County of Yolo

Yolo County Airport Drainage Plan Update

December 2005

WOOD RODGERS

DEVELOPING INNOVATIVE DESIGN SOLUTIONS

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I. INTRODUCTION

A. BACKGROUND

The Yolo County Airport (Airport) consists of approximately 498 acres, and is located west of County Road 96, south of County Road 29, east of County Road 95, and north of County Road 31 within Yolo County, California. The location of the Airport is shown on Map 1.

The Airport was constructed circa 1942 by the U.S. Army Corps of Engineers (USACOE). Existing drainage facilities on the Airport property include a network of ditches and underground pipes designed to keep the Airport's runway and other primary facilities drained during storm events.

The Airport is a publicly owned general aviation airport. The Airport was ceded to Yolo County by the United States Government following the end of World War II. The existing north-south runway is approximately 6,000 feet long by 100 feet wide, and has a 35-foot-wide parallel taxiway, as well as several right angle taxiways along the parallel taxiway that service various aircraft hangars and aprons on the Airport property. There is an additional hangar south of the Airport's southern property line that has a "through the fence" access to the runway via a gravel taxiway. The northeastern corner of the Airport property is currently leased to the Yolo Sportsmen's Association as a recreation area for its members.

According to local knowledge, historically, on-site runoff created only minor flooding on the Airport property in the initial years following the construction of the Airport. However, areas on the east side of the Airport property now experience flooding during certain storm events due to changes in the drainage system adjacent to the Airport. Flooding in the low-lying portions of the property occurs fairly regularly in the winter months, particularly after a heavy or prolonged storm, or a series of storms. This is primarily the result of alterations to adjoining and nearby drainage facilities and other natural drainage patterns that have occurred east of the Airport which have raised receiving waters and restrict the outlet at the southeastern corner of the Airport property. As a result, a 100-year floodplain area was delineated on the Airport in FEMA's "Flood Insurance Study for Yolo County, California, Unincorporated Areas," updated December 20, 2002 (Map 2).

To address this flooding issue, the "Yolo County Airport Drainage Plan" was initially prepared in October 1984 by Borcalli, Ensign, and Buckley on behalf of the County. The purpose of this study was to address development on the airport property without adversely impacting drainage and flooding along Airport Slough.

In 1998, Yolo County adopted the Yolo County Airport Master Plan, which proposes development within the existing floodplain and across the north-south runoff corridor on the eastern side of the Airport property, as shown on Map 3. Portions of the proposed development on the Airport property are within and adjacent to the existing floodplain and runoff corridors. As part of the planning efforts of the Yolo County Department of Planning and Public Works, Airport Division, to accommodate existing and potential development on the Airport property, the County retained the services of Wood Rodgers, Inc. to update the Yolo County Airport Drainage Plan. Funding for this work was provided through the Community Development Block Grant Program.

B. PURPOSE

The purpose of this Drainage Plan Update is to identify facilities to accommodate existing and planned development on the Airport property, while mitigating adverse impacts to storm water runoff and flooding.

II. FORMULATION OF STORM DRAINAGE AND SURFACE WATER QUALITY TREATMENT DESIGN CRITERIA AND STANDARDS

Wood Rodgers gathered and evaluated information regarding historic and current hydrologic methodologies, data, and design standards used within the region. Based upon review of the available information, Wood Rodgers developed design criteria and standards for flood control and surface water quality treatment to incorporate into the revised Drainage Analysis and Plan.

Since different types of drainage facilities serve different purposes that may require different levels of flood protection, water quality treatment, and/or maintenance and operation, it is appropriate to define various types of drainage facilities. To be consistent with other drainage plans in the region, the definitions adopted for the Airport include the following two categories:

- Type 1 Drainage Facilities – Runoff corridors, channels, culverts associated with channels, bridges, detention ponds, pump stations, and levees. Generally, these facilities serve as regional or "backbone" infrastructure for general or specific plan areas.
- Type 2 Drainage Facilities – Roadside ditches, storm drainage pipe systems, and overland conveyance systems. Generally, these facilities serve as on-site facilities that are tributary to Type 1 facilities.

Developing an Airport-wide drainage plan will ensure that existing and proposed drainage facilities meet the immediate and long-term goals of the Airport. The analysis should identify drainage facilities that accommodate existing and planned future land use within the Airport. Although phasing of development is not known with certainty, it is important to maintain the integrity of the proposed drainage facilities as development occurs.

The design standards and criteria developed for this report are intended to be acceptable to all parties with jurisdiction over drainage and flood control for the area.

A. TYPE 1 DRAINAGE FACILITIES

Type 1 drainage facilities include conveyance, flood protection, water quality treatment, and recreational, environmental, and aesthetic elements, which may consist of channels, culverts associated with channels, bridges, detention ponds, pump stations, and levees.

Type 1 drainage facilities should meet objectives consistent with the Airport's General Plan. In most cases, an analysis of the 10-year and 100-year storm events will provide the information necessary to design and evaluate the existing and proposed drainage system. The duration of the storms used in the analysis should represent the worst-case flooding scenarios with respect to peak flows and peak volume. As such, long duration storms (36-hour, 5-, and 10-day 100-year events) should be evaluated and compared with the 24-hour 100-year event, to determine whether runoff volume or peak discharge is of the most importance. The facility design shall be evaluated under a 200-year storm to determine how sensitive the level of protection is to the basic criteria.

Hydrology – Design Flow

Within the area, the hydrologic model developed by the Yolo County Flood Control & Water Conservation District (YCFCWCD) for the Willow Slough, Dry Slough, and Covell Drain drainages has been widely used to evaluate existing drainage and flooding patterns for flood insurance studies and to design regional drainage facilities. The model utilizes HEC-1, a computer model developed by the USACOE, which is applied throughout the United States and other countries. HEC-1 is a valuable tool used to calculate, route, and combine runoff hydrographs.

For evaluation and design of Type 1 and Type 2 drainage facilities within the Airport, the modeling methods presented in Table 1 shall apply.

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 Type 1 drainage facilities are as follows:

Water Quality Treatment Volume – Storm water runoff carries with it many pollutants in varying concentrations that are suspended and/or dissolved in runoff. As property is developed, Best Management Practices (BMPs) provide an opportunity to reduce the loading of pollutants to receiving waters. Yolo County has been classified as a Phase II community under the NPDES Stormwater Program, and in response to that the County adopted the "Yolo County Stormwater Management Program (SWMP) Planning Document," Revised October 2004. As part of the SWMP, the County must implement BMPs that reduce pollutants in storm water to the "maximum extent practicable" (MEP).

Storm water runoff would normally convey a disproportionate loading of pollutants in the initial period of runoff during a storm event. This initial period is usually the most critical and is commonly referred to as the "first flush." The "first flush" contaminants most frequently associated with storm water include sediment, nutrients, bacteria, oxygen demanding substances, oil and grease, other toxic chemicals, and floatables.

Detention ponds can include water quality treatment elements to minimize potential impacts to the quality of surface runoff entering receiving waters. The State of California has developed methodology to determine the optimum volume of storage for water quality detention ponds according to given impervious acreage of a drainage area. These methods are applicable within the Airport. The report entitled, "California Best Management Practices Handbook: New Development and Redevelopment Handbook," updated in September 2004, describes the analyses that establish the methods and criteria acceptable for water quality facilities. The mean storm event for the Airport area is 0.42 inch (obtained from the California Best Management Practices Handbook). Dry and wet ponds can be used to provide water quality treatment.

Storage Facilities – Storage facilities, where volume rather than peak flow generally governs the size, shall be designed to contain or attenuate a 10-day 100-year storm event, while maintaining at least one foot of freeboard in the pond and without creating excessive backwater effects on the tributary drainage storm system. Shorter duration 100-year storms (24-hour, 36-hour, and 5-day) should also be evaluated to test the sensitivity of the system.

