PLACER COUNTY DEPARTMENT OF PUBLIC WORKS

Final Report

AUBURN/BOWMAN COMMUNITY PLAN HYDROLOGY STUDY

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AUBURN/BOWMAN COMMUNITY PLAN HYDROLOGY STUDY

EXECUTIVE SUMMARY

GOALS AND SCOPE

The Auburn/Bowman Community is a largely rural area located in the Sierra foothills in Placer County. The community, however, is experiencing rapid growth with much of the agricultural and open space land being developed for residential and commercial purposes. Placer County is currently updating its General Plan for the Auburn/Bowman Community (excluding the City of Auburn) and one concern in the formulation of the Plan is the potential of existing and future flooding along streams in the study area as well as degradation of water quality in the numerous streams, canals and reservoirs in the study area.

Flooding occurs when heavy rains cause streams to overflow their banks, flooding property and structures located adjacent to the stream. Streams also back up and overtop at culverts and bridges, blocking roads or making them unsafe for passage. Emergency services can also be restricted by the flooded roads. In addition, there are numerous open canals in the study area that can intercept sheet runoff from one part of the study area and spill it into another. Excessive spills from these canals may also increase the potential for downstream flooding.

Placer County is concerned not only with the existing flooding problems, but also with future problems that can result from the development occurring in the area. Continued development in the watersheds that comprise the study area has the potential for making existing flooding and water quality problems worse unless adequate steps are taken to plan and implement comprehensive area-wide solutions to the drainage problems.

Not only are the impacts of flooding a concern for this study, but also the water quality impacts from stormwater runoff in the study area. Water quality degradation from stormwater runoff is primarily the result of runoff carrying pollutants from the land surface (i.e., streets, parking lots, pastures) to the receiving waters (i.e., streams and lakes). This type of pollution is termed "non-point source" pollution due to the fact that the pollutants are typically spread out over the land surface area (as opposed to point source pollution that refers to a specific managed source of pollution such as an industrial or wastewater treatment plant outfall to a stream). Non-point source pollution is of specific concern in the Auburn/Bowman Community Plan area not only because of the potential water quality impacts on streams, but also because of potential impacts on the numerous reservoirs and canals in the study area. In addition, the changing land uses (i.e., conversion of agricultural land to residential) in the study area may also have an adverse impact on future water quality due to increased pollutant loads.

Satisfactory solutions to the drainage problems in the study area cannot always be provided on a site by site basis because of possible adverse downstream impacts of any proposed solution. These downstream impacts must be taken into consideration when planning flood control projects and setting flood control policies. The purpose of this drainage study is to provide Placer County with the information and policies necessary to manage the storm waters within the study area. It also includes consideration of required improvements and the associated funding programs to accomplish the improvements. The results from this study are intended to provide an approach for meeting existing and future flood and water quality control needs in the study area.

MAJOR ASSUMPTIONS

The following paragraphs contain a list of the major assumptions used in the Auburn/Bowman Hydrology study.

- *The land use estimates for existing watershed conditions are based on a 1990 survey by Placer County Planning Department.* Placer County Planning Department performed a land use survey of the entire study area in which residential, commercial and industrial developments were identified and mapped. The results from this survey were utilized in developing the present conditions hydrology.
- *The land use estimates for projected future watershed conditions are based on full buildout according to the proposed community plan (Alternative 2).* A consistent set of land use designations was developed and applied to all areas of the watershed based on general plan information from the Placer County Planning Department. If the selected general plan is amended drastically, it may be necessary to make adjustments in the flood control plan to match those changes.
- *The following flood control and water quality management measures were considered as part of the flood control plan:*
    - Regional stormwater detention basins
    - Local, on-site stormwater detention basins
    - Bridge and culvert replacement
    - Rock Creek Reservoir Protection
    - Canal Protection
    - Best Management Practices
    - Channel improvements and levees
    - Floodplain management program
    - Flood warning and water quality monitoring system
- *Where bridge and culvert improvements are recommended, the design capacities were calculated assuming no other mitigation measures were in effect.* This assumption was necessary because it was not possible to know when or if other mitigation measures will be constructed.

FINDINGS

The following paragraphs contain a summary of the principal findings of this study.

1. *The magnitude of the potential peak flood flow increases due to development will vary throughout the study area from 2 to 22 percent within individual watersheds, depending on the level of development.* In areas where extensive development is planned, such as Rock Creek watershed, flows may increase up to 22 percent, while areas with little or no future development (i.e., Orr Creek and Dry Creek watersheds) will have insignificant increases in flow.
2. *Many of the bridges and culverts in the watershed are inadequate to pass the 100-year flows for both existing and future conditions.* Approximately 70% of the bridges and culverts were determined to be inadequate to pass the 100-year peak flow. In most cases, the flood flows will back up upstream of the bridge or culvert and will then flow across the roadway, interfering with traffic and emergency services. This flow can also damage the road embankment and bridge or culvert structure and endanger motorists. Flood damages can occur to structures upstream of the bridge due to the increased water levels.
3. *Flooding will occur with the 100-year flood under existing conditions along Dry Creek Road.* The Dry Creek channel adjacent to Dry Creek Road was the only area identified where the channel was inadequate to pass the 100-year flood without the flooding of the existing roadway. Specifically, flooding of up to 2 to 3 feet has been known to occur on Dry Creek Road between Dry Creek Road bridge and Twin Pines Trail bridge during a major storm event (March 1986).
4. *Local or on-site detention basins may be effective in reducing local and regional flooding problems due to development.* The implementation of on-site detention for new developments will eliminate increased flows just downstream of each detention basin. The greatest impact of local detention will be on Rock Creek watershed where the increase in future flows can be reduced from about 22 percent of existing to 8 percent. In North Ravine the increase in flows over present conditions is estimated to be approximately 8 percent. However, with local detention, the future flows can be reduced to about the same flows as occur under present conditions. In the Dry and Orr Creek watersheds the future flows increase only 3 percent over the present conditions and local detention can reduce these increases to existing conditions.
5. *Due to the lack of suitable sites in the study area, local regional detention basins were not included in the recommended improvements and policies.* Regional detention has proven to be an effective method in mitigating increased flows from urbanization in many instances. However, due to the relatively steep nature of the watersheds and the present level of development, no suitable sites were identified for a regional detention basin within the study area.
6. *Any significant clearing of the vegetation in floodplains and channels in the watershed will cause an overall increase in the magnitude of flood flows throughout the watershed.* Local exceptions should occur only where inadequate channel and/or floodplain capacity is currently causing flood damages along the stream. Other than these few exceptions,

channel clearing should be prohibited throughout the watershed. Any filling in the stream channel or floodplain may also cause local flooding due to increased water surface elevation and the resulting loss of flow capacity and storage. The loss of storage may also cause increased flooding impacts downstream.

7. *There are numerous canals in the study area that may be subject to water quality degradation through the interception of stormwater runoff.* As development of lands adjacent to these open canals occurs, the likelihood for increased pollutant levels increases. In addition to the potential impacts on canal water quality, urbanization may also result in increased flows into the canals from surface water runoff. These increased flows may cause damage to the canals by overtopping, erosion, or other structural damages to the canals or spill structures on the canals.

RECOMMENDED PLAN

The following paragraphs describe the elements of the recommended improvements and policies as part of the Auburn/Bowman Hydrology study.

Structural Alternatives

1. *Regional Detention Basins.* Regional detention basins were not recommended inside the study area due to efficacy of local, on-site detention basins in reducing peak flood flows, and the lack of suitable sites. A need for regional detention basins outside the study area was identified as part of the Coon Creek and Auburn Ravine study done previously (CH2M-Hill, 1992). These regional detention basins are needed to reduce both the peak flows and volumes resulting from development in the Coon Creek and Auburn Ravine watersheds.

2. *Bridge and Culvert Replacement.* Approximately 70% percent of the bridges and culverts in the Auburn/Bowman Community Plan study area are inadequate to pass the 100-year flood without overtopping. However, not all of these bridges and culverts are recommended for replacement. Some of the crossings in rural areas have been designed as low flow crossings and as such would not be damaged from high flows. In addition, other crossings were built in such a way within the floodplain that it would not be feasible to pass the 100-year flows without significant channel improvements and modifications (in addition to replacement of the crossing). Of the 48 total crossings identified as being inadequate to pass the 100-year flood, 26 are recommended for replacement.

3. *Channel Improvements.* A local channel improvement project should be considered for Dry Creek between Dry Creek Road bridge and Twin Pines Trail bridge to provide 25-year protection of the road. The Dry Creek channel in this area (adjacent to Dry Creek Road) was the only channel identified in this study where the stream channel was inadequate to pass the 25 and 100-year flows without impacting existing structures (i.e., Dry Creek Road). A hydraulic analysis of this stream reach indicated that it was not feasible to provide 100-year protection of the road without significant channel excavation

and clearing. However, 25-year protection should be provided through moderate channel excavation and the maintenance of a clear channel and floodplain (i.e., removal of blackberries and other undergrowth in the channel and overbanks).

4. *Rock Creek Reservoir Protection* The various structural methods considered for protection of Rock Creek Reservoir included a bypass channel around the reservoir, sedimentation basins upstream of the reservoir, and constructed wetlands upstream of the reservoir. Both the bypass channel and sedimentation basins are considered to be viable methods of protecting the water quality in the reservoir from pollutants associated with urban runoff. However, due to site constraints and the large size of the upstream watersheds, constructed wetlands were not considered to be an effective method for treating the runoff and thereby protecting the reservoir water quality.

   For protection of the reservoir from pollutants associated with stormwater runoff as well as protecting the downstream water quality, it is recommended that both a bypass channel and sedimentation basins be constructed. The bypass channel will provide protection for the reservoir by routing runoff around the reservoir while the sedimentation basins will provide a degree of treatment of this runoff by settling out solids prior to discharge into the bypass channel.

Nonstructural Alternatives

1. *Local, On-site Detention.* Local, on-site detention facilities are recommended for all future developments in the Auburn/Bowman Community Plan study area as indicated on Figure 6-2. These local detention facilities should be designed to reduce post-development flows from the 2- through 100-year storms to pre-development levels.

   It is understood that in many cases suitable sites that would allow a particular development to collect and store stormwater before release into a major stream, are not available. In these cases the developer should instead contribute an in-lieu of local detention fee to a fund that could be used to construct off-site local detention basins, improve the local conveyance facilities, and/or construct regional detention facilities to replace the local, on-site detention that was not constructed.

