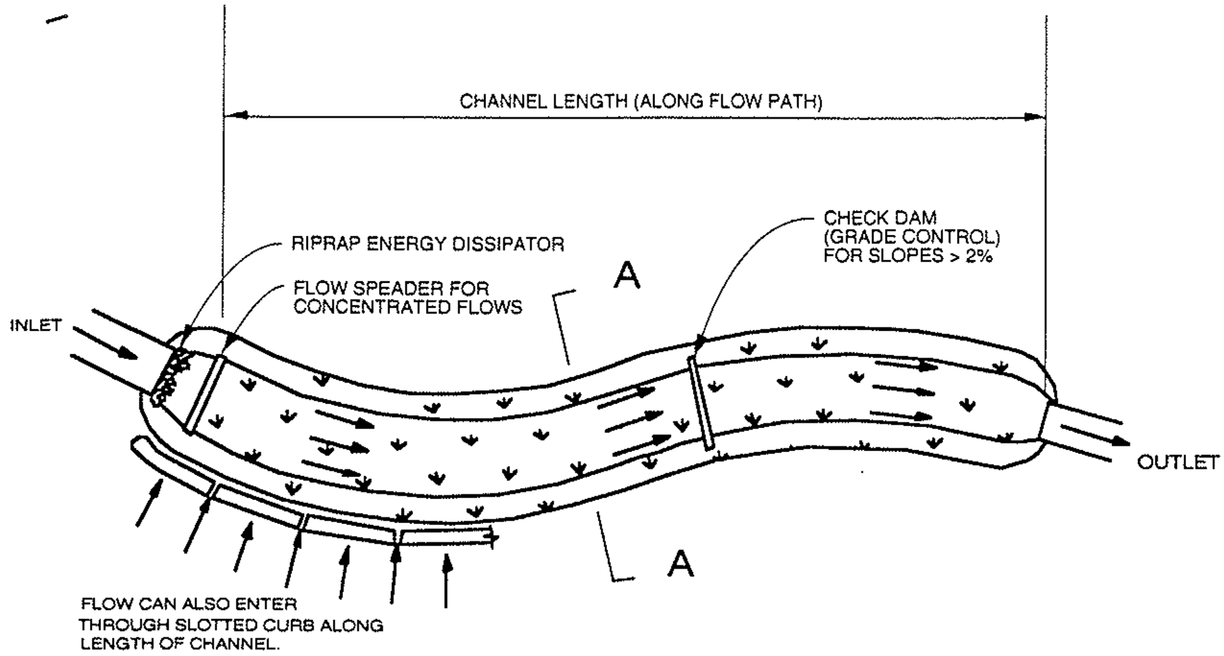
Design Parameter	Unit	Design Criteria
Design Flow (SQDF)	cfs	0.20 × C × Area
Channel geometry	–	Trapezoidal or triangular
Maximum channel side slope	H:V	4 :1
Minimum slope in flow direction	%	0.2 (provide underdrains for slopes < 0.5)
Maximum slope in flow direction	%	2.0 (provide grade-control checks for slopes >2.0)
Maximum flow velocity	ft/sec	1.5 (based on Manning's n = 0.05)
Maximum depth of slow at SQDF	ft.	2.0 (based on Manning's n = 0.05)
Vegetation	–	Turf grass

Design procedure and application of design criteria are outlined in the following steps:

1.	Design Flow	Determine Stormwater Quality Design Flow (SQDF) for impervious area to be mitigated. SQDF = 0.20 × C × Area (see Calculation Fact Sheet, Section 5)
2.	Channel Geometry	Use trapezoidal or triangular cross section.
3.	Maximum Side Slope	Side slopes shall not be steeper than 4:1 (5:1 or flatter preferred).
4.	Minimum Slope	Slope of the channel in the direction of flow shall not be less than 0.2 percent. Channel with slopes less than 0.5 percent should be provided with underdrains (see Figure 3-3).
5.	Maximum Slope	Slope of the channel in the direction of flow shall not be greater than 2 percent. Provide grade control checks for slopes greater than 2.0 percent (see Figure 3-3).
6.	Flow Velocity	Maximum flow velocity at design flow should not exceed 1.5 ft/sec. based on a Manning's n = 0.05.
7.	Flow Depth	Maximum depth of flow at design flow should not exceed 2.0 ft. based on a Manning's n = 0.05.
8.	Vegetation	Provide irrigated perennial turf grass to yield full, dense cover. (See Appendix F for suitable grasses).
9.	Drainage and Flood Control	Provide sufficient flow depth for flood event flows to avoid flooding of critical areas or structures.

Design Example

A completed design form follows as a design example. Blank design forms are provided in Appendix G.



TRAPEZOIDAL GRASS -LINED CHANNEL – PLAN

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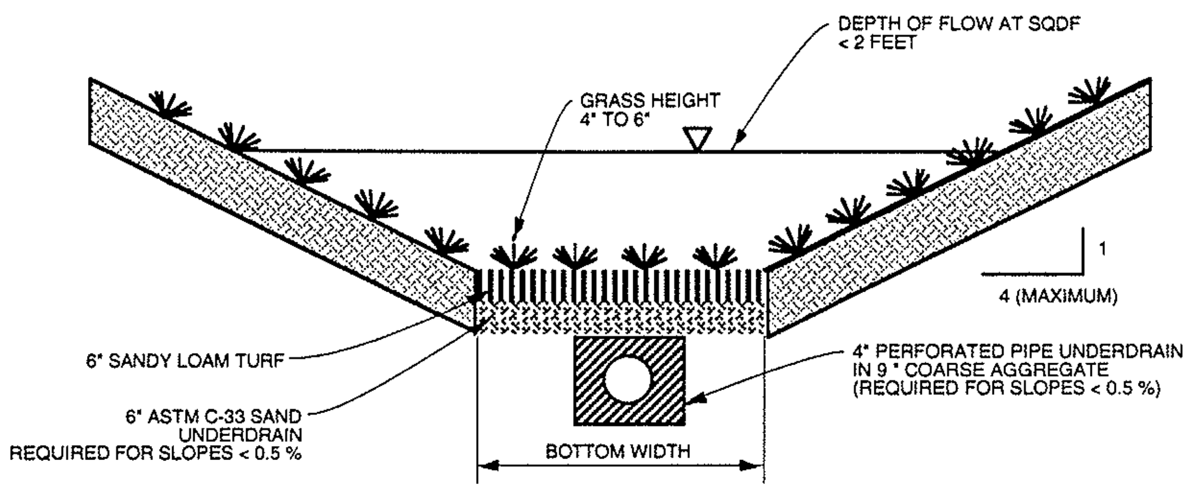


TRAPEZOIDAL GRASS-LINED CHANNEL – SECTION

NOT TO SCALE

Figure 3-3 GRASS-LINED CHANNEL

Design Procedure Form for G-5.2: Grass-lined Channel

Designer:________________

Company:________________

Date:________________

Project:________________

Location:________________

1. Design Flow	SQDF = 10.0 cfs
2. Channel Geometry	
A. Channel Bottom Width (b)	b = 1.0 ft.
B. Side slope (Z)	Z = 4:1
3. Depth of flow at SQDF (d = 2 ft max, Manning n= 0.05)	d = 1.4 ft.
4. Design Slope	
A. s = 2 percent maximum	s = 0.20 %
B. No. of grade controls required	0 (number)
5. Design velocity at SQDF (v = 1.5 ft/s max, Manning n= 0.05)	v= 1.08 ft/s
6. Vegetation (describe)	Tall Fescue
7. Outflow Collection (Check type used or describe "Other")	_X_ Grated Inlet ____ Infiltration Trench ____ Other ________

Notes ________________

Calculating Effective Imperviousness

The effective imperviousness of a site may be reduced if flow from impervious areas are routed over general site design controls G-5.1: Turf Buffers and/or G-5.2: Grass-lined Channels that are designed in conformance to the criteria presented in this fact sheet.

Calculation Procedure

The allowable reduction in impervious percentage is determined with the use of Figure 3-4 as described in the following steps:

1. Estimate the total imperviousness (impervious percentage) of the site by the determining the weighted average of individual areas of like imperviousness. Table 3-3 may be used as guide for estimating imperviousness of typical site elements.

Table 3-3. Recommended Percent Imperviousness for Typical Site Elements

Site Element	Percent Imperviousness
Asphalt/concrete pavement	100
Gravel pavement	40
Roofs	90
Porous pavement	35[1]
Lawn/turf	0
Open space	0

1. Variable with product type, assumes porous subsoil and use of underdrains

Table 3-4 may be used as an aid in calculating total imperviousness.

Table 3-4. Calculation Sheet for Determination of Total Imperviousness

Site Element	Unit Area (ft^2)	Percent Imperviousness	Weighting Factor[2]	Weighted % Imperviousness [3,4]
Asphalt/concrete pavement		100		
Gravel pavement		40		
Roofs		90		
Porous pavement		35[5]		
Lawn/turf		0		
Open space		0		
Total Contributing Area[1]		–	–	

1. Total contributing area = sum of unit areas
2. Weighting factor = unit area / total contributing area
3. Weighted imperviousness = weighting factor × percent imperviousness
4. Total imperviousness = sum of weighted imperviousness
5. Variable with product type, assumes porous subsoil and use of underdrains

2. Enter Figure 3-4 along the horizontal axis with the value of total imperviousness calculated in Step 1. Move vertically up Figure 3-4 until the appropriate curve (G-5.1 or G-5.2 employed individually or G-5.1 and G-5.2 employed together) is intercepted. Move horizontally across Figure 3-4 until the vertical axis is intercepted. Read the Effective Imperviousness value along the vertical axis.

   Note that if G-5.1 and/or G-5.2 are implemented on only a portion of the site, the site may be divided and effective imperviousness determined for the portion of the site for which site design controls have been implemented. The resulting effective imperviousness may be combined with total imperviousness of the remainder of the site to determine a weighted average total imperviousness for the entire site.

Calculation Example

The calculation procedure described above is illustrated by the following example.

<u>Design Conditions:</u>

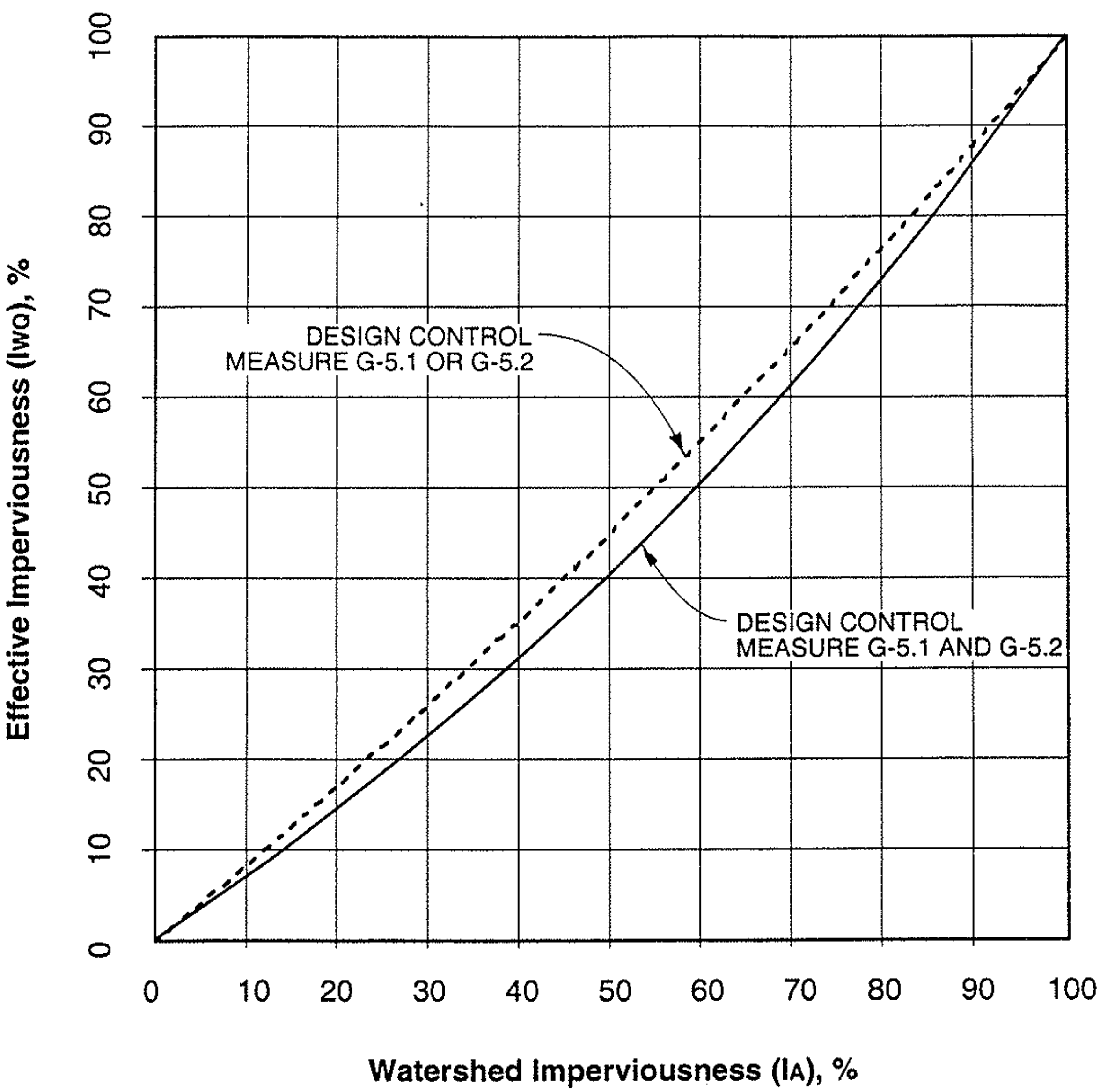
1. All flow from impervious areas is routed over a Turf Buffer (G-5.1).
2. The site consists of the site elements and associated unit areas shown in Table 3-5.

Table 3-5. Example Calculation Sheet for Determination of Total Imperviousness

Site Element	Unit Area (ft^2)	Percent Imperviousness	Weighting Factor[4]	Weighted % Imperviousness[5,6]
Asphalt/concrete pavement	10,000	100	0.20	20
Gravel pavement	0	40		
Roofs	10,000	90	0.20	18
Porous pavement	0	35		
Lawn	20,000	0	0.40	0
Open space	10,000	0	0.20	0
Total Contributing Area[3]	50,000	–	–	38

<u>Calculations:</u>

3. Total contributing area = sum of unit areas
4. Weighting factors = unit area/total contributing area
5. Weighted imperviousness = Weighting factor × percent imperviousness
6. Total imperviousness = sum of weighted imperviousness
7. Effective imperviousness = 32 percent (from Figure 3-4)



G-5.1: TURF BUFFER
G-5.2: GRASS-LINED CHANNEL

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Figure 3-4. DETERMINATION OF EFFECTIVE IMPERVIOUSNESS

SECTION 4
SITE-SPECIFIC SOURCE CONTROL MEASURES

Introduction

Source control measures are low-technology practices designed to prevent pollutants from contacting stormwater runoff or to prevent discharge of contaminated runoff to the storm drainage system. This Section addresses site-specific, structural type source control measures consisting of specific design features or elements. Non-structural type source control measures; such as good housekeeping and employee training are not included in this Manual. The California Stormwater Best Management Practices Handbooks may be consulted for information on non-structural type source control measures practice (CSQA, 2003). The City may require additional source control measures not included in this Manual for specific pollutants, activities or land uses.

This Section describes control measures for specific types of sites or activities that have been identified as potential significant sources of pollutants in stormwater. Each of the measures specified in this Section should be implemented in conjunction with appropriate nonstructural source control measures to optimize pollution prevention.

The measures addressed in this Section apply to both stormwater and non-stormwater discharges. Non-stormwater discharges are the discharge of any substance, such as cooling water, process wastewater, etc., to the storm drainage system or water body that is not composed entirely of stormwater. Stormwater that is mixed or commingled with other non-stormwater flows is considered non-stormwater. Discharges of stormwater and non-stormwater to the storm drainage system or a water body may be subject to local, state, or federal permitting prior to any discharge commencing. The appropriate agency should be contacted prior to any discharge. Discuss the matter with the stormwater staff if you are uncertain as to which agency should be contacted.

Some of the measures presented in this Section require connection to the sanitary sewer system. Connection and discharge to the sanitary sewer system without prior approval or obtaining the required permits is prohibited. Contact the City stormwater staff to obtain information regarding obtaining sanitary sewer permits from the City. Discharges of certain types of flows to the sanitary sewer system may be cost prohibitive. The designer is urged to contact the City prior to completing site and equipment design of the facility.

Description

Site-specific source control measures and associated design features specified for various sites and activities are summarized in Table 4-1. Fact sheets are presented in this Section for each source control measure. These sheets include design criteria established by the City to ensure effective implementation of the required source control measures:

Table 4-1. Summary of Site-specific Source Control Design Features

Site-specific Source Control Measure [(a)]	Design Feature or Element						
	Signs, placards, stencils	Surfacing (compatible, impervious)	Covers, screens	Grading/berming to prevent runon	Grading/berming to provide secondary containment	Sanitary sewer connection	Emergency Storm Drain Seal
Storm Drain Message and Signage (S-1)	X						
Outdoor Material Storage Area Design (S-2)		X	X	X	X		X
Outdoor Trash Storage and Waste Handling Area Design (S-3)		X	X	X		X	
Outdoor Loading/Unloading Dock Area Design (S-4)		X	X	X	X		
Outdoor Repair/Maintenance Bay Design (S-5)		X	X	X	X		X
Outdoor Vehicle/Equipment/ Accessory Washing Area Design (S-6)		X	X	X	X	X	X
Fueling Area Design (S-7)		X	X	X	X		X
Parking Lot Design [(b)]							

(a) Refer to Fact Sheets in Section 4 for detailed information and design criteria

(b) Requirements for proper design of parking lots are covered by requirements for General Site Design Control Measures (see Section 3) and Treatment Control Measures (see Section 5).

Storm Drain Message and Signage

Purpose

Waste materials dumped into storm drain inlets can have severe impacts on receiving and ground waters. Posting notices regarding discharge prohibitions at storm drain inlets can prevent waste dumping. This fact sheet contains details on the installation of storm drain messages at storm drain inlets located in new or redeveloped commercial, industrial, and residential sites.

Design Criteria

Storm drain messages have become a popular method of alerting the public about the effects of and the prohibitions against waste disposal into the storm drain system. The signs are typically stenciled or affixed near the storm drain inlet. The message simply informs the public that dumping of wastes into storm drain inlets is prohibited and/or the drain discharges to a receiving water.

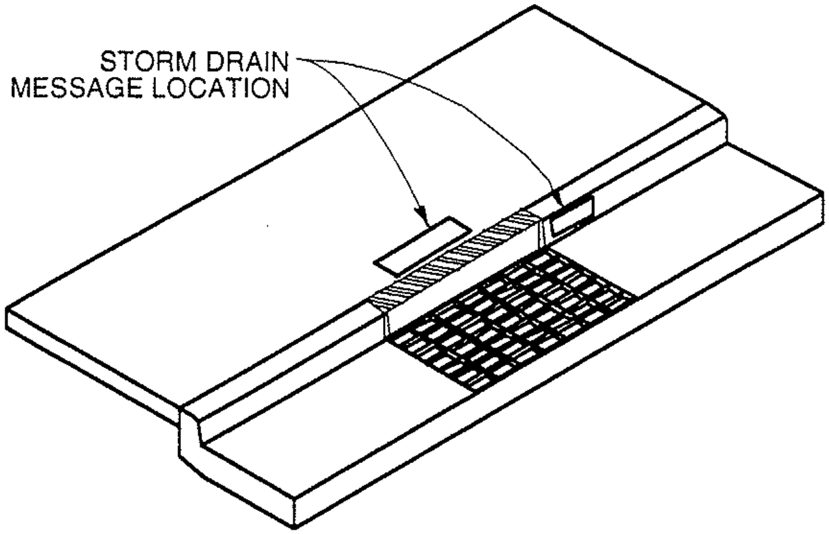
Storm drain message markers or placards are required at all storm drain inlets within the boundary of the development project. The marker should be placed in clear sight facing toward anyone approaching the inlet from either side (see Figure 4-1). All storm drain inlet locations must be identified on the development site map.

The City will develop standards for design and installation of storm drain messages. Consult City stormwater staff to determine specific requirements for storm drain messages.

Signs with language and/or graphical icons, which prohibit illegal dumping, shall be posted at designated public access points along channels and streams within a project area. Consult City stormwater staff to determine specific signage requirements.

Maintenance Requirements

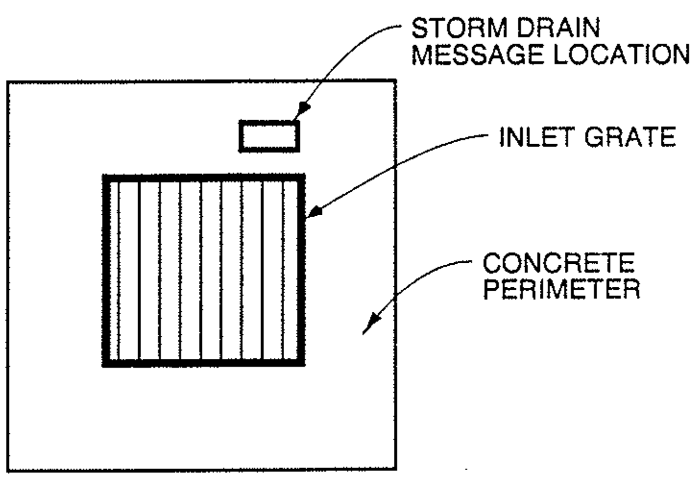
Legibility of markers and signs shall be maintained. If required by the City, the owner/operator or homeowner's association shall enter into a maintenance agreement with the agency or record a deed restriction upon the property title to maintain the legibility of messages and signs.



CURB TYPE INLET

NOTES:

1. STORM DRAIN MESSAGE SHALL BE APPLIED IN SUCH A WAY AS TO PROVIDE A CLEAR, LEGIBLE IMAGE.
2. STORM DRAIN MESSAGE SHALL BE PERMANENTLY APPLIED DURING THE CONSTRUCTION OF THE CURB AND GUTTER USING A METHOD APPROVED BY THE LOCAL AGENCY.



AREA TYPE INLET

FIGURE 4-1. STORM DRAIN MESSAGE LOCATION

Outdoor Material Storage Area Design

Purpose

Materials that are stored outdoors can become sources of pollutants in stormwater runoff if not handled or stored properly. Materials can be in the form of raw products, by-products, finished products, and waste products. The type of pollutants associated with the materials will vary depending on the type of commercial or industrial activity.

Some materials are more of a concern than others. Toxic and hazardous materials must be prevented from coming in contact with stormwater. Non-toxic or non-hazardous materials do not have to be prevented from stormwater contact. However, these materials may have toxic effects on receiving waters if allowed to be discharged with stormwater in significant quantities. Accumulated material on an impervious surface could result in significant debris and sediment being discharged with stormwater runoff causing a significant impact on the rivers or streams that receive the runoff.

Materials may be stored in a variety of ways, including bulk piles, containers, shelving, stacking, and tanks. Stormwater contamination may be prevented by eliminating the possibility of stormwater contact with the material storage areas either through diversion, cover, or capture of the stormwater. Control measures may also include minimizing the storage area. Control measures are site specific, and must meet City requirements.

Design Criteria

Design requirements for material storage areas are governed by Building and Fire Codes, and by current City or County ordinances and zoning requirements. Source controls described in the fact sheet are intended to enhance and be consistent with these code and ordinance requirements. The following design features should be incorporated into the design of material storage area when storing materials outside that will contribute significant pollutants to the storm drain.

Source Control Design Feature	Design Criteria
Surfacing	• Construct the storage area base with a material impervious to leaks and spills.
Covers	• Install a cover that extends beyond the storage area, or use a manufactured storage shed for small containers.
Grading/Containment	• Minimize the storage area. • Slope the storage area towards a dead-end sump to contain spills. • Grade or berm storage areas to prevent run-on from surrounding areas. • Direct runoff from downspouts/roofs away from storage areas.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Outdoor Trash Storage Area Design

Purpose

Stormwater runoff from areas where trash is stored or disposed of can be polluted. In addition, loose trash and debris can be easily transported by the forces of water or wind into nearby storm drain inlets, channels, and/or creeks. Waste handling operations that may be sources of stormwater pollution include dumpsters, litter control, and waste piles. This fact sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff associated with trash storage and handling.

Design Criteria

Design requirements for waste handling areas are governed by Building and Fire Codes, and by current local agency ordinances and zoning requirements. The design criteria described in the fact sheet are meant to enhance and be consistent with these code and ordinance requirements. Hazardous waste should be handled in accordance with legal requirements established in Title 22, California Code of Regulations.

Wastes from commercial and industrial sites are typically hauled by either public or commercial carriers that may have design or access requirements for waste storage areas. The design criteria listed below are recommendations and are not intended to be in conflict with requirements established by the waste hauler. The waste hauler should be contacted prior to the design of your site trash collection area. Conflicts or issues should be discussed with the City staff.

The following trash storage area design controls were developed to enhance the local agency codes and ordinances and should be implemented depending on the type of waste and the type of containment:

Source Control Design Feature	Design Criteria
Surfacing	• Construct the storage area base with a material impervious to leaks and spills.
Screens/Covers	• Install a screen or wall around trash storage area to prevent off-site transport of loose trash. • Use lined bins or dumpsters to reduce leaking of liquid wastes. • Use water-proof lids on bins/dumpsters or provide a roof to cover enclosure (City discretion) to prevent rainfall from entering containers
Grading/Contouring	• Berm or grade the waste handling area to prevent runon of stormwater. • Do not locate storm drains in immediate vicinity of the trash storage area.
Signs	• Post signs on all dumpsters informing users that hazardous materials are not to be disposed of therein.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g. screens, covers and signs) must be maintained by the owner/operator. Maintenance agreements between the City and the owner/operator may be required. If required by the City, maintenance agreements or deed restrictions must be executed by the owner/operator before improvement plans are approved. Refer to Appendix C and D for a further guidance regarding maintenance plans agreements.

Outdoor Loading/Unloading Dock Area Design

Purpose

Materials spilled, leaked, or lost during loading or unloading may collect on impervious surfaces or in the soil and be carried away by runoff or when the area is cleaned. Also, rainfall may wash pollutants from machinery used to load or unload materials. Depressed loading docks (truck wells) are contained areas that can accumulate stormwater runoff. Discharge of spills or contaminated stormwater to the storm drain system is prohibited. This fact sheet contains details on specific measures recommended to prevent or reduce pollutants in stormwater runoff from outdoor loading or unloading areas.

Design Criteria

Design requirements for outdoor loading/unloading of materials are governed by Building and Fire Codes, and by current local agency ordinances and zoning requirements. Source controls described in the fact sheet are meant to enhance and be consistent with these code and ordinance requirements. Companies may have their own design or access requirements for loading docks. The design criteria listed below are not intended to be in conflict with requirements established by individual companies. Conflicts or issues should be discussed with the City staff.

The following design criteria should be followed when developing construction plans for material loading/unloading areas:

Source Control Design Feature	Design Criteria
Surfacing	• Construct floor surfaces with material that is compatible with materials being handled in the loading/unloading area.
Covers	• Cover loading/unloading areas to a distance of at least 3 feet beyond the loading dock or install a seal or door skirt to be used for all material transfers between the trailer and the building.
Grading/Contouring	• Grade or berm storage areas to prevent run-on from surrounding areas. • Direct runoff from downspouts/roofs away from loading areas.
Emergency Storm Drain Seal	• Do not locate storm drains in the loading dock area. Direct connections to storm drains from depressed loading docks are prohibited. • Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces, such as depressed loading docks. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Purpose

Activities that can contaminate stormwater include engine repair, service and parking (leaking engines or parts). Oil and grease, solvents, car battery acid, coolant and gasoline from the repair/maintenance bays can severely impact storm water if allowed to come into contact with storm water runoff. This fact sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment maintenance and repair areas.

Design Criteria

Design requirements for vehicle maintenance and repair areas are governed by Building and Fire Codes, and by current local agency ordinances, and zoning requirements. The design criteria described in the fact sheet are meant to enhance and be consistent with these code requirements.

The following design criteria are required for vehicle and equipment maintenance, and repair. All hazardous and toxic wastes must be prevented from entering the storm drainage system.

Source Control Design Feature	Design Criteria
Surfacing	• Construct the vehicle maintenance/repair floor area with Portland cement concrete.
Covers	• Cover or berm areas where vehicle parts with fluids are stored. • Cover or enclose all vehicle maintenance/repair areas.
Grading/Contouring	• Berm or grade the maintenance/repair area to prevent runon and runoff of stormwater or runoff of spills. • Direct runoff from downspouts/roofs away from maintenance/repair areas. • Grade the maintenance/repair area to drain to a dead-end sump for collection of all wash water, leaks and spills. Direct connection of maintenance/repair area to storm drain system is prohibited. • Do not locate storm drains in the immediate vicinity of the maintenance/repair area.
Emergency Storm Drain Seal	• Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Outdoor Vehicle/Equipment/Accessory Washing Area Design

Purpose

Washing vehicles and equipment in areas where wash water flows onto the ground can pollute storm water. Wash waters can contain high concentrations of oil and grease, solvents, phosphates and high suspended solids loads. Sources of washing contamination include outside vehicle/equipment cleaning or wash water discharge to the ground. This fact sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment washing areas.

Design Criteria

Design requirements for vehicle and equipment washing areas are governed by Building and Fire Codes, and by current local agency ordinances, and zoning requirements. The design criteria described in the fact sheet are meant to enhance and be consistent with these code requirements.

The following design criteria are required for vehicle and equipment washing areas. All hazardous and toxic wastes must be prevented from entering the storm drain system.

Source Control Design Feature	Design Criteria
Surfacing	• Construct the vehicle/equipment wash area floors with Portland cement concrete.
Covers	• Provide a cover that extends over the entire wash area.
Grading/Contouring	• Berm or grade the maintenance/repair area to prevent runon and runoff of stormwater or runoff of spills. • Grade or berm the wash area to contain the wash water within the covered area and direct the wash water to treatment and recycle or pretreatment and proper connection to the sanitary sewer system. Obtain approval from the City before discharging to the sanitary sewer. • Direct runoff from downspouts/roofs away from wash areas. • Do not locate storm drains in the immediate vicinity of the wash area.
Emergency Storm Drain Seal	• Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Purpose

Spills at vehicle and equipment fueling areas can be a significant source of pollution because fuels contain toxic materials and heavy metals that are not easily removed by storm water treatment devices. When storm water mixes with fuel spilled or leaked onto the ground, it becomes contaminated with petroleum-based materials that are harmful to humans, fish and wildlife. This contamination can occur at large industrial sites or at small commercial sites such as gas stations and convenience stores. This fact sheet contains details on specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment fueling areas, including retail gas stations.

Design Criteria

Design requirements for fueling areas are governed by Building and Fire Codes and by current local agency ordinances and zoning requirements. The design requirements described in this fact sheet are meant to enhance and be consistent with these code and ordinance requirements.

Source Control Design Feature	Design Criteria
Surfacing	• Fuel dispensing areas must be paved with Portland cement concrete. The fuel dispensing area is defined as extending 6.5 feet from the corner of each fuel dispenser or the length at which the hose and nozzle assemble may be operated plus 1 foot, whichever is less. The paving around the fuel dispensing area may exceed the minimum dimensions of the "fuel dispensing area" stated above. • Use asphalt sealant to protect asphalt paved areas surrounding the fueling area.
Covers	• The fuel dispensing area must be covered[1], and the cover's minimum dimensions must be equal to or greater than the area within the grade break or the fuel dispensing area, as defined above. The cover must not drain onto the fuel dispensing area.
Grading/Contouring	• The fuel dispensing area shall have a 2% to 4% slope to prevent ponding and must be separated from the rest of the site by a grade break that prevents run-on of stormwater to the extent practicable. • Grade the fueling area to drain toward a dead-end sump. • Direct runoff from downspouts/roofs away from fueling areas. • Do not locate storm drains in the immediate vicinity of the fueling area.

1. If fueling large equipment or vehicles that would prohibit the use of covers or roofs, the fueling island should be designed to sufficiently accommodate the larger vehicles and equipment and to prevent run-on and run-off of stormwater. Uncovered fueling areas must be graded to direct stormwater to a dead-end sump.

Source Control Design Feature	Design Criteria
Emergency Storm Drain Seal	• Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Proof of Control Measure Maintenance

Purpose

Continued effectiveness of control measures specified in this Manual depends on diligent ongoing inspection and maintenance. To ensure that such maintenance is provided, the City may require both a Maintenance Agreement and a Maintenance Plan from the owner/operator of stormwater control measures.

Maintenance Agreement

On-site treatment control measures are to be maintained by the owner/operator. Maintenance agreements between the City and the owner/operator may be required. A Maintenance Agreement with the governing agency must be executed by the owner/operator before occupancy of the project is approved. A sample Maintenance Agreement form is provided in Appendix C.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility;
- Responsible party for operation and maintenance.

Additional guidelines for Maintenance Plans are provided in Appendix D.

SECTION 5

TREATMENT CONTROL MEASURES

Introduction

Treatment control measures are required to augment source controls to reduce pollution from stormwater discharges to the maximum extent practicable. Treatment control measures are engineered technologies designed to remove pollutants from stormwater runoff. The type of treatment control measure(s) to be implemented at a site depends on a number of factors including: type of pollutants in the stormwater runoff, quantity of stormwater runoff to be treated, project site conditions, receiving water conditions, and state industrial permit requirements, when applicable. Land requirements, and costs to design, construct and maintain treatment control measures vary by treatment control measure.

Unlike flood control measures that are designed to handle peak flows, stormwater treatment control measures are designed to treat the more frequent, lower-flow storm events, or the first flush portions of runoff from larger storm events (typically referred to as the first-flush events). Small, frequent storm events represent most of the total average annual rainfall for the area. The flow and volume from such small events, referred to as the Stormwater Quality Design Flow (SQDF) and Stormwater Quality Design Volume (SQDV), are targets for treatment. There is marginal water quality benefit gained by sizing treatment facilities to treat flows or volumes greater than the SQDF or SQDV.

The treatment control measures presented in this Manual are designed based on flow rates or volume of runoff. Those designed based on flow are to be designed for the SQDF, and those designed based on volume are to be designed for the SQDV. Definitions and calculation procedures to determine SQDF and SQDV are presented in this Section. The treatment control measures specified in this Manual are to be sized for the SQDF or SQDV only. Flows in excess of SQDF or SQDV are to be diverted around or through the treatment control measure.

The stormwater treatment control measures specified in this Section are the more common non-proprietary measures being implemented nationwide. Studies have shown these measures to be reasonably effective if properly installed and maintained. The relative effectiveness of treatment controls specified in this Section for removal of pollutants of concern is shown in Table 5-1. Pollutants of concern listed are those that have been identified as causing or contributing to impairment of beneficial uses of water bodies in California. As discussed in Section 2, the measures presented in this Section are preferred and will ensure timely plan check review. Alternative technologies that provide equivalent treatment must be approved by the City on a case-by-case basis and may result in additional time for City review and approval, unless coordinated in advance with the City staff.

Unless otherwise agreed to by the City, the landowner, site operator, or homeowner's association is responsible for the operation and maintenance of the treatment control measures. Failure to properly operate and maintain the measures could result in reduced treatment of stormwater runoff, or a concentrated loading of pollutants to the storm drain system. To protect against failure, a Maintenance Plan must be developed and implemented for all treatment control measures. Guidelines for maintenance plans are provided in Appendix D of this Manual. The Plan must be made available at the City's request. In addition, a maintenance agreement with the

City may be required. The example maintenance agreements are included in Appendix C.

In addition to maintenance, the City may require water quality monitoring agreements for any of the treatment control measures recommended in this Manual. Monitoring may be conducted by the site operator, the City, or both. Monitoring may be required for a period of time to help the City evaluate the effectiveness of treatment control measures in reducing pollutants in stormwater runoff.

Description

This Section provides fact sheets for design and implementation of recommended treatment control measures. The fact sheets include siting, design, and maintenance requirements to ensure optimal performance of the measures. This Manual also contains calculation fact sheets and worksheets to aid in the design of water quality treatment control measures.

Table 5-1. Effectiveness of Treatment Controls Measures for Removal of Pollutants of Concern

Pollutant of Concern	Stormwater Treatment Control Measures[a]										
	Grass Strip Filter (T-1)	Grass Swale Filter (T-2)	Extended Detention Basin (T-3)	Wet Detention Basin (T-4)	Constructed Wetland (T-4)	Detention Basin/Sand Filter (T-6)	Porous Pavement Detention (T-7)	Porous Landscape Detention (T-8)	Infiltration Basin (T-9)	Infiltration Trench (T-10)	Media Filter (T-11)
Sediment	H	M	H	H	H	H	H	H	H	H	H
Nutrients	M	L	M	M	M	M	M	M	M	M	M
Metals	M	M	M	M	M	M	M	M	M	M	M
Trash and Debris	H	H	H	H	R	R	R	R	R	R	R
Oxygen Demand	M	M	M	M	M	M	M	M	M	M	M
Toxic Organics	M	M	M	M	M	M	M	M	M	M	M
Bacteria	M	L	L	H	M	M	M	M	M	M	M

(a) = Refer to Fact Sheets in Section 5 for detailed information and design criteria
H = >75% expected removal efficiency for typical urban stormwater runoff
M = 75% to 25% expected removal efficiency for typical urban stormwater runoff
L = <25% expected removal efficiency for typical urban stormwater runoff
R = Recommended for use only downstream of other treatment controls recommend for removal of trash and debris

Calculation of Stormwater Quality Design Flow and Volume

Introduction

The primary control strategy for all of the treatment control measures specified in this Section is to treat the Stormwater Quality Design Flow (SQDF) or Stormwater Quality Design Volume (SQDV) of the storm water runoff. The following paragraphs present calculation procedures and design criteria necessary to determine the SQDF and SQDV.

The treatment control measure equations specified in this Section are listed in Table 5-2 along with the basis of design, SQDF or SQDV, to be used for the listed control measure.

Table 5-2. Sizing Criteria for Treatment Control Measures

Treatment Control Measure	Design Basis
T-1: Grass Strip Filter	SQDF
T-2: Grass Swale Filter	SQDF
T-3: Dry Detention Basin	SQDV
T-4: Wet Detention Basin	SQDV
T-5: Constructed Wetland	SQDV
T-6: Detention Basin/Sand Filter	SQDV
T-7: Porous Pavement Detention	SQDV
T-8: Porous Landscape Detention	SQDV
T-9: Infiltration Basin	SQDV
T-10: Infiltration Trench	SQDV
T-11: Media Filter	SQDV
T-12: Proprietary Control Measures	SQDV or SQDF

Contributing Impervious Area Determination

The SQDF and SQDV are calculated by determining runoff from the impervious and pervious areas of a site that are connected to the treatment control measure. Impervious areas include sidewalks, roadways, parking areas, staging areas, storage areas, slabs, roofs, and other non-vegetated areas, including compacted soil areas. Off-site areas that could run-on to a site and contribute drainage to the treatment control measure should be included in the impervious area determination. The effective imperviousness of a site can be reduced through implementation of general site design control measures (e.g. G-5.1 and G-5.2) to reduce flow from impervious areas, as described in Section 3. Procedures for calculating effective imperviousness are presented in Section 3, Fact Sheet G-5.

Stormwater Quality Design Flow (SQDF) Calculation

Hydrologic calculations for design of flow-based stormwater treatment control measures in the City of Woodland shall be in accordance with latest version of the *Storm Drainage Guidance and Criteria, Storm Drainage Master Plan,* produced by the City of Woodland, together with the procedure set forth herein.

The Stormwater Quality Design Flow (SQDF) is defined to be equal to the maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two. The 85th percentile hourly rainfall intensity for Woodland is estimated to be 0.10 inches/hour, based on cumulative frequency curve for Sacramento presented in the *California Storm Water Best Management Practices Handbook – New Development and Redevelopment,* (2003) for representative rainfall gauges throughout California. The curve for Sacramento is considered representative of rainfall intensities in the Woodland area.

Calculation Procedure

1. Determine the 85th percentile hourly rainfall intensity for City of Woodland. <u>Use 0.10 inches/hour.</u>

2. Multiply the 85th percentile hourly rainfall intensity by a factor of two to obtain design rainfall intensity. <u>Use I = 0.10 × 2 = 0.20 inches/hour.</u>

3. Determine the project drainage area and the runoff coefficient "C" for the project drainage area using the procedures set forth in the *Storm Drainage Guidance and Criteria* or as directed by the City Stormwater Drainage Master Plan.

4. Calculate the SQDF

$$SQDF = I \times C \times A = 0.20 \times C \times A$$

Example Stormwater Quality Design Flow Calculation

The steps below illustrate calculation of SQDF:

Step 1: Set design rainfall intensity (I = 0.20 inches/hour).

Step 2: Determine project drainage area (Example: Area = 10 acres)

Step 3: Determine runoff coefficient "C" for project drainage area (Example: C = 0.50)

Step 4: Calculate SQDF = C × I × Area

Example: $SQDF = 0.20 \times 0.50 \times 10 = 1.0$ cfs

Stormwater Quality Design Volume (SQDV) Calculation

Hydrologic calculations for design of volume-based stormwater treatment controls in the City of Woodland shall be in accordance with the procedures set forth herein.

The Stormwater Quality Design Volume (SQDV) is defined as the volume necessary to capture and treat 80 percent or more of the average annual runoff volume from the site at the design drawdown period specified in the Fact Sheet for the proposed treatment control measure.

Calculation Procedure

1. Review the area draining to the proposed treatment control measure. Determine the effective imperviousness (I_{WQ}) of the drainage area using the procedure presented in Section 3, Fact Sheet G-5.
2. Figure 5-1 provides a direct reading of Unit Basin Storage Volumes required for 80% annual capture of runoff for values of "I_{WQ}" determined in Step 1. Enter the horizontal axis of Figure 5-1 with the "I_{WQ}" value from Step 1. Move vertically up Figure 5-1 until the appropriate drawdown period line is intersected. (The design drawdown period specified in the respective Fact Sheet for the proposed treatment control measure.) Move horizontally across Figure 5-1from this intersection point until the vertical axis is intersected. Read the Unit Basin Storage Volume along the vertical axis.

   Figure 5-1 is based on rain gauge data from the Sacramento International Airport.
3. The SQDV for the proposed treatment control measure is then calculated by multiplying the Unit Basin Storage Volume by the contributing drainage area. Due to the mixed units that result (e.g., acre-inches, acre-feet), it is recommended that the resulting volume be converted to cubic feet for use during design.

Example Stormwater Quality Design Volume Calculation

1. Determine the drainage area contributing to control measure, A_t. Example: 10 acres.
2. Determine the area of impervious surfaces in the drainage area, A_i. Example: 6.4 acres.
3. Calculate the percentage of impervious, $I_A = (A_i / A_t) \times 100$

   Example: Percent Imperviousness = $(A_i / A_t) \times 100$ = (6.4 acres/10 acres) × 100 = 64%
4. Determine Effective Imperviousness using Figure 3-4.

   Example: G-5.1 employed → I_{WQ} = 60%
5. Determine design drawdown period for proposed control measure.

   Example: T-3: Extended Detention Basin → Drawdown period = 40 hours
6. Determine the Unit Basin Storage Volume for 80% Annual Capture, V_u using Figure 5-1.

   Example: for $I_{WQ}/100 = 0.60$ and drawdown = 40 hrs, V_u = 0.41 in.
7. Calculate the SQDV for the basin, where SQDV = $V_u \times A_t$.

   Example: SQDV = (0.41 in)(10 ac)(1ft/12 in)(43,560 ft^2/ac) = 14,883 ft^3.

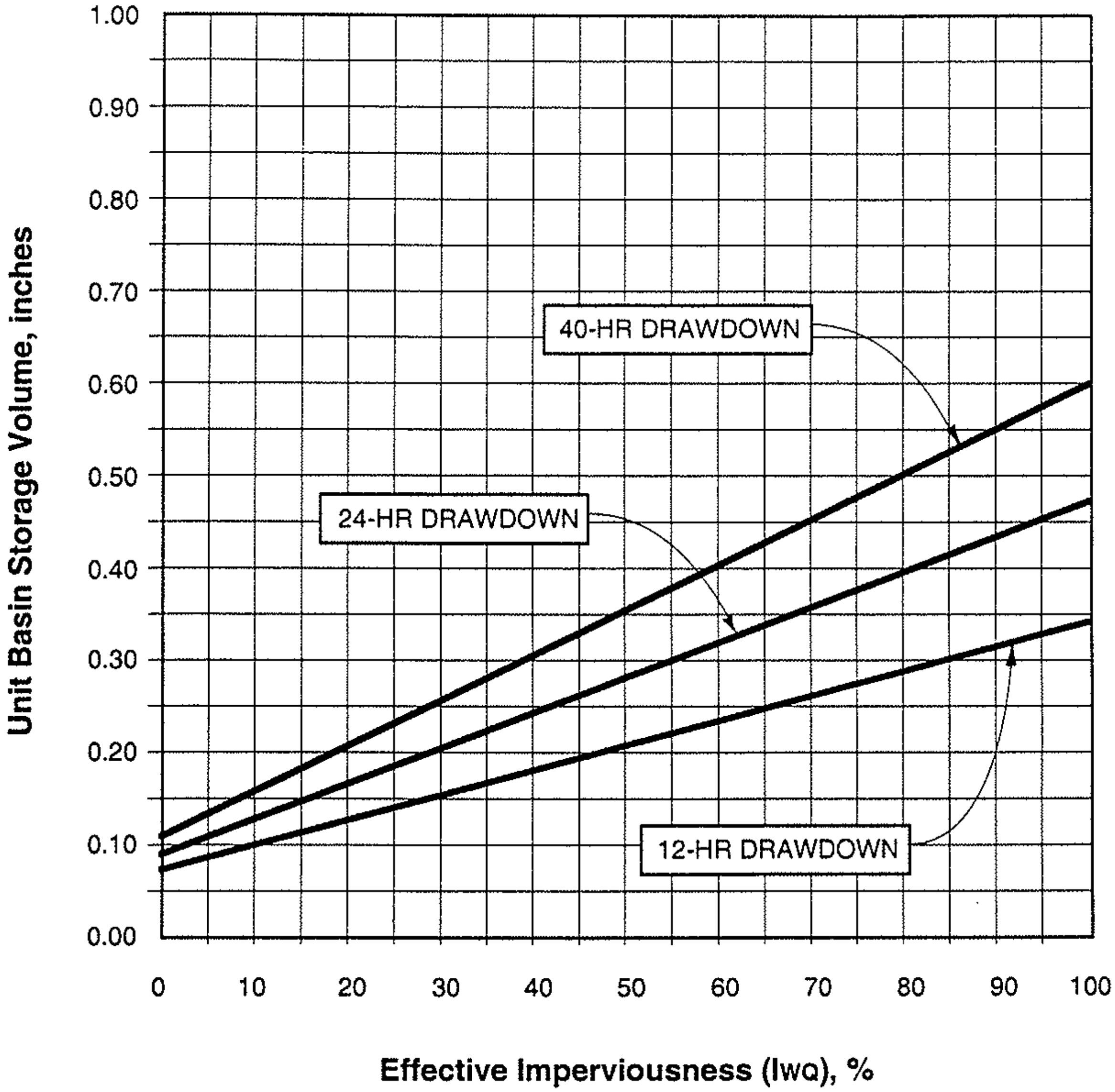


Figure 5-1. Unit Basin Storage Volume vs. Effective Imperviousness

Grass Strip Filter (GSTF)

Description

Grass Strip Filters (GSTF) are uniformly graded and densely vegetated strips of turf grass. Runoff flow to be treated is distributed uniformly across the top width of the strip to achieve sheet flow down the length of the strip. Uniform application to the top of the grass strip may be achieved by routing sheet flow from impervious areas, such as parking lots, directly to the top of the GSTF or by redistributing concentrated flow across the top of the GSTF by means of a level spreader. A GSTF is sized to treat the SQDF from the tributary area. Grass Strip Filters are essentially the same as Grass Buffers described in Fact Sheet G-5.1 in Section 3, with the only differences being design criteria for the linear rate of application along top of the strip and the length of strip and maximum slope in the.direction of flow. Applications of GSTFs are illustrated in Figure 5-2.

General Application

Grass Strip Filters are appropriate for use in residential, commercial, industrial and institutional settings and are typically incorporated into the landscape design of the site. They are typically located adjacent to impervious areas to be mitigated. The contributing flow that can be accommodated by the GSTF will be limited according to the design criteria in this fact sheet. Tributary areas are typically less than 5 acres. Several Grass Strip Filters may be used on a single site, each sized according to the tributary area from which it receives flow. To limit the size of units when space is limited, runoff flow from pervious off-site areas should not be routed over Grass Strip Filters. Irrigation and regular mowing are required to maintain the turf grass cover.

Advantages/Disadvantages

General

Grass Strip Filters are relatively easy to design, install and maintain. Vegetated areas that would normally be included in the site layout, if designed for appropriate flow patterns, may be used as Grass Strip Filters. Landscape architects can easily alter planting schemes to include appropriate turf species to meet design requirements for strips. Finally, maintaining a Grass Strip Filter often requires little more than normal landscape maintenance activities such as irrigation and mowing. Compared with some other means for improving stormwater runoff quality, GSTFs provide a relatively unobtrusive, attractive, long-term, and inexpensive stormwater quality management technique. In addition to pollutant removal, GSTFs provide opportunity for infiltration of runoff and reduction of peak flows.

Site Suitability

After final grading the site should have a uniform slope and be capable of maintaining sheet flow conditions. Grass Strip Filters should be located away from, or protected from, excessive pedestrian or vehicular traffic that can damage the grass cover and affect achievement of sheet flow over the surface.

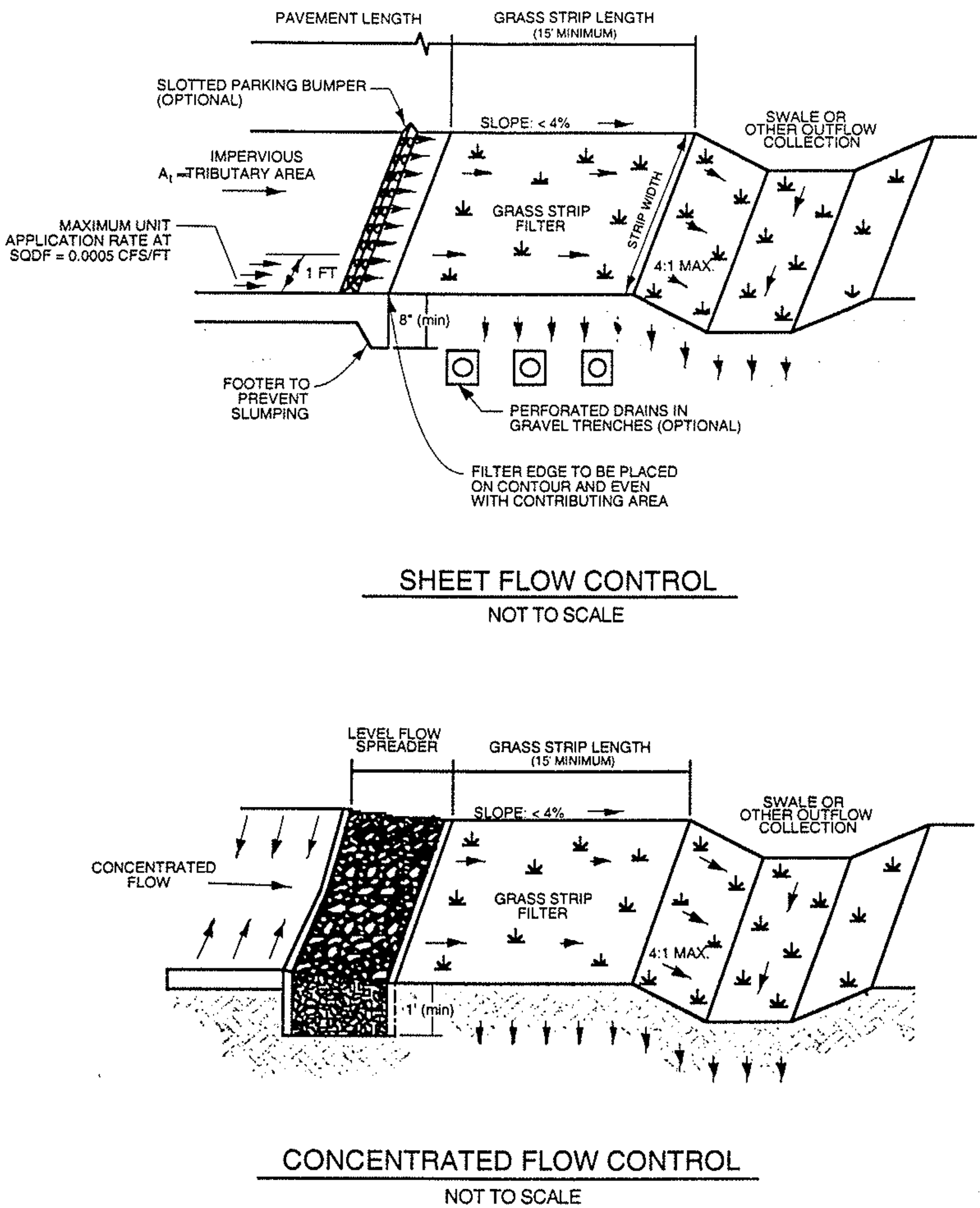


Figure 5-2 GRASS STRIP FILTER

ADAPTED FROM URBAN STORM DRAIN CRITERIA MANUAL
VOL. 3 - BEST MANAGEMENT PRACTICES,
URBAN DRAINAGE AND FLOOD CONTROL DISTRICT, 11/99

Pollutant Removal

Relative pollutant removal effectiveness of a GSTF is presented in Table 5-1. Removal effectiveness of GSTF for sediment and particulate forms of metals, nutrients and other pollutants is considered high to moderate. Grass Strip Filters are particularly effective when used as an upstream control measure in combination with grass swale filters, sand filters, and infiltration control measures.

Design Criteria and Procedure

Principal design criteria for GSTFs are listed in Table 5-3.

Table 5-3. Grass Strip Filter Design Criteria

Design Parameter	Unit	Design Criteria
Design Flow (SQDF)	cfs	0.20 × C × Area
Maximum linear unit application rate (q_a)	cfs/ft • width	0.005
Minimum width (normal to flow) (W_{GSTF})	ft	(SQDF) / (q_a)
Minimum length (flow direction) (L_{GSTF})	ft	15
Maximum slope (flow direction)	%	4
Vegetation	–	Turf grass (irrigated) or approved equal
Minimum grass height	inches	2
Maximum grass height	inches	4 (typical) or as required to prevent lodging or shading

Design procedure and application of design criteria are outlined in the following steps:

1. Design Flow — Determine Stormwater Quality Design Flow (SQDF) for impervious area to be mitigated.

   SQDF = 0.20 × C × Area (see Calculation Fact Sheet, Section 5)

2. Minimum Width — Calculate minimum width of the Grass Strip Filter (W_{GSTF}) normal to flow direction.

   W_{GSTF} = (SQDF) / (q_a)

   W_{GSTF} = (SQDF) / 0.005 cfs/ft (minimum)

3. Minimum Length — Length of the Grass Strip Filter (L_{GSTF}) in the direction of flow shall not be less than 15 feet.

   L_{GSTF} = 15 feet (minimum)

4. Maximum Slope — Slope of the ground in the direction of flow shall not be greater than 4 percent.

5. Flow Distribution — Incorporate a device at the upstream end of the GSTF to evenly distribute flows along the top width, such as slotted curbing,

	modular block porous pavement, or other spreader devices. Concentrated flow delivered to the GSTF must distributed evenly by means of a level spreader of similar concept.
6. Vegetation	Provide irrigated perennial turf grass to yield full, dense cover. (See Appendix F for suitable grasses). Submit a Landscape Plan for City stormwater staff review. Plan shall be prepared by a landscape or other appropriate specialist and shall include a site plan showing location and type of vegetation. Mow grass to maintain height approximately between 2 and 4 inches.
7. Outflow Collection	Provide a means for outflow collection and conveyance (e.g. grass channel/swale, storm sewer, street gutter)

Design Example

A completed design form follows as a design example. Blank design forms are provided in Appendix G.

Design Procedure Form for T-1: Grass Strip Filter (GSTF)

Designer:______

Company:______

Date:______

Project:______

Location:______

1. Design Flow	SQDF = ___0.5___ cfs
2. Design Width W_{GSTF} = (SQDF) / 0.005 cfs/ft	W_{GSTF} = ___100.0___ ft.
3. Design Length (15 ft minimum)	L_{GSTF} = ___15.0___ ft.
4. Design Slope (4 percent maximum)	S_{GSTF} = ___3.0___ %
5. Flow Distribution (Check type used or describe "Other")	_X_ Slotted curbing ___ Modular Block Porous Pavement ___ Level Spreader ___ Other ______
6. Vegetation (describe)	Tall Fescue
7. Outflow Collection (Check type used or describe "Other")	___ Grass Swale _X_ Street Gutter ___ Storm Sewer ___ Underdrain Used ___ Other ______

Notes ______

Construction Considerations

Scheduling

Grass Strip Filters should be established and operational by October 1, unless another schedule has been justified in the Landscape Plan and approved by the City. To meet the October 1 deadline, the following schedule must be met:

- Seeding should be conducted during the dry season, no later than September 1 to ensure sufficient vegetation by October 1. Irrigation may be required.
- Within 30 days of seeding, or by September 30, whichever is earlier, the site shall be inspected to determine adequacy of vegetation growth, and to determine if erosion or damage has occurred. Areas of damage shall be repaired, seeded, and mulched immediately.
- If vegetation growth is insufficient, or excessive damage or erosion has occurred, the site will be further stabilized with other appropriate erosion control measures such as matting, mulching, etc. If the site can not be adequately stabilized prior to October 1, temporary measures must be installed to divert storm flows around the GSTF until adequate vegetation and stabilization occurs.

During Construction

If active construction is being conducted upstream of the GSTF, all construction activity BMPs must remain in place to prevent high sediment loads into the GSTF. If necessary additional BMPs must be installed to protect the GSTF during construction.

Post Construction

After all construction activities are complete, necessary temporary BMPs to protect the integrity of the GSTF shall be installed, if necessary, until:

- the drainage area for the GSTF is adequately stabilized,
- vegetation in the GSTF is adequately established, and
- the GSTF maintenance plan is fully implemented.

Maintenance Requirements

To provide optimum treatment, Grass Strip Filters need to be regularly maintained to ensure a dense vegetation growth, and to prevent erosion of the underlying soils.

Maintenance Agreement

Treatment controls are to be maintained by the owner/operator. Maintenance agreement between the owner/operator of the Grass Strip Filters and the City may be required. (See Appendix C for example maintenance agreement)

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address at least the following items (see Appendix D for more detailed suggested Maintenance Plan content and format:

- Operation plan and schedule, including site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility;
- Responsible party for operation and maintenance activities.

Maintenance Activities

At a minimum the following activities must occur to properly maintain a GSTF:

- Mow regularly to maintain vegetation height between 2 and approximately 4 inches, and to promote thick, dense vegetative growth. Clippings are to be removed immediately after mowing.
- Regularly maintain the GSTF to remove all litter, branches, rocks, or other debris.
- Repair damaged areas of the filter strip immediately by reseeding and applying mulch.
- Remove all accumulated sediment that may obstruct flow through the GSTF. Replace the grass areas damaged in the process.
- Regularly maintain inlet flow spreader.
- Irrigate GSTF during dry season (April through October) when necessary to maintain the vegetation.
- After installing, inspect GSTF after seeding and after major storms. Repair all damage immediately.
- Once the GSTF is established, inspect at least three times per year. Repair all damage immediately.

Grass Swale Filter (GSWF)

Description

Grass Swale Filters (GSWF) are densely vegetated (turf grass) drainageways with gentle sideslopes and gradual slopes in the direction of flow that collect and slowly convey runoff flow to downstream points of discharge. Berms or check dams may be installed perpendicular to flow to provide grade control in steeper slopped areas. Underdrains may be installed at sites with very gradual slopes to avoid standing water. A GSWF is sized to treat the SQDF from the tributary area. Grass Swale Filters are similar to Grass-lined Channels described in Fact Sheet G-5.2 in Section 3, with the only differences being design criteria for hydraulic design parameters (e.g. flow depth, friction factor, and contact time.) Grass Swale Filters require shallower flow depths and longer contact times to provide treatment. Applications of GSWFs are illustrated in Figure 5-3.

General Application

Grass Swale Filters are appropriate for use in residential, commercial, industrial and institutional settings and are typically incorporated into the landscape design of the site. They are often used in conjunction with Turf Buffers or GSTFs to provide effluent collection and conveyance as well as treatment. The contributing flow that can be accommodated by the GSWF will be limited according to the design criteria in this fact sheet. Tributary areas are typically less than 5 acres. Several Grass Swale Filters may be used on a single site, each sized according to the tributary area from which it receives flow. To limit the size of units when space is limited, runoff flow from pervious off-site areas should not be routed to Grass Swale Filters. Irrigation and regular mowing are required to maintain the turf grass cover.

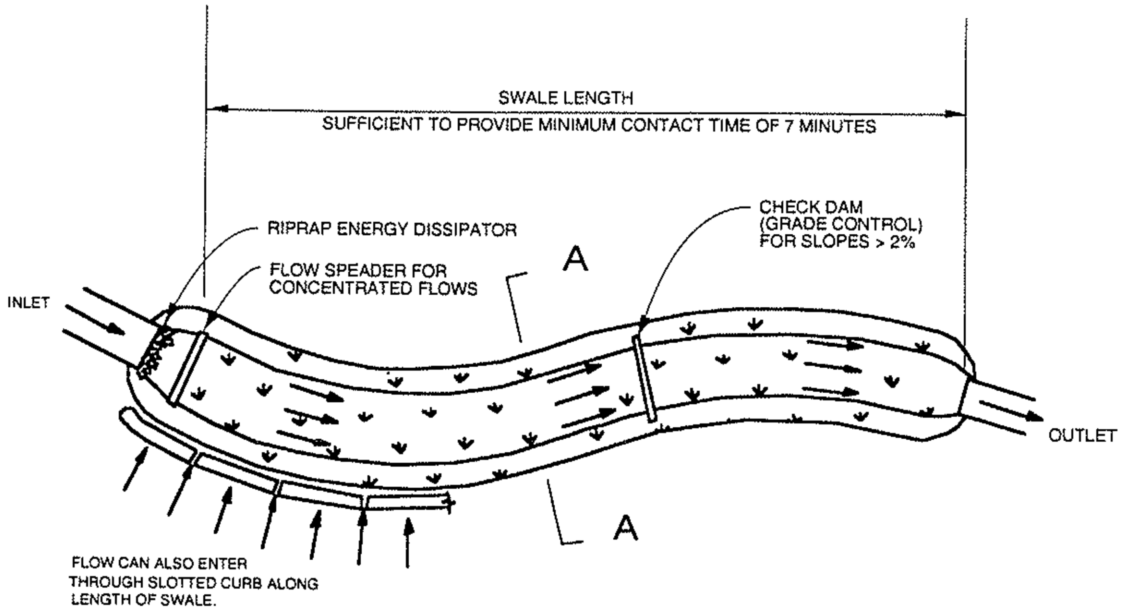
Advantages/Disadvantages

General

Like Grass Strip Filters, Grass Swale Filters are relatively easy to design, install and maintain. Vegetated areas that would normally be included in the site layout, if designed for appropriate flow patterns, may be used as Grass Swale Filters. Landscape architects can easily alter planting schemes to include appropriate turf species to meet design requirements for swales. Finally, maintaining a GSWF often requires little more than normal landscape maintenance activities such as irrigation and mowing. Compared with some other means for improving stormwater runoff quality, grass filters provide a relatively unobtrusive, attractive, long-term and inexpensive stormwater quality management technique. In addition to pollutant removal, GSWFs provide opportunity for infiltration of runoff and reduction of peak flows.

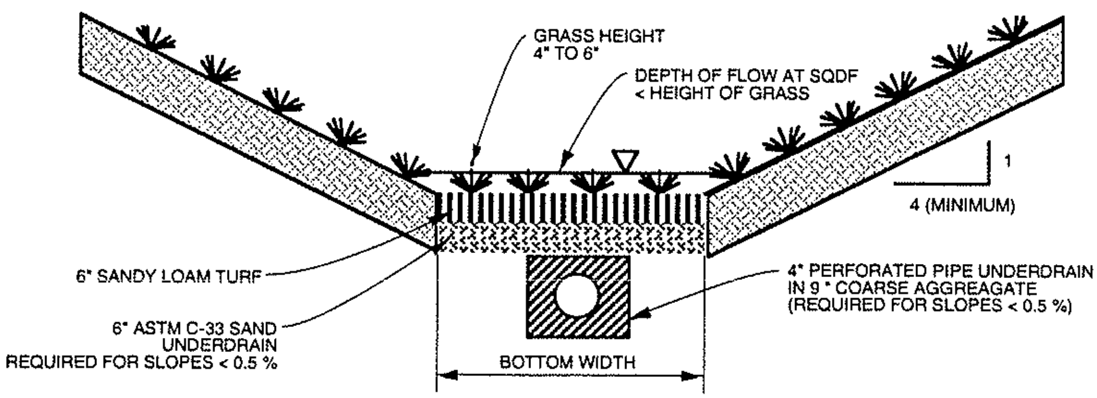
Site Suitability

Grass Swale Filters are not practical for sites with slopes greater than about 4 percent. Underdrains are recommended for design slopes less than 0.5 percent when soils types C or D (see Appendix E) are present.



TRAPEZOIDAL GRASS SWALE PLAN

NOT TO SCALE



TRAPEZOIDAL GRASS SWALE SECTION

NOT TO SCALE

Figure 5-3 GRASS SWALE FILTER

ADAPTED FROM URBAN STORM DRAIN CRITERIA MANUAL VOL. 3 - BEST MANAGEMENT PRACTICES, URBAN DRAINAGE AND FLOOD CONTROL DISTRICT, 11/99

Pollutant Removal

Relative pollutant removal effectiveness of a GSWF is presented in Table 5-1. Removal effectiveness of GSWF for sediment and particulate forms of metals, nutrients and other pollutants is considered moderate to low. Grass Swale Filters are the least effective of the approved treatment control measures. Consequently, they should generally be used in conjunction with one of the other approved treatment control measures.

Design Criteria and Procedure

Principal design criteria for GSWFs are listed in Table 5-4.

Table 5-4. Grass Swale Filter Design Criteria

Design Parameter	Unit	Design Criteria
Design Flow (SQDF)	cfs	0.20 × C × Area
Swale geometry	–	Trapezoidal or triangular
Maximum channel side slope	H:V	4 :1
Minimum slope in flow direction	%	0.2 (provide underdrains for slopes < 0.5)
Maximum slope in flow direction	%	2.0 (provide grade-control checks for slopes >2.0)
Maximum flow velocity	ft/sec	1.0 (based on Manning n = 0.20)
Maximum depth of flow at SQDF	inches	3 to 5 (1 inch below top of grass)
Minimum contact time	minutes	10 (Provide sufficient length to yield min contact time)
Minimum length	ft	Sufficient length to provide minimum contact time, or 100 feet, whichever is greater
Vegetation	–	Turf grass or approved equal
Grass height	Inches	4 to 6 (mow to maintain height)

Design procedure and application of design criteria are outlined in the following steps:

1.	Design Flow	Determine Stormwater Quality Design Flow (SQDF) for impervious area to be mitigated. $Q_{P,\,SQDF} = 0.20 \times C \times \text{Area}$ (see Calculation Fact Sheet, Section 5)
2.	Swale Geometry	Use trapezoidal or triangular cross section.
3.	Maximum Side Slope	Side slopes shall not be steeper than 4:1 (5:1 or flatter preferred).
4.	Minimum Slope	Slope of the swale in the direction of flow shall not be less than 0.2 percent. Swales with slopes less than 0.5 percent should be provided with underdrains (see Figure 5-3).
5.	Maximum Slope	Slope of the swale in the direction of flow shall not be greater than 2 percent. Provide grade control checks for slopes greater than 2.0 percent (see Figure 5-3).
6.	Flow Depth	Maximum depth of flow at design flow should not exceed 3 to 5 inches based on a Manning's n = 0.20
7.	Flow Velocity	Maximum flow velocity at design flow should not exceed 1.0 ft/sec. based on a Manning's n = 0.20.
8.	Swale Length	Provide length in the flow direction sufficient to yield a minimum contact time of 10 minutes at SQDF, or 100 feet, whichever is greater. $L = (10\text{ min}) \times (\text{flow velocity, ft/sec}) \times 60\text{ sec/min}$
9.	Vegetation	Provide irrigated perennial turf grass to yield full, dense cover. (See Appendix F for suitable grasses). Mow to maintain height of 4 to 6 inches.
10.	Drainage and Flood Control	Provide sufficient flow depth for flood event flows to avoid flooding of critical areas or structures

Design Example

A completed design form follows as a design example. Blank design forms are provided in Appendix G.

Design Procedure Form for T-2: Grass Swale Filter (GSWF)

Designer: ______

Company: ______

Date: ______

Project: ______

Location: ______

1. Design Flow	SQDF = 1.0 cfs
2. Swale Geometry a. Swale Bottom Width (b) b. Side slope (Z)	 b = 10.0 ft. Z = 4:1
3. Design Slope a. s = 2 percent maximum b. No. of grade controls required	 s = 0.26 % 0 (number)
4. Depth of flow at SQDF (d=5 in. max, Manning n= 0.20)	d = 5.0 inches
5. Design flow velocity (v= 1.0 ft/s max, Manning n= 0.20)	V = 0.21 ft/sec
6. Design Length (minimum) Minimum L = (10 min) × (flow velocity, ft/sec) × 60, or 100 ft	 L = 126.0 feet
7. Vegetation (describe)	Tall Fescue
8. Outflow Collection (Check type used or describe "Other")	X Grated Inlet __ Infiltration Trench __ Underdrain Used __ Other ______

Notes ______

Construction Considerations

Scheduling

Grass Swale Filters should be established and operational by October 1, unless another schedule has been justified in the Landscape Plan and approved by the City. To meet the October 1 deadline, the following schedule must be met:

- Seeding should be conducted during the dry season, no later than September 1 to ensure sufficient vegetation by October 1. Irrigation may be required.
- Within 30 days of seeding, or by September 30, whichever is earlier, the site shall be inspected to determine adequacy of vegetation growth, and to determine if erosion or damage has occurred. Areas of damage shall be repaired, seeded, and mulched immediately.
- If vegetation growth is insufficient, or excessive damage or erosion has occurred, the site should be further stabilized with other appropriate erosion control measures such as matting, mulching, etc. If the site can not be adequately stabilized prior to October 1, temporary measures must be installed to divert storm flows around the swale until adequate vegetation and stabilization occurs.

During Construction

If active construction is being conducted upstream of the GSWF, all construction activity BMPs must remain in place to prevent high sediment loads into the GSWF. If necessary, additional BMPs must be installed to protect the GSWF during construction.

Post Construction

After all construction activities are complete, temporary BMPs to protect the integrity of the GSWF shall be installed, if necessary, until:

- the drainage area for the GSWF is adequately stabilized,
- vegetation in the GSWF is adequately established, and
- the GSWF maintenance plan is fully implemented.

Maintenance Requirements

To provide optimum treatment, Grass Swale Filters need to be regularly maintained to ensure a dense vegetation growth, and to prevent erosion of the underlying soils.

Maintenance Agreement

Treatment controls are to be maintained by the owner/operator. Maintenance agreement between the owner/operator of the Grass Swale Filters and the City may be required. (See Appendix C for example maintenance agreement.)

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address at least the following items (see Appendix D for more detailed suggested Maintenance Plan content and format:

- Operation plan and schedule, including site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility;
- Responsible party for operation and maintenance activities.

Maintenance Activities

At a minimum the following activities must occur to properly maintain a GSWF:

- Mow regularly to maintain vegetation height between 4 and approximately 6 inches, and to promote thick, dense vegetative growth. Clippings are to be removed immediately after mowing.
- Regularly maintain the GSWF to remove all litter, branches, rocks, or other debris.
- Repair damaged areas of the filter strip immediately by reseeding and applying mulch.
- Remove all accumulated sediment that may obstruct flow through the GSWF. Replace the grass areas damaged in the process.
- Regularly maintain inlet flow spreader (if applicable).
- Irrigate GSWF during dry season (April through October) when necessary to maintain the vegetation.
- After installing, inspect GSWF after seeding and after major storms. Repair all damage immediately.
- Once the GSWF is established, inspect at least three times per year. Repair all damage immediately.

Extended Detention Basin

Description

Extended detention basins (EDB) are permanent basins formed by excavation and/or construction of embankments to temporarily detain the Stormwater Quality Design Volume (SQDV) of stormwater runoff to allow sedimentation of particulates to occur before the runoff is discharged. Extended detention basins are typically dry between storms, although a shallow pool, 1 to 3 feet deep, can be included in the design for aesthetic purposes and to promote biological uptake and conversion of pollutants. A bottom outlet provides controlled slow release of the detained runoff over a specified time period (40 hours for SQDV). The basic elements of an extended detention basin are shown in Figure 5-4. This configuration is most appropriate for large sites.