Where practical, ponds shall include a minimum 20-foot perimeter buffer with an all-weather access road. The access road shall allow an adequate turning radius for maintenance vehicles. Ramps to the bottom of the pond with 10 percent maximum slope shall be provided. The side slopes of the pond shall be 3:1, or flatter.

For detention ponds that incorporate lake features, a lake/wetlands consultant shall be retained to provide detailed information regarding the operation and maintenance elements of the entire facility.

Pump Stations - To the extent possible, gravity systems are preferred over systems that rely on storm drainage pumping. Where pump stations are employed, they shall be designed to discharge the design capacity using a minimum of two equal sized mixed-flow vertical pump and motor units. A redundant pump and motor unit of equal size shall be included as a backup. An attempt shall be made to control the outflow from pump stations for storm events equal to and less than the 100-year storm event by staggering the "set point" for initiating pump operation, to provide a reasonable downstream flow pattern similar to existing conditions.

The sump for each pump station will be sized according to the "Hydraulic Institute Standards for Centrifugal, Rotary, and Reciprocating Pumps." 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 shall pass through a power-driven catenary trash rack system. The invert of each sump shall be lower than the invert of the pond or intake channel so the detention pond can be completely dewatered to facilitate maintenance.

Typically, each pump shall discharge into a separate pipe that includes a combined siphon breaker and air relief valve 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 shall be manifolded to discharge through a single pipeline. Electrical control equipment shall be enclosed in a prefabricated metal or concrete block building on a concrete foundation with minimum outside dimensions 8-feet wide by 20-feet long. The electrical equipment shall include pump controls, water level detection system, float switch for sump high-water level alarm and low-level automatic shutoff, solenoid-controlled automatic pump motor oiler, and telemetry system. The type of pump controls and telemetry system shall be uniform throughout the Airport. In addition, the building shall be equipped with two doors, wall louvers, rotary turbine roof vent, interior and exterior lighting, and a space heater.

Provision shall be made to accommodate a diesel generator to provide back-up power for each pump station. Each generator shall 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 shall be radiator-cooled and skid-mounted, and shall include a heater, batteries, battery charger, control panel with auto-start, critical silencer, and generator circuit breaker. The diesel generator and fuel storage tank shall be placed on a concrete pad. The fuel storage tank shall also be provided with the appropriate secondary containment feature.

As a minimum, and depending upon architectural or aesthetic considerations, the pump station site shall be enclosed with a 6-foot-high chain link fence topped with three strands of barbed wire. The fencing shall include a 20-foot-wide, electrically operated double gate and a 4-foot-wide pedestrian gate. The pump station lot shall be sized and the sump, electrical control building, diesel generator, and transformer arranged to allow adequate operating space for vehicles, pump, and motor removal equipment, and maintenance of the trash rack system. The paved access yard shall be at a minimum elevation of two feet above the 100-year water surface elevation, and shall be sloped to provide adequate on-site drainage.

Open Channels, Culverts Associated with Open Channels, and Bridges – Open channels, including runoff corridors, shall have 3:1 side slopes, or flatter. For open channel design, a Manning's "n" roughness coefficient shall be used to account for vegetation to minimize maintenance requirements as presented in Table 2. A 20-foot buffer including a 15-foot-wide all-weather access road for maintenance shall be provided adjacent to open channels. A minimum of one foot of freeboard for the 100-year event shall be provided for unleveed open channels, culverts, and bridges. In areas where fill is required to provide freeboard for open channels, three feet of freeboard shall be provided.

Hydraulic computations may be based upon the Manning's Formula, as well as either of the USACOE computer programs HEC-2 or HEC-RAS. A more in-depth description of hydraulic computer modeling methodology is presented in a subsequent section of this report.

Hydrologic Modeling

The HEC-1 or HEC-HMS computer programs developed by the USACOE 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 would be used to develop HEC-1 or HEC-HMS models are presented in this section.

Prepare Basic Information – Lay out the proposed storm sewer system and delineate the subbasins tributary to points of concentration for 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 varies by the type and size of the facility.

Storm Duration – The storm duration shall be greater than the lag time or time of concentration for the entire watershed. Long-duration storms, 36-hour, 5-day, and 10-day events shall be evaluated, as appropriate, where runoff volume rather than peak discharge is of importance.

Precipitation – As part of the "Covell Drainage System Comprehensive Drainage Plan," in 1993, Mr. James D Goodridge prepared design storm information for Yolo and Solano counties. This information is included in Appendix A.

Rainfall Depth-Duration-Frequency – The depth-duration-frequency information shall be obtained using the data in Appendix A, and based upon a mean annual precipitation of 19 inches.

Storm Distribution – The temporal distribution of rainfall, which varies with storm type, intensity, and duration, impacts the characteristics of the runoff hydrograph. There is no typical distribution that is applicable to all precipitation events. For design purposes, two different temporal distributions based on the storm duration are presented below:

Short-Duration Storm – For short duration storms, a symmetrical storm distribution is considered appropriate. This pattern is applicable for storms up to 24 hours in duration. For purposes of modeling a short-duration storm, a balanced storm distribution shall be modeled using the PH records in the HEC-1 model, or using the "Frequency Storm" method in HEC-HMS.

Long-Duration Storm – For storm durations greater than 24 hours, Sacramento City/County has prepared generalized storm distributions. Long duration storms in the Sacramento region typically consist of several precipitation events separated by periods of either low intensity precipitation or no precipitation. Sacramento City/County developed precipitation patterns for long duration storm events based on analysis of historical storms. The hourly precipitation records for the Downtown Sacramento NWS gage were examined to identify the 10 maximum depth storms for a duration of 36-hours, five days, and 10 days. From these storms generalized temporal distributions of precipitation were derived. The resulting distributions are presented in Table 3, Table 4, and Table 5. Although it would be desirable to apply this same methodology to historical precipitation in Yolo County to develop long duration storm distributions specific to Yolo County, historical hourly precipitation data in the County is extremely limited. As the climate in Yolo County is considered very similar to that of the Sacramento region, the storm distributions developed for the City/County of Sacramento are considered applicable for purposes of modeling long duration storms in Yolo County.

Computation Time Interval – 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 shall be rounded down to the closest 5, 10, 15, or 30 minutes; or one, two, three, or six 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 a number of computation intervals in conjunction with a computation time interval to define the duration of simulation.

The number of computation intervals to use 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 rather than peak discharge is of importance, the number of computation intervals should be large enough so the final hydrograph ordinates on the receding limb of the hydrograph are close to zero.

Antecedent Moisture Content (AMC) – The AMC is based upon the condition of the soil prior to the modeled storm event occurring. Presented in Table 6 is the way AMC would vary with storm frequency. These values were based upon information developed for the "Covell Drainage System Comprehensive Drainage Plan, WMP-93-01-3," September 1993.

Soil Conservation Service Curve Numbers – The SCS Curve Number (CN) is based upon land use soil type and AMC. The curve number model estimates precipitation excess as a function of cumulative precipitation, soil cover, land use, and antecedent moisture using the following equation:

$$P_e = \frac{(P - I_a)^2}{(P - I_a + S)}$$

Where:

P_e is accumulated precipitation at time t; P is accumulated rainfall depth at time t; and S is potential maximum retention, a measure of the ability of a watershed to abstract and retain storm precipitation. From analysis of results from many small experimental watersheds, the SCS developed an empirical relations ship of I_a and S:

$$I_a = 0.2S$$

Where:

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

For CN values between AMC I, AMC II, or AMC III, the CN shall be interpolated. Based upon SCS Technical Release 55 (June 1986), presented in Table 7 are the CNs for each land use type for a 24-hour storm for AMC II. Refer to Table 6, if necessary for the storm recurrence/AMC correlation. The CN shall be adjusted for storm durations other than 24 hours in accordance with the National Engineering Handbook, Section 4 and SCS Technical Release 60. Presented in Table 8 is the adjusted CNs for a 10-day storm. The CN shall be adjusted from AMC II values, if necessary, using Table 8.