   Adequate maintenance of the local detention basins is essential if they are to maintain their effectiveness in reducing peak flows. A means must be found to ensure that the local detention basins are maintained adequately.

2. *Floodplain Management.* Continuing enforcement of floodplain management ordinances, grading ordinances, and policies to control development in the floodplain and prevent modification of natural channels or removal of vegetation is needed.

   Changes in the natural channel of major streams and/or the removal of existing vegetation in their floodplains can substantially increase downstream flood flows. Prohibitions against channel and floodplain modification are stated in most general plan policies; however, these policies are not believed to be fully enforceable and are not fully enforced at the present time. Flooding problems can also be exacerbated by modifications of minor tributary channels and their floodplains.

- *Floodplain Mapping.* Floodplain mapping is essential to provide direction for the Placer County Planning Department as land is developed along the streams in the Auburn/Bowman Community Plan area. As part of this study the approximate 100-year floodplain (for Future flows) was delineated for Orr Creek, Dry Creek, Rock Creek and North Ravine. This mapping should be extended and updated for the area on a one-time basis because the increase in runoff from future development is not expected to significantly affect the floodplain boundaries. The cost for floodplain mapping is estimated to be $550,000.
- *Channel and Floodplain Clearing.* Control of channel and floodplain clearing throughout the watershed is an important facet of the recommended plan. Clearing channels and floodplains of the existing vegetation will increase flood flows downstream. The dense vegetation existing in the channels and floodplains throughout the watershed is a flood retarding feature. It is recommended that floodplain management and grading ordinances and policies be enacted where such ordinances and policies are not already in place. These ordinances should restrict the removal of riparian vegetation from the channels and floodplains of major streams in the Auburn/Bowman Community Plan area except where removal and maintenance are required to solve existing local flooding problems.

3. *Canal Protection* In order to protect the canals from increased water quality degradation and increased flows as a result of new developments, it is recommended that the following canal protection measures be implemented to prevent any future increase in pollutant loadings or interception of stormwater runoff from occurring as a result of new development in the study area.

    - *Land Use Controls* A zoning ordinance should be implemented which limits the development of commercial, industrial and multi-family residential developments directly upstream of an open canal. The ordinance should state that a 100-foot setback is required from the uphill bank of a canal, with a 50-foot setback required from the downhill bank of a canal.
    - *Drainage Controls.* No new development uphill of an open canal should be allowed to let storm drainage enter the canal through a storm drainage collection system.
    - *Canal Encasement.* Canals should be encased in new residential developments with lot sizes of two acres or less, in new residential subdivisions where roads are constructed within 100 feet of a canal, and in commercial, industrial, institutional and multi-family residential developments. Canals should be encased in new residential developments with lot sizes of three acres or less if the canal carries the raw water supply for a downstream water treatment plant.
    - *Canal Fencing* Fencing should be required for canals that are not encased but which are within rural residential developments with lot sizes of five acres or less. The requirement for fencing along open canals in other developments should be determined on a case by case basis depending on the location and size of buildings, parking lots, roads and other improvements, the canal size and downstream water

use, and the presence or use of hazardous or toxic materials. The location of the fences as well as their design and construction should be approved by the County Engineer as well as the responsible canal agency.

4. *Best Management Practices.* Best Management Practices (BMPs) can be effective methods in removing pollutants from stormwater runoff (i.e., oil/grit separators, detention ponds) as well as in controlling the pollutants at their source (i.e., street cleaning, public education). A list of BMPs applicable to the Auburn/Bowman Community Plan area is presented in Section Four. This list is not exhaustive; however, it does present the most common BMPs in use in other rural and urban areas as well as at construction sites.

   In order to provide water quality protection of the streams, canals, and reservoirs in the study area, it is recommended that all new developments be required to implement appropriate BMPs such that the net increase in pollutant loads from the development is minimized. The specific BMPs and their design should be approved by the County Engineer prior to development of a site.

5. *Regional Monitoring Program.* It is recommended that the County implement a monitoring program that includes seven stations for stream level and precipitation monitoring in addition to automatic water quality samplers at each of the seven locations. In addition, two extra monitoring stations at Rock Creek at Bell Road and at Rock Creek Reservoir (water quality monitoring only) will provide additional data on the Rock Creek Reservoir and the upper Rock Creek watershed (where significant development is anticipated over the next twenty years).

   This monitoring program is designed to provide data (flow and water quality) throughout the Auburn/Bowman Community Plan area to determine the influence changing land use conditions have on the quantity and quality of storm water runoff. The seven locations were selected to provide data for all of the primary watersheds in the study area including Orr Creek, Dry Creek, Rock Creek and North Ravine. Stream level and precipitation data from the proposed monitors will be sent to the Flood Control District base station where it can be used to provide flooding forecasts for lower portions of the Coon Creek and Auburn Ravine watersheds. The estimated capital cost of the recommended regional monitoring program is $97,500.

6. *Rates and Charges.* Placer County or the Placer County Flood Control and Water Conservation District should collect fees to fund flood control services. These fees should be collected either as a benefit assessment or as rates and charges for services. County fees may be assessed and collected through establishment of a County Service Area (CSA) zone of benefits. Revisions to the District's enabling legislation may be needed before rates and charges can be used as a major funding source. The rates and charges should be set at a level to collect $455,000 annually for the Auburn/Bowman Area. This includes ongoing services and debt service on capital improvements. The ongoing services include maintenance, engineering, insurance, monitoring, and water quality studies. The capital improvements costs are the ones which cannot be allocated to new development. Billing rates should vary based on a properties land use, location and size. Initial recommended

billing rates for single family homes vary from $63 per house per year in the Rock Creek Zone, to a high of $326 per house per year for homes in the Dry Creek Zone.

7. *Funding for Flood Control Services Related to New Development.* A total of 5.3 million dollars should be collected from new development in the Dry Creek Watershed to fund regional flood control capital improvements necessitated by that development. The simplest way to collect those funds would be through a development fee. That development fee should vary based on the property use, location and size. Recommended single family home development fees vary from $658 per house in Rock Creek Zone to $3,414 per house in the Orr Creek Zone.

SECTION 1
INTRODUCTION

PURPOSE

The Auburn/Bowman Community is a largely rural area located in the Sierra foothills in Placer County. The community, however, is experiencing rapid growth with much of the agricultural and open space land being developed for residential and commercial purposes. Placer County is currently updating its General Plan for the Auburn/Bowman Community (excluding the City of Auburn) and one concern in the formulation of the Plan is the potential of existing and future flooding along streams in the study area.

Flooding occurs when heavy rains cause streams to overflow their banks, flooding property and structures located adjacent to the stream. Streams also back up at culverts and bridges, blocking roads or making them unsafe. Emergency services can also be restricted by the flooded roads. In addition, there are numerous open canals in the study area which can intercept sheet runoff from one part of the study area and spill it into another. Excessive spills from these canals may also increase the potential for downstream flooding.

Placer County is concerned, not only with the existing flooding problems, but also with future problems which can result from the development occurring in the area. Continued development in the watersheds that comprise the study area has the potential for making existing flooding problems worse unless adequate steps are taken to plan and implement comprehensive watershed-wide solutions to the drainage problems.

Satisfactory solutions to the flooding problems in the study area cannot be provided on a site by site basis because of the possible adverse downstream impacts of any proposed solution. Also, the cumulative downstream impacts can be significant even when local flooding problems appear to be insignificant. These downstream impacts must be taken into consideration when planning flood control projects and setting flood control policies. The purpose of this drainage study is to provide Placer County with the information and policies necessary to manage the storm waters within the study area. It also includes consideration of required improvements and the associated funding programs to accomplish the improvements. This Flood Control Plan is intended to provide an approach for meeting existing and future flood control needs in the study area. Implementation of the plan will require additional detailed planning, design, and Environmental Impact Review.

WATERSHED DESCRIPTIONS

The Auburn/Bowman area covers approximately 41.5 square miles and is contained in portions of six different drainage basins; Bear River, Orr Creek, Dry Creek (including Rock Creek), Auburn Ravine (including North Ravine), Mormon Ravine, Dutch Ravine and the American River (North

TABLE 1-1

WATERSHEDS IN AUBURN/BOWMAN COMMUNITY

Watershed	Area (Square Miles)
Bear River	2.1
Orr Creek	9.3
Dry Creek	15.5
Rock Creek	4.3
Auburn Ravine	10.8
North Ravine	4.6
Mormon Ravine	1.4
Dutch Ravine	1.0
American River	9.8
Deadman's Canyon	1.0

Fork). Each watershed and the respective areas that are in the study area (or that contribute flows to the study area) are listed in Table 1-1.

A map of the study area and watersheds is presented in Figure 1-1. Over 85% of the study area is drained by the Orr Creek, Dry Creek and Auburn Ravine watersheds whereas the Bear River, American River, Mormon Ravine and Dutch Ravine watersheds together make up less than 15% of the total study area. The Area Map in Figure 1-1 also shows the watershed and subbasin boundaries that were used in developing the model. Rectangles, representing detailed map coverage, are shown on the Index Map, Figure 1-2.

The Orr Creek watershed is located in the northern portion of the study area and drains water from east to west across the study area. A small portion of the watershed (approximately one square mile) is located northeast outside the study area. The Dry Creek watershed is located south of the Orr Creek watershed and also drains water from east to west across the study area. Approximately 1.7 square miles of the Dry Creek watershed is located outside the study area to the north and east. Rock Creek, a major tributary to Dry Creek, drains approximately 4.3 square miles in the southern portion of the watershed. Dry Creek and Orr Creek meet approximately 2000 feet outside the western boundary of the study area to form Coon Creek.

Auburn Ravine is located in the southern portion of the study area with the head waters primarily located within the City of Auburn. The upper portion of Auburn Ravine drains most of Auburn with a flow pattern to the south and west. North Ravine is a primary tributary to Auburn Ravine and drains the eastern portion of the Auburn Ravine watershed that is located in the study area. North Ravine generally drains water from north to south and the confluence with Auburn Ravine is located in the study area approximately one mile from the western boundary.

The very northern portion of the study area is drained by a portion of the Bear River watershed. This area consists primarily of small unnamed tributaries that drain water north directly into the Bear River. The very eastern portion of the study area is drained by the American River watershed. As with the Bear River, this portion of the study area consists primarily of small, short drainage basins which flow directly into the North Fork of the American River. The exception to this is Clipper Creek which drains approximately five square miles outside the study area and then drains into the North Fork within the study Area boundaries.