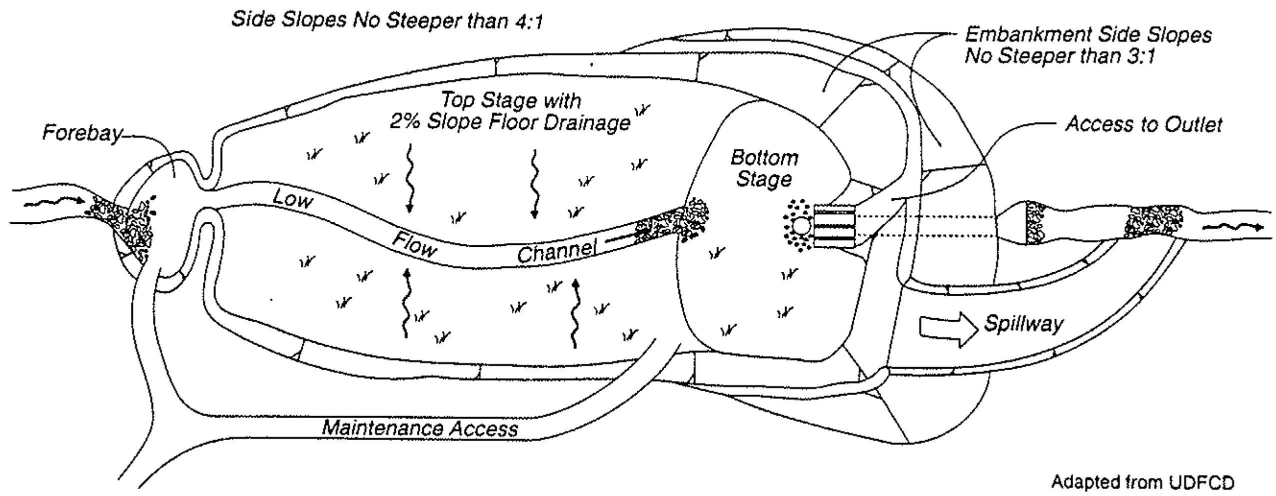
Surface basins are typical, but underground vaults may be appropriate in a small commercial development. Where irrigation water is available, basins should be vegetated to protect the basin slopes and bottom from erosion. To minimize erosion from inlet flow, basins are to be designed with an inlet energy dissipater and an inlet forebay section divided from the main basin by a secondary berm. The bottom of the basin is sloped toward the outlet end at a grade of approximately two percent. A low flow channel is provided to convey incidental flows directly to the outlet end of the basin.

EDBs are sized to detain and release the SQDV. Storm volumes greater than the SQDV are passed through the basin by means of a secondary outlet or spillway. Outlets are designed to include erosion protection.

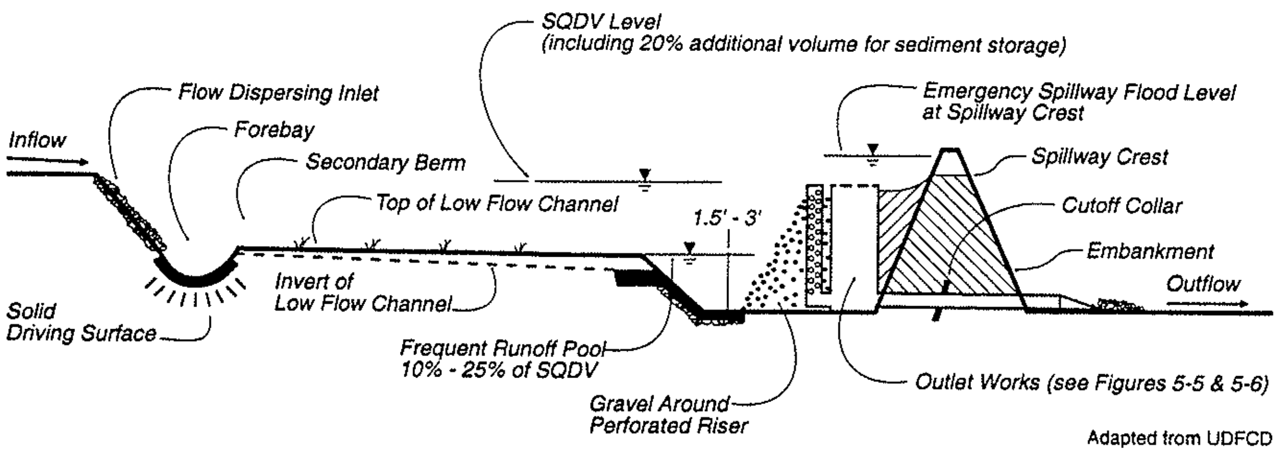
General Application

An EDB serves to reduce peak stormwater runoff rates, as well as provide treatment of stormwater runoff. If the basins are constructed early in the development cycle, they can also serve as sediment traps during construction within the tributary area. However, accumulated sediment must be removed after construction activities are complete and before the basin is placed into final long-term use as an EDB. Basins may be designed as dual-use facilities to provide recreational use during the dry season, and can be designed into flood control basins or sometimes retrofitted into existing flood control basins. EDBs that are intended to serve as a flood control basin, as well as a stormwater treatment control measure, must also be designed in accordance with applicable flood control design standards.

EDBs can serve essentially any size tributary area from an individual commercial development to a large residential or regional area, but are typically used for tributary areas greater than 10 acres. They work well in conjunction with other control measures, such as onsite source controls and downstream infiltration basins.



Plan View



Section View

Figure 5-4. Extended Detention Basin Conceptual Layout

Advantages/Disadvantages

General

EDBs may be designed to provide other benefits such as recreation, wildlife habitat, and open space. Safety issues must be address through proper design.

Site Suitability

Space requirements for EDBs are significant. Land requirements for EDBs typically range from approximately 0.5 to 2.0 percent of the of the tributary development area. Groundwater levels must be considered during site evaluation and design. Vector and vegetation control problems can develop when the seasonal high ground water level is above the basin bottom elevation.

Pollutant Removal

Relative pollutant removal effectiveness of an EDB is presented in Table 5-1. Removal effectiveness of EDBs for sediment and particulate forms of metals, nutrients and other pollutants is considered high to moderate. Removal effectiveness for dissolved pollutants is considered low. EDBs may be used upstream of control measures that are more effective at removing soluble pollutants, such as infiltration basins, filters or wetlands.

Design Criteria and Procedure

Principal design criteria for EDBs are listed in Table 5-5.

Table 5-5. Extended Detention Basin Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV / 50% SQDV	hrs	40 / 12 (minimum)
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 40-h drawdown
Basin design volume	acre-ft	1.2 × SQDV (provide 20% sediment storage volume)
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Forebay volume/ drain time	%/min	5 to 10 % of SQDV / Drain time < 5 minutes @ 5%
Low-flow channel depth/ flow capacity	in/–	9 / 2 × forebay outlet rate
Bottom slope of upper stage	%	2.0
Length to width ratio (minimum)	–	2:1 (larger preferred)
Upper stage depth/width (minimum)	ft	2.0/30
Bottom stage volume	%	10 to 25 % of SQDV
Bottom stage depth	ft	1.5 to 3 ft deeper than top stage
Freeboard (minimum)	ft	1.0
Embankment side slope (H:V)	–	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	hrs	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt or concrete

Design procedure and application of design criteria are outlined in the following steps:

a) Basin Storage Volume

Provide a storage volume equal to 120 percent of the SQDV, based on a 40-hr drawdown time, above the lowest outlet (i.e. perforation or orifice) in the basin. The additional 20 percent provides an allowance for sediment accumulation.

a. Determine the percent imperviousness of the tributary area (I_a).

b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from Step 1.b.

d. Calculate the SQDV in acre-ft as follows:

$$SQDV = (V_u / 12) \times Area$$

where

Area = Watershed area tributary to EDB (acres)

e. Calculate Design Volume in acre-ft as follows:

$$\text{Design Volume} = SQDV \times 1.2$$

where

1.2 factor = Multiplier to provide for sediment accumulation

2. Outlet Works

The Outlet Works are to be designed to release the SQDV (i.e. not Design Volume) over a 40-hour period, with no more than 50 percent released in 12 hours. Refer to Figures 5-5 and 5-6 for schematics pertaining to structure geometry; grates, trash racks, and screens; outlet type: orifice plate or perforated riser pipe.

a. For perforated pipe outlets or vertical plates with multiple orifices (see Figure 5-5), use the following equation to determine required area per row of perforations, based on the SQDV(acre-ft) and depth of water above the centerline of the bottom perforation D_{BS} (ft).

$$\text{Area/row (in}^2) = SQDV/K_{40}$$

where

$$K_{40} = 0.013D_{BS}^2 + 0.22D_{BS} - 0.10$$

Select appropriate perforation diameter and number of perforations per row (i.e. columns) with the objective of minimizing the number of columns and using a maximum perforation diameter of 2 inches. Rows are spaced at 4 inches on center from the bottom perforation. Thus, there will be 3 rows for each foot of depth plus the top row. The number of rows (nr) may be determined as follows:

$$nr = 1 + (D_{BS} \times 3)$$

Calculate total outlet area by multiplying the area per row by number of rows.

$$\text{Total orifice area} = \text{area/row} \times nr$$

b. For single orifice outlet control or single row of orifices at the basin bottom surface elevation (see Figures 5-6), use the following equation based on the SQDV (ft^3) and depth of water above orifice centerline D_{BS} (ft) to determine total orifice area (in^2):

$$\text{Total orifice area} = (SQDV) \div [(60.19)(D_{BS}^{0.5})(T)]$$

where

T = drawdown period (hrs)= 40 hrs

3. Trash Rack/Gravel Pack

A trash rack or gravel pack around perforated risers shall be provided to protect outlet orifices from clogging. Trash racks are better suited for use with perforated vertical plates for outlet control and allow easier access to outlet orifices for purposes of inspection and cleaning. Trash rack shall be sized to prevent clogging of the primary water quality outlet without restricting with the hydraulic capacity of the outlet control orifices.

4. Basin Shape

Whenever possible, shape the basin with a gradual expansion from the inlet toward the middle and a gradual contraction from middle toward the outlet. The length to width ratio should be a minimum of 2:1. Internal baffling with berms may be necessary to achieve this ratio.

5. Two-Stage Design

A two-stage design with a pool that fills often with frequently occurring runoff minimizes standing water and sediment deposition in the remainder of the basin.

a. Upper Stage: The upper stage should be a minimum of 2 feet deep with the bottom sloped at 2 percent toward the low flow channel. Minimum width of the upper stage should be 30 ft.

b. Bottom Stage: The active storage basin of the bottom stage should be 1.5 to 3 feet deeper than the top stage and store 10 to 25 percent of the SQDV. A micro-pool below the active storage volume of the bottom stage, if provided, should be one-half the depth of the top stage, or 2 feet, whichever is greater.

6. Forebay Design

The forebay provides a location for sedimentation of larger particles and has a solid bottom surface to facilitate mechanical removal of accumulated sediment. The forebay volume should

	be 5 to 10 percent of the SQDV. A berm should separate the forebay from the upper stage of the basin. The outlet pipe from the forebay to the low-flow channel should be sized to drain 5 percent of the SQDV in 5 minutes . The outlet pipe entrance should be offset from the forebay inlet to prevent short-circuiting.
7. Low-flow Channel	The low-flow channel conveys flow from the forebay to the bottom stage. Erosion protection should be provided where the low-flow channel enters the bottom stage. Lining of the low flow channel with concrete is recommended. The depth of the channel should be at least 9 inches. The flow capacity of the channel should be twice the release capacity of the forebay outlet.
8. Inlet/Outlet Design	Basin inlet and outlet points should be provided with an energy dissipation structure and/or erosion protection.
9. Vegetation	Bottom vegetation provides erosion protection and sediment entrapment. Basin bottoms, berms, and side slopes may be planted with native grasses or with irrigated turf.
10. Embankment	Design embankments to conform to requirements State of California Division of Safety of Dams, if the basin dimensions cause it to fall under that agency's jurisdiction. Interior slopes should be no steeper than 4:1 and exterior slopes no steeper than 3:1. Flatter slopes are preferable.
11. Access	All-weather access to the bottom, forebay, and outlet works shall be provided for maintenance vehicles. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete.
12. Bypass	Provide for bypass or overflow of runoff volumes in excess of the SQDV. Spillway and overflow structures should be designed in accordance with applicable standards of the City of Woodland Storm Drainage Guidance and Criteria.
13. Geotextile Fabric	Non-woven geotextile fabric used in conjunction with gravel packs around perforated risers shall conform to the specifications listed in Table 5-6.

Table 5-6. Non-woven Geotextile Fabric Specifications

Property	Test Reference	Minimum Specification
Grab Strength	ASTM D4632	90 lbs
Elongation at peak load	ASTM D4632	50 %
Puncture Strength	ASTM D3787	45 lbs
Permitivity	ASTM D4491	0.7 sec^{-1}
Burst Strength	ASTM D3786	180 psi
Toughness	% Elongation X Grab Strength	5,500 lbs
Ultraviolet Resistance (Percent strength retained at 500 Weatherometer hours)	ASTM D4355	70%

Adapted from SSPWC, 1997.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-3: Extended Detention Basin

Designer: ____________________

Company: ____________________

Date: ____________________

Project: ____________________

Location: ____________________

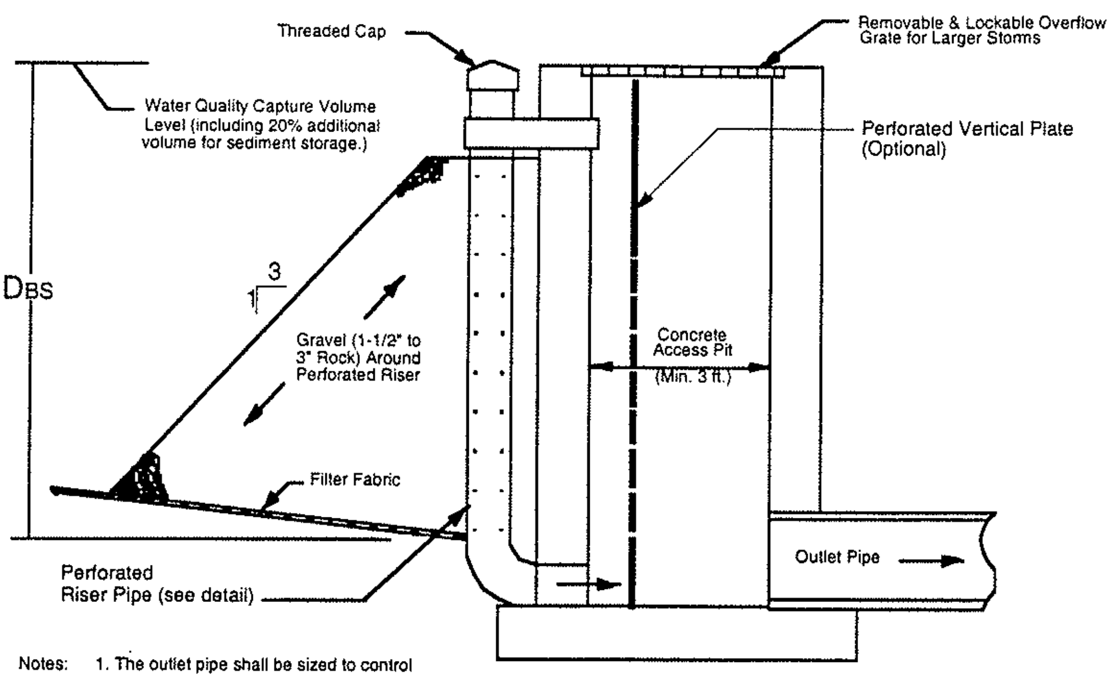
1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = 64 %
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} = 60 %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u= 0.41 in.
d. Watershed Area Tributary to EDB	Area = 10 acres
e. Calculate SQDV SQDV = (V_u / 12) × Area	SQDV = 0.34 acre-ft
f. Calculate Design Volume Design Volume = SQDV × 1.2	Design Volume = 0.41 acre-ft
2. Outlet Works	
a. Outlet Type (check one)	Single Row Orifice X Perforated Plate ____ Perforated Pipe ____ Other ____
b. Depth of water above bottom orifice	Depth = 3 feet
c. Single Orifice or Single Row Outlet	
1) Total Area	A = 3.55 square inches
2) Diameter or W × L	D = 2 × 1.77 inches
d. Perforated Outlet (Plate or Pipe)	
1) Area per row of perforations	A = ____
2) Perforation Diameter (2 inches max.)	D = ____
3) No. of Perforations (columns) per Row	Perforations = ____
4) No. of Rows (4 inch spacing)	Rows = ____
5) Total Orifice Area (Area per row) × (Number of Rows)	Area = ____

Design Procedure Form for T-3: Extended Detention Basin (Page 2 of 2)

Project: ______________________________

3. Trash Rack or Gravel Pack (check one)	Trash Rack __X__ Gravel Pack_____		
4. Basin Length-Width Ratio (2:1 minimum)	Ratio =	3:1	L:W
5. Two-Stage Design			
a. Upper Stage			
1) Depth (2 feet minimum)	Depth =	3	feet
2) Width (30 feet minimum)	Width =	40	feet
3) Bottom Slope (2% to low flow channel)	Slope =	2	%
b. Bottom Stage			
1) Depth (1.5 to 3 feet deeper than Upper)	Depth =	5	feet
2) Storage Volume (5-15% of SQDV min.)	Volume =	0.08	acre-ft
6. Forebay Design			
a. Forebay Volume (5-10% of SQDV min.)	Volume =	0.017	acre-ft
b. Outlet pipe drainage time (< 5 minutes @ 5%)	Drainage Time	5	minutes
7. Low Flow Channel			
a. Depth (9 inches min.)	Depth =	2.0	feet
b. Flow Capacity (2 X outlet for Forebay)	Flow Capacity =	60 cfs	cfs
8. Vegetation	Native Grasses	______	
	Irrigated Turf	X	
	Other	______	
9. Embankment			
a. Interior Slope (4:1 max.)	Interior Slope =	4:1	H/V
b. Exterior Slope (3:1 max.)	Exterior Slope =	3:1	H/V
10. Access			
a. Slope (10% max.)	Slope =	9	%
b. Width (16 feet min.)	Width =	16	feet

Notes: ______________________________

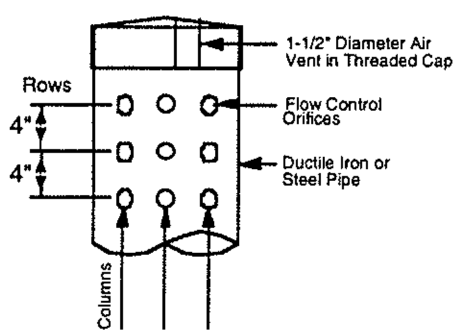


Notes:
1. The outlet pipe shall be sized to control overflow into the concrete riser.
2. Alternate designs include a Hydrobrake outlet (or orifice designs) as long as the hydraulic performance matches this configuration.

OUTLET WORKS

NOT TO SCALE

Notes:
1. Minimum number of holes = 8
2. Minimum hole diameter = 1/4"
3. Maximum hole diameter = 2"



PERFORATED VERTICAL RISER PIPE

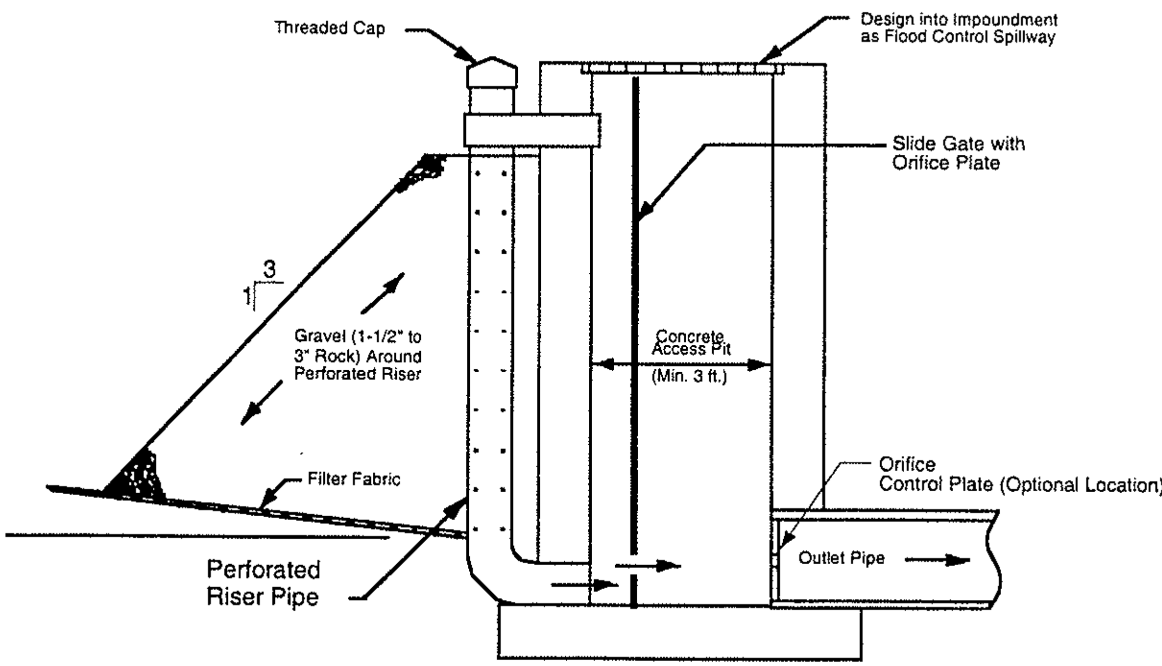
NOT TO SCALE

Maximum Number of Perforated Columns				
Riser Diameter (in.)	Hole Diameter, in.			
	1/4"	1/2"	3/4"	1"
4	8	8	--	--
6	12	12	9	--
8	16	16	12	8
10	20	20	14	10
12	24	24	18	12

Hole Diameter, in.	Area of Hole (in.)^2
1/8	0.013
1/4	0.049
3/8	0.110
1/2	0.196
5/8	0.307
3/4	0.442
7/8	0.601
1	0.785

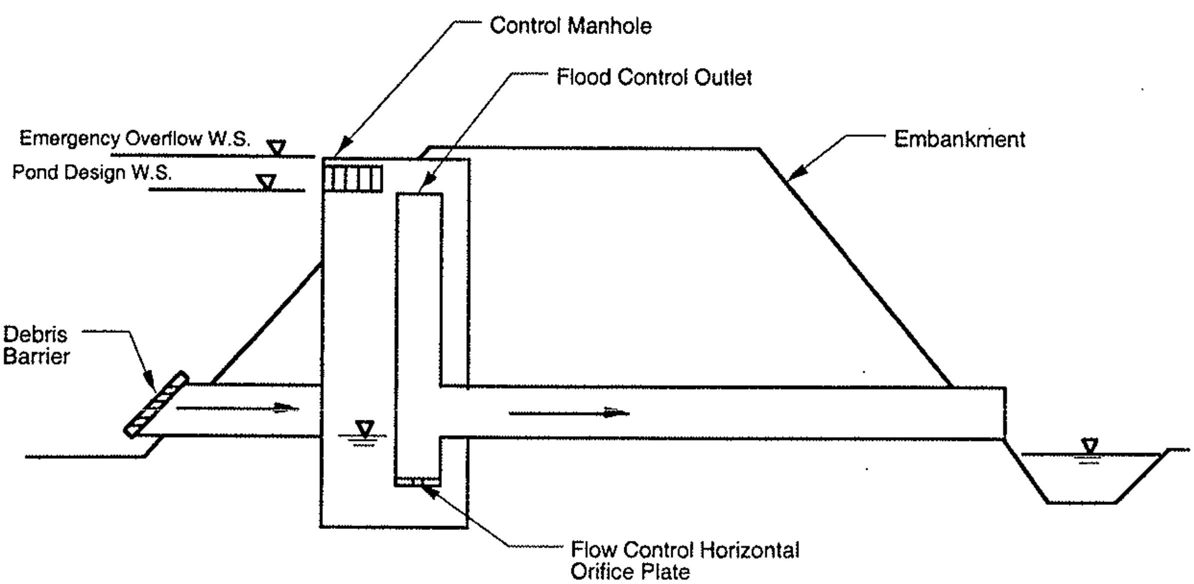
ADAPTED FROM UDFCD, 1999

Figure 5-5 . OUTLET CONFIGURATIONS USING MULTIPLE ORIFICE FLOW CONTROL



PERFORATED RISER PIPE WITH VERTICAL FLOW CONTROL ORIFICE

NOT TO SCALE



CONTROL MANHOLE WITH SUBMERGED HORIZONTAL ORIFICE PLATE

NOT TO SCALE

Figure 5-6. OUTLET CONFIGURATIONS USING SINGLE ORIFICE FLOW CONTROL

Maintenance Requirements

The following maintenance requirements apply to extended detention basins

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. (See Appendix C for example maintenance agreement.)

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address at least the following items (see Appendix D for more detailed suggested Maintenance Plan content and format:

- Operation plan and schedule, including a site map
- Maintenance and cleaning activities and schedule
- Equipment and resource requirements necessary to operate and maintain facility
- Responsible party for operation and maintenance

Maintenance Activities

- Inspect basin semiannually, after each significant storm, or more frequently, if needed.. Some important items to check for include: differential settlement, cracking; erosion, leakage, or tree growth on the embankment; the condition of the riprap in the inlet, outlet and pilot channels; sediment accumulation in the basin; and the vigor and density of the grass turf on the basin side slopes and floor. Correct observed problems as necessary.
- Remove litter and debris from banks and basin bottom as required.
- Repair erosion to banks and bottom as required.
- Remove sediment when accumulation reaches 25% of original design depth, or if resuspension is observed. Clean in early spring so vegetation damaged during cleaning has time to re-establish.
- Inspect outlet for clogging a minimum of twice a year, before and after the rainy season, after large storms, and more frequently if needed. Correct observed problems as necessary.
- Clean forebay frequently to reduce frequency of main basin cleaning.
- Control mosquitoes, as necessary.

Description

Wet detention basins (WDBs) are open earthen basins that feature a permanent pool of water that is displaced by storm water flow, in part or in total, during storm runoff events. Like Extended Detention Basins (see T-3), WDBs are designed to temporarily detain the Stormwater Quality Design Volume (SQDV) of stormwater runoff and to slowly release this volume over a specified period (12 hours). WDBs differ from EDBs in that the influent runoff flow water mixes with and displaces the permanent pool as it enters the basin. The design drawdown time for WDBs (12 hours) is shorter than for EDBs (40 hours), because enhanced treatment is provided in the permanent pool. A dry-weather base flow is required to maintain the permanent pool. The basic elements of a WDB are shown in Figure 5-7.

General Application

Wet Detention Basins function similarly to EDBs, serving to reduce peak stormwater runoff rates and providing treatment of runoff primarily through sedimentation. These basins can improve the quality of urban runoff from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites and are generally used as a regional or follow-up treatment because of the base-flow requirements. Because there is a permanent pool present, wet detention basins can also serve as passive recreational areas during the dry season, and can be designed into flood control basins or sometimes retrofitted into existing flood control basins.

Wet detention basins can serve essentially any size tributary area from an individual commercial development to a large residential or regional area, but are typically used for areas greater than 10 acres. These basins work well in conjunction with other BMPs, such as upstream onsite source controls and downstream filter basins or wetland channels.

Advantages/Disadvantages

General

Wet Detention Basins may be designed to provide other benefits such as passive recreation, wildlife habitat, and open space. Safety issues must be addressed through proper design.

Site Suitability

Wet Detention Basin space requirements are significant. Land requirements for WDBs typically range from approximately 0.5 to 2 percent of the tributary development area. These basins are also not suitable for dense urban areas or sites with steep and unstable slopes. Although site suitability concerns are similar to those stated for an EDB, Wet Detention Basins are not suitable for areas with long dry spells and high evaporation rates without perennial groundwater base flow or supplemental water to maintain permanent pool and aquatic vegetation. A complete water budget under the projected watershed conditions should be performed to assure that the base flow will exceed evaporation, envirotranspiration, and seepage losses. This control measure is most appropriate for sites with low-permeability soils (Type C and D).

Vegetation Maintenance

Considerable resources must be committed to properly maintain peripheral aquatic vegetation in WDBs to control mosquito propagation and to maintain effective permanent pool volume.

Pollutant Removal

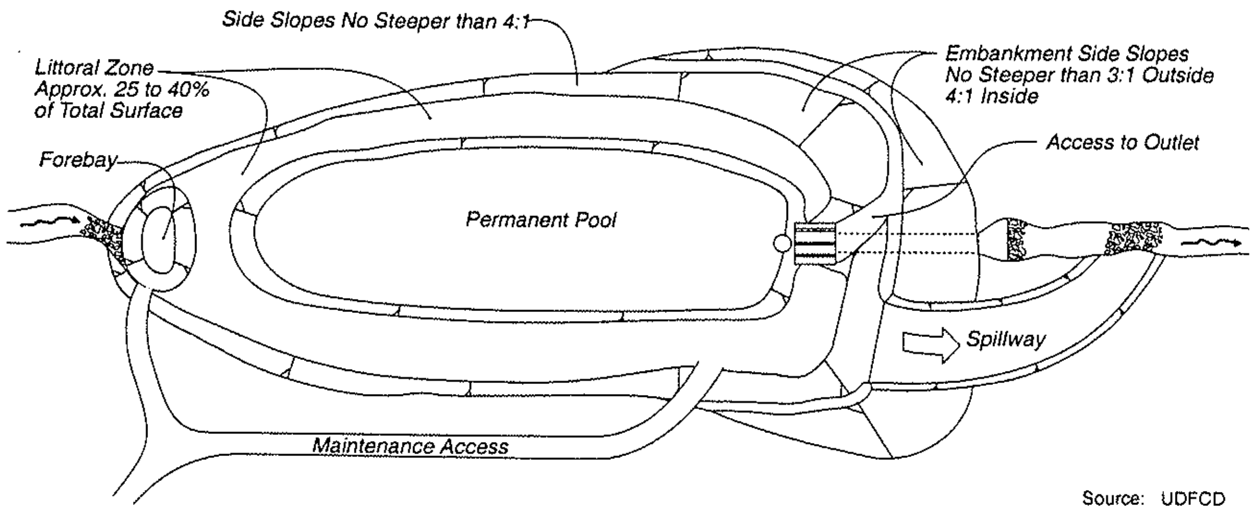
Relative pollutant removal effectiveness of a Wet Detention Basin is presented in Table 5-1. Removal effectiveness of WDBs for sediment and particulate forms of metals, nutrient and other settleable solids is considered high to moderate. WDBs also remove flotables and achieve some degree of dissolved contaminant removal, but effectiveness against dissolved contaminants is low. WDBs may be used upstream of control measures that are more effective at removing soluble pollutants, such as infiltration basins, filters or wetlands.

Design Criteria and Procedure

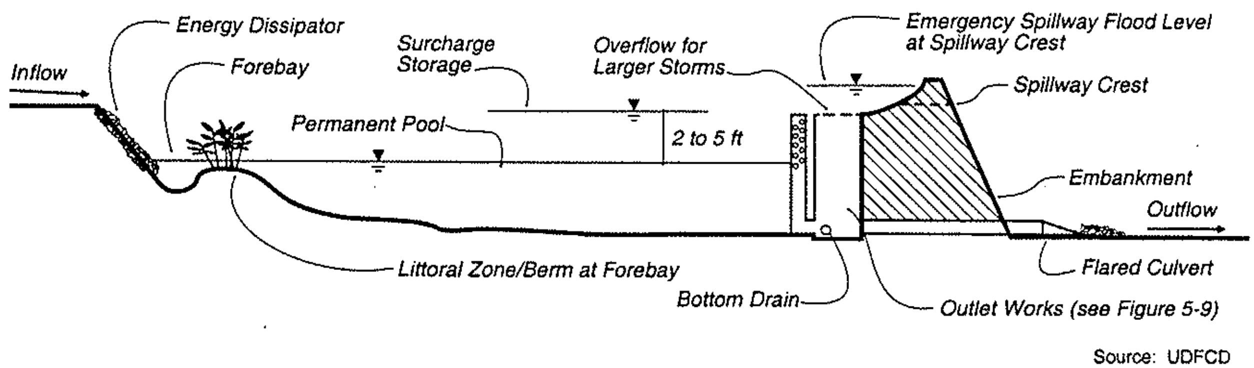
Principal design criteria for WDBs are listed in Table 5-7.

Table 5-7. Wet Detention Basin Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	12
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 12-h drawdown
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Permanent Pool volume	–	1.0 to 1.5 × SQDV
2 Depth Zones Required	–	Littoral Zone (6-12 inches deep, 25-40% of permanent pool surface area) Deeper Zone (4-8 feet average depth of remaining pond area, 12 feet max. depth)
Forebay volume	%	5 to 10% of SQDV.
Length to width ratio (minimum)	–	2:1 (larger preferred)
Minimum bottom width	ft	30
Freeboard (minimum)	ft	1.0
Embankment side slope (H:V)	–	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	hrs	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete



Plan View



Section View

Figure 5-7. Conceptual Layout of Wet Detention Basin

Design procedure and application of design criteria for WDBs are outlined in the following steps:

1. Basin Surcharge Volume

Provide a surcharge volume equal to the SQDV, based on a 12-hr drawdown time, above the lowest outlet (i.e. perforation or orifice) in the basin.

a. Determine the percent imperviousness of the tributary area (I_a).

b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 12-hr drawdown and I_{wq} value from step 1.b.

d. Calculate the SQDV in acre-ft as follows:

$$SQDV = (V_u / 12) \times Area$$

where Area = Watershed area tributary to WDB (acres)

2. Permanent Pool

The permanent pool provides stormwater quality enhancement between storm runoff events through biochemical processes and continuing sedimentation.

a. Determine the volume of the permanent pool (V_p), which is 1.0 to 1.5 times the SQDV.

b. Depth Zones (see Figure 5-8)

Littoral Zone should be between 6 to 12 inches deep that is between 25 to 40 percent of the permanent pool surface for aquatic plant growth along the perimeter of the pool.

Deeper Zone should be 4 to 8 feet average depth with a maximum depth of 12 feet. This zone should cover the remaining pond area and promote sedimentation and nutrient uptake by phytoplankton.

3. Base Flow

A net influx of water must be available through a perennial base flow and must exceed the losses. The following equation and parameters can be used to estimate the net quantity of base flow available at the time.

$$Q_{net} = Q_{inflow} - Q_{E\text{-}P} - Q_{seepage} - Q_{ET}$$

Q_{net} = Net quantity of base flow (acre-ft/year)

Q_{inflow} = Estimated base flow (acre-ft/year). (Estimate by seasonal measurements and/or comparison to similar watersheds.)

Q_{E-P} = Loss due to evaporation minus the precipitation (acre-ft/year)

$Q_{seepage}$ = Loss or gain due to seepage to groundwater (acre-ft/year)

Q_{ET} = Loss due to evapotranspiration (additional loss through plant area above water surface not including the water surface)

4. Outlet Works

The Outlet Works are to be designed to release the SQDV (i.e. not Design Volume) over a 12-hour period. Refer to Figure 5-9 for schematics pertaining to structure geometry; grates, trash racks, and outlet.

a. For perforated pipe outlets or vertical plates with multiple orifices, use the following equation to determine required area per row of perforations, based on the SQDV(acre-ft) and depth of water above the centerline of the bottom perforation D (ft).

$$\text{Area/row (in}^2\text{)} = SQDV/K_{12}$$

where

$$K_{12} = 0.008D^2 + 0.056D - 0.012$$

Select appropriate perforation diameter and number of perforations per row (columns) with the objective of minimizing the number of columns and using a maximum perforation diameter of 2 inches. Rows are spaced at 4 inches on center from the bottom perforation. Thus, there will be 3 rows for each foot of depth plus the top row. The number of rows (nr) may be determined as follows:

$$nr = 1 + (D \times 3)$$

Calculate total outlet area by multiplying the area per row by number of rows.

$$\text{Total orifice area} = \text{area/row} \times nr$$

b. For single orifice outlet control or single row of orifices at the basin bottom surface elevation use the following equation based on the SQDV (ft3) and depth of water above orifice centerline D (ft) to determine orifice area (in^2):

$$\text{Total orifice area} = (SQDV) \div [(60.19)(D^{0.5})(T)]$$

where

$$T = \text{drawdown period (hrs)} = 12 \text{ hrs}$$

5. Basin Side Slopes

Side slopes should be stable and sufficiently gentle to limit rill erosion and to facilitate maintenance. Side slopes above the permanent pool should be no steeper than 4:1, preferable 5:1 or flatter. The littoral zone should be very flat (40:1 or flatter) with the depth ranging from 6 inches near the shore and extending to no more than 12 inches at the furthest point from the shore. The side slope below the littoral zone shall be 3:1 or flatter.

6. Forebay Design — The forebay provides a location for sedimentation of larger particles and has a solid bottom surface to facilitate mechanical removal of accumulated sediment. The forebay volume should be 5 to 10 percent of the SQDV. A berm consisting of rock and topsoil mixture should be part of the littoral bench to create the forebay and have a minimum top width of 8 feet and side slopes no steeper than 4:1.

7. Inlet/Outlet Design — Basin inlet and outlet points should provided with an energy dissipation structure and/or erosion protection.

8. Vegetation — Bottom vegetation provides erosion protection and sediment entrapment. Berms, and side slopes may be planted with native grasses or with irrigated turf. The shallow littoral bench should have a 4 to 6 inch thick organic topsoil layer and be vegetated with aquatic species.

9. Embankment — Design embankments to conform to requirements State of California Division of Safety of Dams, if the basin dimensions cause it to fall under that agency's jurisdiction. Interior slopes should be no steeper than 4:1 and exterior slopes no steeper than 3:1. Flatter slopes are preferable.

10. Access — All-weather access to the bottom, forebay, and outlet works shall be provided for maintenance vehicles. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete.

11. Bypass — Provide for bypass or overflow of runoff volumes in excess of the SQDV. Spillway and overflow structures should be designed in accordance with applicable standards of the City of Woodland Storm Drainage Guidance and Criteria.

12. Underdrains — Provide underdrain trenches near the edge of the pond. The trenches should be no less than 12 inches wide filled with ASTM C-33 sand to within 2 feet of the pond's permanent pool water surface, and with an underdrain pipe connected through a valve to the outlet. These underdrains will permit the drying out of the pond when it has to be "mucked out" to restore volume lost due to sediment deposition.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

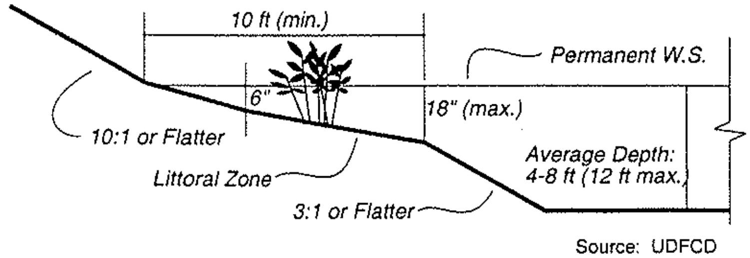
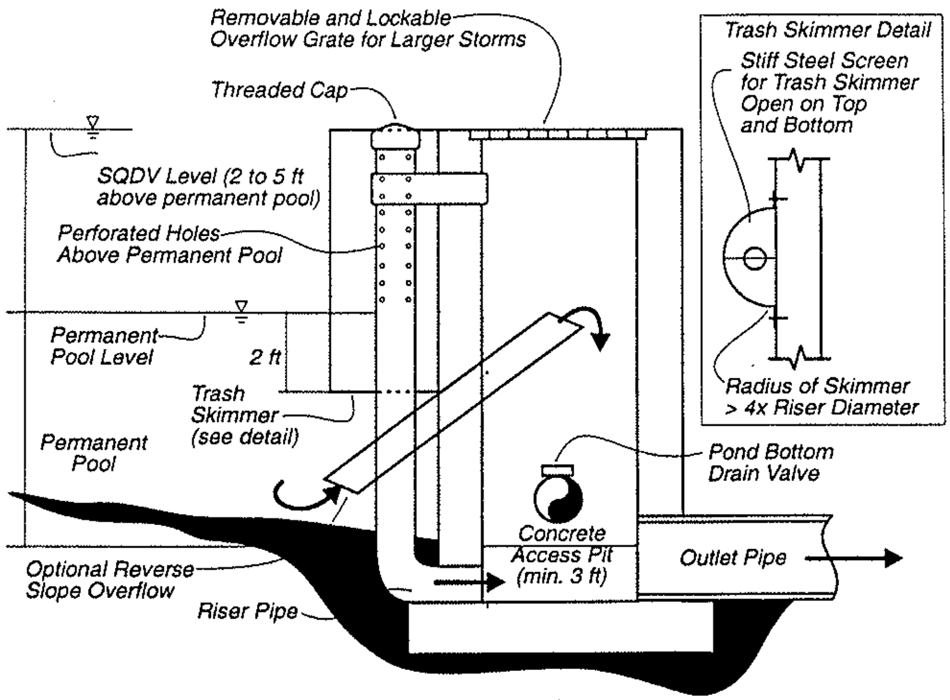


Figure 5-8. Depth Zones for Wet Detention Basin



Notes: 1. Alternate designs are acceptable as long as the hydraulics provides the required emptying times.
2. Use trash skimmer screens of stiff green steel material to protect perforated riser. Must extend from the top of the riser to 2 ft below the permanent pool level.

Source: UDFCD

Figure 5-9. Outlet Works for Wet Detention Basin

Design Procedure Form for T-4: Wet Detention Basin

Designer: ____________________

Company: ____________________

Date: ____________________

Project: ____________________

Location: ____________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	64	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	60	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12 hr drawdown and I_{wq}	V_u=	0.23	in.
d. Watershed Area Tributary to WDB	Area =	100.0	acres
Calculate SQDV = (V_u / 12) × Area	SQDV =	1.91	acre-ft
2. Permanent Pool			
a. Volume of Permanent Pool (1.0 to 1.5 times SQDV minimum)	V_p =	1.91	acre-ft
b. Depth			
1) Littoral Zone Depth (6 to 12 inches)	Depth =	1.0	feet
2) Deeper Zone Depth (4 to 8 ft average, 10 ft max)	Average Depth =	6.0	feet
	Max Depth =	9.0	feet
c, Permanent Pool Surface Area			
1) Littoral Zone Area (25%-40% Permanent Pool Surface)	Area =	0.175	acres
	% of total	30.0	%
2) Deeper Zone Area (60%- 40% Permanent Pool Surface)	Area =	0.408	acres
	% of total	70.0	%
3) Total Area	Total area =	0.583	acres
3. Estimated Net Base Flow (must be > 0)			
$Q_{net} = Q_{inflow} - Q_{evap} - Q_{seepage} - Q_{evapotranspiration}$	Q_{inflow} =	1.91	acre-ft
	Q_{evap} =	0.3	acre-ft
	$Q_{seepage}$ =	0.4	acre-ft
	$Q_{evapotranspiration}$	0.8	acre-ft
	Q_{net} =	0.41	acre-ft

Design Procedure Form for T-4: Wet Detention Basin (Page 2 of 3)

Project:____

4. Outlet Works			
a. Outlet Type (check one)	Single Row Orifice	X (1 row)	
	Perforated Plate	______	
	Perforated Pipe	______	
	Other	______	______
b. Depth of water above bottom orifice	Depth =	3.0	feet
c. Single Orifice (or Single Row) Outlet			
1) Total Area	A =	66.5	square inches
2) Diameter or L × W	D =	4 @ 4.6	inches
d. Perforated Outlet (Plate or Pipe)			
1) Area per row of perforations	A =	______	
2) Perforation Diameter (2 inches max.)	D =	______	
3) No. of Perforations (columns) per Row	Perforations =	______	
4) No. of Rows (4 inch spacing)	Rows =	______	
5) Total Orifice Area (Area per row) × (Number of Rows)	Area =	______	
5. Trash Rack or Gravel Pack Present?	Yes/No	Yes	
6. Basin Shape			
a. Length-Width Ratio	Ratio =	3:1	L/W
7. Forebay Design			
a. Forebay Volume (5-10% of SQDV min.)	Volume =	0.12	acre-ft
8. Embankment Slope			
a. Interior Slope (4:1 max.)	Interior Slope =	4:1	L/W
b, Exterior Slope (3:1 max.)	Exterior Slope =	3:1	L/W

Design Procedure Form for T-4: Wet Detention Basin (Page 3 of 3)

Project:________________________________

9. Vegetation (Check type used or describe "Other")	__X__ Native Grasses _____ Irrigated Turf Grass _____ Emergent Aquatic Plants (specify type / density) _____ Other ____________________
10. Underdrains Provided?	Yes /No ___No___

Notes:

Maintenance Requirements

The following maintenance requirements apply to wet detention basins

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. (See Appendix C for example maintenance agreement.)

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address at least the following items (see Appendix D for more detailed suggested Maintenance Plan content and format:

- Operation plan and schedule, including a site map
- Maintenance and cleaning activities and schedule
- Equipment and resource requirements necessary to operate and maintain facility
- Responsible party for operation and maintenance

Maintenance Activities

- Inspect basin semiannually, after each significant storm, or more frequently, if needed.. Some important items to check for include: differential settlement, cracking; erosion, leakage, or tree growth on the embankment; the condition of the riprap in the inlet, outlet and pilot channels; sediment accumulation in the basin; and the vigor and density of the grass turf on the basin side slopes and floor. Correct observed problems as necessary.
- Remove litter and debris from banks and basin bottom as required.
- Repair erosion to banks and bottom as required.
- Remove sediment when accumulation reaches 25% of original design depth, or if resuspension is observed. Clean in early spring so vegetation damaged during cleaning has time to re-establish.
- Inspect outlet for clogging a minimum of twice a year, before and after the rainy season, after large storms, and more frequently if needed. Correct observed problems as necessary.
- Clean forebay frequently to reduce frequency of main basin cleaning.
- Control mosquitoes, as necessary. Mosquito control is an important issue for WDBs and may require extensive and frequent control of peripheral vegetation.

Description

A Constructed Wetland Basin (CWBs) is a single-stage treatment system consisting of a forebay and a permanent micropool with aquatic plants. CWBs function in a similar manner to Wet Detention Basins (WDBs) in that the influent runoff flow water mixes with and displaces a permanent pool as it enters the basin. The surcharge volume above the permanent pool is slowly released over a specified period (24 hours for SQDV). CDBs require a longer release period for the surcharge volume than WDBs, because the depth and volume of the permanent pool are less for a CDBs than for WDBs. A base flow is required to maintain the permanent water pool. CDBs also differ from WDB in terms of the extensive presence of aquatic plants (rushes, willows, cattails, and reeds). Plants provide energy dissipation and enhance pollutant removal by sedimentation and biological uptake. A conceptual layout of a CWB is shown in Figure 5-10.

Constructed Wetlands differ from "natural" wetlands in that they are man-made and are designed to enhance stormwater quality. Sometimes natural wetlands can be incorporated into the constructed wetland system. Such action, however, requires the approval of federal and state regulators. Constructed wetlands are generally not allowed to be used to mitigate the loss of natural wetlands, but are allowed to be disturbed by maintenance activities. Nevertheless, any activity that disturbs a constructed wetland should be first cleared through the U.S. Army Corps of Engineers to ensure some form of an individual, general, or nationwide 404 permit coverage.

General Application

Constructed Wetlands are ideal for large, regional tributary areas where space is available to provide shallow water conditions. Land uses for which this BMP is appropriate include large residential developments, and commercial, institutional and industrial areas where incorporation of a green space and a wetland into the landscape is desirable and feasible. CWBs can be used effectively in combination with upstream treatment controls such as Grass Strip Filters and Grass Swale Filters. A base flow of water is required to maintain aquatic conditions.

Advantages/Disadvantages

General

CWBs offer an attractive, effective means for improving stormwater quality. As part of a landscape design, a constructed wetland can offer the beauty of water and vegetation in a predominantly dry area, if base flow is available or provisions are made to maintain the permanent pool. CWBs offer the potential for wildlife habitat and passive recreation. For example, a constructed wetland can be used in a park-like area where people can picnic, stroll or bird watch.

The primary drawback to wetlands is the need for a continuous base flow to maintain aquatic plants. In addition, salts and scum can accumulate and, unless properly designed and managed, can be flushed out during larger storms.

Site Suitability

Adequate space of around 1 to 2 percent of the tributary watershed is usually required. Constructed wetlands, however, require more land space than WDBs for similar drainage areas because part of the constructed wetland must be shallower than a wet detention basin. A perennial base flow is needed to sustain a wetland, and should be determined using a complete water budget analysis.

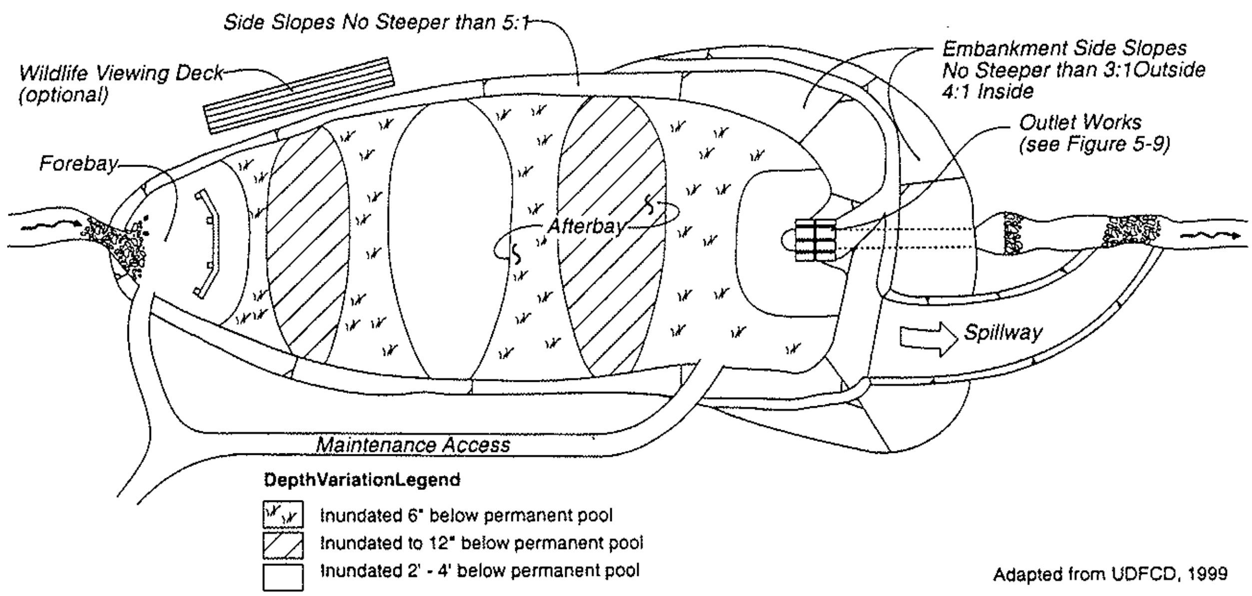
This control measure is most appropriate for sites with low-permeability soils (Type C and D) that will support aquatic plant growth. Infiltration through a wetland bottom cannot be relied upon because the bottom is either covered by soils of low permeability or because the groundwater is higher than the wetland's bottom. Wetland bottom channels also require a near-zero longitudinal slope; drop structures are used to create and maintain a flat grade.

Vegetation Maintenance

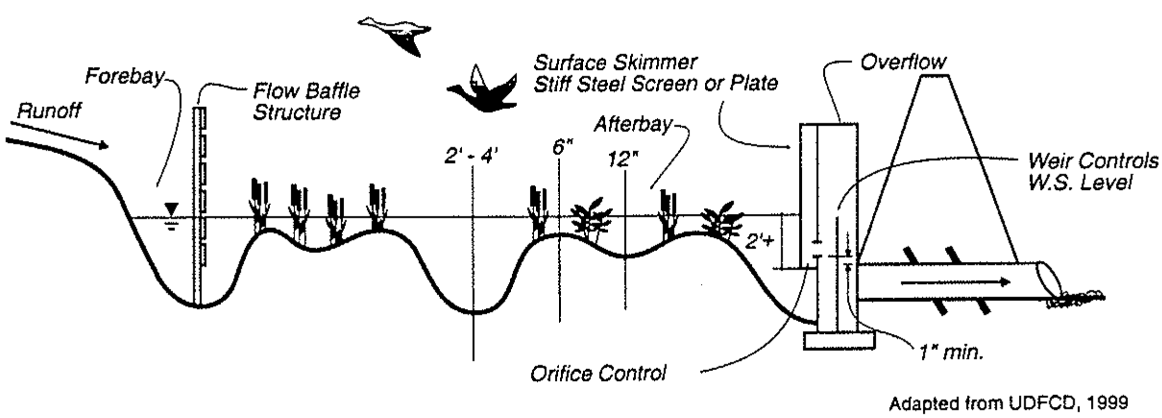
Considerable resources must be committed to provide nutrient removal and to maintain desirable mix and density of vegetation. Regular harvesting and removal of aquatic plants is required if the removal of nutrients is to be assured. Sediment removal is also necessary to maintain the proper distribution of growth zones and of water movement within the wetland. Water and plant management to avoid mosquito propagation is also essential.

Pollutant Removal

Wetlands remove a variety of constituents but their effectiveness varies significantly. Relative pollutant removal effectiveness of a CWB is presented in Table 5-1. With periodic sediment removal and plant harvesting, expected removal efficiencies for sediments, organic matter, and metals can be moderate to high; for phosphorus and nitrogen, low to moderate. Pollutants are removed primarily through sedimentation and entrapment, with some of the removal occurring through biological uptake by vegetation and microorganisms. Without a continuous dry-weather base flow, salts and algae can concentrate in the water column and can be released into the receiving water in higher levels at the beginning of a storm event as they are displaced. Harvesting aquatic plants and periodic removal of sediment also removes nutrients and pollutants associated with the sediment.



Plan View



Section View

Figure 5-10. Conceptual Layout of Constructed Wetland Basin

Design Criteria and Procedure

Principal design criteria for CWBs are listed in Table 5-8.

Table 5-8. Constructed Wetland Basin Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	24
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 24-h drawdown
Permanent pool volume (minimum)	%	75% of SQDV
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Permanent Pool Area / Depth		
Forebay, free water surface, and outlet areas	% / ft	30% to 50% of the permanent pool surface area / 2 to 4ft
Wetland zones with emergent vegetation	% / ft	50% to 70% of the permanent pool surface area / 0.5 to 1.0 ft (30% to 50 % should be 0.5 ft deep)
Forebay volume	%	5 to 10 % of SQDV
Surcharge depth above permanent pool	ft	2.0 ft maximum
Length to width ratio (minimum)	–	2:1 (larger preferred)
Freeboard (minimum)	ft	1.0
Wetland (Littoral) zone bottom slope	%	10.0 maximum
Embankment side slope	(H:V)	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	hrs	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume Provide a storage volume equal to 100 percent of the SQDV, based on a 24-hr drawdown time, above the lowest outlet (i.e. perforation or orifice) in the basin.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 24-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $SQDV = (V_u /12) \times Area$

   where Area = Watershed area tributary to CWB (acres)

2. Basin Depth/Volume

The volume of the permanent wetland pool shall be not less than 75% of the SQDV. Distribution of wetland area is needed for a diverse ecology. Distribute component areas as follows:

Components	Percent of Permanent Pool Surface Area	Design Water Depth
Forebay, outlet and free water surface areas	30-50%	2 to 4 feet
Wetland zones with emergent vegetation	50-70%	6 to 12 inches (1/3 to 1/2 of this area should be 6 inches deep with bottom slope ≤ 10%)

3. Depth of Surcharge

The surcharge depth of the SQDV above the permanent pool's water surface should not exceed 2.0 feet.

4. Outlet Works

Provide outlet works that limit the SQDV depth to 2 feet or less. The Outlet Works are to be designed to release the SQDV over at least a 40 hour period. A single orifice outlet control is depicted in Figure 5-10.

For single orifice outlet control or single row of orifices at the basin bottom surface elevation (see Figures 5-6), use the following equation based on the SQDV (ft^3) and depth of water above orifice centerline D (ft) to determine orifice area (in^2):

$$\text{Total orifice area} = (\text{SQDV}) \div [(60.19)(D^{0.5})(T)]$$

where

T = drawdown period (hrs) = 24 hrs

For perforated pipe outlets or vertical plates with multiple orifices (see Figure 5-5), use the following equation to determine required area per row of perforations, based on the SQDV (acre-ft) and depth of water above centerline of the bottom perforation D (ft).

$$\text{Area/row } (in^2) = \text{SQDV}/K_{24}$$

where

$$K_{24} = 0.012D^2 + 0.14D - 0.06$$

Select appropriate perforation diameter and number of perforations per row (columns) with the objective of minimizing the number of columns and using a maximum perforation diameter of 2 inches. Rows are spaced at 4 inches on center from the bottom perforation. Thus, there will be 3 rows for each foot of depth plus the top row. The number of rows (nr) may be determined as follows:

$$nr = 1 + (D_{BS} \times 3)$$

Calculate total outlet area by multiplying the area per row by number of rows.

$$\text{Total orifice area} = \text{area/row} \times nr$$

5. Basin Use — Determine if flood storage or other uses will be provided for above the wetland surcharge storage or in an upstream facility. Design for combined uses when they are provided for.

6. Basin Shape — Whenever possible, shape the basin with a gradual expansion from the inlet and a gradual contraction toward the outlet. The length to width ratio should be between 2:1 to 4:1 with a 3:1 recommended. Internal baffling with berms or modification of inlet and outlet points may be necessary to achieve this ratio.

7. Basin Side Slopes — Side slopes should be stable and sufficiently gentle to limit rill erosion and to facilitate maintenance. Internal side slopes should be no steeper than 4:1, external side slopes should be less than 3:1.

8. Base Flow — A net influx of water must be available through a perennial base flow and must exceed the losses. The following equation and parameters can be used to estimate the net quantity of base flow available at the time.

$$Q_{net} = Q_{inflow} - Q_{E\text{-}P} - Q_{seepage} - Q_{ET}$$

where

Q_{net}	=	Net quantity of base flow (acre-ft/year)
Q_{inflow}	=	Estimated base flow (acre-ft/year). (Estimate by seasonal measurements and/or comparison to similar watersheds.)
$Q_{E\text{-}P}$	=	Loss due to evaporation minus the precipitation (acre-ft/year)
$Q_{seepage}$	=	Loss or gain due to seepage to groundwater (acre-ft/year)
Q_{ET}	=	Loss due to evapotranspiration (additional loss through plant area above water surface not including the water surface)

9. Inlet/Outlet Design — Basin inlet and outlet points should provided with an energy dissipation structure and/or erosion protection. Outlets should be placed in an outlet bay that is at least 3 feet deep. The outlet should be protected from clogging by a skimmer shield that starts at the bottom of the permanent pool and extends above the maximum SQDV depth. Also, provide for a trash rack.

11. Forebay/Afterbay — The forebay provides a location for sedimentation of larger particles and has a solid bottom surface to facilitate mechanical removal of accumulated sediment. The after bay is optional. The forebay volume should be 5% to 10 % of the SQDV. Depth should be 2.0 to 4.0 ft.

12. Vegetation — Selected wetland plants and grasses should be planted in the

wetland bottom. The shallow littoral bench should have a 4 to 6 inch layer of organic topsoil. Berms and side-sloping areas should be planted with native or irrigated turf grasses. The selection of plant species for a constructed wetland shall take into consideration the water fluctuation likely to occur in the wetland. Permanent pool water level should controlled as necessary to establish wetland plants and raised to final operating level after plants are established.

12. Access — All-weather access to the forebay, and outlet works shall be provided for maintenance vehicles. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete.

13. Bypass — Provide for bypass or overflow of runoff volumes in excess of the SQDV. Spillway and overflow structures should be designed in accordance with applicable standards of the City of Woodland Storm Drainage Guidance and Criteria.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-5: Constructed Wetlands Basin

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	50	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	50	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 24 hr drawdown and I_{wq}	V_u=	0.28	in.
d. Watershed Area Tributary to CWB	Area =	100	acres
e. Calculate SQDV SQDV = (V_u / 12) × Area	SQDV =	2.33	acre-ft
2. Wetland Pond Volume, Depth, and Water Surface Area		**Minimums**	
a. Permanent Pool: Minimum $Vol_{pool} \geq 0.75 \times$ SQDV	Vol_{pool} >	1.75	acre-ft
	Water Area>	0.70	acres, estimated
		Actual Design	
	Vol_{pool} =	1.80	acre-ft, actual
	Water Area =	1.20	acres, actual
b. Forebay Depth Range = 2.0' – 4.0'	Depth =	3.0	ft
Volume Range = 5%to 10 % of SQDV	Volume =	0.09	acre-ft,% = 5.0
c. Outlet Pool Depth Range = 2.0' – 4.0'	Depth =	3.0	ft
Volume Range = 6%to 10% of SQDV	Volume =	0.18	acre-ft,% = 10.0

Continued on next page

Design Procedure Form for T-5: Constructed Wetlands Basin (Page 2 of 3)

Project:____________________

3. Wetland Pond Volume, Depth, and Water Surface Area (Continued)			
d. Free Water Surface Areas (Depth Range = 2.0' – 4.0') (Area = 30-50% combined)	Depth =	2.0	ft
	Area =	0.60	acres, % = 50
	Volume =	1.20	acre-ft
e. Wetland Zones with Emergent Vegetation (Depth Range = 6" – 12") (Area = 50-70%)	Depth =	1.0	ft
	Area =	0.60	acres, % = 50
	Volume =	0.60	acre-ft
4. Estimated Net Base Flow (must be > 0)			
$Q_{net} = Q_{inflow} - Q_{evap} - Q_{seepage} - Q_{evapotranspiration}$	Q_{inflow} =	362.0	acre-ft
	Q_{evap} =	1.40	acre-ft
	$Q_{seepage}$ =	2.80	acre-ft
	$Q_{evapotranspiration}$	1.50	acre-ft
	Q_{net} =	356.30	acre-ft
5. Outlet Works			
a. Outlet Type (check one)	Single Row Orifice	X	
	Perforated Plate		
	Perforated Pipe		
	Other		
b. Depth of water above bottom orifice	Depth =	3.0	feet
c. Single Orifice (or Single Row) Outlet			
1) Total Area	A =	40.56	square inches
2) Diameter (or L × W)	D =	5 × 8.11	inches
d. Perforated Outlet (Plate or Pipe)			
1) Area per row of perforations	A =		
2) Perforation Diameter (2 inches max.)	D =		
3) No. of Perforations (columns) per Row	Perforations =		
4) No. of Rows (4 inch spacing)	Rows =		
5) Total Orifice Area (Area per row) × (Number of Rows)	Area =		

Design Procedure Form for T-5: Constructed Wetlands Basin (Page 3 of 3)

Project:______________________________

6. Trash Rack or Gravel Pack Present?	Yes/No Yes
7. Basin Shape a. Length-Width Ratio	Ratio = 3:1 L:W
8. Embankment Side Slope a. Interior Side Slope (4:1 max.) b, Exterior Side Slope (3:1 max.)	Int. Side Slope = 4:1 L:W Ext. Side Slope = 3:1 L:W
9. Vegetation (Check type used or describe "Other")	X Native Grasses ____ Irrigated Turf Grass X Emergent Aquatic Plants (specify type / density)* ____ Other __________ *Describe Species Density and Mix: See attached specification

Notes:

Maintenance Requirements

The following maintenance requirements apply to Constructed Wetland Basins

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map
- Maintenance and cleaning activities and schedule
- Equipment and resource requirements necessary to operate and maintain facility
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

- Inspect constructed wetlands a minimum of twice a year, before and after the rainy season, after large storm events, or more frequently if needed. Some important items to check for include: differential settlement, cracking; erosion, leakage, or tree growth on the embankment; the condition of the riprap in the inlet, outlet and pilot channels; sediment accumulation in the basin; and the vigor and density of the vegetation on the basin side slopes and floor. Correct observed problems as necessary.
- Remove litter and debris from banks and basin bottom as required.
- Repair erosion to banks and bottom as required.
- Clean forebay every two years at a minimum, to avoid accumulation in main wetland area. Environmental regulations and permits may be involved with the removal of wetland deposits. When the main wetland area needs to be cleaned, it is suggested that the main area be cleaned one half at a time with at least one growing season in between cleanings. This will help to preserve the vegetation and enable the wetland to recover more quickly from the cleaning.
- Inspect outlet for clogging a minimum of twice a year, before and after the rainy season, after large storms, but more frequently if needed. Correct observed problems as necessary.
- Control mosquitoes, as necessary. The forebay (deep water only) can be stocked with Gambusia fish (mosquito fish), if approved by the Department of Fish and Game and other appropriate agencies.

Description

A detention basin/sand filter (DBSF) consists of a runoff storage zone underlain by a sand bed filter with an underdrain system constructed in an earthen basin. The basin is divided into a forebay settling basin to remove large sediment followed by sand filter basin. During storm events, runoff accumulates in the surcharge zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually dewaters the sand bed and discharges the runoff to downstream conveyance. Schematic plan and section views of a typical DBSF are shown in Figure 5-11.

General Application

A DBSF is generally suited to offline, onsite configurations where there is no base flow and the sediment load is relatively low. Drainage areas of up to 100 acres are appropriate for DBSFs.

Advantages/Disadvantages

General

Primary advantages of DBSFs include effective water quality enhancement through settling and filtering.

The primary disadvantage is the potential for clogging of the filter media. For this reason, systems should not be put into operation while construction activities are taking place in the tributary catchment. Maintenance requirements to maintain permeability of the filter media can be high if sediment loads are excessive.

Site Suitability

Because an underdrain system is incorporated into this control measure, DBSFs are suited to most soil types; presence of sandy soils is not a requirement. DBSFs are best suited to flat or gently sloping terrain, because of the need to construct zero-slope filter beds.

Pollutant Removal

Relative pollutant removal effectiveness of a DBSF is presented in Table 5-1. Removal effectiveness of DBSFs for sediment and particulate forms of metals, nutrients and other pollutants is considered high to moderate. Removal effectiveness for dissolved pollutants is considered low.

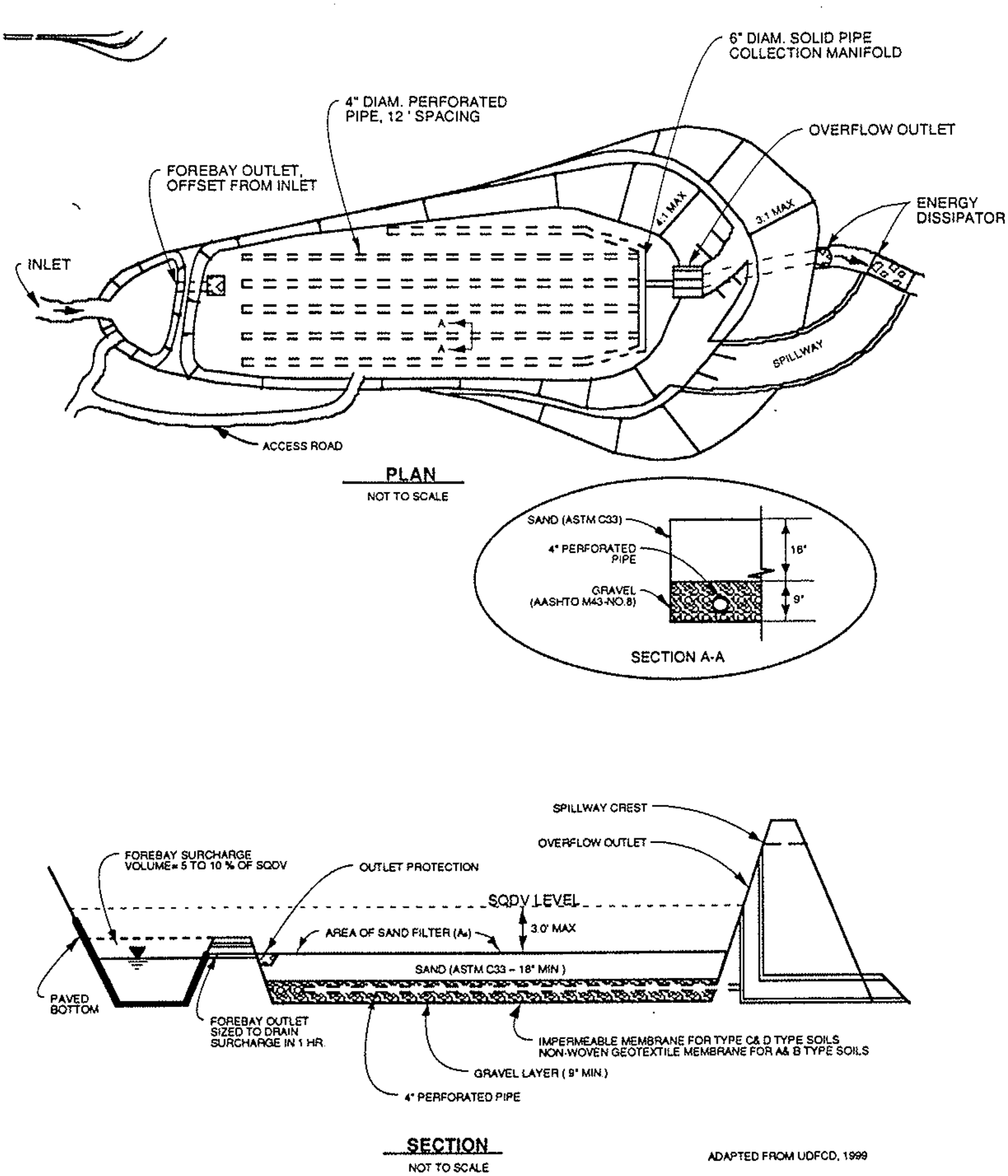


FIGURE 5-11. DETENTION BASIN/SAND FILTER

Design Criteria and Procedure

Principal design criteria for DBSFs are listed in Table 5-9.

Table 5-9. Detention Basin /Sand Filter Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV / 50% SQDV	hrs	40 / 12 (minimum)
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 40-h drawdown
Forebay surcharge volume	%	5 to 10% of SQDV
Max depth at SQDV	ft	3 feet
Inlet/outlet erosion control	--	Energy dissipater to reduce inlet/outlet velocity
Length to width ratio (minimum)	--	2:1 (larger preferred)
Freeboard (minimum)	ft	1.0
Filter bed media	--	Sand: 18 inches, Gravel: 9 inches.
Embankment side slope (H:V)	--	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	hrs	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 40-hr drawdown time, above the sand bed of the basin.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u / 12) \times Area$$

   where

   Area = Watershed area tributary to DBSF (acres)

2. Basin Depth — Maximum design volume depth should be 3 feet.

3. Filter Surface Area — Calculate the minimum sand filter area (A_s at the basin's bottom with the following equation:

$$A_s\ (min) = (SQDV / 3) \times 43{,}560\ ft^2$$

4. Filter Bed — An 18-inch layer of sand (ASTM C 33) over a 9-inch gravel layer (ASSHTO M43-No. 8) shall line the entire DBSF for purposes of filtering and draining the SQDV.

   If expansive soils are a concern or if the tributary catchment has chemical or petroleum products handled or stored, install an impermeable membrane below the gravel layer.

5. Outlet Works — A grated outlet structure with overflow should be provided to convey flows in excess of the SQDV out of the basin.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-6: Detention Basin / Sand Filter

Designer: ____________________

Company: ____________________

Date: ____________________

Project: ____________________

Location: ____________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	64	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	60	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	0.41	in.
d. Watershed Area Tributary to DBSF	Area =	10.0	acres
e. Calculate SQDV SQDV = $(V_u / 12) \times$ Area	SQDV =	0.34	acre-ft
2. Filter Surface Area (A_s)			
a. A_s (min) = (SQDV / 3) $\times$ 43,560 ft^2	A_s (min) =	4,961	ft^3
b. Design A_s	Design A_s =	5,000	ft^2
3. Design basin depth, based on design filter area			
D = Design Volume/ Design A_s	D =	3.0	ft
4. Filter Bed			
a) ASTM C33 Sand Layer (18 in. minimum)		18	inches
b) ASSHTO M43-No.8 Gravel Layer (9 in. min.)		9	inches

Notes:

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Maintenance Requirements

The following maintenance requirements apply to Detention Basin/Sand Filters.

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map
- Maintenance and cleaning activities and schedule
- Equipment and resource requirements necessary to operate and maintain facility
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

- Inspect basin a minimum of twice a year, before and after the rainy season, after large storm events, or more frequently if needed. Some important items to check for include: differential settlement, cracking; erosion, leakage, or tree growth on the embankment; the condition of the riprap in the inlet, outlet and pilot channels; sediment accumulation in the basin; and the vigor and density of the vegetation on the basin side slopes and floor. Correct observed problems as necessary.
- Remove litter and debris from banks and basin bottom as required.
- Repair erosion to banks and bottom as required.
- Check infiltration rate of sand bed twice annually, once after significant rainfall.
- Scarify top 3 to 5 inches of filters surface by raking once annually or as required to restore infiltration rate of the filter.
- Clean forebay every two years at a minimum, to avoid accumulation in main basin.
- Inspect outlet for clogging a minimum of twice a year, before and after the rainy season, after large storms, and more frequently if needed. Correct observed problems as necessary.

Description

A Porous Pavement Detention system (PPD) consists of an installation of Modular Block Porous pavement that is flat (i.e., S_0 = 0.00% in all directions) and is provided with a 2-inch deep surcharge zone to temporarily store the WQCV draining from an adjacent area. Runoff will infiltrate into the porous pavement and sublayers of sand a gravel and will slowly exit through an underdrain.

Modular Block Porous Pavement consists of open void concrete block units laid on a two-layer sand and gravel subgrade. The surface pavement voids are filled with sand. A typical cross section of a PPD system is shown in Figure 5-12. An alternate approach is to use stabilized-grass porous pavement, consisting of grass turf reinforced with plastic rings and filter fabric underlain by gravel.