Base Flow – Base flow is considered the normal day-to-day flow from groundwater, spring contributions, or even from landscaping runoff. In the vicinity of the Airport, groundwater is typically 15 feet or more below ground and is not considered a significant contributing factor with respect to base flow. However, during the rain season, some residual base flow is anticipated to be in the drainage system between storm events. To account for this, a base flow rate of one cfs/square mile of drainage area shall be included.

Lag Time – The temporal distribution of the unit hydrograph is a function of the basin lag time. The lag time shall be calculated by using one of two methods. Basin "n" lag method, or travel time component method. The Basin "n" method is typically used for planning level analyses or in basins with limited conveyance systems. The travel time component method should be used for detailed conveyance system design and runoff analyses of existing conveyance systems. The calculation procedure for each method is outlined below:

Basin "n" Lag Time 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 U.S. Bureau of Reclamation is expressed as:

$$L_g = C \bullet n\ ([L \bullet L_c]/S^{0.5})^{0.33}$$

Where:

C = 1560 (174)
L_g = lag time, minutes (seconds)
L = length of longest watercourse, measured as approximately 90percent of the distance from the point of interest to the headwater divide of the basin, miles (m)
L_c = 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" (Table 9)

The basin "n" value is dependent upon 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. Presented in Table 9 are recommended basin "n" values. The shaded values in Table 9 are not normally used. However, these values may be used for planning purposes to estimate the effect of channelization, or to estimate composite "n" for large areas with mixed land use channelization.

Travel Time Component Lag Time Method – 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 developed Kinematic wave empirical equation based upon available SCS, USACOE, and the Federal Highways Administration (FHA) overland flow data (Sacramento City/County, 1996) is:

$$T_o = \frac{(0.66L^{0.50} n^{0.52})}{S^{0.31} i^{0.38}}$$

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, i/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, the maximum times of concentration for commercial and residential areas and a range of times of concentration for open space are presented in Table 12.

Gutter Flow – The 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.

$$V_g = \frac{1.12\, S_x^{0.67}\, S^{0.50}\, T^{0.67}}{n}$$

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 = 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:

$$V = \frac{1.49\, R^{0.67}\, S^{0.50}}{n}$$

Where:

V = velocity, ft/s;
R = hydraulic radius, D/4 for full pipe flow, ft;
D = diameter of pipe, ft;
S = slope, ft/ft.
n = Manning's "n" for channel flow (Table 2); and

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 depth.
- Top width is seven times the bottom width.

Flow velocity in trapezoidal channels is calculated using the following equation:

$$V = \frac{0.995\ b^{0.67}\ S^{0.50}}{n}$$

Where:

V = velocity, ft/s;
b = bottom width, ft;
n = Manning's "n" for channel flow (Table 2); and
S = slope, ft/ft.

Lag Frequency Factors – It is assumed that much of the existing storm sewer system on the Airport was designed to convey runoff from the 2-year storm event. Flow exceeding the storm sewer capacity backs up behind the runway, taxiway, and streets; or if an overland release has been provided, flows in the streets.

Lag times, regardless of the method of calculation, should be adjusted to account for flows exceeding pipe capacities, causing temporary flooding in paved areas, and thereby increasing lag times. The multiplication factors presented in Table 13 are applied to the lag times for piped areas with overland release.

Synthetic Unit Hydrograph - The U.S Bureau of Reclamation 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 Airport. The procedure below outlines the steps used to compute the urban unit hydrograph:

1. Determine basin lag time (hours) and area (square mi.).
2. Determine unit duration (hours).
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 14.

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 rainfall over the basin. To obtain ordinates as a result of any other rainfall depth, multiply by the rainfall depth, in inches.

The unit hydrograph ordinates are entered on the UI records in HEC-1, which calculates runoff hydrographs based upon the effective precipitation over the basin.

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. The following section lists the routing methods that would be permitted using HEC-1. 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, Muskingham-Cunge, and Muskingham are recommended for use in the Airport. The methods, applications, and required parameters are summarized in Table 15, in order of preference. In most cases, Modified Puls routing is required where HEC-2 or HEC-RAS 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:

$$NSTPS = \frac{(\text{reach length/average velocity})}{2 \times NMIN}$$

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. This is considered applicable to the Airport drainage as well. The maximum NSTPS has been set to five, and is usually set to 1 for a reservoir.

Muskingham Routing – The Muskingham routing method is used 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 User's Manual. The Muskingham "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 Muskingham "X" value are given below:

Channel Description	Muskingham "X" Range
Most Channel Flow is in the Floodplain	0.00 - 0.15
Natural Channels	0.20 – 0.35
Excavated Earth or Concrete Channels	0.40 – 0.50

Muskingham-Cunge Routing – The Muskingham-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 diverting a flow form a channel based upon the total flow in the channel. The typical steps for modeling off-channel detention are:

- 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 (e.g. 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.

Hydraulic Modeling

Hydraulic computations may be based upon the Manning's formula, as well as either of the USACOE computer programs HEC-2 or HEC-RAS. Both HEC-2 and HEC-RAS are used throughout the United States and other countries. HEC-RAS was released by the USACOE with the intention of replacing HEC-2. Generally speaking, HEC-RAS is preferable in terms of its ability to model unsteady state flow, which provides a more accurate representation of routing and timing with respect to peak flows in a drainage system.

Manning's "n" values shall be obtained from Table 2, but may be calculated using other widely practiced engineering methods if circumstances dictate.

Open channel contraction and expansion loss coefficients for gradual transitions will be 0.1 and 0.3, respectively. Contraction and expansion coefficients of 0.3 and 0.5, respectively, shall be used for losses between bridge or culvert cross-sections.

B. TYPE 2 DRAINAGE FACILITIES

Type 2 drainage facilities include conveyance, flood protection, water quality treatment, and recreational, environmental, and aesthetic elements, which may consist of roadside ditches, storm drainage pipe systems, and overland conveyance systems. It is important to note that emphasis should be placed upon the appropriate design of the overland conveyance system for the on-site development of the land so designated for the Airport. If the overland conveyance system is appropriately designed, the capacity of the storm drainage pipe systems, roadside ditches, and culverts would have little effect on the risk of property damage or threat to public safety from flooding.

It is not known at this time as to how the land will be planned and developed. Accordingly, traditional methodology is presented herein for design of on-site drainage facilities. To the extent development is planned for respective Development Areas, consideration could be given to the application of Low Impact Development features consistent with criteria described in the document entitled, "Unified Facilities Criteria, Design: Low Impact Development Manual," Department of Defense, October 24, 2004.

Hydrology – Design Flow

The *Modified Rational Method* shall be used to design Type 2 drainage facilities. The *Modified Rational Method* calculates flow based upon storm intensity, time of concentration, imperviousness, and basin size. The *Modified Rational Method* has been widely used and tested throughout the United States.

The *Modified Rational Method* for the 10-year storm event shall be used to calculate the peak design flow for storm drainage pipe systems and roadside ditches.

When the design capacity of a storm drainage pipe system is exceeded, overland conveyance systems, generally streets, are relied upon to safely convey flow downstream to detention ponds or other receiving waters. The 100-year storm event would be used for evaluating and designing overland conveyance systems.