Headwaters of Mormon Ravine and Dutch Ravine watersheds are located in the very southern portion of the study area. The general drainage pattern is to the south for Mormon Ravine and to the west for Dutch Ravine. In addition, the headwaters for Deadman's Canyon are also located within the western portion of the study area adjacent to the Dry Creek and Auburn Ravine watersheds. Deadman's Canyon flows into Coon Creek approximately two miles outside the study area boundary.

Topography

The entire study area is located in the foothills of the Sierra Nevada Mountains and the watersheds in the study area are characterized by relatively steep slopes and moderate relief. Elevations in the study area range from approximately 800 feet (msl) in the southern portion of the study area to over 2000 feet (msl) in upper Dry Creek and Orr Creek watersheds. Overall, most of the study area has elevations ranging from 1000 to 1500 feet (msl).

Soils

Soils in the study area have been given hydrologic classifications by the Soil Conservation Service (SCS) in the Placer County Soil Survey (1978). These classifications divide the soils based on infiltration rates and runoff potential and are:

- Group A - Low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well- to excessively-drained sands or gravels.
- Group B - Moderately low runoff potential. Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well-drained soils with fine to moderately coarse textures. These soils have a moderate rate of water transmission.
- Group C - Moderately high runoff potential. Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
- Group D - High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

The soils within the study area are predominantly Group D - high runoff potential. Only in the northeastern portion of the study area do any significant amounts of Group B or Group C type soils occur. Figures 1-3A to 1-3C are maps showing the distribution of the various hydrologic soil types occurring throughout the study area.

Land Use

The types of land use that occur in a watershed are significant in determining the amount of runoff that results from a given amount of rainfall. Much of the difference in runoff from different land uses can be attributed to the difference in the percentage of the land that is impervious (paved or covered by buildings) for each land use type. Another important factor that is determined by the type of land use is the condition, or hydraulic efficiency, of the smaller tributaries and streams in an area. For example, an area that is mostly rural residential will have streams that are largely in their natural state, with relatively inefficient hydraulic properties. This results in a slower and less intense concentration of runoff from the area. In comparison, the small tributary streams in a commercial area will most likely be improved. This improvement in the efficiency of the hydraulic properties causes the runoff in those tributary streams to reach the main streams and combine together more quickly, producing a faster and more intense concentration of runoff from the area.

Existing land use maps were obtained from the Placer County Planning Department which had performed a field survey of the land use of the entire study area (including Auburn) in 1990. The land use in the study area varies widely, from agricultural, to residential, to commercial. Most of the commercial land use is located in the City of Auburn and along the Highway 49 corridor south of Dry Creek. The areas outside of the city limits and the Highway 49 corridor are predominantly rural, agriculture and open space. Table 1-2 contains a listing of the land use categories used in this study.

Placer County has developed several alternative land use plans for the Auburn/Bowman Community (excluding the City of Auburn) - one of which will be incorporated in the final General Plan. The alternatives range from very limited development of the study area to much more extensive development of the area. For the purpose of this study, Alternative 2 (an intermediate plan) was utilized in the analysis of future land use conditions. This plan calls for continued commercial development along the Highway 49 corridor along with the conversion of much of the agriculture and open space land to rural estates and rural residential areas.

Figures 1-4A to 1-4C present the land use maps for Future conditions in the study area.

Canals and Reservoirs

An extensive network of canals and reservoirs are located in study area. The canals are owned and operated by three different agencies; Placer County Water Agency (PCWA), Nevada Irrigation District (NID) and Pacific Gas and Electric Company (PG&E). The source of water for most of the canals is the Bear River and Lake Combie to the north. In general, most canals transport the water from north to south through the study area with many side diversions and spills located within the study area.. Some of the canals are used solely for water supply purposes

TABLE 1-2

GENERALIZED LAND USE CODES

Code	Description	Definition
COMM	Commercial, Professional, Industrial, Highways	Self explanatory
HDR	High Density Residential	4-10 Dwelling Units/Acre
MDR	Medium Density Residential	2-4 Dwelling Units/Acre
LDR	Low Density Residential	0.4-0.9 Acre Minimum
RLDR	Rural Low Density Residential	0.9-2.3 Acre Minimum
RR	Rural Residential	2.3-5 Acre Minimum
RE	Rural Estates	5-20 Acre Minimum
OS	Open Space (undeveloped)	Self explanatory

(municipal and agricultural) whereas others are also used for power generation. There are also five reservoirs in the study area ranging in surface area from less than three acres to over fifty acres. Most of these reservoirs are used primarily for storing and diverting water to canals. A listing of all canals and reservoirs are presented in Tables 1-3 and 1-4. Figures 1-5a to 1-5c are maps indicating canal systems and spill locations.

Nevada Irrigation District maintains canals in the northwestern portion of the study area. The primary canals operated by NID are the Combie-Ophir, Lone Star, and Gold Hill Canals. Smaller canals include the Pickett, Rock Creek, Columbia, and Bean Cullers Canals. These canals are all used exclusively for water supply (agriculture and domestic) and are not encased except for short portions of: the Combie-Ophir Canal (approximately 900 feet in the vicinity of Bell Road); Rock Creek Canal (1,100 feet); Columbia Canal (3,800 feet); and Bean Cullers Canal (700 feet). In addition NID operates a small reservoir on Orr Creek located approximately one mile upstream of the confluence of Orr Creek and Dry Creek. Nevada Irrigation District releases water from Combie-Ophir Canal to a tributary of Orr Creek in the very northern area of the study area and this water is later diverted to Gold Hill Canal via the small reservoir on Orr Creek.

Placer County Water Agency operates and maintains canals primarily in the eastern portion of the study area. These canals include the Boardman, Fiddler Green, Bowman, Shirland, and Freeman Canals. Boardman Canal extends from the northeastern portion of the study area across to the southwestern corner and is the primary canal operated by PCWA in the study area. As with the NID canals, these canals are operated solely for water supply purposes, and only small portions of these canals have been encased. PCWA also operates two small reservoirs, Lake Arthur and Lake Theodore, that are used to supply water to their canal system in the event of an interruption in supply.

Pacific Gas and Electric Company operates and maintains canals in the study area primarily for the purpose of water supply and power generation. The primary canal maintained by PG&E in the study area for power generation is the Wise Canal which carries water from north to south through the study area. The Wise Canal is the largest canal in the study area (capacity over 500 cfs) and is not encased except in short segments where the water is diverted into penstocks. The following is a brief description of the source and operation of the Wise Canal and associated reservoirs located in the study area:

The Bear River Canal releases water to Halsey Forebay located in the northeastern portion of the study area. This water is the released via a penstock to Halsey Powerhouse and Halsey Afterbay (located on upper Dry Creek). The water is then diverted from the Afterbay to Wise Canal. This segment of the canal transports the water from upper Dry Creek watershed to Rock Creek watershed and is released into Rock Creek Lake (owned by PG&E). Water is then diverted from Rock Creek Lake into a lower section of Wise Canal passing into the Auburn Ravine watershed, and ending up in the Wise Forebay. At the Wise Forebay the canal water enters into a penstock and is carried to Wise Powerhouse located along the Auburn Ravine. From here canal water is released both to Auburn Ravine and South Canal.

TABLE 1-3
CANALS IN AUBURN/BOWMAN COMMUNITY

PG&E CANALS
Upper Bowman
Wise
Middle Fiddler Green
Lower Fiddler Green, lower 1/2
South Canal
PCWA CANALS
Shockley
Lower Bowman
Boardman
Fiddler Green Boardman Diversion
Shirland and Shirland Stub
Upper Banvard
Lower Fiddler Green, upper 1/2
Freeman
NID CANALS
Combie-Ophir
Lone Star
Gold Hill
Pickett
Kemper (East and West)
Willits
Oest
Rock Creek
Columbia (East, West)
Bean Cullers

TABLE 1-4
RESERVOIRS IN AUBURN/BOWMAN COMMUNITY

Reservoir	Agency	Surface Area (Acres)
Orr Creek	NID	2.8
Dry Creek	Private	11.5
Halsey Forebay	PG&E	15.1
Halsey Afterbay	PG&E	7.3
Rock Creek	PG&E	54.2
Wise Forebay	PG&E	4.1
McCrary	PCWA	0.9

The Wise Canal differs from other smaller water supply canals in the study area in that the Wise Canal has no spill points except for those into reservoirs. An emergency spill for the canal is located at the Wise Forebay and would spill to a small tributary of the North Ravine. However, this is designed to be used only in the event of penstock failure and has not been used to date.

INVENTORY OF STREAM CROSSINGS

Many of the problems that occur as a result of flooding are related to inadequate conveyance structures (culverts or bridges) at stream crossings. Table 1-5 lists all the stream crossings in the watershed that were examined as part of this study. Also included in Table 1-5 are other major points of interest in the watershed. The crossing number can be used to locate the stream crossing on Figures 1-6A to 1-6C.

RELEVANT PREVIOUS STUDIES

The following is a list of relevant previous studies:

- Dairy Road Watershed Master Plan (Draft), CH2M HILL, August 1991.
- Flood Insurance Study, Placer County - Unincorporated Areas CA, Placer County, CA. FEMA, Revised January 1987.

TABLE 1-5
LIST OF STREAM CROSSINGS AND MAJOR POINTS OF INTEREST

CROSSING NUMBER	STREAM	CROSSING
1	ORR CREEK	INFLOW TO COON CR.
2		BELL RD.
3		TRIB. CONFLUENCE
4		TRIB. CONFLUENCE
5		HWY 49 (State)
6		TRIB. CONFLUENCE
7		W. STANLEY DR.
8		TRIB. CONFLUENCE
9		E. STANLEY DR.
10		COMBIE-OPHIR SIPHON
11		CHRISTIAN VALLEY RD.
12		TRIB. CONFLUENCE
13		STUDY BOUNDARY
14		TRIB. CONFLUENCE
15	ORR CR TRIB #1	LITTLE CREEK RD. (Private)
16	ORR CR TRIB #2	VIRGINIA WAY
17		KENNETH WY. (Private)
17	ORR CR TRIB #3	LONE STAR RD.
19	DRY CREEK	INFLOW TO COON CR
20		BELL RD.
21		TRIB. CONFLUENCE
22		ROCK CR. CONFLUENCE
23		HWY 49 (State)
24		TRIB. CONFLUENCE
25		BLUE GRASS RD.
26		BELOW DAM
27		INFLOW TO RES.
28		DRY CR. ROAD
29		TWIN PINES TRAIL. (Private)
30		HAINES RD.
31		HALSEY AFTBAY OUTFLOW
32		BOWMAN RD.
33		LAKE ARTHUR RD.
34		LAKE ARTHUR RD.
35		BELOW LAKE ARTHUR
36	DRY CR TRIB #1	DRY CREEK RD.