General Application

A PPD may be used in low vehicle-movement zones such as residential driveways and is often used as a parking pad surface. Although PPDs are typically used as parking pads in a parking lot, there are other potential applications such as:

- Low vehicle movement airport zones such as parking aprons and maintenance roads
- Crossover/emergency stopping/parking lanes on divided highways.
- Residential street parking lanes
- Residential driveways
- Maintenance roads and trails
- Emergency vehicle and fire access lanes in apartment/multi-family/complex situations

Vehicle movement lanes that lead up to the porous pavement parking pads should be solid asphalt or concrete pavement. Grass can be used in the block voids; however it may require irrigation and lawn care.

Advantages/Disadvantages

General

In addition to relatively high pollutant removal effectiveness, PPD can reduce flooding potential by infiltrating or slowing down runoff. Modular Block patterns, colors and materials can serve functional and aesthetic purposes. An additional advantage is to provide a means to provide storm water capture for sites that have little available open area for detention.

The primary disadvantage for use of PPD is cost. Also, uneven driving surfaces and potential traps for the high heels of women's shoes may be a problem. The cost of restorative maintenance can be somewhat high if the system seals with sediment and no longer functions properly as a permeable pavement.

Site Suitability

PPDs may be installed without free draining subsoils when provided with underdrains. An underdrain ensures the drainage of the gravel subgrade whenever the subsoils are not free draining. In cases when the subsoils are not free draining, an impermeable liner should be provided to contain the water in the gravel pack and to mitigate concerns about expansive soils.

The PPD should also be located far enough from foundations in expansive soils so as to limit damage to potential structures. In addition, when a commercial or an industrial site may be handling chemicals and petroleum products that may spill to the ground, an impermeable liner with an underdrain is required to prevent groundwater and soil contamination.

Pollutant Removal

Removal rates for both suspended sediment and associated constituents are projected to be high to moderate. Runoff through the sand and gravel of the modular block voids and entrapment in the gravel media are the primary removal mechanisms of pollutants. Removal rates for dissolved constituents are expected to be low to moderate. Relative pollutant removal effectiveness of a DBSF is presented in Table 5-1.

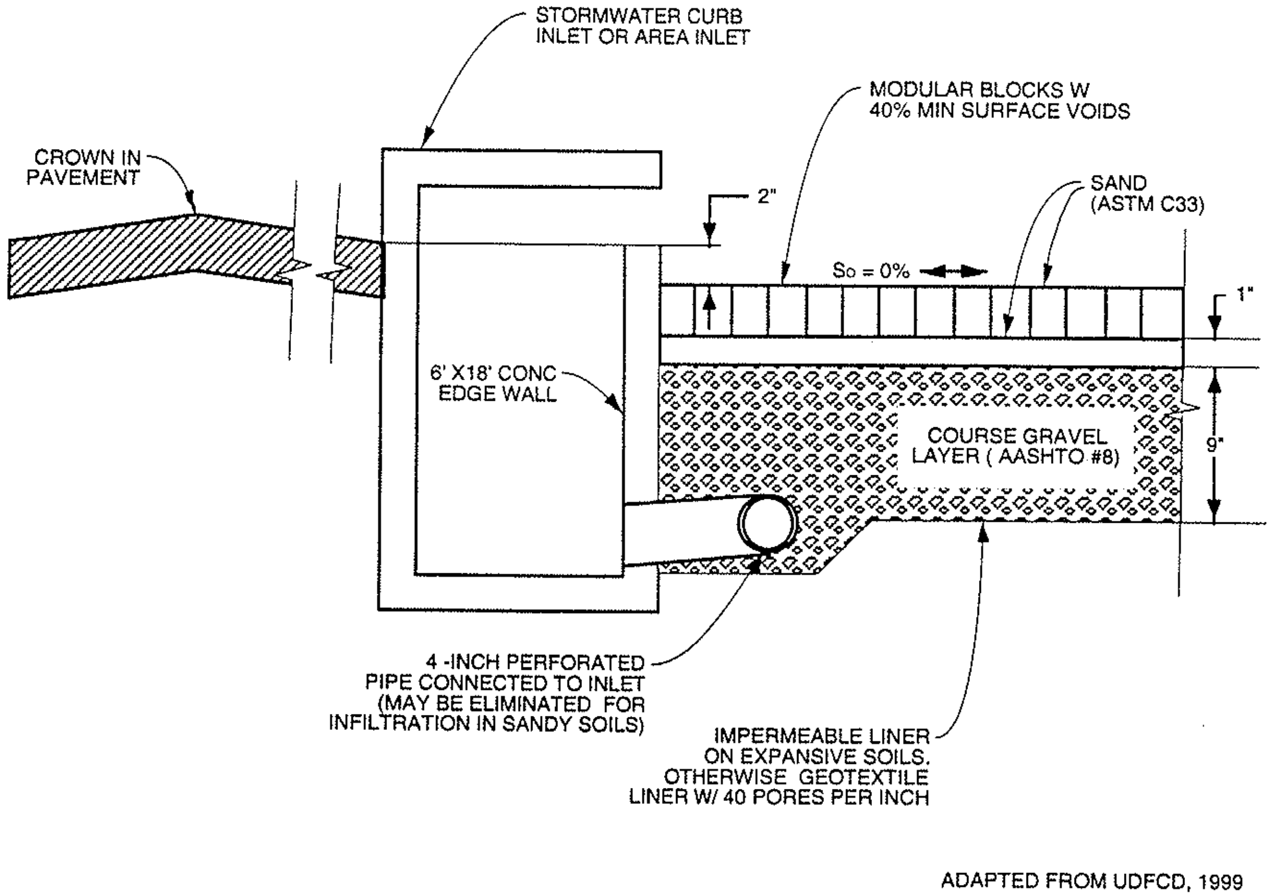

Figure 5-12. Porous Pavement Detention

Design Criteria and Procedure

Principal design criteria for PPDs are listed in Table 5-10.

Table 5-10. Porous Pavement Detention Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	12 (minimum)
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 12-h drawdown
Modular Porous Block Type	%	40% surface area open
Porous Pavement Infill	--	ASTM C-33 Sand or equivalent
Base courses	–	1-inch sand (ASTM C-33) over 9-inch gravel
Perimeter Wall Width	in	6

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 12-hr drawdown time.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 12-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u / 12) \times Area$$

   where Area = Watershed area tributary to PPD (acres)

2. Basin Surface Area — Calculate minimum required surface area based on surcharge depth of 2 inches as follows:

   $$\text{Surface Area} = SQDV\ (ft^3) / 0.17\ (ft)$$

3. Select Block Type — Select appropriate modular blocks that have no less than 40 percent of the surface area open. The manufacturer's installation requirements shall be followed with the exception that porous pavement infill material requirements and base course dimension are adhered to.

4. Porous Pavement Infill — The Modular Block Pavement openings should be filled with ASTM C-33 graded sand (fine concrete aggregate, not sandy loam turf).

5. Base Courses	Provide 1-inch sand over 9-inch gravel base courses as shown in Figure 5-12.
6. Perimeter Wall	Provide a concrete perimeter wall to confine the edges of the PPD area. The wall should be minimum 6-inch wide and at least 6 inches deeper than all the porous media and modular block depth combined.
7. Subbase	If expansive soils or rock are a concern or the tributary catchment has chemical or petroleum products handled or stored, install an impermeable membrane below the base course. Otherwise install a non-woven geotextile membrane to encourage filtration.
8. Overflow	Provide an overflow, possibly with an inlet to a storm sewer, set at 2 inches above the level of the porous pavement surface. Make sure the 2-inch ponding depth is contained and does not flow out of the area at ends or sides.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-7: Porous Pavement Detention

Designer:__________

Company:__________

Date:__________

Project:__________

Location:__________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	100	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	100	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12 hr drawdown and I_{wq}	V_u=	0.34	in.
d. Watershed Area Tributary to PPD	Area =	0.1	acres
e. Calculate SQDV SQDV = (V_u / 12) × Area	SQDV =	0.0028	acre-ft
2. Basin Surface Area			
a. Design Volume (minimum = SQDV)	Design Volume =	125	ft^3
b. A_s = Design Volume / (0.17 ft) (based on surcharge depth of 2 inches)	A_s =	726	ft^2
3. Block Type	Block name:	Uni-Green	
	Manufacturer:	Pavestone	
a. Minimum open area = 40%	Open Area =	40	%
b. Minimum thickness = 4 inches	Thickness	4.0	inches
4. Base Course (Check)			
a. ASTM C33 Sand Layer (1 inch)	Sand Layer	X	
b. ASSHTO M43-No.8 Gravel Layer (9 inches)	Gravel Layer	X	

Notes:

Maintenance Requirements

The following maintenance requirements apply to Porous Pavement Detention.

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map
- Maintenance and cleaning activities and schedule
- Equipment and resource requirements necessary to operate and maintain facility
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

- Inspect PPD a minimum of twice a year during storm events to determine if runoff is infiltrating properly.
- If infiltration is significantly reduced, remove surface sand by vacuuming. Dispose and replace sand with fresh ASTM C-33 sand.
- Remove litter and debris from PPD area as required.

Porous Landscape Detention

Description

A Porous Landscape Detention (PLD) system functions in a similar manner to Porous Pavement Detention (PPD) except that vegetation is used instead of porous blocks. A PLD system consists of a low-lying vegetated area underlain by a sand bed with an underdrain pipe. A shallow surcharge zone is provided above the PLD for temporary storage of the SQDV. During runoff events, runoff accumulates in the vegetated zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually dewaters the sand bed and discharges the runoff to downstream conveyance. Like the PPD, a PLD allows detention of the SQDV to be provided on sites with limited open area available for stormwater detention. A typical cross section of a PLD is shown in Figure 5-13.

General Application

A PLD can be located in most any open areas of a site. It is ideally suited for small installations such as:

- Parking lot islands
- Street medians
- Roadside swale features
- Site entrance or buffer features

A PLD can be implemented on a larger scale, serving as an infiltration basin/sand filter for an entire site, if desired, provided the stormwater quality capture volume and average depth requirements are met.

Advantages/Disadvantages

General

PLDs provide storm water capture on a site while reducing the impact on developable land. In addition to the relatively high degree of pollutant removal provided, PLDs can reduce flooding potential by infiltrating or slowing down runoff. A PLD provides a natural moisture source for vegetation, enabling "green areas" to exist with reduced irrigation.

The primary disadvantage of a PLD is the potential for clogging if sediment loading is excessive. The cost of restorative maintenance can be high if the system seals with sediment and no longer functions as a storm water basin. A PLD should be placed away from building foundations or other areas where expansive soils are present, although underdrain and impermeable liner can ameliorate some of these concerns.

Site Suitability

If an underdrain system is incorporated into the design, PLDs are suited for almost any site regardless of soil type. An underdrain ensures the drainage of the subgrade whenever the subsoils are not free draining. If sandy soils (type A or B) are present, the facility can be installed without an underdrain. However, sandy subsoils are not a requirement. In cases when the subsoils are not free draining, an impermeable liner should be provided to contain the water in the subgrade and to mitigate concerns about expansive soils. This BMP has a relatively flat surface area and may be more difficult to incorporate it into steeply sloping terrain.

The PLD should be located far enough from foundations in expansive soils so as to limit damage to potential structures. In addition, when a commercial or an industrial site may be handling chemicals and petroleum products that may spill to the ground, an impermeable liner with an underdrain is required to prevent groundwater and soil contamination.

Pollutant Removal

The degree of pollutant removal by a PLD should be significant and should equal or exceed the removal effectiveness provided by sand filters. In addition to removal by settling, PLDs provides filtering, adsorption, and biological uptake of constituents in stormwater. Relative pollutant removal effectiveness is indicated in Table 5-1.

Design Criteria and Procedure

Principal design criteria for SFBs are listed in Table 5-11.

Table 5-11. Porous Landscape Detention Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	12 hrs
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 12-h drawdown
Average surcharge depth	in	6-12
Sand-peat layer	in	18" (minimum)– 75% ASTM C-33 Sand + 25% peat
Gravel layer	in	9" – ASSHTO #8 Coarse Aggregate
Vegetative (sandy loam turf) layer	in	6"

When implementing multiple small PLDs on a site, it is increasingly important to accurately account for each upstream drainage area tributary to each PLD site to make sure that each facility is properly sized, and that all portions of the development site are directed to a PLD.

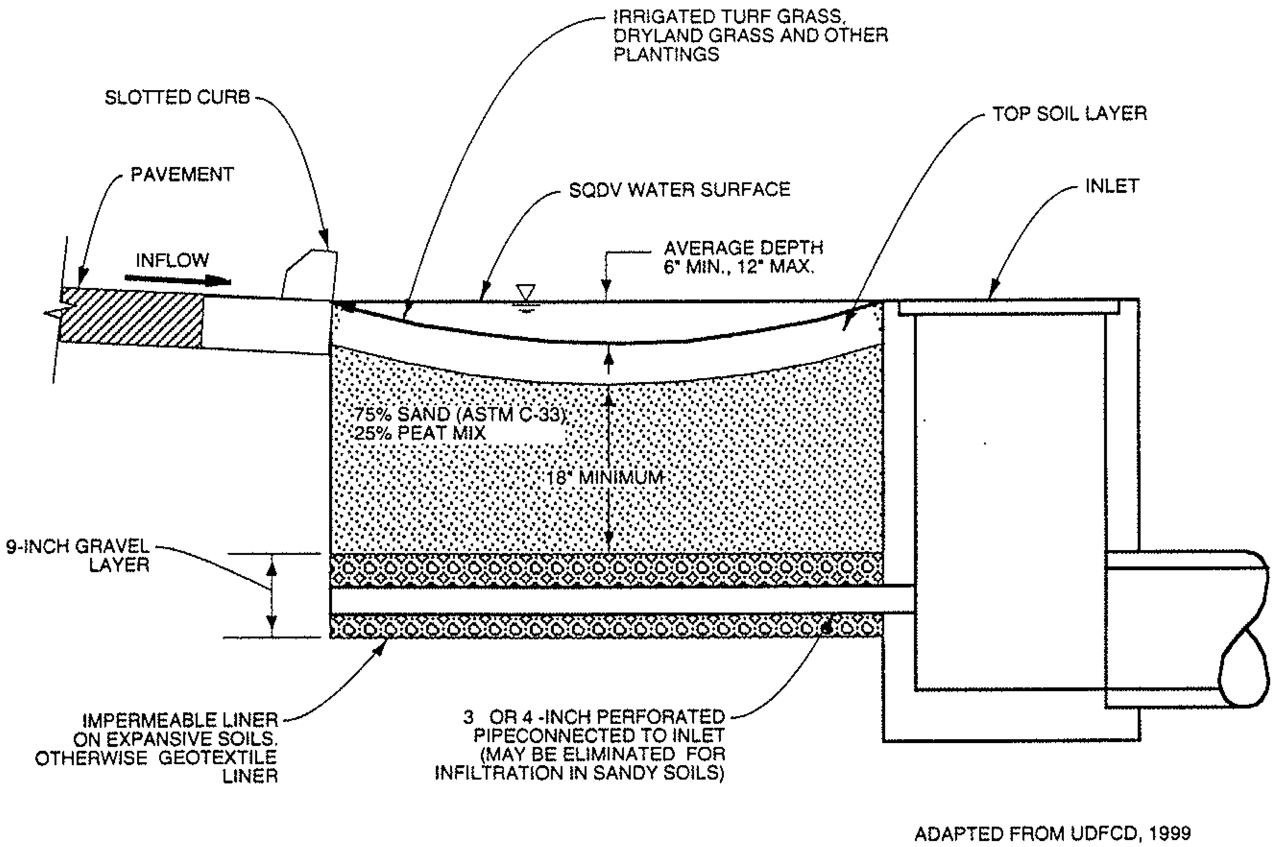

Figure 5-13. POROUS LANDSCAPE DETENTION

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume	Provide a storage volume equal to 100 percent of the SQDV, based on a 12-hr drawdown time. a. Determine the percent imperviousness of the tributary area (I_a). b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate. c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 12-hr drawdown and I_{wq} value from step 1.b. d. Calculate the SQDV in acre-ft as follows: $SQDV = (V_u /12) \times Area$ where Area = Watershed area tributary to PLD (acres)
2. Basin Surface Area	Calculate minimum required surface area as follows: Surface Area = SQDV / average surcharge depth
3. Base Courses	Provide 18-inch sand + peat layer over 9-inch gravel layer as shown in Figure 5-13. Thoroughly mix 75% sand (ASTM C-33) with 25% peat for filtration and adsorption of contaminants.
4. Subbase	If expansive soils or rock are a concern or the tributary catchment has chemical or petroleum products handled or stored, install an impermeable membrane below the base course. Otherwise install a non-woven geotextile membrane to encourage filtration.
5. Surcharge Depth	Maintain the average SQDV depth between 6 and 12 inches. Average depth is defined as water volume divided by the water surface area.
6. Vegetative Layer	Provide a sandy loam turf layer above the sand-peat mix layer. This layer shall be no less than 6 inches thick, but a thicker layer is recommended to promote healthier vegetation.
7. Overflow	Provide an overflow, possibly with an inlet to a storm sewer, set above the SQDV surcharge water level

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-8: Porous Landscape Detention Basin

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

1. Determine Basin Storage Volume			
a. Percent imperviousness of Tributary Area	I_a =	100	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	100	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12 hr drawdown and I_{wq}	V_u=	0.34	in.
d. Watershed Area Tributary to PLD	Area =	0.25	acres
e. Calculate SQDV SQDV = (V_u / 12) X Area	SQDV =	0.007	acre-ft
2. Basin Surface Area			
a. Design Volume (Minimum = SQDV)	Design Volume =	308	ft^3
b. Average Depth	Average Depth =	1.0	ft
c. A_s = Design Volume / Average Depth	A_s =	308	ft^2
3. Base Course Layers (check)	Sandy Loam Turf	X	in. (6" min)
	Sand/peat mix	X	in. (18" min)
	Gravel	X	in. (9" min)
4. Subsurface Drainage (check type used)	X	Infiltration to subgrade with permeable geotextile membrane	
	____	Underdrain with impermeable membrane	
	____	Underdrain with permeable goetextile membrane	

Notes:

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Maintenance Requirements

The following maintenance requirements apply to Porous Landscape Detention.

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map
- Maintenance and cleaning activities and schedule
- Equipment and resource requirements necessary to operate and maintain facility
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

- Mow grass and remove weeds to limit unwanted vegetation as required. Maintain irrigated turf grass height at 2 to 4 inches and non-irrigated native grasses at 4 to 6 inches.
- Remove litter and debris from PPD area as required.
- Inspect PLD a minimum of twice a year during storm events to determine if runoff is infiltrating properly.
- If infiltration is significantly reduced, remove and replace sandy loam turf and landscaping layer. May be required every 5 to 10 years or more frequently depending on sediment loads to the PLD.

Description

An Infiltration Basin (INB) consists of an earthen basin constructed in naturally pervious soils (Type A or B soils) with a flat bottom and provided with inlet structure to dissipate energy of incoming flow and an emergency spillway to control excess flows. An optional relief underdrain may be provided to drain the basin if standing water conditions occur. A forebay settling basin as described for EDBs should be provided if high sediment loads are anticipated. An INB functions by retaining the SQDV in the basin and allowing the retained runoff to percolate into the underlying native soils over a specified period of time (40 hours). The bottoms of basins are typically vegetated with dry-land grasses or irrigated turf grass. . A typical layout of an INB system is shown in Figure 5-14.

General Application

Infiltration basins can serve drainage areas up to 50 acres. Infiltration basins can be sized to pass storm volumes greater than the storm quality capture volume (SQDV). However, treatment efficiencies are reduced and the threat of system failure increases as the volume of runoff directed to the infiltration basin increases above the SQDV. It is recommended that the basin be sized to treat the storm quality capture volume only and divert all other flows around the treatment control measure.

Advantages/Disadvantages

General

In addition to removing pollutants effectively, infiltration basins also control runoff volume, which may serve to reduce downstream bank erosion in watercourses. INBs, are empty when not in use and can be dual-purpose facilities. A grass-covered area in a park, for example, could function as an infiltration basin during the wet season, and as a park during the dry season.

The primary disadvantage of an infiltration basin is the potential for clogging if excessive sediment is allowed to flow into the facility. The cost of restorative maintenance can be high if soil infiltration rates are significantly reduced due sediment deposition. Basins cannot be put into operation until the upstream tributary area is stabilized.

Site Suitability

An infiltration basin requires significant space and is suitable for large drainage areas (10 to 50 acres. INBs infiltration basins cannot be placed on fill or unstable sites. Also, INBs should not be placed in high-risk areas such as service/gas stations, truck stops, and heavy industrial sites due to risk of groundwater contamination.

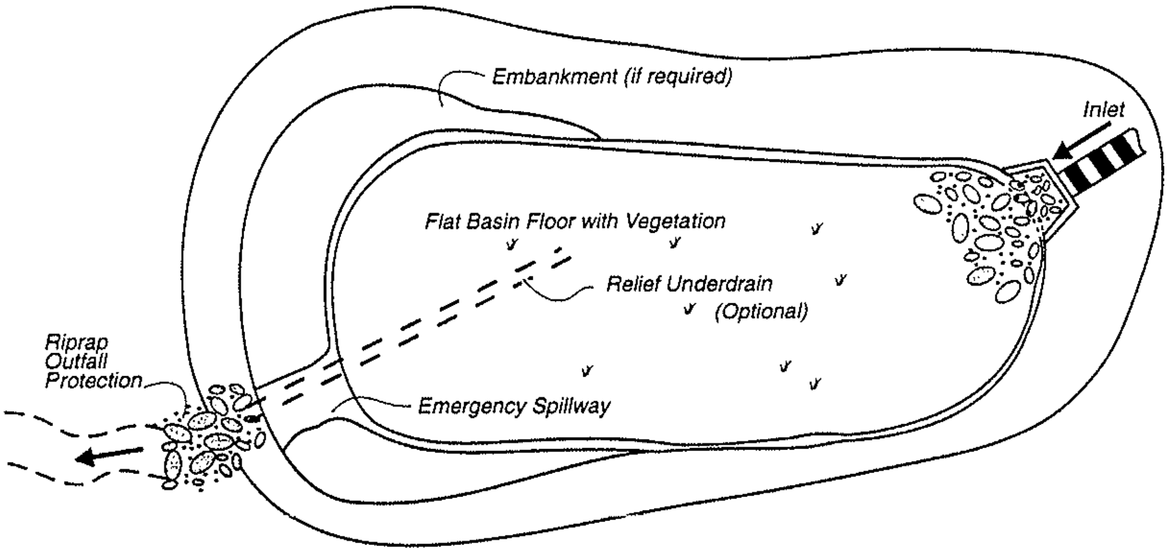
Before further considering the use of infiltration BMPs, preliminary site investigations should be performed to determine soil permeability and depth to groundwater table. For infiltration BMPs to be feasible, the permeability of the least-permeable horizon of the soil profile should be at least 0.5 inches per hour, based on extended infiltration rate measurements performed under saturated conditions, and the vertical separation between the bottom of the infiltration basin and the groundwater table (or bedrock) should be a minimum of 10 feet. Tributary area should have a low potential for erosion. Also, there is a risk of groundwater contamination in very coarse soils, as coarse soils do not effectively remove dissolved pollutants. Use of course soils may require groundwater monitoring. Other suitability considerations include the soil makeup (Appendix E), site topography, and the location of other facilities. Prior to selecting infiltration BMPs for implementation, project proponents should consult with City staff to verify the appropriateness of this type of BMP for the site in question.

The site must further provide a relatively flat area in which to construct the facility. Infiltration facilities shall be sited at least 50 feet away from slopes steeper than 15 percent. Adequate spacing (100 feet or more) shall be provided between infiltration facilities and non-potable wells, tanks, drain fields and springs. For separation between infiltration BMPs and potable water supply wells, follow Department of Health Services requirements in the Guidelines for Location of Water Wells. INBs shall also be sited at least 20 feet down slope or 100 feet up slope from building foundations. A geotechnical expert shall be consulted when necessary to verify appropriate placement on site.

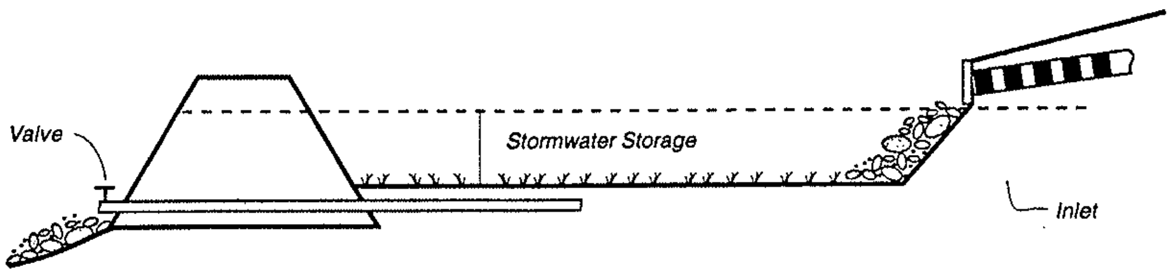
An important consideration for all infiltration facility configurations is that, during construction, great care must be taken not to reduce the infiltration capacity of the soil in the facility through compaction or by using the infiltration area as a sediment trap. Infiltration facilities shall be constructed late in the site development after soils (that might erode and clog the units) have been stabilized, or shall be protected until the site is stabilized.

Pollutant Removal

The amount of pollutant removed by INBs should be significant and should equal or exceed the removal rates provided by sand filters. In addition to settling, infiltration basins provide filtering, adsorption, and biological uptake of constituents in stormwater. Relative pollutant removal effectiveness is indicated in Table 5-1.



Plan



Section

Source: Schueler, 1987

Figure 5-14. INFILTRATION BASIN

Design Criteria and Procedure

Principal design criteria for INBs are listed in Table 5-12.

Table 5-12. Infiltration Basin Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	40
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 40-h drawdown
Bottom Basin Elevation	ft	10 feet above seasonally high groundwater table minimum.
Freeboard (minimum)	ft	1.0
Setbacks	ft ft.	100 feet from wells, tanks, fields, springs 20 feet down slope or 100 feet up slope from foundations
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Embankment side slope (H:V)	–	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	hrs	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete
Vegetation	–	Side slopes and bottom (may require irrigation during summer)

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 40-hr drawdown time.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u / 12) \times Area$$

   where

   Area = Watershed area tributary to INB (acres)

2. Basin Surface Area — Calculate the minimum surface area of the infiltration system:

   $$A_m = V/D_m$$

where:

$A_m =$ minimum area required (ft^2)

$V =$ volume of the infiltration basin (ft^3)

$D_m =$ maximum allowable depth (ft)

where:

$D_m = (t \times I)/(12 \times s)$

and: I = site infiltration rate in (in/hr)

s = safety factor

t = minimum drawdown time = 40 hours

In the formula for maximum allowable depth, the safety factor accounts for the possibility of inaccuracy in the infiltration rate measurement. The less certain the infiltration rate the higher the safety factor shall be. Minimum safety factors shall be as follows:

- Without site-specific borings and percolation tests, use s=10
- With borings (but no percolation test), use s=6
- With percolation test (but no borings), use s=5
- With borings and percolation test, use s=3

3. Inline/Offline

Basins may be on-line or off-line with flood control facilities, although off-line basins are recommended. For on-line basins, the water quality outlet may be superimposed on the flood control outlet or may be constructed as a separate outlet.

4. Vegetation

Bottom vegetation provides erosion protection and sediment entrapment. Basin bottoms, berms, and side slopes may be planted with native grasses or with irrigated turf.

5. Embankments

Design embankments to conform to requirements State of California Division of Safety of Dams, if the basin dimensions cause it to fall under that agency's jurisdiction. Interior slopes should be no steeper than 4:1 and exterior slopes no steeper than 3:1. Flatter slopes are preferable.

6. Access

All-weather access to the bottom, forebay, and outlet works shall be provided for maintenance vehicles. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete. Provide security fencing, except when used as a recreation area.

7. Bypass

Provide for bypass or overflow of runoff volumes in excess of the SQDV. Spillway and overflow structures should be designed in accordance with applicable standards of the City of Woodland Storm Drainage Guidance and Criteria.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-9: Infiltration Basin

Designer:________________

Company:________________

Date:________________

Project:________________

Location:________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	100	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	100	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	0.60	in.
d. Watershed Area Tributary to INB	Area =	0.2	acres
e. Calculate SQDV SQDV = (V_u / 12) × Area	SQDV =	0.010	acre-ft
2. Maximum Allowable Depth (D_m = tI/12s)			
a. Site infiltration rate (I)	I =	2.0	in/hr
b. minimum drawdown time (t = 40 hours)	t =	40	hrs
c. safety factor (s)	s =	3	
d. D_m = tI/12s	D_m =	2.22	ft.
3. Basin Surface Area A_s = SQDV / D_m	A_s =	196	ft^2
4. Vegetation (Check type used or describe "Other")	_X_ Native Grasses ____ Irrigated Turf Grass ____ Other ________		

Notes:

____

____

____

Maintenance Requirements

The following maintenance requirements apply to Infiltration Basins.

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map
- Maintenance and cleaning activities and schedule
- Equipment and resource requirements necessary to operate and maintain facility
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

- Inspect a minimum of twice a year, before and after the rainy season, after large storms, or more frequently if needed.
- Clean when loss of infiltrative capacity is observed. If drawdown time is observed to have increased significantly over the design drawdown time, removal of sediment may be necessary. This is an expensive maintenance activity and the need for it can be minimized through prevention of upstream erosion.
- Mow, as appropriate for vegetative cover species.
- Monitor health of vegetation and replace as necessary.
- Control mosquitoes as necessary.
- Remove litter and debris from INB area as required.

Infiltration Trench

Description

An Infiltration Trench (INT) consists of subsurface gravel and sand bed constructed in naturally pervious soils (Type A or B soils) where runoff is stored until it infiltrates into the soil profile. Upstream control measures such as Turf Buffers (see G-5.1), Grass-lined Channels (see G-5.2), Grass Strip Filters (see T-1), or Grass Swales Filters (see T-2), are typically combined with INTs to provide sediment removal upstream of the INT. The trench is designed to retain and infiltrate the SQDV over a specified period of time (40 hours). A screened overflow pipe or outlet should be provided to convey runoff in excess of the SQDV to downstream drainage. An observation well constructed of perforated PVC pipe should be provided to allow the depth of water in the trench to be monitored. Typical elements of an INT system are shown in Figure 5-15. Infiltration vaults and leach fields are variations of the infiltration trench concept in which runoff is distributed to upper zone of the subsurface gravel bed by means of perforated pipes. Illustrations of infiltration vaults and leach fields are shown in Figure 5-16 and 5-17, respectively.

General Application

Infiltration trenches are typically used to serve areas less than 10 acres and are usually combined with upstream treatment control measures to reduce sediment load to the INT. For example, INTs are commonly used in combination with Turf Buffers to treat runoff from parking lots or other paved areas as illustrated in Figure 5-15. Infiltration trenches are easily incorporated into the landscape features of development sites.

Advantages/Disadvantages

General

In addition to removing pollutants effectively, infiltration trenches, like infiltration basins, also control runoff volume, which may serve to reduce downstream bank erosion in watercourses.

The primary disadvantage of an infiltration trench is the potential for clogging if excessive sediment is allowed to flow into the facility. The cost of restorative maintenance can be high if soil infiltration rates are significantly reduced due sediment deposition. Infiltration trenches cannot be put into operation until the upstream tributary area is stabilized.

Site Suitability

INTs cannot be placed on fill or unstable sites. Also, INTs should not be placed in high-risk areas such as service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk.

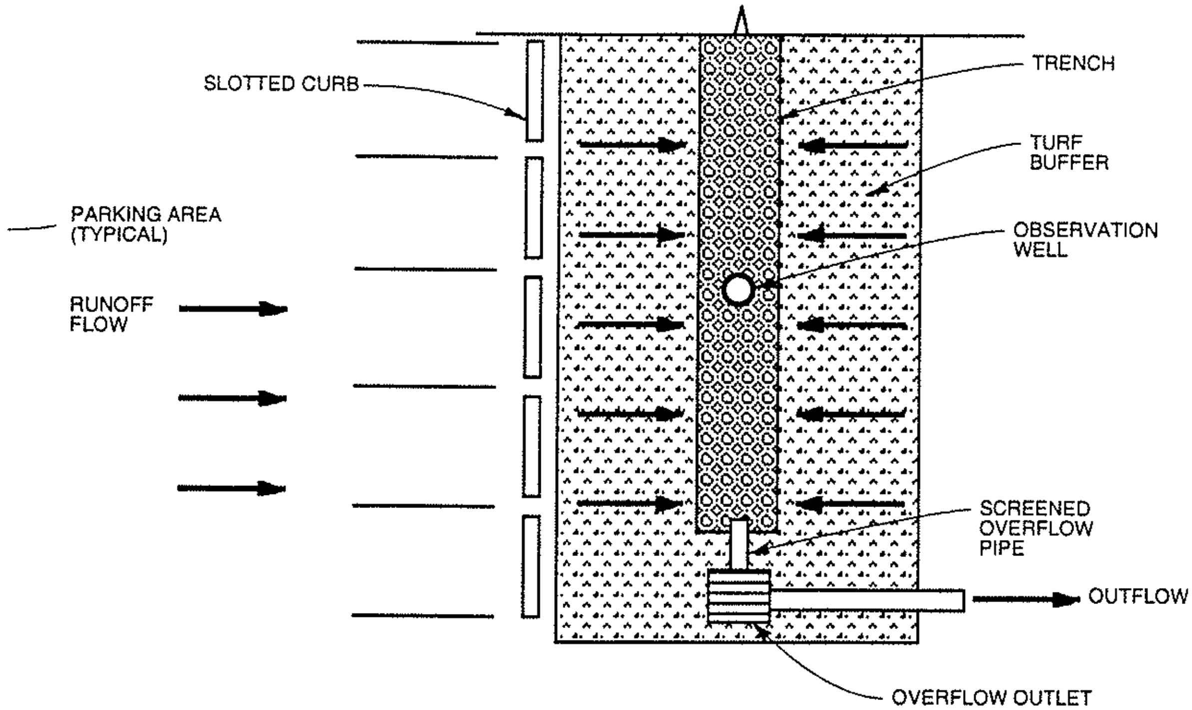
Before further considering the use of infiltration BMPs, preliminary site investigations should be performed to determine soil permeability and depth to unconfined groundwater table. For infiltration BMPs, to be feasible the permeability of the least-permeable horizon of the soil profile should be at least 0.5 inches per hour, based on extended infiltration rate measurements performed under saturated conditions, and the vertical separation between the bottom of the infiltration trench and the groundwater table (or bedrock) should be a minimum of 10 feet. Also, there is a risk of groundwater contamination with infiltration in very coarse soils, as coarse soils do not effectively remove dissolved pollutants. Use of course soils may require groundwater monitoring. Tributary area should have a low potential for erosion. Other suitability considerations include the soil makeup (Appendix E), site topography, and the location of other facilities. Prior to selecting infiltration BMPs for implementation, project proponents should consult with City staff to verify the appropriateness of this type of BMP for the site in question.

Infiltration facilities shall be sited at least 50 feet away from slopes steeper than 15 percent. Adequate spacing (100 feet or more) shall be provided between infiltration facilities and non-potable wells, tanks, drain fields and springs. For separation between infiltration BMPs and potable water supply wells, follow Department of Health Services requirements in the Guidelines for Location of Water Wells. INTs shall also be sited at least 20 feet down slope or 100 feet up slope from building foundations. A geotechnical expert shall be consulted when necessary to verify appropriate placement on site.

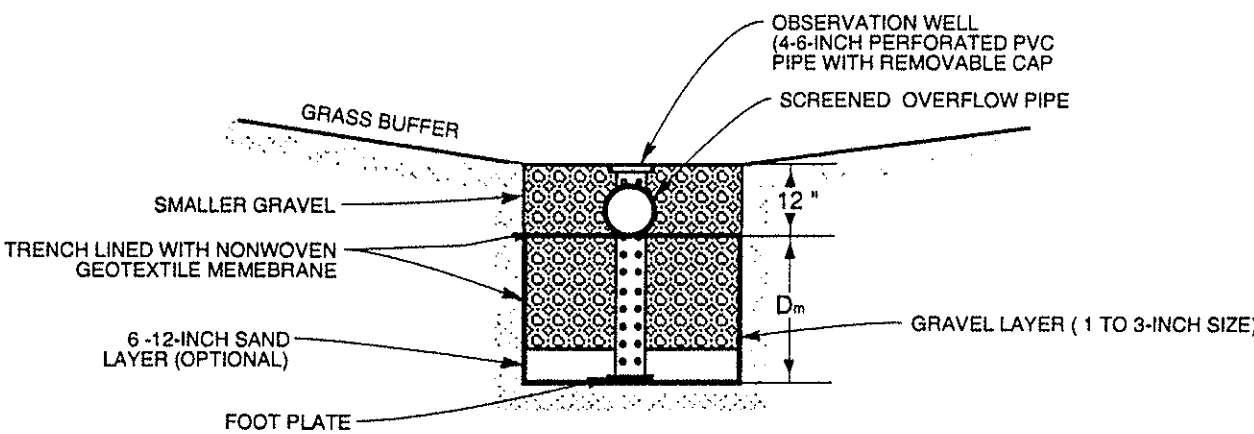
An important consideration for all infiltration facility configurations is that, during construction, great care must be taken not to reduce the infiltration capacity of the soil in the facility through compaction or by using the infiltration area as a sediment trap. Infiltration facilities shall be constructed late in the site development after soils (that might erode and clog the units) have been stabilized, or shall be protected until the site is stabilized.

Pollutant Removal

The amount of pollutant removed by INTs should be significant and should equal or exceed the removal rates provided by sand filters. In addition to settling, infiltration basins provide filtering, adsorption, and biological uptake of constituents in stormwater. Relative pollutant removal effectiveness is indicated in Table 5-1.



PLAN VIEW



SECTION VIEW

Figure 5-15. IINFILTRATION TRENCH

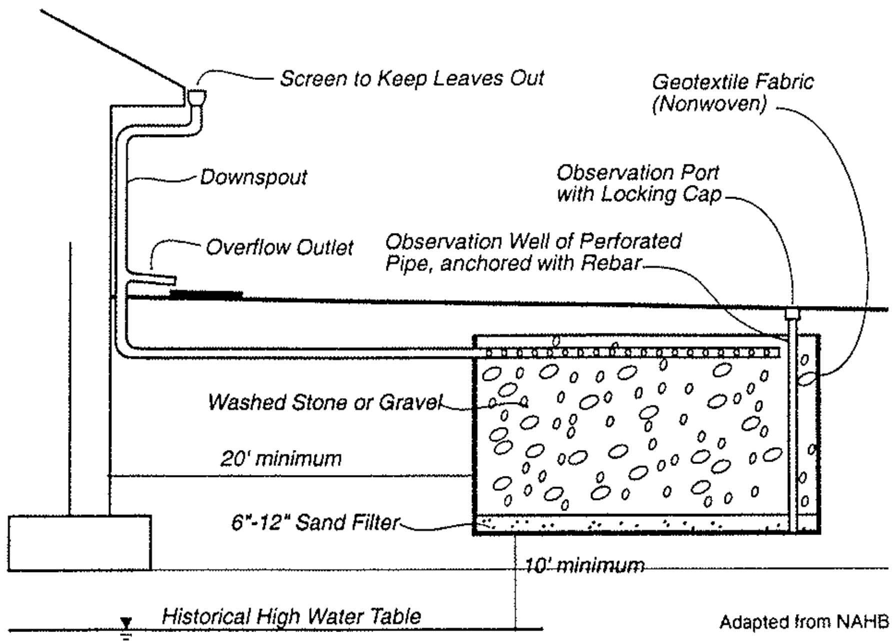


FIGURE 5-16. INFILTRATION VAULT

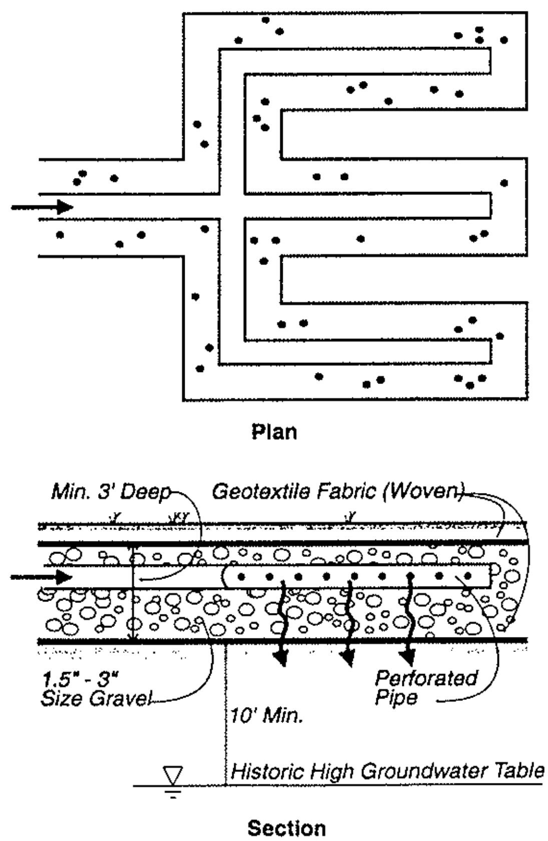


FIGURE 5-17. LEACH FIELD

Design Criteria and Procedure

Principal design criteria for INTs are listed in Table 5-13. These criteria also apply to vaults and leach fields

Table 5-13. Infiltration Trench Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	40
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 40-h drawdown
Trench bottom elevation	ft	10 feet above seasonally high groundwater table minimum.
Trench surcharge depth (D_m)	ft	$D_m = \leq 8.0$ ft
Gravel bed material	ft	Clean, washed aggregate 1 to 3 inches in diameter
Trench lining material	–	Geotextile fabric (see Table 5-7)
Setbacks	ft ft.	100 feet from wells, tanks, fields, springs 20 feet down slope or 100 feet up slope from foundations Do not locate under tree drip-lines

Design procedure and application of design criteria are outlined in the following steps:

1. Trench Storage Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 40-hr drawdown time.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u / 12) \times Area$$

   where

   Area = Watershed area tributary to INB (acres)

2. Trench Water Depth — Calculate the maximum allowable depth of water surcharge in the trench. Maximum depth should not exceed 8 feet.:

   $$D_m = tI/12s$$

   where I = site infiltration rate in (in/hr)

   s = safety factor

   t = minimum drawdown time = 40 hours

In the formula for maximum allowable depth, the safety factor accounts for the possibility of inaccuracy in the infiltration rate measurement. The less certain the infiltration rate the higher the safety factor shall be. Minimum safety factors shall be as follows:

- Without site-specific borings and percolation tests, use s=10
- With borings (but no percolation test), use s=6
- With percolation test (but no borings), use s=5
- With borings and percolation test, use s=3

3. Trench Surface Area — Calculate the minimum surface area of the trench bottom:

$$A_m = V/D_m$$

where:

A_m = minimum area required (ft^2)

V = SQDV (ft^3)

D_m = maximum allowable depth (ft)

4. Observation Well — Provide a vertical section of perforated PVC pipe, 4 to 6 inches in diameter, installed flush with top of trench on a foot plate and with a locking, removable cap.

5. Bypass — Provide for bypass or overflow of runoff volumes in excess of the SQDV by means of a screened overflow pipe connected to downstream storm drainage or grated overflow outlet.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-10: Infiltration Trench

Designer: ____________________

Company: ____________________

Date: ____________________

Project: ____________________

Location: ____________________

1. Determine Basin Storage Volume				
a. Percent Imperviousness of Tributary Area	I_a =	70	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	66	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	0.44	in.
d. Watershed Area Tributary to INT	Area =	0.5	acres
e. Calculate SQDV $SQDV = (V_u / 12) \times Area$	SQDV =	0.018	acre-ft
2. Maximum Allowable Depth ($D_m = tI/12s$)			
a. Site infiltration rate (I)	I =	3.0	in/hr
b. minimum drawdown time (t = 40 hours)	t =	40	hrs
c. safety factor (s)	s =	3	
d. $D_m = (t \times I)/(12 \times s)$	D_m =	3.33	ft.
3. Trench Bottom Surface Area			
$A_s = SQDV \times 43{,}560 / D_m$	A_s =	240	ft^2

Notes:

Maintenance Requirements

The following maintenance requirements apply to Infiltration Trenches.

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map
- Maintenance and cleaning activities and schedule
- Equipment and resource requirements necessary to operate and maintain facility
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

- Inspect a minimum of twice a year, before and after the rainy season, after large storms, or more frequently if needed.
- Clean when loss of infiltrative capacity is observed. If drawdown time is observed to have increased significantly over the design drawdown time, removal of sediment may be necessary. This is an expensive maintenance activity and the need for it can be minimized through prevention of upstream erosion.
- Mow, as appropriate for vegetative cover species.
- Monitor health of vegetation and replace as necessary.
- Control mosquitoes as necessary.
- Remove litter and debris from INT area as required.

Description

A media filter (MF) is a two-stage constructed treatment system, including a pretreatment settling basin and a filter bed containing sand or other filter media. Media filters are typically concrete vault structures with a solid wall or baffle wall separating the sediment chamber from the filter bed. The filter bed is supported by a gravel base course and is underdrained with perforated pipe.

This Section provides design information for three types of media filters, each named after the area of the country where they were developed:

- T11.1: Austin Sand Filter System – large units, above or below surface, used in large drainage areas (up to 50 acres).
- T-11.2: DC Underground Sand Filter – underground line system used for small drainage areas (up to 1.5 acres); receives concentrated flows.
- T-11.3: Delaware (Linear) Sand Filter - situated along perimeter of small drainage area (up to 5 acres); receives sheet or concentration flows; can be used in areas of high ground water.

Due to size constraints, media filters are designed to only treat the SQDV. Diversion structures are used to route storm volumes in excess of the SQDV around the filter (see Appendix B).

General Application

Media Filters are generally suited to offline, onsite configurations where there is no base flow and the sediment load is relatively low. Media Filters remove particulate and floatable materials and are appropriate for drainage areas of up to 100 acres. Media filters are well suited to California because they do not require vegetation and require less space than other treatment control measures with similar removal efficiencies when a partial treatment sedimentation basin is used. The effectiveness of the MF was proven in the City of Austin, where they are widely used today.

Selection of a unit configuration for a MF depends on the size of the drainage area and the facility location. Land uses for which MF are appropriate include residential, commercial, institutional, and industrial, except for extractive, chemical/petroleum, food and printing. A MF is not appropriate for agricultural sites or other areas with expanses of erosive soil upstream of the unit.

For large watersheds (10 to 100 acres) an Austin sand filter is recommended. For small catchments requiring underground facilities, a DC sand filter is recommended. Delaware sand filters are especially suitable for paved sites and industrial sites because they can be situated to accept sheet flow from adjacent pavement.

To operate effectively, the filter media must be protected against clogging caused by excessive sediment or highly turbid waters. Placing a settling basin upstream of the filter provides this protection. For this reason, filters should not be put into operation while construction activities are taking place in the tributary catchment.

Advantages/Disadvantages

General

Primary advantages of MFs include effective water quality enhancement through settling and filtering. They also require less space than other treatment practices and can be located underground. Media Filters may be used when there is a lack of water for irrigation or base flow and it is infeasible to use a wet detention basin, wetlands or biofilter, which could be advantageous for California.

The primary disadvantage of MFs is the potential for clogging. Although settling basins or other control measures effective for sediment removal, such as Grass Strip Filters or Grass Swale Filters, placed upstream of the filter will reduce this potential. Other disadvantages include significant head loss that may limit use on flat sites.

Site Suitability

Media Filter systems are designed to function by gravity. For systems located at sites without sufficient vertical relief to operate the filter by gravity, the design must be augmented to include a clear well and pumps to lift the stormwater from the settling basin to the filter. Costs for operation and maintenance increase significantly when pumping is employed.

Because an underdrain system is incorporated into its design, MFs are suited for most soil conditions; presence of sandy soils is not a requirement. This BMP requires a relatively flat surface area, consequently its use in steeply sloping terrain may be challenging. MFs should not be located close to construction sites or close to building foundations or areas where expansive soils are a concern.

Pollutant Removal

Media Filters effectively remove sediment and pollutants associated with sediment. Relative pollutant removal effectiveness of MFs is presented in Table 5-1.

Design Criteria and Procedure

T-11.1: Austin Sand Filter

There are two possible filter configurations used by Austin that may be considered.

- Full Sedimentation

  In this configuration, sedimentation occurs in a settling basin designed to hold the entire SQDV and release it to the filter over an extended draw-down time (40 hours). (See Figure 5-18 for typical configuration).

- Partial Sedimentation

  In this configuration, the settling basin holds a minimum of 20% of the water quality volume and does not incorporate an extended draw-down period. This basin removes the heavier sediment and large trash only and requires more intensive maintenance than the full sedimentation system. A larger filter surface area will be required to compensate for the more rapid clogging of the filter.

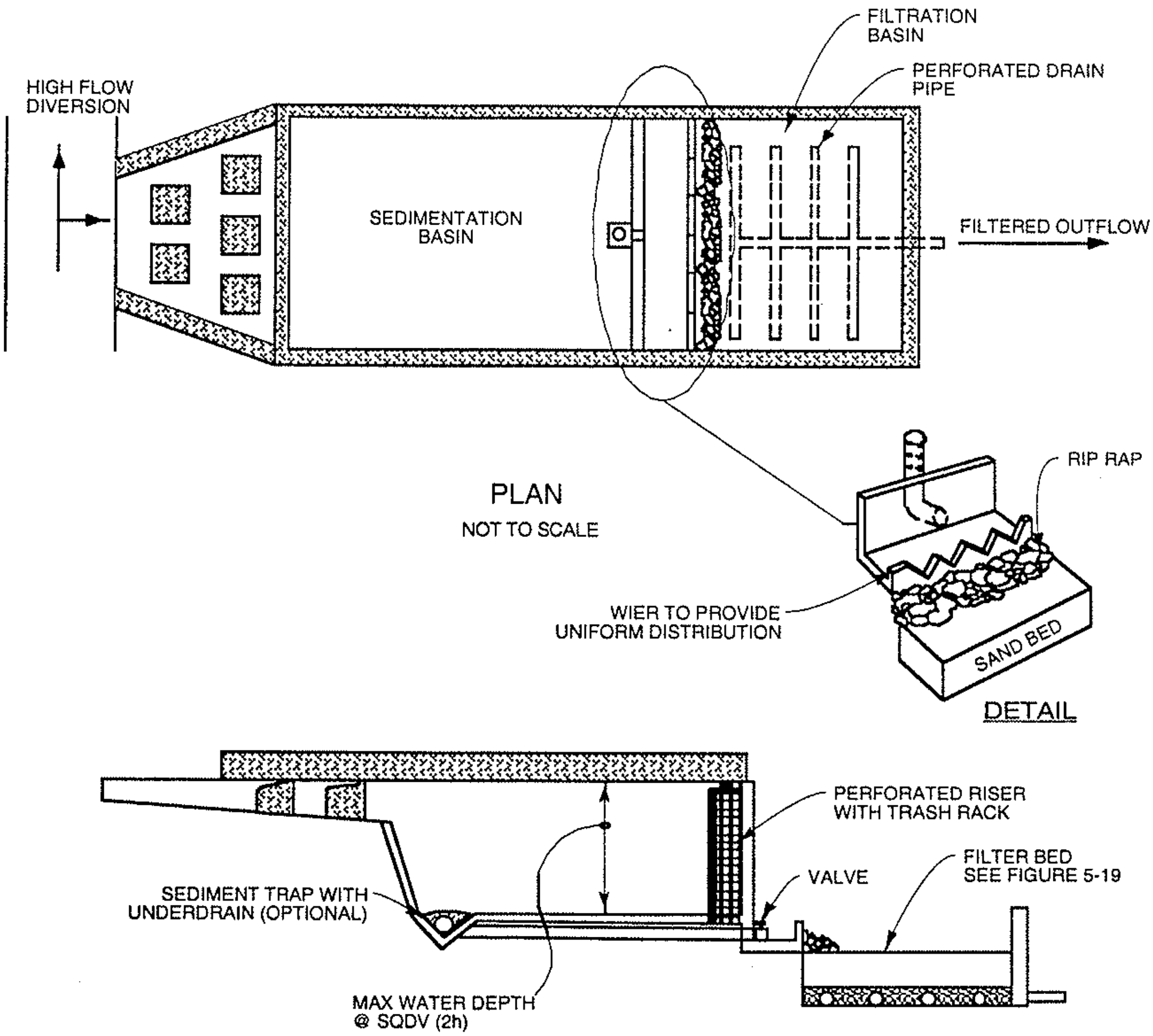
Design criteria for partial sedimentation are not included in this Manual due to the increased maintenance required for this type of control measure. This configuration will only be considered when it is adequately shown that space limitations will not allow full sedimentation, and other control measures recommended in this Manual are not viable alternatives.

Settling Basin Design

Settling basin design criteria for Austin Sand Filters with full sedimentation are summarized in Table 5-14.

Table 5-14. Austin Sand Filter Sedimentation Basin Design Criteria

Design Parameter	Unit	Design Criteria
Maximum drainage area	acres	100
Minimum basin depth	ft	3.0
Minimum surface area (A_s)	ft^2	SQDV ÷ 10 ft
Length to width ratio, L:W	–	2:1 or greater
Minimum draw-down time	hrs	40
Freeboard	ft	1.0 ft above maximum water surface elevation
Minimum basin volume	ft^3	SQDV + freeboard volume
Maximum inlet velocity	fps	3.0
Minimum particle sized removed	micron	20 (specific gravity = 2.65)



Source: Austin, Texas

NOTE: SEDIMENTATION POND MAY BE USED IN LIEU OF CONCRETE BASIN. FILTRATION BASIN MAY BE BUILT DIRECTLY INTO GROUND OVER AN IMPERVIOUS GEOMEMBRANE IF SOIL CONDITIONS ALLOW.

ELEVATION

NOT TO SCALE

FIGURE 5-18. AUSTIN SAND FILTER

Design procedure and application of design criteria for Austin Filter Full Sedimentation Basin are outlined in the following steps:

1. Basin Storage Volume

Provide a storage volume equal to 100 percent of the SQDV, based on a 40-hr drawdown time, above the lowest outlet (i.e. perforation or orifice) in the basin.

a. Determine the percent imperviousness of the tributary area (I_a).

b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from step 1.b.

d. Calculate the SQDV in acre-ft as follows:

$$SQDV = (V_u/12) \times Area$$

where

Area = Watershed area tributary to Media Filter (acres)

2. Inlet/Outlet Design

Basin inlet and outlet points should be provided with an energy dissipation structure and/or erosion protection. Energy dissipation devices may be necessary in order to reduce inlet velocities that exceed three (3) feet per second.

3. Basin Shape

Whenever possible, shape the basin with a gradual expansion from the inlet and a gradual contraction toward the outlet. The sedimentation basin design should maximize the distance from where the heavier sediment is deposited near the inlet to where the outlet structure is located. This will improve basin performance and reduce maintenance requirements.

Short circuiting (i.e., flow reaching the outlet structure before it passes through the sedimentation basin volume) flow should be avoided. Dead storage areas (areas within the basin which are by-passed by the flow regime and are, therefore, ineffective in the settling process) should be minimized. The length to width ratio should be a minimum of 2:1. Internal baffling may be necessary to achieve this ratio and could be used to mitigate short-circuiting and/or dead storage problems.

4. Trash Rack/Gravel Pack

A trash rack or gravel pack around perforated risers shall be provided to protect outlet orifices from clogging. Trash racks are better suited to use of perforated vertical plates for outlet control and allow easier access to outlet orifices for purposes of inspection and cleaning. Trash rack shall be sized to prevent clogging of the primary water quality outlet without restricting with the hydraulic capacity of the outlet controls orifices.

5. Sediment Trap (optional)	A sediment trap is a storage area that captures sediment and removes it from the basin flow regime. In so doing the sediment trap inhibits resuspension of solids during subsequent runoff events, improving long-term removal efficiency. The trap also maintains adequate volume to hold the water quality volume that would otherwise be partially lost due to sediment storage. Sediment traps may reduce maintenance requirements by reducing the frequency of sediment removal. It is recommended that the sediment trap volume be equal to 10 percent of the sedimentation basin volume. All water collected in the sediment trap shall drain out within 40 hours. The invert of the drain pipe should be above the surface of the sand bed filtration basin. The minimum grading of the piping to the filtration basin should be 1/4 inch per foot (two percent slope). Access for cleaning the sediment trap drain system is necessary.
6. Settling Basin Liner	If the sedimentation basin is an earthen structure and an impermeable liner is required to protect ground water quality, the liner shall meet the specifications for clay liner given in Table 5-20. The clay liner should have a minimum thickness of 12 inches. If an impermeable liner is not required then a geotextile fabric liner shall be installed that meets the specifications listed in Table 5-17 unless the basin has been excavated to bedrock. If a geotextile liner is used it should have a minimum thickness of 30 mils and be ultraviolet resistant.

Filter Basin Design

Filter basin design criteria for Austin Sand Filters are summarized in Table 5-15.

Table 5-15. Austin Sand Filter Basin Design Criteria

Design Parameter	Unit	Design Criteria
Minimum gravel depth over sand filter	inches	2.0
Minimum water depth over filter, h	ft	3.0
Minimum sand depth, d_f	inches	18.0
Minimum filtration rate of filter, k	ft/d	3.5
Slope of sand filter surface	%	0
Minimum gravel cover over underdrain	inches	2
Sand size, diameter	inches	0.02 – 0.04
Under drain gravel size, diameter	inches	0.5 – 2.0
Minimum inside diameter underdrain	inches	6.0
Underdrain pipe type	–	PVC schedule 40 (or thicker)
Minimum slope of underdrain	%	1.0
Minimum underdrain peroration, diameter	inches	0.375
Minimum perorations per row	–	6
Minimum space between perforation rows	inches	6
Maximum drawdown time, t_f	hr	40.0
Minimum gravel bed depth, d_g	inches	16

Design procedure and application of design criteria for Austin Sand Filter are outlined in the following steps:

1. Maximum Water Depth — Determine maximum allowable depth of water (2h) in the sedimentation basin considering elevation differences between inlet and outlet invert elevations of sedimentation basin and filter surface elevation. (This height will establish weir height or elevation of inlet invert for bypass pipes and orifices.)

2. Filter Surface Area — Surface area is the primary design parameter, and is a function of sand permeability, bed depth, hydraulic head and sediment loading. The required filter surface area (A_f) can be calculated using the following equation and design criteria provided in Table 5-15

$$A_{fm} = \frac{(SQDV)(d_f)}{k(h+d_f)t_f}$$

Where: WQV = SQDV, cf

A_{fm} = filter surface area, ft^2

d_f = sand bed depth, ft

k = coefficient of permeability for sand filter (ft./hr.)

h = one-half of maximum allowable water depth (2h) over filter, ft.

t_f =time required for runoff volume to pass through filter, hrs.

2. Filter Basin Volume — The storage capacity of the filtration basin, above the surface of the filter media, should be greater than or equal to 20 percent of the SQDV. This capacity is necessary in order to account for backwater effects resulting from partially clogged filter media.

3. Inlet Structure — The inlet structure should spread the flow uniformly across the surface of the filter media. Flow spreaders, weirs or multiple orifice openings are recommended.

4. Filter Bed — The sand bed may be a choice of one of the two configurations given below. Note: Sand bed depths are final, consolidated depths. Consolidated effects must be taken into account.

a) Sand Bed with Gravel Layer (Figure 5-19A)

The sand layer is a minimum depth of 18 inches consisting of 0.02-0.04 inch diameter sand. Under the sand is a layer of 0.5 to 2.0-inch diameter gravel that provides a minimum of two inches of cover over the top of the underdrain lateral pipes. No gravel is required under the lateral pipes. A layer of geotextile fabric meeting the specifications in Table 5-16 must separate the sand and gravel and must be used to be wrap around the lateral pipes.

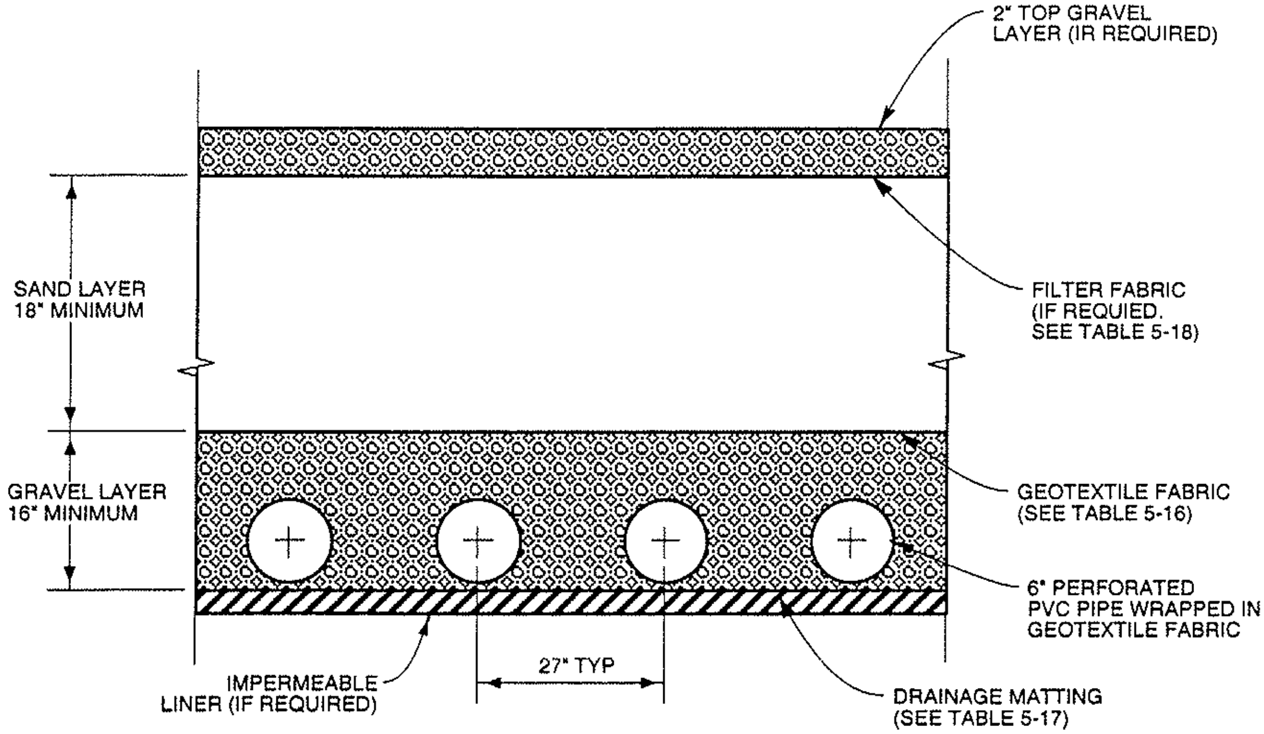
Drainage matting meeting the specifications in table 5-17 should be placed under the laterals to provide for adequate vertical and horizontal hydraulic conductivity to the laterals.

In areas with high sediment load (total suspended solids concentration ≥200 mg/L), the two-inch layer of stone on top of the sand filter should be underlain with Enkadrain 9120 filter fabric or equivalent meeting the specifications in Table 5-18.

b) Sand Bed - Trench Design (Figure 5-19B)

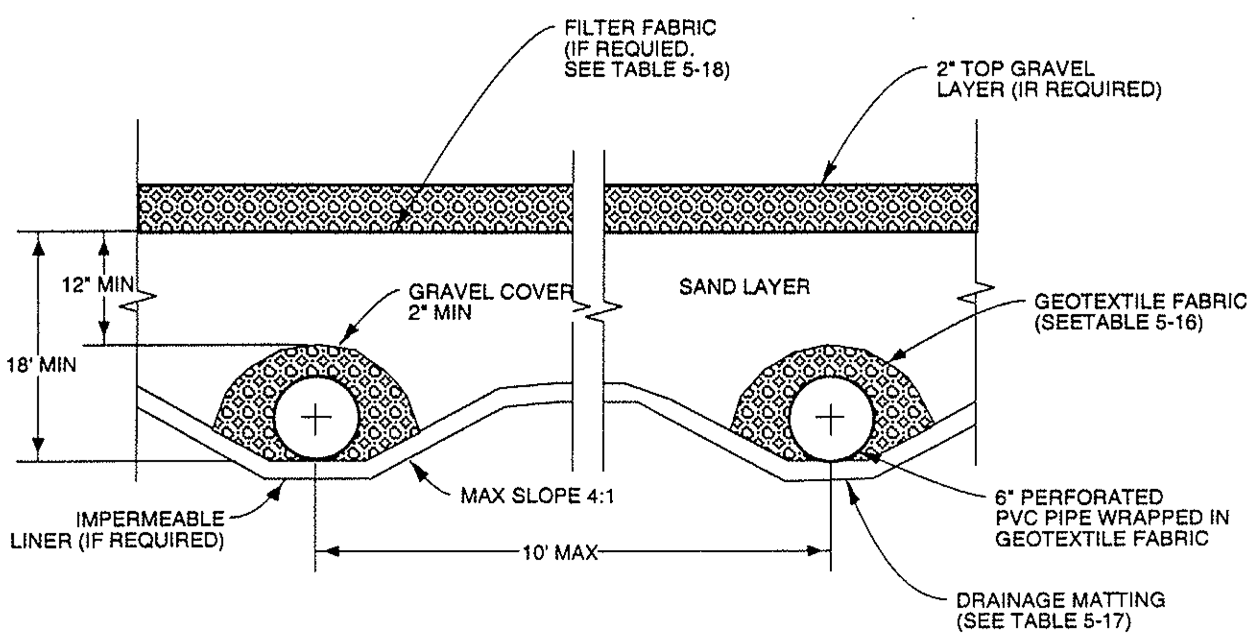
The top layer shall be 12-18 inches of 0.02-0.04 inch diameter sand. Laterals shall be placed in trenches with a covering of 0.5 to 2.0-inch gravel and geotextile fabric (see Table 5-16). The laterals shall be underlain by a layer of drainage matting (see Table 5-17).

In areas with high sediment load (total suspended solids concentration ≥200 mg/L), the two-inch layer of stone on top of the sand filter should be underlain with Enkadrain 9120 filter fabric or equivalent meeting the specifications in Table 5-18.



NOT TO SCALE

FIGURE 5-19A. FILTER BED WITH GRAVEL UNDERDRAIN



NOT TO SCALE

FIGURE 5-19B. FILTER BED WITH TRENCH UNDERDRAIN

Table 5-16. Geotextile Fabric Specifications

Property	Test Method	Unit	Specification
Material			Non-woven geotextile fabric
Unit Weight		oz./sq. yd.	8 (min.)
Filtration Rate		in/sec	0.08 (min.)
Puncture Strength	ASTM D-751 (Modified)	lbs.	125 (min.)
Mullen Burst Strength	ASTM D-751	psi	400 (min.)
Tensile Strength	ASTM-D-1682	lbs.	300 (min.)
Equiv. Opening Size	US Standard Sieve	No.	80 (min.)

Table 5-17. Drainage Matting Specifications

Property	Test Method	Unit	Specification
Material			Non-woven geotextile fabric
Unit Weight		oz./sq. yd.	20
Flow Rate (fabric)		gpm/ft^2	180 (min.)
Permeability	ASTM D-2434	cm/sec.	12.4×10^{-2}
Grab strength (fabric)	ASTM D-1682	lbs.	Dry Lg. 90 Dry Wd:70 Wet Lg.95 Wet Wd: 70
Puncture strength (fabric)	COE CW-02215	lbs	42 (min.)
Mullen burst strength	ASTM D-1117	psi	140 (min.)
Equiv. opening size	US Standard Sieve	No.	100 (70-120)
Flow rate (drainage core)	Drexel Univ. Test Method	gpm/ft. width	14

Source: City of Austin

Table 5-18. Filter Fabric Specifications

Property	Test Method	Unit	Specification
Material			Non-woven geotextile fabric
Unit Weight		oz./sq. yd.	4.3 (minimum)
Flow rate		gpm/ft^2	120 (minimum
Puncture Strength	ASTM D-751 (Modified)	lbs.	60 (minimum
Thickness		in.	0.8 (minimum

5. Underdrain Piping

The underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes. The piping should be reinforced to withstand the weight of the overburden. Internal diameters of lateral branch pipes should be six (6) inches or greater and perforations should be 3/8 inch. Each row of perforations should contain at least six (6) holes and the maximum spacing between rows of perforations should not exceed six (6) inches. All piping is to be schedule 40 polyvinyl chloride or greater strength. The minimum grade of piping shall be 1/8 inch per foot (one (1) percent slope)(slopes down to 0.5 percent are acceptable with prior approval). Access for cleaning all underdrain piping is needed.

Note: No draw-down time is to be associated with sand filtration basins, only with sedimentation basins. Thus, it is not necessary to have a specifically designed orifice for the filtration outlet structure.

6. Filter Basin Liner

If an impermeable liner is required to protect ground water quality it shall meet the specifications for clay liner given in Table 5-19. The clay liner should have a minimum thickness of 12 inches. If an impermeable liner is not required then a geotextile fabric liner shall be installed that meets the specifications listed in Table 5-16 unless the basin has been excavated to bedrock. If a geotextile liner is used it should have a minimum thickness of 30 mils and be ultraviolet resistant.

Table 5-19. Clay Liner Specifications

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	cm./sec.	$1x10^{-6}$
Plasticity Index of Clay	ASTM D-423 & D-424	%	Not less than 15
Liquid Limit of Clay	ASTM D-2216	%	Not less than 30
Clay Particles Passing	ASTM D-422	%	Not less than 30
Clay Compaction	ASTM D-2216	%	95% of Standard Proctor Density

Source: City of Austin

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-11.1: Austin Sand Filter

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	100	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	100	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	0.60	in.
d. Watershed Area Tributary to DBSF	Area =	2.46	acres
e. Calculate SQDV SQDV = (V_u / 12) × Area	SQDV =	0.123	acre-ft
2. Maximum Water Depth			
a. Storm drainage system invert elevation at proposed connection to storm drain	Inlet Elevation	90	ft
b. Minimum control measure outlet invert elevation of sand filter at minimum grade:	Outlet Elevation	90.75 @ 1%	ft
c, Estimate filter depth or use minimum depth of filter media and determine the difference in elevation between inverts of filter inlet and outlet:	Filter Depth	97.5	ft
d. Site plan surface elevation at control measure location	Surface Elevation	103.0	ft
e. Determine inlet invert elevation into sedimentation basin	Inlet Elevation (Sed. Basin)	100.0	ft
f. Determine maximum allowable depth of water (2h) in the sedimentation basin considering elevation differences between inlet and outlet invert elevations of sedimentation basin and filterand surface elevation. (This height will establish weir height or elevation of inlet invert for bypass pipes and orifices.)	Maximum Allowable Depth	3.0	ft

Design Procedure Form for T-11.1: Austin Sand Filter (Page 2 of 2)

Project:______________________________

3. Filter Surface Area			
a. Sand Bed Depth	d_f =	1.5	ft
b. Coefficient of permeability for sand filter	k =	0.1458	ft. / hr.
c. One half of maximum allowable depth over filter. (h)	h =	1.5	ft
d. Time required for runoff to pass through filter.	t_f =	40	hrs.
e. Filter Surface Area (minimum) $A_{fm} = \frac{(SQDV)(d_f)}{k(h+d_f)t_f}$	A_{fm} =	459	ft^2
4. Filter Basin Volume			
Filter Basin Volume = 0.2 × SQDV	FBV =	1,072	ft^3

Notes:

T-11.2: DC Filter

The District of Columbia (D.C.) Environmental Regulation Administration developed an underground stormwater sand filter (referred to as the D.C. Sand Filter) contained in a structural shell with three chambers (see Figure 5-20). The shell may consist of precast or cast-in-place concrete.

The plunge pool in the first chamber and the throat of the second chamber, which are hydraulically connected by an underwater rectangular opening, absorbs energy and provides pretreatment, trapping grit and floating organic material such as oil, grease, and tree leaves. The second chamber contains a typical sand filter with a subsurface drainage system consisting of perforated PVC pipe in a stone bed. The third chamber, or clearwell, collects the flow from the underdrain pipes, and overflow pipes when installed, and directs the waters to the storm drainage system. A hooded large storm bypass pipe directly connecting the first chamber with the clearwell is illustrated in Figure 5-21. When storm flows are diverted upstream of the sediment chamber, an in-system overflow or bypass is neither necessary nor desired.

A major advantage of the D.C. sand filter is that it does not take up any space on the surface. It can be placed under on-site roadways (e.g., not public rights of way), parking lots, or sidewalks, and under planting spaces adjacent to buildings. The system works best for watersheds of approximately one acre of impervious surface. For larger watersheds, two or more DC sand filters will be required.

The load-carrying capacity of the filter structure must be considered when it is located under parking lots, driveways, roadways, and certain sidewalks (such as those adjacent to State highways). Traffic intensity may also be a factor. The structure must be designed by a licensed structural engineer. The effects of buoyancy must be considered in the design of an underground vault in areas with high ground water.

For cost, reliability, and maintenance considerations, it is preferable that the filter work by gravity flow. This requires sufficient vertical clearance between the invert of the prospective inflow storm piping and the invert of the storm drain which will receive the outflow.