Rational Method

The *Rational Method* may be used for peak flow calculations to design street drainage, storm sewers, and culverts not associated with channels. The application of the *Rational Method* would be limited to areas up to 640 acres.

The *Rational Method* equation is expressed as:

$$Q = CiA$$

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 presented in Table 16.

Prepare Basic Information – Lay out the proposed storm sewer system and delineate the subbasins tributary to the 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, represented as "C," for a storm having a 10-year recurrence interval are presented in Table 17 by land use designation and hydrologic soil group. The 10-year runoff coefficients are to be used with the frequency factors presented in Table 18 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 16 is the weighted average of the C values for the subareas within the system being designed. Presented in Table 19 is a sample calculation for weighted average C computations for a basin.

Determine Time of Concentration – The time of concentration, or the travel time, is the time required for runoff to flow form 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 Component Lag Time Method" outlined in the design criteria for Type 1 facilities shall be used to determine the time of concentration.

Determine Intensity – As part of the "Covell Drainage System Comprehensive Drainage Plan," in 1993, Mr. James D Goodridge prepared design storm information for Yolo and Solano counties. This information is included in Appendix A.

Storm Drainage Pipe Systems – The invert of any storm drainage pipe outfall at ponds shall be designed to prevent standing water within the pipe systems, which can cause sedimentation that could affect the conveyance capacity and longevity of the pipes.

The storm drainage pipe systems shall be designed using the 10-year storm event design flow and the 10-year storm event peak water surface elevation in the downstream pond or other receiving water. Hydraulic grade lines shall be computed using Manning's formula with an "n" value to account for friction and minor losses, in accordance with the information presented in Table 20. The minimum pipe slope shall be equal to or greater than the hydraulic slope. To the extent practical, the hydraulic grade line shall be within the pipe. The hydraulic grade line shall be at least one foot below the flow line of inlet grates and manhole covers. The minimum velocity in closed conduits shall be 2.5 feet per second when flowing full.

The minimum drainage inlet elevation shall be one foot above the 100-year water surface elevation in the downstream detention pond or other receiving water.

Pipe inverts shall be designed to provide minimum cover at the upstream areas of the drainage. The minimum allowable pipe diameter is 18 inches.

Once flow at a point in a storm drain system exceeds the capacity of a 72-inch pipe, the facility must be designed as a Type 1 facility and cannot be placed inside parallel pipes to avoid sizing for a 100-year frequency. Additionally, downstream components within a drainage system cannot revert back to a Type 2 facility once a Type 1 designation is reached (i.e., pipes draining detention ponds).

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 (B.C.) and ending of curve (E.C.) and at 300 feet maximum intervals along the curve. On curves with a radius exceeding 400 feet, manholes shall be placed at the B.C. and E.C. and at 400 feet 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.

Inlets – The spacing of storm water drainage inlets shall not exceed a maximum of 500 feet. Storm water drainage inlets shall be located to prevent surface flow through street intersections.

Pipes – Storm water drainage pipes shall be reinforced concrete pipe, non-reinforced concrete pipe, or cast-in-place concrete pipe. All pipes shall be constructed with a minimum cover of two feet. The minimum velocity in closed conduits shall be 2.5 feet per second when flowing full.

Flowage Easements – Where the flooding of land outside the Airport 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 Airport's storm drainage system is preserved over time.

Pipe Discharges into Water Quality Ponds – The location of pipe discharges at a pond shall be designed to enhance water quality treatment within the pond and to prevent the "short-circuiting" flow through the pond.

Overland Conveyance Systems – All new development within the Airport shall include the design of street systems or other suitable release paths to convey flow in excess of pipe capacity, in an unobstructed manner, to the detention pond or other receiving waters. The overland conveyance facilities shall provide water surface elevations below the pad elevations in the 100-year storm event. The street system would be designed to minimize flooding depths within the street. To the extent practical, the overland flooding depths should be designed with a maximum of one foot from the gutter flow line. The street design shall incorporate designated overland flow paths from the streets to the pond.

Roadside Ditches – Roadside ditches shall be designed to minimize safety hazards and emphasize water quality treatment by implementing BMPs. At a minimum, roadside ditches would be designed to convey the 10-year storm event design flow.

Non-Regional Water Quality Treatment – In addition to regional water quality treatment detention ponds previously discussed, other water quality treatment BMPs should be implemented. Source and treatment control BMPs may include:

- Grassy Swales
- Filter Strips
- Media Filters
- Infiltration Devices
- Storm Drain Signage

C. FEMA Criteria

In addition to complying with the Airport's standards, drainage facilities shall comply with FEMA criteria. These criteria and standards include, but are not limited to:

- One foot of freeboard to existing ground in the 100-year storm event for open channels and ponds.

- Minimum three feet of freeboard in the 100-year storm event for levees. The structural integrity of levees must be certified in accordance with FEMA guidelines.

- Back-up power and redundant pump capacity for pump stations.

- Finished floor elevations one foot above the base flood elevation (100-year storm event).

- Fill within the 100-year floodplain would be compacted to 95 percent of the maximum density obtainable with the standard proctor test method issued by the American Society for Testing and Materials, or an equivalent test method acceptable to FEMA.

D. FAA Criteria

Review of the FAA's drainage standards indicates that in general, many of the criteria contained therein are less conservative than the standards set forth previously for design of Type 1 and Type 2 drainage facilities in the Drainage Plan Update as described below:

- With respect to precipitation depth, the FAA recommends consulting the NOAA atlas. However, the precipitation data for Yolo County compiled by James D. Goodridge is a more accurate source for local precipitation data, and should be used for hydrologic analysis within Yolo County.
- The FAA also specifies using a 5-year recurrence interval for purposes of designing storm drain facilities on airports. The standards adopted for the Drainage Plan Update call for 10-year or 100-year design, depending upon the type of facility.
- To calculate runoff, the FAA specifies using the *Modified Rational Method.* Although this is an acceptable method for designing storm drains under the Drainage Plan Update, hydrologic modeling should generally be used for purposes of designing Type 1 facilities.

FAA's design criteria are more stringent than many local storm drain design criteria with respect to minimum flow velocity in pipes. Several local municipalities including the Cities of West Sacramento, Woodland, and Winters; specify that a minimum design velocity of 2 feet per second shall be used to provide sufficient cleaning velocity to avoid sedimentation within the system. However, the FAA specifies using a minimum design velocity of 2.5 fps in pipes. The FAA's design velocity is more conservative, and has been adopted in the standards for the Drainage Plan Update.

With respect to on-site drainage design for airports, the FAA has issued "Advisory Circular 150/530-5B," published July 1, 1970. In addition to this, the FAA has published the, "Airport Environmental Handbook, Order 5050.4A," dated October 8, 1985. Order 5050.4A provides instructions and guidance for preparing and processing the environmental assessments, findings of no significant impact (FONSI), and environmental impact statements (EIS) for airport development proposals and other airport actions as required by various laws and regulations.

E. INTERIM CONDITIONS

As development progresses within the Airport, interim drainage conditions must be evaluated. Some flexibility in criteria and standards may be considered for interim conditions, but in no case would the following be allowed:

- Risking property damage from flooding.
- Jeopardizing public safety.
- Increasing floodplain elevations to surrounding lands.
- Creating significant impacts to surface or groundwater quality.

Impacting the facilities and operation of YCFCWCD's Pleasant Prairie Canal and Flightline Ditch and operations on surrounding land requires close coordination with YCFCWCD and landowners.