TABLE 1-5 (continued)

CROSSING NUMBER	STREAM	CROSSING
37	**DRY CR TRIB #2**	DRY CREEK RD.
38	**DRY CR TRIB #3**	BLACK OAK RD.
39	**DRY CR TRIB #4**	DRY CREEK RD
40	**DRY CR TRIB #5**	JOGGER RD.
41	**DRY CR TRIB #6**	HOE RD. (Private)
42		HUBBARD RD. (Private)
43		JOEGER RD.
44	**ROCK CREEK**	INFLOW TO DRY CREEK
45		JOEGER RD.
46		SHERWOOD WY.
47		DRY CREEK RD.
48		RICHARDSON RD.
49		HWY 49 (State)
50		ROCK CREEK RD.
51		ROCK CR LAKE OUTFLOW
52		ROCK CR LAKE INFLOW
53		BELL RD.
54		NEW AIRPORT RD.
55		CRYSTAL SPRINGS RD.
56		TRIB. CONFLUENCE
57		CREEKVIEW CT.
58		RAILROAD
59	**ROCK CR TRIB #1**	RAILROAD
60	**ROCK CR TRIB #2**	NEW AIRPORT RD.
61		BELL RD.
62	**ROCK CR TRIB #3**	LOCALE LN.
63	**ROCK CR TRIB #4**	ROCK CREEK RD.
64		BELL RD.
65	**NORTH RAVINE**	WISE RD.
66		WARREN WY. (Private)
67		CALNICK RD. (Private)
68		BELOW MILLERTOWN RD.
69		TRIB. CONFLUENCE
70		MILLERTOWN RD.

TABLE 1-5 (continued)

CROSSING NUMBER	STREAM	CROSSING
71		MT. VERNON RD.
72		HARRIS RD. (Private)
73		VISTA ROBLE RD. (Private)
74		ATWOOD RD.
75	N. RAV. TRIB #1	KEMPER RD. (Private)
76	N. RAV. TRIB #2	HIDDEN OAKS LN. (Private)
77		RAILROAD
78		HWY 49 (State)
79		PEAR RD. (Private)
80	N. RAV. TRIB #3	MILLERTOWN RD.
81		MT. VERNON RD.
82	N. RAV. TRIB #4	MILLERTOWN RD.
83		BAR RANCH RD. (Private)
84	AUBURN RAVINE	AUBURN RAVINE OUTFLOW
85		N. RAVINE CONFLUENCE
86		WISE RD.
87		OPHIR RD.
88		OPHIR RD.
89		FORGOTTEN RD. (Abandoned)
90	AUBURN R. TRIB	I-80 (State)
91		RAILROAD
92	DUTCH RAVINE	RAILROAD
93		AUBURN-FOLSOM RD.
94	MORMON RAVINE	SHIRLAND RD.
95	MORMON R. TRIB	NO NAME RD
96		ANDREGG RD.
97	AMER. RIVER TRIB #1	HWY 49 (State)
98	AMER. RIVER TRIB #2	HWY 49 (State)
99	DEADMAN CANYON	JOEGER RD.
100		OAK CREEK CT.

SECTION 2
HYDROLOGIC ANALYSIS

The hydrologic analysis for the Auburn/Bowman Drainage Study is based on parameters and techniques specified in the Placer County Flood Control and Water Conservation District "Stormwater Management Manual." The purpose of the hydrologic analysis portion of this study is to determine how the watershed reacts to various levels of precipitation. This is accomplished through the use of a computer model that mathematically represents the physical processes of rainfall and the resulting runoff.

DESCRIPTION OF MODELS

A major portion of this study entailed the development and calibration of the hydrologic model HEC-1 of the watersheds in the study area. This model simulates the runoff in the watersheds in response to precipitation and is a tool that is used to predict the amounts and timing of runoff from a wide variety of simulated rainfall events.

A hydraulic model (HEC-2) was also developed to model the hydraulics of streams with 10-year flows exceeding 200 cfs. This hydraulic model aided in the determination of the water surface elevations associated with various streamflows within the stream channels as well as at hydraulic structures such as bridges and culverts.

HEC-1 Model

The HEC-1 model is designed to simulate the surface runoff response of a watershed to precipitation. This is accomplished by representing the watershed as an interconnected system of hydrologic and hydraulic components. Each model component represents a specific aspect of the rainfall-runoff processes occurring in a portion of the watershed. A component may represent the runoff occurring in a subbasin, the routing of flows down a stream channel, or the routing of flows through a reservoir. Description of the components of a model requires estimation of a set of parameters that describes the hydrologic and hydraulic characteristics of the components. Parameters describing the various components of the model are based on land use, soils, vegetation, and topography. For example, the land use in a subbasin will determine the percent of that subbasin that is impervious and the average condition of the drainage channels. The end result of the modeling process is the computation of streamflow hydrographs (including peak flows) at specified locations throughout the watershed.

HEC-2 Model

The HEC-2 hydraulics model was developed for stream reaches with 10-year flows exceeding 200 cfs. These stream reaches are designated as natural streams and are to remain in their natural conditions as much as possible. Figure 2-1 shows the stream reaches in the Auburn/Bowman Community Plan area in which the 10-year flows exceed 200 cfs. As apart of this study, a field survey was performed for the natural stream reaches in which stream cross sections and elevations were surveyed at 1000 foot intervals for the 24 miles of designated natural streams in the study area. These stream reaches included portions of Orr Creek, Rock Creek, Dry Creek and North Ravine.

The HEC-2 model is used to compute the water surface profiles of one-dimensional, steady, gradually varied flow in streams. The program uses and solves energy and energy loss equations between adjacent flow cross sections. Output from HEC-2 is in the form of steady-state water surface profiles for the modeled stream reaches. It is also possible to obtain the storage in a reach based on a given flow rate. This capability of HEC-2 was used, where possible, to develop Modified Puls routing parameters for use in HEC-1 routing.

HEC-1 Model Development

This section of the report describes the assumptions and criteria that were used in developing the HEC-1 model of the watersheds in the Auburn/Bowman Community.

Model Overview

Whenever the use of a model is considered, or when the results of a model are interpreted, it is very important to understand the limitations that apply to the use of the model. Probably the most crucial limitation is that any model can only approximate the real world hydrologic and hydraulic processes. The HEC-1 model uses a number of simple mathematical and empirical methods to represent the complex physical processes that produce runoff from precipitation and route that runoff through a watershed. Although these methods are among the best currently available, they are still only mathematical or empirical simplifications of complex physical processes.

One of the important goals of the modeling effort for the study area was to set up the model using standard, accepted, consistent, and logical rules that could be applied to all areas in the in the study area with consistent and reliable results. This took the form of a spreadsheet database containing all of the parameters describing each subbasin and routing reach. The parameters were combined with formulas in the spreadsheet to develop the input data needed for the HEC-1 model. For example, subbasin 'n' values, lengths, and slopes are combined in the spreadsheet to produce T_p, the basin lag time for the Snyder unit hydrograph method. Subbasin infiltration coefficients and percent impervious are obtained in a similar manner.

By its very nature, the HEC-1 model does not give a complete and detailed representation of any of the subbasins or of the watersheds as a whole. Drainage subbasins used in the HEC-1 computer model of the study area cover more than 64 acres as a minimum, with the average size of a subbasin being 300 acres or slightly less than half of a square mile. Using subbasins of this size requires simplifying the representation of the subbasin. All of the methods used to simplify the subbasin representation revolve around that basic assumption that the subbasin is homogeneous, or if it is not, that the subbasin parameters can be averaged to model the subbasin as if it were homogeneous.

Because of the large number of subbasins involved, it is not possible to assure that every subbasin is represented in the highest level of detail. There may be features in any watershed that, upon more detailed investigation, may be found to affect streamflows. However, on the average, it is expected that the streamflows obtained from the model will be accurate for the watershed as a whole.

It was necessary to obtain peak flow results at many locations that were not represented explicitly in the model. Peak flow estimates from locations specified in the model were used to interpolate peak flows at other locations of interest, such as areas where historic flooding has occurred or a location where a stream crosses a road. This interpolation had to take into account not only the peak flow produced by a particular subbasin or group of subbasins, but also the routing of the flow to the location in question and the timing of the peaks of the subbasin runoff and the routed runoff.

Model Assumptions and Criteria

This section of the report details the assumptions and criteria that were used in developing and calibrating the HEC-1 model of the watersheds in the study area. Many of the assumptions were made in order to provide consistency and ease of use of the model as described above.

Unit Hydrograph Parameters. As suggested in the Stormwater Management Manual, the Snyder unit hydrograph method was chosen to represent the rainfall/runoff process occurring in each basin. This method requires two input parameters, standard lag (T_p) in hours and a peaking coefficient (C_p). Standard lag, or lag time, is described as the time that the rise in runoff lags the rainfall causing the rise.

The equation used to compute the T_p was taken from the USBR's "Flood Hydrology Manual" (1989) and is given below.

$$T_p = 26 * n\left(\frac{LL_c}{S^{0.5}}\right)^{0.33}$$

where
- Tp = lag time in hours
- L = length of the longest watercourse in the subbasin, in miles
- Lc = length along the longest watercourse from the point of concentration to a point opposite the centroid of the subbasin, in miles
- S = overall slope of the channel in ft/mile
- n = a physical parameter related to the hydraulic roughness characteristics of the watershed

Loss Rates. Loss rates represent the infiltration of rainfall into the ground. The initial and uniform loss rate option in HEC-1 (LU card) was used to describe the loss rates in the study area. In order to account for the variability of the soil and land use characteristics at the various subbasins, a weighted infiltration coefficient was developed for each subbasin. Table 5-4 in the Placer County Stormwater Management Manual defines soil loss rates for each soil group and vegetative cover. For the purposes of estimating soil loss rates for this study, the vegetative cover in developed areas was assumed to be urban landscaping, and the cover in undeveloped areas was assumed to be annual grasses. The weighting formula for determining subbasin loss rate is given below.

$$\frac{1}{A}\sum_{i=1\rightarrow A}\left[(A_i)_{dev}*(L_i)_{ls}+(A_i)_{und}*(L_i)_{ag}\right]$$

where

Ai = Area in i-type soil group within the subbasin
Li = Loss rate in inches/hr for i-type soil group
dev = developed areas
und = undeveloped areas
ls = landscaped cover
ag = annual grass cover

The constant (uniform) loss rate for each subbasin was not changed for each of the design storm events under study because it represents the loss rate of saturated soil. However, the initial loss rates were changed for each of the design storms as shown below:

Design Storm Return Period	**Initial Loss (inches)**
2-year	0.40
10-year	0.20
25-year	0.15
100-year	0.10

Initial losses for the 100-year design storm were determined from the model calibration to the February 1986 flood event. Initial losses for the 2-year, 10-year, and 25-year were obtained from work previously completed in the Dry Creek watershed in Placer and Sacramento Counties (Draft Dry Creek Watershed Flood Control Plan, 1991).