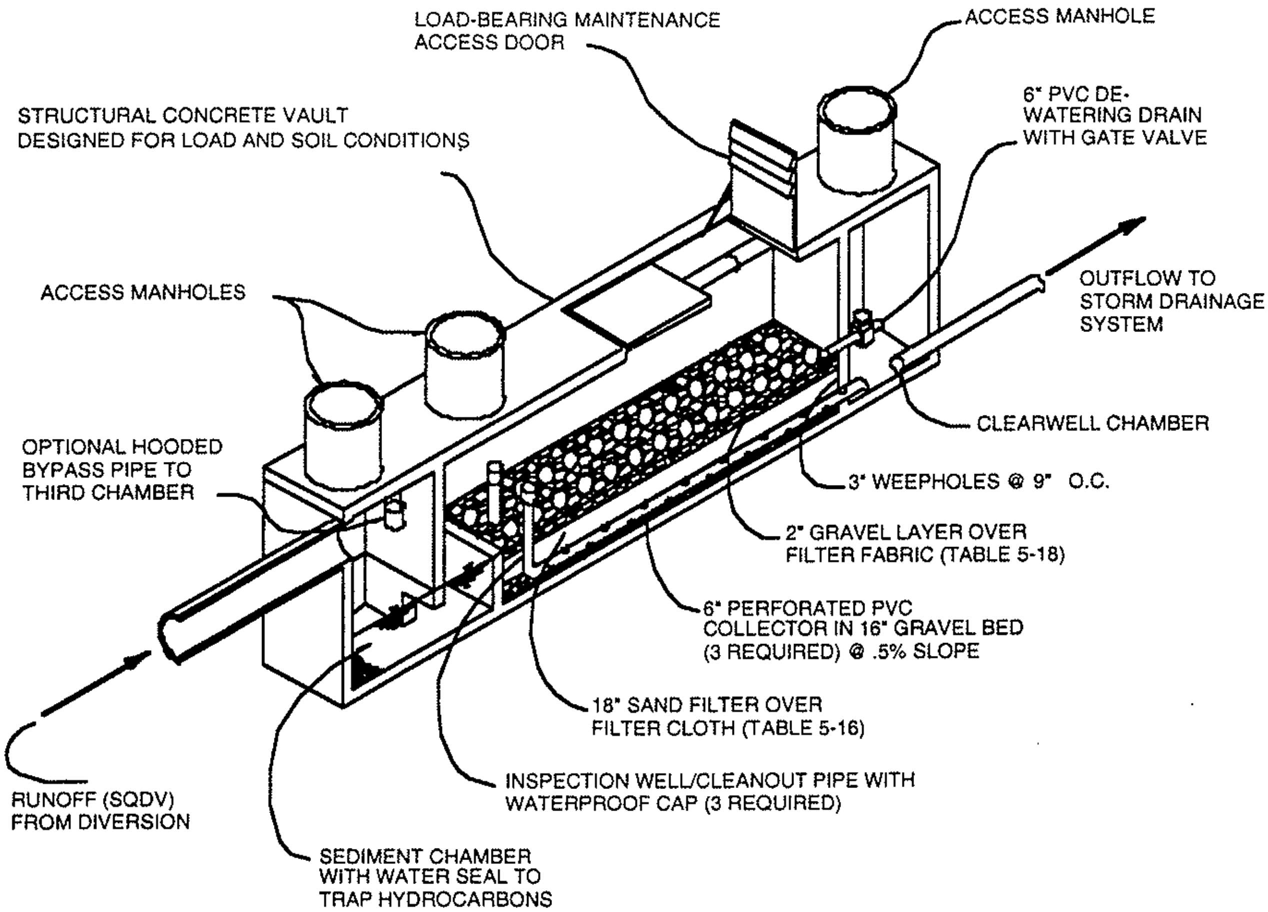
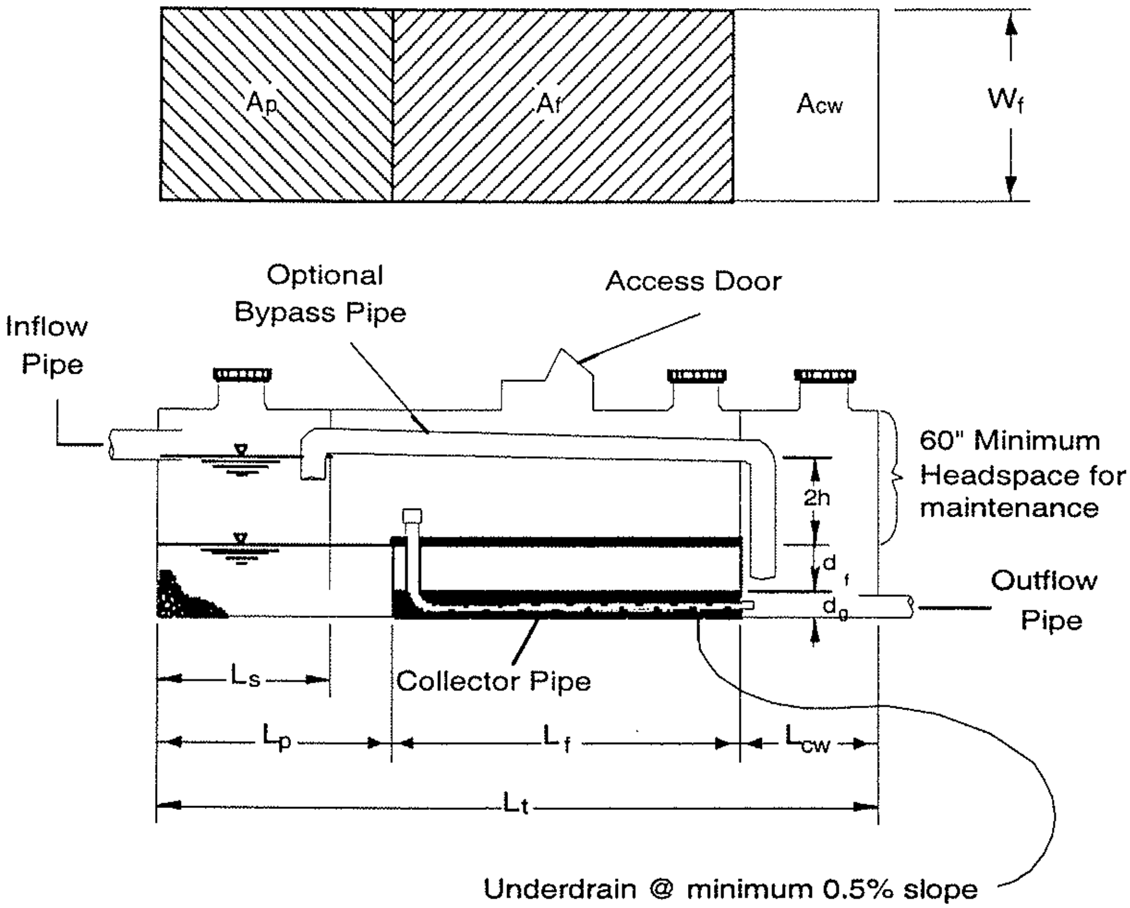


FIGURE 5-20. DC SAND FILTER



Where:
- A_p = Area of sediment chamber
- A_f = Area of sand filter
- A_{cw} = Area of clearwell
- W_f = Width of filter
- L_s = Minimum length of sediment chamber
- L_p = Final length of permanent pool
- L_f = Filter length
- L_{cw} = Length of clearwell
- L_t = Total length, sum of $L_p + L_f + L_{cw}$
- 2h = Maximum achievable ponding depth over filter
- d_f = sand bed depth
- d_g = gravel depth

Figure 5-21. DIMENSIONAL RELATIONSHIPS FOR DC SAND FILTER

Design Criteria

Principal design criteria for DC Sand Filters are summarized in Table 5-20.

Table 5-20. DC Sand Filter Design Criteria

Design Parameter	Unit	Criteria Value
Maximum drainage area	acres	1.5
Maximum draw down time in filter, t_f	hrs	40
Minimum gravel depth over filter media	in.	2.0
Minimum sand filter depth, d_f	in.	18
Minimum gravel depth below filter, d_g	in.	16
Minimum cover of gravel over underdrain pipe	in.	2
Filter coefficient, k	ft/day	2
Minimum volume of SQDV to be contained in sediment chamber	%	20
Minimum slope of underdrain	%	1
Maximum diameter of upper level gravel cover	in.	1
Minimum length of clearwell, L_{cw}	ft.	3.0
Filter sand sizing	—	ASTM C 33 concrete sand
Minimum size diameter gravel in underdrain	in.	0.5 to 2
Minimum size underdrain pipe	—	6" Sch 40 reinforced PVC pipe
Minimum size diameter perforation in drainage pipe	in.	3/8
Minimum number of perforation holes per underdrain pipe	—	6
Maximum spacing between perforation holes	in.	6
Maximum spacing of underdrain pipes	in.	27 (center to center)

Design Procedure

Design procedure and application of design criteria for DC Sand Filter are outlined in the following steps (see Figure 5-21 for dimensional relationships):

1. Maximum Water Depth — Determine maximum allowable depth of water (2h) in the filter basin considering elevation differences between inlet and outlet invert elevations. (This height will establish weir height or elevation of inlet invert for bypass pipes and orifices).

2. Sand Filter Area — Determine the minimum area of the DC Filter using the Austin Filter Formula for partial sedimentation treatment.

$$A_{fm} = \frac{(SQDV)(d_f)}{(k)(h+d_f)(t_f)}$$

where:

A_{fm} = filter surface area, ft^2

d_f = sand bed depth, ft

k = filter coefficient @ 0.0833 ft./hr.

h = one-half of maximum allowable water depth (2h), ft.

t_f = 40 h draw-down time

3. Filter Width / Length — Considering site constraints, select a Filter Width (W_f). Then compute the Filter Length (L_f) using the minimum area required (A_{fm}).

$L_f = A_{fm}/W_f$

Round the length and determine adjusted area, Af.

$A_f = W_f \times L_f$

(After Note: From this point, formulas assume rectangular cross section of filter shell.)

4. Storage Volume
   a. above filter (V_{tf}) — $V_{tf} = A_f \times 2h$
   b. in filter voids (Vv) — $V_v = A_f \times (d_f + d_g) \times (0.4)$ {assume 40% voids}

5. Flow Through Filter During Filling (V_Q) — $V_Q = k \times A_f \times (d_f + d_g) \times t_f / d_f$

   Use: k = 2 ft/day = 0.0833 ft/hr.

   t_f = 1 hr. to fill voids

6. Net Volume to be Stored in Sediment Chamber Awaiting Filtration (Vst) — $V_{st} = SQDV - V_{tf} - V_v - V_Q$

7. Minimum Length of Permanent Pool (L_{pm}) — $L_{pm} = V_{st} /(2h)(W_f)$ {See Figure 5-21 for dimensional relationships}

8. Minimum Length of Sediment Chamber (L_s)
   a. If $V_{st} > (0.2SQDV)$ — use: $L_s = V_{st} /(2h)(W_f)$
   b. If $V_{st} < (0.2SQDV)$ — use: $L_s = 0.2SQDV /(2h)(W_f)$

   Note: It may be economical to adjust final dimensions to correspond with standard precast structures or to round off to simplify measurements during construction.

9. Final Length of Permanent Pool (L_p)
   a. If L_{pm}, $< (L_s + 2)$ — use: $L_p = L_{pm}$
   b. If L_{pm}, $> (L_s + 2)$ — use: $L_p = (L_s + 2)$

10. Length of Clearwell (L_{cw})	Set the length of the clearwell (L_{cw}) for adequate maintenance and/or access for monitoring flow rate and chemical composition of effluent (minimum 3 ft.).
11. Filter Bed	
a. Top Gravel Layer	The washed gravel layer at the top of the filter should be two inches thick composed of stone 0.5-inch to 2.0-inch diameter in size. In areas with high sediment load (TSS concentration >200 mg/L), the two-inch layer of stone on top of the sand filter should be underlain with filter fabric meeting the specifications in Table 5-19.
b. Sand Layer	The sand layer should be a minimum depth of 18 inches consisting of ASTM C33 concrete sand. A layer of geotextile fabric meeting the specifications in Table 5-16 must separate the sand and gravel layer below.
c. Gravel Layer	The gravel layer surrounding the collector pipes should be at least 16 inches thick and be composed of 0.5 to 2-inch diameter stone and provide at least two inches of cover over the tops of the drainage pipes.
12. Underdrain Piping	The underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes. The piping should be reinforced to withstand the weight of the overburden. Internal diameters of lateral branch pipes should be six (6) inches or greater and perforations should be 3/8 inch. Each row of perforations should contain at least six (6) holes and the maximum spacing between rows of perforations should not exceed six (6) inches. All piping is to be schedule 40 polyvinyl chloride or greater strength. The minimum grade of piping shall be 1/8 inch per foot (one (1) percent slope)(Note: slopes down to 0.5 percent are acceptable with prior approval). Access for cleaning all underdrain piping is needed.
13. Weep Holes	In addition to the underdrain pipes, weepholes should be installed between the filter chamber and the clearwell to provide relief in case of pipe clogging. The weepholes should be three (3) inches in diameter. Minimum spacing should be nine (9) inches center to center. The openings on the filter side of the dividing wall should be covered to the width of the trench with 12 inch high plastic hardware cloth of 1/4 inch mesh or galvanized steel wire, minimum wire diameter 0.03-inch, number 4 mesh hardware cloth anchored firmly to the dividing wall structure and folded a minimum of six (6) inches back under the bottom stone.
14. Dewatering Drain	A six (6) inch diameter DIP or PVC dewatering drain with a gate valve is to be installed at the top of the stone/sand filter bed through the partition separating the filtration chamber from the clearwell chamber.

15. Bypass Pipe	Where a bypass pipe is needed, it shall be DIP or PVC with supports every 18 inches minimum.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-11.2: DC Sand Filter

Designer:______________________

Company:______________________

Date:______________________

Project:______________________

Location:______________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	100	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	100	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	0.60	in.
d. Watershed Area Tributary to DC Filter	Area =	1.0	acres
e. Calculate SQDV SQDV = (V_u / 12) × Area	SQDV =	0.050	acre-ft
2. Minimum Filter Area $$A_{fm} = \frac{(SQDV)(d_f)}{k(h+d_f)t_f}$$			
a. SQDV	SQDV =	2,178	ft^3
b. Sand bed depth (d_f)	d_f =	1.5	ft
c. Filter Coefficient (k)	k =	0.0833	ft. / hr.
d. Draw-down time (t_f= 40 hour)	t =	40	hr
e. one half maximum allowable water depth over filter (h)	h =	1.67	ft
f. Minimum filter area (A_{fm})	A_{fm} =	309.3	ft^2
3. Select Filter Width, Compute Filter Length			
a. Select a Filter Width (W_f)	W_f =	12.0	ft.
b. Compute filter length $L_f = A_{fm}/W_f$	L_f =	25.78	ft.
c. Determine adjusted filter area (Round L_f to closest whole number) A_f = $W_f \times L_f$	A_f =	312	ft^2
(From this point, formulas assume rectangular cross section of filter shell.)			

Design Procedure Form for T-11.2: DC Filter (Page 2 of 2)

Project:____________________

4. Compute the Storage Volume of Top of the Filter (V_{tf}) $V_{tf} = A_f \times 2h$	V_{tf} = 1,042 ft^3
5. Compute the Storage in the Filter Voids (Vv) (Assume 40% voids in the filter media) $V_v = A_f \times (d_f + d_g) \times 0.40$	V_v = 353.6 ft^3
6. Flow Through Filter During Filling (V_Q) (Assume 1-hour to fill) $V_Q = k \times A_f \times (d_f + h) \times t_{ff} / d_f$ Use: k = 2 ft/day = 0.0833 ft/hr. t_{ff} = 1 hr. to fill voids	V_Q = 54.5 ft^3
7. Compute Net Volume to be Stored in Permanent Pool Awaiting Filtration (Vst) $V_{st} = SQDV - V_{tf} - V_v - V_Q$	V_{st} = 727.9 ft^3
8. Compute Minimum Length of Permanent Pool (Lpm) $L_{pm} = V_{st} /(2h \times W_f)$	L_{pm} = 18.16 ft
9. Compute Minimum Length of Sediment Chamber (L_s) (to contain 20% of SQDV) If $V_{st} < (0.2SQDV)$, use: $L_s = 0.2 \times SQDV/(2h \times W_f)$ If $V_{st} > (0.2SQDV)$, use: $L_s = V_{st} /(2h \times W_f)$	L_s = 18.16 ft
10. Set Final Length of Permanent Pool (L_p) If $L_{pm} \geq (L_s + 2\text{ ft})$, use: $L_p = L_{pm}$ If $L_{pm} < (L_s + 2\text{ ft})$, use: $L_p = (L_s + 2\text{ ft})$	L_p = 20.16 ft
11. Set Final Length of Clear Well (L_{cw}) L_{cw} = 3 ft minimum	L_{cw} = 4.0 ft

Notes: ____________________

T-11.3: Delaware (Linear) Sand Filter

A schematic drawing of the modified Delaware Sand Filter (DSF) is shown in Figure 5-22. The system consists of two parallel concrete trenches divided by a close-spaced wall. The first trench serves as the sedimentation chamber. When accepting sheet flow, it is fitted with a grated cover. Concentrated stormwater may also be conveyed to the chamber in enclosed storm drain pipes. The second chamber, which contains the sand filter, is always fitted with a solid cover.

Storm flows enter the sedimentation chamber through the grates, causing the sedimentation pool to rise and overflow into the filter chamber through the weir notches at the top of the dividing wall. This provides assurance that the water to be treated arrives at the filter as sheet flow. This is essential to prevent scouring of the sand. The permanent pool in the sedimentation chamber is dead storage, which inhibits resuspension of particles that were deposited in earlier storms and prevents the heavier sediments from being washed into the filter chamber. Floatable materials and hydrocarbon films, however, may reach the filter media through the surface outflow.

The second trench contains the top 2 inches stone filter layer, the middle 18 inches of sand, and the bottom 16-inch stone layer. Six-inch diameter PVC underdrains are provided in this stone layer to carry the filtered water to the clearwell and ultimately to the storm drain. For smaller units, less than 20 feet in length, a gravel underdrain bed with the weep holes may be used in place of PVC pipe.

For systems where storm flows in excess of the SQDV are not diverted upstream of the filter, an overflow weir into the clearwell from the sedimentation chamber will convey the runoff greater than the SQDV directly to the storm sewer. The overflow weir shall be sized to pass volume of water that exceeds the SQDV. Where retention of hydrocarbons is a concern, the weir should be fitted with a metal hood or commercial catch basin trap.

To ensure the filter can be drained if plugged, a 6-inch dewatering drain with gate valve is included in the design of the filter.

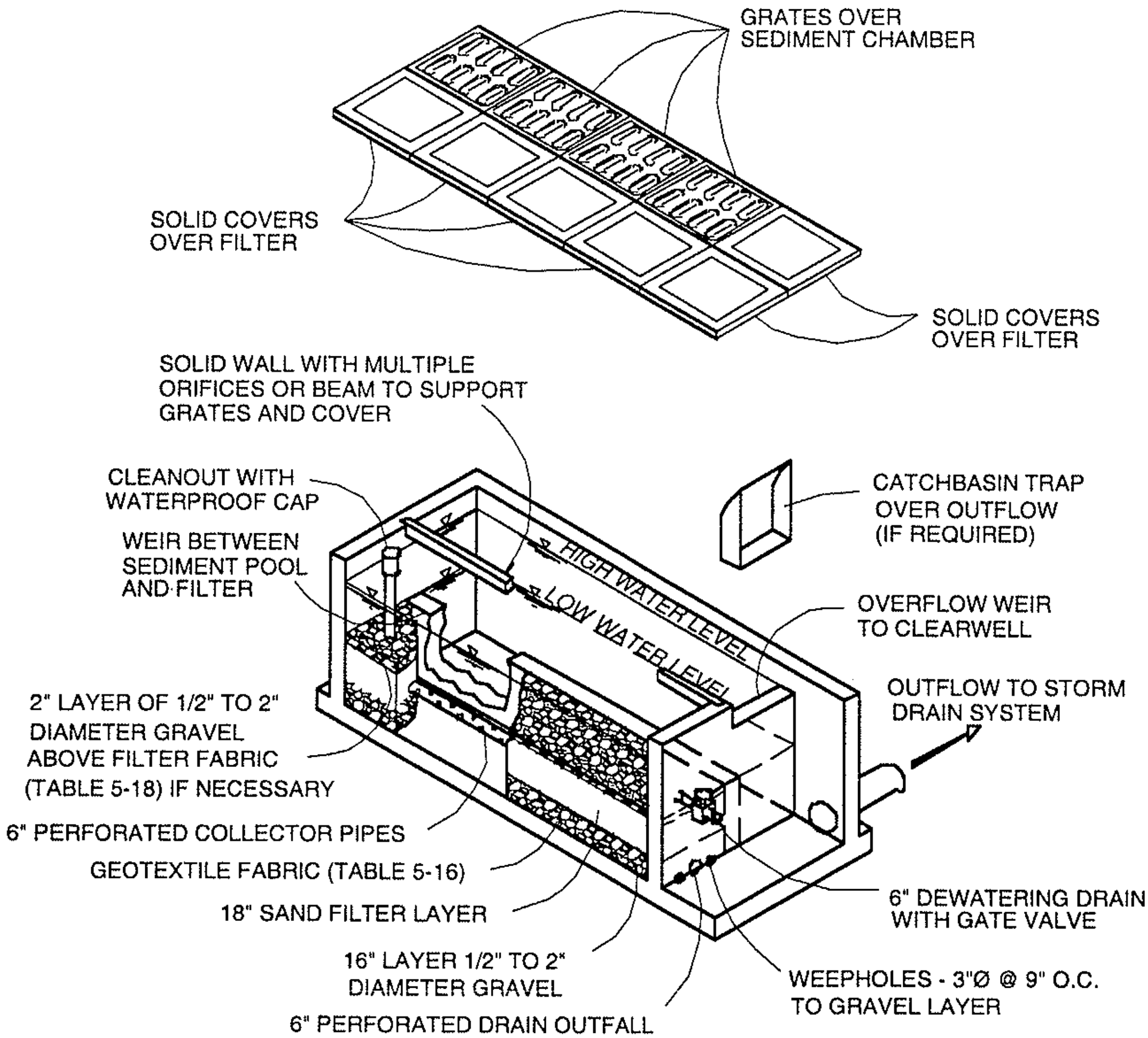


FIGURE 5-22. DELAWARE SAND FILTER

Design Criteria

Principal design criteria for the Delaware Sand Filter are summarized in Table 5-21

Table 5-21. Delaware Sand Filter Design Criteria

Design Parameter	Unit	Criteria
Maximum drainage area	acres	5
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 40-h drawdown
Weir height between sedimentation chamber and sand filter	in.	Set weir height 2" above sand filter bed
Minimum draw down time, t_f	hrs	40
Minimum gravel depth over sand	in.	2
Minimum sand depth, d_f	in.	18
Minimum gravel underdrain depth, d_g	in.	16
Filter coefficient, k	ft/day	2.0
Top layer and underdrain gravel size	in.	0.5 to 2-inch diameter stone
Sand size	—	ASTM C33 concrete sand
Slope of top layer	%	0 (horizontal)
Minimum slope of underdrain or bottom of filter	%	0.5%
Minimum size underdrain	—	6" PVC schedule 40
Minimum size diameter perforation	in.	3/8
Minimum number of holes per row	—	6
Minimum spacing between rows	in.	6
Minimum weephole diameter	in.	3
Minimum spacing between weepholes	in.	9 (center to center)
Sedimentation chamber and sand filter width	in.	18 to 30

Design Procedure

Design procedure and application of design criteria for Delaware Sand Filter are outlined in the following steps:

1. Maximum Water Depth — Based on site constraints determine the maximum ponding depth over filter (2h). If an overflow device is built into the DSF shell, size the overflow weir in procedures in Appendix B.

2. Sand Filter / Sediment Chamber Surface Area — The DSF shell must have the capacity to accept and store the SQDV. The dimensions are sized to provide a filter area which processes the SQDV in the desired time frame (40 hrs.). The areas of the sedimentation chamber and filter bed are typically set equal. The required areas are calculated as follows depending on the maximum depth of water above the

filter bed:

a. If 2h < 2.67 ft — Use: $A_{sm} = A_{fm} = SQDV/(4.1h + 0.9)$

b. If 2h > 2.67 ft — Use: $A_{sm} = A_{fm} = \dfrac{(SQDV)(d_f)}{(k)(h + d_f)(t_f)}$

Where:

$SQDV$ = Stomwater Quality Design Volume, ft^3

A_{fm} = filter surface area, ft^2

A_{sm} = sediment chamber area, ft^2

d_f = sand bed depth, ft

k = filter coefficient @ 0.0833 ft./hr.

h = one-half of max allowable water depth (2h), ft.

t_f = 40 h draw-down time

3. Select sediment chamber and filter width ($W_s = W_f$) — Site considerations usually dictate the final dimensions of the facility. Sediment chambers and filter chambers are normally 18-30 inches wide. Use of standard grates requires a width of 26 inches.

4. Sediment Chamber/ Filter Length — $L_s = L_f = A_{fm} / W_f$

   Round length upward as appropriate. Compute adjusted Area

   $A_s = A_f = W_f \times L_f$

5. Storage Volume in filter voids (Vv) — $V_v = A_f \times (d_f + d_g) \times (0.4)$ {assume 40% voids}

6. Flow Through Filter During Filling (V_Q) — $V_Q = k \times A_f \times (d_f + d_g) \times t_f / d_f$

   Use: k = 2 ft/day = 0.0833 ft/hr.

   t_f = 1 hr. to fill voids

7. Net Volume Required to be Stored in Chambers Awaiting Filtration (V_{st}) — $V_{st} = SQDV - V_v - V_Q$

8. Available Storage in Chambers (V_{sf}) — $V_{sf} = 2h(A_f + A_s)$

   If $V_{sf} \geq V_{st}$, proceed with design

   If $V_{sf} < V_{st}$, adjust width and/or length and repeat steps 3 –8.

9. Filter Bed

   a. Top Gravel Layer — The washed gravel layer at the top of the filter should be two inches thick composed of stone 0.5 to 2.0 inches in diameter.

   In areas with high sediment load (TSS concentration >200

	mg/L), the two-inch layer of stone on top of the sand filter should be underlain with filter fabric meeting the specifications in Table 5-18.
b. Sand Layer	The sand layer should be a minimum depth of 18 inches consisting of ASTM C33 concrete sand. A layer of geotextile fabric meeting the specifications in Table 5-16 must separate the sand and gravel layer below.
c. Gravel Layer	The gravel layer surrounding the collector pipes should be at least 16 inches thick and be composed of 0.5 to 2-inch diameter stone and provide at least two inches of cover over the tops of the drainage pipes.
10. Underdrain Piping	The underdrain piping should follow the same criteria and design as the Austin Sand Filter (see T-11.1). Shallow rectangular drain tiles may be fabricated from such materials as fiberglass structural channels, saving several inches of filter depth. Drain tiles should be in two-foot lengths and spaced to provide gaps 1/8-inch less than the smallest gravel sizes on all four sides. Sections of tile may be cast in the dividing wall between the filter and the clearwell to provide shallow outflow orifices.
11. Weep Holes	Weephole configuration should follow the same criteria as the DC Sand Filter (see T-11.2).
12. Grates and Covers	Grates and cast steel covers are designed to take the same wheel loads as the adjacent pavement. Where possible, use standard grates to reduce costs. Grates and covers should be supported by a galvanized steel perimeter frame
13. Hoods / Traps	In applications where trapping of hydrocarbons and other floating pollutants is required, large-storm overflow weirs should be equipped with a 10-gauge aluminum hood or commercially available catch basin trap. The hood or trap should extend a minimum of one foot into the permanent pool.
14. Dewatering Drain	A six-inch diameter dewatering drain with gate valve is to be installed at the top of the stone/sand filter bed through the partition separating the filter chamber from the clearwell chamber.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-11.3: Delaware Sand Filter

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

1. Minimum Surface Areas of the Chambers If 2h < 2.67 feet (2'-8") $A_{sm} = A_{fm} = SQDV / (4.1h + 0.9)$ If 2h > 2.67 feet (2'-8") $A_{sm} = A_{fm} = \frac{(SQDV)(d_f)}{(k)(h + d_f)(t_f)}$			
a. SQDV	SQDV =	1300	ft^3
b. Sand bed depth (d_f)	d_f =	1.5	ft
c. Filter Coefficient (k)	k =	0.0833	ft. / hr.
d. Draw-down time (t_f)	t =	40	hr
e. One half maximum allowable water depth over filter (h)	h =	1.67	ft
f. A_{sm} (Sediment Chamber Area) and A_{fm} (Filter Surface Area)	A_{sm} and A_{fm} =	185	ft^2
2. Sediment Chamber and Filter Width / Length			
a. Select width ($W_s = W_f$ = 18 to 30 inches)	$W_s = W_f$ =	2.167	ft.
b. Filter length ($L_s = L_f = A_{fm} / W_f$)	$L_s = L_f$ =	85.2	ft.
c. Adjusted length (rounded)	$L_s = L_f$ =	86.0	ft.
d. Adjusted area ($A_s = A_f = W_f \times L_f$)	$A_s = A_f$ =	186.4	ft^2
3. System Storage Volume			
a. Storage in filter voids ($V_v = A_f \times (d_f + d_g) \times 0.4$)	V_v =	211.0	ft.
b. Flow through filter ($V_Q = k \times A_f \times (d_f + h) \times 1hr/d_f$)	V_Q =	32.8	ft.
c. Required net storage ($V_{st} = SQDV - V_v - V_Q$)	V_{st} =	1,056	ft.
d. Available storage ($V_{sf} = 2h(A_f + A_s)$)	V_{sf} =	1,245	ft^2
If $V_{sf} \geq V_{st}$, sizing is complete If $V_{sf} < V_{st}$, repeat steps 2 and 3			

Construction Considerations

- Erosion and sediment control measures must be configured to prevent any inflow of stormwater into the sand filter during its construction.
- The sand filter must be adequately protected once constructed and not be placed in service until all soil surfaces in the drainage watershed have been stabilized with vegetated cover. Should construction runoff enter the filter system prior to site revegetation, all contaminated materials must be removed and replaced with new clean materials.
- The top of the sand filter must be completely level. No grade is allowed.
- The inverts of the notches, multiple orifices, or weirs dividing the sedimentation chamber from the filter chamber must also be completely level. Otherwise, water will not arrive at the filter as sheet flow and only the down-gradient end of the filter will function.
- Inflow grates or slotted curbs may conform to the grade of the completed pavement as long as the filters, notches, multiple orifices, and weirs connecting the sedimentation and filter chambers are completely level.
- If precast concrete lids are used, lifting rings or threaded sockets must be provided to allow easy removal with lifting equipment. Lifting equipment must be readily available to the facility operators.
- Where under-drains are used, the minimum slope of the pipe shall be 0.5%. Where only gravel filtered water conveyance is provided, the filter floor must be sloped towards the weepholes at a minimum slope of 0.5%.

Maintenance Requirements

Maintenance Agreement

On-site treatment control measures are to be maintained by the owner/operator. Maintenance agreements between the City and the owner/operator may be required. A Maintenance Agreement with the City must be executed by the owner/operator before the improvement plans are approved.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility;
- Responsible party for operation and maintenance.

Additional guidelines for Maintenance Plans are provided in Appendix D.

Maintenance Activities

- During the first year of operation, the cover grates or precast lids on the chambers must be removed quarterly and an inspection made to assure that the system is functioning. Once the system is functioning properly, this inspection may be made on a semiannual basis.

- When the filter takes 36 hours or more to drain or when deposition of sediments in the filtration chamber indicate that the filter media is clogging and not performing properly, sediments and sand must be removed. The coloration of the sand will provide a good indication of what depth of removal is required. Clean sand must then be placed in the filter to restore the design depth. Where a layer of geotextile fabric and gravel overlay the filter, the fabric and gravel shall be rolled up and removed and a similar layer of clean fabric and gravel installed. Any discolored sand shall also be removed and replaced.
- Grass must be prevented from washing into the filter.
- Disposal of petroleum hydrocarbon contaminated sand, gravel or filter cloth must be done in accordance with all applicable laws.
- Trash collected on the grates protecting the inlets should be removed no less frequently than weekly to assure preserving the inflow capacity of the control measures.
- Monitoring manholes, flumes, and other facilities should be kept clean and ready for use.

Monitoring Agreement

The owner/operator may be required to enter into a monitoring agreement with the City to establish pollutant removal efficiencies of the sand filter.

Sand filters may be required to be designed to accommodate the installation, operation and maintenance of automatic sampling equipment to measure the input and output flow rates and the chemical composition of the inflow and outflow.

At a minimum, the sand filter system will be equipped with monitoring manholes in the inflow and outflow pipes. The City and its consultants will conduct the monitoring program unless otherwise agreed to by the agency. The type and length of monitoring program will be determined on a case-by-case basis.

Alternative and Proprietary Control Measures

This Manual provides guidance for the selection and design of some of the more common on-site stormwater treatment control measures for new development. The standard treatment control measures (T-1 through T-11) included in this Section are non-proprietary designs that have been reviewed and evaluated by the City and determined to be generally acceptable. Because the performance of these measures has already been demonstrated and reviewed by the City, the plan check review and approval process will be routine for development projects that have selected one of the control measures from this guidance Manual.

The City recognizes, however, that these pre-accepted treatment control measures may not be appropriate for all projects due to physical site constraints. Thus, the City will consider the use of alternative or proprietary control measures under the follow conditions:

1. If design guidelines for standard treatment control measures cannot be met due to physical site constraints, the City retains the discretion of using a lesser performance or design standard prior to accepting proprietary devices. For example: a grass swale filter with 1.5 feet/sec velocity would be considered preferable to installation of a proprietary fabric filter.
2. Alternative or proprietary treatment control devices will only be considered for approval after standard treatment control measures in the guidance Manual have been rejected.
3. If, for a specific development, the average cost of installation and operation of standard treatment controls is substantially greater than the average costs for similar installations, alternative or proprietary treatment technologies may be considered for approval.
4. Alternative or proprietary treatment technologies may be approved for redevelopment projects where existing site constraints preclude installation of standard treatment controls.

Alternative control measures may include landscape-type features or proprietary devices. Site designers should contact the City stormwater staff early on in the planning process in order to adequately demonstrate that the level and reliability of treatment provided by an alternative control measure is equivalent to that of the pre-accepted designs. The City shall review the design and construction method of the proposed technology to determine if the device is suitable for the specific land use and pollutant to be removed.

In general, any alternative measure must be designed to treat the stormwater quality design volume, SQDV or the water quality flow, SQDF. Procedures to calculate the SQDV and SQDF are provided in the Calculation Fact Sheets. Site runoff in excess of the SQDV and SQDF may be diverted around or through the treatment device. In addition, the project applicant must demonstrate that the pollutant removal of the proposed alternative control measure will be comparable to the pre-accepted control measures. Reliable performance data and sound engineering principles must be provided to demonstrate effective reliable treatment. Any proposed alternative must include all maintenance, operation, and construction requirements.

There are numerous manufactured proprietary devices available on the market. When proprietary control measures have been determined by the City to be pre-accepted, an Appendix may be added to this guidance Manual and updated periodically to provide a list and description of acceptable proprietary devices.

The City encourages the development of innovative stormwater control measures and may consider a limited number of promising alternative control measures, including proprietary devices, on a 'pilot basis'. In order for a pilot project to be considered for proprietary devices, the manufacturer and/or property owner must commit to participate and fund a monitoring program to verify the device's performance. Site designers should anticipate additional review time and contact the City stormwater staff early in the process to request consideration of pilot installation projects.

Glossary of Terms

1-Acre Commercial Development : Any commercial development that creates at least one (1) acre of impermeable area, including parking areas.

Automotive Repair Shop: A facility that is categorized in any one of the following Standard Industrial Classification (SIC) codes: 5013, 5014, 5541, 7532-7534, or 7536-7539.

Backfill: Earth or engineered material used to refill a trench or an excavation.

Berm: An earthen mound used to direct the flow of runoff around or through a structure.

Best Management Practice (BMP): Any program, technology, process, siting criteria, operational methods or measures, or engineered systems, which when implemented prevent, control, remove, or reduce pollution.

Best Management Practices (BMPs): Includes schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the United States. BMPs also include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

Buffer Strip or Zone: Strip of erosion-resistant vegetation over which stormwater runoff is directed.

Catch Basin: Box-like underground concrete structure with openings in curbs and gutters designed to collect runoff from streets and pavements.

Clean Water Act (CWA): (33 U.S.C. 1251 et seq.) requirement of the National Pollutant Discharge Elimination System (NPDES) program are defined under Sections 307, 402, 318 and 405 of the CWA.

Commercial Development: Any development on private land, including industrial uses, that is not residential. The category includes, but is not limited to: hospitals, laboratories and other medical facilities, educational institutions, recreational facilities, plant nurseries, multi-apartment buildings, car wash facilities, mini-malls and other business complexes, shopping malls, hotels, office buildings, public warehouses, material handling facilities, and other industrial complexes.

Conduit: Any channel or pipe for directing the flow of water.

Construction General Permit: A NPDES permit issued by the State Water Resources Control Board (SWRCB) for the discharge of stormwater associated with construction activity from soil disturbance of one (1) acre or more.

Conveyance System: Any channel or pipe for collecting and directing the Stormwater.

Culvert: A covered channel or a large diameter pipe that crosses under a road, sidewalk, etc.

Dead-end Sump: A below surface collection chamber for small drainage areas that is not connected to the public storm drainage system. Accumulated water in the chamber must be pumped and disposed in accordance with all applicable laws.

Designated Public Access Points: Any pedestrian, bicycle, equestrian, or vehicular point of access to jurisdictional channels in the area subject to permit requirements.

Detention: The temporary storage of stormwater runoff to allow treatment by sedimentation and metered discharge of runoff at reduced peak flow rates.

Directly Adjacent: Situated within 200 feet of the contiguous zone required for the continued maintenance, function, and structural stability of an environmentally sensitive area.

Directly Connected Impervious Area (DCIA): The area covered by a building, impermeable pavement, and/ or other impervious surfaces, which drains directly into the storm drain without first flowing across permeable land area (e.g. turf buffers, grass-lined channels).

Directly Discharging: Outflow from a drainage conveyance system that is composed entirely or predominantly of flows from the subject, property, development, subdivision, or industrial facility, and not commingled with the flows from adjacent lands.

Discharge: A release or flow of Stormwater or other substance from a conveyance system or storage container.

Erosion: The wearing away of land surface by wind or water. Erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices relating to farming, residential or industrial development, road building, or timber cutting.

Excavation: The process of removing earth, stone, or other materials, usually by digging.

Facility: Is a collection of industrial process discharging stormwater associated with industrial activity within the property boundary or operational unit.

Filter Fabric: Geotextile of relatively small mesh or pore size that is used to: (a) allow water to pass through while keeping sediment out (permeable); or (b) prevent both runoff and sediment from passing through (impermeable).

Grading: The cutting and/or filling of the land surface to a desired shape or elevation.

Hazardous Substance: (1) Any material that poses a threat to human health and/or the environment. Typical hazardous substances are toxic, corrosive, ignitable, explosive, or chemically reactive; (2) Any substance named by EPA to be reported if a designated quantity of the substance is spilled in the waters of the United States or if otherwise emitted into the environment.

Hazardous Waste: By-products of society that can pose a substantial or potential hazard to human health or the environment when improperly managed. Possesses at least one of four characteristics (flammable, corrosivity, reactivity, or toxicity), or appears on special EPA lists.

Illegal Discharges: Any discharge to a municipal separate storm sewer that is not composed entirely of stormwater except discharges authorized by an NPDES permit (other than the NPDES permit for discharges from the municipal separate storm sewer) and discharges resulting from fire fighting activities.

Industrial General Permit: A NPDES permit issued by the State Water Resources Control Board for the discharge of Stormwater associated with industrial activity.

Infiltration: The downward entry of water into the surface of the soil.

Inlet: An entrance into a ditch, storm sewer, or other waterway.

Material Storage Areas: On site locations where raw materials, products, final products, by-products, or waste materials are stored.

New Development: Land disturbing activities; structural development, including construction or installation of a building or structure, creation of impervious surfaces; and land subdivision.

Non-Stormwater Discharge: Any discharge to municipal separate storm drain that is not composed entirely of stormwater. Discharges containing process wastewater, non-contact cooling water, or sanitary wastewater are non-stormwater discharges.

Non-Structural Source Control Measure: Low technology, low cost activities, procedures or management practices designed to prevent pollutants associated with site functions and activities from being discharged with Stormwater runoff. Examples include good housekeeping practices, employee training, standard operating practices, inventory control measures, etc.

Notice of Intent (NOI): A formal notice to State Water Resources Control Board submitted by the owner/developer that a construction project is about to begin. The NOI provides information on the owner, location, type of project, and certifies that the permittee will comply with the conditions of the construction general permit.

NPDES Permit: An authorization, license, or equivalent control document issued by EPA or an approved State agency to implement the requirements of the NPDES program.

Outfall: The point where stormwater discharges from a pipe, channel, ditch, or other conveyance to a waterway.

Parking Lot: Land area or facility for the temporary parking or storage of motor vehicles used personally, for business or for commerce with an impervious surface area of 5,000 square feet or more, or with 25 or more parking spaces.

Permeability: A property of soil that enables water or air to move through it. Usually expressed in inches/hour or inches/day.

Pollutant: A substance introduced into the environment that adversely affects the usefulness of a resource.

Precipitation: Any form of rain or snow.

Pretreatment: Treatment of wastewater before it is discharged to a wastewater collection system.

Process Wastewater: Wastewater that has been used in one or more industrial processes.

Receiving Stream: (for purposes of this Manual only) any natural or man-made surface water body that receives and conveys stormwater runoff.

Redevelopment: Development that includes, but is not limited to the following: the expansion of a building footprint or addition or replacement of a structure; structural development including an increase in gross floor area and/or exterior construction or remodeling; replacement of impervious surface that is not part of a routine maintenance activity; land disturbing activities related with structural or impervious surfaces. Redevelopment that results in the creation or addition of 5,000 square feet or more of impervious surfaces is subject to the requirements for stormwater mitigation. If the creation or addition of impervious surfaces is fifty percent or more of the existing impervious surface area, then stormwater runoff from the entire area (existing and changes) must be considered for purposes of stormwater mitigation. If the creation or changed area is less than fifty percent of the existing impervious area, then Stormwater runoff from only the changed area needs mitigation.

Restaurant: A stand-alone facility that sells prepared foods and drinks for consumption, including stationary lunch counters and refreshment stands selling prepared foods and drinks for immediate consumption (SIC code 5812).

Retail Gasoline Outlet: Any facility engaged in selling gasoline and lubricating oils.

Retention: The storage of stormwater to prevent it from leaving the development site; may be temporary or permanent.

Runoff: Water originating from rainfall and other precipitations (e.g., sprinkler irrigation) that is found in drainage facilities, rivers, streams, springs, seeps, ponds, lakes, wetlands, and shallow groundwater.

Runon: Stormwater surface flow or other surface flow which enters property other than that where it originated.

Secondary Containment: Structures, usually dikes or berms, surrounding tanks or other storage containers and designed to catch spilled material from the storage containers.

Sedimentation: The process of depositing soil particles, clays, sands, or other sediments that were picked up by runoff.

Sediments: Soil, sand, and minerals washed from land into water usually after rain, that accumulate in reservoirs, rivers, and harbors, destroying aquatic animal habitat and clouding the water so that adequate sunlight might not reach aquatic plants.

Source Control BMP or Measure: Any schedules of activities, structural devices, prohibitions of practices, maintenance procedures, managerial practices or operational practices that aim to prevent stormwater pollution by reducing the potential for contamination at the source of pollution.

Spill Guard: A device used to prevent spills of liquid materials from storage containers.

Spill Prevention Control and Countermeasures Plan (SPCC): Plan consisting of structures, such as curbing, and action plans to prevent and respond to spills of hazardous substances as defined in the Clean Water Act.

Storm Drains: Above and below ground structures for transporting stormwater to streams or outfalls for flood control purposes.

Storm Drain System: Network of above and below-ground structures for transporting stormwater to streams or outfalls.

Storm Event: A rainfall event that produces more than 0.1 inch of precipitation and is separated from the previous storm event by at least 72 hours of dry weather.

Stormwater Discharge Associated with Industrial Activity: Discharge from any conveyance which is used for collecting and conveying stormwater which is related to manufacturing processing or raw materials storage areas at an industrial plant [see 40 CFR 122.26(b)(14)].

Stormwater: Stormwater runoff, snow-melt runoff, surface runoff, and drainage, excluding infiltration and irrigation tailwater.

Structural BMP or Control Measure: Any structural facility designed and constructed to mitigate the adverse impacts of stormwater and urban runoff pollution (e.g. canopy, structural enclosure). The category may include both Treatment Control BMPs and Source Control BMPs.

Treatment Control BMP or Measure: Any engineered system designed to remove pollutants by simple gravity settling of particulate pollutants, filtration, biological uptake, media adsorption or any other physical, biological, or chemical process.

Treatment: The application of engineered systems that use physical, chemical, or biological processes to remove pollutants. Such processes include, but are not limited to, filtration, gravity settling, media adsorption, biodegradation, biological uptake, chemical oxidation and UV radiation.

Standard Calculations for Diversion Structure Design

Introduction

Storm water runoff in excess of the water quality flow or volume is to be diverted around or through the treatment control measure. The following paragraphs provide equations and design criteria necessary to design diversion structures to divert runoff in excess of the SQDV or SDQF around or through the treatment control measures.

Diversion Structure Design

Capture or isolation of the SQDV is typically achieved by employing one of the following techniques:

- Divert the SQDV into the treatment control measure from the on-site storm drain system using weirs or orifices at or upstream of the point of entrance to the treatment control measure.
- Bypassing flows in excess of the SQDV within the treatment control measure using weirs and pipes for channel or pipe storm drain systems or routing excessive flows through a vegetated swale.

By employing diversion techniques, the water quality flow or volume is treated and discharged to the storm drain system and runoff that exceeds the water quality flow or volume is diverted or bypassed, untreated, directly to the downstream storm drain system.

Equations and criteria to design a diversion structure are provided below. Alternative designs may be considered subject to approval.

All diversion structures are designed using the on-site storm design event. The drainage design storm is established by the governing agency and is not the same as the stormwater quality design flow or volume. The drainage design storm is used to design the conveyance system, i.e. pipes, swales, etc. of the site without regard for treatment. The design engineer must ensure sufficient head room in the on-site system above the diversion to accommodate overflows.

Diverting Flows at the Inlet or Upstream of the Treatment Control Device

Diverting flow at the inlet to the treatment control is the more common approach to divert excess runoff. Figure B-1 illustrates the more commonly used diversion structures. The height of the weir to divert the flow is determined a follows:

<u>Treatment Control Measures Designed Based on the SQDV</u>

1. Determine the SQDV (see Section 5)
2. Utilizing design techniques provided in the treatment control measure fact sheets, determine the maximum height of the water level in the treatment control measure when

the entire SQDV is being held,

3. Set the height of the diversion weir to the maximum height of the water level.
4. Determine weir dimensions needed to divert peak flows of the drainage design storm using the following equation for a rectangular sharp-crested weir:

$$Q_d = CLh^{1.5} \qquad \textit{eqn B-1}$$

Where: Q_d = Peak flow rate for drainage design storm, cfs

L = Effective length of weir, ft

C = Weir discharge coefficient

h = Depth of the flow above the crest of the weir, ft

The discharge coefficient "C" accounts for many factors, such as velocity of approach, in the weir equation. The height of the weir (H) and the height of the flow over the weir (h) are two characteristics of the sharp-crested weir that affect the value of C. Table B-1 can be used to approximate C for rectangular sharp-crested weirs without end contractions.

5. Provide sufficient head room in the treatment control to accommodate depth of flow over the weir.

Table B-1. Weir Discharge Coefficient (C) for Rectangular Sharp-crested Weirs Without End Contractions[1]

H/h	Head (h) over weir, ft						
	0.2	0.4	0.6	0.8	1.0	2.0	5.0
0.5	4.18	4.13	4.12	4.11	4.11	4.10	4.10
1.0	3.75	3.71	3.69	3.68	3.68	3.67	3.67
2.0	3.53	3.49	3.48	3.47	3.46	3.46	3.45
10.0	3.36	3.32	3.30	3.30	3.29	3.29	3.28
∞	3.32	3.28	3.26	3.26	3.25	3.25	3.24

1. From Lindsay and Franzini , (1979)

<u>Treatment Control Measures Designed Based on the SQDF</u>

1. Establish the size of the on-site drainage system (pipe diameter or dimensions) based on the drainage design storm
2. Determine the SQDF (see Section 5)
3. Determine the depth of flow in the on-site drainage system when carrying the SQDF using Manning's equation (eqn B-2)

$$SQDF = \frac{1.49}{n} A R^{\frac{2}{3}} s^{\frac{1}{2}} \qquad \textit{eqn B-2}$$

Where: SQDF = Water Quality Flow, cfs

n = Manning's roughness coefficient

A = Cross sectional area of drainage pipe or channel, ft^2

R = Hydraulic radius, ft

S = Slope of pipe or channel, ft/ft

4. Using nomographs or computer programs, determine the depth of flow at SQDF. Set the weir height at this depth.

5. Using Equation B-1, establish weir dimensions. Provide sufficient head room in treatment control to accommodate flows over the weir.

Bypassing Excess Flows within the Treatment Control Measure

For certain site conditions, bypassing runoff in excess of the SQDV must be achieved in the treatment control measure. When this occurs, the control measure must be designed to ensure the bypass system can be accommodated in the unit, i.e. sufficient depth, width and length to accommodate pipes, length of weirs, etc. The following discusses design considerations for the different treatment control measures.

Bypassing Flows through Infiltration and Sedimentation/Filtration Treatment Control Measures

Weirs, orifices or pipes in treatment control measures are used to bypass runoff in excessive of the SQDV and SQDF. Design of these measures is similar to the approach described above under diverting flows at the inlet to the treatment control measure. Bypass for filtration devices occurs in the sedimentation chamber.

Weirs

Weirs are commonly used to bypass excess storm events. Determining the height of the weir is based on the maximum water elevation in a treatment control device when holding the entire SQDV. To design the weir, use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV.

Orifices

Orifices can be considered in place of weirs or pipes. To avoid drawing floatables into the bypass, a hooded orifice (see Figure B-2) should be designed using the equation B-3:

$$Q_d = CA(2gh)^{0.5} \qquad \textit{eqn B-3}$$

Where: Q_d = Peak flow rate for drainage design storm, cfs

C = Orifice discharge coefficient, (use 0.6)

A = Area of orifice, ft^2

h = Depth of the water above midpoint of orifice, ft

g = 32.2 ft/sec^2

Hoods should extend into one-third of the permanent pool depth or one-foot whichever is greater. Commercial catch basin traps can be used in lieu of a hood.

Determining the elevation of the orifice is based on determining the maximum water elevation in a treatment control device when holding the entire SQDV. Use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV to establish the elevation of the mid-point of the orifice opening.

The size of the orifice is determined by using Equation B-3 for the orifice to bypass the peak flow of the on-site storm.

Ensure sufficient head room in the treatment unit to accommodate flows through orifice.

Pipes

Pipes can also be employed to bypass excess runoff. Determining the invert elevation of the bypass inlet is based on determining the maximum water elevation in a treatment control device when holding the entire SQDV. To do this, use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV to design a diversion weir.

For filtration control measures, a hooded inlet using a 90° elbow should be considered at the inlet to the bypass pipe to prevent drawing floatables into the bypass (see Figure B-2). Hoods should extend into one-third of the permanent pool depth or one-foot whichever is greater. Commercial catch basin traps can be used in lieu of a hood.

For infiltration control measures (see Figure B-3) bypass pipes are perforated and wrapped with filter fabric to avoid drawing sediment and small particles into the bypass pipe. Hoods are not necessary for these overflow pipes.

Bypass pipes are sized using the Manning's equation (Equation B-4) and sized to pass the peak flow of the drainage design storm, and assume the bypass pipes are flowing full. With this assumption, the Manning's equation, Equation B-4, reduces to:

$$D = \left(\frac{2.159 Q_d n}{s^{\frac{1}{2}}} \right)^{\frac{3}{8}} \qquad \textit{eqn B-4}$$

Where:
- D = Diameter of pipe, ft
- Q_d = Peak flow rate for drainage design storm, cfs
- n = Manning's coefficient for pipe material
- s = Slope of pipe, ft/ft (0.5% minimum required)

Provide sufficient head room in the treatment control to accommodate flows.

Routing Excess Runoff Through a Grass Swale Filter

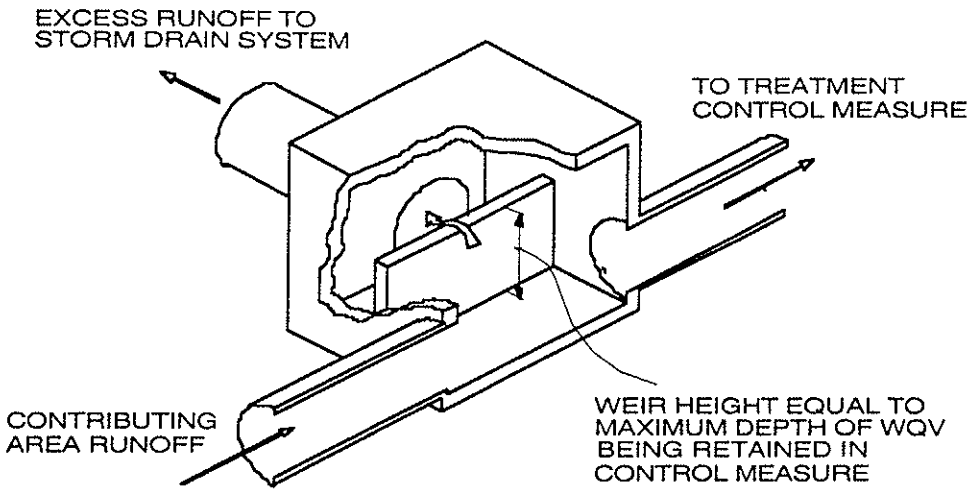
The depth of flow in a grass swale filter at SQDF is determined using a roughness coefficient of 0.2. If additional flows beyond the SQDF are to be directed to the grass swale filter, the roughness coefficient for these flows will be lower (approximately 0.03), because the flows exceeding the SQDF do not flow through the grass and are only influenced by surface friction/roughness. Swales with distinctly different roughness coefficients can be designed using an equivalent roughness coefficient that is determined based on the roughness associated with the wetted perimeters (P). For most on-site grass swale filter designs, there will be two different "n" values. An equivalent "n_e" value can be determined using equation B-5:

$$n_e^{\frac{3}{2}} = \frac{P_1 n_1^{\frac{3}{2}} + P_2 n_2^{\frac{3}{2}}}{P} \qquad \textit{eqn B-5}$$

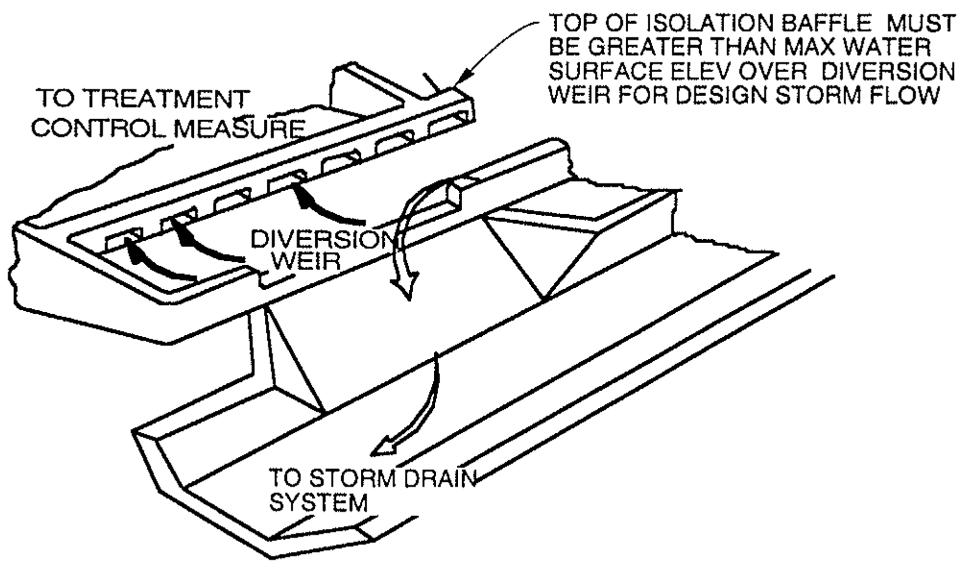
An iterative approach is used to develop an equivalent "n_e", that can be calculated with most computer hydraulic program applications:

1. Estimate an equivalent roughness coefficient (estimated "n_e"),
2. Using the estimated roughness coefficient, determine the depth of flow using trial and error solution of Equation B-2 substituting the peak flow of the drainage design storm for the SQDF,
3. Using the calculated depth determine the wetted perimeter for the drainage system,
4. Using the wetted perimeter associated with each "n" for the drainage system, and using Equation B-5, calculate the equivalent roughness coefficient (calculated "n_e"), and compare to the estimated "n_e",
5. The process continues until the calculated "n_e" equals the estimated "n_e". This value is the equivalent roughness coefficient and used to design the grass swale filter according to recommendations provided in Fact Sheet T-2.

Note - This approach results in conservative n values. High flows in the swale may cause some vegetation to bend resulting in a lower n_l and lower equivalent "n_e".



PIPE INTERCEPTOR ISOLATION/DIVERSION STRUCTURE



SURFACE CHANNEL DIVERSION STRUCTURE

FIGURE B-1. COMMON DIVERSION STRUCTURES AT INLETS

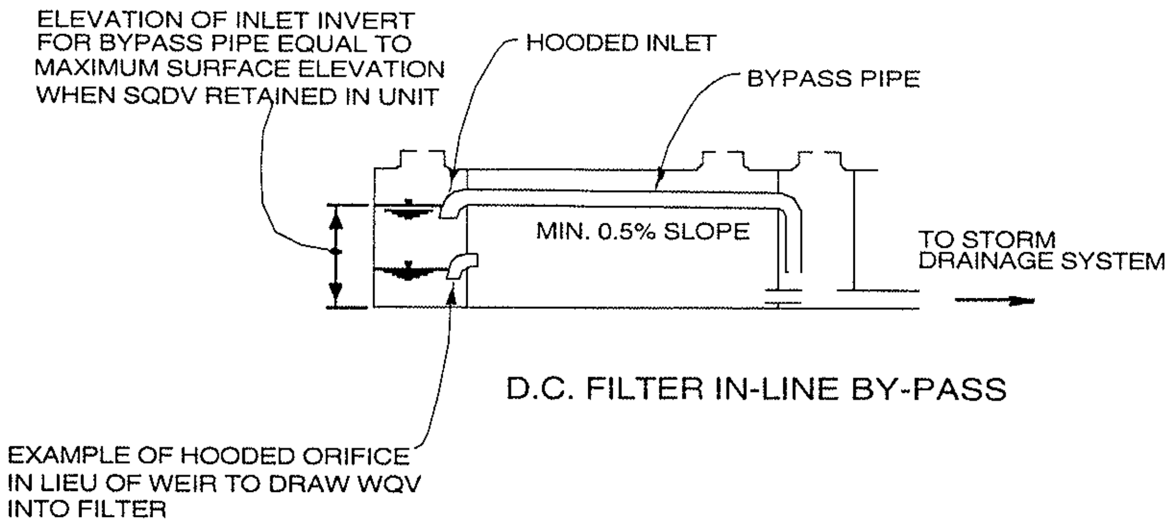


FIGURE B-2. ILLUSTRATION OF PIPE BYPASS IN A FILTRATION DEVICE

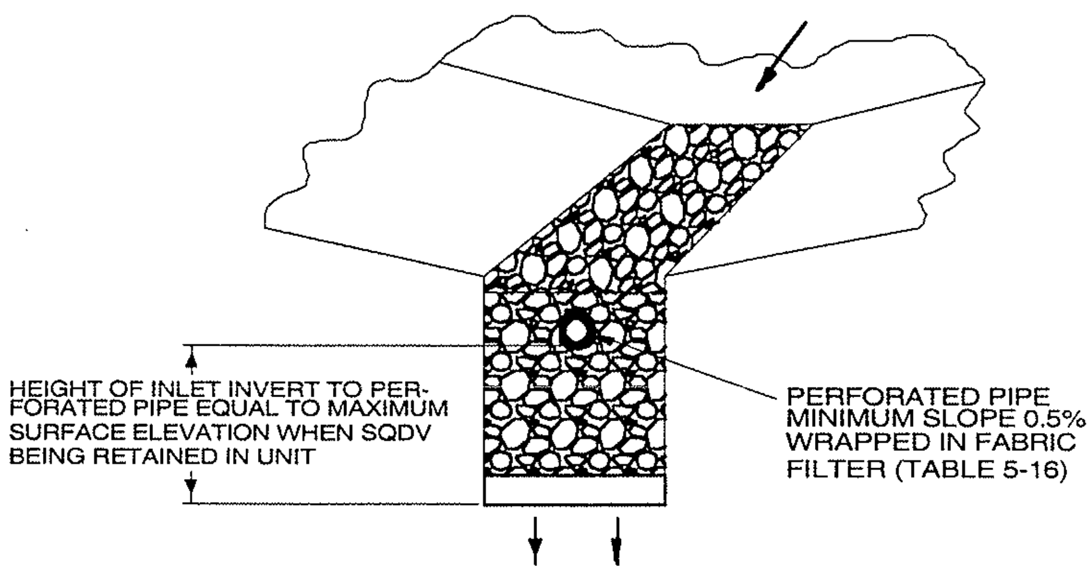


FIGURE B-3. ILLUSTRATION OF PIPE BYPASS IN INFILTRATION TRENCH

(Long Form)

Recorded at the request of:
City of Woodland

____

After recording, return to:
City of Woodland
City Clerk
____
____

Stormwater Treatment Device
Access and Maintenance
Agreement

OWNER: ______________________________

PROPERTY ADDRESS: ______________________________

APN: ______________________________

THIS AGREEMENT is made and entered into in____________________, California, this___day of_____________, by and between______________________________________, hereinafter referred to as "Owner" and the CITY OF WOODLAND, a municipal corporation, located in the County of Yolo, State of California hereinafter referred to as "CITY";

WHEREAS, the Owner owns real property ("Property") in the City of Woodland, County of Yolo, State of California, more specifically described in Exhibit "A" and depicted in Exhibit "B", each of which exhibits is attached hereto and incorporated herein by this reference;

WHEREAS, at the time of initial approval of development project known as__________ ___________________________________within the Property described herein, the City required the project to employ on-site control measures to minimize pollutants in urban runoff;

WHEREAS, the Owner has chosen to install a ____________________________ ____, hereinafter referred to as "Device", as the on-site control measure to minimize pollutants in urban runoff;

WHEREAS, said Device has been installed in accordance with plans and specifications accepted by the City;

WHEREAS, said Device, with installation on private property and draining only private property, is a private facility with all maintenance or replacement, therefore, the sole responsibility of the Owner in accordance with the terms of this Agreement;

WHEREAS, the Owner is aware that periodic and continuous maintenance, including, but not necessarily limited to, filter material replacement and sediment removal, is required to assure peak performance of Device and that, furthermore, such maintenance activity will require compliance with all Local, State, or Federal laws and regulations, including those pertaining to confined space and waste disposal methods, in effect at the time such maintenance occurs;

NOW THEREFORE, it is mutually stipulated and agreed as follows:

1. Owner hereby provides the City or City's designee complete access, of any duration, to the Device and its immediate vicinity at any time, upon reasonable notice, or in the event of emergency, as determined by City's Director of Public Works no advance notice, for the purpose of inspection, sampling, testing of the Device, and in case of emergency, to undertake all necessary repairs or other preventative measures at owner's expense as provided in paragraph 3 below. City shall make every effort at all times to minimize or avoid interference with Owner's use of the Property.

2. Owner shall use its best efforts diligently to maintain the Device in a manner assuring peak performance at all times. All reasonable precautions shall be exercised by Owner and Owner's representative or contractor in the removal and extraction of material(s) from the Device and the ultimate disposal of the material(s) in a manner consistent with all relevant laws and regulations in effect at the time. As may be requested from time to time by the City, the Owner shall provide the City with documentation identifying the material(s) removed, the quantity, and disposal destination.

3. In the event Owner, or its successors or assigns, fails to accomplish the necessary maintenance contemplated by this Agreement, within five (5) days of being given written notice by the City, the City is hereby authorized to cause any maintenance necessary to be done and charge the entire cost and expense to the Owner or Owner's successors or assigns, including administrative costs, attorneys fees and interest thereon at the maximum rate authorized by the Civil Code from the date of the notice of expense until paid in full.

4. The City may require the owner to post security in form and for a time period satisfactory to the City of guarantee the performance of the obligations stated herein. Should the Owner fail to perform the obligations under the Agreement, the City may, in the case of a cash bond, act for the Owner using the proceeds from it, or in the case of a surety bond, require the sureties to perform the obligations of the Agreement. As an additional remedy, the Director may withdraw any previous stormwater related approval with respect to the property on which a

Device has been installed until such time as Owner repays to City it's reasonable costs incurred in accordance with paragraph 3 above.

5. This agreement shall be recorded in the Office of the Recorder of Yolo County, California, at the expense of the Owner and shall constitute notice to all successors and assigns of the title to said Property of the obligation herein set forth, and also a lien in such amount as will fully reimburse the City, including interest as herein above set forth, subject to foreclosure in event of default in payment.

6. In event of legal action occasioned by any default or action of the Owner, or its successors or assigns, then the Owner and its successors or assigns agree(s) to pay all costs incurred by the City in enforcing the terms of this Agreement, including reasonable attorney's fees and costs, and that the same shall become a part of the lien against said Property.

7. It is the intent of the parties hereto that burdens and benefits herein undertaken shall constitute covenants that run with said Property and constitute a lien there against.

8. The obligations herein undertaken shall be binding upon the heirs, successors, executors, administrators and assigns of the parties hereto. The term "Owner" shall include not only the present Owner, but also its heirs, successors, executors, administrators, and assigns. Owner shall notify any successor to title of all or part of the Property about the existence of this Agreement. Owner shall provide such notice prior to such successor obtaining an interest in all or part of the Property. Owner shall provide a copy of such notice to the City at the same time such notice is provided to the successor.

9. Time is of the essence in the performance of this Agreement.

10. Any notice to a party required or called for in this Agreement shall be served in person, or by deposit in the U.S. Mail, first class postage prepaid, to the address set forth below. Notice(s) shall be deemed effective upon receipt, or seventy-two (72) hours after deposit in the U.S. Mail, whichever is earlier. A party may change a notice address only by providing written notice thereof to the other party.

IF TO CITY:	IF TO OWNER:
________________________	________________________________
________________________	________________________________
________________________	________________________________
________________________	________________________________

IN WITNESS THEREOF, the parties hereto have affixed their signatures as of the date first written above.

APPROVED AS TO FORM:

____
City Attorney

OWNER:

____
Name:__________________________
Title:__________________________

CITY OF WOODLAND:

____
Name:__________________________
Title:__________________________

OWNER:

____
Name:__________________________
Title:__________________________

ATTEST:

____
City Clerk Date

NOTARIES ON FOLLOWING PAGE

EXHIBIT A
(Legal Description)

EXHIBIT B
(Map/llustration)

(Short Form)

Recorded at the request of and mail to :

____

____

____

Covenant and Agreement Regarding
Stormwater Treatment Device Maintenance

The undersigned hereby certify that we are the owners of hereinafter legally described real property located in the City of Woodland County of Yolo, State of California.

Legal Description: ____

____

as recorded in Book ______________________, Page________, Records of Yolo County,

which property is located and known as **(Address):** ______________________________

____.

And in consideration of the City of Woodland allowing______________________________

____

on said property, we do hereby covenant and agree to and with said City to maintain according to the Maintenance Plan (Attachment 1), all structural stormwater treatment devices including the following:

____

____.

This Covenant and Agreement shall run all of the above described land and shall be binding upon ourselves, and future owners, encumbrancers, their successors, heirs, or assignees and shall continue in effect until released by the authority of the City upon submittal of request, applicable fees, and evidence that this Covenant and Agreement is no longer required by law.

NOTARIES ON FOLLOWING PAGE

Maintenance Plan Guidance

This form identifies the basic information that shall be included in a maintenance plan. Refer to Fact Sheets for individual control measures regarding device-specific maintenance requirements.

A. Site Map:

1. Provide a site map showing boundaries of the site, acreage and drainage patterns/contour lines. Show each discharge location from the site and any drainage flowing onto the site. Distinguish between soft and hard surfaces on the map.
2. Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems and grade-breaks for purposes of pollution prevention.
3. With legend, show locations of expected sources of pollution generation (outdoor work and storage areas, heavy traffic areas, delivery areas, trash enclosures, fueling areas, industrial clarifiers, wash-racks, etc). Identify any areas having contaminated soil or where toxins are stored or have been stored/disposed of in the past.
4. With legend, indicate types and locations of stormwater control measures that will be built to permanently control stormwater pollution. Distinguish between pollution prevention, treatment, sewer diversion, and containment devices.

B. Baseline Descriptions:

1. List the property owners and persons responsible for operation and maintenance of the stormwater control measures on site. Include phone numbers and addresses.
2. Identify the intended method of providing financing for operation, inspection, routine maintenance and upkeep of stormwater control measures.
3. List all permanent stormwater control measures. Provide a brief description of stormwater control measures selected and if appropriate, facts sheets or additional information.
4. As appropriate for each stormwater control measure provide:
   a. A written description and check list of all maintenance and waste disposal activities that will be performed. Distinguish between the maintenance appropriate for a 2-year establishment period and expected long-term maintenance. For example, maintenance requirements for vegetation in a constructed wetland may be more intensive during the first few years until the vegetation is established. The post-establishment maintenance plan shall address maintenance needs (e.g., pruning, irrigation, weeding) for a larger, more stable system. Include maintenance performance procedures for facility components that require relatively unique maintenance knowledge, such as specific plant removal / replacement, landscape features, or constructed wetland maintenance. These procedures shall provide enough detail for a person unfamiliar with maintenance to perform the activity, or identify the specific skills or knowledge necessary to perform and document the maintenance.

b. A description of site inspection procedures and documentation system, including record-keeping and retention requirements.

c. An inspection and maintenance schedule, preferably in the form of a table or matrix, for each activity for all facility components. The schedule shall demonstrate how it will satisfy the specified level of performance, and how the maintenance / inspection activities relate to storm events and seasonal issues.

d. Identification of the equipment and materials required to perform the maintenance.

5. As appropriate, list all housekeeping procedures for prohibiting illicit discharges or potential illicit discharges to the storm drain. Identify housekeeping BMPs that reduce maintenance of treatment control measures. These procedures are listed based on facility operations and can be found in the Ventura County Industrial/Commercial Clean Business Program document.

C. Spill Plan:

1. Provide emergency notification procedures (phone and agency/persons to contact)
2. As appropriate for site, provide emergency containment and cleaning procedures.
3. Note downstream receiving water bodies or wetlands which may be affected by spills or chronic untreated discharges.
4. As appropriate, create an emergency sampling procedure for spills. (Emergency sampling can protect the property owner from erroneous liability for down-stream receiving area clean-ups).

D. Facility Changes:

1. Operational or facility changes which significantly affect the character or quantity of pollutants discharging into the stormwater control measures will require modifications to the Maintenance Plan and/or additional stormwater control measures.

E. Training:

1. Identify appropriate persons to be trained and assure proper training.
2. Training to include:
   a. Good housekeeping procedures defined in the plan.
   b. Proper maintenance of all pollution mitigation devices.
   c. Identification and cleanup procedures for spills and overflows.
   d. Large-scale spill or hazardous material response.
   e. Safety concerns when maintaining devices and cleaning spills.

F. Basic Inspection and Maintenance Activities:

1. Create and maintain on site, a log for inspector names, dates and stormwater control measure devices to be inspected and maintained. Provide a checklist for each inspection and maintenance category.

2. Once annually, perform testing of any mechanical or electrical devices prior to wet weather.
3. Report any significant changes in stormwater control measures to the site management. As appropriate, assure mechanical devices are working properly and/or landscaped BMP plantings are irrigated and nurtured to promote thick growth.
4. Note any significant maintenance requirements due to spills or unexpected discharges.
5. As appropriate, perform maintenance and replacement as scheduled and as needed in a timely manner to assure stormwater control measures are performing as designed and approved.
6. Assure *unauthorized* low-flow discharges from the property do not by-pass stormwater control measures.
7. Perform an annual assessment of each pollution generation operation and it's associated stormwater control measures to determine if any part of the pollution reduction train can be improved.

G. Revisions of Stormwater Control Measures:

1. If future correction or modification of existing stormwater control measures or procedures is required, the owner shall obtain approval from the governing stormwater agency prior to commencing any work. Corrective measures or modifications shall not cause discharges to by-pass or otherwise impede existing stormwater control measures.

H. Monitoring & Reporting Program

1. The governing stormwater agency may require a Monitoring & Reporting Program to assure the stormwater control measures approved for the site are performing according to design.
2. If required by local agency, the Maintenance Plan shall include performance testing and reporting protocols.

Hydrologic Soil Groups

This appendix includes information on the Hydrologic Soil Groups in Yolo County to use in designing various stormwater control measures:

Relevance of Hydrologic Soil Groups Information

The hydrologic soil groups of a development area are pertinent to design of controls that involve infiltration and for identifying sites appropriate for detention basins. The predominant soil group will control the effectiveness of infiltration facilities or the suitability of an area for impounding water. Hydrologic soil group information should be used for preliminary siting studies only. Actual design should be based on in-situ soil investigations and testing by a qualified engineer or geologist.