III. DESCRIPTION OF EXISTING CONDITIONS

A. Topography and Subbasin Boundaries

The Airport is located within the Airport Slough subbasin, which consists of approximately 4.9 square miles. Within the Airport Slough subbasin, the terrain generally slopes from west to east. The approximate ground elevations range from a maximum El. 120 in the western portion of the watershed, to a minimum El. 72.5 where the Airport Slough forms a confluence with Union School Slough. Elevations specified are in National Geodetic Vertical Datum of 1929 (NGVD 29).

The Union School Slough subbasin is located north of the Airport Slough subbasin, and the Moody/Dry Slough subbasin is located to the south.

Presented on Map 4 are the existing Airport Slough subbasin boundary, its internal subbasin boundaries, as well as topographic mapping of Airport Slough and adjacent areas. The sources of the topographic mapping presented on Map 4 are the following:

- Federal Emergency Management Agency, "Flood Insurance Study, Yolo County, California, Unincorporated Areas," Revised December 20, 2002.
- TopoDepot, digitized topographic mapping, 2002.

The vertical and horizontal data are National Geodetic Vertical Datum of 1929 (NGVD 29) and North American Datum of 1927 (NAD 27), respectively.

B. Land Use

The existing land use within the Airport Slough subbasin outside of the Airport primarily consists of agricultural, rural residential, and open space. Land within the Airport itself is a mix of commercial development and open space.

C. Soils

Based upon a report prepared by the U.S. Department of Agriculture, Soil Conservation Service, entitled, "Soil Survey of Yolo County, California," June 1972, the soils within the Airport Slough subbasin have generally been classified as hydrologic soil type D. Refer to the referenced SCS document for specific area delineations.

D. GROUNDWATER ELEVATION

Historical data for spring and fall groundwater levels, are presented in the "Annual Engineer's Report – 2002," prepared on the behalf of the YCFCWCD by Wood Rodgers in December of 2002. The groundwater table within low-lying areas of the Airport Slough subbasin is rarely less than 15 feet below existing ground level.

E. EXISTING DRAINAGE

On-site runoff on the Airport property generally drains from west to east under the runway and main taxiway, into three primary drainage ditches that drain east to a single north-south drainage ditch, which parallels the Pleasant Prairie Canal/Flightline Ditch. This north-south drainage ditch conveys flows southward along the eastern boundary of the Airport property parallel to the Pleasant Prairie Canal, eventually draining to Airport Slough to the south. The existing drainage facilities are presented on Map 5. The Airport's on-site tributary area consists of approximately 357.2 acres of land, and consists of a mix of undeveloped and developed land.

The Airport is also subject to runoff that drains from off-site. West of the airport, flow drains generally from west to east. Portions of this land drain southeasterly and directly to Airport Slough. The remainder flows northeasterly, with the majority of the runoff collecting and pooling in a low-lying area on the western side of the Airport, between the airstrip and County Road 95. The water that drains to this location has two outlets: a 36 inch RCP that drains eastward under the airstrip and onto the Airport property, and a section of low lying ground which allows water to spill northward, eventually overtopping County Road 29 and draining to Union School Slough. As the invert of the pipe is considerably lower than the ground serving as an overland release to the north, flow will primarily flow east until the capacity of the pipe is exceeded. The tributary area for the Airport's off-site runoff component is approximately 230.8 acres of agricultural land.

F. HYDROLOGIC AND HYDRAULIC MODELING

Wood Rodgers prepared hydrologic and hydraulic computer models to represent existing drainage and flooding conditions for the Airport for the following storm events:

- 10-year 24-hour storm
- 10-year 36-hour storm
- 10-year 5-day storm
- 10-year 10-day storm
- 100-year 24-hour storm
- 100-year 36-hour storm

- 100-year 5-day storm
- 100-year 10-day storm
- 200-year 10-day storm

The USACOE HEC-1 and HEC-RAS computer programs were used in accordance with the criteria and standards previously identified in this report.

Due to conveyance restrictions at the downstream end of the Airport's drainage system, the 10-day storm event results in the worst-case flooding scenarios for both the 100-year and 10-year storm events. For purposes of evaluating the sensitivity of proposed drainage facilities, a 200-year 10-day storm model was also prepared.

Hydrologic and hydraulic modeling computer files are presented in Appendix B.

G. FLOODING

Due to the limited conveyance capacity at the downstream end of the Airport's drainage system, there is a significant 100-year floodplain located on the eastern side of the Airport. Within the Airport property, the FEMA FIRM Community Panel Number listed under Section II.D of this report shows the effective flood insurance zone designations.

Presented on Map 6 is the delineation of the revised 100-year floodplain on the Airport property.

Wood Rodgers' analysis indicates that the 100-year maximum peak stage in the flooded portion of the Airport property is approximately El. 86.7 and that the peak flow discharging from the Airport is approximately 150 cfs. This is considerably lower than the 100-year peak stage of El. 87.8 indicated on the effective FIRM, and the 511 cfs outflow indicated in the effective FIS. Although the difference in stages and flow rates between the two analyses is significant, it is not unexpected and can largely be attributed to the methodology used in the FIS to delineate the 100-year floodplain. Specifically, the effective FIS modeling injected the peak flow from the entire tributary watershed into the upstream end of the Airport ditch using a steady state analysis. In reality, runoff from the watershed will enter the ditch at numerous points along the reach, and the timing of the peak at each of these locations would not necessarily be coincident. Wood Rodgers' analysis also features updated hydrology and application of HEC-RAS' unsteady state modeling capabilities, which accounts for the effects of routing with respect to peak flow attenuation. Additionally, Wood Rodgers identified an overland spill to Union School Slough that had not been accounted for in the FIS, which further reduced the peak flow contribution from off-site runoff. Although the approach taken in the FIS was in fact conservative, it is considered to have over represented existing flooding conditions on the Airport.

IV. FORMULATION OF DRAINAGE PLAN

A drainage plan was formulated for the Ultimate Developed Conditions. The objective was to identify cost-effective drainage facilities that would provide protection to the proposed development and mitigate potential adverse impacts to surrounding lands. The feasibility of phasing the improvements was also considered. To the extent possible, interim facilities were minimized.

A. LAND USE

Existing and proposed land uses within the Airport are presented on Map 3 and are in accordance with the "Final Environmental Assessment/Environmental Impact Report, Yolo County Airport Master Plan," prepared by P&D Consultants, Inc. on behalf of Yolo County and the FAA. The phasing of development on the Airport property is undetermined at this time. Nevertheless, Wood Rodgers designated Development Areas for purposes of formulating the drainage plan and providing a basis for allocating costs for the drainage infrastructure if necessary to do so as development occurs.

B. HYDROLOGIC AND HYDRAULIC MODELING

Wood Rodgers prepared hydrologic and hydraulic computer models to represent proposed drainage and flooding conditions for the Airport for the following storm events:

- 10-year 10-day storm
- 100-year 24-hour storm
- 100-year 10-day storm
- 200-year 10-day storm

The USACOE HEC-1 and HEC-RAS computer programs were used in accordance with the criteria and standards previously identified in this report.

Due to conveyance restrictions at the downstream end of the Airport's drainage system, the 10-day storm event results in the worst-case flooding scenarios for both the 100-year and 10-year storm events. For purposes of designing conveyance facilities such as open channels and culverts, the 100-year 24-hour storm was evaluated as well. For purposes of evaluating the sensitivity of proposed drainage facilities, a 200-year 10-day storm model was also prepared.

Hydrologic and hydraulic modeling computer files are presented in Appendix B.

Presented on Map 7 are the subbasins used in the hydrologic analysis of the Airport Slough subbasin for Ultimate Conditions.

C. FORMULATION OF ALTERNATIVES

In updating the drainage plan for the Airport is was deemed appropriate to consider alternatives for dealing with drainage infrastructure. Two alternatives were identified as described below.