Initial Conditions. Initial conditions describe the streamflows at the beginning of the storm that is being modeled. If the storm is an historical one, initial conditions can be determined from stream gage records, if they are available. The HEC-1 model uses the Base Flow variable (BF card) to quantify the streamflow at the beginning of the simulation. This parameter is intended to describe the flows that can be attributed to groundwater recession flows. The definition attributed to the BF variable in HEC-1 was changed for the Auburn/Bowman model to describe the streamflow at the beginning of the simulation, independent of the source. This change in definition and use of the BF variable allows the model to simulate antecedent conditions that can play a major role in the overall streamflow and potential flooding in a watershed. The values of the BF variable, in cfs flow per square mile, for the various design storms were obtained from the

Dry Creek Watershed Flood Control Plan and are presented below. The recession coefficient controls the rate at which the base flow decreases during the simulation, and is defined as the ratio of the base flow occurring at the present time to the base flow that will occur in one hour. The recession coefficient is set to 1.05 for all watersheds.

Design Storm Return Period	BF - Initial Conditions (cfs/sq.mi.)
2-year	2.0
10-year	5.0
25-year	6.0
100-year	23.0

Precipitation. Design storm precipitation for the HEC-1 model of the Auburn/Bowman study area was derived from tables given in the Placer County Stormwater Management Manual. Depth-Duration-Frequency data was used to construct synthetic design storms of 6-hour duration (with five-minute time steps) for cloudburst events. Precipitation was adjusted for average basin elevation for each duration and the average subbasin elevations were classified into three categories for this purpose: 500 - 1000 feet, 1000 - 1500 feet and 1500 - 2000 feet mean sea level. Cloudburst storm centering resulted in additional adjustments to the 1-hour maximum intensity values depending on the location of the storm template isohyets. As an example, Figure 2-2 is a map of the Orr Creek watershed with the 100-year cloudburst template superimposed. Maximum runoff from each individual subbasin was developed using a storm centered over that subbasin, but different storm centers were used to develop the maximum runoff at each combination point in the study area. Table 2-1 indicates the location (subbasin) and inclination of the storm center used to determine 100-year flows at each of the combination points in the study area. Table 2-2 lists the location and names of each of the combination points used in the models.

The use of cloudburst storm data requires that the cloudburst be centered over different locations in the watershed depending on the point at which the peak flow is wanted. From previous studies in Placer and Sacramento Counties, it was determined that the highest flows for any given point in a watershed occur when the cloudburst is centered slightly downstream of the centroid of the area upstream of the point of interest. For this study, storm centering was developed for the 2-, 10-, 25-, and 100-year storms at each of the 100 stream crossings and points of interest. However, it should be noted that in many cases the same storm centering was used for different crossing points when they are in close proximity to each other.

Routing. One of the most critical components in the development of the HEC-1 model is the specification of routing of flows from one subbasin to another. For this study, the Modified Puls, Muskingum-Cunge and Muskingum routing techniques were utilized. The HEC-2 backwater computer program allowed the use of the Modified Puls storage routing in reaches covered by

TABLE 2-1
100-YEAR STORM CENTER LOCATIONS

COMBINATION POINT	LOCATION (subbasin)	INCLINATION (degrees)
OCC1	OC2	60
OCC2	OC15	60
OCC4	OC2	60
OCC5	OC20	60
OCC6	OC10	60
OCC9	OC10	60
OCC11	OC62	60
OCC13	OC25	60
OCC16	OC30	60
OCC19	OC62	60
OCC20	OC62	60
DCC1	DC5	60
DCC3	DC15	60
DCC4	DC10	60
DCC6	DC15	60
DCC9	DC15	60
DCC10	DC35	60
DCC11	DC35	60
DCC13	DC35	60
DCC14	DC55	60
DCC15	DC55	60
DCC16	DC45	60
DCC19	DC60	60
DCC20	DC60	60
RCC1	RC5	60
RCC3	RC10	60
RCC4	RC20	60
RCC7	RC20	60
RCC8	RC25	60
RCC9	RC25	60
RCC10	RC40	60
CCC1	DC65	60
ARC1	AR10	0
ARC3	AR10	10
ARC4	AR10	10
ARC5	AR10	10
ARC6	AR35	10
ARC8	AR50	10
ARC10	AR45	0
ARC12	AR40	10
ARC13	AR45	10
ARC14	AR45	10
ARC15	AR70	10
ARC16	AR70	10

TABLE 2-2
HEC-1 COMBINATION POINTS

COMBINATION POINT		COMBINATION POINT	
NAME	LOCATION	NAME	LOCATION
ORR CREEK		**ROCK CREEK**	
OCC1	OC2,OC15	RCC1	RC5,RC10
OCC2	OC5	RCC2	RC15
OCC3	OC10	RCC3	RC15,RC20
OCC4	OC10,OC20	RCC4	RC25
OCC5	OC25	RCC5	RC30
OCC6	OC30	RCC6	RC40
OCC7	OC35	RCC7	RC30,RC40
OCC8	OC45	RCC8	RC45
OCC9	OC35,OC40	RCC9	RC50
OCC10	OC50	RCC10	RC55
OCC11	OC55	**CLIPPER CREEK**	
OCC12	OC60	CLC1	CL10
OCC13	OC50,OC60	CLC2	AM5
OCC14	OC65	**DEADMAN CANYON**	
OCC15	OC75	DMC1	DM10
OCC16	OC65,OC75	**AUBURN RAVINE**	
OCC17	OC80	ARC1	AR10
OCC18	OC90	ARC2	AR15
OCC19	OC80,OC90	ARC3	AR15,AR20
OCC20	OC95	ARC4	AR25
CCC1	OC95,DC105	ARC5	AR30
DRY CREEK		ARC6	AR40
DCC1	DC10	ARC7	AR45
DCC2	DC20	ARC8	AR50,AR55
DCC3	DC15,DC20	ARC9	AR60
DCC4	DC25	ARC10	AR45,AR60,AR62
DCC5	DC30	ARC11	AR65
DCC5A	DC40	ARC12	AR65,AR70
DCC6	DC30,DC35,DC40	ARC13	AR75
DCC7	DC45	ARC14	AR80
DCC8	DC55	ARC15	AR30,AR80
DCC9	DC45,DC55	ARC16	AR85
DCC10	DC60	**MORMON RAVINE**	
DCC11	DC65	MRC1	MR10
DCC12	DC70	MRC2	
DCC13	DC70,DC75	MRC3	MR20
DCC14	DC80	MRC4	MR25
DCC15	DC85	MRC5	
DCC16	DC85,RC55		
DCC17	DC90		
DCC18	DC100		
DCC19	DC90,DC100		
DCC20	DC105		

these models. The Modified Puls routing is a more accurate routing technique in that it takes into account the in-channel and overbank storage available in a reach. In addition, routing through the various reservoirs in the study area was also modeled with the Modified Puls method by developing storage-outflow rating curves for each reservoir. These curves were developed based on spillway design and depth-volume-area relationships for each reservoir.

The Muskingum-Cunge routing technique was utilized in areas in stream reaches not modeled by the HEC-2 models. This included the upper reaches of Orr Creek, Dry Creek, Rock Creek, and North Ravine as well as all of the tributaries to these streams. In addition Muskingum-Cunge routing was used for all stream reaches in the Bear River, American River, Mormon Ravine, Dutch Ravine and Deadman Canyon watersheds. For this routing method, the HEC-1 model requires the following input data: channel length, channel slope, roughness (Manning's 'n') and cross-section. Channel length and slopes were obtained from USGS 1:24,000 scale topographic maps and channel cross-sections were obtained from field surveys that were performed as part of this study. In stream reaches where surveys were not done, cross-sections from other streams with similar drainage areas and slopes were utilized. A Manning's 'n' value of 0.15 was used for the main stream channels and a value of 0.07 was used for the overbanks. The higher value in the main channel was used to take into account the blackberries and other vegetation that occurs in most of the stream channels.

As mentioned in Section 1, the City of Auburn did not participate in this study. However, flows from this area contribute to a section of Auburn Ravine which is located in the study area. CH2M-Hill had previously developed a HEC-1 model of western Placer County which included these sections of Auburn Ravine. Hence, the portion of the CH2M Hill model that covers the city limits was incorporated into the model which includes the Muskingum routing technique. In addition, since Auburn Ravine was not surveyed as part of this study, the Muskingum routing used in the CH2M Hill model for Auburn Ravine located in the study area was also incorporated into the model.

Subbasin Descriptions

The study area was subdivided into 105 subbasins to provide the necessary detail for the purpose of this study. This subdivision is made on the basis of hydrologic characteristics of the watershed with the goal of providing HEC-1 model output at stream junctions, major bridges and crossings, problem areas, and downstream boundaries. Subbasin hydrologic divisions were based on topography from the USGS 1:24,000 scale topographic maps. The subbasin areas range from 0.10 square miles (64 acres) to over two square miles (1300 acres). Figure 2-2 shows all the study subbasins in the study area. Table 2-5 presents most of the pertinent data and parameters for each subbasin in the watershed for the Base Conditions. The method of obtaining the data and parameters is described in the following sections.

Unit Hydrograph Parameters. Each subbasin in the watershed was described hydrologically using the parameters listed in the following paragraphs.

Basin Area. The subbasin areas for input into the model were taken from digitized USGS 1:24,000 scale topographic maps using Intergraph computer software.

Lengths. The lengths along the longest watercourse and along the main channel within each subbasin were measured using a map wheel on the same maps used for basin area determination. The centroid of each subbasin was estimated based on subbasin shape.