Table C-1. Typical Infiltration Rates

Soil Type (Hydrologic Soil Group)	Infiltration Rate (in/hr)[1]
A	1.00 -8.3
B	0.5 -1.00
C	0.17-0.27
D	0.02-0.10

1. Infiltration rates shown represent the range covered by multiple sources, e.g. ASCE, BASMAA, etc.

Hydrologic Soil Groups

The hydrologic soil groups are classified by the USDA Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service. There are four hydrologic soil groups: A, B, C and D. Soils may be classified by two groups. Soil groups A and B have the highest infiltration rates, unless the soils under consideration have been compacted during construction. Soil groups A and B are typically the best candidate soils for construction of infiltration facilities. Sites with soil groups C and D are usually more appropriate for detention basins.

Soils in group A have a low runoff potential and high infiltration rate, as the soils typically are sands and gravel. Soil group B includes soils with moderate infiltration rates when completely wetted. Group B soils are sandy loam soils with moderately fine to moderately coarse textures. Soils in group C have slow infiltration rates when thoroughly wetted and these soils typically are silty-loam soils with an impeding layer or soils with moderately fine to fine texture. Group D soils have a high runoff potential and very slow infiltration rate when thoroughly wetted. Group D soils include clay soils with high swelling potential, soils in a permanent high water table and shallow soils over nearly impervious material.

The hydrologic soil information presented here should be used as a general overview. For more specific information, consult the *Yolo County Soil Survey* (USDA, NRCS) or contact the NRCS at (530) 662-3986.

Plants Suitable for Vegetative Control Measures

Vegetation serves primarily to maintain soil porosity and prevent erosion. The effectiveness and aesthetic appeal of control measures are enhanced by selection of appropriate vegetative cover. Turf grass is preferred, and some other ground covers also may be appropriate. An important maintenance consideration in the selection of appropriate vegetation is whether irrigation is planned for the site. Consult with City stormwater staff regarding selection of appropriate vegetation.

Table F-1 provides a sample list of appropriate vegetative covers. Additional suggested vegetative species are listed in Table F-2. The tables are intended as guides in selecting vegetative covers. For specific species suitability and care information, refer to the sources listed for these tables. Contact the Natural Resources Conservation Service for additional information.

Table F-1. Sample List of Appropriate Vegetative Covers

Plant Name Common (Latin)	Appropriate Species	Maintenance and Usage Notes*
Bermuda Grass (Cynodon)	Common	Moderate maintenance. Dormant (brown) in winter. Heat tolerant. Erosion control, swales.
Fescue (Festuca)	Red fescue (F. rubra)	Low to moderate maintenance. Tolerates some shade and poor soil. Lawns, swales, erosion control.
	"Kentucky 31" Tall Fescue (F. elatior)	Low maintenance. Tolerate shade and compacted soils. Rapid germination. Lawns, swales, erosion control. Useful as overseed for Bermuda grass during dormant (winter) season.
Ryegrass (Lolium)	Perennial (L. perenne)	Moderate maintenance. Heat intolerant. Fast sprouting. Useful as overseed for Bermuda grass during dormant (winter) season. Swales.
	Annual (L. multiflorum)	Annual (may live several seasons in mild climate). Moderate maintenance. Heat intolerant. Fast growing. Useful as overseed for winter-dormant species. Swales.

*Generally, these species will require supplemental irrigation.
Sources: ASCE, MWCG, Sunset

Table F-2. Additional Suggested Vegetative Covers

Plant Name Common (Latin)	Appropriate Species	Usage Notes
Kentucky Bluegrass	(Poa pratensis)	Irrigated Sites
Orchard grass (Dactylis)	"Akaroa" or "Berber" (D. glomerata)	Irrigated and Non-irrigated Sites
Wheatgrass (Agropyron)	"Luna" or "Topar" pubescent (A. intermedium trichophorum)	Irrigated and Non-irrigated Sites
Zorro Fescue (Vulpia)	(V. myuros)	Irrigated and Non-irrigated Sites
Creeping wild Rye (Leymus)	(L. triticoides)	Nonirrigated Sites
Brome (Bromus)	Blando (B. mollis)	Nonirrigated Sites
	California or "Cucamonga" (B. carinatus)	Nonirrigated Sites

Sources: NRCS-FOTG

Manual of Standards for Erosion and Sediment Control Measures, Association of Bay Area Governments, 1995

Appendix G

Design Forms

Design Procedure Form for G-5.1: Turf Buffer

Designer: ____________________

Company: ____________________

Date: ____________________

Project: ____________________

Location: ____________________

1. Design Flow	$Q_{P,\ SQDF}$ = ________ cfs
2. Design Width W_{TB} = (SQDF) / 0.05 cfs/ft	W_{TB} = ________ ft.
3. Design Length (8 ft minimum)	L_{TB} = ________ ft.
4. Design Slope (10 percent maximum)	L_{TB} = ________ %
5. Flow Distribution (Check type used or describe "Other")	____ Slotted curbing ____ Modular Block Porous Pavement ____ Level Spreader ____ Other ________
6. Vegetation (describe)	____ ________
7. Outflow Collection (Check type used or describe "Other")	____ Grass-lined Channel / Swale ____ Street Gutter ____ Storm Drain ____ Underdrain Used ____ Other ________

Notes ____________________

Design Procedure Form for G-5.2: Grass–lined Channel

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

1. Design Flow	$Q_{P, SQDF}$ = ________ cfs
2. Channel Geometry A. Channel Bottom Width (b) B. Side slope (Z)	 b = ________ ft. Z = ________
3. Design Slope A. s = 2 percent maximum B. No. of grade controls required	 s = ________ % ________ (number)
4. Depth of flow at SQDF (d = 2 ft max, Manning n= 0.05)	d = ________ ft.
5. Flow velocity at SQDF (v= 1.5 ft/s max, Manning n= 0.05)	v = ________ ft/s
6. Vegetation (describe)	________ ________
7. Outflow Collection (Check type used or describe "Other")	____ Grated Inlet ____ Infiltration Trench ____ Other ________ ________

Notes ____________________

Design Procedure Form for T-1: Grass Strip Filter (GSTF)

Designer: ______________________________

Company: ______________________________

Date: ______________________________

Project: ______________________________

Location: ______________________________

1. Design Flow	$Q_{P,SQDF}$ = ____________ cfs
2. Design Width W_{GSTF} = (SQDF) / 0.005 cfs/ft	W_{GSTF} = ____________ ft.
3. Design Length (15 ft minimum)	L_{GSTF} = ____________ ft.
4. Design Slope (s_{GSTF} =4 percent maximum)	s_{GSTF} = ____________ %
5. Flow Distribution (Check type used or describe "Other")	_____ Slotted curbing _____ Modular Block Porous Pavement _____ Level Spreader _____ Other ____________ ____________
6. Vegetation (describe)	_____ ____________
7. Outflow Collection (Check type used or describe "Other")	_____ Grass Channel / Swale _____ Street Gutter _____ Storm Drain _____ Underdrain Used _____ Other ____________ ____________

Notes ______________________________

____

____

____

Design Procedure Form for T-2: Grass Swale Filter (GSWF)

Designer:________________________________

Company:________________________________

Date:________________________________

Project:________________________________

Location:________________________________

1. Design Flow	$Q_{P, SQDF}$ = __________ cfs
2. Swale Geometry a. Swale Bottom Width (b) b. Side slope (Z)	b = __________ ft. Z = __________
3. Design Slope a. s = 2 percent maximum b. No. of grade controls required	s = __________ % __________ (number)
4. Depth of flow at SQDF (d=5 in. max, Manning n= 0.20)	d = __________ inches
5. Design flow velocity (v= 1.0 ft/s max, Manning n= 0.20)	V = __________ft/sec
6. Design Length (minimum) Minimum L = (10 min) × (flow velocity, ft/sec) × 60, or 100 ft, whichever is greater	L = __________feet
7. Vegetation (describe)	Tall Fescue __________ __________
8. Outflow Collection (Check type used or describe "Other")	_____ Grated Inlet _____ Infiltration Trench _____ Underdrain Used _____ Other __________ __________

Notes ________________________________

Design Procedure Form for T-3: Extended Detention Basin

Designer:__________

Company:__________

Date:__________

Project:__________

Location:__________

1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = ______ %
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} = ______ %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u= ______ in.
d. Watershed Area Tributary to EDB	Area = ______ acres
e. Calculate SQDV SQDV = (V_u / 12) × Area	SQDV = ______ acre-ft
f. Calculate Design Volume Design Volume = SQDV × 1.2	Design Volume = ______ acre-ft
2. Outlet Works	
a. Outlet Type (check one)	Single Row Orifice ______ Perforated Plate ______ Perforated Pipe ______ Other ______
b. Depth of water above bottom orifice	Depth = ______ feet
c. Single Orifice (or Single Row) Outlet	
1) Total Area	A = ______ square inches
2) Diameter or W × L	D = ______ inches
d. Perforated Outlet (Plate or Pipe)	
1) Area per row of perforations	A = ______ square inches
2) Perforation Diameter (2 inches max.)	D = ______
3) No. of Perforations (columns) per Row	Perforations = ______
4) No. of Rows (4 inch spacing)	Rows = ______
5) Total Orifice Area (Area per row) × (Number of Rows)	Area = ______ square inches

Design Procedure Form for T-3: Extended Detention Basin (Page 2 of 2)

Project:____________________

3. Trash Rack or Gravel Pack (check one)	Trash Rack_____ Gravel Pack_____
4. Basin Length-Width Ratio (2:1 minimum)	Ratio = __________ L:W
5. Two-Stage Design	
a. Upper Stage	
1) Depth (2 feet minimum)	Depth = __________ Feet
2) Width (30 feet minimum)	Width = __________ Feet
3) Bottom Slope (2% to low flow channel)	Slope = __________ %
b. Bottom Stage	
1) Depth (1.5 to 3 feet deeper than Upper)	Depth = __________ Feet
2) Storage Volume (5-15% of SQDV min.)	Volume = __________ Acre-ft
6. Forebay Design	
a. Forebay Volume (5-10% of SQDV min.)	Volume = __________ Acre-ft
b. Outlet pipe drainage time (<5 minutes @ 5 %)	Drainage Time __________ Minutes
7. Low Flow Channel	
a. Depth (9 inches min.)	Depth = __________ Feet
b. Flow Capacity (2 × outlet for Forebay)	Flow Capacity = __________ GPM/CFM
8. Vegetation	Native Grasses __________
	Irrigated Turf __________
	Other __________
9. Embankment Slope	
a. Interior Slope (4:1 max.)	Interior Slope = __________ H/V
b. Exterior Slope (3:1 max.)	Exterior Slope = __________ H/V
10. Access	
a. Slope (10% max.)	Slope = __________ %
b. Width (16 feet min.)	Width = __________ Feet

Notes

Design Procedure Form for T-4: Wet Detention Basin

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	________	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12-hr drawdown and I_{wq}	V_u=	________	acre-ft
d. Watershed Area Tributary to WDB	Area =	________	acres
Calculate SQDV = (V_u / 12) × Area	SQDV =	________	acre-ft
2. Permanent Pool			
a. Volume of Permanent Pool (1.0 to 1.5 times SQDV minimum)	V_p =	________	acre-ft
b. Depth			
1) Littoral Zone Depth (6 to 12 inches)	Depth =	________	feet
2) Deeper Zone Depth (4 to 8 ft average, 10 ft max)	Average Depth =	________	feet
	Max Depth =	________	feet
c, Permanent Pool Surface Area			
1) Littoral Zone Area (25%-40% Permanent Pool Surface)	Area =	________	acres
	% of total	________	%
2) Deeper Zone Area (60%- 40% Permanent Pool Surface)	Area =	________	acres
	% of total	________	%
3) Total Area	Total area =	________	acres
3. Estimated Net Base Flow (must be > 0)			
$Q_{net} = Q_{inflow} - Q_{evap} - Q_{seepage} - Q_{evapotranspiration}$	Q_{inflow} =	________	Acre-ft
	Q_{evap} =	________	Acre-ft
	$Q_{seepage}$ =	________	Acre-ft
	$Q_{evapotranspiration}$	________	Acre-ft
	Q_{net} =	________	Acre-ft

Design Procedure Form for T-4: Wet Detention Basin (Page 2 of 3)

Project:____

4. Outlet Works		
a. Outlet Type (check one)	Single Row Orifice ________ Perforated Plate ________ Perforated Pipe ________ Other ________________	
b. Depth of water above bottom orifice	Depth = ________	feet
c. Single Orifice (or Single Row) Outlet		
1) Total Area	A = __________	square inches
2) Diameter or W × L	D = __________	inches
d. Perforated Outlet (Plate or Pipe)		
1) Area per row of perforations	A = ________	square inches
2) Perforation Diameter (2 inches max.)	D = ________	
3) No. of Perforations (columns) per Row	Perforations = ________	
4) No. of Rows (4 inch spacing)	Rows = ________	
5) Total Orifice Area (Area per row) × (Number of Rows)	Area = __________	square inches
5. Trash Rack or Gravel Pack Present?	Yes/No ________	
6. Basin Shape		
a. Length-Width Ratio	Ratio = __________	L:W
7. Forebay Design		
a. Forebay Volume (5-10% of SQDV min.)	Volume = ________	Acre-ft
8. Embankment Slope		
a. Interior Slope (4:1 max.)	Interior Slope = ________	L/W
b, Exterior Slope (3:1 max.)	Exterior Slope = ________	L/W

Design Procedure Form for T-4: Wet Detention Basin (Page 3 of 3)

Project:______________________________

9. Vegetation (Check type used or describe "Other")	_____ Native Grasses _____ Irrigated Turf Grass _____ Emergent Aquatic Plants (specify type / density) _____ Other ____________________
10. Underdrains Provided?	Yes /No __________

Notes:

Design Procedure Form for T-5: Constructed Wetlands Basin

Designer:______________________________

Company:______________________________

Date:______________________________

Project:______________________________

Location:______________________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	________	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 24 hr drawdown and I_{wq}	V_u=	________	in.
d. Watershed Area Tributary to CWB	Area =	________	acres
e. Calculate SQDV SQDV = (V_u / 12) × Area	SQDV =	________	acre-ft
2. Wetland Pond Volume, Depth, and Water Surface Area		**Minimums**	
a. Permanent Pool: Minimum $Vol_{pool} \geq 0.75 \times$ SQDV	Vol_{pool} >	________	acre-ft
	Water Area>	________	acres, estimated
		Actual Design	
	Vol_{pool} =	________	acre-ft, actual
	Water Area =	________	acres, actual
b. Forebay Depth Range = 2.0' – 4.0'	Depth =	________	ft
Volume Range = 5% to 10 % of SQDV	Volume =	________	acre-ft,% =____
c. Outlet Pool Depth Range = 2.0' – 4.0'	Depth =	________	ft
Volume Range = 6% to 10% of SQDV	Volume =	________	acre-ft,% =____

Continued on next page

Design Procedure Form for T-5: Constructed Wetlands Basin (Page 2 of 3)

Project:___________________________

2. Wetland Pond Volume, Depth, and Water Surface Area (Continued)			
d. Free Water Surface Areas			
(Depth Range = 2.0' – 4.0')	Depth =	______	ft
(Area = 30-50% combined)	Area =	______	acres, % = ____
	Volume =	______	acre-ft
e. Wetland Zones with Emergent Vegetation	Depth =	______	ft
(Depth Range = 6" – 12")	Area =	______	acres, % = ____
(Area = 50-70%)	Volume =	______	acre-ft
3. Estimated Net Base Flow (must be > 0)			
$Q_{net} = Q_{inflow} - Q_{evap} - Q_{seepage} - Q_{evapotranspiration}$	Q_{inflow} =	______	acre-ft
	Q_{evap} =	______	acre-ft
	$Q_{seepage}$ =	______	acre-ft
	$Q_{evapotranspiration}$	______	acre-ft
	Q_{net} =	______	acre-ft
4. Outlet Works			
a. Outlet Type (check one)	Single Row Orifice	______	
	Perforated Plate	______	
	Perforated Pipe	______	
	Other	______	
b. Depth of water above bottom orifice	Depth =	______	feet
c. Single Orifice (or Single Row) Outlet			
1) Diameter	D =	______	feet
2) Area	A =	______	square feet
d. Perforated Outlet (Plate or Pipe)			
1) Area per row of perforations	A =	______	square inches
2) Perforation Diameter (2 inches max.)	D =	______	
3) No. of Perforations (columns) per Row	Perforations =	______	
4) No. of Rows (4 inch spacing)	Rows =	______	
5) Total Orifice Area (Area per row) × (Number of Rows)	Area =	______	square inches

Design Procedure Form for T-5: Constructed Wetlands Basin (Page 3 of 3)

Project:____

5. Trash Rack or Gravel Pack Present?	Yes/No __________
6. Basin Shape a. Length-Width Ratio	Ratio = __________ L:W
7. Embankment Slope a. Interior Slope (4:1 max.) b, Exterior Slope (3:1 max.)	Interior Slope = ________ L:W Exterior Slope = ________ L:W
8. Vegetation (Check type used or describe "Other")	____ Native Grasses ____ Irrigated Turf Grass ____Wetland Plants (specify type / density)* ____ Other ____________________ *Describe Species Density and Mix: __________

Notes:

Design Procedure Form for T-6: Detention Basin / Sand Filter

Designer: ______________________________

Company: ______________________________

Date: ______________________________

Project: ______________________________

Location: ______________________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	________	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	________	acre-ft
d. Watershed Area Tributary to DBSF	Area =	________	acres
e. Calculate SQDV $SQDV = (V_u / 12) \times Area$	SQDV =	________	acre-ft
2. Filter Surface Area (A_s)			
a. A_s (min) = (SQDV / 3) × 43,560 ft^2	A_s (min) =	________	ft^2
b. Design A_s	Design A_s =	________	ft^2
3. Design basin depth, based on design filter area			
D = Design Volume/ Design A_s	D =	________	ft
4. Filter Bed		________	
a. ASTM C33 Sand Layer (18 in. minimum)		________	inches
b. ASSHTO M43-No.8 Gravel Layer (9 in. min.)			inches

Notes:

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Design Procedure Form for T-7: Porous Pavement Detention

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	________	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12 hr drawdown and I_{wq}	V_u=	________	acre-ft
d. Watershed Area Tributary to PPD	Area =	________	acres
e. Calculate SQDV SQDV = (V_u / 12) × Area	SQDV =	________	acre-ft
2. Basin Surface Area			
a. Design Volume (minimum = SQDV)	Design Volume =	________	ft^3
b. A_s = Design Volume / (0.17 ft) (based on surcharge depth of 2 inches)	A_s =	________	ft^2
3. Block Type	Block name:	________	
	Manufacturer:	________	
a. Minimum open area = 40%	Open Area =	________	%
b. Minimum thickness = 4 inches	Thickness	________	inches
4. Base Course (Check)			
a. ASTM C33 Sand Layer (1 inch)	Sand Layer	________	
b. ASSHTO M43-No.8 Gravel Layer (9 inches)	Gravel Layer	________	

Notes:

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Design Procedure Form for T-8: Porous Landscape Detention Basin

Designer: ______________________________

Company: ______________________________

Date: ______________________________

Project: ______________________________

Location: ______________________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	________	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12 hr drawdown and I_{wq}	V_u=	________	acre-ft
d. Watershed Area Tributary to PLD	Area =	________	acres
e. Calculate SQDV SQDV = (V_u / 12) × Area	SQDV =	________	acre-ft
2. Basin Surface Area			
a. Design Volume (Minimum = SQDV)	Design Volume =	________	ft^3
b. Average Depth	Average Depth =	________	ft
c. A_s = Design Volume / Average Depth	A_s =	________	ft^2
3. Base Course Layers (check)	Sandy Loam Turf	________	in. (6" min)
	Sand/peat mix	________	in. (18" min)
	Gravel	________	in. (9" min)
4. Subsurface Drainage (check type used)	________	Infiltration to subgrade with permeable geotextile membrane	
	________	Underdrain with impermeable membrane	
	________	Underdrain with permeable goetextile membrane	

Notes:

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Design Procedure Form for T-9: Infiltration Basin

Designer:______________________________

Company:______________________________

Date:______________________________

Project:______________________________

Location:______________________________

1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = ________ %
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} = ________ %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u= ________ acre-ft
d. Watershed Area Tributary to INB	
e. Calculate SQDV SQDV = (V_u / 12) × Area	Area = ________ acres SQDV = ________ acre-ft
2. Maximum Allowable Depth ($D_m = (I \times t) / (12 \times s)$)	
a. Site infiltration rate (I)	I = ________ in/hr
b. Drawdown time (t = 40 hours)	t = ________ hrs
c. Safety factor (s)	s = ________
d. $D_m = (I \times t) / (12 \times s)$	D_m = ________ ft.
3. Basin Surface Area $A_m = SQDV \times 43{,}560 / D_m$	A_m = ________ ft^2
4. Vegetation (Check type used or describe "Other")	____ Native Grasses ____ Irrigated Turf Grass ____ Other ________________

Notes:

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Design Procedure Form for T-10: Infiltration Trench

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	________	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	________	acre-ft
d. Watershed Area Tributary to DBSF	Area =	________	acres
e. Calculate SQDV SQDV = (V_u / 12) × Area	SQDV =	________	acre-ft
2. Trench Water Depth			
a. Soil infiltration rate	I =	________	In/hr
b. Safety factor (S)	s =	________	ft
c. Drawdown time (t = 40 hours)	t =	________	hrs
d. Max water depth (≤ 8 ft)			
$D_m = (I \times t) / (12 \times s)$	D_m =	________	ft.
3. Trench Bottom Surface Area			
$A_s = SQDV \times 43{,}560 / D_m$	A_s =	________	ft^2

Notes:

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Design Procedure Form for T-11.1: Austin Sand Filter

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = ________ %
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} = ________ %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u = ________ in.
d. Watershed Area Tributary to Austin Filter	Area = ________ acres
e. Calculate SQDV SQDV = (V_u / 12) × Area	SQDV = ________ acre-ft
2. Maximum Water Depth	
a. Storm drainage system invert elevation at proposed connection to storm drain	Inlet Elevation ________ ft
b. Minimum control measure outlet invert elevation of sand filter at minimum grade:	Outlet Elevation ________ ft
c, Estimate filter depth or use minimum depth of filter media and determine the difference in elevation between inverts of filter inlet and outlet:	Filter Depth ________ ft
d. Site plan surface elevation at control measure location	Surface Elevation ________ ft
e. Determine inlet invert elevation into sedimentation basin	Inlet Elevation (Sed. Basin) ________ ft
f. Determine maximum allowable depth of water (2h) in the sedimentation basin considering elevation differences between inlet and outlet invert elevations of sedimentation basin and filter and surface elevation. (This height will establish weir height or elevation of inlet invert for bypass pipes and orifices.)	Maximum Allowable Depth ________ ft

Design Procedure Form for T-11.1: Austin Sand Filter (Page 2 of 2)

Project:_______________

3. Filter Surface Area			
a. Sand Bed Depth	d_f =	______	ft
b. Coefficient of permeability for sand filter	k =	______	ft. / hr.
c. One half of maximum allowable depth over filter. (h)	h =	______	ft
d. Time required for runoff to pass through filter.	t_f =	______	hrs.
e. Filter Surface Area (minimum) $A_{fm} = \frac{(SQDV)(d_f)}{(k)(h+d_f)(t_f)}$	A_{fm} =	______	ft^2
4. Filter Basin Volume			
Filter Basin Volume = 0.2 × SQDV	FBV =	______	ft^3

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Design Procedure Form for T-11.2: DC Sand Filter

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = ________ %
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} = ________ %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u= ________ in.
d. Watershed Area Tributary to DC Filter	Area = ________ acres
e. Calculate SQDV SQDV = (V_u / 12) × Area	SQDV = ________ acre-ft
2. Minimum Filter Area $A_{fm} = \dfrac{(SQDV)(d_f)}{(k)(h+d_f)(t_f)}$	
a. SQDV	SQDV = ________ ft^3
b. Sand bed depth (d_f)	d_f = ________ ft
c. Filter Coefficient (k)	k = ________ ft. / hr.
d. Draw-down time (t_f= 40 hour)	t = ________ hr
e. one half maximum allowable water depth over filter (h)	h = ________ ft
f. Minimum filter area	A_{fm} = ________ ft^2
3. Select Filter Width, Compute Filter Length	
a. Select a Filter Width (W_f)	W_f = ________ ft.
b. Compute filter length $L_f = A_{fm}/W_f$	L_f = ________ ft.
c. Determine adjusted filter area (Round L_f to closest whole number) $A_f = W_f \times L_f$	A_f = ________ ft^2
(From this point, formula assume rectangular cross section of filter shell.)	

Design Procedure Form for T-11.2: DC Filter (Page 2 of 2)

Project:__________

4. Compute the Storage Volume of Top of the Filter (V_{tf}) $V_{tf} = A_f \times 2h$	V_{tf} = ________ ft^3
5. Compute the Storage in the Filter Voids (Vv) (Assume 40% voids in the filter media) $V_v = A_f \times (d_f + d_g) \times 0.40$	V_v = ________ ft^3
6. Flow Through Filter During Filling (V_Q) (Assume 1-hour to fill) $V_Q = k \times A_f \times (d_f + h) \times t_{ff} / d_f$ Use: k = 2 ft/day = 0.0833 ft/hr. t_{ff} = 1 hr. to fill voids	V_Q = ________ ft^3
7. Compute Net Volume to be Stored in Permanent Pool Awaiting Filtration (Vst) $V_{st} = SQDV - V_{tf} - V_v - V_Q$	V_{st} = ________ ft^3
8. Compute Minimum Length of Permanent Pool (Lpm) $L_{pm} = V_{st} / (2h \times W_f)$	L_{pm} = ________ ft
9. Compute Minimum Length of Sediment Chamber (L_s) (to contain 20% of SQDV) If $V_{st} < (0.2SQDV)$, use: $L_s = (0.2 \times SQDV)/(2h \times W_f)$ If $V_{st} > (0.2SQDV)$, use: $L_s = V_{st} / (2h \times W_f)$	L_s = ________ ft
10. Set Final Length of Permanent Pool (Lp) If $L_{pm} \geq (L_s + 2\text{ ft})$, use: $L_p = L_{pm}$ If $L_{pm} < (L_s + 2\text{ ft})$, use: $L_p = (L_s + 2\text{ ft})$	L_p = ________ ft
11. Set Final Length of Clear Well (L_{cw}) L_{cw} = 3 ft minimum	L_{cw} = ________ ft

Notes:__________

Design Procedure Form for T-11.3: Delaware Sand Filter

Designer:________________

Company:________________

Date:________________

Project:________________

Location:________________

1. Minimum Surface Areas of the Chambers If 2h < 2.67 feet (2'-8") $A_{sm} = A_{fm} = SQDV / (4.1 \times h + 0.9)$ If 2h > 2.67 feet (2'-8") $A_{sm} = A_{fm} = \frac{(SQDV)(d_f)}{(k)(h + d_f)(t_f)}$	
a. SQDV	SQDV = ________ ft^3
b. Sand bed depth (d_f)	d_f = ________ ft
c. Filter Coefficient (k)	k = ________ ft. / hr.
d. Draw-down time (t_f)	t = ________ hr
e. One half maximum allowable water depth over filter (h)	h = ________ ft
f. A_{sm} (Sediment Chamber Area) and A_{fm} (Filter Surface Area)	A_{sm} and A_{fm} = ________ ft^2
2. Sediment Chamber and Filter Width / Length	
a. Select width ($W_s = W_f$ = 18 to 30 inches)	$W_s = W_f$ = ________ ft.
b. Filter length ($L_s = L_f = A_{fm} / W_f$)	$L_s = L_f$ = ________ ft.
c. Adjusted length (rounded)	$L_s = L_f$ = ________ ft.
d. Adjusted area ($A_s = A_f = W_f \times L_f$)	$A_s = A_f$ = ________ ft^2
3. System Storage Volume	
a. Storage in filter voids ($V_v = A_f \times (d_f + d_g) \times 0.4$)	V_v = ________ ft.
b. Flow through filter $V_Q = k \times A_f \times (d_f + h) \times 1hr/d_f$	V_Q = ________ ft.
c. Required net storage ($V_{st} = SQDV - V_v - V_Q$)	V_{st} = ________ ft.
d. Available storage ($V_{sf} = 2h(A_f + A_s)$) If $V_{sf} \geq V_{st}$, sizing is complete If $V_{sf} < V_{st}$, repeat steps 2 and 3	V_{sf} = ________ ft^2

Design Procedure Form for T-11.3: Delaware Sand Filter

Location: ______________________

Notes: ______________________

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CITY OF WOODLAND

STORM DRAINAGE FACILITIES MASTER PLAN UPDATE AND PRELIMINARY ENGINEERING

STORM DRAINAGE GUIDELINES AND CRITERIA

MARCH 2005

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INTRODUCTION

This document presents the study guidelines and criteria that will be used to formulate and complete conceptual designs for the City of Woodland's (City) Storm Drainage Facilities Master Plan. To provide a regional approach to storm drainage planning and design, the study guidelines and criteria were established after reviewing current practices of the City of Woodland, the City of Sacramento, the County of Sacramento, and the County of Yolo.

DRAINAGE GUIDELINES

The City's 1996 General Plan formalizes the long-term proposal for the physical development of the City. The Plan also outlines policies, standards, and programs to guide development-related decisions through the year 2020.

The City's 1996 General Plan Policy Document was reviewed for drainage-related policies and standards. The purpose of the review was to identify the drainage principles to formulate the Storm Drainage Facilities Master Plan. The resulting guidelines are as follows:

- The City shall require public facilities be developed to serve new development. The City will continue to improve the efficiency and quality of its public facilities and services.

- The City shall require the new developments to pay a fair share of the new public services and/or the cost to upgrade all existing facilities that are used, based upon the demand for these facilities attributable to the new developments.

- The City shall require the new developments to provide for the overland flow of storm water exceeding the City's standard design capacity of the storm drainage system. These overland flow waters shall be conveyed over public streets where possible and shall be at least one foot below building pad elevations.

- The City shall encourage project designs that minimize drainage concentrations and impervious coverage.

- The City shall prohibit grading activities during the rainy season, unless adequately mitigated, to avoid sedimentation of storm drainage facilities.

- The City shall require projects that have significant impacts on the quantity and quality of surface water runoff to incorporate mitigation measures for impacts related to urban runoff.

- The City shall require future drainage systems to comply with applicable state and federal pollutant discharge requirements.

- The City shall seek to minimize operational complexities and maintenance requirements of the storm drainage system.

- The City shall allow the construction of storm water detention facilities to mitigate drainage impacts and reduce storm drainage system costs. To the extent practical, storm water detention facilities should be designed for multiple purposes, including recreational and/or storm water quality improvement.

- The City shall consider using storm water of adequate quality to replenish local groundwater basins, restore wetlands and riparian habitat, and irrigate agricultural land.

STORM DRAINAGE DESIGN CRITERIA

The design criteria for storm drainage facilities are presented in this section. These criteria will provide the basis to determine the size and configuration of the respective facilities. The City has developed and adopted Standard Specifications and Details in 2002 that will take precedence over any conflict with these criteria.

Since different types of facilities serve different purposes that may require different levels of flood protection, storm water quality treatment, and/or maintenance and operation, it is appropriate to classify and define various types of drainage facilities.

1. Facilities Classifications

For the purpose of presentation and design, the following classifications/definitions will be used to define storm drainage facilities.

Primary Drainage (Type 1) – Drainage facilities including open channels, culverts associated with channels, bridges, detention ponds, pump stations, regional storm water quality treatment serving greater than 30 acres, and levees.

Secondary Drainage (Type 2) – Drainage facilities such as roadside ditches, storm drainage pipe systems (pipes, inlets, outlets, manholes, etc.), storm water quality treatment serving less than 30 acres, and overland conveyance systems.

Minor/On-Site Drainage (Type 3) – Drainage facilities serving areas of less than 30 acres or drainage facilities required to carry runoff within the development, such as yard drains/swales, footing drains, and roof drains. Note that minor/on-site storm drains are considered part of on-site infrastructure development from a cost perspective and are to conform to design criteria consistent with secondary drainage.

2. Design Capacities

Drainage facilities shall be designed to accommodate the future development of the entire upstream watershed. The future development shall be defined as full build-out of the General Plan Land Use Designations.

The capacity design criteria for storm drainage facilities are as follows:

Pipelines – Pipelines shall be designed to convey the 10-year flood event while maintaining the hydraulic grade line at least one foot below the elevation of inlet grates and manhole covers.

Open Channel – Open channels shall be designed to convey the 100-year flood event while maintaining at least one foot of freeboard in cut sections and three feet of freeboard in leveed sections, except where Federal Emergency Management Agency (FEMA) freeboard requirements stipulate more stringent requirements.

Bridges – Bridges shall be designed to pass the 100-year flood while maintaining a minimum of one foot of freeboard to the low chord.

Culverts – Culverts (associated with open channels) shall be designed to pass the channel design capacity while meeting freeboard requirements.

Storage Facilities – Storage facilities shall be designed to contain or attenuate the appropriate long duration 100-year storm event (three, five, or ten days), while maintaining at least three feet of freeboard in leveed sections and one foot of freeboard in cut sections in the pond, and without creating excessive backwater effects on the tributary storm drainage system.

Overland Conveyance System

Due to the variability of development, the City will require sufficient identification, on a project-by-project basis, for the design of overland conveyance to determine the maximum 100-year flooding created by new development. This will include hydrologic and hydraulic consideration of runoff draining through or around the proposed development as well as peak flow, normal depth, backwater, and storage calculation checks at key locations (upstream, adjacent, or downstream), identified on a project-by-project basis during the improvement plan check process. All overland conveyance shall be considered with simultaneous 50% blockage of inlets to any proposed/designed subsurface drainage system.

Roadways – All roadways may be used to convey runoff from developed areas in excess of storm drain capacities. Such conveyance shall be designed to convey the 100-year runoff while maintaining a 12-foot travel way that does not exceed 8 inches of flood depth anywhere along the travel way for emergency vehicular access. All overland release shall be consistent with and directed to Drainage Master Plan facilities and shall not supersede or override other City requirements related to Planning, Transportation, or other departments. As a drainage conveyance facility, it shall also meet all freeboard requirements associated with structures in the National Flood Insurance Program.

Greenbelts – Greenbelts may be used to convey runoff consistent with and directed to Drainage Master Plan facilities. Conveyance through greenbelts shall meet all applicable freeboard requirements and not conflict with other primary or secondary uses associated with the greenbelt designation. Storm water quality treatment shall not be incorporated into greenbelt design unless all storm water quality criteria are in accordance with the City's Technical Guidance Manual, and greenbelt runoff does not co-mingle with urban runoff downstream of the greenbelt runoff point situated upstream of planned regional storm water quality treatment facilities. When conveyance of storm water through a greenbelt is considered, the City shall have the final determination for the most appropriate vegetation/landscaping as it relates to hydraulic capacity as well as operation and maintenance considerations. Final determinations shall be made on a project-by-project basis during the City planning processes.

3. Hydrologic Methodologies

Three methods of estimating design flow are allowable. The methods, allowable applications, and locations of additional information are summarized in Table 1.

4. Hydraulic Methodologies

Hydraulic computations may be based upon the Manning's Formula, the U.S. Army Corps of Engineers' (USACOE) HEC-RAS (or the older HEC-2) computer program, or the EXTRAN Block of the Environmental Protection Agency's (EPA) Storm Water Management Model (SWMM) Computer Model. Manning's "n" values shall be obtained from Table 2.

Open channel contraction and expansion loss coefficients for gradual transitions will be 0.1 and 0.3, respectively. Computational step-backwater contraction (downstream face) and expansion (upstream face) loss coefficients of 0.3 and 0.5, respectively, shall be used for losses between bridge cross sections.

Storm sewer systems consisting of concrete pipe may be designed using a Manning's "n" of 0.013, provided the losses at the manholes are adequately accounted for. Manhole losses shall be computed as follows:

$$H_{ah} = K(\frac{V_o^2}{2g})$$

$$K = K_O\, C_D\, C_d\, C_Q\, C_P\, C_B$$

Where:

H_{ah} = manhole head loss;

g = acceleration due to gravity;

K = adjusted loss coefficient;

K_O = initial head loss coefficient based upon relative access hole size;

C_D = correction factor for pipe diameter (pressure flow only);

C_d = correction factor for flow depth;

C_Q = correction factor for relative flow;

C_P = correction factor for plunging flow;
C_B = correction factor for benching; and

V_O = velocity of outlet pipe.

Note: For correction factors, refer to the report entitled, "Urban Drainage Design Manual Hydraulic Engineering Circular No. 22," U.S. Department of Transportation, Washington, D.C., November 1996.

For planning purposes, the following adjusted loss coefficients (K) may be used depending upon the angle between the inflow and outflow pipes:

Angle	K
180 degrees	0.114
135 degrees	0.834
90 degrees	1.129

A value of n = 0.015 may be used if manhole losses are not computed.

5. Drainage Easements

All drainage facilities other than on-site systems shall be located in one of the following:

a. Public street or alley.

b. Public utility easement, specifically dedicated to include drainage facilities.

c. Dedicated drainage easement.

Closed Conduit – Easements for closed conduits shall meet the following requirements:

- Minimum width of ten feet with the centerline of the pipe at quarter point; pipe may reverse sides at angle points.

- For pipes exceeding 24 inches in diameter or trenches exceeding five feet in depth, the easement width shall be based upon the following formula:

  WIDTH = (2 x Trench Depth) + Pipe Diameter + Two Feet; or 15 feet, whichever is greater.

- Minimum width of 15 feet for side and back lot drains in a subdivision. Note that side and back lot drains are discouraged and require specific approval from the City Engineer.

Open Channels – Easements for open channels shall have a minimum width to contain the channel, fencing where required, and a fifteen-foot all-weather service road, and a secondary 10-foot service road, where required by the City. The City, on a project-by-project basis may require a larger easement at specific locations to accommodate appurtenances and operation and maintenance considerations.

6. Pipes

Storm drainage pipes shall be reinforced concrete pipe (single-gasket or double-gasket joints) unless specific approvals are obtained from the City to use other pipe material. The City will not consider the construction of non-reinforced or cast-in-place concrete.

For planning purposes, development shall consider the installation of reinforced concrete pipe for all cost estimates. All pipes shall be constructed with a minimum cover of two feet, or as approved by the City's Director of Public Works or the City Engineer.

The minimum velocity in closed conduits shall be two feet/sec when flowing full. The minimum pipe diameter shall be eighteen inches.

7. Flowage Easements

Where the flooding of land outside the City and urban growth area serves to attenuate the peak runoff similar to a detention pond, a flowage easement shall be acquired to ensure the functional integrity of the land as a component of the City's storm drainage system is preserved over time.

8. Manholes

Standard pre-cast concrete or saddle type manholes shall be used where required. Maximum spacing between manholes shall be 500 feet for pipe sizes of 48 inches and under, and 800 feet for pipes of 54 inches and larger.

Manholes shall be located at junction points, angle points greater than 20 degrees, and changes in conduit size. On curved pipes with a radius of 200 feet to 400 feet, manholes shall be placed at the beginning of curve, ending of curve and at 300 feet maximum intervals along the curve. On curves with a radius exceeding 400 feet, manholes shall be placed at the beginning of curve, ending of curve and at 400 maximum intervals along the curve for pipes 24 inches and less in diameter and 500 feet maximum intervals along the curve for pipes greater than 24 inches in diameter.

9. Inlets

The spacing of storm drain inlets shall not exceed a maximum of 500 feet. Drainage inlets shall be located to prevent surface flow through street intersections under 10-year (design pipe) conditions.

10. Open Channels

Requirements for open channels are as follows:

a. Drainage may be conveyed through an open channel under the following criteria:

   (1) The flow exceeds the capacity of a 72-inch pipe.

   (2) The outfall is at an elevation where minimum cover cannot be obtained over the pipe.

   (3) City policy requires the channel to remain natural.

   (4) Approval of the City's Director of Public Works is obtained.

b. Channels shall be constructed to a typical cross section. Fully lined channels shall be designed with maximum side slopes of 1V:1H; channels with unlined sides shall be designed with maximum side slopes of 1V:3H. Lined channels shall have a minimum bottom width of six feet and shall have an access ramp for maintenance equipment.

c. Channels shall be designed to convey the design flow with a minimum velocity of two feet per second (fps). The maximum velocities shall be as follows:

   (1) Earth channels, six fps.

   (2) Concrete (or compatible inert structural material) lined channels, 10 fps.

   (3) Bottom lined or grass lined channels, eight fps.

d. The centerline curve radius of an open channel shall be equal to or greater than twice the bottom width (35-foot minimum).

e. Wherever possible, channels within the City shall be designed with vegetation that requires little or no maintenance of the sides slopes or bottom with roughness characteristics consistent with "natural" channel classifications.

f. A low-flow meandering channel shall be constructed along the bottom of all flood control channels that have a bottom width of ten feet or greater. The low-flow meandering channel shall have a maximum width of one-half the overall channel bottom width and a minimum width of three feet, with a maximum depth of two feet. The top of the slope of any low-flow meandering channel shall be offset horizontally from the toe of the overall channel slope, a minimum distance equivalent to the proposed depth.

g. Fencing, as designated by City Planning, shall be installed to prevent access to slopes steeper than 3H:1V, or along grass-lined channels. Unlined channels shall have a minimum bottom width of three feet and will be designed for little or no channel maintenance with vegetation considered at levels consistent with "natural" channel classifications, as defined in other sections of this document.

h. Slope Protection: Where channel slope protection is designated as required by the City, an acceptable materials list shall be requested from the City. Materials such as reinforced earth fills, articulating block, gabion mattresses/boxes, "shotcrete" or other common alternative slope protection system shall be approved on a project-by-project basis. Where slope protection is proposed with stone riprap it shall be designed in accordance with EM 1110-02-1601, "Hydraulic Design of Flood Control Channels," by the USACOE.

11. Levees

Where new levees are constructed, the land side levee slope will be 1V:2H. The water side slope of the new levee embankment will be constructed at 1V:3H. The top width of the levee berm will be 15 feet and will also function as a patrol road. The limits of the right-of-way will extend ten feet beyond the toe of the land side slope of the new levee embankment to provide access for levee maintenance. When levees are considered for containment of detention basins, the land side slopes shall be considered compatible with buffer/setback requirements.

12. Slope Protection

Where channel slope protection is required, stone riprap protection shall be designed in accordance with EM 1110-02-1601, "Hydraulic Design of Flood Control Channels," prepared by the USACOE.

13. Detention Ponds

The design for the detention ponds shall be established on a case-by-case basis. The design will vary depending upon whether or not the particular pond is a dual or multi-purpose facility, with drainage, storm water quality, and possibly recreational components. In all cases, unless variance is obtained from the City, all ponds shall be planned and designed with 6H:1V side slopes with no fencing.

All public access areas and areas prohibiting public access, as well as recreational and operation and maintenance facilities shall be designated by the City on a project-by-project basis. Where access is prohibited with approved vegetative or fencing barriers, side slopes may be reduced to a minimum of 3H:1V. Otherwise, detention pond side slopes shall be a minimum of 4:1.

All detention ponds incorporating storm water quality treatment aspects shall be lined, if necessary, with suitable material to prevent the migration of urban runoff pollutants into the groundwater.

All detention ponds with permanent "wet-pond" areas shall be constructed with an island, or combination of islands, constructed with a minimum island area (above the permanent pool water surface) of 2% of the total wet-pond area, at least two feet above the permanent wet-pond water surface elevation, with vegetation and irrigation designated by the City on a project-by-project basis. Location of the island will also be approved on a project-by-project basis, but shall be at least 30 feet from the pond shoreline. Constructed slopes for the island shall not be steeper than 4H:1V. Islands shall not be required for permanent wet-pond areas totaling less than one acre.

Recreational uses could be incorporated into the ponds, however, this could significantly increase the area required. Target outflows from the ponds will be established based upon an economic analysis of the cost for a pump station at the detention pond and main pumping plants, and the cost of the detention ponds.

For planning purposes, the surface areas for the detention ponds will reflect a 20-foot perimeter buffer containing a 15-foot perimeter road and side slopes of 6H:1V. The ponds shall be configured to provide the necessary storage while maintaining a minimum of one foot of freeboard for the worst-case 100-year recurrence storm for basins cut below existing grade or contained by fill areas meeting FEMA fill (rather than levee) containment classification.

14. Detention Pond Pump Stations

Each detention pond pump station will be designed to discharge the design capacity (target outflows) using two mixed flow vertical pump and motor units. A third pump and motor unit of equal size will be included as a backup to provide an installed pumping capacity of one and one-half times the design capacity of the drainage system.

A minimum ten horsepower pump and motor will be incorporated into the pump station to discharge runoff during the summer months. The summer flow pump will be omitted where the horsepower of the pumps required for the design capacity is less than 20 horsepower.

The sump for each pump station will be sized according to the Hydraulic Institute Standards for Centrifugal, Rotary & Reciprocating Pumps, Fourteenth Edition. Storm water will be conveyed from the detention pond into the sump through an open inlet section. Before entering the pump vault, the storm water will pass through a power-driven catenary trash rack system. As appropriate, the invert of each sump will be lower than the invert of the permanent (water quality) pool for the respective pond, so that the detention ponds can be completely drained through the pump stations to facilitate maintenance.

Typically, each pump will discharge into a separate discharge pipe that includes a combined siphon breaker, air relief valve and vault at the high point on the discharge pipe, and a flap gate with headwall at the terminal structure in the drain. Where discharge lines tend to be long (over 200 feet) or where the discharge line must cross under existing drains,

roads, or railroads, the discharge line will be manifolded for discharge through a single pipeline.
Electrical control equipment and aboveground mechanical equipment will be enclosed in a prefabricated metal building or concrete masonry building on a concrete foundation. The selection of building materials shall be determined by the City on a project-by-project basis. The concrete foundation for such a building shall be set at a minimum of six inches above the design 100-year floodplain adjacent to the building location. The electrical equipment will include pump controls, a water-level detection system, a float switch for sump high-water alarm and low-water automatic shutoff, a solenoid-controlled automatic pump motor oiler, and a SCADA system. In addition, the building will be equipped with two doors, wall louvers, a rotary turbine roof vent, interior and exterior lighting with motion-sensing nighttime operation, building security alarm system, a space heater, and telephone communications ability on-site for operator on-site to off-site communications.

Back up power for each pump station will be provided by on-site diesel generators. Each generator will be sized to supply power to the drainage pumps running at design capacity, as well as to the electrical control equipment, lighting, and electrical building space heater. The generators will be radiator-cooled and skid-mounted, and will include a heater, batteries, battery charger, control panel with auto-start, critical silencer, and generator circuit breaker. Both the diesel generator and fuel storage tank will be placed on a concrete spill containment pad constructed at least six inches above the design 100-year floodplain. The fuel tank will also be provided with a secondary containment feature.

The pump station sites will be enclosed by a 6-foot high chain link fence topped with three strands of barbed wire or a 7-foot-high concrete masonry unit fence as designated by the City on a project-by-project basis. The fencing will include a 20-foot wide electronically operated double gate and a 3-foot wide pedestrian gate. The pump station lot will be sized and the sump, electrical control building, diesel generator, and PG&E transformer arranged for adequate operating space for vehicles and pump and motor removal equipment. The paved access yard will be elevated approximately one foot above the high point of the natural ground surface at the site, and will be sloped to provide adequate on-site drainage.

15. Main Drainage System Pump Stations

The basis for the preliminary design and layout of the main drainage system pump stations, including the sump, outlet works, electrical controls, backup power, and site improvements is similar to that used for the subarea drainage pump stations.

The pump stations will be sized to pump the design flow into the Outfall Channel. Additional pumps will be included as backup to provide an installed pumping capacity of one and one-quarter times the design capacity.

16. Seepage

The seepage of groundwater into or out of the detention ponds and open channels will be evaluated based upon available groundwater information and driller logs to determine if inflow of groundwater into the drainage facilities would affect the design capacities or operations.

17. Retention Storage

Retention ponds may be used with prior written authorization by the City Engineer. If authorized, the retention ponds will be sized using the criteria provided below:

a. Configure all retention storage (effective flood control storage) above maximum groundwater elevation for the proposed retention pond site. Maximum groundwater elevations will be estimated using all the best available information, including actual seasonal groundwater measurements of monitoring wells, preferably within a one-mile radius. The maximum groundwater elevation shall be approximated using data from the California Department of Water Resources groundwater database for Yolo County, and the worst-case condition from either site-specific or regional estimations. Minimum allowable groundwater separation is 0' from a flood control perspective, however, as soil conditions may vary, separation shall be increased if groundwater contamination is a permit issue with federal, state, or local agencies.

b. Determine the pervious and impervious tributary areas within the directly contributing watershed. Include the retention pond site/area as an impervious surface.

c. Determine/verify that the surrounding (non-tributary) area 100-year (worst-case) flood condition does not overflow and/or spill into or across the contributing watershed of the retention pond, utilizing established City Standards for assessing flooding impacts.

d. Determine the precipitation on the contributing watershed resulting from the 100-year storm with a one-year duration from Figure 4d (from 2002 Standards) of the City of Woodland's current Standard Specifications and Details. Distribute the precipitation from this step according to the following distribution:

Month	Percent Total
October	0.8
November	10.1
December	6.9
January	30.9
February	20.7
March	23.1
April	3.4
May	1.6
June	1.7
July	0.8
August	0
September	0
TOTAL	**100**

e. Attribute no losses to impervious areas within the contributing watershed. Attribute losses to pervious areas differently each month using effective rainfall estimates (reaching retention storage) expressed as a percentage of the monthly rainfall below (for each month): (Note the monthly effective rainfall for pervious areas varies due to varying saturation levels during the year)

Month	Effective Rainfall (%) (% Monthly Rainfall as Runoff)
October	0
November	43.4
December	31.4
January	51.5
February	90.4
March	58.0
April	5.0
May	0
June	0
July	0
August	0
September	0

f. Develop a table to calculate month-by-month water balance accounts to assess the impacts of infiltration (percolation into soil), evaporation, transpiration, rainfall (from steps C. and D. above), total runoff volume, impervious area and runoff volume, pervious area and runoff volume, and incidental runoff volume (lawn over-watering). Monthly evaporation (pan) and transpiration estimates shall be estimated according to Bulletin 113 of the California Department of Water Resources or other appropriate climatological station. Full evaporation will only be allowed to deplete the storage volume if the operation and maintenance activities include annual removal/destruction of all vegetation within the water storage prism. Otherwise, transpiration values shall be used as if the pond is completely vegetated. On-site percolation tests shall be performed at a minimum of two tests per acre of pond footprint, at the elevation of the proposed soil interface. This pond design calculation shall begin with an empty pond and leave no more than 25% of the total design volume in the pond at the end of a year's cycle.

g. All retention ponds must be designed to be dewatered for a two-month period between September 1 and October 31 (or other period specified by the City) to an elevation at or below the invert of all connecting storm drain inlet pipes to allow for City inspection and maintenance. If pumping becomes necessary to dewater the pond, installation and operation of dewatering pump(s) shall be provided at no additional cost to the City. If pumping is required to dewater the pond for five consecutive years, a permanent pump installation to effectively dewater the pond within a two-month period between September 1 and October 31 will be required.

h. All retention ponds shall be designed with a minimum 15-foot-wide operating road around the perimeter of the pond that is a minimum of one foot above the maximum calculated (design) pond level. If overland release is considered, the overland release shall be at or above the maximum design pond level (based upon the 100-year annual volume calculations noted above). Overland release over the perimeter road shall include sufficient erosion control measures to armor the release path. All other applicable release criteria adopted by the City shall still apply.

i. Retention pond design shall include a staff gage for reliably monitoring the water level in the pond at all times. Retention pond design shall also include an access ramp and sump area to provide the City with an emergency pumping/dewatering and discharge location that is easily accessible.

j. If the pond design is proven to be inadequate/incorrect after the operation of the pond, the tributary area to the pond will provide a permanent pump installation, or other reliable dewatering construction, i.e., channel or pipe, to the satisfaction of the City Engineer. The pond design shall be considered inadequate if the water surface exceeds maximum design pond stage at any time, unless the previous year's rainfall records indicate the design precipitation was exceeded. The pond design shall also be considered inadequate if greater than 25% of the design volume is present in the pond at the end of August of any year.

18. Hybrid Retention/Detention Storage

a. If groundwater pumping is introduced as a means of gaining effective flood control storage, it shall be done only with the written approval of the City Engineer. If the groundwater table is invaded by design, the design shall include volume influences on the pond with groundwater permanently at maximum levels during the water balance calculations in Step F. of the Retention Storage Criteria section. The location of proposed flood control storage below the groundwater table will only be allowed with reliable pumping or gravity drainage that can effectively drain both rainfall and groundwater inflows.

b. If permanent pumping is introduced as a means of dewatering the pond (by design) during months where there is expected rainfall that reaches design storage (November 1 – April 30), then such a pond will be considered a "Hybrid Retention/Detention" Pond, and pumping will be evaluated for downstream impacts during downstream design flood event analyses. Such pumping will be considered continually "on" for any such downstream impacts calculations. Such pumping shall not exceed the 2-year peak flow determined at the point of discharge under existing conditions. Note: Existing conditions tributary areas will be utilized for determining peak pumping flow, as tributary areas to a designed storage pond are generally larger. All permanent pump installations shall be designed according to current adopted City Standards with back-up power supply and pumping redundancies.

STORM WATER QUALITY CRITERIA

Review of current laws and regulations indicates that the City is required to develop and has developed a storm water quality management plan to control storm runoff quality from its storm drainage system. The City is required to obtain a Phase 2 National Pollutant Discharge Elimination System Municipal Storm Water Permit, as the EPA defines "other discharges" not included in the first phase. The storm water quality plan will:

- Address a variety of sources of pollutants for runoff, and implement, at a minimum, BMPs either recommended by the EPA, or equivalent alternative BMPs.
- Provide for implementing nonstructural and structural BMPs. Structural BMPs can be public domain city/drainage area-wide or site-specific, or site-specific privately owned.
- Address post-construction runoff from new development and redevelopment areas.
- Recommend BMPs for post-construction. These type of BMPs are preferred and appropriate for developing communities, such as the City, and will be addressed in the City's Storm Drainage Facilities Master Plan, as appropriate.

The Storm Drainage Facilities Master Plan incorporated the development of City/drainage area-wide public structural BMPs. The planning and design of these BMPs has been completed by Larry Walker Associates in August 2003 and adopted by the City of Woodland for use in sizing and designed storm water quality treatment facilities, contained in the document entitled "Technical Guidance Manual for Stormwater Quality Control Measures, August 2003". This manual is available for review and/or download on the City's Website at:

www.cityofwoodland.org/pubworks/stormwater/docs/SWQCM_TG-All.pdf.

HYDROLOGY STANDARDS

This section presents basic information and hydrology standards which will be used to estimate storm runoff flow rates and volumes. Depending upon the application, one of three methodologies could be used. These include the *Rational Method*, the HEC-HMS/HEC-1 computer programs, and the RUNOFF Block of the SWMM computer program.

1. Topography

   Topographic information will be obtained from the U.S. Geological Survey (USGS) Quad Maps, topographic mapping provided by the City, and supplemental field surveys (Map 1).

2. Natural Resources Soil Conservation Service (NRCS) Hydrologic Soil Group

   The hydrologic soil group information will be obtained from Map 2, which was developed based upon information prepared by the NRCS. No significant areas of Type A soils are located within the City.

3. Land Use and Effective Percent Impervious

   Land use designations will be consistent with those proposed in the City's 1996 General Plan (latest update). City land use designations are presented in Table 3, with a description of density assumptions and associated effective percent impervious.

   The percent impervious characteristic of a drainage basin is primarily related to land use. The Storm Drainage Facilities Master Plan will require determining runoff for existing and future development and uses. The impervious area for existing conditions will be estimated from visual inspection of the basin, aerial photos dated March 10, 1993, and land use maps (Map 3). The future development is defined as the land use described in the most recent general plans for the City and Yolo County (Map 4 through Map 6).

4. Precipitation

   The design storms will be based upon the results of statistical analysis of historical precipitation gage data conducted by Mr. James Goodridge. The purpose of the Goodridge analysis was to develop design storm information for any location within Solano and Yolo counties. This was accomplished by establishing a relationship between design storm depth/duration/frequencies and mean annual precipitation amounts throughout the counties. The Goodridge analysis and results are presented in the report entitled, "Solano and Yolo County Design Rainfall," James D. Goodridge, Revised June 26, 1992, which was prepared for the Yolo County Flood Control & Water Conservation District and included in the report entitled, "Covell Drainage System Comprehensive Drainage Plan," September 1993.

   Isohyetal contours of mean annual precipitation values within the vicinity of the Woodland General Plan Area are delineated on Map 7. Review of Map 7 indicates the mean annual precipitation is 18 inches for the City's General Plan Area. The mean annual precipitation increases from 18 to 19 inches within the relatively small area located to the west of the City and to the east of Cache Creek.

Depth-Duration-Frequency (DDF) Relationships reflecting mean annual precipitation values of 17, 18, and 19 inches are presented in Table 4. A comparison of the DDF values in Table 4 indicates that there is very little difference between the values associated with a mean annual precipitation of 18 and 19 inches, particularly for the events having durations of one hour and less.

Intensity-Duration-Frequency (IDF) Relationships reflecting mean annual precipitation values of 17, 18, and 19 inches are presented in Table 5. A comparison of the IDF values in Table 5 indicates that there is very little difference between the values associated with a mean annual precipitation of 18 or 19 inches, particularly for the events having durations of one hour and less.

The majority of the area in the vicinity of the Woodland Plan Area has a mean annual precipitation of 18 inches. Because of this and the fact that there is little difference between the DDF relationships, the design storms for the area in the vicinity of the Woodland General Plan Area will reflect the DDF relationship associated with a mean annual rainfall of 18 inches.

5. *Rational Method*

The *Rational Method* may be used for peak flow calculations for the design of street drainage, storm sewers, and culverts not associated with channels. Application of the *Rational Method* will be limited to areas up to 640 acres.

The *Rational Method* equation has the form:

$$Q = CiA$$

Where:

- Q = rate of runoff, acre-inches per hour or cubic feet per second (acre-inch per hour = 1.008 cubic feet per second, a negligible difference);
- C = runoff coefficient, which is the ratio of peak runoff to average rainfall intensity;
- i = average rainfall intensity, inches per hour; and
- A = drainage area, acres.

The *Rational Method* shall be applied using the procedure outlined below and the sample computation form shown in Table 6. A sample electronic spreadsheet file "sample.xls" showing layout and format of the spreadsheet is included as part of this document.

Prepare Basic Information – Layout the proposed storm sewer system and delineate the subbasins tributary to points of concentration for the design of inlets, junctions, pipelines, etc. Delineate the land uses and hydrologic soil groups within each subbasin.

Determine Runoff Coefficient – The runoff coefficients, C, for a storm having a 10-year recurrence interval are presented in Table 7 by land use designation and hydrologic soil group. The 10-year runoff coefficients are to be used with the frequency factors presented in Table 8 for design storm frequencies other than the 10-year. The frequency factor adjusts the 10-year C for changes in infiltration and other losses with a change in storm frequency. The C value used in Table 6 is the weighted average of the C values for the subareas within the system being designed. Table 9 shows a sample calculation form for weighted average C computations for a basin. A sample electronic spreadsheet file "c_runoff.xls" is also included with this document.

Determine Time of Concentration – The time of concentration or the travel time is the time required for runoff to flow from the most upstream point of the drainage area through the conveyance system to the point of interest. The travel time is calculated by dividing the length of the conveyance system component by the corresponding velocity of flow. The travel time, T_c, is computed as follows:

$$T_c = T_o + T_g + T_p + T_{ch}$$

Where:

T_o = overland flow time of concentration;

T_g = gutter flow travel time;

T_p = pipe flow travel time; and

T_{ch} = channel flow travel time.

The equation used to compute the travel time for each conveyance component is described below.

Overland Flow – The recently developed Kinematic wave empirical equation based upon available NRCS, USACOE, and Federal Aviation Administration (FAA) overland flow data (Papadakis, 1987) is:

$$T_0 = \frac{0.66 L^{0.50} n^{0.52}}{S^{0.31} i^{0.38}}$$

Where:

T_o = overland flow time of concentration, minute;

L = overland flow length, ft, should generally be in the range of those specified in Table 10;

n = roughness coefficient for overland flow (Table 10);

S = average slope of flow path, ft/ft; and

i = intensity of precipitation, in/hr (Table 11).

Use of the overland time of concentration equation requires an iterative approach: an initial estimate of the time of concentration updated by successive estimates of precipitation intensity.

To assure that consistent and reasonable values are used to calculate the total time of concentration, Table 12 presents maximum times of concentration for commercial and residential areas and a range of times of concentration for open space. The land use applies only to the most upstream reach of the basin, prior to entering the gutter or street.

Gutter Flow – Manning's equation for a triangular channel cross section is used to determine the flow velocity and travel times for street gutter flow. The average distance from the overland flow surface to the nearest inlet is divided by flow velocity to obtain street gutter flow time. The gutter flow equation was derived using the following assumptions:

- The cross slope of the street is 0.02 ft/ft.
- The flow in the gutter is six inches deep and contained by the curb.
- The street surface is smooth asphalt or concrete.

The velocity of flow in the gutter is computed by the equation:

$$V_g = \frac{1.12}{n} S_x^{0.67} S^{0.50} T^{0.67}$$

Where:

V_g = velocity of flow in the gutter, ft/s;

Sx = street cross slope, ft/ft, design value = 0.02;

S = street longitudinal slope, ft/ft;

T = spread of flow in gutter = d/S_x, ft;

D = depth of flow in the gutter, ft, design value = 0.5 ft; and

n = Manning's "n" for pavement, design value = 0.02.

Pipe Flow – Manning's equation can also be used to determine travel time of flow through pipes. Travel time is usually calculated by assuming full pipe flow. Flow velocity is calculated with the equation:

$$V = \frac{1.49}{n} R^{0.67} S^{0.50}$$

Where:

V = velocity in pipe, ft/s;

R = hydraulic radius, D/4 for full pipe flow, ft;

D = diameter of pipe, ft;

S = slope, ft/ft; and

n = Manning's "n", design value = 0.015.

Trapezoidal Channels – A modified Manning's equation is used for open channel flow to derive the velocity for trapezoidal grass-lined channels. The following assumptions were made in the derivation of the modified equation:

- Channel side slopes are 3V:1H.
- Channel bottom width equals the depth.
- Top width is seven times the bottom width.

$$V = \frac{0.995}{n} b^{0.67} S^{0.5}$$

Where:

V = velocity, in ft/s;

b = bottom width, ft;

n = Manning's "n" for channel flow (Table 2); and

S = slope, ft/ft.

Determine Intensity – The rainfall intensity shall be determined from Figure 1, using the computed time of concentration.

6. HEC-1/HEC-HMS Modeling

The HEC-1 and HEC-HMS computer programs may be used to compute and route runoff hydrographs. The results may be used to design open channels, major road crossings, detention ponds, etc. The criteria that will be used to develop the HEC-1 or HEC-HMS models are presented in this section.
Prepare Basic Information – Layout the proposed storm sewer system and delineate the subbasins tributary to points of concentration for the design of inlets, junctions, pipelines, etc. Delineate the land uses and hydrologic soil groups within each subbasin.

Storm Frequency – The frequency of the design storm to be used will vary by the type and size of the facility and are given in the section entitled, "Storm Drainage Design Criteria, Section 2 Design Capacities."

Storm Duration – The storm duration shall be greater than the lag time or time of concentration for the entire watershed. Long-duration storms, 36 hours, 5- and 10-day events shall be evaluated, as appropriate, where runoff volume rather than peak discharge, is of importance. The temporal distribution of different long-duration storms shall be consistent with the methods used in the Sacramento City/County Hydrology Manual and are shown in Table 13 through Table 15.

Rainfall Depth-Duration-Frequency – The depth-duration-frequency information shall be obtained from Table 16, which is based upon a mean annual precipitation of 18 inches.

Storm Distribution – A balanced storm distribution shall be used using the PH records in the HEC-1/HEC-HMS model for shorter duration storm events.

Computation Time Internal – The computation time interval, which is used in the IT records of the HEC-1 program, shall be computed by dividing the shortest subbasin lag time or time of concentration by 5.5. This calculated value should be rounded down to the closest 5, 10, 15, or 30 minutes; or 1, 2, 3, or 6 hours. If the calculated value is less than five minutes (a lag time of less than 33 minutes) it should be rounded down to the nearest minute.

HEC-1 uses number of computation intervals in conjunction with computation time interval to define the duration of simulation.

The number of computation intervals to be used in the IT records of the HEC-1 program shall be computed as:

$$\text{Number of Computation Intervals} >= \frac{\text{Storm duration} + \text{Basin Lag or } T_c}{\text{Computation Interval}}$$

For design considerations where runoff volume rather than peak discharge is of importance, the number of computation intervals should be large enough so that the final hydrograph ordinates on the recession limb of the hydrograph are close to zero.

Initial Losses – There is a correlation between the recurrence frequency of a storm and the initial loss. Calibration modeling with HEC-1 in the Sacramento area has shown that higher initial losses were appropriate for the more frequent events. Initial losses are shown in Table 17.

Constant Losses – The constant loss is an infiltration rate in inches per hour based upon the infiltration rate of saturated soil. The infiltration potential is dependent on the soil type and land use. Average infiltration rates for combinations of hydrologic soil type and land use designations for the City are provided in Table 18.

The Synthetic Urban Unit Hydrograph – The U.S. Bureau of Reclamation (USBR) dimensionless urban unit hydrograph will be used to calculate runoff. The urban unit hydrograph was developed based upon many urban watersheds throughout the United States. The applicability of the unit hydrograph in Sacramento County was confirmed by successful comparisons of recorded runoff for several drainage basins and storms with the runoff calculated using the urban unit hydrograph. Due to similar hydrologic conditions, it is also applicable to the City.

Lag Time – The temporal distribution of the unit hydrograph is a function of the basin lag time. The lag time will be calculated by using one of two methods. Basin "n" lag method, or travel time component method. Selection of the method depends upon the available information and the purpose of the runoff analysis.

Unit Duration – The unit duration that is used in the IT records of the HEC-1 program, is the incremental period of time for which hydrograph ordinates are calculated. The unit duration should be approximately the lag time divided by 5.5, to provide adequate definition of the runoff hydrograph.

Calculation Procedure – The procedure below outlines the steps used to compute an urban unit hydrograph.

Computing Urban Unit Hydrographs	
Step	Description
1	Determine basin lag time (hrs) and area (sq mi).
2	Determine unit duration (hrs).
3	Calculate Lag Time + Unit Duration/2.
4	Calculate volume of runoff resulting from one inch of rainfall on basin areas, in one-day cfs. V = Basin area x 26.89 The conversion factor, 26.89, is used to convert one inch of rainfall excess to over one square mile in 24 hours to runoff expressed in one-day cfs.
5	Calculate unit hydrograph time steps as percent of Lag + Unit Duration/2, up to 600 percent.
6	Determine dimensionless synthetic unit hydrograph ordinates from Table 19.
7	Calculate unit hydrograph ordinates by multiplying V from Step 4 by dimensionless synthetic unit graph ordinates in Step 6. The ordinates in Step 7 are in cubic feet per second as a result of one inch of rain over the basin. To get ordinates as a result of any other rain depth multiply by the rain depth, in inches.

The enclosed spreadsheet "uh_wdlnd.xls" generates unit hydrographs for drainage basins based upon the urban unit hydrograph, the basin area, and the basin lag. The unit hydrograph ordinates are entered on the UI records. These are used as input to HEC-1, which calculates runoff hydrographs based upon the effective precipitation over the basin.

Base Flow – Base flow is considered the normal day-to-day flow from groundwater, spring contributions, or even from landscaping runoff. A study of the Sacramento area determined that base flow is not significant for most drainage studies and therefore, will not normally be included. Due to hydrologic similarities, base flow will not be included for the City.

Basin Lag – The lag time of a basin is required to calculate runoff hydrographs. Two methods will be permitted to calculate basin lag, the Basin "n" method and the Travel Time Component method. Both methods may be used in any given multi-basin model. This section covers the recommended applications and the equations for each method. The spreadsheet "lagwdlnd.xls" is provided with this document to aid the user in calculating the basin lag time.

Basin "n" Method – The Basin "n" method of computing lag should be used for:

- Planning level analyses.
- Basins with limited conveyance systems.

The Basin "n" lag equation, which was originally developed by Snyder and later revised by the USACOE and the USBR, is expressed as:

$$L_g = Cn\left[\frac{LL_c}{S^{0.5}} \right]^{0.33}$$

Where:

C = 1560 (174);

L_g = lag time, min (sec);

L = length of longest watercourse, measured as approximately 90 percent of the distance from the point of interest to the headwater divide of the basin, miles (m);

L = length along the longest watercourse measured upstream from the point of interest to a point close to the centroid of the basin, miles(m);

S = overall slope of the longest watercourse between the headwaters and concentration point, ft/mile (m/m); and

n = basin "n" from Table 20.

The basin "n" value is dependent on the basin land use and the condition of the main drainage course. For basins with mixed land use and/or varying characteristics of the main drainage course, the basin "n" should be weighted for the areas draining to each type of channel development. Table 20 contains recommended basin "n" values. The shaded values in Table 20 are normally not used. However, these values may be used for planning purposes to estimate the effect of channelization, or to estimate a composite "n" for large areas with mixed land use channelization.

<u>Travel Time Component Method</u> – The Travel Time Component method of computing basin lag should be used for the following applications:

- Detailed conveyance system design.
- Runoff analyses of existing conveyance systems.

The travel time is the time required for runoff to flow from the most upstream point of the drainage area through the conveyance system to the point of interest. The travel time is calculated by dividing the length of the conveyance system component by the corresponding velocity of flow. The travel time, T_c, is computed as follows:

$$T_c = T_o + T_g + T_p + T_{ch}$$

Where:

T_o = overland flow time of concentration;

T_g = gutter flow travel time;

T_p = pipe flow travel time; and

T_{ch} = channel flow travel time.

The equation used to compute the travel time for each conveyance component is described below.

Overland Flow – The recently developed Kinematic wave empirical equation based upon available NRCS, USACOE, and FAA overland flow data (Papadakis, 1987) is:

$$T_0 = \frac{0.66L^{0.50}n^{0.52}}{S^{0.31}i^{0.38}}$$

Where:

T_o = overland flow time of concentration, min;

L = overland flow length, ft, should generally be in the range of those specified in Table 10;

n = roughness coefficient for overland flow (Table 10);

S = average slope of flow path, ft/ft; and

i = intensity of precipitation, in/hr (Table 11).

Use of the overland time of concentration equation requires an iterative approach: an initial estimate of time of concentration updated by successive estimates of precipitation intensity. In many cases, overland flow accounts for a large part of the lag time in a basin.

To assure that consistent and reasonable values are used to calculate the total time of concentration, Table 12 presents maximum times of concentration for commercial and residential areas, and a range of times of concentration for open space. The land use applies only to the most upstream reach of the basin, prior to entering the gutter or street.

Gutter Flow – Manning's equation for a triangular channel cross section is used to determine the flow velocity and travel times for street gutter flow. The average distance from the overland flow surface to the nearest inlet is divided by flow velocity to obtain street gutter flow time. The gutter flow equation was derived using the following assumptions:

- The cross slope of the street is 0.02 ft/ft.
- The flow in the gutter is six inches deep and contained by the curb.
- The street surface is smooth asphalt or concrete.

$$V_g = \frac{1.12}{n} S_x^{0.67} S^{0.50} T^{0.67}$$

Where:

V_g = velocity of flow in the gutter, ft/s;

S_x = street cross slope, ft/ft, design value = 0.02;

S = street longitudinal slope, ft/ft;

T = spread of flow in gutter = d/S_x, ft;

d = depth of flow in the gutter, ft, design value = 0.5 ft; and

n = Manning's "n" for pavement, design value = .02.

Pipe Flow – Manning's equation can also be used to determine travel time of flow through pipes. Travel time is usually calculated by assuming full pipe flow. Flow velocity is calculated with the equation:

$$V = \frac{1.49}{n} R^{0.67} S^{0.50}$$

Where:

V = velocity in pipe, ft/s;

R = hydraulic radius, D/4 for full pipe flow, ft;

D = diameter of pipe, ft;

S = slope, ft/ft; and

n = Manning's "n", design value = 0.015.

Trapezoidal Channels – A modified Manning's equation is used for open channel flow to derive the velocity for trapezoidal grass-lined channels. The following assumptions were made in the derivation of the modified equation:

- Channel side slopes are 3:1, horizontal: vertical.
- Channel bottom width equals the depth.
- Top width is seven times the bottom width.

$$V = \frac{0.995}{n} b^{0.67} S^{0.5}$$

Where:

V	=	velocity, in ft/s;
b	=	bottom width, ft;
n	=	Manning's "n" for channel flow (Table 2); and
S	=	slope, ft/ft.

Lag Frequency Factors – Much of the existing storm sewer system in the City was designed to convey runoff from the 2-year storm event. Flows exceeding the storm sewer capacity back up in the streets and either pond, or if an overland release has been provided, flow in the streets.

Lag times, regardless of the method of calculations, should be amended to account for flow exceeding pipe capacities, causing temporary flooding in the streets and thereby increasing lag times. The multiplication factors given in Table 21 are applied to the lag times for piped areas with overland release.

Hydrograph Routing – Hydrograph routing in HEC-1 can be used to represent hydrograph movement in a channel or through a storage facility. The hydrograph is routed based upon the characteristics of the channel or the storage-outflow characteristics of the storage facility. This section lists the routing methods using HEC-1 that will be permitted. It also describes techniques for modeling two types of detention basins.

Routing Methods – The HEC-1 program contains several methods to route runoff hydrographs. Three of the methods, Modified Puls, Muskingum-Cunge, and Muskingum, are recommended for use in the City. These methods, applications, and required parameters are summarized in Table 22 in order of preference. In most cases Modified Puls routing will be required where HEC-2 models are available. Additional information on these routing methods is available in the HEC-1 User's Manual.