Alternative 1: The approach taken for Alternative 1 was to maximize the land for potential development in the southeast portion of the Airport property on the east side of Aviation Ave. This required encroachment into the 100-year floodplain, which would require the creation of compensating storage volume. The impact of encroachment into the floodplain and the impact of development are dealt with on a regional or airport wide basis. Flood conveyance and water quality treatment is dealt with for each development area separately.

Alternative 2: The approach taken for Alternative 2 was to not encroach into the 100-year floodplain and to mitigate the impacts of development and provide water quality treatment for each development area separately.

A specific consideration or criteria for the drainage plan was to keep Aviation Ave. dry during the 100-year storm. An evaluation of each alternative is presented in following sections of this report.

D. EVALUATION OF ALTERNATIVE 1

As noted previously, the development areas were identified for purposes of evaluating and developing the overall drainage plan. These respective development areas for Alternative 1 are delineated on Map 8. The major elements of the drainage plan for this alternative include regional or airport detention and flood conveyance and water quality features for the respective development areas as discussed below.

Airport Detention

Additional storage is required within the existing floodplain to mitigate the impact of encroachment into the existing floodplain and the impact of development within the Airport property. The features required to mitigate adverse impacts under Alternative 1 include the following:

- Excavating a "bench" at El. 85.5 east of Aviation Ave. to replace floodplain storage displaced by development in the southeastern corner of the Airport.
- Constructing a flood control outlet structure (30-foot weir crest width, with 36-inch RCP low flow outlet) to control runoff draining south to Airport Slough. The weir crest shall be set at El. 86.2 and shall consist of grouted riprap.

- Material excavated in creating the "bench" would be placed on the portion of Development Area 5 west of Aviation Ave. and on Development Area 6 and compacted and graded for future development.

Development Area 1

Flood Conveyance- In large storm events, overland flow from Development Area 1 will drain south and be conveyed across Aviation Avenue through a culvert crossing shared with Development Area 2. This crossing shall consist of two pipes: a 48-inch RCP and a 54-inch RCP, designed to drain east to the shared water quality facility described below. Low flows will continue to drain as they do in existing conditions, to the pond adjacent to the Yolo County Sportsmen's Association shooting range.

In order for runoff from Development Area 1 to reach the proposed culvert crossing however, the existing drainage ditch that conveys flow from the west through Development Area 2 shall be removed and replaced with a 66-inch RCP. Replacing the existing ditch with a pipe will allow for more efficient use of the property for development. This pipe would also serve to isolate and prevent commingling of offsite runoff with the water quality treatment volume. If offsite runoff were allowed to commingle with development runoff, the required water quality volume would be increased significantly.

Water Quality- A water quality pond shall be constructed below the flood control "bench" in the floodplain. The pond will consist of a dry detention basin, consisting of approximately 2.22 ac-ft. of storage volume. The pond will drain via a low flow pipe with an orifice plate designed to drain the design water quality volume over the course of 72-hours. The pond is designed to treat runoff from both Development Area 1 and Development Area 2.

Development Area 2

Flood Conveyance- As noted above, in large storm events, overland flow from Development Area 1 will drain south and be conveyed across Aviation Avenue through a culvert crossing shared with Development Area 2. This crossing shall consist of two pipes: a 48-inch RCP and a 54-inch RCP, designed to drain east to the shared water quality facility described below. These culverts have been designed to accommodate runoff from the runway area west of Development Area 2 as well, as large storm events are anticipated to exceed the capacity of the existing 36-inch RCP that currently drains that portion of the Airport.

As noted above, the existing drainage ditch that conveys flow from the west through Development Area 2 shall be removed and replaced with a 66-inch RCP. Replacing the existing ditch with a pipe will allow for more efficient use of the property for development. In addition to conveying existing off-site runoff, this pipe will convey low flows from the runway area west of Development Area 2 during normal low flow storm events. The pipe is considered to isolate that land from commingling with the water quality volume and ensures that the design water quality volume described below need only accommodate Development Areas 1 and 2. Additionally, placing the offsite drainage into a pipe instead of the existing open channel, serves to increase the footprint of developable land within Development Area 2.

Water Quality- A water quality pond shall be constructed below the flood control "bench" in the floodplain. The pond will consist of a dry detention basin, consisting of approximately 2.22 ac-ft. of storage volume. The pond will drain via a low flow pipe with an orifice plate designed to drain the design water quality volume over the course of 72-hours. The pond is designed to treat runoff from both Development Area 1 and Development Area 2.

Development Area 3

Flood Conveyance- In order to for Development Area 3 to develop, a 54-inch RCP culvert crossing shall be installed at Aviation Ave. In addition to conveying on-site runoff, this crossing will convey runoff that currently drains from the runway west of Development Area 3. The culvert will then drain to the water quality facility described below.

Water Quality- A water quality pond shall be constructed below the flood control "bench" in the floodplain. The pond will consist of a dry detention basin, consisting of approximately 1.23 ac-ft. of storage volume. The pond will drain via a low flow pipe with an orifice plate designed to drain the design water quality volume over the course of 72-hours. The pond is designed to treat runoff from Development Area 3 as well as runoff from the airstrip to the west.

Development Area 4

Flood Conveyance- In order to for Development Area 4 to develop, a culvert crossing shall be installed at Aviation Ave. This crossing shall consist of two 66-inch RCPs. In addition to conveying on-site runoff, this crossing will convey runoff that currently drains from the runway west of Development Area 4. The culvert will then drain to the water quality facility described below.

Water Quality- A water quality pond shall be constructed below the flood control "bench" in the floodplain. The pond will consist of a dry detention basin, consisting of approximately 4.4 ac-ft. of storage volume. The pond will drain via a low flow pipe with an orifice plate designed to drain the design water quality volume over the course of 72-

hours. The pond is designed to treat runoff from Development Area 4 as well as runoff from the airstrip to the west.

Development Area 5

Flood Conveyance- In order to for Development Area 5 to develop, a 48-inch pipe shall be installed to convey runoff from land west of Aviation Ave. to the proposed water quality pond. Land east of Aviation Ave. shall drain to the pond via on-site drainage facilities.

Water Quality- A water quality pond shall be constructed on the eastern side of Development Area 5. The pond will consist of a dry detention basin, consisting of approximately 3.9 ac-ft. of storage volume. The pond will drain via a low flow pipe with an orifice plate designed to drain the design water quality volume over the course of 72-hours. The pond is designed to treat runoff from Development Area 5 only.

Development Area 6

Flood Conveyance- In order to for Development Area 6 to develop, on-site drainage facilities shall be designed to deliver runoff to the water quality pond described below.

Water Quality- A water quality pond shall be constructed on the eastern side of Development Area 6. The pond will consist of a dry detention basin, consisting of approximately 0.84 ac-ft. of storage volume. The pond will drain via a low flow pipe with an orifice plate designed to drain the design water quality volume over the course of 72-hours. The pond is designed to treat runoff from Development Area 6 only.

The opinion of probable costs associated with the facilities described above is presented in Appendix D. The total opinion of probable cost without contingencies, contractor overhead and profit, and engineering and environmental services is $1,235,253.

E. Evaluation of Alternative 2

As noted previously, the development areas were identified for purposes of evaluating and developing the overall drainage plan. These respective development areas for Alternative 2 are delineated on Map 9. The major elements of the drainage plan for this alternative include non-regional detention, flood conveyance and water quality features for the respective development areas as discussed below.

10

Development Area 1

Flood Conveyance- In large storm events, overland flow from Development Area 1 will drain south and be conveyed across Aviation Avenue through a culvert crossing shared with Development Area 2. This crossing shall consist of two pipes: a 48-inch RCP and a 54-inch RCP, designed to drain east to the shared water quality facility described below. Low flows will continue to drain as they do in existing conditions, to the pond adjacent to the Yolo County Sportsmen's Association shooting range.