Slopes. The slope of the subbasin and of the main channel in the subbasin are dependent on the lengths of both the longest watercourse and of the main channel, as described above, and the elevation of the upstream and downstream ends of the longest watercourse and the main channel. The elevations at the upstream and downstream end of the main channel and the longest watercourse in each subbasin were read off the USGS topographic maps.

Loss Rates. Soil maps from the Soil Conservation Service (SCS) were used to determine the hydrologic soil types in the watershed. A list of most of the soils in the United States with the hydrologic soil group classification for each soil is provided in the SCS manual TR-55. This list was used to color code the SCS soil maps covering the Dry Creek watershed by hydrologic soil type. Subbasin outlines were placed over the soil maps and the approximate percentage of each soil group in each subbasin was determined and entered into the spreadsheet. Loss rates for each soil group, based on the soil infiltration rate and the assumed ground cover for each land use in the subbasin, is calculated as described previously. A weighted loss rate for each of the subbasins is calculated in the spreadsheet and put into the model. The loss rates used for the urban landscaping assumed for the developed areas are 0.48, 0.25, 0.16, and 0.12 inches per hour for soil types A, B, C, and D respectively. The corresponding loss rates used for annual grasses in undeveloped areas are 0.31, 0.16, 0.09, and 0.07.

Effective Impervious Area. The effective impervious area for a subbasin is defined as the percent of the area that is impervious and which does not drain across a neighboring pervious area. The effective impervious area for each subbasin is based on averages for a given land use description, and was determined by estimating the percent of the subbasin contained in each type of land use discussed in Section 1. Current land use was estimated from land use maps provided by Placer County Planning Department with overlays of the subbasin boundaries. Future land use was determined from the general plan maps. In order to go from land use to effective impervious area, an imperviousness factor had to be assumed for each land use as shown in Table 2-3.

Basin 'n'. Basin 'n' values for the subbasins range from a low of around 0.018, in subbasins with a high percentage of commercial development and well developed channels, to a high of around 0.130 in subbasins with very low density development and/or open space combined with dense vegetation in the channels and floodplains. The 'n' values for the study subbasins were determined using Table 2-3. In this table, the subbasin 'n' value is chosen by selecting the row in the table that has land use matching the subbasin weighted land use. This weighted land use was determined in the spreadsheet by weighting the effective impervious area for each of the land use types in the basin and then using that effective impervious area to determine which line of Table 2-3 to use. The subbasin 'n' is then selected from one of four columns of 'n' values based on the condition of the channels and floodplains in the subbasin. Determination of the channel/floodplain type was based on examination of normal aerial photography and actual visits to the watershed.

TABLE 2-3
SUBBASIN 'N', C_p, AND EFFECTIVE IMPERVIOUS

Basin 'n' by Type Channel/Floodplain Description							
1 Pipe/ Conc.	2 Grass/ Earth	3 Open Woods	4 Dense Veg.	Snyder C_p	Basin Land Use	Effective Impervious Low	Effective Impervious High
0.015	0.023	0.032	0.040	0.85	Commercial/Highways/Parking Lots	0.80	0.99
0.016	0.024	0.033	0.042	0.80	Apartments/Offices/Mobile Homes	0.70	0.90
0.018	0.026	0.035	0.044	0.75	Condominiums/Schools/Industrial	0.50	0.70
0.020	0.028	0.037	0.046	0.70	Residential 8-10 Houses per Acre	0.45	0.60
0.022	0.030	0.039	0.048	0.65	Residential 6-8 Houses per Acre	0.35	0.50
0.024	0.032	0.041	0.050	0.60	Residential 4-6 Houses per Acre	0.30	0.40
0.026	0.034	0.044	0.055	0.60	Residential 3-4 Houses per Acre	0.20	0.30
0.028	0.037	0.048	0.060	0.60	Residential 2-3 Houses per Acre	0.15	0.25
0.030	0.040	0.052	0.065	0.60	Residential 1-2 Houses per Acre	0.10	0.20
0.032	0.045	0.058	0.075	0.60	Residential 1-2 Acres per House	0.07	0.15
0.035	0.050	0.070	0.090	0.60	Residential 2-5 Acres per House	0.05	0.10
0.040	0.060	0.090	0.120	0.60	Rural Residential/Rural Estates	0.02	0.05
0.050	0.080	0.110	0.150	0.60	Open Space (undeveloped)	0.01	0.02

Notes:

1. Low effective impervious is appropriate for 2-year and less recurrence interval events. High effective impervious is appropriate for 10-year and greater recurrence interval events.
2. If suitable land use description cannot be found in table, basin 'n' is a weighted average, by length of a typical flow path, using Manning's 'n' for expected depths for overland flow, gutters, storm drains, channels, and floodplains.
3. System constraints due to undersized inlets and storm drains cause temporary flooding in streets and will increase basin lag time and should be taken into account when determining basin 'n'.

Canals. As discussed in Section 1, the majority of the canals within the study area are not encased and hence, the canals have the capabilities of intercepting sheet runoff from areas directly upstream of the canals. In addition during storm events, the canals also have the potential to spill excess water into streams at various spill locations located along the canals. Therefore, it may be possible for a canal to intercept storm runoff in one watershed and transport the water to another watershed where it may be spilled to a stream.

All canals with capacities greater than 10 cfs were incorporated in the HEC-1 model by utilizing the diversion options in the model. In effect, the canals were simulated by diverting water from subbasins where canals cross through and then adding the diversion to the subbasins where the spills are located.

The following assumptions were made in the development of canals into the HEC-1 model:

- The canals were assumed to be at design capacity at the start of the storm event.
- The maximum canal capacity is 25% above the design capacity.
- Canals can only intercept the difference between maximum capacity and design capacity
- Canals spill at spill locations with maximum spill no greater than the difference between maximum capacity and design capacity
- Amount of flow intercepted by a canal in any given subbasin is proportional to the area of the subbasin upstream of the canal.

Data on canal locations and capacities as well as spill locations and capacities were obtained from PG&E, PCWA and NID. Table 2-4 lists the canals that were incorporated into the model along with the associated canal capacities and subbasins where diversions and spills take place. In addition, spill locations are also presented in the map of canal systems in the study area (Figures 1-5a to 1-5c).

Calibration of Model

Calibration of a model is the process used to insure that the model predicts actual system behavior as closely as possible. In model calibration, known input data for a historical event is entered into the model and the output from the model is compared with the known flood conditions. Parameters in the model are then adjusted until the model output matches historic data for the event.

The HEC-1 model of the Auburn/Bowman Community Plan area was calibrated to observed flows and high water marks for flood events occurring in February 1986. Peak flows in the February 18-19, 1986 event had recurrence intervals for most of the study area of approximately 100 years.

The precipitation used for calibration of the HEC-1 model was based on actual rain gage data collected during the calibration event (February 1986 storm). The precipitation station used for calibration of the HEC-1 model is located in Auburn, however, in order to take into account elevation effects, subbasins in higher elevations than Auburn were given a 10-20% higher total rainfall.

TABLE 2-4
CANALS INCORPORATED INTO HEC-1 MODEL

CANAL	CANAL NORMAL CAPACITY* (CFS)	CANAL MAXIMUM CAPACITY** (CFS)	MAXIMUM SUBBASIN DIVERSION*** (CFS)	SUBBASIN	NO. OF SPILL LOCATIONS	DIVERSIONS: % SUBBASIN DIVERTED TO CANAL	DIVERSIONS: DIVERSION NAME	ADDITIONS: DIVERSIONS ADDED TO SUBBASIN	ADDITIONS: ADDED DIVERSION NAME
LONE STAR	20	25	5	BR30	0	15	LNE1	---	
	20	25	5	BR25	2	5	LNE2		
	20	25	5	OC75	0	10	LNE3	---	
	20	25	5	OC70	2	0	LNE4	OC75	LNE1
									LNE2
									LNE3
	20	25	5	OC75	0	5	LNE5	---	
	20	25	5	OC80	2	<5	---	OC75	LNE5
	20	25	5	OC90	0	10	LNE6	---	
	20	25	5	OC85	0	5	LNE7	---	
GOLD HILL	20	25	5	OC55	0	0	---	---	
	20	25	5	OC60	0	0	---	---	
	20	25	5	OC65	0	0	---	---	
	20	25	5	OC80	0	5	GLD1	---	
	20	25	5	OC95	0	<5	---	---	
	20	25	5	DC105	1	5	GLD2	OC95	GLD1
	20	25	5	DC90	0	40	GLD3	---	
	20	25	5	DC100	4	10	GLD4	DC105	GLD2
							---	DC90	GLD3
	20	25	5	DC105	0	10	GLD5	---	
COMBIE - OPHIR	40	50	10	BR30	1	0	---	---	
	40	50	10	OC55	0	35	CMB1	---	
	40	50	10	OC62	2	0	---	OC55	CMB1
	40	50	10	OC35	0	0	---	---	
	40	50	10	OC45	0	15	CMB2	---	
	40	50	10	OC40	1	0	---	OC45	CMB2
	40	50	10	DC65	1	0	---	---	
	40	50	10	DC70	0	7	CMB3	---	
	40	50	10	DC80	0	7	CMB4	---	
	40	50	10	RC45	0	0	---	---	
	40	50	10	DC95	0	<5	---	---	
	40	50	10	AR50	0	<5	---	---	
	40	50	10	DM5	1	<5	---	DC70	CMB3
								DC80	CMB4
	40	50	10	AR50a	1	<5	---	---	
	40	50	10	AR62	1	<5	---	---	
	40	50	10	AR65	1	<5	---	---	
WISE CANAL	510	638	128	DC30	0	40	WIS1	---	
	510	638	128	DC40	0	10	WIS2	---	
	510	638	128	DC45	0	40	WIS3	---	
	510	638	128	RC25	0	---	---	---	
	510	638	128	RC20	0	---	---	---	
	510	638	128	RC25	0	---	---	DC30	WIS1
								DC40	WIS2
								DC45	WIS3
	510	638		RC35			WIS4		
	510	638		AR35			WIS5		
	510	638		AR40			WIS6		
	510	638		AR70			WIS7		

* From data provided by operating agencies
** Assumed to be 25% greater than normal capacity
*** 25% of normal capacity

TABLE 2-4 (continued)