Modified Puls Routing – The Modified Puls routing method is used for channels with available HEC-2 storage discharge information. The number of steps (NSTPS) is calculated from reach length and velocity with the following equation.

$$NSTPS = \frac{reach / length / velocity}{2xNMIN}$$

Where: NMIN is the time interval.

The factor of 2 in the denominator was added to reflect hydrograph attenuation typical of developed channels in Sacramento County. The maximum NSTPS has been set to five.

Muskingum Routing – The Muskingum Routing methods is for channels where limited cross-sectional information is available. The number of subreaches is chosen to satisfy stability criteria as described in the HEC-1 manual. The Muskingum "K" value may be approximated as the travel time in hours for the reach based upon the flow velocity at normal depth. Typical ranges for the Muskingum "X" value are given below:

Channel Description	Muskingum "X" Range
Most channels flow is in the floodplain	0.0-0.15
Natural Channels	0.20-0.35
Excavated earth or concrete channels	0.40-0.50

Muskingum Cunge Routing – The Muskingum Cunge Routing method is used for channels with standard cross sections.

Reservoir Routing – Reservoir routing is used to route a hydrograph through a storage facility such as a detention basin.

Off-Channel Detention Routing – Off-channel detention basins are usually the most effective means of reducing peak flow in a channel for a given storage volume. Off-channel detention basins are located adjacent to, but separate from a channel. Peak flows in the channel are diverted into the detention basin over a weir in the side of the channel. Off-channel detention can be conceptually modeled using the diversion option in HEC-1. The diversion option allows a flow to be diverted from a channel based upon the total flow in the channel. The typical steps for modeling off-channel detention are outlined below.

- Divert flow to limit flow in the channel to the desired design flow.
- Determine the required channel overflow structure and off-channel storage based upon diverted hydrograph (in some cases, the detention volume is known and the reduction of flow in the channel is determined).

- Route the diverted flow through the off-channel detention basin.

- Return the routed detention basin flow to the channel.

On-Channel Detention Routing – On-channel detention includes using the excess storage capacity of a channel by building a berm across the channel and/or expanding the storage in a reach of the channel, for example, through excavation. Another example of on-channel detention is an "end-of-pipe" basin that collects runoff from a subdivision before entering the channel. With on-channel detention, the entire runoff hydrograph is routed through the detention facility. On-channel detention can be modeled in HEC-1 by using the Modified Puls routing methods for reservoirs. In cases where detention storage is provided predominantly by the natural floodplain of the channel, it may be more appropriate to use the Modified Puls routing method for channels.

7. SWMM Modeling – RUNOFF Block

The EPA SWMM Program is a dynamic rainfall-runoff simulation model, primarily used for urban areas. The RUNOFF Block of the EPA SWMM program may be used to compute runoff hydrographs. The EXTRAN Block is used to route hydrographs through the storm drainage system. A review of the criteria to be used for developing a RUNOFF model is presented in this section.

Prepare Basic Information – Layout the proposed storm sewer system and delineate the subbasins tributary to points of concentration for the design of inlets, junctions, pipelines, etc. Delineate the land uses and hydrologic soil groups within each subbasin.
Storm Frequency – The frequency of the design storm used will vary by facility and is given in the section entitled, "Storm Drainage Design Criteria, Design Capacities."

Storm Duration – The storm duration shall be greater than the lag time or time of concentration for the entire watershed. Long-duration storms, 36 hours, 5- and 10-day events shall be evaluated, as appropriate, where runoff volume rather than peak discharge, is of importance.

Rainfall Depth-Duration-Frequency – The depth-duration-frequency information will be obtained from Table 16, which is based upon a mean annual precipitation of 18 inches.

Storm Distribution – A balanced storm distribution will be generated using the electronic spreadsheet file "stormdist.xls" included with this document.

Number of Computation Time Intervals – The number of computation intervals shall be computed as follows:

$$\text{Number of Computation Intervals} = \leq \frac{\text{Storm Duration} + \text{Basin Lag or } T_c}{\text{Computation Interval}}$$

Percent Impervious – The percent impervious for land uses within the drainage basin will be obtained from "Land Use Designation and Effective Percent Impervious," Table 3. The weighted percent imperviousness will be computed for each subbasin.

Manning's "n" – Manning's "n" values for pipelines shall be 0.015. Manning's "n" values for overland flow for impervious and pervious areas shall be 0.05 and 0.30, respectively.

Depression Storage – Depression storage is the depth in inches that is not available to runoff; it is subtracted from net precipitation prior to calculating the runoff Q.

For impervious surfaces, depression storage will be estimated as a function of slope according to the Kidd equation as reported in the SWMM manual:

$$D_p = 0.0303 * S^{-0.49}$$

Where:

D_p = depression storage in inches; and

S = runoff surface slope.

For pervious areas, a weighted depression storage will be computed based upon hydrologic soil groups using the following values:

Surface Type	Depression Storage-inches
B	0.15
C	0.12
D	0.10

Infiltration – Infiltration will be modeled in SWMM RUNOFF using the Green-Ampt Infiltration equation. The equation requires three soil parameters: saturated hydraulic conductivity (Ks), average capillary sections at the wetting front (Su), and initial soil moisture deficit (IMD).

The Woodland area has a total of 16 soil series as mapped by the NRCS in the Yolo County Soil Survey. These were classified in the NRCS hydrological soil classification scheme as A, B, C, or D soils. For estimation of Green Ampt parameters, the soil series in each class which dominated the respective Woodland soils map was selected to represent its hydrological soil class.

Table 23 lists the selected representative soil series for each hydrological soil group and the resulting hydraulic conductivity and wetted front sections and resulting values. Weighted average values will be computed for each subbasin.

The soil initial moisture deficit (IMD) shall be varied as a function of design storm. The IMD values to be used are shown in Table 24.

Width – Subbasin widths shall be estimated in accordance with the SWMM manual. For subcatchments that are not rectangular in shape, the width will be computed using a skew factor as follows:

$$S_k = (A_2 - A_1)/A$$

Where:

S_k = skew factor $O \leq S_k \leq 1$;

A_1 = area to one side of channel;

A2 = area to other side of channel; and

A = total area.

The width is simply weighted between the two limits of L and 2L as:

$$W - (2 - S_k)L$$

Where:

W = subcatchment width; and

L = length of main drainage channel.

Slope – The subbasin slope will be estimated to reflect the primary drainage course using available topographic and survey information.

REFERENCES

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Larry Walker Associates, "Technical Guidance Manual for Stormwater Treatment Control Measures", August 2003.

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Woodland, City of, "Standard Specifications and Details," February 2002, and Amendment 1.

Woodland, City of, "General Plan Policy Document," 2002.

Woodland, City of, "General Plan Background Report," February 1996.

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TABLES

TABLE 1

CITY OF WOODLAND
STORM DRAINGAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

METHODS FOR ESTIMATING DESIGN FLOW

Application	Method	Maximum Basin Size	Design Parameter	Reference
Design of: • Street Drainage • Storm Drains • Culverts not Associated With Channels	Rational	640 ac	Flow	Hydrology Standards, Section 5
Master Plans or Designs of: • Storm Drains • Open Channels • Bridges and Culverts • Detention Basins	HEC-1/HEC-HMS, Runoff Block of SWMM	No Limit	Flow and Volume	Hydrology Standards, Section 6 and Section 7
Water Quality Detention Basins	Developed by Larry Walker Under Reference	No Limit	Volume	Technical Guidance Manual for Storm Water Quality Control Measures, August 2003

TABLE 2

CITY OF WOODLAND
STORM DRAINGAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

MANNING'S "n" FOR CHANNEL FLOW

Land Use Description	Manning's "n"
Concrete Pipe	0.015
Corrugated Metal Pipe	0.024
Concrete-Lined Channels	0.015
Earth Channel – Straight/Smooth	0.022
Earth Channel – Dredged	0.028
Mowed Grass Lined Channel	0.035
Natural Channel – Clean/Some Pools	0.040
Natural Channel – Winding/Some Vegetation	0.048
Natural Channel – Winding/Stony/Partial Vegetation	0.060
Natural Channel – Debris/Pools/Rocks/Full Vegetation	0.070
Floodplain – Isolated Trees/Mowed Grass	0.040
Floodplain – Isolated Trees/High Grass	0.050
Floodplain – Few Trees/Shrubs/Weeds	0.080
Floodplain – Scattered Trees/Shrubs	0.120
Floodplain – Numerous Trees/Dense Vines	0.200

Source: Sacramento City/County Drainage Manual, Volume 2, “Hydrology Standards,” December 1996.

TABLE 3

CITY OF WOODLAND
STORM DRAINGAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

LAND USE DESIGNATION AND EFFECTIVE PERCENT IMPERVIOUS

Land Use from Aerial Photography[2]	Summary of Density/Intensity Assumptions by General Plan Land Use Designation[1]				Effective % Impervious[2]
	General Plan Land Use Designation	Maximum Allowable Density/Intensity DUs per Gross Acre	Assumed Average Density/Intensity DUs per Gross Acre	Land Use Category (units or employees) Type of Units	
Highways, Parking	Central Commercial (CC)	4.00	1.00	Retail, Office, Government	95
Commercial, Office	General Commercial (GC) Neighborhood Commercial (NC) Service Commercial (SC) Highway Commercial (HC) Business Park (BP)	0.40 0.50 0.50 0.50	0.25 0.25 0.25 0.35	Retail, Office, Medical Office Retail, Service Retail Office	90
Industrial	Industrial (I)	0.60	0.40	Industrial	85
Apartments	N/A	N/A	N/A	N/A	80
Mobile Home Park	N/A	N/A	N/A	N/A	75
Condominiums	Medium Density Residential (MDR)	8.0 to 25.0	20.0	Multi-Family DUs	70
Residential: 8-10 du/acre (20-25 du/ha)	Medium/Low Density Residential (MLDR)	5.0 to 12.0	8.0	Single-Family DUs	60
Residential: 6-8 du/acre (15-20 du/ha)	Neighborhood Preservation (NP); Planned Neighborhood (PN) Public Service (PS)	3.0 to 8.0 1.0 to 25.0	7.0 6.5	Single-Family DUs Single-Family DUs, Multi-Family DUs, Retail, Schools	5

TABLE 3

CITY OF WOODLAND
STORM DRAINGAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

LAND USE DESIGNATION AND EFFECTIVE PERCENT IMPERVIOUS

Residential: 4-6 du/acre (10-15 du/ha)	Low Density Residential (LDR)	3.0 to 8.0	5.0	Single Family DUS	40
Residential: 3-4 du/acre (7.5-10 du/ha)	N/A	N/A	N/A	N/A	30
Residential: 2-3 du/acre (5-7.5 du/ha)	Very Low-Density Residential (VLDR)	1.0 to 4.0	3.0	Single-Family DUS	25
Residential: 1-2 du/acre (2.5-5 du/ha)	N/A	N/A	N/A	N/A	20
Residential: .5-1 du/acre (1-2.5 du/ha)	Rural Residential (RR)	0.0 to 2.0	1.0	Single-Family DUs	15
Residential: .2-.5 du/acre (0.5-1 du/ha)	N/A	N/A	N/A	N/A	10
Residential: <.2 du/acre (.05 du/ha)	N/A	N/A	N/A	N/A	5
Open Space, Grassland	Open Space (OS)	N/A	N/A	N/A	2
Agriculture	Agriculture (A) Urban Reserve (UR)	N/A	N/A	N/A	2

[1] J. Laurence Mintier & Associates, 1995.

[2] Sacramento City/County Drainage Manual, Volume 2, "Hydrology Standards," December 1996.

TABLE 4

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

MEAN ANNUAL PRECIPITATION VS.
RAINFALL DEPTH-DURATION-FREQUENCY
(inches)

Storm	Recurrence Interval																	
	2-Year			5-Year			10-Year			25-Year			50-Year			100-Year		
Duration	17	18	19	17	18	19	17	18	19	17	18	19	17	18	19	17	18	19
5M	0.17	0.18	0.19	0.21	0.23	0.24	0.25	0.26	0.28	0.29	0.31	0.33	0.32	0.34	0.36	0.35	0.37	0.40
10M	0.23	0.24	0.26	0.29	0.31	0.32	0.33	0.36	0.38	0.39	0.42	0.44	0.43	0.46	0.49	0.47	0.51	0.54
15M	0.27	0.29	0.30	0.34	0.36	0.39	0.40	0.43	0.45	0.47	0.50	0.53	0.52	0.55	0.59	0.57	0.60	0.64
30M	0.37	0.39	0.41	0.46	0.49	0.52	0.54	0.58	0.61	0.63	0.68	0.72	0.70	0.75	0.79	0.77	0.82	0.87
1H	0.49	0.53	0.56	0.63	0.67	0.71	0.73	0.78	0.83	0.86	0.92	0.97	0.95	1.01	1.07	1.04	1.11	1.17
2H	0.67	0.71	0.76	0.85	0.91	0.96	0.99	1.06	1.12	1.16	1.24	1.32	1.29	1.37	1.46	1.41	1.50	1.59
3H	0.80	0.85	0.90	1.02	1.08	1.15	1.18	1.26	1.34	1.39	1.48	1.57	1.54	1.64	1.74	1.68	1.79	1.90
6H	0.99	1.05	1.12	1.38	1.47	1.56	1.47	1.56	1.66	1.72	1.83	1.94	1.90	2.03	2.15	2.08	2.21	2.35
12H	1.33	1.42	1.51	1.86	1.98	2.11	1.97	2.10	2.23	2.32	2.47	2.62	2.56	2.73	2.89	2.80	2.98	3.16
24H	1.99	2.12	2.24	2.52	2.69	2.85	2.94	3.13	3.33	3.45	3.68	3.90	3.82	4.07	4.32	4.17	4.44	4.71
2D	2.51	2.67	2.83	3.16	3.37	3.58	3.69	3.93	4.17	4.33	4.61	4.90	4.79	5.10	5.41	5.23	5.57	5.91
3D	2.94	3.14	3.33	3.72	3.96	4.20	4.33	4.62	4.90	5.08	5.42	5.75	5.62	5.99	6.36	6.14	6.54	6.94
4D	3.26	3.48	3.69	4.12	4.39	4.66	4.80	5.12	5.43	5.63	6.00	6.37	6.23	6.64	7.04	6.81	7.25	7.70
5D	3.57	3.80	4.03	4.50	4.80	5.09	5.25	5.60	5.94	6.16	6.57	6.97	6.82	7.26	7.71	7.45	7.93	8.42
6D	3.82	4.07	4.32	4.82	5.13	5.45	5.62	5.99	6.35	6.59	7.03	7.46	7.29	7.77	8.24	7.97	8.49	9.01
8D	4.30	4.58	4.86	5.43	5.78	6.14	6.33	6.74	7.16	7.43	7.91	8.40	8.21	8.75	9.28	8.97	9.56	10.14
10D	4.62	4.92	5.23	5.83	6.21	6.60	6.80	7.25	7.69	7.98	8.50	9.03	8.83	9.40	9.98	9.64	10.27	10.90
15D	5.29	5.64	5.98	6.68	7.12	7.55	7.79	8.30	8.81	9.14	9.74	10.34	10.11	10.77	11.43	11.04	11.76	12.49
20D	5.92	6.30	6.69	7.47	7.96	8.44	8.71	9.28	9.85	10.22	10.89	11.56	11.30	12.04	12.78	12.35	13.15	13.96
30D	6.97	7.43	7.88	8.80	9.37	9.95	10.26	10.93	11.60	12.04	12.83	13.61	13.32	14.19	15.06	14.55	15.50	16.45
60D	10.27	10.94	11.61	12.96	13.81	14.65	15.12	16.10	17.09	17.74	18.89	20.05	19.61	20.89	22.17	21.43	22.83	24.22
Year	17.24	18.37	19.49	21.76	23.18	24.60	25.38	27.04	28.69	29.78	31.72	33.67	32.93	35.08	37.23	35.98	38.33	40.67

Source: "Solano and Yolo County Design Rainfall," prepared by James D. Goodridge, Consulting Engineer, revised June 26, 1992.

TABLE 5

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELIINES AND CRITERIA

MEAN ANNUAL PRECIPITATION VS.
RAINFALL INTESITY-DURATION-FREQUENCY
(inches/hour)

Storm	Recurrence Interval																	
	2-Year			5-Year			10-Year			25-Year			50-Year			100-Year		
Duration	17	18	19	17	18	19	17	18	19	17	18	19	17	18	19	17	18	19
5M	2.04	2.16	2.28	2.52	2.76	2.28	3.00	3.12	3.36	3.48	3.72	3.96	3.84	4.08	4.32	4.20	4.44	4.80
10M	1.38	1.44	1.56	1.74	1.86	1.92	1.98	2.16	2.28	2.34	2.52	2.64	2.58	2.76	2.94	2.82	3.06	3.24
15M	1.08	1.16	1.20	1.36	1.44	1.56	1.60	1.72	1.80	1.88	2.00	2.12	2.08	2.20	2.36	2.28	2.40	2.56
30M	0.74	0.78	0.82	0.92	0.98	1.04	1.08	1.16	1.22	1.26	1.36	1.44	1.40	1.50	1.58	1.54	1.64	1.74
1H	0.49	0.53	0.56	0.63	0.67	0.71	0.73	0.78	0.83	0.86	0.92	0.97	0.95	1.01	1.07	1.04	1.11	1.17
2H	0.34	0.36	0.38	0.43	0.46	0.48	0.50	0.53	0.56	0.58	0.62	0.66	0.65	0.69	0.73	0.71	0.75	0.80
3H	0.27	0.28	0.30	0.34	0.36	0.38	0.39	0.42	0.45	0.46	0.49	0.52	0.51	0.55	0.58	0.56	0.60	0.63
6H	0.17	0.18	0.19	0.23	0.25	0.26	0.25	0.26	0.28	0.29	0.31	0.32	0.32	0.34	0.36	0.35	0.37	0.39
12H	0.11	0.12	0.13	0.02	0.17	0.18	0.16	0.18	0.19	0.19	0.21	0.22	0.21	0.23	0.24	0.23	0.25	0.26
24H	0.08	0.09	0.09	0.16	0.11	0.12	0.12	0.13	0.14	0.14	0.15	0.16	0.16	0.17	0.18	0.17	0.19	0.20
2D	0.05	0.06	0.06	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12
3D	0.04	0.04	0.05	0.05	0.06	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.10
4D	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.06	0.07	0.07	0.07	0.08	0.08
5D	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.07	0.07
6D	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06
8D	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05
10D	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05
15D	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
20D	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03
30D	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
60D	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02
Year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: "Solano and Yolo County Design Rainfall," prepared by James D. Goodridge, Consulting Engineer, revised June 26, 1992.

TABI

CITY OF WO
STORM DRAINAGE FACILITI
AND PRELIMINAR
STORM DRAINAGE GUID

RATIONAL METHOD C

Inlet		Area A	C	CA	Sum CA	Time of Conce									
						Overland Flow				Gutter Flow			Pipe Flo		
								Overland							
From	To	(Acres)		(Acres)	(Acres)	L_O (ft)	S_O	"n"	T_O	L_g (ft)	S_g	T_g	S_p	D (in)	V (fps

TABLE 7

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

LAND USE VS. EFFECTIVE PERCENT IMPERVIOUS AND
10-YEAR RUNOFF COEFFICIENTS FOR THE RATIONAL METHOD

Land Use From Aerial Photography	General Plan Land Use Designation	Effective % Impervious	10-Year Runoff Coefficient By Hydrologic Soil Group		
			B	C	D
Highways, Parking	Central Commercial (CC)	95	0.86	0.87	0.87
Commercial, Office	General Commercial (GC) Service Commercial (SC) Highway Commercial (HC) Business Park (BP)	90	0.82	0.84	0.85
Industrial	Industrial (I)	85	0.78	0.80	0.82
Apartments	N/A	80	0.74	0.77	0.79
Mobile Home Park	N/A	75	0.70	0.74	0.76
Condominiums	Medium-Density Residential (MDR)	70	0.66	0.71	0.74
Residential: 8-10 du/ac (20-25 du/ha)	Medium/Low-Density Residential (MLDR)	60	0.58	0.64	0.68
Residential: 6-8 du/ac (15-20 du/ha)	Neighborhood Preservation (NP) Planned Neighborhood (PN)	50	0.50	0.58	0.63

TABLE 7

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

LAND USE VS. EFFECTIVE PERCENT IMPERVIOUS AND 10-YEAR RUNOFF COEFFICIENTS FOR THE RATIONAL METHOD

Land Use From Aerial Photography	General Plan Land Use Designation	Effective % Impervious	10-Year Runoff Coefficient By Hydrologic Soil Group		
			B	C	D
Residential: 3-4 du/ac (7.5-10 du/ha)	N/A	30	0.34	0.45	0.52
Residential: 2-3 du/ac (5-7.5 du/ha)	Very Low-Density Residential (VLDR)	25	0.30	0.41	0.49
Residential: 1-2 du/ac (2.5-5 du/ha)	N/A	20	0.26	0.38	0.46
Residential: .5-1 du/ac (1-2.5 du/ha)	Rural Residential (RR)	15	0.22	0.35	0.43
Residential: .2-.5 du/ac (0.5-1 du/ha)	N/A	10	0.18	0.32	0.41
Residential: <.2 du/ac (.05 du/ha)	Agricultural Residential (AR)	5	0.14	0.28	0.38
Open Space, Grassland	N/A	2	0.12	0.26	0.36
Agriculture	N/A	2	0.26	0.41	0.51

TABLE 8

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

RATIONAL METHOD
RUNOFF COEFFICIENT FREQUENCY FACTORS

Return Period, Yrs	Frequency Factor "F"
2	0.83
5	0.90
10	1.00
25	1.08
50	1.15
100	1.24

TABLE 9

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

RATIONAL METHOD
SUBBASIN RUNOFF COEFFICIENT CALCULATION SHEET

Land Use	Effective Percent Impervious	Hydrologic Soil Group B			Hydrologic Soil Group C			Hydrologic Soil Group D		
		Runoff Coeff (C)	Area, ac	F X C X Area[1]	Runoff Coeff (C)	Area, ac	F X C X Area[1]	Runoff Coeff (C)	Area, ac	F X C X Area[1]
Central Commercial (CC)	95	0.86			0.87			0.87		
General Commercial (GC)	90	0.82			0.84			0.85		
Service Commercial (SC)	90	0.82			0.84			0.85		
Highway Commercial (HC)	90	0.82			0.84			0.85		
Business Park (BP)	90	0.82			0.87			0.85		
Industrial (I)	85	0.78			0.80			0.82		
Apartments	80	0.74			0.77			0.79		
Mobile Home Park	75	0.70			0.74			0.76		
Medium-Density Res. (MDR)	70	0.66			0.71			0.74		
Medium/Low-Density Residential (MLDR)	60	0.58			0.64			0.68		
Neighborhood Preservation (NP)	50	0.50			0.58			0.63		
Planned Neighborhood (PN)	50	0.50			0.58			0.63		
Low-Density Residential (LDR)	40	0.42			0.51			0.57		
Residential, 3-4 du/ac	30	0.34			0.45			0.52		
Very-Low-Density Residential (VLDR)	25	0.30			0.41			0.49		
Residential, 1-2 du/ac	20	0.26			0.38			0.46		
Rural Residential (RR)	15	0.22			0.35			0.43		
Residential, 0.2-.5 du/ac	10	0.18			0.32			0.41		
Agricultural Residential (AR)	5	0.14			0.28			0.38		
Open Space, Grassland	2	0.12			0.26			0.36		
Agricultural	2	0.26			0.41			0.51		
TOTALS			0.00	0.00		0.00	0.00		0.00	0.00

Total Area	0.00
Sum (Coeff x Area)	0.00
Weighted Subbasin noff Coefficient	Sum (Coeff x Area)/Total Area

[1]Apply Runoff Coefficient Frequency F Factor of 0.83, 0.90, 1.00, 1.08, 1.15, and 1.24 to 10-Year Runoff Coefficient for design storm return periods of 2, 5, 10, 25, 50, and 100 years, respectively.

TABLE 10

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

PARAMETERS FOR OVERLAND FLOW
WITH FLOW DEPTHS LESS THAN 2 INCHES (50 mm)

Surface	Overland "n"	Distance, Foot (m)
Pavement – Smooth	0.02	50 (15)
Pavement – Rough/Cracked	0.05	50 (15)
Bare Soil – Newly Graded Areas	0.10	100 (30)
Range – Heavily Grazed	0.15	100 (30)
Turf – 1-2"/Lawns/Golf Course	0.20	100 (30)
Turf – 2-4"/Parks/Medians/Pasture	0.30	200 (60)
Turf – 4-6"/Natural Grassland	0.40	200 (60)
Few Trees – Grass Undergrowth	0.50	300 (90)
Scattered Trees – Weed/Shrub Undergrowth	0.60	300 (90)
Numerous Trees – Dense Undergrowth	0.80	300 (90)

Source: Sacramento City/County Drainage Manual, Volume 2, "Hydrology Standards," December 1996.

TABLE 11

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

OVERLAND FLOW PRECIPITATION INTENSITY

Design Frequency (yr)	Precipitation Intensity in/hr (mm/hr)	C	Initial Estimates	
			T_O = 5 min in/hr (mm/hr)	T_O = 10 min in/hr (mm/hr)
2	$i=CT_O^{-0.519}$	3.8 (96.5)	1.65 (41.9)	1.15 (29.2)
5	$i=CT_O^{-0.558}$	6.3 (160)	2.57 (65.3)	1.74 (44.2)
10	$i=CT_O^{-0.576}$	8.13 (206.5)	3.22 (81.8)	2.16 (54.9)
25	$i=CT_O^{-0.601}$	16 (279.4)	4.18 (106.2)	2.76 (70.1)
50	$i=CT_O^{-0.620}$	13.6 (345)	4.84 (122.9)	3.12 (79.2)
100	$i=CT_O^{-0.627}$	15.8 (401)	5.76 (146.3)	3.73 (94.7)
200	$i=CT_O^{-0.642}$	18.4 (467)	6.55 (166.4)	4.20 (106.7)
500	$i=CT_O^{-0.652}$	22.1 (561)	7.74 (196.5)	4.92 (125.0)

Source: Sacramento City/County Drainage Manual, Volume 2, "Hydrology Standards," December 1996.

TABLE 12

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

STANDARD OVERLAND FLOW PARAMETERS

Land Use	Overland Flow Time, min	Slope Foot/ Foot, m/m	Overland, "n"	Distance, ft
Commercial	3	-	-	-
Residential	9	-	-	-
Open Space	17-44[1]	.001-.01	0.30	200 (61)

[1]Computed using overland flow equation depending upon slope.

Source: Sacramento City/County Drainage Manual, Volume 2, "Hydrology Standards," December 1996.

TABLE 13

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

36-HOUR-LONG-DURATION STORM PRECIPITATION
AS A PERCENT OF TOTAL STORM DEPTH

Hour	%	Hour	%	Hour	%	Hour	%	Hour	%	Hour	%
1	1.3	7	1.4	13	2	19	3.5	25	2.8	31	1.6
2	1.4	8	1.4	14	2.3	20	3.7	26	1.7	32	1.4
3	1.4	9	1.4	15	2.5	21	3.9	27	6.1	33	1.4
4	1.4	10	1.4	16	2.7	22	4.2	28	7.8	34	1.4
5	1.4	11	1.7	17	3	23	4.6	29	9.7	35	1.4
6	1.4	12	1.8	18	3.1	24	3.8	30	6.6	36	1.4

TABLE 14

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINERING
STORM DRAINAGE GUIDELINES AND CRITERIA

5-DAY-LONG DURATION STORM PRECIPITATION
AS A PERCENT OF TOTAL STORM DEPTH

Hour	%	Hour	%	Hour	%	Hour	%	Hour	%	Hour	%
1	0.2	21	0	41	1.6	61	0.4	81	2.4	101	0
2	2	22	0	42	0.8	62	0.5	82	2.2	102	0
3	4.2	23	0	43	0.6	63	0.6	83	1.7	103	0
4	2.9	24	0	44	0.4	64	0.7	84	1	104	0
5	1.1	25	0	45	0.3	65	0.8	85	3.6	105	0
6	0.2	26	0	46	0.2	66	0.8	86	4.6	106	0
7	0.1	27	0	47	0.1	67	0.9	87	7.8	107	0.1
8	0	28	0	48	0	68	1	88	3.2	108	0.2
9	0	29	0	49	0	69	1.1	89	0.9	109	0.4
10	0	30	0	50	0	70	1.2	90	0.8	110	0.5
11	0	31	0.1	51	0	71	1.3	91	0.7	111	0.7
12	0	32	0.2	52	0	72	1.4	92	0.5	112	0.9
13	0	33	0.3	53	0	73	1.5	93	0.4	113	2.1
14	0	34	0.4	54	0	74	1.6	94	0.3	114	5
15	0	35	0.5	55	0	75	1.7	95	0.2	115	1.4
16	0	36	0.7	56	0	76	1.8	96	0.1	116	0.8
17	0	37	0.9	57	0	77	1.9	97	0	117	0.5
18	0	38	2.5	58	0.1	78	2	98	0	118	0.4
19	0	39	6.2	59	0.2	79	2.1	99	0	119	0.2
20	0	40	3.5	60	0.3	80	2.3	100	0	120	0.1

TABLE 15

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

10-DAY-LONG DURATION STORM PRECIPITATION AS A PERCENT OF TOTAL STORM DEPTH

Hour	%	Hour	%	Hour	%	Hour	%	Hour	%	Hour	%
1	0.3	41	0.5	81	0	121	0	161	0	201	0
2	1.1	42	0.7	82	0	122	0	162	0	202	0
3	2.7	43	0.9	83	0	123	0	163	0	203	0
4	1.5	44	1.3	84	0	124	0	164	0	204	0
5	0.5	45	3	85	0	125	0	165	0	205	0
6	0.3	46	1.9	86	0	126	0	166	0	206	0
7	0.1	47	1	87	0	127	0	167	0	207	0
8	0	48	0.8	88	0	128	0	168	0	208	0
9	0	49	0.6	89	0	129	0.1	169	0	209	0
10	0	50	0.5	90	0	130	0.1	170	0	210	0
11	0	51	0.4	91	0	131	0.2	171	0	211	0
12	0	52	0.3	92	0	132	0.2	172	0	212	0
13	0	53	0.2	93	0	133	0.2	173	0	213	0
14	0	54	0.1	94	0.1	134	0.3	174	0	214	0
15	0	55	0	95	0.2	135	0.5	175	0	215	0
16	0	56	0	96	0.3	136	0.6	176	0	216	0
17	0	57	0	97	0.4	137	0.7	177	0	217	0
18	0	58	0	98	0.5	138	0.9	178	0	218	0
19	0	59	0	99	0.6	139	1	179	0	219	0
20	0	60	0	100	0.7	140	1.1	180	0	220	0
21	0	61	0	101	0.9	141	1.3	181	0.1	221	0
22	0	62	0	102	1.5	142	1.4	182	0.2	222	0
23	0	63	0	103	5.3	143	1.6	183	0.3	223	0
24	0	64	0	104	2.2	144	1.7	184	0.4	224	0
25	0	65	0	105	1	145	1.8	185	0.5	225	0
26	0	66	0	106	0.8	146	1.9	186	0.7	226	0
27	0	67	0	107	0.6	147	2.1	187	0.9	227	0
28	0	68	0	108	0.5	148	1.5	188	1.3	228	0
29	0	69	0	109	0.4	149	1.2	189	3.9	229	0
30	0	70	0	110	0.3	150	0.9	190	2	230	0.1
31	0	71	0	111	0.3	151	3.1	191	1	231	0.2
32	0	72	0	112	0.2	152	3.9	192	0.8	232	0.5
33	0	73	0	113	0.2	153	6.7	193	0.7	233	0.7
34	0	74	0	114	0.1	154	3.3	194	0.6	234	1
35	0	75	0	115	0.1	155	0.5	195	0.5	235	2.9
36	0	76	0	116	0	156	0.3	196	0.4	236	1.6
37	0	77	0	117	0	157	0.2	197	0.3	237	0.8
38	0.1	78	0	118	0	158	0.1	198	0.2	238	0.6
39	0.2	79	0	119	0	159	0.1	199	0.1	239	0.4
40	0.3	80	0	120	0	160	0.1	200	0	240	0.2

TABLE 16

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

RAINFALL DEPTH-DURATION-FREQUENCY

Storm	Recurrence Interval (Units)					
Duration	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
5M	0.18	0.23	0.26	0.31	0.34	0.37
10M	0.24	0.31	0.36	0.42	0.46	0.51
15M	0.29	0.36	0.43	0.50	0.55	0.60
30M	0.39	0.49	0.58	0.68	0.75	0.82
1H	0.53	0.67	0.78	0.92	1.01	1.11
2H	0.71	0.91	1.06	1.24	1.37	1.50
3H	0.85	1.08	1.26	1.48	1.64	1.79
6H	1.05	1.47	1.56	1.83	2.03	2.21
12H	1.42	1.98	2.10	2.47	2.73	2.98
24H	2.12	2.69	3.13	3.68	4.07	4.44
2D	2.67	3.37	3.93	4.61	5.10	5.57
3D	3.14	3.96	4.62	5.42	5.99	6.54
4D	3.48	4.39	5.12	6.00	6.64	7.25
5D	3.80	4.80	5.60	6.57	7.26	7.93
6D	4.07	5.13	5.99	7.03	7.77	8.49
8D	4.58	5.78	6.74	7.91	8.75	9.56
10D	4.92	6.21	7.25	8.50	9.40	10.27
15D	5.64	7.12	8.30	9.74	10.77	11.76
20D	6.30	7.96	9.28	10.89	12.04	13.15
30D	7.43	9.37	10.93	12.83	14.19	15.50
60D	10.94	13.81	16.10	18.89	20.89	22.83
Year	18.37	23.18	27.04	31.72	35.08	38.33

Source: "Solano and Yolo County Design Rainfall," prepared by James D. Goodridge, Consulting Engineer, revised June 26, 1992.

TABLE 17

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

INITIAL LOSSES

Recurrence Interval	Loss, inches
2	0.40
5	0.25
10	0.20
25	0.15
50	0.12
100	0.10
200	0.08
500	0.06

Source: Sacramento City/County Drainage Manual, Volume 2, "Hydrology Standards," December 1996.

TABLE 18

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

LAND USE VS. EFFECTIVE PERCENT IMPERVIOUS
AND INFILTRATION RATES

Land Use From Aerial Photography	General Plan Land Use Designation	Effective % Impervious	Infiltration Rates (in/hr) by Hydrologic Soil Group		
			B	C	D
Highways, Parking	Central Commercial (CC)	95	0.14	0.07	0.04
Commercial, Office	General Commercial (GC) Service Commercial (SC) Highway Commercial (HC) Business Park (BP)	90	0.06	0.08	0.05
Industrial	Industrial (I)	85	0.162	0.082	0.052
Apartments	N/A	80	0.165	0.085	0.055
Mobile Home Park	N/A	75	0.167	0.087	0.057
Condominiums	Medium-Density Residential (MDR)	70	0.17	0.09	0.06
Residential: 8-10 du/ac (20-25 du/ha)	Medium/Low-Density Residential (MLDR)	60	0.18	0.10	0.07
Residential: 6-8 du/ac (15-20 du/ha)	Neighborhood Preservation (NP) Planned Neighborhood (PN)	50	0.18	0.10	0.07
Residential: 4-6 du/ac (10-15 du/ha)	Low-Density Residential (LDR) Planned Neighborhood (PN)	40	0.18	0.10	0.07

TABLE 18

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

LAND USE VS. EFFECTIVE PERCENT IMPERVIOUS
AND INFILTRATION RATES

Land Use From Aerial Photography	General Plan Land Use Designation	Effective % Impervious	Infiltration Rates (in/hr) by Hydrologic Soil Group		
			B	C	D
Residential: 3-4 du/ac (7.5-10 du/ha)	N/A	30	0.18	0.10	0.07
Residential: 2-3 du/ac (5-7.5 du/ha)	Very Low-Density Residential (VLDR)	25	0.18	0.10	0.07
Residential: 1-2 du/ac (2.5-5 du/ha)	N/A	20	0.18	0.10	0.07
Residential: . 5-1 du/ac (1-2.5 du/ha)	Rural Residential (RR)	15	0.18	0.10	0.07
Residential: .2-.5 du/ac (0.5-1 du/ha)	N/A	10	0.18	0.10	0.07
Residential: <.2 du/ac (.05 du/ha)	Agricultural Residential (AR)	5	0.18	0.10	0.07
Open Space, Grassland	N/A	2	0.18	0.10	0.07
Agriculture	N/A	2	0.18	0.10	0.07

TABLE 19

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

USBR'S DIMENSIONLESS URBAN UNIT HYDROGRAPH

Ordinate Number	Time t in % of L_g + 0.5D	q
1	0	0.00
2	5	0.64
3	10	1.56
4	15	2.52
5	20	3.57
6	25	4.36
7	30	5.80
8	35	6.95
9	40	8.38
10	45	9.87
11	50	11.52
12	55	13.19
13	60	15.18
14	65	17.32
15	70	19.27
16	75	19.74
17	80	20.00
18	85	19.74
19	90	19.27
20	95	17.72
21	100	16.12
22	105	14.50
23	110	13.08

TABLE 19

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

USBR'S DIMENSIONLESS URBAN UNIT HYDROGRAPH

Ordinate Number	Time t in % of L_g + 0.5D	q
24	115	12.19
25	120	11.31
26	125	10.27
27	130	9.63
28	135	8.96
29	140	8.27
30	145	7.75
31	150	7.22
32	155	6.75
33	160	6.27
34	165	5.94
35	170	5.55
36	175	5.24
37	180	4.92
38	185	4.63
39	190	4.39
40	195	4.18
41	200	3.93
42	205	3.73
43	210	3.55
44	215	3.37
45	220	3.24
46	225	3.04

TABLE 19

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

USBR'S DIMENSIONLESS URBAN UNIT HYDROGRAPH

Ordinate Number	Time t in % of L_g + 0.5D	q
47	230	2.93
48	235	2.75
49	240	2.67
50	245	2.53
51	250	2.47
52	255	2.37
53	260	2.30
54	265	2.21
55	270	2.12
56	275	2.04
57	280	1.98
58	285	1.90
59	290	1.83
60	295	1.78
61	300	1.71
62	305	1.64
63	310	1.60
64	315	1.53
65	320	1.49
66	325	1.42
67	330	1.39
68	335	1.32
69	340	1.28

TABLE 19

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

USBR'S DIMENSIONLESS URBAN UNIT HYDROGRAPH

Ordinate Number	Time t in % of $L_g + 0.5D$	q
70	345	1.23
71	350	1.21
72	355	1.15
73	360	1.11
74	365	1.07
75	370	1.03
76	375	1.00
77	380	0.97
78	385	0.93
79	390	0.90
80	395	0.87
81	400	0.84
82	405	0.81
83	410	0.78
84	415	0.75
85	420	0.73
86	425	0.69
87	430	0.67
88	435	0.64
89	440	0.62
90	445	0.60
91	450	0.58
92	455	0.56

TABLE 19

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

USBR'S DIMENSIONLESS URBAN UNIT HYDROGRAPH

Ordinate Number	Time t in % of $L_g + 0.5D$	q
93	460	0.54
94	465	0.52
95	470	0.50
96	475	0.49
97	480	0.48
98	485	0.46
99	490	0.45
100	495	0.43
101	500	0.41
102	505	0.40
103	510	0.39
104	515	0.37
105	520	0.36
106	525	0.34
107	530	0.33
108	535	0.32
109	540	0.31
110	545	0.30
111	550	0.29
112	555	0.28
113	560	0.27
114	565	0.26

TABLE 19

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

USBR'S DIMENSIONLESS URBAN UNIT HYDROGRAPH

Ordinate Number	Time t in % of L_g + 0.5D	q
115	570	0.25
116	575	0.24
117	580	0.24
118	585	0.23
119	590	0.22
120	595	0.21
121	600	0.21

TABLE 20

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

BASIN "n" FOR UNIT HYDROGRAPH LAG EQUATION

Basin Land Use	Percent Impervious	Channelization Description	
		Developed Pipe/Channel	Undeveloped Natural
Highways, Parking	95	0.030	0.067
Commercial, Offices	90	0.031	0.070
Intensive Industrial	85	0.032	0.071
Apartments, High-Density Residential	80	0.033	0.072
Mobile Home Park	75	0.034	0.073
Condominiums, Medium-Density Residential	70	0.035	0.074
Residential: 8-10 du/ac (20-25 du/ha), Ext Industrial	60	0.037	0.076
Residential: 6-8 du/ac (15-20 du/ha), Low-Density Residential, School	50	0.040	0.080
Residential: 4-6 du/ac (10-15 du/ha)	40	0.042	0.084
Residential: 3-4 du/ac (7.5-10 du/ha)	30	0.046	0.088
Residential: 2-3 du/ac (5-7.5 du/ha)	25	0.050	0.090
Residential: 1-2 du/ac (2.5-5 du/ha)	20	0.053	0.093
Residential: .5-1 du/ac (1-2.5 du/ha)	15	0.056	0.096
Residential: .2-.5 du/ac (0.5-1 du/ha), Ag Res.	10	0.060	0.100
Residential: <.2 du/ac (0.5 du/ha), Recreation	5	0.065	0.110
Open Space, Grassland, Agriculture	2	0.070	0.115
Open Space, Woodland, Natural	1	0.075	0.120
Dense Oak, Shrubs, Vines	1	0.080	0.150
Shaded values are normally not used.			

Source: Sacramento City/County Drainage Manual, Volume 2, "Hydrology Standards," December 1996.

TABLE 20

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

BASIN "n" FOR UNIT HYDROGRAPH LAG EQUATION

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Open Space, Grassland, Agriculture	2	0.070	0.115
Open Space, Woodland, Natural	1	0.075	0.120
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Shaded values are normally not used.			

Source: Sacramento City/County Drainage Manual, Volume 2, "Hydrology Standards," December 1996.

TABLE 21

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

LAG MULTIPLICATION FACTORS FOR OVERLAND RELEASE

Frequency (yrs)	2	5	10	25	50	100	200	500
Multiplication Factor	1.0	1.0	1.0	1.1	1.2	1.3	1.4	1.5

Source: Sacramento City/County Drainage Manual, Volume 2, "Hydrology Standards," December 1996.

TABLE 22

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

HYDROGRAPH ROUTING OPTIONS

Method	Application	Required Parameters
Modified Puls	Channels Influenced by Backwater Channels With Available HEC-2 Storage-Discharge Information	Reach Length Velocity in Reach Storage-Discharge Information
	Reservoir Routing	Storage-Elevation Information Elevation-Discharge Information or Orifice Data and Spillway Data
Muskingum-Cunge	Channels With Insignificant Backwater Effects Channels Represented by Eight-Point Cross Sections Channels With a Standard Cross Section, Trapezoidal, Rectangular or Circular	Channel Length Channel Slope Manning's Roughness for Overbanks and Channel Cross-Section Data
Muskingum	Channels With Limited Cross-Sectional Information	Number of Subreaches Muskingum "K" Coefficient, hrs Muskingum "X" Attenuation Coefficient

Source: Sacramento City/County Drainage Manual, Volume 2, "Hydrology Standards," December 1996.

TABLE 23

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE DESIGN STANDARDS

GREEN AMPT PARAMETERS SELECTED FOR WOODLAND

Soil Hydrological Class	Representative Woodland Soil Series[1]	Soil Texture Class[1]	Hydraulic Conductivity in/hr (ks)[1]	Wetted Front Suction inches (su)[2]
B	Yolo-Ya	Silty Loam	0.26	6.57
C	Marvin-Mn	Silty Clay Loam	0.04	10.75
D	Myers-Ms	Clay	0.01	12.45

[1]USDA, "SCS Soil Survey," Yolo County, California, June 1972.

[2]Dodson & Associates, "Hands On HEC-1," June 1995.

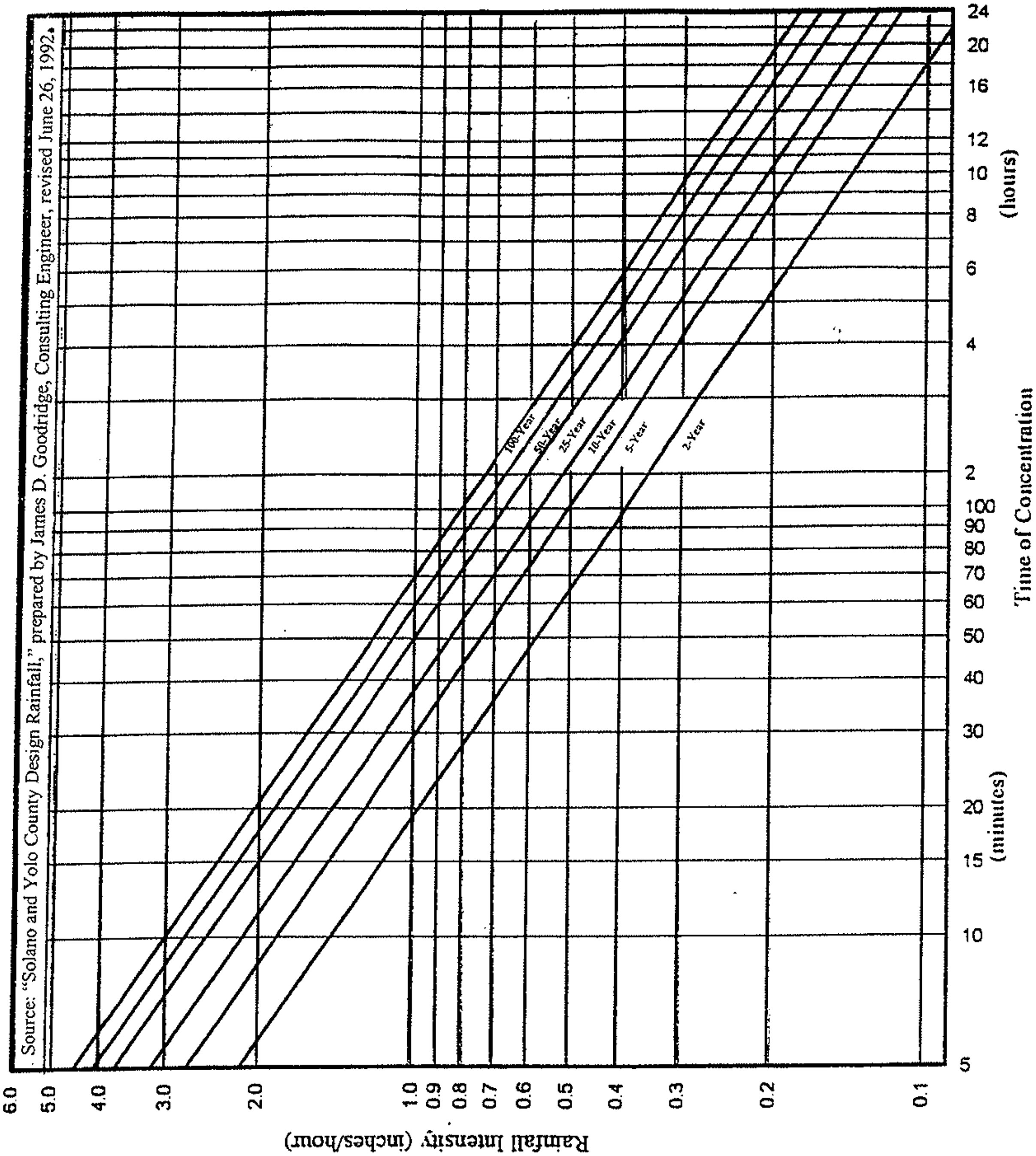
TABLE 24

CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE
AND PRELIMINARY ENGINEERING
STORM DRAINAGE GUIDELINES AND CRITERIA

INITIAL MOISTURE DEFICIT AS FUNCTION OF STORM FREQUENCY

Return Period, Yrs	Initial Moisture Deficit (IMD) inch/inch
2	.48
5	.30
10	.24
100	.12

FIGURE



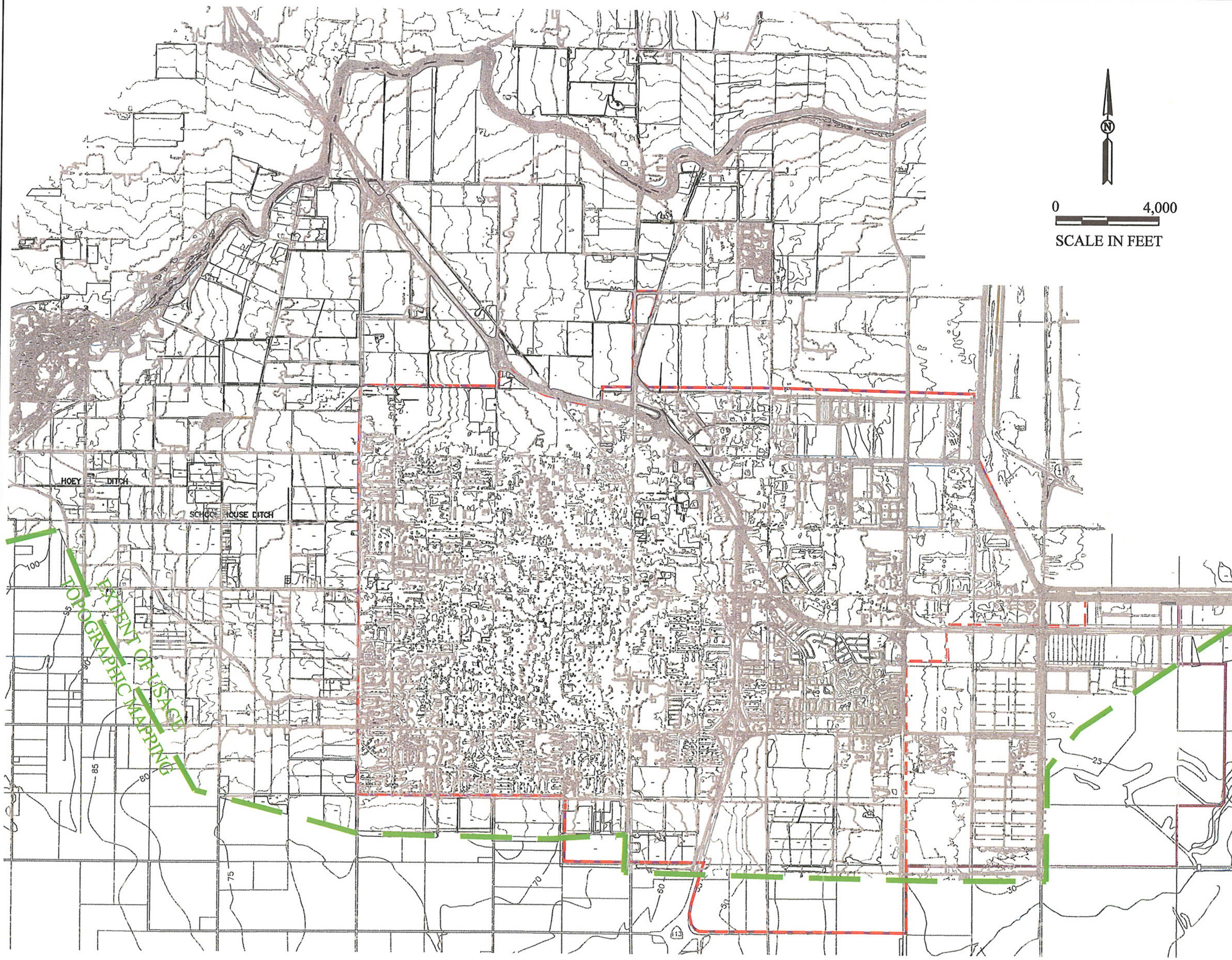
CITY OF WOODLAND
STORM DRAINAGE FACILITIES MASTER PLAN
YOLO COUNTY, CALIFORNIA

RAINFALL INTENSITY DURATION FREQUENCY

Borcalli & Associates, Inc.
Sacramento, California

FIGURE 1

MAPS



0 4,000

SCALE IN FEET

LEGEND

URBAN LIMIT LINE

PLANNING AREA BOUNDARY

SOURCES:

USArmy Corps of Engineers, "Cache Creek Feasibility Study", 2000. Vertical Datum is North American Vertical Datum of 1988 (NAVD 88).

USGS 7.5 Minute Series (Topographic) Woodland Quadrangle, 1952 Series, Photo Revised 1981. Vertical Datum is National Geodetic Vertical Datum of 1929 (NGVD 29).

City of Woodland

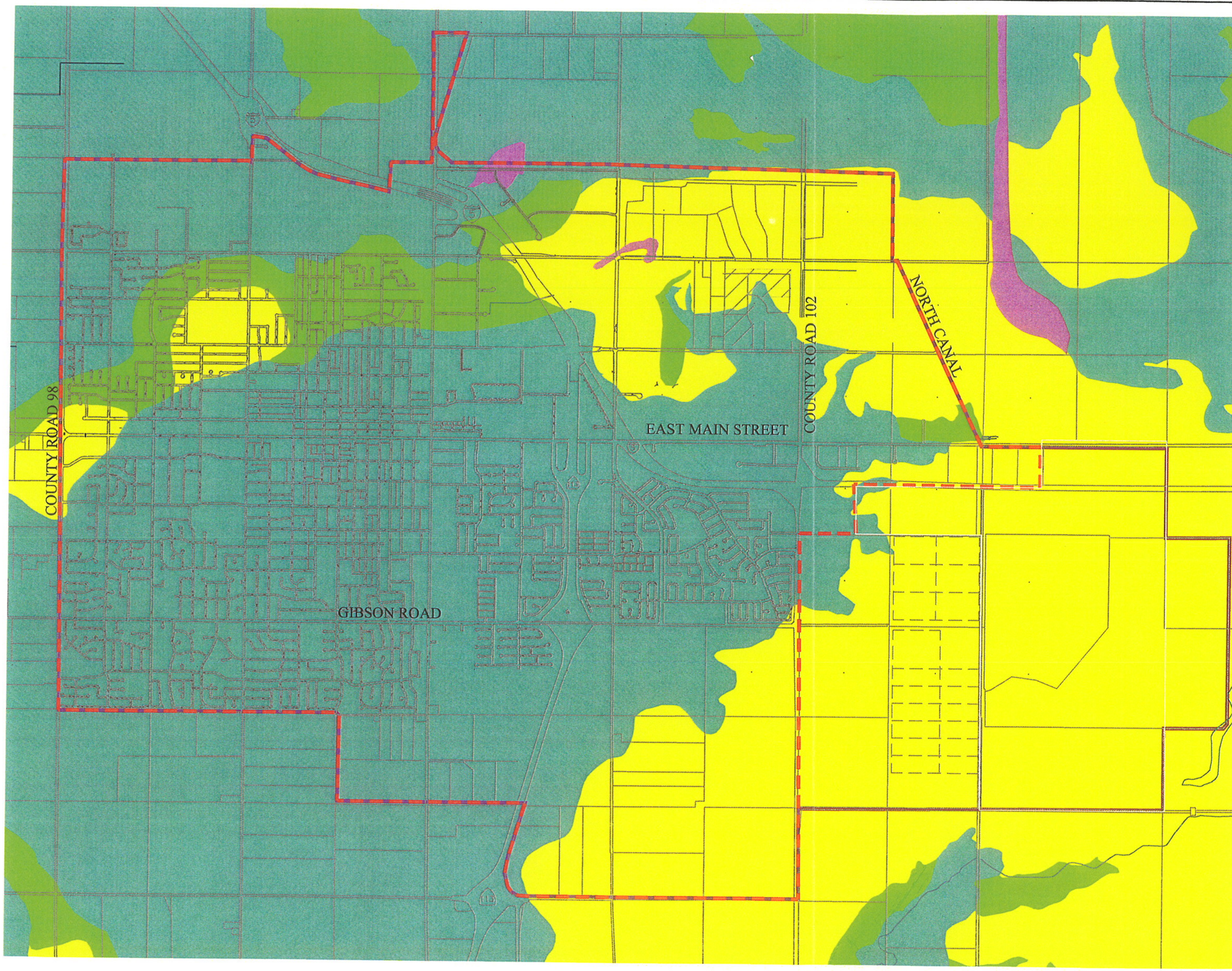
STORM DRAINAGE FACILITIES MASTER PLAN UPDATE AND PRELIMINARY ENGINEERING

STORM DRAINAGE GUIDELINES AND CRITERIA

EXISTING TOPOGRAPHY

WOOD RODGERS

MAP 1



LEGEND

- URBAN LIMIT LINE
- PLANNING AREA BOUNDARY
- GROUP A
- GROUP B
- GROUP C
- GROUP D

SOURCE:

USDA Soil Conservation Service, "Soil Survey of Yolo County, California", 1972.

N

0 3,000

SCALE IN FEET

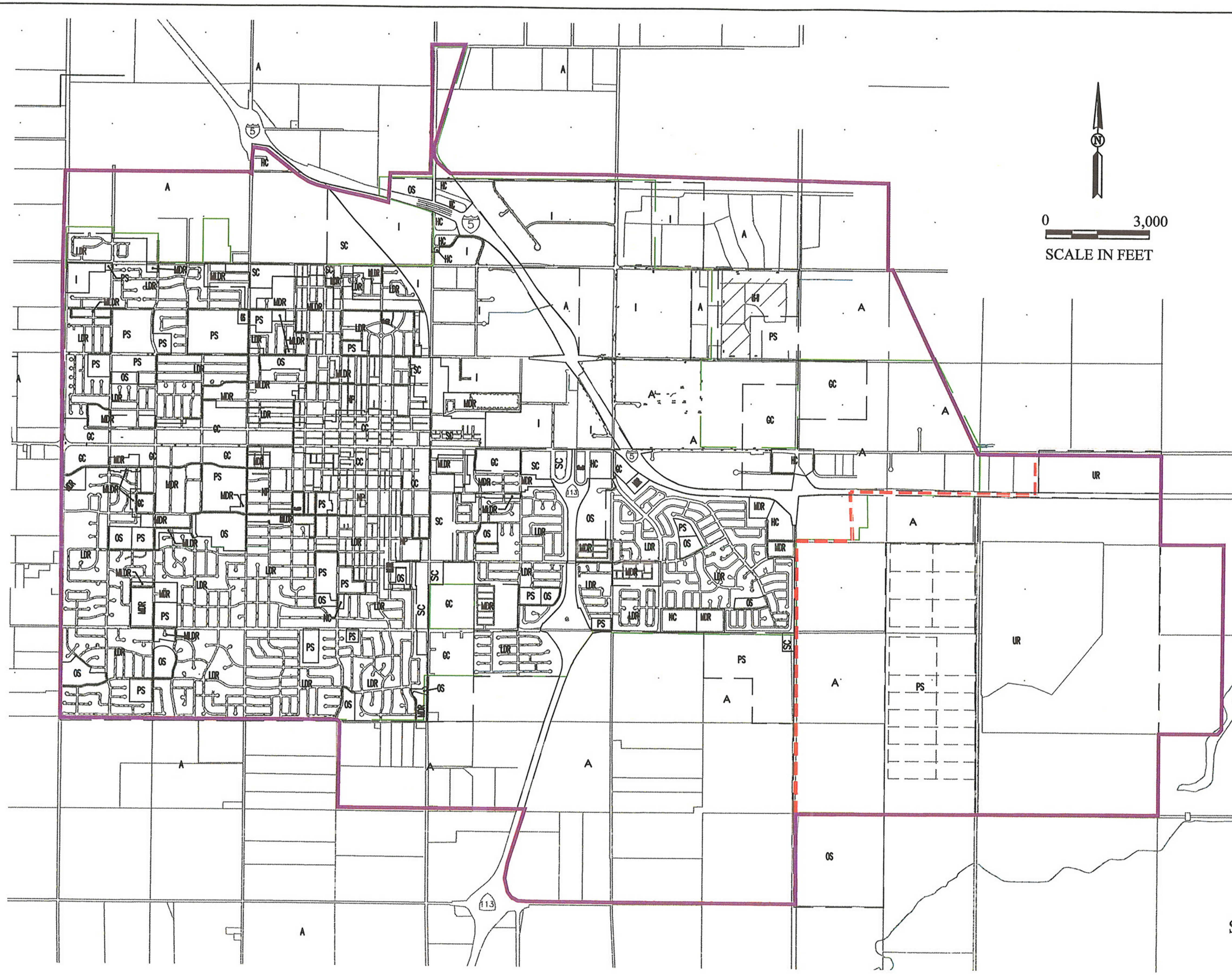
City of Woodland

STORM DRAINAGE FACILITIES MASTER PLAN UPDATE AND PRELIMINARY ENGINEERING

STORM DRAINAGE GUIDELINES AND CRITERIA

HYDROLOGIC SOIL GROUPS

WOOD RODGERS



LEGEND

URBAN LIMIT LINE

PLANNING AREA BOUDNARY

AREA LAND USE

RESIDENTIAL

RR	RURAL RESIDENTIAL
VLDR	VERY LOW DENSITY RESIDENTIAL
LDR	LOW DENSITY RESIDENTIAL
MLDR	MEDIUM/LOW DENSITY RESIDENTIAL
NP	NEIGHBORHOOD PRESERVATION
MDR	MEDIUM DENSITY RESIDENTIAL
PN	PLANNED NEIGHBORHOOD

COMMERCIAL

CC	CENTRAL COMMERCIAL
GC	GENERAL COMMERCIAL
NC	NEIGHBORHOOD COMMERCIAL
HC	HIGHWAY COMMERCIAL
SC	SERVICE COMMERCIAL

INDUSTRIAL

I	INDUSTRIAL
BP	BUSINESS PARK

OTHER

OS	OPEN SPACE
PS	PUBLIC SERVICE
UR	URBAN RESERVE
A	AGRICULTURE

SOURCE:

City of Woodland General Plan Policy Document, 2002.

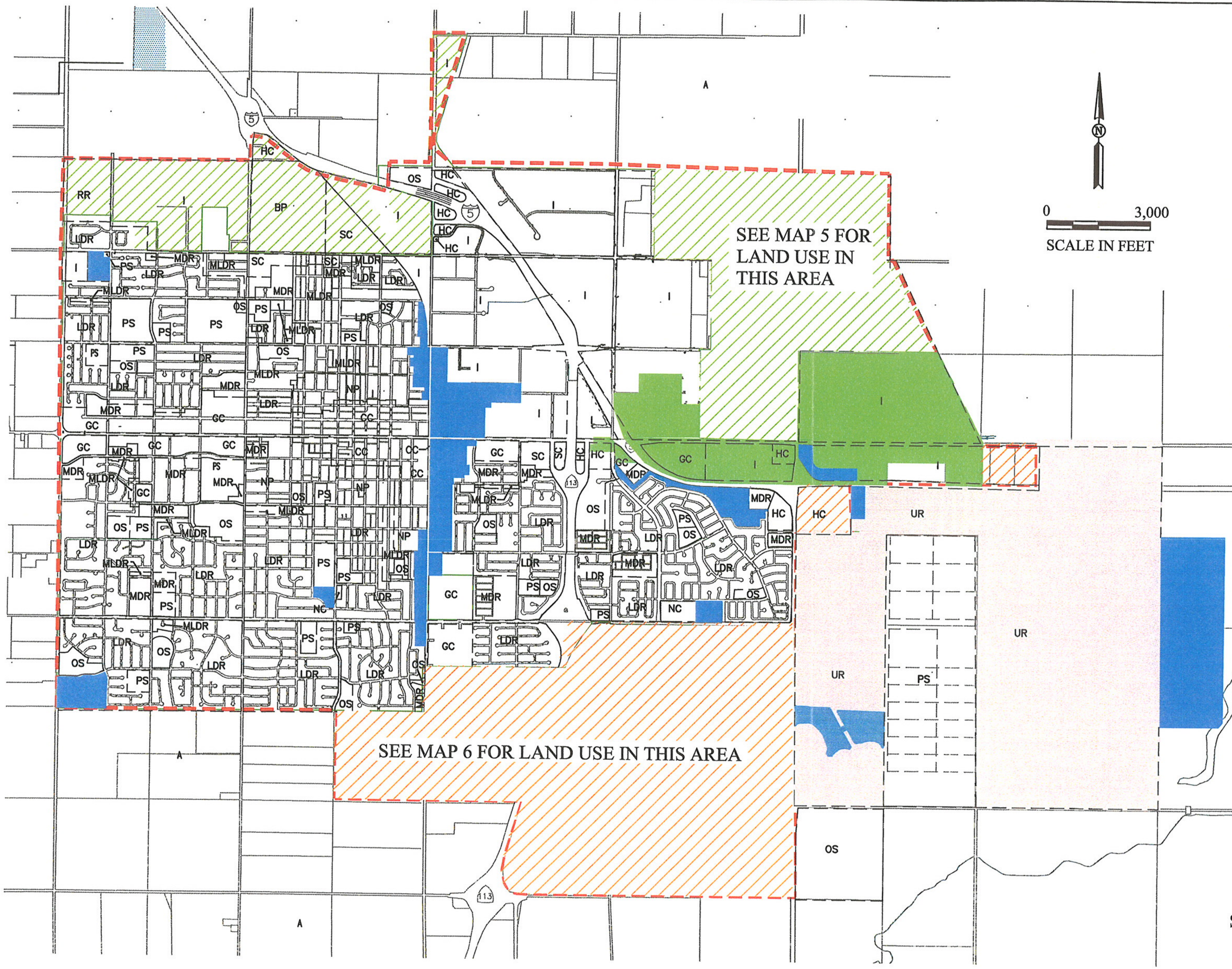
City of Woodland

STORM DRAINAGE FACILITIES MASTER PLAN UPDATE AND PRELIMINARY ENGINEERING

STORM DRAINAGE GUIDELINES AND CRITERIA

EXISTING LAND USE

WOOD RODGERS



LEGEND

- URBAN LIMIT LINE
- CHANGE IN DESIGNATED LAND USE FROM THE 1996 GENERAL PLAN TO THE 2002 GENERAL PLAN
- NORTH URBAN GROWTH AREA
- SOUTH URBAN GROWTH AREA
- URBAN RESERVE AREA
- EAST MAIN ASSESSMENT DISTRICT

AREA LAND USE

RESIDENTIAL

- RR RURAL RESIDENTIAL
- VLDR VERY LOW DENSITY RESIDENTIAL
- LDR LOW DENSITY RESIDENTIAL
- MLDR MEDIUM/LOW DENSITY RESIDENTIAL
- NP NEIGHBORHOOD PRESERVATION
- MDR MEDIUM DENSITY RESIDENTIAL
- PN PLANNED NEIGHBORHOOD

COMMERCIAL

- CC CENTRAL COMMERCIAL
- GC GENERAL COMMERCIAL
- NC NEIGHBORHOOD COMMERCIAL
- HC HIGHWAY COMMERCIAL
- SC SERVICE COMMERCIAL

INDUSTRIAL

- I INDUSTRIAL
- BP BUSINESS PARK

OTHER

- OS OPEN SPACE
- PS PUBLIC SERVICE
- UR URBAN RESERVE
- A AGRICULTURE

SOURCE: City of Woodland General Plan Policy Document, 2002.

City of Woodland

STORM DRAINAGE FACILITIES MASTER PLAN UPDATE AND PRELIMINARY ENGINEERING

STORM DRAINAGE GUIDELINES AND CRITERIA

FUTURE LAND USE

WOOD RODGERS

Land Use Category	Phase 1 Acres	Phase 2 Acres	Total Acres	Total % Distribution
Warehouse/Dist.	91	257	348	40%
Medium/Heavy Industrial	71	0	71	8%
LI/Sales Service	91	196	287	33%
Office/R&D Flex	22	88	110	13%
Business Support Retail	0	9.5	9.5	1%
Open Space	15	0	15	2%
Detention	1.5	36	37.5	4%
Total Acreage	**291.5**	**586.5**	**878**	**100%**

LEGEND

WOODLAND PARK SPECIFIC PLAN AREA

0 1,000

SCALE IN FEET

SOURCE:

EDAW, "Woodland Park Specific Plan, Draft Preferred Alternative," October 7, 2004.

City of Woodland

STORM DRAINAGE FACILITIES MASTER PLAN UPDATE AND PRELIMINARY ENGINEERING

STORM DRAINAGE GUIDELINES AND CRITERIA

FUTURE LAND USE - WOODLAND PARK SPECIFIC PLAN AREA

WOOD RODGERS

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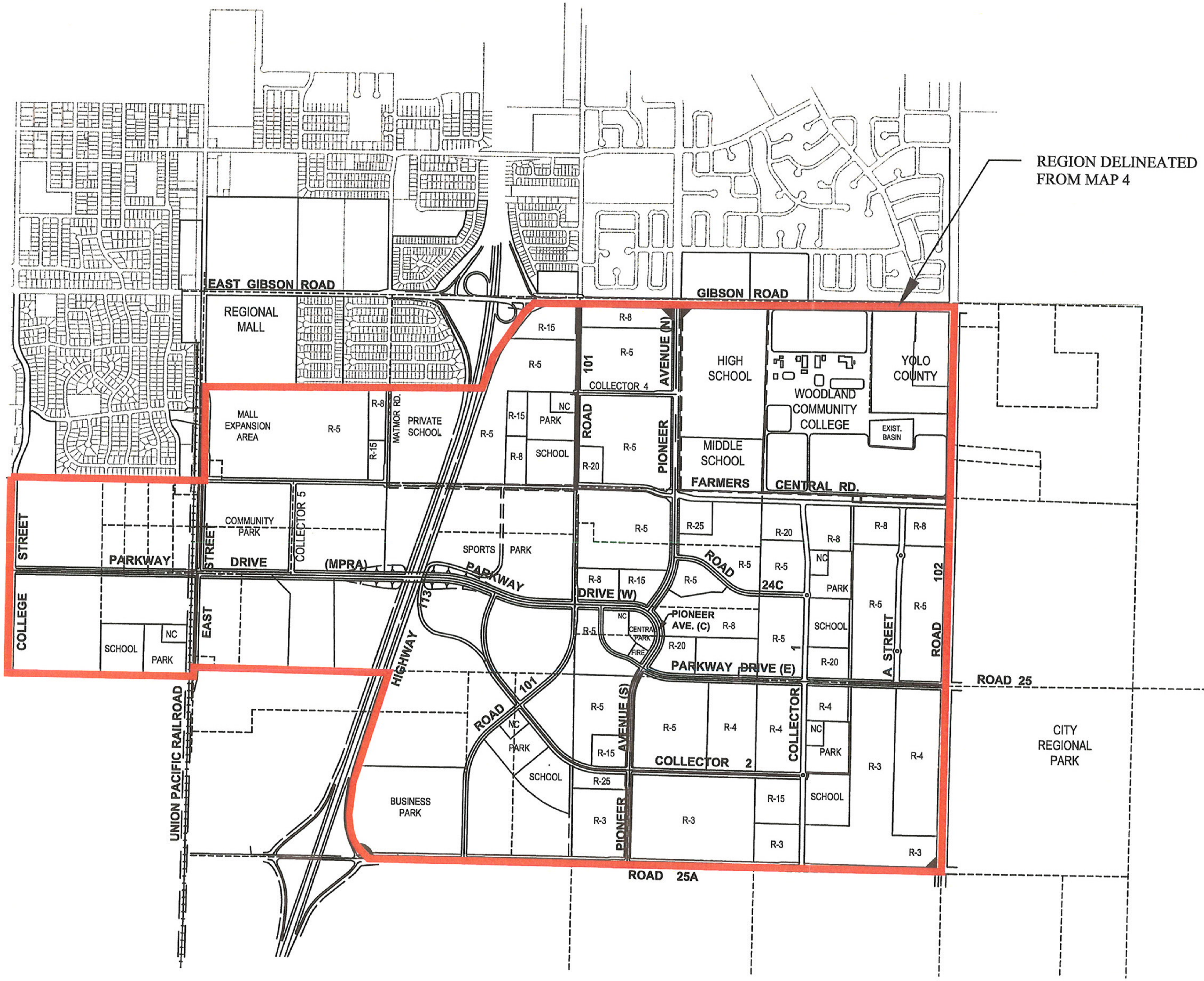

LEGEND

WOODLAND PARK PLAN AREA

LAND USE

R-3	SINGLE FAMILY RESIDENTIAL (3 DU/AC)
R-4	SINGLE FAMILY RESIDENTIAL (4 DU/AC)
R-5	SINGLE FAMILY RESIDENTIAL (5 DU/AC)
R-8	SINGLE FAMILY RESIDENTIAL (8 DU/AC)
R-15	MULTI-FAMILY RESIDENTIAL (15 DU/AC)
R-20	MULTI-FAMILY RESIDENTIAL (20 DU/AC)
R-25	MULTI-FAMILY RESIDENTIAL (25 DU/AC)
NC	NEIGHBORHOOD COMMERICAL

SOURCE:

Cunningham Engineering, "Spring Lake Specific Plan," December, 2003.