In order for runoff from Development Area 1 to reach the proposed culvert crossing however, the existing drainage ditch that conveys flow from the west through Development Area 2 shall be removed and replaced with a 66-inch RCP. Replacing the existing ditch with a pipe will allow for more efficient use of the property for development. This pipe would also serve to isolate and prevent commingling of offsite runoff with the water quality treatment volume. If offsite runoff is allowed to commingle with development runoff, the required water quality volume would be increased significantly.

In order to mitigate the increased runoff volume from Development Areas 1 and 2, a "benched" area shall be excavated within the existing floodplain east of Aviation Ave. to increase the volume of storage in the floodplain.

Water Quality- A water quality pond shall be constructed below the flood control "bench" in the floodplain. The pond will consist of a dry detention basin, consisting of approximately 2.22 ac-ft. of storage volume. The pond will drain via a low flow pipe with an orifice plate designed to drain the design water quality volume over the course of 72-hours. The pond is designed to treat runoff from both Development Area 1 and Development Area 2.

Development Area 2

Flood Conveyance- As noted above, in large storm events, overland flow from Development Area 1 will drain south and be conveyed across Aviation Avenue through a culvert crossing shared with Development Area 2. This crossing shall consist of two pipes: a 48-inch RCP and a 54-inch RCP, designed to drain east to the shared water quality facility described below. These culverts have been designed to accommodate runoff from the runway area west of Development Area 2 as well, as large storm events are anticipated to exceed the capacity of the existing 36-inch RCP that currently drains that portion of the Airport.

As noted above, the existing drainage ditch that conveys flow from the west through Development Area 2 shall be removed and replaced with a 66-inch RCP. Replacing the existing ditch with a pipe will allow for more efficient use of the property for development. In addition to conveying existing off-site runoff, this pipe will convey low flows from the runway area west of Development Area 2 during normal low flow storm events. The pipe is considered to isolate that land from commingling with the water quality volume and ensures that the design water quality volume described below need only accommodate Development Areas 1 and 2. Additionally, placing the offsite drainage into a pipe instead of the existing open channel, serves to increase the footprint of developable land within Development Area 2.

As noted above, in order to mitigate the increased runoff volume from Development Areas 1 and 2, a "benched" area shall be excavated within the existing floodplain east of Aviation Ave. to increase the volume of storage in the floodplain.

Water Quality- A water quality pond shall be constructed below the flood control "bench" in the floodplain. The pond will consist of a dry detention basin, consisting of approximately 2.22 ac-ft. of storage volume. The pond will drain via a low flow pipe with an orifice plate designed to drain the design water quality volume over the course of 72-hours. The pond is designed to treat runoff from both Development Area 1 and Development Area 2.

Development Area 3

Flood Conveyance- In order to for Development Area 3 to develop, a 54-inch RCP culvert crossing shall be installed at Aviation Ave. In addition to conveying on-site runoff, this crossing will convey runoff that currently drains from the runway west of Development Area 3. The culvert will then drain to a detention/water quality pond. The flood control component of the detention pond will include approximately 1 ac-ft. of flood control volume to offset the increase in runoff volume generated by development within Development Area 3. The detention pond will include an emergency spillway provision that shall consist of a 30-foot wide overland release set at El. 86.5

Water Quality- A water quality pond shall be constructed below the flood control volume of the detention/water quality pond. The water quality component of the pond will consist of a dry detention basin, consisting of approximately 1.23 ac-ft. of storage volume. The pond will drain via a low flow pipe with an orifice plate designed to drain the design water quality volume over the course of 72-hours. The pond is designed to treat runoff from Development Area 3 as well as runoff from the airstrip to the west.

Development Area 4

Flood Conveyance- In order to for Development Area 4 to develop, a culvert crossing shall be installed at Aviation Ave. This crossing shall consist of two 66-inch RCPs. In addition to conveying on-site runoff, this crossing will convey runoff that currently drains from the runway west of Development Area 4. The culvert will then drain to a detention/water quality pond. The flood control component of the detention pond will include approximately 7.5 ac-ft. of flood control volume to offset the increase in runoff volume generated by development within Development Area 4. The detention pond will include an emergency spillway provision that shall consist of a 50-foot wide overland release set at El. 86.5

Water Quality- A water quality pond shall be constructed below the flood control volume of the detention/water quality pond. The pond will consist of a dry detention basin, consisting of approximately 4.4 ac-ft. of storage volume. The pond will drain via a low flow pipe with an orifice plate designed to drain the design water quality volume over the course of 72-hours. The pond is designed to treat runoff from Development Area 4 as well as runoff from the airstrip to the west.

Development Area 5

Flood Conveyance- In order to for Development Area 5 to develop, a 54-inch RCP culvert crossing shall be installed at Aviation Ave. The culvert will then drain to a detention/water quality pond. The flood control component of the detention pond will include approximately 4.8 ac-ft. of flood control volume to offset the increase in runoff volume generated by development within Development Area 5. The detention pond will include an emergency spillway provision that shall consist of a 30-foot wide overland release set at El. 88.0

Water Quality- A water quality pond shall be constructed below the flood control volume of the detention/water quality pond. The pond will consist of a dry detention basin, consisting of approximately 1.95 ac-ft. of storage volume. The pond will drain via a low flow pipe with an orifice plate designed to drain the design water quality volume over the course of 72-hours. The pond is designed to treat runoff from Development Area 5 only.

The opinion of probable costs associated with the facilities described above is presented in Appendix D. The total opinion of probable cost without contingencies, contractor overhead and profit, and engineering and environmental services is $745,576.

F. ULTIMATE CONDITIONS DRAINAGE PLAN

Alternative 2 was selected as the preferred alternative for the Ultimate Conditions Drainage Plan on the basis of cost as well as the opportunity it provides with respect to developing the Airport in phases. Alternative 2 does not however, include developing land east of Aviation Ave. currently in the floodplain. Should it become desirable to develop land east of Aviation Ave., the regional flood control facilities described in Alternative 1 could be implemented to mitigate development impacts to runoff.

A schematic of the proposed drainage facilities is presented on Map 10. Preliminary Engineering Drawings for the facilities proposed on Map 10 are included in Appendix C.

Drainage, Flooding, and SurfaceWater Quality Impacts

The drainage facilities described above would protect the proposed development from the risk of flood damage and threat to public safety. Additionally, implementation of the Ultimate Conditions Drainage Plan would result in no significant adverse drainage, flooding, or irrigation impacts to adjacent lands. Water surfaces in the floodplain on the eastern side of the Airport would be somewhat reduced, from El. 86.7 (existing) to El. 86.6 (proposed). The proposed floodplain lower than the water surface delineated on the effective FIRM (El. 87.7) and is not considered problematic with respect to development on the Airport. Presented on Map 11 is a comparison between the revised 100-year floodplain and the floodplain presented on the effective FIRM.

The sequence of development west of Aviation Ave. remains undetermined at this time. As such, proposed drainage patterns and grading have not been established. As such, Wood Rodgers has focused solely on facilities necessary to convey flow across and downstream of Aviation Ave. It will be the responsibility of the development community to ensure that proposed development projects upstream of Aviation Ave. conform to the standards and ultimate drainage facilities concept described in this report.

There is sufficient water quality treatment volume within the proposed detention ponds to accommodate treatment for areas slated for development within the Airport.

V. DRAINAGE FACILITIES PHASING

Although development phasing is not known at this time, it is important to note that development within the Airport is not contingent on all of the Ultimate Conditions Drainage Plan facilities being completed at one time. Each of the Development Areas identified in this report can be developed independently of one another without adverse impacts to flooding.