CANAL	CANAL NORMAL CAPACITY* (CFS)	CANAL MAXIMUM CAPACITY** (CFS)	MAXIMUM SUBBASIN DIVERSION*** (CFS)	SUBBASIN	NO. OF SPILL LOCATIONS	DIVERSIONS		ADDITIONS	
						% SUBBASIN DIVERTED TO CANAL	DIVERSION NAME	DIVERSIONS ADDED TO SUBBASIN	ADDED DIVERSION NAME
FIDDLER GREEN	40	50	10	RC25	0	5	FG1	---	
	40	50	10	RC40	0	<5	---	---	
	40	50	10	RC35	0	10	FG2	---	
	40	50	10	AR35	2	15	FG3	RC25	FG1
								RC35	FG2
	40	50	10	AR40	0	10	FG4	---	
	40	50	10	AR70	1	5	FG5	AR35	FG3
								AR40	FG4
	40	50	10	AR15	0	<5	---	---	
	40	50	10	AR80	0	<5	---	---	
	40	50	10	AR15	0	5	FG6	---	
	40	50	10	AR25	0	0	---	---	
	40	50	10	AR30	0	35	FG7	---	
	40	50	10	AR85	0	<5	---	---	
	40	50	10	DR10	0	<5	---	---	
BOWMAN	6	8	2	DC10	1	7	BOW1	---	
	6	8	2	DC15	1	8	BOW2	DC10	BOW1
	15	19	4	OC15	0	8	BOW3	---	
	15	19	4	DC35	0	8	BOW4	---	
	15	19	4	DC25	1	0	---	DC15	BOW2
								OC15	BOW3
								DC35	BOW4
SHIRLAND	10	13	3	AM45	1	0	---	---	
	10	13	3	AM50	0	50	SHR1	---	
	10	13	3	AM55	0	25	SHR2	---	
	10	13	3	AM60	1	<5	---	AM50	SHR1
								AM55	SHR2
	10	13	3	AM65	2	0	---	---	
	10	13	3	AM70	0	<5	---	---	
	10	13	3	MR20	0	50	SHR3	---	
	10	13	3	MR15	0	10	SHR4	---	
	10	13	3	MR5	2	0	---	MR20	SHR3
								MR15	SHR4
BOARDMAN	30	38	8	DC10	0	5	BRD1	---	
	30	38	8	DC20	0	35	BRD2	---	
	30	38	8	DC25	0	7	BRD3	---	
	30	38	8	DC40	0	<5	---	---	
	30	38	8	AM5	1	10	BRD4	DC10	BRD1
								DC20	BRD2
								DC25	BRD3
	30	38	8	AM10	1	0	---	AM5	BRD4
	30	38	8	AR5	1	10	BRD5	---	
	30	38	8	AR10	2	<5	---	AR5	BRD5
	30	38	8	AM30	0	0	---	---	
	30	38	8	AM35	0	0	---	---	
	30	38	8	AM40	0	0	---	---	
	30	38	8	AM45	0	7	BRD6	---	
	30	38	8	AR20	0	10	BRD7	---	
	30	38	8	DR5	3	5	BRD6	AM45	BRD6
								AR20	BRD7
	30	38	8	DR10	0	10	BRD9	---	

* From data provided by operating agencies
** Assumed to be 25% greater than normal capacity
*** 25% of normal capacity

Unfortunately, no stream gages are located within the study area and hence, very limited information was available on flows resulting from the February 1986 storm. However, through interviews with County officials, flooding problem areas were identified. These areas are discussed in greater detail in Section 3.

In addition, PG&E did record the high water mark at the spill of Rock Creek Reservoir as a result of the storm. From this information PG&E estimated the peak spill to Rock Creek to be approximately 1100 cfs (with an additional release of 350 cfs from Rock Creek Reservoir to Wise Canal). PG&E also estimated the peak flow from Halsey Afterbay to Dry Creek to approximately 1400 cfs. A comparison of these estimated flows to model simulated flows is presented in Table 2-5.

Base Condition (1990) Model

The Base Condition Model was developed utilizing the land use survey by Placer County Planning Department (1990) and is taken to represent the present condition of the study area. Channel and floodplain descriptions for determining subbasin 'n' type were based on the aerial photography and personal visits to each of the locations where streams cross roadways in the watershed. Table 2-6 contains the hydrologic data for the Base Condition Model.

Future Condition (General Plan) Model

A Future Conditions HEC-1 model was developed by modifying the base model for the General Plan Future condition. This mainly involved incorporating the changes in land use from the base condition to the Future condition. Land use values were changed in the spreadsheet to match the land use from the Alternative 2 General Plan. Where the change in land use was extensive enough to warrant a change in the channel and floodplain description used to determine basin 'n', that parameter was also modified in the spreadsheet. The changes in land use and channel/floodplain description affected the unit hydrograph parameters of subbasin 'n', lag time (T_p), and peaking coefficient (C_p); the effective impervious area of the subbasin; and the constant loss rates because of the change in cover type that occurs with development. Table 2-7 contains the Future Condition hydrologic data for each of the subbasins.

TABLE 2-5
HEC-1 MODEL CALIBRATION RESULTS

	PG&E estimated	HEC-1 Model
Rock Creek Lake Spill	1121 cfs	958 cfs
Halsey Afterbay Spill (Dry Creek)	1400 cfs	1455 cfs

TABLE 2-6
1990 BASE CONDITION SUBBASIN HYDROLOGIC DATA

BASIN ID	BASIN DESCRIPTION	Basin Area (Sq Mi)	Chan DElev (ft)	Basin UElev (ft)	Basin Length (ft)	Basin Centrd (ft)	Basin Slope (ft/mi)	Basin Type	Basin 'n'	Basin Ct	Basin Lag (hr)	Basin Cp	Imp Area (%)	1990 LAND USE CONDITIONS (%) Comm 0.90	HDR 0.60	MDR 0.30	LDR 0.20	RLDR 0.15	RR 0.10	RE 0.10	Ag 0.10	Open 0.02	Loss Rates (In/hr)	SCS Soil Classification A:.48 A:.31	B:.25 B:.16	C:.16 C:.09	D:.12 D:.07
BR2	Bear River	0.30	940	1355	3390	2368	646	4	0.15	3.90	0.89	0.60	2.0								50	50	0.084		15		85
BR5	Bear River	0.26	1080	1380	3025	2349	524	4	0.15	3.90	0.88	0.60	2.0								40	60	0.075		5		95
BR10	Bear River	0.57	1100	1460	4446	2794	428	4	0.15	3.90	1.10	0.60	2.0								10	90	0.07		0.5		99.5
BR15	Bear River	0.31	1200	1360	1913	2348	442	4	0.15	3.90	0.78	0.60	2.0								10	90	0.07				100
BR20	Bear River	0.15	1250	1480	3000	1801	405	4	0.15	3.90	0.84	0.60	2.0								65	35	0.072		2		98
BR25	Bear River	0.33	1250	1415	3400	1662	256	3	0.15	3.90	0.92	0.60	2.0								75	25	0.072		2	0.5	97.5
BR30	Bear River	0.19	1310	1430	3000	2100	211	4	0.15	3.90	0.99	0.60	2.0								100		0.118		43	44	13
CL1	Clipper Creek	2.17	1760	1980	8100	3960	143	4	0.15	3.90	1.80	0.60	2.0									100	0.118		43	44	13
CL2	Clipper Creek	1.46	1560	1760	4270	4270	247	4	0.15	3.90	1.37	0.60	2.0									100	0.118		43	44	13
CL5	Clipper Creek	1.48	1230	1560	13400	8300	130	4	0.15	3.90	2.76	0.60	2.0									100	0.118		43	44	13
CL10	Clipper Creek	0.55	700	1230	4387	3256	638	4	0.15	3.90	1.08	0.60	2.8							10	90		0.09		20	8	72
AM5	American River	0.45	575	1570	3530	2618	1488	4	0.15	3.90	0.81	0.60	3.2						5	10		85	0.116		48	15	37
AM10	American River	0.54	600	1480	4166	2958	1115	4	0.14	3.64	0.87	0.60	8.6	5			10		5		50	30	0.094		13	18	69
AM15	American River	0.37	580	1560	4800	3400	1078	3.5	0.11	2.86	0.76	0.60	17.4	15			10		5		30	40	0.088		5		95
AM20	American River	0.14	530	1320	3800	2386	1098	4	0.15	3.90	0.85	0.60	2.9				5				30	65	0.109		40		60
AM25	American River	0.46	530	1500	6000	2850	854	3.5	0.08	2.08	0.58	0.60	13.7			5	40	5	30			20	0.114		20		80
AM30	American River	0.30	600	1380	4400	2576	936	3.5	0.09	2.34	0.56	0.60	14.9	5		15	15			20		45	0.114		25		75
AM35	American River	0.15	540	1355	2100	1325	2049	4	0.12	3.12	0.41	0.60	10.4			30					30	40	0.144		57	3	40
AM40	American River	0.15	500	1280	4000	2502	1030	4	0.08	2.08	0.47	0.60	24.4			80					20		0.123		10	1	89
AM45	American River	0.49	500	1320	3800	2049	1139	3.5	0.11	2.86	0.59	0.60	6.2			15					85		0.089		12		88
AM50	American River	0.17	560	1220	3600	2550	968	3.5	0.13	3.38	0.75	0.60	2.0									100	0.121	1	54		45
AM55	American River	0.14	500	1360	3400	2000	1336	3.5	0.13	3.38	0.65	0.60	2.0									100	0.113	1	45		54
AM60	American River	0.17	500	1120	2800	1610	1169	4	0.15	3.90	0.67	0.60	2.0									100	0.083		14		86
AM65	American River	0.24	490	1240	4095	2966	967	3.5	0.13	3.38	0.83	0.60	2.0								40	60	0.084		16		84
AM70	American River	0.32	480	1200	4400	1927	864	4	0.14	3.64	0.81	0.60	2.7					5			90	5	0.077		8		92
OC2	Bear River Canal	0.46	1695	1800	3730	3260	149	3.5	0.13	3.38	1.13	0.60	2.8							10		90	0.132		63	25	12
OC5	Irrig. Reservoir	0.37	1660	1880	4400	2600	264	3	0.11	2.86	0.85	0.60	2.8							10		90	0.097		10	90	
OC10	Sugar Pine Mtn.	0.53	1560	1660	4163	3603	127	4	0.15	3.90	1.43	0.60	2.8							10		90	0.09			100	
OC15	Halsey Forebay	0.32	1695	1765	4400	3800	84	3.5	0.13	3.38	1.37	0.60	2.8							10		90	0.115		35	65	
OC20	Christian Valley R.	0.39	1545	1680	4904	2582	145	3.5	0.11	2.86	0.97	0.60	7.6						10	60		30	0.095		7	93	
OC25	Christian Valley R	0.59	1475	1640	4200	1870	207	4	0.11	2.86	0.78	0.60	5.6						40	5		55	0.104		20	80	
OC30	Stanley Drive	0.59	1400	1475	2907	2007	136	3.5	0.11	2.86	0.76	0.60	6.4						40	15	25	20	0.096		15	60	25
OC35	Shirley Lane	0.17	1340	1400	3388	1489	94	3.5	0.11	2.86	0.77	0.60	5.2						40		25	35	0.097		30		70
OC40	Sunshine Mdw. Dr.	0.31	1495	1640	3583	2250	214	3.5	0.11	2.86	0.78	0.60	9.6							95		5	0.073			14	86
OC45	Kimo Way	0.17	1340	1495	1954	1054	419	3	0.09	2.34	0.37	0.60	9.6						10	85		5	0.07				100