N

0 1,500

SCALE IN FEET

City of Woodland

STORM DRAINAGE FACILITIES MASTER PLAN UPDATE AND PRELIMINARY ENGINEERING

STORM DRAINAGE GUIDELINES AND CRITERIA

FUTURE LAND USE
WOODLAND SOUTH AREA

WOOD RODGERS

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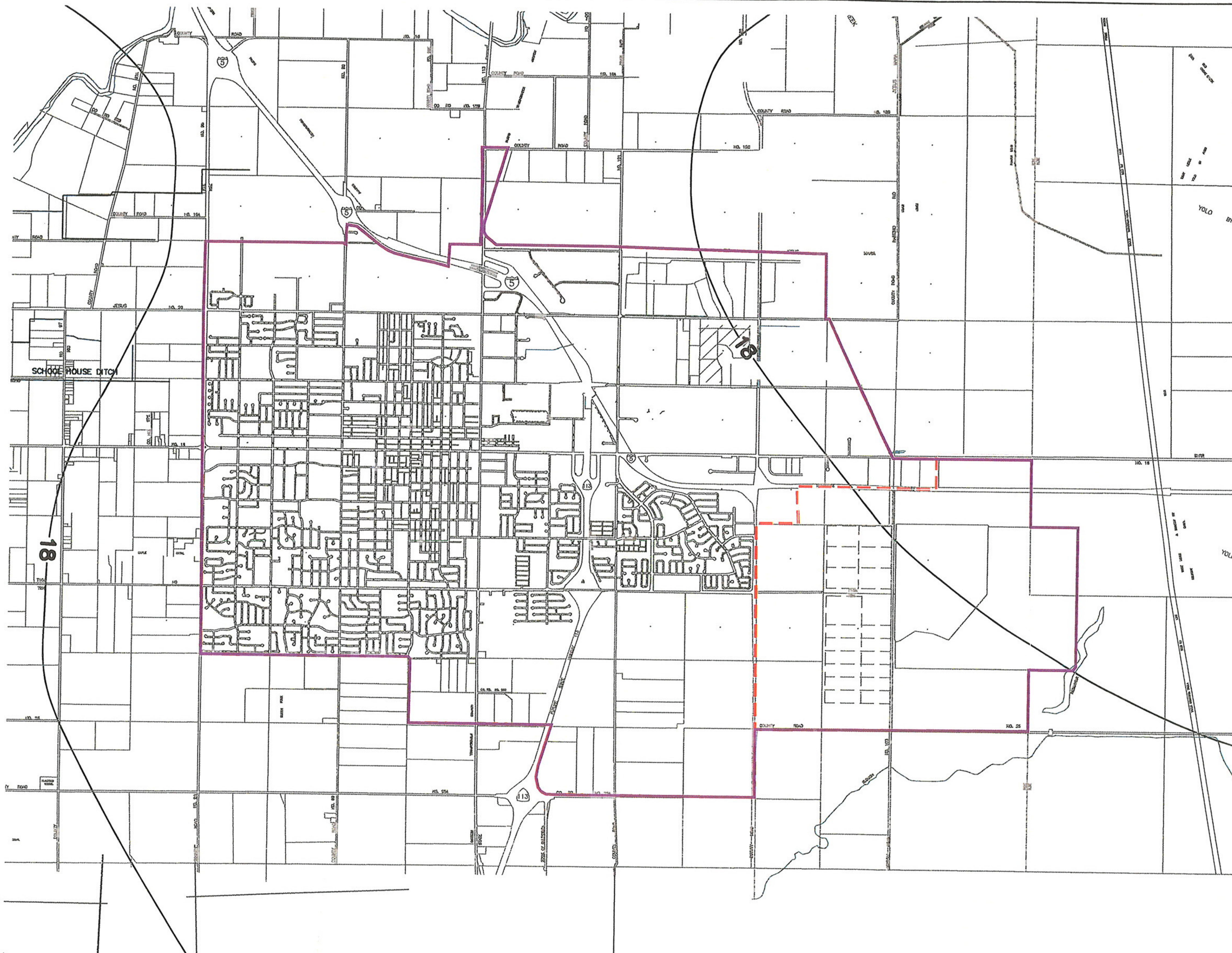

LEGEND

URBAN LIMIT LINE

PLANNING AREA BOUNDARY

MEAN ANNUAL PRECIPITATION

SOURCE:

City of Woodland, Storm Drainage Master Plan, April 1985, Revised October 1987.

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SCALE IN FEET

City of Woodland

STORM DRAINAGE FACILITIES MASTER PLAN UPDATE AND PRELIMINARY ENGINEERING

STORM DRAINAGE GUIDELINES AND CRITERIA

MEAN ANNUAL PRECIPITATION

WOOD RODGERS

APPENDIX

ELECTRONIC SPREADSHEET FILES

(AVAILABLE FROM THE CITY OF WOODLAND UPON REQUEST)

CITY OF WOODLAND
Woodland, CA

STORM DRAINAGE FACILITIES MASTER PLAN UPDATE AND PRELIMINARY ENGINEERING

WOODLAND PRECIPITATION/YOLO BYPASS HYDROLOGIC CONCURRENCE

NOVEMBER 2004

Prepared By:

WOOD RODGERS
ENGINEERING · PLANNING · MAPPING · SURVEYING
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Woodland Precipitation/Yolo Bypass Hydrologic Concurrence

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WOODLAND PRECIPITATION/YOLO BYPASS HYDROLOGIC CONCURRENCE

INTRODUCTION

There are various considerations involved in the field of hydrology when it comes to establishing the interdependence of events. Part of the work as engineers is to decrease uncertainties and increase confidence to gain some measure of security where flood control and drainage design work are concerned. The engineering community assigns different levels of certainty to its work, depending upon whether the elements of the design are under its control. Unfortunately within the field of hydrology, the biggest factor, the weather, is out of its control and can be quite unpredictable. Design flows and flood insurance thresholds have been established at storm levels that are projected as infrequent (the "100-year event"). The quantification of a "100-year event," even utilizing what can be considered a long period of data, is still not an exact prediction, but is the best estimation given an unpredictable environment and the limits of measurability of such an environment.

There are situations where engineering uncertainty can lead to an overly conservative approach, given the time, resources, and expertise necessary to come to a more definitive solution. There are systems where the hydrologic components can obviously be treated as connected, or dependent; but there are other systems where the relationship is not as obvious. Unless a concerted effort is undertaken to analyze and evaluate all pertinent contributing factors before formulating final determinations, simpler, more conservative approaches are utilized, often resulting in more expensive oversized facilities. The following report represents the effort of Wood Rodgers, Inc. to define the worst-case hydrologic conditions for the City of Woodland (City). The goal is to identify only the facilities that are needed for the City as drainage improvements.

WOODLAND PRECIPITATION/YOLO BYPASS
HYDROLOGIC CONCURRENCE

BACKGROUND

The total drainage area served by the City during large storm events is approximately 39 square miles. The land use within the drainage area is a mixture of agricultural and urbanized runoff. Prior to 1990, this localized runoff was directed (pumped) to the Cache Creek Settling Basin. In the early 1990's the south levee for the Cache Creek Settling Basin was relocated to the north, leaving a remnant low flow channel and existing levee to act as containment and conveyance for the City's drainage. The City refers to this remnant channel, which was created by the new Cache Creek Settling Basin levee to the north and the older levee to the south, as the "Outfall Channel." All drainage from the City is currently pumped to the Outfall Channel, thereafter draining by gravity to the Yolo Bypass Channel. As proposed development within the City increases runoff (peak flow), the cost of pumping associated with mitigating peak flow can become quite expensive, and direct gravity conveyance to the Yolo Bypass becomes more economically feasible, as long as it is technically feasible.

As the City's drainage as well as drainage from substantially agricultural land around the City, was previously pumped to the Cache Creek Settling Basin, the main downstream constraint from the City's perspective was its pumping capacity. Once flows were pumped into the Cache Creek Settling Basin, drainage was no longer an issue. With the current configuration, there is now some opportunity for the City to drain by gravity and minimize the City's pumping requirements; however, the new system's constraints must be established to adequately size and plan for future drainage.

With a more direct (gravity) connection of the City's drainage to the Yolo Bypass, the stages in the Yolo Bypass must be taken into consideration when determining the worst-case overall 100-year drainage conditions for the City. The larger event stages (greater than 25 years) in the Yolo Bypass are high enough to create tailwater constraints for draining the lowest portions of the City by gravity.

The high stages in the Yolo Bypass are primarily created when there is significant flow spilling from the Sacramento River at the Fremont Weir in combination with the downstream (backwater) influence from flow spilling into the Yolo Bypass at the Sacramento Weir downstream. There are also more localized contributions from the Cache Creek system, which spill (and drain) into the Yolo Bypass just north of the City's outfall connection, however, these Cache Creek contributions are not considered large enough to create flood stages in the Yolo Bypass.

Wood Rodgers, as part of the Storm Drainage Facilities Master Plan Update, was tasked to evaluate the hydrologic relationship between the City and surrounding drainage constraints, particularly the Yolo Bypass. The cost for the City to modify the Yolo Bypass to improve downstream drainage constraints appears very high, therefore defining the Yolo Bypass constraints and designing upstream drainage facilities to fit these constraints offers the prospects of more benefit for less cost.

PRELIMINARY EVALUATIONS

Wood Rodgers evaluated the available data records for the Yolo Bypass as well as available rainfall data for the Woodland area. After speaking with the U.S. Army Corps of Engineers (USACOE), wood Rodgers was informed the best available information for establishing the stage-frequency relationship in the Yolo Bypass was contained in the report generated by the USACOE entitled, "Sacramento Metropolitan Area – Reconnaissance Report," dated February 1989, and revised April 1989. Relating stage in the Yolo Bypass to a recurrence interval (frequency) is critical to understanding and deriving any combined recurrence relationship with the local Woodland area.

The recorded (historical) data available for establishing specific event conditions in the Yolo Bypass is in the form of flow data obtainable through the U.S. Geological Survey (USGS) at the Woodland gage and the Sacramento Weir. The USGS provided the rating curve information necessary to convert the flow data to a stage, recognizing the Woodland gage measures stage and that the available flow data was originally derived from a stage reading (Appendix "A" for the USGS rating curve information). Once the flows were converted, each daily stage value was converted to a frequency value using the USACOE established stage-frequency curve (Figure 1). The USACOE figure contains point data to establish a best-fit curve/line, and shows both the point and curve information. The point event data is labeled, identifying a number of the same storms we have determined as significant events from our recurrence analysis. Wood Rodgers estimated the USACOE curve at different intervals and used spreadsheets to graph and calculate a formula that closely represents the curve line (Figure 2). Wood Rodgers used the relationship that this curve establishes to determine frequency values for the entire period, including the same events that were used to make the curve in the first place. Wood Rodgers decided a more consistent representation of the entire data set, using the same relationship for all storms, was appropriate. For the majority of the data this should make little difference as the points and curve closely match. For the very largest storm in 1986, however, it skewed the frequency of this one event higher as a 111-year stage, rather than the frequency of the graphed point, which is approximately a 70-year event. The effects of this will be evaluated during the following analysis.

As mentioned previously, the maximum stage in the Yolo Bypass at Woodland is influenced by backwater conditions resulting from downstream spills over the Sacramento Weir, therefore, it was necessary to obtain flow data at the Sacramento Weir as well, to establish an accurate stage-frequency event history at the Woodland gage.

The primary rainfall information for the Woodland area was obtained through the website of the University of California Statewide Integrated Pest Management Program (UCSIPMP). The station representing the City's rainfall is a climate station established and connected to the National Weather Service and the National Oceanic and Atmospheric Administration's National Climatic Data Center. The data inventory ranged from 1951 to the present with very few data omissions, and provided the longest continuous data record for the City. A second precipitation measurement location was recently established in 1997, at the Office of Emergency Services in Woodland, and its data was obtained through the California Data Exchange Center (CDEC) and used to compare with the readings from the UCSIPMP station. A precipitation station in the Davis area was also used for comparative purposes to corroborate the data retrieved from the UCSIPMP Woodland station. Both the Davis station and the CDEC station provide data that is consistent (though not exactly matching) with the measured values at the UCSIPMP Woodland station.

This daily data from UCSIPMP at Woodland was evaluated by Wood Rodgers and correlated to a frequency (recurrence) by utilizing the analyses performed by James Goodridge in his report entitled, "Solano & Yolo County Design Rainfall." Refer to Appendix B for a copy of Mr. Goodridge's report as well as Wood Rodgers' best-fit rainfall frequency curves from the Goodridge 24-hour, 2-day, 3-day, 5-day and 10-day duration data. Mr. Goodridge's report is currently the accepted reference for establishing rainfall frequency in the City under the Storm Drainage Facilities Master Plan (1999). It is also the basis for rainfall values used in the currently effective FEMA HEC-1 modeling for a large portion of Yolo County. Utilizing a spreadsheet program, the daily rainfall data was evaluated for shorter and longer duration events, with the shortest reasonable duration being limited to a 24-hour storm by the data itself. While a particular daily rainfall value may not be considered a large storm, Wood Rodgers recognizes that several consecutive days of continuous rainfall may equate to a higher recurrence storm than any individual day's rainfall within that event. Also, Wood Rodgers recognizes the importance of accurately representing the most frequent storms recurrence value if it less than one year. If all small storms were arbitrarily rounded up to a one-year recurrence when in fact the storm magnitude is much smaller, equating to a 0.2-year recurrence, this could skew the distribution possibly making the magnitude of the larger storms appear relatively more frequent in any distribution. Therefore we estimated the rainfall frequency to the nearest 0.1 for all storm rainfall frequencies.

Wood Rodgers graphed the independent data histories for the Yolo Bypass stages parallel to the rainfall/precipitation in the City. The detailed comparison of the data included identifying all periods in real-time that Bypass stage and Woodland rainfall events occurred simultaneously in history, overlapping the timelines for each of the data records to compare and correlate the relationship between each.

Comparing the peak events for each of the separate data records and looking at coincident events indicates the rainfall event that creates a peak stage in the Yolo Bypass is generally not the same storm as any simultaneously occurring rainfall event in the City. There appears to be relatively little dependence between the simultaneous occurrence of peak stage in the Yolo Bypass and peak rainfall in the City. For examples of the significant coincident historical events refer to Figure 3, Figure 4, and Figure 5 for a graphical representation.

Some storm events show rainfall in the City sometimes preceding peak stages in the Yolo Bypass with little or no rainfall in the City during the peak Yolo Bypass stage period. The data also shows that historically there has been significant rainfall in the City with much lower stages in the Yolo Bypass. Generally, looking at the size of the area draining to the Sacramento River system and spilling over the Fremont Weir, precipitation occurs greater than 24 hours before peak Yolo Bypass stages can be reached from that event, if it is large enough to spill in the first place. If the same storm event was evaluated for the City (assuming the City received rainfall at all for that same event) the local runoff from the City should have time to drain from the local system before peak stages in the Yolo Bypass are reached, as the time of concentration for the City is approximately 12 hours.

Wood Rodgers asserts that the relative sizes and locations of the drainage areas and corresponding times of concentration for each of the systems, as well as the available historical data, strongly indicate that any precipitation occurring in the City simultaneously with peak stages in the Yolo Bypass originates from a separate storm event than the storm creating the Yolo Bypass conditions.

Generally, probability predictions of storm recurrence are not tied to any specific day but a broad window in time. It is a prediction that a certain magnitude event has a quantified probability of occurring in a given year. This methodology does not preclude the occurrence of back-to-back large events. Any specific (time dependent) probability of two separate events occurring simultaneously (or immediately after one another) should be less than the individual probability of each event occurring independently in a broad period of time. If the events are determined independent of one another, the combined probability (simultaneous occurrence) is the product of the independent probabilities.

APPROACH

Predictable recurrence of a certain magnitude storm event (or its probability) in hydrology is expressed as a % chance exceedance in any given year. The 100-year storm, as it is commonly referred to, can be expressed as a storm that has a 1% chance annual exceedance (in any given year). This expression is not day-specific. For example, it does not predict that on December 31 of any given year there is a 1% chance of the (100-year) storm occurring. The 1% probability only refers to it happening any time during a given year. If one wanted the probability of the 1% storm occurring on a specific day, then one would need to introduce the variability of days in the year.

Typically, it is more likely to rain during the winter season, but it can also rain during the summer months with thunderstorm cloudbursts, such as the one that occurred over Sacramento in September of 2004. These types of storms in the summer, however, are generally much smaller (area) and more intense than a storm that would be needed to produce a Sacramento River overflow into the Yolo Bypass. Conservatively the window of time in a given year could be reduced to a six-month period, where rainfall is likely to occur (at all) in the California valley areas. So the probability should involve a 1 in (365/2) chance of occurrence, or once in 182.5 days. If simultaneity is to be a consideration then the probabilities must encompass a specific time probability that reflects two independent yet simultaneous events.

Wood Rodgers' approach assumes, as most hydrologic analyses do, that the measured region-specific historical record accurately represents that region's rainfall/runoff response. It should logically also reflect any relationship or interdependence between otherwise independent systems, such as the effects meteorological seasonal patterns have on storm probability, specifically in this case with Woodland precipitation and Yolo Bypass stages.

A difficulty in evaluating any potential combined relationship between rainfall events in the City and flood stages in the Yolo Bypass was to define each separate event in a common fashion. The measured rainfall record in the City is measured in inches of precipitation for each day. The measured Yolo Bypass stage is a value representing a maximum daily stage (flooded elevation) for each day. It would seem that these two values are "apples and oranges." Wood Rodgers' approach was to represent the magnitude of each type of event by its "stand-alone" recurrence value, based upon frequency analyses established by others. In other words, the recurrence value of any particular historical storm event can represent the relative magnitude of that storm.

Wood Rodgers' approach was to evaluate the period of record for the local Woodland rainfall and the regional flows/stages in the Yolo Bypass, together, to determine if a combined frequency relationship exists. Wood Rodgers evaluated the overlapping record and identified the simultaneous "Bypass-stage" and "Woodland-rainfall" events that happened during the period of record, each event with a separately derived independent frequency.

ANALYSIS

The events being considered under this exercise must occur within a day of one another to reasonably influence one another (hydrologically and hydraulically). The events during the 50-year period of record that have occurred within a day of one another were plotted as simultaneously occurring on Figure 6, with the event's recurrence for Woodland rainfall plotted against the event's recurrence for stage in the Yolo Bypass. There are other events that are part of the overall data set that were not plotted, as they were not simultaneous storms but were storms that happened locally but not regionally, or vice versa. On Figure 6 these storms would fall on the axes and would not be visible anyway. Reviewing the data from a 50-year period of record there are fewer simultaneous events during the data history than the number of overall storms (events). The data, as presented on Figure 6, together with the remainder of the historical record, strongly suggests that rainfall in Woodland is independent of stage occurrence in the Yolo Bypass, as all the data falls closely along either of the plotted axes or is clustered around the origin (0,0) of the plot.

DATA SET ANOMALIES

There appeared to be several periods of record where stage in the Yolo Bypass was not available. After speaking with USGS personnel, the reason there are gaps in the data period at the Woodland gage is because the flows did not exceed 1,000 cfs. Each period of "missing" data for the Woodland gage was corroborated with the Sacramento Weir flows and, in every instance, there was zero flow data at the Sacramento Weir location when there was purportedly less than 1,000 cfs flowing at the Woodland gage. Therefore, the gaps were reinterpreted, equating them to periods of <1,000 cfs flow.

HISTORICAL SYSTEM CHANGES

Wood Rodgers recognizes the watershed system that creates a flood stage event in the Yolo Bypass has undergone changes during the period of record. Most significant are the additions of the Oroville and Folsom lakes (and dams). Generally, the addition of flood control storage within a system tends to lessen the peak values. Given the complexity of the system, however, Wood Rodgers recognizes that regulation of flows in a portion of the system can change the relative timing of peaks and can, at some locations, serve to increase rather than lessen peak values if times of concentration for different parts of the system become more coincident, or if runoff hydrograph lengths are longer and produce overlap where none previously occurred.

The relationships between different flood control components in the Sacramento River watershed together create a very complex system. For purposes of this study, the design of flood control systems, including dam and reservoir systems, and the operation, are assumed to be improving and not worsening flooding conditions. Although development has occurred in the system, adding runoff, its contribution is assumed to be minute in comparison to addition of reservoirs and dams to the system.

Wood Rodgers asserts that using the longer (maximum) period of record is preferable to establish a relationship between recurrences of events for this analysis, as it produces the most conservative results.

CONCLUSIONS

The results of the analysis indicate there is no direct relationship of recurrence and coincidence between precipitation in the City and the flooded water surface of the Yolo Bypass (near Woodland). Even so, the historical information is useful in estimating a reasonably conservative simultaneous occurrence for storm drainage design purposes, such as what worst-case stage (water surface) in the Yolo Bypass could be expected to occur when the City is experiencing a 100-year rainfall event. The reverse condition can also be estimated for the worst-case local rainfall that could reasonably occur when the Yolo Bypass is experiencing a 100-year flooded condition.

The Yolo Bypass creates a tailwater (backwater) influence on the gravity portion of the proposed drainage system for the City, so it only influences design of systems that are within the backwater influences of the Yolo Bypass. Upper Woodland will continue to be designed with a local 100-year storm for Type 1 facilities and with a local 10-year storm for Type 2 facilities with the City's conveyance of the same local locally generated flows governing the hydraulic conditions. Accordingly, the results must be interpreted from a worst-case flooding perspective as it relates to Woodland's drainage system design.

The 50-year record shows that when an approximate 100-year event has occurred in either the Yolo Bypass, or in Woodland, there has been a simultaneous event in the other that was approximately a 5- to 15-year event. To be conservative we will assign a 25-year concurrent storm with any 100-year independent event, even though such a simultaneous event is likely much less probable overall than a 100-year event.

The "combined" frequency of the simultaneous events is not established as a result of this report. What has occurred in the historical record as simultaneous events has not been evaluated under a combined frequency distribution to assign a single frequency to the two events together. They are still "separate" events from a recurrence perspective under this report. As mentioned earlier, we believe that the simultaneity of independent events must factor in the day-specific occurrence into each probability estimate to properly account for predicting future simultaneous occurrence. This will most likely decrease the probability overall under a combined evaluation. A combined 100-year frequency should factor the probability of each separate event as well as the added probability of their simultaneous occurrence to "add up" (it is not suggested that the probabilities are additive) to the total probability.

Basic probability tells us that the probability of an outcome of a two-sided coin being flipped is generally one chance in two on any given flip. If two coins are tossed simultaneously then the combined probability of any given combined outcome is the product of the independent probabilities. In this case the four possible outcomes are H-T, T-H, H-H, and T-T, or ½ x ½, or ¼. In this example it is clear that the events are independent as the outcome of one coin's toss has no bearing on the outcome of the other coin's toss. In this simplistic example the simultaneity of the events is controlled by the flipper. The simultaneity of independent weather events is not controlled by human intervention, so there should be another factor to account for uncontrolled simultaneous occurrence. Given these issues, the combined probability of two independent weather events occurring simultaneously is likely less than the product of their individual probabilities.

Therefore we believe that our combination of a 25-year event and a 100-year event for the two systems is conservatively representing the worst-case 100-year drainage conditions.

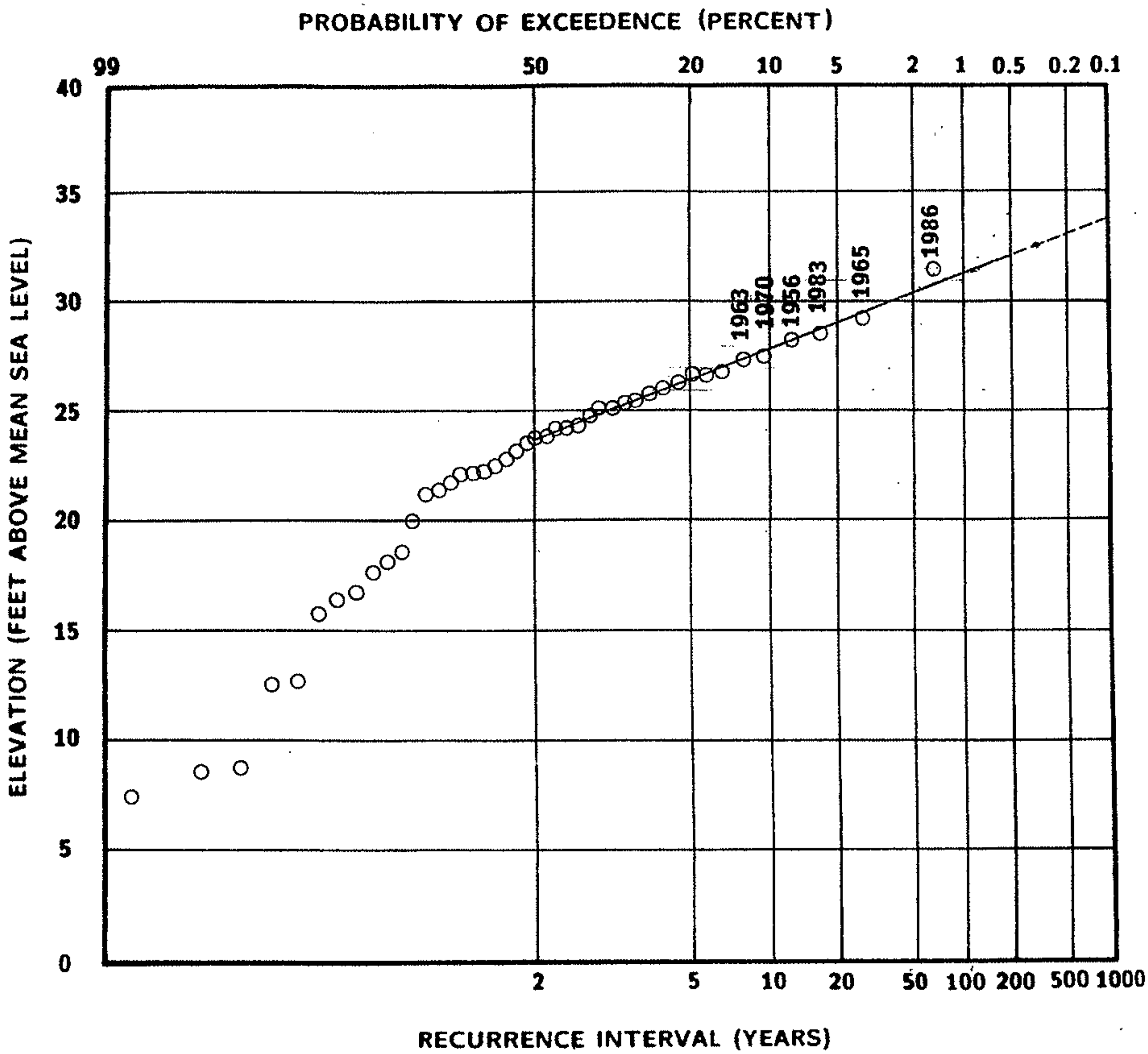
ACKNOWLEDGEMENTS AND RECOMMENDATIONS

This evaluation expands upon accepted independent frequency distributions and basic probability and frequency derivation techniques to evaluate the relationship between Yolo Bypass stages and Woodland rainfall occurring simultaneously.

The relationship is based upon real-world historical (measured) data. The interdependence between the two separate events should be reflected in any results using measured data. There have been simultaneous occurrences of flood stage in the Yolo Bypass and rainfall in Woodland in the past, and there will be in the future. Wood Rodgers strongly recommends the relationships determined in this report should be reevaluated as the period of record grows, to ensure some future pattern does not occur. If there are significant changes to the physical hydraulic system contributing to the Yolo Bypass these should also be addressed in reevaluating any combined relationship from the previous data. Wood Rodgers recommends retaining earlier data to make estimates more conservative. Given the assumption that any physical changes to the system will be designed to lessen peak values in the future, keeping higher (earlier) data should maintain a conservative review of the system.

The availability of reliable data and long periods of record were of paramount importance in performing this exercise. Wood Rodgers' work could not have been completed without being an extension of the excellent work completed by the USACOE in establishing the Yolo Bypass stage-frequency, as well as James Goodridge for establishing the rainfall frequency relationships for Yolo County and Solano County, the UCIPM system for measuring and recording rainfall, and the USGS for recording and sharing the flow and stage relationships in the Yolo Bypass and making recorded daily flow data available.

FIGURES



SACRAMENTO METROPOLITAN AREA
CALIFORNIA

STAGE-FREQUENCY RELATIONSHIP

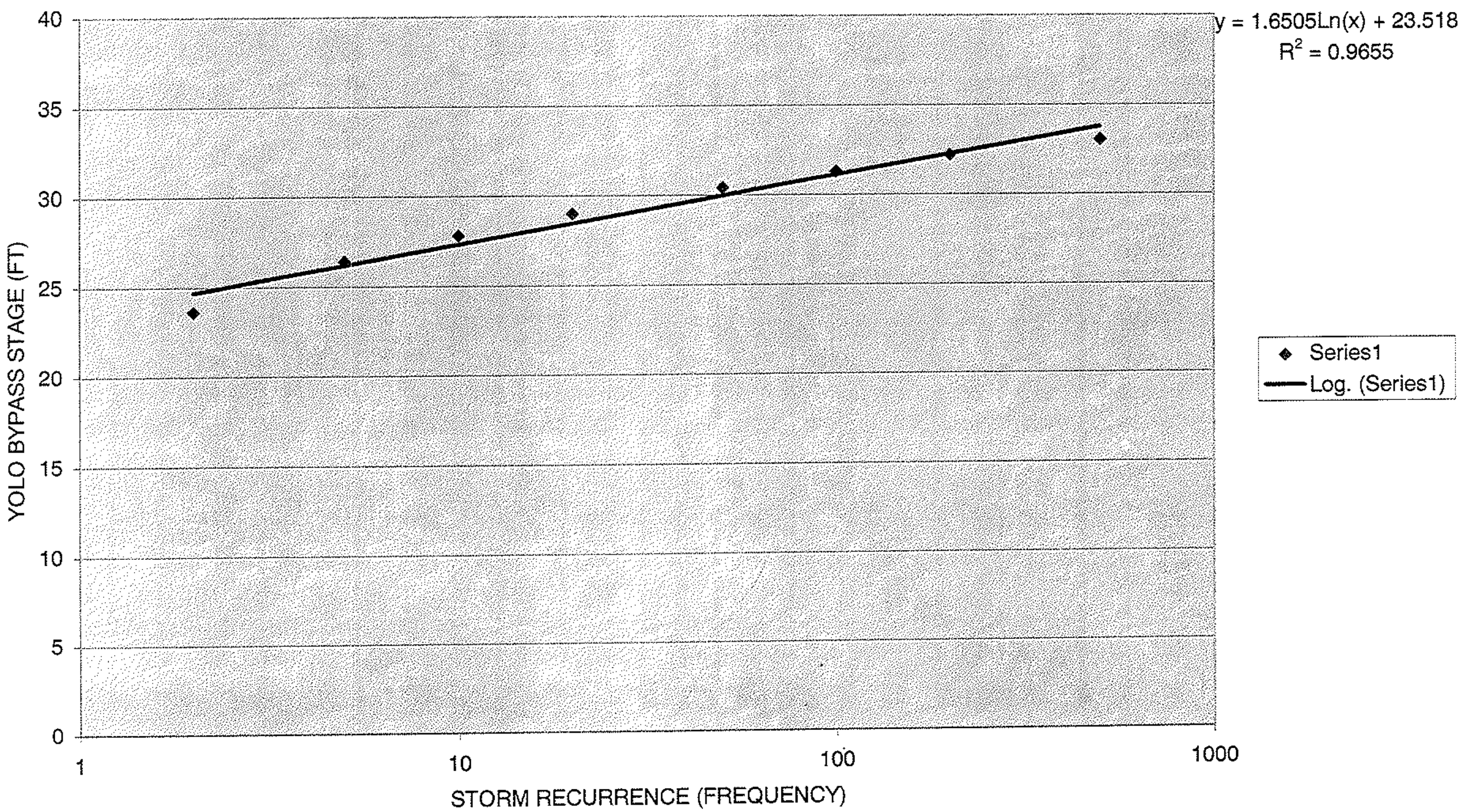
YOLO BYPASS NEAR WOODLAND

SACRAMENTO DISTRICT, CORPS OF ENGINEERS

June 1988

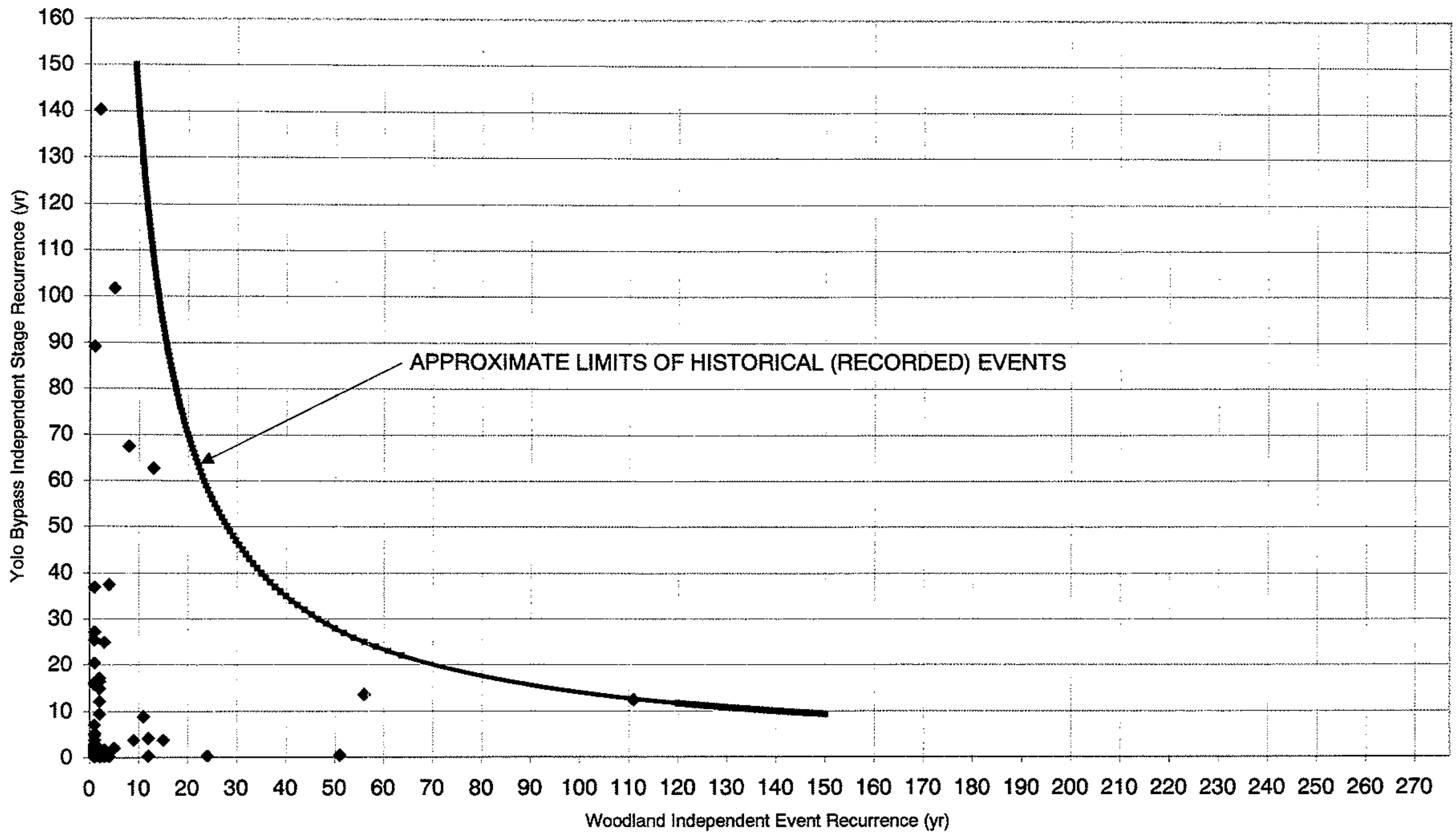
FIGURE 1

FIGURE 2
CITY OF WOODLAND
WOODLAND PRECIPITATION/YOLO BYPASS HYDROLOGIC CONCURRENCE
BEST FIT CURVE - FLOOD STAGE FREQUENCY



color 8.5x11
figures 3-5

FIGURE 6
CITY OF WOODLAND
WOODLAND PRECIPITATION/YOLO BYPASS HYDROLOGIC CONCURRENCE
SIMULTANEOUS STAGE/PRECIPITATION FREQUENCY COMPARISON



APPENDICES

APPENDIX A

EXPANDED RATING TABLE TYPE: LOG

11453000 DATE PROCESSED: 08-16-2002 @ 13:02 BY smithson

YOLO BYPASS NR WOODLAND CA DD: 5 TYPE: 001 RATING NO: 0018

OFFSET: 8.00 START DATE/TIME: 10-01-1987 (0015)

BASED ON _______ DISCHARGE MEASUREMENTS, NOS ________, AND ________, AND IS _______ WELL DEFINED BETWEEN _______ AND _______ CFS

COMP BY _____ DATE _________ CHK. BY _____ DATE _________

THE SAME AS RATING TABLES 16 & 17 BELOW 25.9 ft.

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND .00	.01	.02	.03	.04	(EXPANDED PRECISION) .05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
10.70	192.0*	192.8	193.6	194.4	195.2	196.1	196.9	197.7	198.5	199.3	8.100
10.80	200.1	200.9	201.8	202.6	203.4	204.2	205.0	205.8	206.6	207.5	8.200
10.90	208.3	209.1	209.9	210.7	211.6	212.4	213.2	214.0	214.8	215.7	8.200
11.00	216.5	217.3	218.1	219.0	219.8	220.6	221.4	222.2	223.1	223.9	8.200
11.10	224.7	225.5	226.4	227.2	228.0	228.9	229.7	230.5	231.3	232.2	8.300
11.20	233.0*	234.0	234.9	235.9	236.8	237.8	238.8	239.7	240.7	241.7	9.600
11.30	242.6	243.6	244.6	245.5	246.5	247.5	248.4	249.4	250.4	251.4	9.700
11.40	252.3	253.3	254.3	255.3	256.2	257.2	258.2	259.2	260.2	261.1	9.800
11.50	262.1	263.1	264.1	265.1	266.1	267.1	268.1	269.0	270.0	271.0	9.900
11.60	272.0	273.0	274.0	275.0	276.0	277.0	278.0	279.0	280.0	281.0	10.00
11.70	282.0*	283.1	284.2	285.3	286.4	287.6	288.7	289.8	290.9	292.0	11.10
11.80	293.1	294.3	295.4	296.5	297.6	298.8	299.9	301.0	302.1	303.3	11.30
11.90	304.4	305.5	306.7	307.8	309.0	310.1	311.2	312.4	313.5	314.7	11.40
12.00	315.8	317.0	318.1	319.3	320.4	321.6	322.7	323.9	325.0	326.2	11.50
12.10	327.3	328.5	329.7	330.8	332.0	333.2	334.3	335.5	336.7	337.8	11.70
12.20	339.0*	340.3	341.6	342.9	344.2	345.5	346.8	348.2	349.5	350.8	13.10
12.30	352.1	353.4	354.7	356.1	357.4	358.7	360.1	361.4	362.7	364.1	13.30
12.40	365.4	366.7	368.1	369.4	370.8	372.1	373.5	374.8	376.2	377.5	13.50
12.50	378.9	380.2	381.6	383.0	384.3	385.7	387.0	388.4	389.8	391.2	13.60
12.60	392.5	393.9	395.3	396.7	398.1	399.4	400.8	402.2	403.6	405.0	13.90
12.70	406.4	407.8	409.2	410.6	412.0	413.4	414.8	416.2	417.6	419.0	14.00
12.80	420.4	421.8	423.2	424.7	426.1	427.5	428.9	430.3	431.8	433.2	14.20
12.90	434.6	436.0	437.5	438.9	440.3	441.8	443.2	444.7	446.1	447.6	14.40
13.00	449.0*	450.6	452.3	454.0	455.6	457.3	458.9	460.6	462.3	463.9	16.60
13.10	465.6	467.3	469.0	470.6	472.3	474.0	475.7	477.4	479.1	480.8	16.90
13.20	482.5	484.2	485.9	487.6	489.3	491.0	492.8	494.5	496.2	497.9	17.20
13.30	499.7	501.4	503.1	504.9	506.6	508.3	510.1	511.8	513.6	515.3	17.40
13.40	517.1	518.8	520.6	522.4	524.1	525.9	527.7	529.4	531.2	533.0	17.70
13.50	534.8	536.6	538.4	540.1	541.9	543.7	545.5	547.3	549.1	550.9	18.00
13.60	552.8	554.6	556.4	558.2	560.0	561.8	563.7	565.5	567.3	569.2	18.20
13.70	571.0*	573.1	575.3	577.4	579.5	581.7	583.8	586.0	588.1	590.3	21.50
13.80	592.5	594.6	596.8	599.0	601.2	603.3	605.5	607.7	609.9	612.1	21.80
13.90	614.3	616.5	618.8	621.0	623.2	625.4	627.7	629.9	632.1	634.4	22.30
14.00	636.6	638.9	641.1	643.4	645.7	647.9	650.2	652.5	654.8	657.0	22.70
14.10	659.3	661.6	663.9	666.2	668.5	670.8	673.2	675.5	677.8	680.1	23.20
14.20	682.5	684.8	687.1	689.5	691.8	694.2	696.5	698.9	701.3	703.6	23.50
14.30	706.0	708.4	710.8	713.2	715.6	718.0	720.4	722.8	725.2	727.6	24.00
14.40	730.0*	732.6	735.3	738.0	740.6	743.3	746.0	748.6	751.3	754.0	26.70

EXPANDED RATING TABLE TYPE: LOG

11453000 DATE PROCESSED: 08-16-2002 @ 13:02 BY smithson

YOLO BYPASS NR WOODLAND CA DD: 5 TYPE: 001 RATING NO: 0018

OFFSET: 8.00 START DATE/TIME: 10-01-1987 (0015)

THE SAME AS RATING TABLES 16 & 17 BELOW 25.9 ft.

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND .00	.01	.02	.03	.04	(EXPANDED PRECISION) .05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
14.50	756.7	759.4	762.1	764.8	767.5	770.2	773.0	775.7	778.4	781.2	27.20
14.60	783.9	786.7	789.5	792.2	795.0	797.8	800.5	803.3	806.1	808.9	27.80
14.70	811.7	814.5	817.4	820.2	823.0	825.8	828.7	831.5	834.4	837.2	28.40
14.80	840.1	842.9	845.8	848.7	851.6	854.4	857.3	860.2	863.1	866.0	28.90
14.90	869.0	871.9	874.8	877.7	880.7	883.6	886.6	889.5	892.5	895.4	29.40
15.00	898.4	901.4	904.4	907.4	910.4	913.4	916.4	919.4	922.4	925.4	30.00
15.10	928.4	931.5	934.5	937.5	940.6	943.6	946.7	949.8	952.8	955.9	30.60
15.20	959.0*	962.4	965.7	969.1	972.5	975.8	979.2	982.6	986.0	989.4	33.90
15.30	992.9	996.3	999.7	1003	1007	1010	1014	1017	1020	1024	34.10
15.40	1027	1031	1034	1038	1041	1045	1049	1052	1056	1059	36.00
15.50	1063	1066	1070	1073	1077	1081	1084	1088	1091	1095	36.00
15.60	1099	1102	1106	1110	1113	1117	1121	1124	1128	1132	36.00
15.70	1135	1139	1143	1147	1150	1154	1158	1162	1165	1169	38.00
15.80	1173	1177	1180	1184	1188	1192	1196	1200	1203	1207	38.00
15.90	1211	1215	1219	1223	1227	1230	1234	1238	1242	1246	39.00
16.00	1250*	1255	1260	1264	1269	1274	1279	1284	1288	1293	48.00
16.10	1298	1303	1308	1313	1318	1323	1328	1333	1338	1343	50.00
16.20	1348	1353	1358	1363	1368	1373	1378	1383	1388	1393	50.00
16.30	1398	1404	1409	1414	1419	1424	1429	1435	1440	1445	52.00
16.40	1450	1456	1461	1466	1472	1477	1482	1488	1493	1498	54.00
16.50	1504	1509	1515	1520	1525	1531	1536	1542	1547	1553	54.00
16.60	1558	1564	1569	1575	1580	1586	1592	1597	1603	1608	56.00
16.70	1614	1620	1625	1631	1637	1643	1648	1654	1660	1666	57.00
16.80	1671	1677	1683	1689	1695	1700	1706	1712	1718	1724	59.00
16.90	1730	1736	1742	1748	1754	1760	1766	1772	1778	1784	60.00
17.00	1790	1796	1802	1808	1814	1820	1826	1833	1839	1845	61.00
17.10	1851	1857	1864	1870	1876	1882	1889	1895	1901	1908	63.00
17.20	1914	1920	1927	1933	1939	1946	1952	1959	1965	1972	64.00
17.30	1978	1984	1991	1997	2004	2011	2017	2024	2030	2037	66.00
17.40	2044	2050	2057	2063	2070	2077	2084	2090	2097	2104	67.00

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
17.50	2111	2117	2124	2131	2138	2145	2151	2158	2165	2172	68.00
17.60	2179	2186	2193	2200	2207	2214	2221	2228	2235	2242	70.00
17.70	2249	2256	2263	2270	2277	2284	2292	2299	2306	2313	71.00
17.80	2320	2328	2335	2342	2349	2357	2364	2371	2378	2386	73.00
17.90	2393	2401	2408	2415	2423	2430	2438	2445	2453	2460	75.00
18.00	2468	2475	2483	2490	2498	2505	2513	2521	2528	2536	76.00
18.10	2544	2551	2559	2567	2574	2582	2590	2598	2606	2613	77.00
18.20	2621	2629	2637	2645	2653	2661	2668	2676	2684	2692	79.00

EXPANDED RATING TABLE TYPE: LOG

11453000 DATE PROCESSED: 08-16-2002 @ 13:02 BY smithson

YOLO BYPASS NR WOODLAND CA DD: 5 TYPE: 001 RATING NO: 0018

OFFSET: 8.00 START DATE/TIME: 10-01-1987 (0015)

THE SAME AS RATING TABLES 16 & 17 BELOW 25.9 ft.

DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
18.30	2700	2708	2716	2724	2732	2740	2749	2757	2765	2773	81.00
18.40	2781	2789	2797	2806	2814	2822	2830	2838	2847	2855	82.00
18.50	2863	2872	2880	2888	2897	2905	2913	2922	2930	2939	84.00
18.60	2947	2956	2964	2973	2981	2990	2998	3007	3016	3024	86.00
18.70	3033	3041	3050	3059	3067	3076	3085	3094	3102	3111	87.00
18.80	3120	3129	3138	3147	3155	3164	3173	3182	3191	3200	89.00
18.90	3209	3218	3227	3236	3245	3254	3263	3272	3281	3290	90.00
19.00	3299	3309	3318	3327	3336	3345	3355	3364	3373	3382	93.00
19.10	3392	3401	3410	3420	3429	3439	3448	3457	3467	3476	94.00
19.20	3486	3495	3505	3514	3524	3533	3543	3553	3562	3572	95.00
19.30	3581	3591	3601	3611	3620	3630	3640	3650	3659	3669	98.00
19.40	3679	3689	3699	3709	3718	3728	3738	3748	3758	3768	99.00
19.50	3778	3788	3798	3808	3818	3828	3839	3849	3859	3869	101.0
19.60	3879	3889	3900	3910	3920	3930	3941	3951	3961	3972	103.0
19.70	3982	3992	4003	4013	4024	4034	4045	4055	4066	4076	105.0
19.80	4087	4097	4108	4118	4129	4140	4150	4161	4172	4182	106.0
19.90	4193	4204	4215	4225	4236	4247	4258	4269	4280	4291	109.0
20.00	4302	4312	4323	4334	4345	4356	4367	4378	4390	4401	110.0
20.10	4412	4423	4434	4445	4456	4467	4479	4490	4501	4512	112.0
20.20	4524	4535	4546	4558	4569	4581	4592	4603	4615	4626	114.0
20.30	4638	4649	4661	4672	4684	4695	4707	4719	4730	4742	116.0
20.40	4754	4765	4777	4789	4801	4812	4824	4836	4848	4860	117.0
20.50	4871	4883	4895	4907	4919	4931	4943	4955	4967	4979	120.0
20.60	4991	5003	5015	5027	5040	5052	5064	5076	5088	5101	122.0
20.70	5113	5125	5137	5150	5162	5175	5187	5199	5212	5224	124.0
20.80	5237	5249	5262	5274	5287	5299	5312	5324	5337	5350	125.0
20.90	5362	5375	5388	5400	5413	5426	5439	5451	5464	5477	128.0
21.00	5490*	5505	5519	5534	5548	5563	5578	5592	5607	5622	146.0
21.10	5636	5651	5666	5681	5696	5711	5726	5741	5756	5771	150.0
21.20	5786	5801	5816	5831	5846	5861	5876	5892	5907	5922	152.0
21.30	5938	5953	5968	5984	5999	6015	6030	6046	6061	6077	154.0
21.40	6092	6108	6124	6139	6155	6171	6187	6202	6218	6234	158.0
21.50	6250*	6268	6286	6304	6322	6341	6359	6377	6395	6414	182.0
21.60	6432	6450	6469	6487	6506	6525	6543	6562	6581	6599	186.0
21.70	6618	6637	6656	6675	6694	6713	6732	6751	6770	6789	190.0
21.80	6808	6827	6846	6866	6885	6904	6924	6943	6963	6982	194.0
21.90	7002	7022	7041	7061	7081	7100	7120	7140	7160	7180	198.0

EXPANDED RATING TABLE TYPE: LOG

11453000 DATE PROCESSED: 08-16-2002 @ 13:02 BY smithson

YOLO BYPASS NR WOODLAND CA DD: 5 TYPE: 001 RATING NO: 0018

OFFSET: 8.00 START DATE/TIME: 10-01-1987 (0015)

THE SAME AS RATING TABLES 16 & 17 BELOW 25.9 ft.

DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
22.00	7200*	7223	7245	7268	7291	7314	7337	7359	7382	7406	229.0
22.10	7429	7452	7475	7498	7522	7545	7569	7592	7616	7639	234.0
22.20	7663	7687	7710	7734	7758	7782	7806	7830	7854	7879	240.0
22.30	7903	7927	7951	7976	8000	8025	8050	8074	8099	8124	245.0
22.40	8148	8173	8198	8223	8248	8274	8299	8324	8349	8375	252.0
22.50	8400*	8430	8460	8490	8520	8550	8580	8611	8641	8672	302.0
22.60	8702	8733	8764	8795	8826	8857	8888	8919	8950	8982	311.0
22.70	9013	9045	9076	9108	9140	9172	9204	9236	9268	9301	320.0
22.80	9333	9365	9398	9431	9463	9496	9529	9562	9595	9629	329.0
22.90	9662	9695	9729	9762	9796	9830	9864	9898	9932	9966	338.0
23.00	10000*	10040	10080	10110	10150	10190	10230	10270	10310	10340	380.0
23.10	10380	10420	10460	10500	10540	10580	10620	10660	10700	10740	400.0
23.20	10780	10820	10860	10900	10940	10980	11020	11060	11100	11140	400.0
23.30	11180	11230	11270	11310	11350	11390	11430	11480	11520	11560	420.0
23.40	11600	11650	11690	11730	11770	11820	11860	11900	11950	11990	440.0
23.50	12040	12080	12120	12170	12210	12260	12300	12350	12390	12440	440.0
23.60	12480	12530	12570	12620	12660	12710	12750	12800	12850	12890	460.0
23.70	12940	12990	13030	13080	13130	13170	13220	13270	13320	13360	470.0
23.80	13410	13460	13510	13560	13610	13650	13700	13750	13800	13850	490.0
23.90	13900	13950	14000	14050	14100	14150	14200	14250	14300	14350	500.0
24.00	14400*	14460	14520	14570	14630	14690	14750	14810	14870	14920	580.0
24.10	14980	15040	15100	15160	15220	15280	15340	15400	15470	15530	610.0
24.20	15590	15650	15710	15770	15830	15900	15960	16020	16090	16150	620.0
24.30	16210	16280	16340	16400	16470	16530	16600	16660	16730	16790	650.0
24.40	16860	16920	16990	17050	17120	17190	17250	17320	17390	17460	660.0
24.50	17520	17590	17660	17730	17800	17870	17930	18000	18070	18140	690.0

24.60	18210	18280	18350	18420	18490	18570	18640	18710	18780	18850	710.0
24.70	18920	19000	19070	19140	19210	19290	19360	19440	19510	19580	740.0
24.80	19660	19730	19810	19880	19960	20030	20110	20190	20260	20340	760.0
24.90	20420	20490	20570	20650	20730	20810	20880	20960	21040	21120	780.0
25.00	21200*	21290	21390	21480	21570	21670	21760	21860	21950	22050	950.0
25.10	22150	22240	22340	22440	22530	22630	22730	22830	22930	23030	980.0
25.20	23130	23230	23330	23430	23530	23630	23730	23840	23940	24040	1020
25.30	24150	24250	24350	24460	24560	24670	24780	24880	24990	25100	1050
25.40	25200	25310	25420	25530	25640	25750	25860	25970	26080	26190	1100
25.50	26300*	26420	26540	26660	26780	26910	27030	27150	27280	27400	1220
25.60	27520	27650	27770	27900	28030	28150	28280	28410	28540	28670	1280
25.70	28800	28930	29060	29190	29320	29450	29590	29720	29850	29990	1320

1 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION PAGE 5

EXPANDED RATING TABLE TYPE: LOG

11453000 DATE PROCESSED: 08-16-2002 @ 13:02 BY smithson

YOLO BYPASS NR WOODLAND CA DD: 5 TYPE: 001 RATING NO: 0018

OFFSET: 8.00 START DATE/TIME: 10-01-1987 (0015)

THE SAME AS RATING TABLES 16 & 17 BELOW 25.9 ft.

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND .00	.01	.02	.03	.04	(EXPANDED PRECISION) .05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
25.80	30120	30260	30390	30530	30670	30800	30940	31080	31220	31360	1380
25.90	31500*	31660	31830	32000	32160	32330	32500	32670	32840	33010	1680
26.00	33180	33360	33530	33700	33880	34050	34230	34410	34590	34770	1770
26.10	34950	35130	35310	35490	35680	35860	36040	36230	36420	36600	1840
26.20	36790	36980	37170	37360	37560	37750	37940	38140	38330	38530	1940
26.30	38730	38920	39120	39320	39520	39730	39930	40130	40340	40540	2020
26.40	40750	40960	41170	41380	41590	41800	42010	42220	42440	42650	2120
26.50	42870	43080	43300	43520	43740	43960	44180	44410	44630	44860	2210
26.60	45080	45310	45540	45770	46000	46230	46460	46690	46930	47160	2320
26.70	47400	47640	47870	48110	48350	48600	48840	49080	49330	49570	2420
26.80	49820	50070	50320	50570	50820	51070	51330	51580	51840	52100	2530
26.90	52350	52610	52870	53140	53400	53660	53930	54190	54460	54730	2650
27.00	55000*	55320	55640	55970	56290	56620	56950	57280	57620	57950	3290
27.10	58290	58630	58970	59310	59650	60000	60350	60700	61050	61400	3460
27.20	61750	62110	62470	62830	63190	63560	63920	64290	64660	65030	3660
27.30	65410	65780	66160	66540	66920	67310	67690	68080	68470	68860	3840
27.40	69250	69650	70050	70450	70850	71250	71660	72070	72480	72890	4060
27.50	73310	73720	74140	74560	74990	75410	75840	76270	76700	77140	4260
27.60	77570	78010	78450	78900	79340	79790	80240	80690	81150	81610	4500
27.70	82070	82530	82990	83460	83930	84400	84870	85350	85830	86310	4720
27.80	86790	87280	87770	88260	88750	89250	89750	90250	90750	91260	4980
27.90	91770	92280	92790	93310	93830	94350	94880	95400	95930	96460	5230
28.00	97000*	97380	97760	98140	98530	98910	99300	99680	100100	100500	3900
28.10	100900	101200	101600	102000	102400	102800	103200	103600	104000	104400	3900
28.20	104800	105200	105700	106100	106500	106900	107300	107700	108100	108500	4200
28.30	109000	109400	109800	110200	110700	111100	111500	111900	112400	112800	4200
28.40	113200	113700	114100	114500	115000	115400	115900	116300	116700	117200	4400
28.50	117600	118100	118500	119000	119400	119900	120400	120800	121300	121700	4600
28.60	122200	122700	123100	123600	124100	124500	125000	125500	125900	126400	4700
28.70	126900	127400	127900	128300	128800	129300	129800	130300	130800	131300	4900
28.80	131800	132300	132800	133300	133800	134300	134800	135300	135800	136300	5000
28.90	136800	137300	137800	138300	138900	139400	139900	140400	140900	141500	5200
29.00	142000*	142400	142900	143300	143700	144200	144600	145000	145500	145900	4400
29.10	146400	146800	147300	147700	148100	148600	149000	149500	149900	150400	4400
29.20	150800	151300	151800	152200	152700	153100	153600	154000	154500	155000	4600
29.30	155400	155900	156400	156800	157300	157800	158200	158700	159200	159700	4700
29.40	160100	160600	161100	161600	162100	162500	163000	163500	164000	164500	4900

1 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION PAGE 6

EXPANDED RATING TABLE TYPE: LOG

11453000 DATE PROCESSED: 08-16-2002 @ 13:02 BY smithson

YOLO BYPASS NR WOODLAND CA DD: 5 TYPE: 001 RATING NO: 0018

OFFSET: 8.00 START DATE/TIME: 10-01-1987 (0015)

THE SAME AS RATING TABLES 16 & 17 BELOW 25.9 ft.

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND .00	.01	.02	.03	.04	(EXPANDED PRECISION) .05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
29.50	165000	165500	166000	166400	166900	167400	167900	168400	168900	169400	4900
29.60	169900	170400	170900	171400	171900	172400	173000	173500	174000	174500	5100
29.70	175000	175500	176000	176500	177100	177600	178100	178600	179200	179700	5200
29.80	180200	180700	181300	181800	182300	182900	183400	183900	184500	185000	5300
29.90	185500	186100	186600	187200	187700	188300	188800	189300	189900	190400	5500
30.00	191000*	191500	192000	192500	193000	193400	193900	194400	194900	195400	4900
30.10	195900	196400	196900	197400	197900	198400	198900	199400	199900	200400	5000
30.20	200900	201400	201900	202500	203000	203500	204000	204500	205000	205500	5200
30.30	206100	206600	207100	207600	208100	208700	209200	209700	210200	210800	5200
30.40	211300	211800	212300	212900	213400	213900	214500	215000	215500	216100	5300
30.50	216600	217200	217700	218200	218800	219300	219900	220400	221000	221500	5500
30.60	222100	222600	223200	223700	224300	224800	225400	225900	226500	227100	5500
30.70	227600	228200	228800	229300	229900	230500	231000	231600	232200	232700	5700
30.80	233300	233900	234500	235000	235600	236200	236800	237300	237900	238500	5800
30.90	239100	239700	240300	240900	241400	242000	242600	243200	243800	244400	5900
31.00	245000*	245500	246100	246600	247200	247700	248300	248800	249400	249900	5400
31.10	250400	251000	251600	252100	252700	253200	253800	254300	254900	255400	5600
31.20	256000	256600	257100	257700	258200	258800	259400	259900	260500	261100	5600
31.30	261600	262200	262800	263300	263900	264500	265100	265600	266200	266800	5800
31.40	267400	268000	268500	269100	269700	270300	270900	271500	272000	272600	5800
31.50	273200	273800	274400	275000	275600	276200	276800	277400	278000	278600	6000
31.60	279200	279800	280400	281000	281600	282200	282800	283400	284000	284600	6000

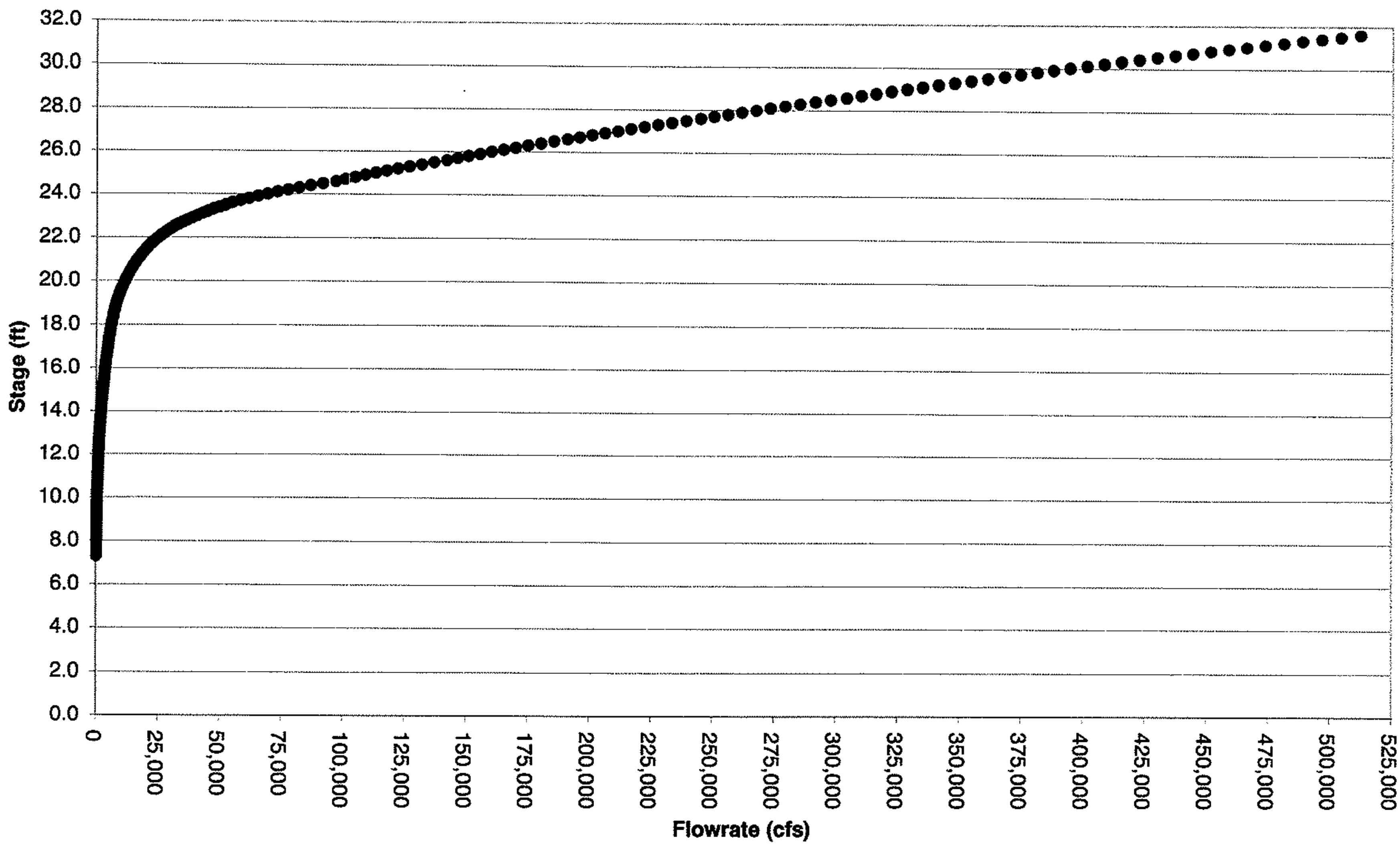
31.70	285200	285800	286400	287100	287700	288300	288900	289500	290100	290800	6200
31.80	291400	292000	292600	293200	293900	294500	295100	295700	296400	297000	6200
31.90	297600	298300	298900	299500	300200	300800	301400	302100	302700	303400	6400
32.00	304000*	304600	305200	305800	306400	307000	307600	308200	308800	309400	6000
32.10	310000	310600	311200	311800	312400	313000	313600	314200	314800	315400	6000
32.20	316000	316700	317300	317900	318500	319100	319700	320300	321000	321600	6200
32.30	322200	322800	323400	324100	324700	325300	325900	326600	327200	327800	6300
32.40	328500	329100	329700	330300	331000	331600	332200	332900	333500	334200	6300
32.50	334800	335400	336100	336700	337400	338000	338700	339300	339900	340600	6400
32.60	341200	341900	342500	343200	343800	344500	345200	345800	346500	347100	6600
32.70	347800	348400	349100	349800	350400	351100	351800	352400	353100	353800	6600
32.80	354400	355100	355800	356400	357100	357800	358500	359100	359800	360500	6800
32.90	361200	361800	362500	363200	363900	364600	365300	365900	366600	367300	6800
33.00	368000*	368600	369300	369900	370600	371200	371900	372500	373200	373800	6500
33.10	374500	375100	375800	376500	377100	377800	378400	379100	379800	380400	6600
33.20	381100	381700	382400	383100	383700	384400	385100	385700	386400	387100	6600

Received from Jerry Smithson-USGS
8-16-02
File: USGS Rating Curve #18

11453000 DATE PROCESSED: 08-16-2002 @ 13:02 BY smithson
YOLO BYPASS NR WOODLAND CA DD: 5 TYPE: 001 RATING NO: 0018
OFFSET: 8.00 START DATE/TIME: 10-01-1987 (0015)
THE SAME AS RATING TABLES 16 & 17 BELOW 25.9 ft.

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND .00	.01	.02	.03	.04	(EXPANDED PRECISION) .05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
33.30	387700	388400	389100	389800	390400	391100	391800	392500	393100	393800	6800
33.40	394500	395200	395900	396600	397200	397900	398600	399300	400000	400700	6900
33.50	401400	402000	402700	403400	404100	404800	405500	406200	406900	407600	6900
33.60	408300	409000	409700	410400	411100	411800	412500	413200	413900	414600	7000
33.70	415300	416000	416800	417500	418200	418900	419600	420300	421000	421700	7200
33.80	422500	423200	423900	424600	425300	426100	426800	427500	428200	429000	7200
33.90	429700	430400	431100	431900	432600	433300	434100	434800	435500	436300	7300
34.00	437000*	437700	438400	439100	439800	440500	441200	442000	442700	443400	7100
34.10	444100	444800	445500	446200	447000	447700	448400	449100	449800	450600	7200
34.20	451300	452000	452700	453500	454200	454900	455600	456400	457100	457800	7300
34.30	458600	459300	460000	460800	461500	462200	463000	463700	464400	465200	7300
34.40	465900	466700	467400	468100	468900	469600	470400	471100	471900	472600	7500
34.50	473400	474100	474900	475600	476400	477100	477900	478600	479400	480200	7500
34.60	480900	481700	482400	483200	484000	484700	485500	486200	487000	487800	7600
34.70	488500	489300	490100	490900	491600	492400	493200	493900	494700	495500	7800
34.80	496300	497000	497800	498600	499400	500200	501000	501700	502500	503300	7800
34.90	504100	504900	505700	506500	507200	508000	508800	509600	510400	511200	7900*
35.00	512000*										

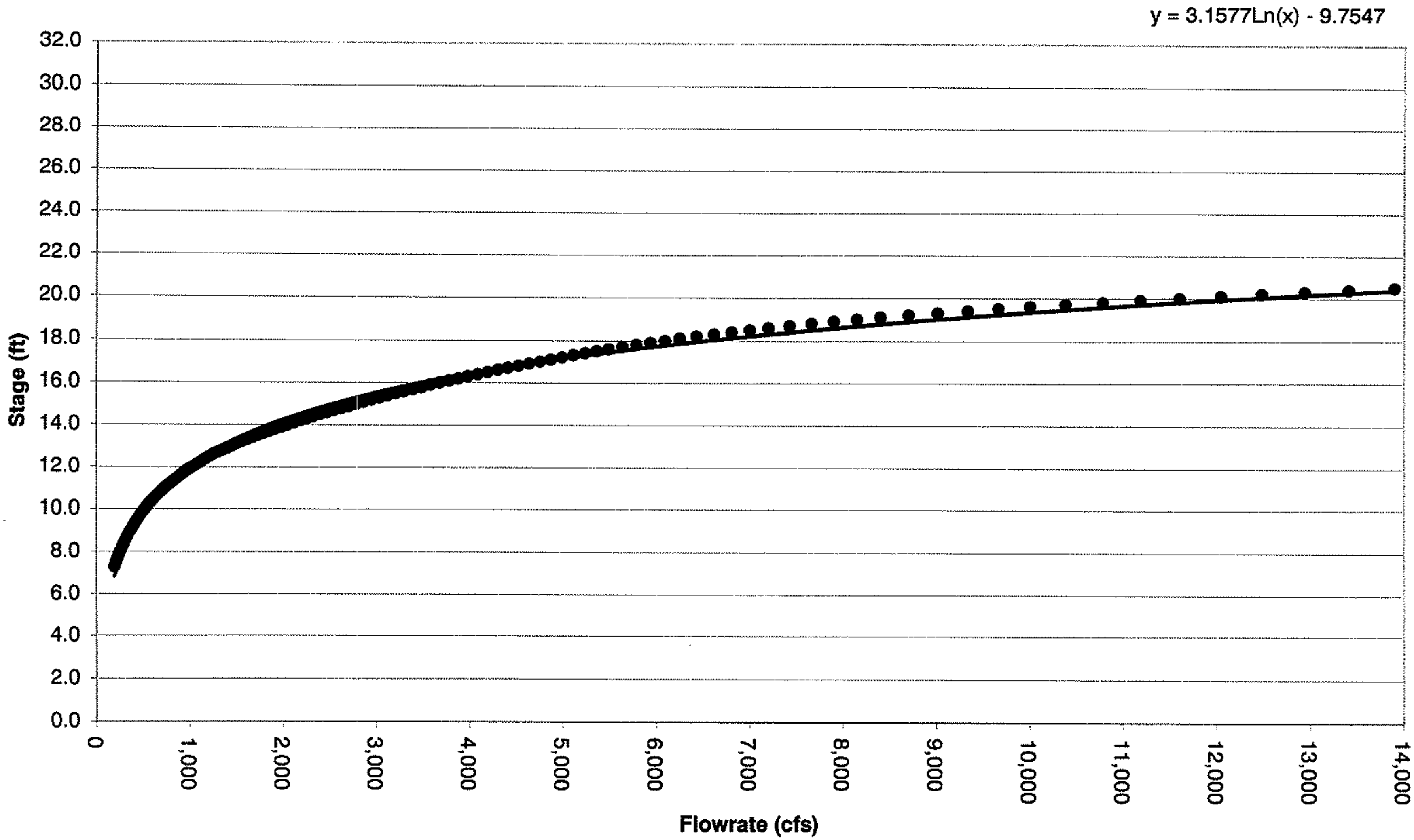
Yolo Bypass Near Woodland
USGS Flow vs. Stage



USGS rating curve 8-16-02.xls
Rating Curve was provided by USGS and was adjusted to NGVD29 datum.

Prepared by Wood Rodgers, Inc.

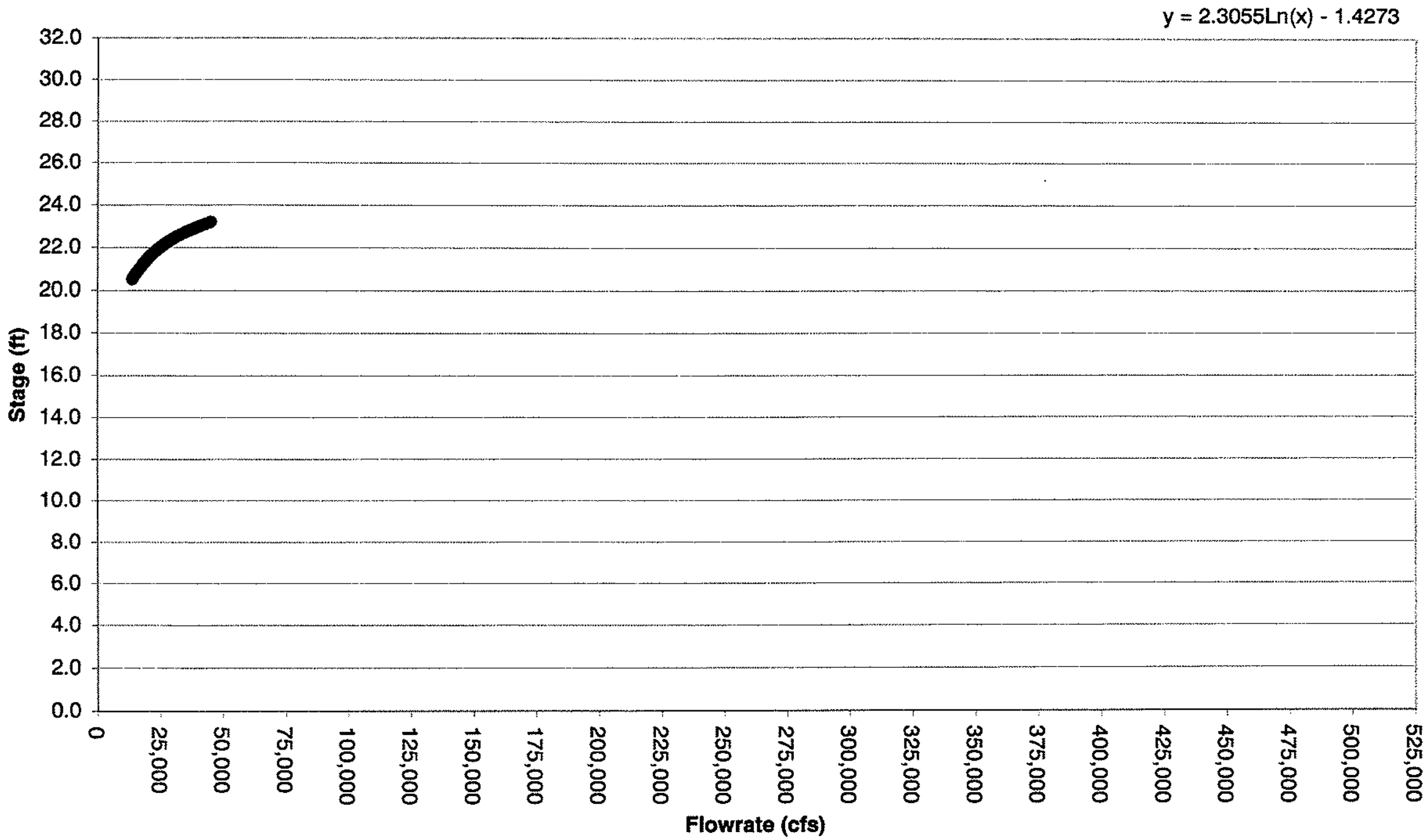
Yolo Bypass Near Woodland
USGS Flow vs. Stage
Q = 0 to 14,000 cfs



USGS rating curve 8-16-02.xls
Rating Curve was provided by USGS and was adjusted to NGVD29 datum.