VI. OPINION OF PROBABLE COSTS

An opinion of probable cost was developed for the improvements identified in the Drainage Plan described in this report. The total cost for proposed Ultimate Conditions Drainage Plan improvements is $1,155,642. The total cost includes estimates of construction contingencies, contractor overhead and profit, as well as administration, engineering, and environmental permitting. A breakdown of the opinion of probable cost is presented in Appendix D.

VIII. FINDINGS AND RECOMMENDATIONS

A. FINDINGS

Summarized below are the findings of Wood Rodgers relative to storm drainage and flood control within the Airport:

1. The eastern portion of the Airport has significant flooding problems resulting directly from the low capacity of the existing outlet at the southeastern corner of the Airport. Areas within the Airport's General Plan planned for development, and that currently provide floodplain storage, would have to be replaced by either additional conveyance capacity and/or replacement storage. However, increasing conveyance capacity poses a problem as it would increase flows downstream and could adversely impact lands downstream. As such, replacing floodplain storage volume would be the most appropriate mitigation measure.

2. The elevation of the 100-year existing conditions floodplain on the Airport property is lower when evaluated with an unsteady state hydraulic model than that show on the FEMA FIRM.

3. The increase in peak flow from development on the Airport property would be fully mitigated with implementation of the facilities proposed.

4. No work is proposed that would impact natural waterways thus no regulatory permits should be required.

5. Implementation of the proposed water quality features would comply with NPDES Phase II and state permit requirements as issued for the County of Yolo.

B. RECOMMENDATIONS

Based upon Wood Rodgers' work in preparing the Drainage Plan Update and the findings noted above, Wood Rodgers recommends the following:

1. A CLOMR should be obtained from FEMA prior to approval of improvement plans for new development within the 100-year floodplain.

2. As development is proposed, require a drainage analysis from the development community consistent with the Airport's adopted drainage standards that accounts for and mitigates adverse on-site and off-site drainage/flooding impacts that may be caused by proposed development.

IX. REFERENCES

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TABLE 1

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

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 IV.B.
Master Plans or Designs of: • Storm Drains • Open Channels • Bridges and Culverts • Detention Basins	HEC-1	No Limit	Flow and Volume	Hydrology Standards, Section IV.A.
Water Quality Detention Basins		No Limit	Volume	California Storm Water Best Management Practices Handbook

TABLE 2

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

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

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

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 4

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

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 5

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

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 6

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

ADJUSTMENT RESULTS FOR HEC-1 MODELS

Recurrence Interval, Yr	Antecedent Moisture Conditions
100	2.00 (II)
50	1.55
10	1.10
2	1.00 (I)

TABLE 7

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

24-HOUR RUNOFF CURVE NUMBERS BY LAND USE, AMC II

	CN			
Land Use	A	B	C	D
Fallow	69	78	83	87
Idle	39	61	74	80
Row Crop (Grown in Winter)	64	74	81	85
Grain	62	73	81	84
Pasture	39	61	74	80
Orchard	32	58	72	79
Lawn Areas	39	61	74	80
Farmstead	59	74	82	86
Oak Areas, Grass Understory		48	57	63
Native Grasses	49	69	79	84
Suburban Residential (Acre Lots)	51	68	79	84
Urban	75	83.5	88.5	91
Urban Residential (1/4 Acre Lots)	61	75	83	87
Urban Industrial	81	88	91	93
Urban Commercial	89	92	94	95
Paved Areas (IE Roadways)	98	98	98	98
Apartments, Duplex	77	85	90	92
Residential (6,000 $foot^2$ Lots)	73	82.5	88.25	90.75
Residential (8,000 $foot^2$ Lots)	65	77.5	84.75	88.25
Residential (1/2 Acre Lots)	54	70	80	85
School (Half Commercial, Half Open Space)	64	76.5	84	87.5
Park	39	61	74	80
Vacant	77	86	91	94

Source: USDA, Soil Conservation Service, Urban Hydrology in Small Watersheds, TR-55, June 1986.

TABLE 8

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

10-DAY RUNOFF CURVE NUMBER ADJUSTMENT[1]

Runoff Curve Numbers					
1 Day	10 Days	1 Day	10 Days	1 Day	10 Days
100	100	80	65	60	41
99	98	79	64	59	40
98	96	78	62	58	39
97	94	77	61	57	38
96	92	76	60	56	37
95	90	75	58	55	36
94	88	74	57	54	35
93	86	73	56	53	34
92	84	72	54	52	33
91	82	71	53	51	33
90	81	70	52	50	32
89	79	69	51	49	31
88	77	68	50	48	30
87	76	67	49	47	29
86	74	66	47	46	28
85	72	65	46	45	28
84	71	64	45	44	27
83	69	63	44	43	26
82	68	62	43	42	25
81	66	61	42	41	24

[1]This table is used only if the 100-year frequency 10-day point rainfall is six or more inches. If it is less, the 10-day CN is the same as that for the 1-day CN.

Source: USDA, Soil Conservation Service, Earth Dams and Reservoirs, TR-60, October 1985.

TABLE 9

COUNTY OF YOLO

YOLO COUNTY AIRPORT DRAINAGE PLAN UPDATE

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 10

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

PARAMETERS FOR OVERLAND FLOW
WITH FLOW DEPTHS LESS THAN TWO (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

COUNTY OF YOLO

**YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE**

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

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

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

[1]Computed Using Overland Flow Equation Depending Upon Slope.

Source: Sacramento City/County Drainage Manual, Volume 2, "Hydrology Standards," December 1996.

TABLE 13

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

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 14

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

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
24	115	12.19

TABLE 14

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

USBR'S DIMENSIONLESS URBAN UNIT HYDROGRAPH

Ordinate Number	Time t in % of $L_g + 0.5D$	q
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
47	230	2.93
48	235	2.75

TABLE 14

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

USBR'S DIMENSIONLESS URBAN UNIT HYDROGRAPH

Ordinate Number	Time t in % of $L_g + 0.5D$	q
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
70	345	1.23
71	350	1.21
72	355	1.15

TABLE 14

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

USBR'S DIMENSIONLESS URBAN UNIT HYDROGRAPH

Ordinate Number	Time t in % of $L_g + 0.5D$	q
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
93	460	0.54
94	465	0.52
95	470	0.50
96	475	0.49

TABLE 14

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

USBR'S DIMENSIONLESS URBAN UNIT HYDROGRAPH

Ordinate Number	Time t in % of $L_g + 0.5D$	q
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
115	570	0.25
116	575	0.24
117	580	0.24
118	585	0.23
119	590	0.22
120	595	0.21

TABLE 14

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

USBR'S DIMENSIONLESS URBAN UNIT HYDROGRAPH

Ordinate Number	Time t in % of $L_g + 0.5D$	q
121	600	0.21

TABLE 15

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

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 16

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

RATIONAL METHOD CALCULATION SHEET

Inlet		Area A (acres)	C	CA (acres)	Sum CA (acres)	Time of Concentration																			i (in/hr)	CiA	Q_{DESIGN} (cfs)	Pipe Capacity (cfs)	Remarks
						Overland Flow				Gutter Flow			Pipe Flow					Channel Flow											
From	To					L_o	S_o	Overland "n"	T_o	L_g	S_g	T_g	S_p	D (in)	V (fps)	L (ft)	T_p (min)	S_c	Bottom Width	Manning's "n"	Velocity (fps)	L_c (ft)	T_c (min)	Total T_c (min)					

TABLE 17

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

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 17

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

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 18

COUNTY OF YOLO

YOLO COUNTY AIRPORT
DRAINAGE PLAN UPDATE

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