Prepared by Wood Rodgers, Inc.

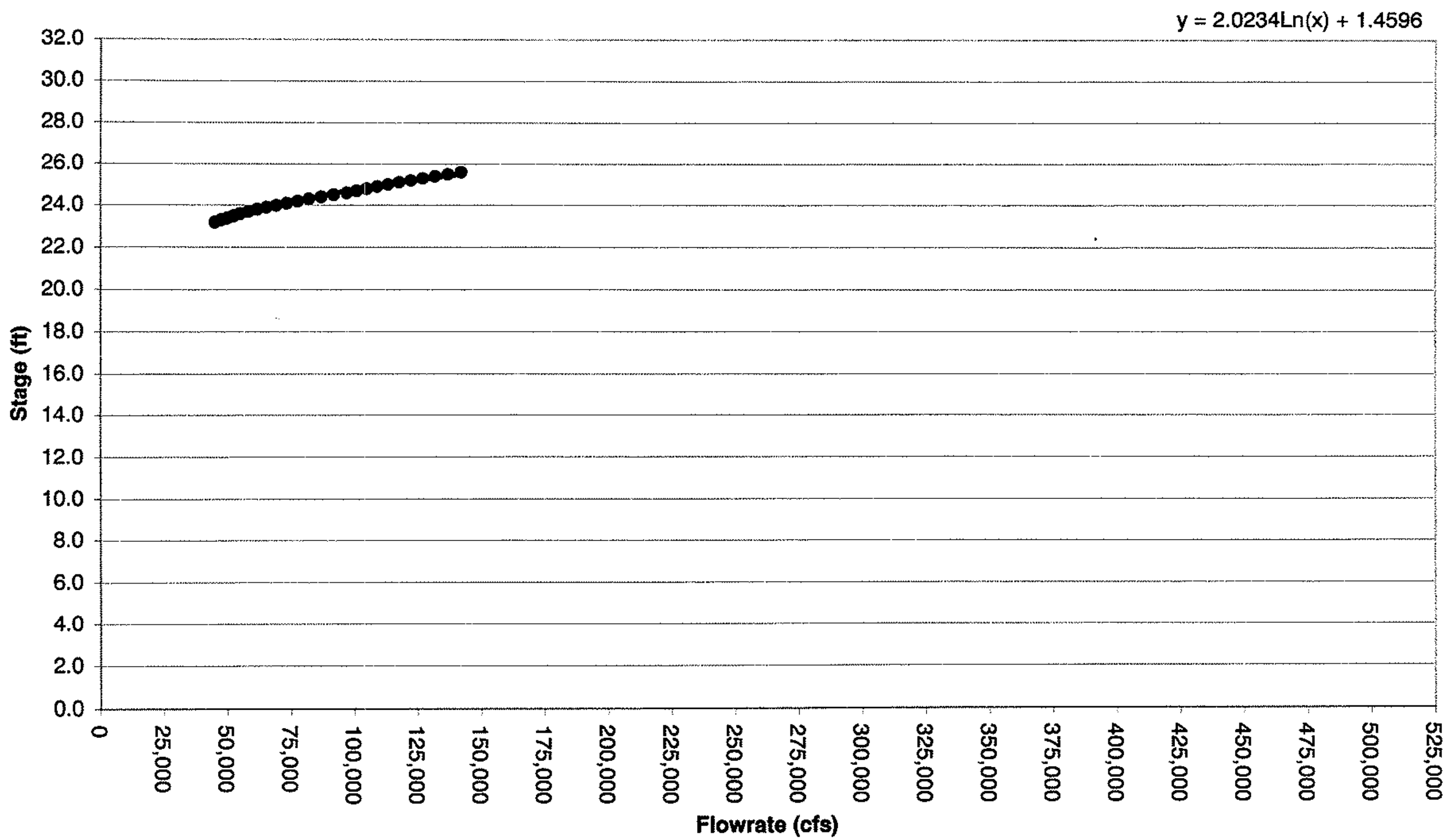
Yolo Bypass Near Woodland
USGS Flow vs. Stage
Q = 14,000 to 45,000 cfs



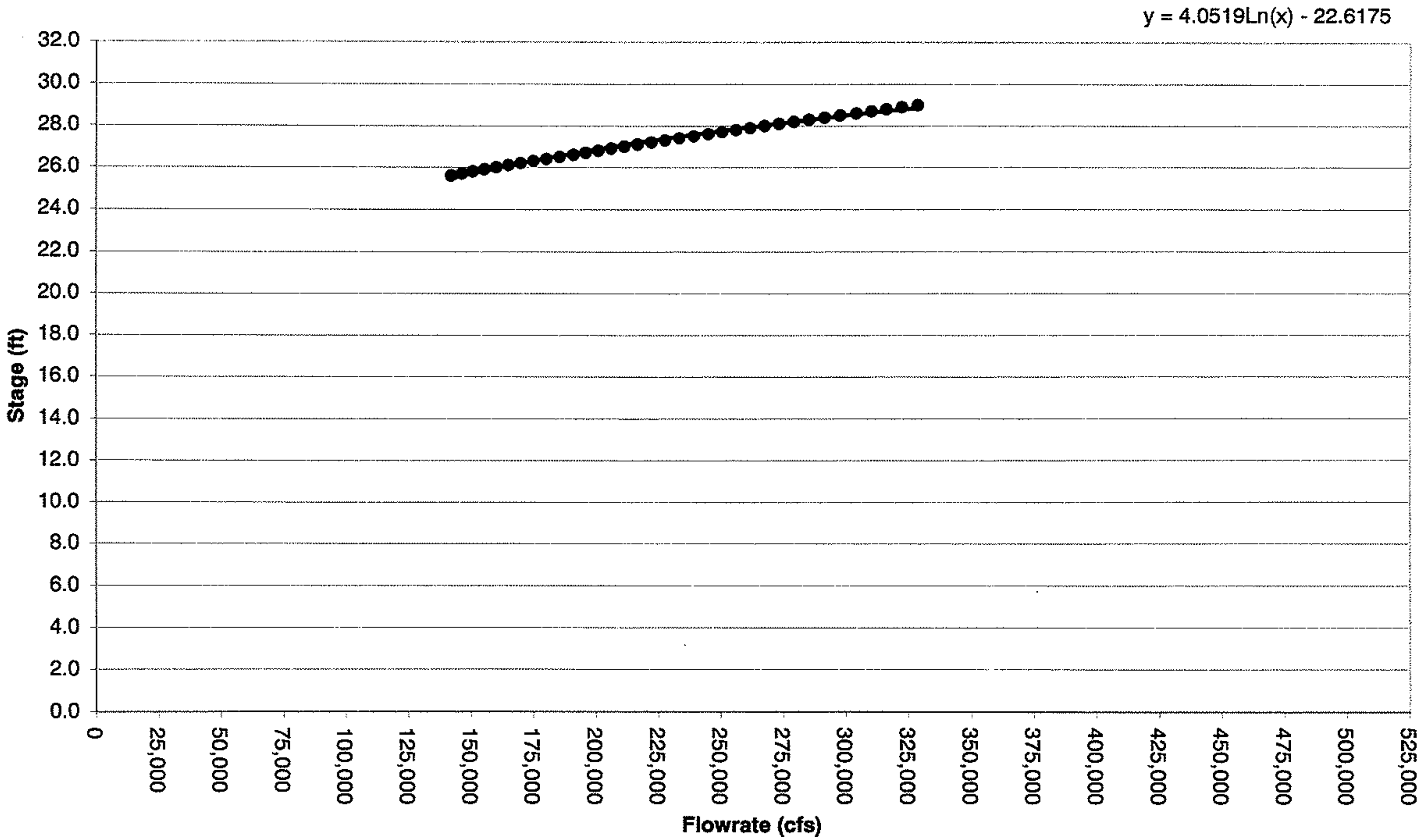
USGS rating curve 8-16-02.xls
Rating Curve was provided by USGS and was adjusted to NGVD29 datum.

Prepared by Wood Rodgers, Inc.

Yolo Bypass Near Woodland
USGS Flow vs. Stage
Q = 45,000 to 142,000 cfs



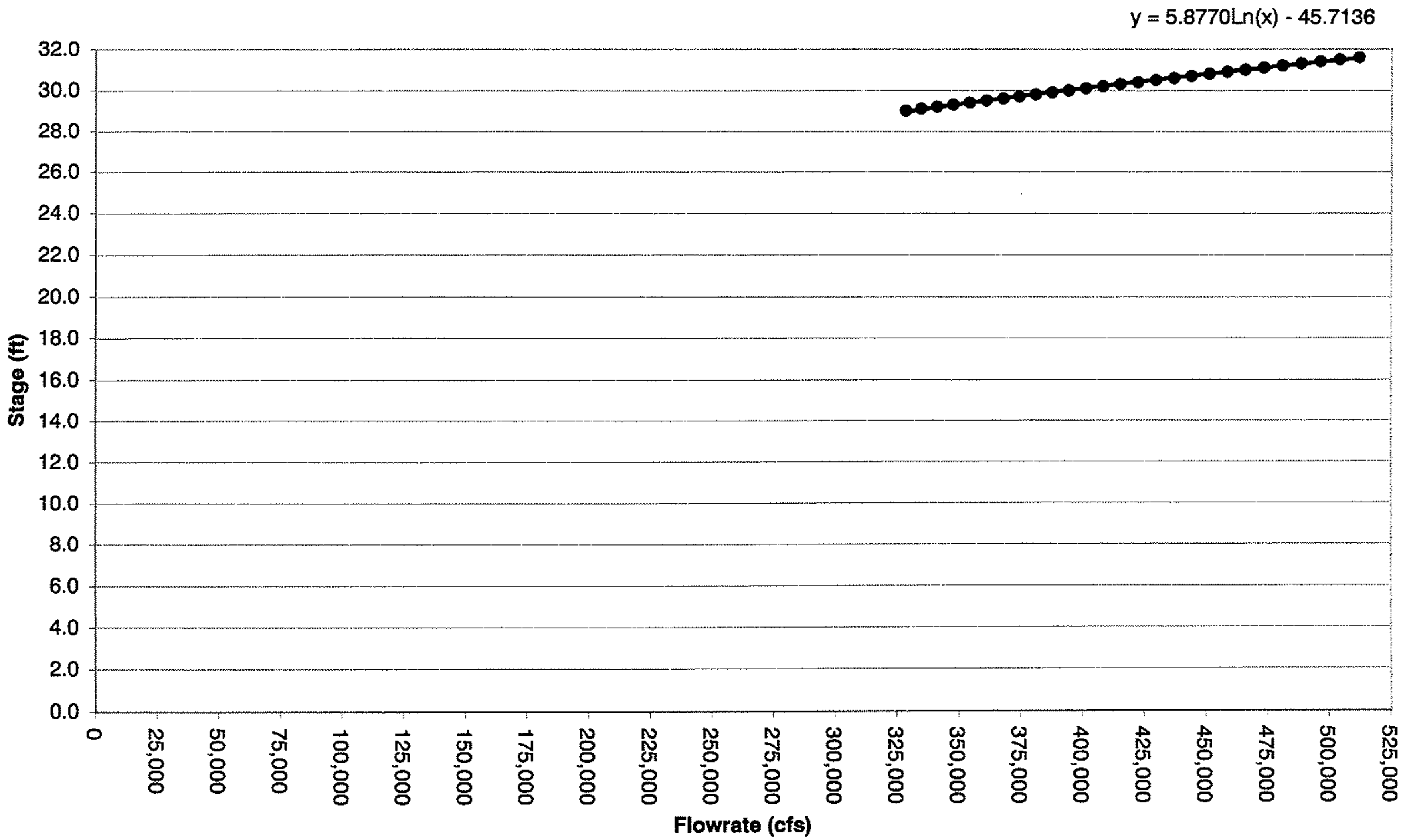
Yolo Bypass Near Woodland
USGS Flow vs. Stage
Q = 142,000 to 327,000 cfs



USGS rating curve 8-16-02.xls
Rating Curve was provided by USGS and was adjusted to NGVD29 datum.

Prepared by Wood Rodgers, Inc.

Yolo Bypass Near Woodland
USGS Flow vs. Stage
Q = 327,000 to 512,000 cfs



USGS rating curve 8-16-02.xls
Rating Curve was provided by USGS and was adjusted to NGVD29 datum.

Prepared by Wood Rodgers, Inc.

APPENDIX B

Solano & Yolo County Design Rainfall

This study was prepared at the request of Mr. Lee Frederiksen of Borcalli and Associates of Sacramento. It is intended to be used in selecting a design storm for any location in Solano or Yolo Counties for storm duration of five minutes to ten days and for return periods of 2 to 100 years.

This revision is to modify the Design Rainfalls on Table 1 for durations of over two days. Also return periods of 500, 1000 and 10,000 years were added to make this tudy useful to a broader range of users.

To find a design storm; first look up the mean annual precipitation (MAP) on (Figure 1) and then enter the MAP column of the Tables 1 for the desired storm duration and return period. The design rainfall shown on Table 1 is in parts, one each for return periods of 2.3, 5, 10, 25, 50 and 100 years. Table 1 is in units if inches.

The data of this study were from Climatological Data for California published by the National Climatic Data Center located in Ashville, N. C. Additional data were obtained from many sources including Mr. Jim Gibboney (916) 322 7159 of the Central District Office of the Department of Water Resources in Sacramento, the Vallejo City Water Works and Contra Costa County Public Works Department.

The methods used in this study to analyze rain records are similar to those used in Rainfall for Drainage Design, Bulletin 195 of the Department of Water Resources, and in Proceedings of a Workshop on County Hydrology Manuals, August 16-17, 1990, sponsored by Water Resources Center, University of California, published by Lighthouse publications, Mission Viejo, CA 92692.

Eighty-one rain gages listed on Table 2 were used in this study. These represent 2953 station years of data. Seventeen of the 82 gages are recording rain records. They are listed on Table 2. Table 2 contains the average annual extreme rainfalls at all of the rain records of this study. Some of the individual rainfall depth duration frequency tables may differ from the design rainfalls of Table 1, because 2953 station years of data are included in Table 1 and the longest individual record of this study is Sacramento with only 120 years of daily rainfall data.

All design storms were calculated as a fraction of the mean annual precipitation (MAP). The relationship between the maximum annual 1440 minute rainfall to the mean annual precipitation (MAP) was shown on Figure 2. The non recording rain gage records were adjusted for fixed interval corrections by a factor of 1.14 so that all maximum daily data would be comparable with the data from the recording gages. The shorter records had a higher value of the ratio of the annual maximum daily to the MAP as shown on Figure 3. The final design value of the relationship between the average maximum one day and the average total annual rainfall was based on records with 70, or more years of data.

The tabulated extreme 1 day precipitation from the recording gages are intended to represent the actual maximum 1440 consecutive minutes for the year. Recording gage extreme rains usually average 14% higher than once a day fixed time observations.

The shorter records also had a larger value of the sample value coefficient of variation as shown on Figure 4. The longer records seem to converge on the design value of .352 that has been used since 1983, by the Department of Water Resources. The coefficient of variation for storms longer than one day are listed on Tables 6, 7 and 8, along with the regional coefficients of skew and Frequency Factors.

The ratios of short duration rainfalls to the one day (or 1440 minute) storm is based on the relationship shown at the bottom of page 6 of Table 2. These values were plotted on Figure 5.

Tables of design storms are for return periods of 2, 5, 10, 25, 50, 100, 500, 1000 and 10,000 years and storm durations of 5, 10, 15, 30 minutes, 1, 2 , 3, 6, 12 hours1, 2, 3, 4, 6, 8, 10, 15, 20, 30, and 60 days and 1 year. The design storms are expressed in terms of the MAP which ranges in Solano and Yolo Counties from 14 to 40 inches. These tables were calculated for storm duration of 3 hours or less using the following relationship:

$$P_{ij} = (-.22 + .13047*MAP)*(1+K_j*CV)*T_i^{.43747}$$

where P_{ij} is the design precipitation for return period j and storm duration i.

MAP is the mean annual precipitation Figure 1

(-.22 + .13047*MAP) is the fraction of MAP occurring in the average maximum day from Figure 2.

CV is the design value of the Coefficient of Variation, specifically .352 for this region of the Sacramento Valley drainage.

T_i is the time in days (note for 5 min use 5 / 1440.)

n is .43747, the slope of the log rain vs., log minutes shown on Figure 5.

K_j is the frequency factor for the Pearsons Type III distribution (for storms of one day or less) with an of skew 1.1 as shown below:

Return Period Years	Frequency Factors
2	-.180
5	.745
10	1.341
25	2.066
50	2.420
100	3.087
200	3.575
500	4.300
1000	4.673
10000	6.185

Frequency factors represent the number of standard deviations in excess of the mean that are used to define storms of various return periods.

The mean annual precipitation (MAP) map Figure 1 is based on the 1951 to 1980 averages corresponding to the period used by the National Weather Service for their climatic normals.

The maximum rainfall for each calendar day from 1917 to 1989 at Davis was plotted on the cover of this study.

Notable large rainfalls in or near Solano and Yolo Counties during historic times include the April 20, 1880 storm at Mount Saint Helena at 4340 feet elevation, where 14.70 inches of rain fell in one day. No records of this event are available for Yolo or Solano Counties, but the largest ever daily rainfall of 5.28 inches occurred at Sacramento on this date. The return period for 5.28 inches in one day at Sacramento is over 500 years.

The December 19 to 27, 1955 deposited record high rainfalls in an area from Winters Northeastward to the Feather River Basin. The Winters-Lewis rain gage cough 14.13 inches in 8 days. The return period was over 1500 years.

The January 4 storm of the San Francisco Bay Area caused many deaths from land slides in Marin and Santa Cruz Counties. The highest rainfall reported for Solano County was 6.04 inches. This occurred at the Vallejo 4 N rain gage. The return period was about 1400 years.

In the last half century the biggest rainfall was during the Columbus Day storm of 1962. During October 12 to 14, 1962 a band of rainfalls with return periods in excess of 1000 years was scattered generally from Oakland northeastward to Marysville and to Alturas. The Solano - Yolo area was bracketed on both sides with heavy rains. The largest return period for the 3 day storm was 340 years at Mare Island, which had 8.28 inches. Davis had 7.81 inches in 3 days with a 275 year return period. It was fortunate that this storm fell on dry ground at the end of the normal summer drought, when there was a large soil moisture deficit to absorb the heavy rains.

The water year 1983 was the wettest year in the 109 years of record which were examined in Yolo and Solano Counties. There was extensive flooding in poorly drained areas due to the years having almost twice the average number of rainy days. At Sacramento where the record starts in 1850. there was 36.57 inches. The previous high year was 36.35 inches in 1853. The five wettest years in the region's history were followed by five of the driest years in the last decade.

The storm of February 11 to 20, 1986 was heaviest in the Sierra Navada and in the Napa River Basin as well as the streams draining into the Fairfield- Cordelia area. Record 10 day rainfalls occurs at Lake Curry, Green Valley and at Lake Frey. The Atlas Road rain gage reported 41.08 inches in 10 days which was 7.4 standard deviations above the mean 10 day storm total. The estimated return period is in excess of 100,000 years. Stream channels to the South East of Atlas Peak were lined with large boulders and swept clear of vegetation suggestive of a debris flow, after this storm.

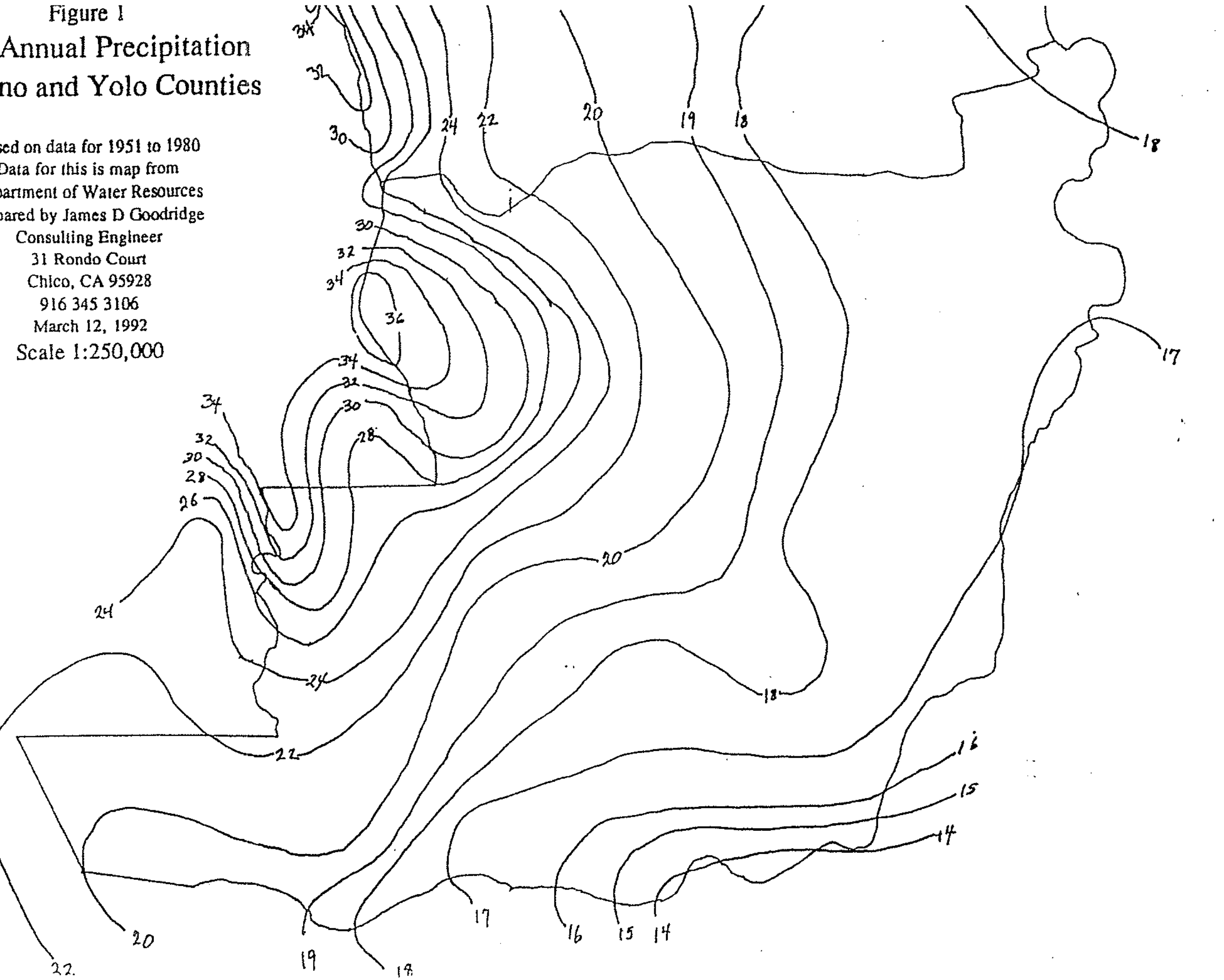
The maximum 24 hour rainfall ever recorded in the San Francisco Bay drainage area was the 15.28 inches at Atlas Road on February 17, 1986. The previous maximum was the Mt. Saint Helena storm of April 1884. The highest ever one day rain in the Central Valley Drainage area was 17.60 at four Trees in the Feather River Basin also on February 17, 1986.

The 20 largest rainfalls at selected stations for each month are listed on Table 3. The maximum daily rainfall for each month at selected stations in or near Solano and Yolo counties is listed on Table 4. The maximum daily rainfall by months for all of California is listed on Table 5. Other data a on extreme rainfalls are included, as well as a plot of 109 year trends in total annual rainfall in Yolo and Solano Counties.

Figure 1

Mean Annual Precipitation in Solano and Yolo Counties

Based on data for 1951 to 1980
Data for this is map from
Department of Water Resources
Prepared by James D Goodridge
Consulting Engineer
31 Rondo Court
Chico, CA 95928
916 345 3106
March 12, 1992
Scale 1:250,000



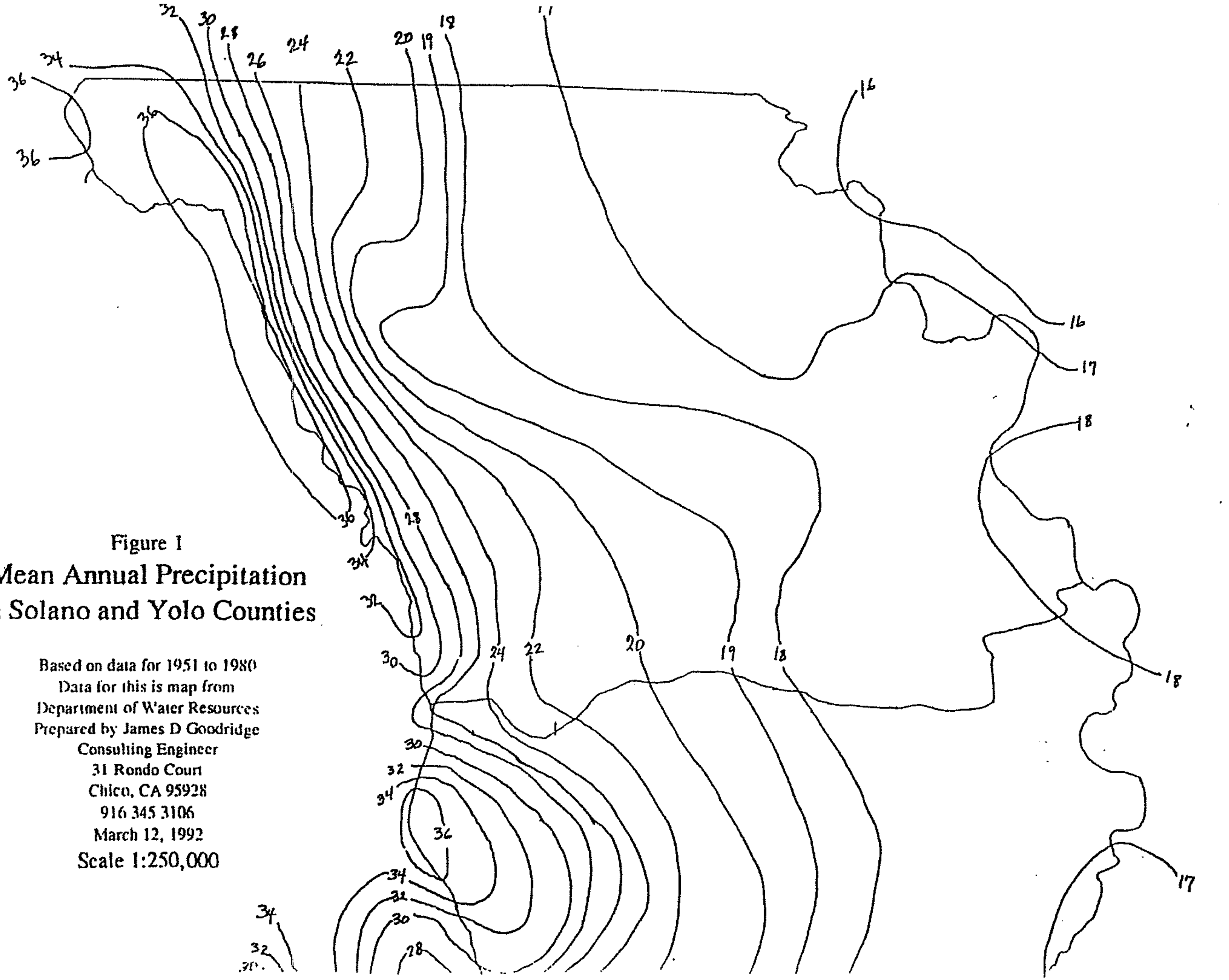


Figure 1
Mean Annual Precipitation in Solano and Yolo Counties

Based on data for 1951 to 1980
Data for this is map from
Department of Water Resources
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March 12, 1992
Scale 1:250,000

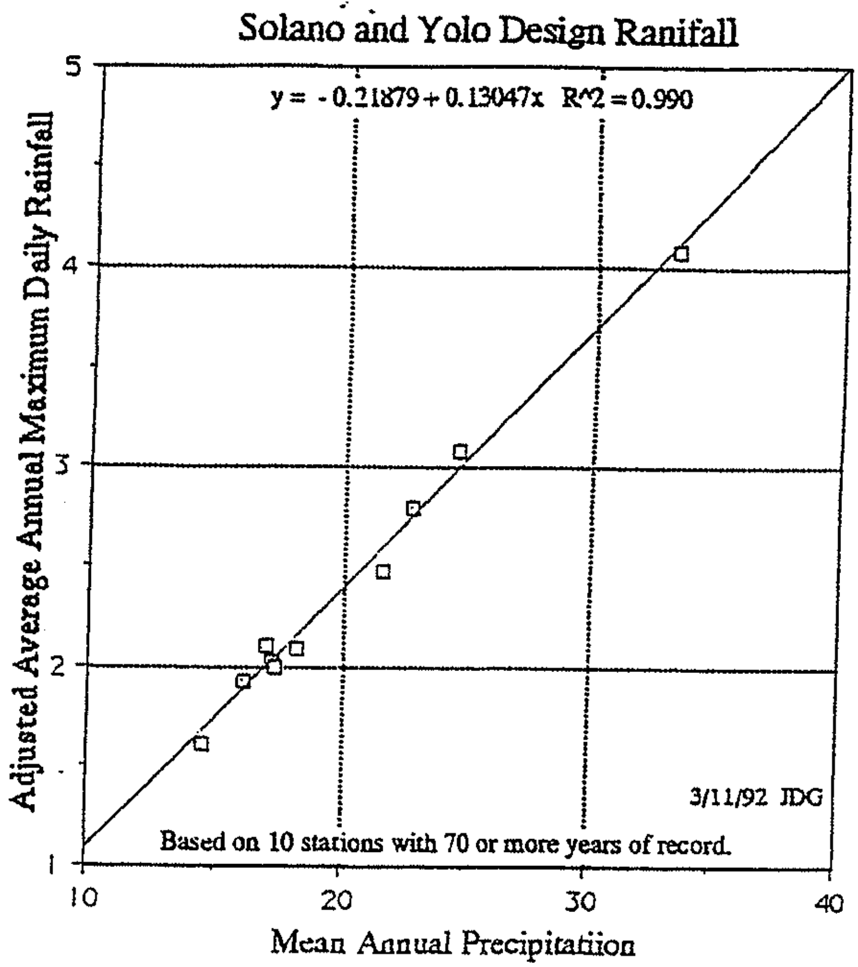

Figure 2

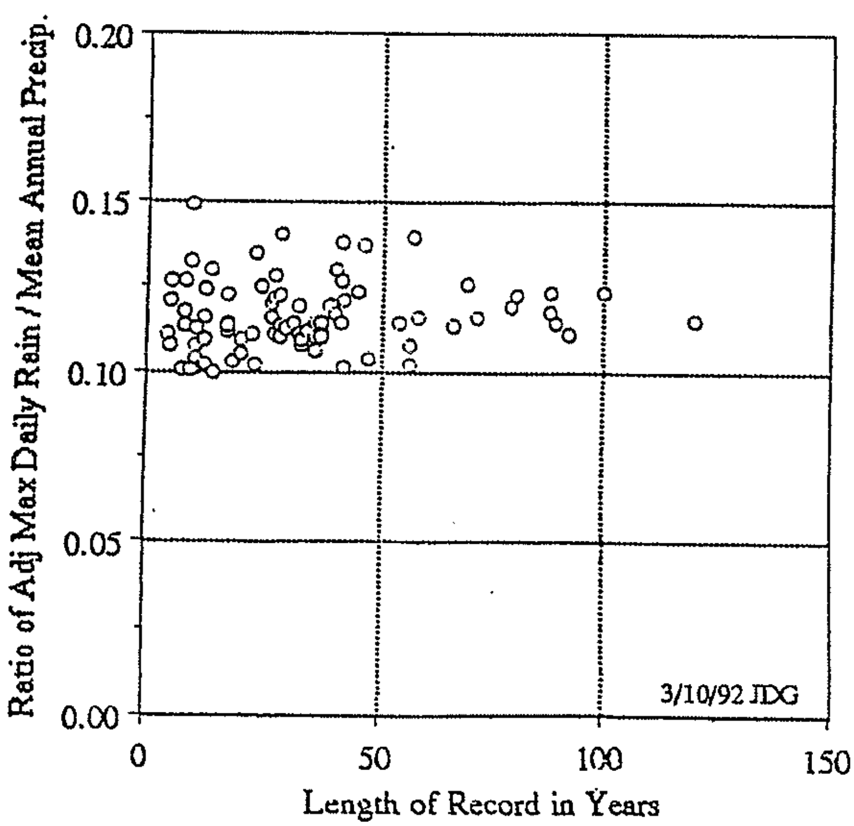

Figure 3

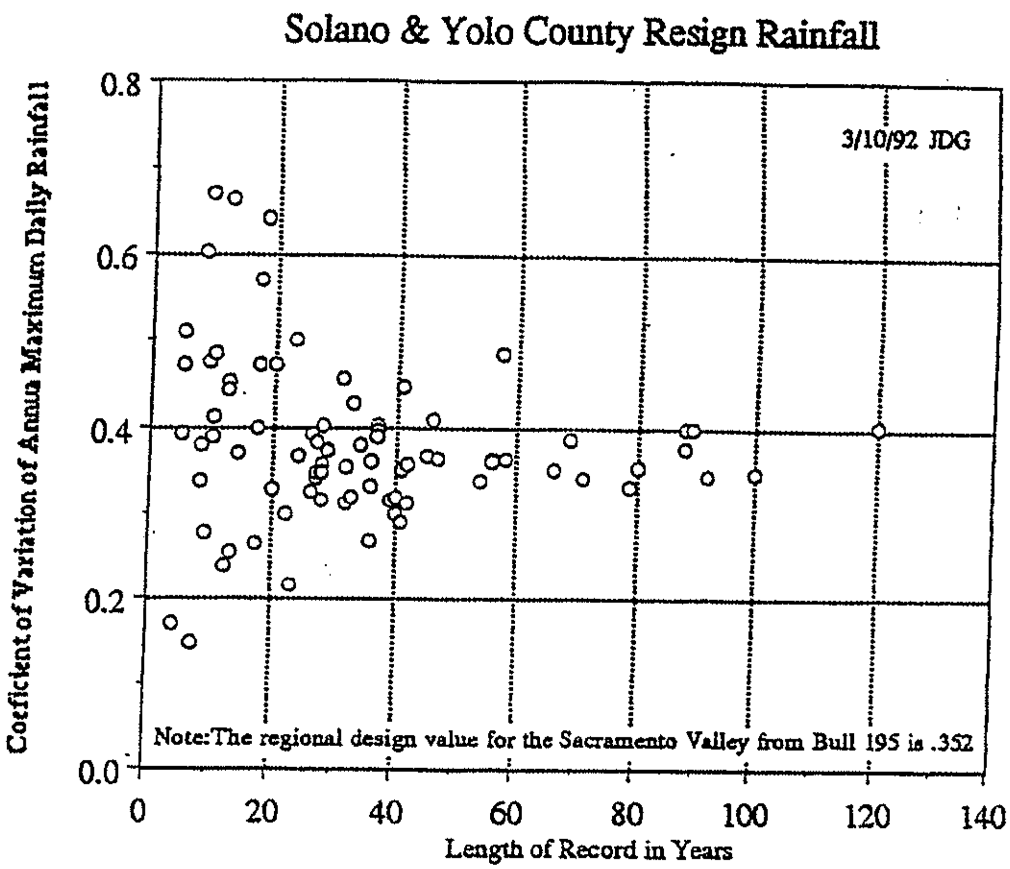

Figure 4

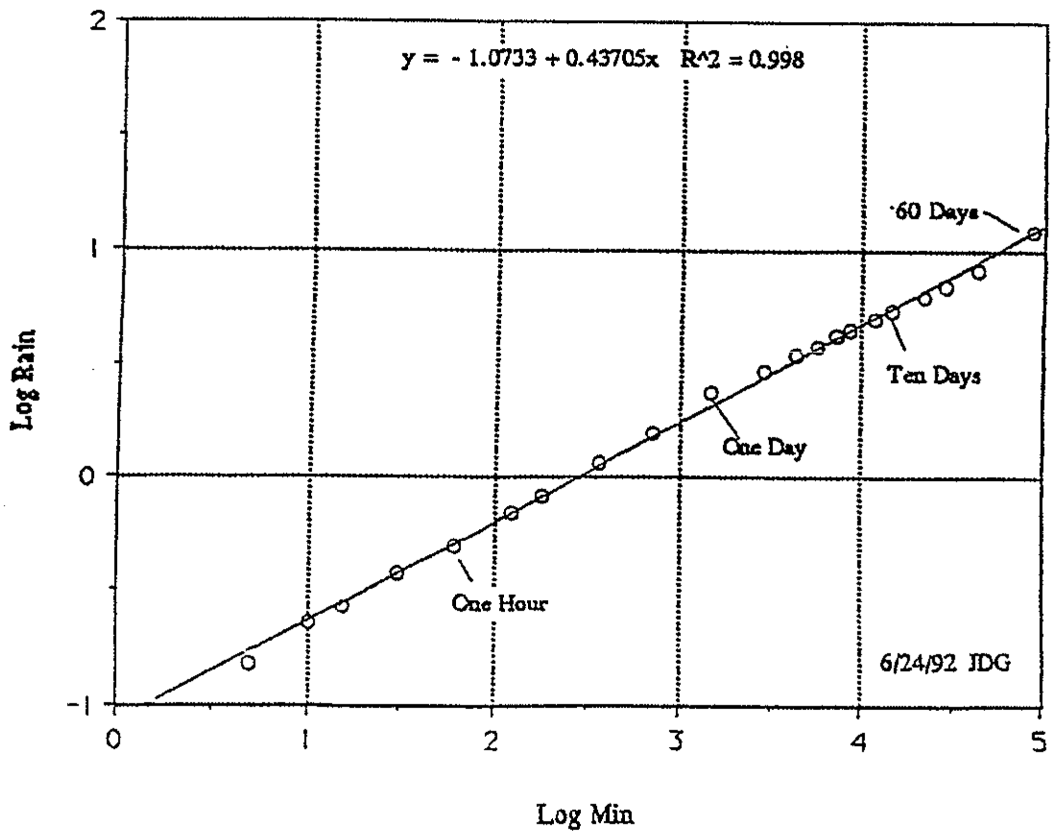

Figure 5

2 Year Storm for Solano and Yolo Counties

Mean Ann Precip	5M	10M	15M	30M	1H	2H	3H	6H	12H	24H	2D	3D	4D	5D	6D	8D	10D	15D	20D	30D	60D	Year
14	0.13	0.18	0.22	0.29	0.40	0.54	0.64	0.80	1.07	1.60	2.02	2.37	2.62	2.87	3.07	3.46	3.72	4.26	4.76	5.61	8.26	13.86
15	0.14	0.20	0.23	0.32	0.43	0.58	0.70	0.86	1.16	1.73	2.18	2.56	2.84	3.10	3.32	3.74	4.02	4.60	5.14	6.06	8.93	14.99
16	0.16	0.21	0.25	0.34	0.46	0.63	0.75	0.92	1.25	1.86	2.34	2.75	3.05	3.34	3.57	4.02	4.32	4.95	5.53	6.52	9.60	16.12
17	0.17	0.23	0.27	0.37	0.49	0.67	0.80	0.99	1.33	1.99	2.51	2.94	3.26	3.57	3.82	4.30	4.62	5.29	5.92	6.97	10.27	17.24
18	0.18	0.24	0.29	0.39	0.53	0.71	0.85	1.05	1.42	2.12	2.67	3.14	3.48	3.80	4.07	4.58	4.92	5.64	6.30	7.43	10.94	18.37
19	0.19	0.26	0.30	0.41	0.56	0.76	0.90	1.12	1.51	2.24	2.83	3.33	3.69	4.03	4.32	4.86	5.23	5.98	6.69	7.88	11.61	19.49
20	0.20	0.27	0.32	0.44	0.59	0.80	0.96	1.18	1.59	2.37	3.00	3.52	3.90	4.27	4.57	5.14	5.53	6.33	7.08	8.34	12.28	20.62
22	0.22	0.30	0.36	0.48	0.66	0.89	1.06	1.31	1.77	2.63	3.33	3.90	4.33	4.73	5.06	5.70	6.13	7.02	7.85	9.25	13.62	22.87
24	0.24	0.33	0.39	0.53	0.72	0.98	1.16	1.44	1.94	2.89	3.65	4.29	4.75	5.20	5.56	6.27	6.73	7.71	8.62	10.16	14.96	25.12
26	0.26	0.36	0.43	0.58	0.79	1.06	1.27	1.57	2.11	3.15	3.98	4.67	5.18	5.67	6.06	6.83	7.34	8.40	9.39	11.07	16.30	27.37
28	0.29	0.39	0.46	0.63	0.85	1.15	1.37	1.70	2.29	3.41	4.31	5.06	5.61	6.13	6.56	7.39	7.94	9.09	10.17	11.98	17.64	29.63
30	0.31	0.42	0.50	0.68	0.91	1.24	1.48	1.83	2.46	3.67	4.64	5.44	6.03	6.60	7.06	7.95	8.55	9.79	10.94	12.89	18.99	31.88
32	0.33	0.45	0.53	0.72	0.98	1.33	1.58	1.96	2.64	3.93	4.96	5.83	6.46	7.06	7.56	8.51	9.15	10.48	11.71	13.80	20.33	34.13
34	0.35	0.48	0.57	0.77	1.04	1.41	1.69	2.09	2.81	4.19	5.29	6.21	6.88	7.53	8.06	9.07	9.75	11.17	12.49	14.71	21.67	36.38
36	0.37	0.51	0.60	0.82	1.11	1.50	1.79	2.22	2.98	4.45	5.62	6.60	7.31	8.00	8.56	9.63	10.36	11.86	13.26	15.62	23.01	38.63
38	0.40	0.54	0.64	0.87	1.17	1.59	1.90	2.35	3.16	4.71	5.94	6.98	7.74	8.46	9.05	10.20	10.96	12.55	14.03	16.53	24.35	40.88
40	0.42	0.56	0.67	0.91	1.24	1.68	2.00	2.47	3.33	4.97	6.27	7.36	8.16	8.93	9.55	10.76	11.56	13.24	14.80	17.44	25.69	43.14

5 Year Storm for Solano and Yolo Counties

Mean Ann Precip	5M	10M	15M	30M	1H	2H	3H	6H	12H	24H	2D	3D	4D	5D	6D	8D	10D	15D	20D	30D	60D	Year
14	0.17	0.23	0.28	0.37	0.51	0.68	0.82	1.11	1.50	2.03	2.54	2.99	3.31	3.62	3.88	4.36	4.69	5.37	6.01	7.08	10.42	17.50
15	0.18	0.25	0.30	0.40	0.55	0.74	0.88	1.20	1.62	2.19	2.75	3.23	3.58	3.92	4.19	4.72	5.07	5.81	6.49	7.65	11.27	18.92
16	0.20	0.27	0.32	0.43	0.59	0.80	0.95	1.29	1.74	2.36	2.96	3.47	3.85	4.21	4.50	5.07	5.45	6.24	6.98	8.23	12.11	20.34
17	0.21	0.29	0.34	0.46	0.63	0.85	1.02	1.38	1.86	2.52	3.16	3.72	4.12	4.50	4.82	5.43	5.83	6.68	7.47	8.80	12.96	21.76
18	0.23	0.31	0.36	0.49	0.67	0.91	1.08	1.47	1.98	2.69	3.37	3.96	4.39	4.80	5.13	5.78	6.21	7.12	7.96	9.37	13.81	23.18
19	0.24	0.32	0.39	0.52	0.71	0.96	1.15	1.56	2.11	2.85	3.58	4.20	4.66	5.09	5.45	6.14	6.60	7.55	8.44	9.95	14.65	24.60
20	0.25	0.34	0.41	0.55	0.75	1.02	1.21	1.64	2.23	3.02	3.78	4.44	4.92	5.39	5.76	6.49	6.98	7.99	8.93	10.52	15.50	26.03
22	0.28	0.38	0.45	0.62	0.83	1.13	1.35	1.82	2.47	3.35	4.20	4.93	5.46	5.98	6.39	7.20	7.74	8.86	9.91	11.67	17.19	28.87
24	0.31	0.42	0.50	0.68	0.92	1.24	1.48	2.00	2.71	3.68	4.61	5.41	6.00	6.56	7.02	7.91	8.50	9.73	10.88	12.82	18.89	31.71
26	0.34	0.46	0.54	0.74	1.00	1.35	1.61	2.18	2.96	4.00	5.02	5.90	6.54	7.15	7.65	8.62	9.26	10.61	11.86	13.97	20.58	34.55
28	0.36	0.49	0.59	0.80	1.08	1.46	1.75	2.36	3.20	4.33	5.44	6.38	7.08	7.74	8.28	9.33	10.02	11.48	12.83	15.12	22.27	37.39
30	0.39	0.53	0.63	0.86	1.16	1.57	1.88	2.54	3.44	4.66	5.85	6.87	7.61	8.33	8.91	10.03	10.79	12.35	13.81	16.27	23.96	40.24
32	0.42	0.57	0.68	0.92	1.24	1.68	2.01	2.72	3.69	4.99	6.26	7.35	8.15	8.92	9.54	10.74	11.55	13.22	14.78	17.42	25.66	43.08
34	0.45	0.61	0.72	0.98	1.33	1.79	2.14	2.90	3.93	5.32	6.68	7.84	8.69	9.50	10.17	11.45	12.31	14.10	15.76	18.57	27.35	45.92
36	0.47	0.64	0.77	1.04	1.41	1.91	2.28	3.08	4.17	5.65	7.09	8.32	9.23	10.09	10.80	12.16	13.07	14.97	16.74	19.72	29.04	48.76
38	0.50	0.68	0.81	1.10	1.49	2.02	2.41	3.26	4.42	5.98	7.50	8.81	9.76	10.68	11.43	12.87	13.83	15.84	17.71	20.87	30.73	51.61
40	0.53	0.72	0.86	1.16	1.57	2.13	2.54	3.44	4.66	6.31	7.92	9.30	10.30	11.27	12.06	13.58	14.60	16.71	18.69	22.02	32.43	54.45

10 Year Storm for Solano and Yolo Counties

Mean Ann Precip	5M	10M	15M	30M	1H	2H	3H	6H	12H	24H	2D	3D	4D	5D	6D	8D	10D	15D	20D	30D	60D	Year
14	0.20	0.27	0.32	0.43	0.59	0.80	0.95	1.18	1.59	2.37	2.97	3.48	3.86	4.22	4.52	5.09	5.47	6.26	7.00	8.25	12.15	20.41
15	0.21	0.29	0.35	0.47	0.64	0.86	1.03	1.27	1.72	2.56	3.21	3.77	4.17	4.57	4.89	5.50	5.91	6.77	7.57	8.92	13.14	22.07
16	0.23	0.31	0.37	0.51	0.68	0.93	1.11	1.37	1.84	2.75	3.45	4.05	4.49	4.91	5.25	5.92	6.36	7.28	8.14	9.59	14.13	23.72
17	0.25	0.33	0.40	0.54	0.73	0.99	1.18	1.47	1.97	2.94	3.69	4.33	4.80	5.25	5.62	6.33	6.80	7.79	8.71	10.26	15.12	25.38
18	0.26	0.36	0.43	0.58	0.78	1.06	1.26	1.56	2.10	3.13	3.93	4.62	5.12	5.60	5.99	6.74	7.25	8.30	9.28	10.93	16.10	27.04
19	0.28	0.38	0.45	0.61	0.83	1.12	1.34	1.66	2.23	3.33	4.17	4.90	5.43	5.94	6.35	7.16	7.69	8.81	9.85	11.60	17.09	28.69
20	0.30	0.40	0.48	0.65	0.88	1.19	1.42	1.75	2.36	3.52	4.41	5.18	5.74	6.28	6.72	7.57	8.14	9.32	10.42	12.27	18.08	30.35
22	0.33	0.44	0.53	0.72	0.97	1.32	1.57	1.94	2.62	3.90	4.90	5.75	6.37	6.97	7.46	8.40	9.02	10.33	11.55	13.61	20.05	33.67
24	0.36	0.49	0.58	0.79	1.07	1.45	1.73	2.13	2.88	4.29	5.38	6.31	7.00	7.65	8.19	9.22	9.91	11.35	12.69	14.95	22.02	36.98
26	0.39	0.53	0.63	0.86	1.16	1.57	1.88	2.33	3.13	4.67	5.86	6.88	7.62	8.34	8.92	10.05	10.80	12.37	13.83	16.29	24.00	40.30
28	0.42	0.57	0.69	0.93	1.26	1.70	2.04	2.52	3.39	5.05	6.34	7.44	8.25	9.03	9.66	10.88	11.69	13.39	14.97	17.63	25.97	43.61
30	0.46	0.62	0.74	1.00	1.35	1.83	2.19	2.71	3.65	5.44	6.82	8.01	8.88	9.71	10.39	11.70	12.58	14.40	16.10	18.98	27.95	46.92
32	0.49	0.66	0.79	1.07	1.45	1.96	2.34	2.90	3.91	5.82	7.31	8.58	9.51	10.40	11.13	12.53	13.47	15.42	17.24	20.32	29.92	50.24
34	0.52	0.71	0.84	1.14	1.55	2.09	2.50	3.09	4.16	6.21	7.79	9.14	10.13	11.08	11.86	13.36	14.36	16.44	18.38	21.66	31.89	53.55
36	0.55	0.75	0.89	1.21	1.64	2.22	2.65	3.28	4.42	6.59	8.27	9.71	10.76	11.77	12.59	14.18	15.24	17.46	19.52	23.00	33.87	56.87
38	0.59	0.79	0.95	1.28	1.74	2.35	2.81	3.47	4.68	6.98	8.75	10.27	11.39	12.46	13.33	15.01	16.13	18.47	20.65	24.34	35.84	60.18
40	0.62	0.84	1.00	1.35	1.83	2.48	2.96	3.67	4.94	7.36	9.23	10.84	12.01	13.14	14.06	15.84	17.02	19.49	21.79	25.68	37.82	63.50

25 Year Storm for Solano and Yolo Counties

Mean Ann Precip	5M	10M	15M	30M	1H	2H	3H	6H	12H	24H	2D	3D	4D	5D	6D	8D	10D	15D	20D	30D	60D	Year
14	0.23	0.32	0.38	0.51	0.69	0.94	1.12	1.38	1.86	2.78	3.48	4.09	4.53	4.96	5.30	5.97	6.42	7.35	8.22	9.68	14.26	23.95
15	0.25	0.34	0.41	0.55	0.75	1.01	1.21	1.49	2.01	3.00	3.76	4.42	4.90	5.36	5.73	6.46	6.94	7.95	8.89	10.47	15.42	25.89
16	0.27	0.37	0.44	0.59	0.80	1.09	1.30	1.61	2.16	3.23	4.05	4.75	5.27	5.76	6.16	6.94	7.46	8.54	9.55	11.26	16.58	27.84
17	0.29	0.39	0.47	0.63	0.86	1.16	1.39	1.72	2.32	3.45	4.33	5.08	5.63	6.16	6.59	7.43	7.98	9.14	10.22	12.04	17.74	29.78
18	0.31	0.42	0.50	0.68	0.92	1.24	1.48	1.83	2.47	3.68	4.61	5.42	6.00	6.57	7.03	7.91	8.50	9.74	10.89	12.83	18.89	31.72
19	0.33	0.44	0.53	0.72	0.97	1.32	1.57	1.94	2.62	3.90	4.90	5.75	6.37	6.97	7.46	8.40	9.03	10.34	11.56	13.61	20.05	33.67
20	0.35	0.47	0.56	0.76	1.03	1.39	1.66	2.06	2.77	4.13	5.18	6.08	6.74	7.37	7.89	8.88	9.55	10.93	12.22	14.40	21.21	35.61
22	0.38	0.52	0.62	0.84	1.14	1.54	1.84	2.28	3.07	4.58	5.74	6.74	7.47	8.18	8.75	9.85	10.59	12.13	13.56	15.97	23.53	39.50
24	0.42	0.57	0.68	0.92	1.25	1.70	2.03	2.50	3.37	5.03	6.31	7.41	8.21	8.98	9.61	10.82	11.63	13.32	14.89	17.55	25.84	43.39
26	0.46	0.62	0.74	1.01	1.36	1.85	2.21	2.73	3.68	5.48	6.88	8.07	8.95	9.79	10.47	11.79	12.67	14.51	16.23	19.12	28.16	47.28
28	0.50	0.67	0.81	1.09	1.48	2.00	2.39	2.95	3.98	5.93	7.44	8.74	9.68	10.59	11.33	12.76	13.72	15.71	17.56	20.69	30.48	51.17
30	0.54	0.73	0.87	1.17	1.59	2.15	2.57	3.18	4.28	6.38	8.01	9.40	10.42	11.40	12.19	13.73	14.76	16.90	18.90	22.26	32.79	55.06
32	0.57	0.78	0.93	1.26	1.70	2.30	2.75	3.40	4.58	6.83	8.57	10.06	11.15	12.20	13.05	14.70	15.80	18.09	20.23	23.84	35.11	58.95
34	0.61	0.83	0.99	1.34	1.81	2.46	2.93	3.63	4.89	7.28	9.14	10.73	11.89	13.01	13.92	15.67	16.84	19.29	21.57	25.41	37.42	62.84
36	0.65	0.88	1.05	1.42	1.93	2.61	3.11	3.85	5.19	7.73	9.70	11.39	12.63	13.81	14.78	16.64	17.89	20.48	22.90	26.98	39.74	66.73
38	0.69	0.93	1.11	1.50	2.04	2.76	3.30	4.08	5.49	8.18	10.27	12.06	13.36	14.62	15.64	17.61	18.93	21.68	24.24	28.56	42.06	70.62
40	0.73	0.98	1.17	1.59	2.15	2.91	3.48	4.30	5.79	8.64	10.83	12.72	14.10	15.42	16.50	18.58	19.97	22.87	25.57	30.13	44.37	74.51

50 Year Storm for Solano and Yolo Counties

Mean Ann Precip	5M	10M	15M	30M	1H	2H	3H	6H	12H	24H	2D	3D	4D	5D	6D	8D	10D	15D	20D	30D	60D	Year
14	0.26	0.35	0.42	0.56	0.76	1.03	1.24	1.53	2.06	3.07	3.85	4.52	5.01	5.48	5.86	6.60	7.10	8.13	9.09	10.71	15.77	26.48
15	0.28	0.38	0.45	0.61	0.83	1.12	1.34	1.65	2.23	3.32	4.16	4.89	5.42	5.93	6.34	7.14	7.67	8.79	9.83	11.58	17.05	28.63
16	0.30	0.41	0.48	0.66	0.89	1.20	1.44	1.78	2.39	3.57	4.48	5.25	5.82	6.37	6.82	7.68	8.25	9.45	10.56	12.45	18.33	30.78
17	0.32	0.43	0.52	0.70	0.95	1.29	1.54	1.90	2.56	3.82	4.79	5.62	6.23	6.82	7.29	8.21	8.83	10.11	11.30	13.32	19.61	32.93
18	0.34	0.46	0.55	0.75	1.01	1.37	1.64	2.03	2.73	4.07	5.10	5.99	6.64	7.26	7.77	8.75	9.40	10.77	12.04	14.19	20.89	35.08
19	0.36	0.49	0.59	0.79	1.07	1.46	1.74	2.15	2.89	4.32	5.41	6.36	7.04	7.71	8.24	9.28	9.98	11.43	12.78	15.06	22.17	37.23
20	0.38	0.52	0.62	0.84	1.14	1.54	1.84	2.27	3.06	4.56	5.73	6.72	7.45	8.15	8.72	9.82	10.56	12.09	13.52	15.92	23.45	39.38
22	0.43	0.58	0.69	0.93	1.26	1.71	2.04	2.52	3.40	5.06	6.35	7.46	8.26	9.04	9.67	10.89	11.71	13.41	14.99	17.66	26.01	43.68
24	0.47	0.63	0.76	1.02	1.38	1.88	2.24	2.77	3.73	5.56	6.98	8.19	9.08	9.93	10.63	11.97	12.86	14.73	16.47	19.40	28.58	47.98
26	0.51	0.69	0.82	1.11	1.51	2.04	2.44	3.02	4.07	6.06	7.60	8.93	9.89	10.82	11.58	13.04	14.01	16.05	17.94	21.14	31.14	52.28
28	0.55	0.75	0.89	1.21	1.63	2.21	2.64	3.27	4.40	6.56	8.23	9.66	10.71	11.71	12.53	14.11	15.17	17.37	19.42	22.88	33.70	56.58
30	0.59	0.80	0.96	1.30	1.76	2.38	2.84	3.51	4.73	7.06	8.85	10.39	11.52	12.60	13.48	15.18	16.32	18.69	20.89	24.62	36.26	60.88
32	0.63	0.86	1.03	1.39	1.88	2.55	3.04	3.76	5.07	7.56	9.48	11.13	12.33	13.49	14.44	16.26	17.47	20.01	22.37	26.36	38.82	65.18
34	0.68	0.92	1.09	1.48	2.01	2.72	3.24	4.01	5.40	8.05	10.10	11.86	13.15	14.38	15.39	17.33	18.63	21.33	23.85	28.10	41.38	69.48
36	0.72	0.97	1.16	1.57	2.13	2.88	3.44	4.26	5.74	8.55	10.73	12.60	13.96	15.27	16.34	18.40	19.78	22.65	25.32	29.84	43.94	73.78
38	0.76	1.03	1.23	1.66	2.25	3.05	3.64	4.51	6.07	9.05	11.35	13.33	14.77	16.16	17.29	19.47	20.93	23.97	26.80	31.58	46.51	78.09
40	0.80	1.09	1.30	1.76	2.38	3.22	3.84	4.76	6.41	9.55	11.98	14.06	15.59	17.05	18.24	20.55	22.08	25.29	28.27	33.32	49.07	82.39

100 Year Storm for Solano and Yolo Counties

Mean Ann Precip	5M	10M	15M	30M	1H	2H	3H	6H	12H	24H	2D	3D	4D	5D	6D	8D	10D	15D	20D	30D	60D	Year
14	0.28	0.38	0.46	0.62	0.83	1.13	1.35	1.67	2.25	3.35	4.21	4.94	5.47	5.99	6.41	7.21	7.75	8.88	9.93	11.70	17.23	28.93
15	0.30	0.41	0.49	0.67	0.90	1.22	1.46	1.81	2.43	3.63	4.55	5.34	5.92	6.47	6.93	7.80	8.38	9.60	10.73	12.65	18.63	31.28
16	0.33	0.44	0.53	0.72	0.97	1.31	1.57	1.94	2.61	3.90	4.89	5.74	6.36	6.96	7.45	8.39	9.01	10.32	11.54	13.60	20.03	33.63
17	0.35	0.47	0.57	0.77	1.04	1.41	1.68	2.08	2.80	4.17	5.23	6.14	6.81	7.45	7.97	8.97	9.64	11.04	12.35	14.55	21.43	35.98
18	0.37	0.51	0.60	0.82	1.11	1.50	1.79	2.21	2.98	4.44	5.57	6.54	7.25	7.93	8.49	9.56	10.27	11.76	13.15	15.50	22.83	38.33
19	0.40	0.54	0.64	0.87	1.17	1.59	1.90	2.35	3.16	4.71	5.91	6.94	7.70	8.42	9.01	10.14	10.90	12.49	13.96	16.45	24.22	40.67
20	0.42	0.57	0.68	0.92	1.24	1.68	2.01	2.48	3.35	4.99	6.26	7.34	8.14	8.91	9.53	10.73	11.53	13.21	14.77	17.40	25.62	43.02
22	0.46	0.63	0.75	1.02	1.38	1.87	2.23	2.75	3.71	5.53	6.94	8.15	9.03	9.88	10.57	11.90	12.79	14.65	16.38	19.30	28.42	47.72
24	0.51	0.69	0.82	1.12	1.51	2.05	2.45	3.03	4.08	6.08	7.62	8.95	9.92	10.85	11.61	13.07	14.05	16.09	17.99	21.20	31.22	52.42
26	0.56	0.75	0.90	1.22	1.65	2.23	2.67	3.30	4.44	6.62	8.31	9.75	10.81	11.82	12.65	14.25	15.31	17.53	19.60	23.10	34.02	57.12
28	0.60	0.81	0.97	1.32	1.78	2.42	2.88	3.57	4.81	7.16	8.99	10.55	11.70	12.80	13.69	15.42	16.57	18.98	21.22	25.00	36.82	61.82
30	0.65	0.88	1.05	1.42	1.92	2.60	3.10	3.84	5.17	7.71	9.67	11.36	12.59	13.77	14.73	16.59	17.83	20.42	22.83	26.90	39.61	66.52
32	0.69	0.94	1.12	1.52	2.06	2.78	3.32	4.11	5.54	8.25	10.36	12.16	13.47	14.74	15.77	17.76	19.09	21.86	24.44	28.80	42.41	71.21
34	0.74	1.00	1.19	1.62	2.19	2.97	3.54	4.38	5.90	8.80	11.04	12.96	14.36	15.71	16.81	18.93	20.35	23.30	26.05	30.70	45.21	75.91
36	0.78	1.06	1.27	1.72	2.33	3.15	3.76	4.65	6.27	9.34	11.72	13.76	15.25	16.69	17.85	20.10	21.61	24.74	27.67	32.60	48.01	80.61
38	0.83	1.12	1.34	1.82	2.46	3.33	3.98	4.92	6.63	9.89	12.40	14.56	16.14	17.66	18.89	21.28	22.87	26.19	29.28	34.50	50.81	85.31
40	0.88	1.19	1.42	1.92	2.60	3.52	4.20	5.20	7.00	10.43	13.09	15.37	17.03	18.63	19.93	22.45	24.13	27.63	30.89	36.40	53.61	90.01

500 Year Storm for Solano and Yolo Counties

Mean Ann Precip	5M	10M	15M	30M	1H	2H	3H	6H	12H	24H	2D	3D	4D	5D	6D	8D	10D	15D	20D	30D	60D	Year
14	0.34	0.46	0.54	0.74	1.00	1.35	1.62	2.00	2.69	4.01	5.04	5.91	6.55	7.17	7.67	8.64	9.28	10.63	11.88	14.00	20.62	34.6
15	0.36	0.49	0.59	0.80	1.08	1.46	1.75	2.16	2.91	4.34	5.44	6.39	7.08	7.75	8.29	9.34	10.04	11.49	12.85	15.14	22.30	37.4
16	0.39	0.53	0.63	0.86	1.16	1.57	1.88	2.32	3.13	4.67	5.85	6.87	7.62	8.33	8.91	10.04	10.79	12.36	13.81	16.28	23.97	40.3
17	0.42	0.57	0.68	0.92	1.24	1.68	2.01	2.49	3.35	4.99	6.26	7.35	8.15	8.91	9.54	10.74	11.54	13.22	14.78	17.41	25.65	43.1
18	0.45	0.60	0.72	0.98	1.32	1.79	2.14	2.65	3.57	5.32	6.67	7.83	8.68	9.50	10.16	11.44	12.30	14.08	15.74	18.55	27.32	45.9
19	0.47	0.64	0.77	1.04	1.41	1.90	2.27	2.81	3.79	5.64	7.08	8.31	9.21	10.08	10.78	12.14	13.05	14.95	16.71	19.69	29.00	48.7
20	0.50	0.68	0.81	1.10	1.49	2.01	2.40	2.97	4.00	5.97	7.49	8.79	9.74	10.66	11.40	12.84	13.81	15.81	17.67	20.83	30.67	51.5
22	0.56	0.75	0.90	1.22	1.65	2.23	2.67	3.30	4.44	6.62	8.31	9.75	10.81	11.82	12.65	14.25	15.31	17.53	19.60	23.10	34.02	57.1
24	0.61	0.83	0.99	1.34	1.81	2.45	2.93	3.62	4.88	7.27	9.12	10.71	11.87	12.99	13.90	15.65	16.82	19.26	21.53	25.37	37.37	62.7
26	0.67	0.90	1.08	1.46	1.97	2.67	3.19	3.95	5.32	7.92	9.94	11.67	12.94	14.15	15.14	17.05	18.33	20.99	23.46	27.65	40.72	68.4
28	0.72	0.98	1.16	1.58	2.14	2.89	3.45	4.27	5.75	8.58	10.76	12.63	14.00	15.32	16.39	18.45	19.84	22.71	25.39	29.92	44.07	74.0
30	0.77	1.05	1.25	1.70	2.30	3.11	3.72	4.60	6.19	9.23	11.58	13.59	15.06	16.48	17.63	19.86	21.34	24.44	27.33	32.20	47.42	79.6
32	0.83	1.12	1.34	1.82	2.46	3.33	3.98	4.92	6.63	9.88	12.40	14.55	16.13	17.64	18.88	21.26	22.85	26.17	29.26	34.47	50.77	85.2
34	0.88	1.20	1.43	1.94	2.62	3.55	4.24	5.25	7.07	10.53	13.21	15.51	17.19	18.81	20.12	22.66	24.36	27.89	31.19	36.74	54.12	90.9
36	0.94	1.27	1.52	2.06	2.78	3.77	4.50	5.57	7.50	11.18	14.03	16.47	18.26	19.97	21.37	24.06	25.87	29.62	33.12	39.02	57.47	96.5
38	0.99	1.35	1.61	2.18	2.95	3.99	4.77	5.89	7.94	11.84	14.85	17.43	19.32	21.14	22.61	25.47	27.37	31.35	35.05	41.29	60.82	102.1
40	1.05	1.42	1.70	2.30	3.11	4.21	5.03	6.22	8.38	12.49	15.67	18.39	20.39	22.30	23.86	26.87	28.88	33.07	36.98	43.57	64.17	107.7

1000 Year Storm for Solano and Yolo Counties

Mean Ann Precip	5M	10M	15M	30M	1H	2H	3H	6H	12H	24H	2D	3D	4D	5D	6D	8D	10D	15D	20D	30D	60D	Year
14	0.45	0.61	0.73	0.99	1.34	1.81	2.16	2.67	3.60	5.36	6.73	7.90	8.76	9.58	10.25	11.54	12.41	14.21	15.88	18.72	27.57	46.3
15	0.49	0.66	0.79	1.07	1.44	1.96	2.34	2.89	3.89	5.80	7.28	8.54	9.47	10.36	11.08	12.48	13.41	15.36	17.17	20.24	29.80	50.0
16	0.52	0.71	0.85	1.15	1.55	2.10	2.51	3.11	4.18	6.24	7.82	9.18	10.18	11.14	11.91	13.42	14.42	16.51	18.46	21.76	32.04	53.8
17	0.56	0.76	0.91	1.23	1.66	2.25	2.69	3.32	4.48	6.67	8.37	9.83	10.89	11.91	12.75	14.35	15.43	17.67	19.75	23.28	34.28	57.6
18	0.60	0.81	0.96	1.31	1.77	2.40	2.86	3.54	4.77	7.11	8.92	10.47	11.60	12.69	13.58	15.29	16.44	18.82	21.04	24.80	36.52	61.3
19	0.63	0.86	1.02	1.39	1.88	2.54	3.04	3.76	5.06	7.54	9.46	11.11	12.31	13.47	14.41	16.23	17.44	19.98	22.33	26.32	38.76	65.1
20	0.67	0.91	1.08	1.47	1.99	2.69	3.21	3.97	5.35	7.98	10.01	11.75	13.02	14.25	15.24	17.17	18.45	21.13	23.62	27.84	41.00	68.8
22	0.74	1.01	1.20	1.63	2.20	2.98	3.56	4.41	5.94	8.85	11.10	13.03	14.45	15.80	16.91	19.04	20.47	23.44	26.20	30.88	45.47	76.4
24	0.82	1.11	1.32	1.79	2.42	3.28	3.91	4.84	6.52	9.72	12.20	14.32	15.87	17.36	18.57	20.92	22.48	25.74	28.78	33.92	49.95	83.9
26	0.89	1.20	1.44	1.95	2.64	3.57	4.26	5.28	7.11	10.59	13.29	15.60	17.29	18.92	20.24	22.79	24.50	28.05	31.36	36.96	54.43	91.4
28	0.96	1.30	1.56	2.11	2.85	3.87	4.62	5.71	7.69	11.46	14.38	16.88	18.71	20.47	21.90	24.67	26.51	30.36	33.94	39.99	58.90	98.9
30	1.04	1.40	1.67	2.27	3.07	4.16	4.97	6.14	8.27	12.33	15.47	18.17	20.14	22.03	23.57	26.54	28.53	32.67	36.52	43.03	63.38	106.4
32	1.11	1.50	1.79	2.43	3.29	4.45	5.32	6.58	8.86	13.21	16.57	19.45	21.56	23.58	25.23	28.42	30.54	34.97	39.10	46.07	67.86	113.9
34	1.18	1.60	1.91	2.59	3.51	4.75	5.67	7.01	9.44	14.08	17.66	20.73	22.98	25.14	26.90	30.29	32.56	37.28	41.68	49.11	72.34	121.5
36	1.26	1.70	2.03	2.75	3.72	5.04	6.02	7.45	10.03	14.95	18.75	22.02	24.40	26.70	28.56	32.17	34.57	39.59	44.26	52.15	76.81	129.0
38	1.33	1.80	2.15	2.91	3.94	5.33	6.37	7.88	10.61	15.82	19.85	23.30	25.83	28.25	30.23	34.04	36.59	41.90	46.84	55.19	81.29	136.5
40	1.40	1.90	2.27	3.07	4.16	5.63	6.72	8.31	11.20	16.69	20.94	24.58	27.25	29.81	31.89	35.91	38.60	44.20	49.42	58.23	85.77	144.0

10,000 Year Storm for Solano and Yolo Counties

Mean Ann Precip	5M	10M	15M	30M	1H	2H	3H	6H	12H	24H	2D	3D	4D	5D	6D	8D	10D	15D	20D	30D	60D	Year
14	0.63	0.85	1.02	1.38	1.87	2.53	3.03	3.74	5.04	7.51	9.43	11.07	12.27	13.42	14.36	16.17	17.38	19.90	22.25	26.22	38.6	64.8
15	0.68	0.92	1.10	1.49	2.02	2.74	3.27	4.05	5.45	8.13	10.19	11.97	13.26	14.51	15.52	17.48	18.79	21.52	24.06	28.35	41.8	70.1
16	0.73	0.99	1.19	1.61	2.18	2.95	3.52	4.35	5.86	8.74	10.96	12.87	14.26	15.60	16.69	18.80	20.20	23.14	25.87	30.48	44.9	75.4
17	0.78	1.06	1.27	1.72	2.33	3.15	3.76	4.65	6.27	9.35	11.72	13.77	15.26	16.69	17.86	20.11	21.62	24.75	27.67	32.61	48.0	80.6
18	0.84	1.13	1.35	1.83	2.48	3.36	4.01	4.96	6.68	9.96	12.49	14.66	16.25	17.78	19.02	21.42	23.03	26.37	29.48	34.74	51.2	85.9
19	0.89	1.20	1.43	1.94	2.63	3.56	4.25	5.26	7.09	10.57	13.26	15.56	17.25	18.87	20.19	22.74	24.44	27.98	31.29	36.87	54.3	91.2
20	0.94	1.27	1.52	2.06	2.78	3.77	4.50	5.57	7.50	11.18	14.02	16.46	18.25	19.96	21.36	24.05	25.85	29.60	33.09	38.99	57.4	96.4
22	1.04	1.41	1.68	2.28	3.09	4.18	4.99	6.17	8.32	12.40	15.55	18.26	20.24	22.14	23.69	26.68	28.67	32.83	36.71	43.25	63.7	107.0
24	1.14	1.55	1.85	2.50	3.39	4.59	5.48	6.78	9.14	13.62	17.08	20.06	22.23	24.32	26.02	29.30	31.50	36.07	40.32	47.51	70.0	117.5
26	1.25	1.69	2.01	2.73	3.69	5.00	5.97	7.39	9.95	14.84	18.62	21.86	24.22	26.50	28.35	31.93	34.32	39.30	43.94	51.77	76.2	128.0
28	1.35	1.83	2.18	2.95	4.00	5.42	6.47	8.00	10.77	16.06	20.15	23.65	26.22	28.68	30.68	34.55	37.14	42.53	47.55	56.03	82.5	138.6
30	1.45	1.96	2.35	3.18	4.30	5.83	6.96	8.61	11.59	17.28	21.68	25.45	28.21	30.86	33.02	37.18	39.96	45.76	51.17	60.29	88.8	149.1
32	1.55	2.10	2.51	3.40	4.61	6.24	7.45	9.21	12.41	18.50	23.21	27.25	30.20	33.04	35.35	39.81	42.79	49.00	54.78	64.54	95.1	159.6
34	1.66	2.24	2.68	3.63	4.91	6.65	7.94	9.82	13.23	19.72	24.74	29.05	32.19	35.22	37.68	42.43	45.61	52.23	58.39	68.80	101.3	170.1
36	1.76	2.38	2.84	3.85	5.21	7.06	8.43	10.43	14.05	20.94	26.27	30.84	34.19	37.40	40.01	45.06	48.43	55.46	62.01	73.06	107.6	180.7
38	1.86	2.52	3.01	4.07	5.52	7.47	8.92	11.04	14.87	22.16	27.80	32.64	36.18	39.58	42.34	47.69	51.26	58.69	65.62	77.32	113.9	191.2
40	1.96	2.66	3.17	4.30	5.82	7.88	9.41	11.65	15.69	23.38	29.33	34.44	38.17	41.76	44.68	50.31	54.08	61.93	69.24	81.58	120.1	201.7