TABLE 2-6 (continued)

BASIN ID	BASIN DESCRIPTION	Basin Area (Sq Mi)	Chan DElev (ft)	Basin UElev (ft)	Basin Length (ft)	Basin Centrd (ft)	Basin Slope (ft/mi)	Basin Type	Basin 'n'	Basin Ct	Basin Lag (hr)	Basin Cp	Imp Area (%)	1990 LAND USE CONDITIONS Comm 0.90	HDR 0.60	MDR 0.30	LDR 0.20 (%)	RLDR 0.15	RR 0.10	RE 0.10	Ag 0.10	Open 0.02	Loss Rates (in/hr)	SCS Soil Classification A:.48 A:.31	B:.25 B:.16	C:.16 C:.09	D:.12 D:.07
OC50	Stanley Drive	0.38	1300	1340	4252	2663	50	4	0.10	2.60	1.01	0.60	9.6						80	15		5	0.106		40		60
OC55	Gold Hill Canal	0.60	1340	1435	5280	3256	95	3.5	0.13	3.38	1.36	0.60	2.4							5	95		0.094		12	68	20
OC60	Lake Valley Drive	0.49	1300	1400	5200	3600	102	3.5	0.12	3.12	1.28	0.60	3.6							20	80		0.081		5	30	65
OC62	McElroy Drive	0.44	1320	2121	4200	2800	1007	3.5	0.12	3.12	0.75	0.60	8.4							80		20	0.081		5	30	65
OC65	Hwy 49 Bridge	0.32	1285	1300	2348	1978	34	3.5	0.13	3.38	1.05	0.60	2.0								95	5	0.084		15		85
OC70	Lone Star School	0.61	1320	1410	3038	1953	156	3	0.11	2.86	0.75	0.60	2.0								75	25	0.081		12		88
OC75	Hwy 49	0.70	1285	1360	6400	4200	62	3	0.11	2.86	1.43	0.60	2.0								97	3	0.084		7	40	53
OC80	Hwy 49	1.01	1160	1285	6617	4059	100	3.5	0.13	3.38	1.56	0.60	2.2							2	90	8	0.075		5		95
OC85	Lone Star Canal	0.33	1285	1460	4800	2300	193	3.5	0.13	3.38	1.05	0.60	2.0								100		0.071		1		99
OC90	Lone Star Spill	0.15	1160	1285	2300	1295	287	3.5	0.13	3.38	0.64	0.60	2.0								100		0.07				100
OC95	Lone Star Cmty	0.38	1050	1120	4211	2074	88	4	0.15	3.90	1.27	0.60	2.0								95	5	0.07				100
DC5	Hwy 80	0.68	1740	1970	6000	3512	202	4	0.13	3.38	1.28	0.60	4.6							33	33	34	0.087		0.5	84.5	15
DC10	Hwy 80	0.98	1600	1860	7335	3966	187	3.5	0.12	3.12	1.33	0.60	4.6							33	33	34	0.087			86	14
DC15	Christian Valley R.	0.48	1540	1820	4833	3469	306	4	0.14	3.64	1.20	0.60	4.4							30		70	0.096		12	75	13
DC20	Hwy 80	0.44	1540	1600	2776	2148	114	4	0.14	3.64	1.00	0.60	4.6							33	33	34	0.094		10	75	15
DC25	Dry Creek Road	0.47	1500	1600	3242	1587	163	3.5	0.13	3.38	0.84	0.60	8.2	7							30	63	0.133		60	20	20
DC30	Dry Creek Road	0.41	1420	1580	4200	2000	201	3.5	0.12	3.12	0.88	0.60	6.4	3						22		75	0.142		70	30	
DC35	Bowman Canal	0.62	1415	1700	5600	3950	269	4	0.15	3.90	1.44	0.60	3.2						8	7		85	0.135		67	25	8
DC40	Bell Road	0.57	1420	1600	5000	3800	190	4	0.14	3.64	1.35	0.60	9.4	5		2				30	25	38	0.121		45	25	30
DC45	Dry Creek Road	0.83	1335	1420	5620	3335	80	3.5	0.12	3.12	1.33	0.60	5.2							40		60	0.095		25	10	65
DC50	Gregg Way	0.27	1400	1645	3400	2138	380	3	0.10	2.60	0.63	0.60	8.4						40	40	15	5	0.139		70	30	
DC55	Black Oak Road	0.55	1335	1760	5200	2400	432	3.5	0.12	3.12	0.88	0.60	5.6							45	45	10	0.12		55		45
DC60	Dry Creek Road	0.32	1305	1490	4300	1300	227	3	0.09	2.34	0.56	0.60	8.0							75		25	0.074		4	2	94
DC65	Dry Creek Road	0.68	1260	1305	3301	1700	72	3.5	0.12	3.12	0.91	0.60	4.8							35		65	0.078		7	8	85
DC70	Dry Creek Road	0.24	1225	1470	3800	1653	340	3.5	0.11	2.86	0.67	0.60	6.8						40	20		40	0.071		1		99
DC75	Moss Rock Drive	0.28	1235	1360	3600	2188	183	3.5	0.11	2.86	0.80	0.60	10.0						5	95			0.07		0.5		99.5
DC80	Hwy 49	0.56	1200	1430	5200	950	234	3.5	0.08	2.08	0.48	0.60	14.7	5			15		30	40		10	0.08		0.5		99.5
DC85	Hwy 49	0.47	1180	1340	3600	2400	235	3.5	0.10	2.60	0.72	0.60	6.0						5	45	50		0.07				100
DC90	Joeger Road	0.69	1080	1180	6180	3472	85	3.5	0.10	2.60	1.14	0.60	5.6						5	40	50	5	0.07				100
DC95	Meadowbrook Dr.	0.29	1270	1410	5212	2777	142	3.5	0.13	3.38	1.20	0.60	2.0								100		0.07				100
DC100	Bell Road	0.94	1080	1270	5587	3365	180	3.5	0.11	2.86	1.07	0.60	7.6							70	25	5	0.07				100
DC105	Bell Road	0.44	1040	1080	3102	1618	68	3.5	0.13	3.38	0.96	0.60	2.0								100		0.084	6			94
RC5	S.P.R.R.	0.40	1500	1620	5400	2880	117	3.5	0.09	2.34	0.88	0.60	11.5	5				30		15		50	0.096		20	25	55
RC10	S.P.R.R.	0.21	1500	1600	4000	2800	132	3.5	0.11	2.86	0.95	0.60	11.9	3			7			75		15	0.115	1	39	5	55
RC15	S.P.R.R.	0.37	1450	1500	4629	2761	57	3.5	0.12	3.12	1.24	0.60	8.8	3			15	10		2		70	0.083		4	2	94
RC20	Bell Road	0.77	1450	1620	7000	2949	128	3	0.10	2.60	1.06	0.60	4.4	2						8	10	80	0.08		8	7	85

TABLE 2-6 (continued)

														1990 LAND USE CONDITIONS										SCS Soil Classification			
BASIN ID	BASIN DESCRIPTION	Basin Area (Sq Mi)	Chan DElev (ft)	Basin UElev (ft)	Basin Length (ft)	Basin Centrd (ft)	Basin Slope (ft/mi)	Basin Type	Basin 'n'	Basin Ct	Basin Lag (hr)	Basin Cp	Imp Area (%)	Comm 0.90	HDR 0.60	MDR 0.30	LDR 0.20 (%)	RLDR 0.15	RR 0.10	RE 0.10	Ag 0.10	Open 0.02	Loss Rates (in/hr)	A:.48 A:.31	B:.25 B:.16	C:.16 C:.09	D:.12 D:.07
RC25	Rock Creek Lake	0.47	1420	1485	3085	1360	111	2	0.07	1.82	0.45	0.60	25.2		40						5	55	0.091			5	95
RC30	Rock Creek Road	0.35	1330	1470	4550	2757	162	2	0.05	1.30	0.43	0.60	36.7	15	35				15			35	0.107		6	18	76
RC35	Hwy 49	0.41	1355	1390	3200	1800	58	2	0.04	1.04	0.32	0.66	52.3	45	12	5		18				20	0.101				100
RC40	Hwy 49	0.35	1330	1355	2823	2055	47	2	0.06	1.56	0.49	0.60	29.2	30						10		60	0.085				100
RC45	Hwy 49	0.47	1265	1330	3601	1599	95	3	0.08	2.08	0.58	0.60	17.0	8		25		7				60	0.087				100
RC50	Dry Creek Road	0.28	1215	1345	2800	1260	245	3.5	0.10	2.60	0.53	0.60	7.8					20		40		40	0.07				100
RC55	Joeger Road	0.21	1180	1215	2437	1854	76	3.5	0.08	2.08	0.56	0.60	6.9					10	20	25	40	5	0.07				100
DM5	Deadman Canyon	0.63	1245	1360	3702	2403	164	3.5	0.11	2.86	0.85	0.60	8.1				5		5	60	25	5	0.073				100
DM10	Deadman Canyon	0.36	1060	1245	2300	1874	425	4	0.14	3.64	0.72	0.60	3.6							20	70	10	0.093		25		75
AR1A	Auburn (CH2M)	1.57			8000	3400	174		0.04		0.34	0.75	24.0										0.15				
AR1B	Auburn (CH2M)	0.29			5000	2600	153		0.02		0.22	0.80	38.0										0.15				
AR2A	Auburn (CH2M)	1.66			6200	2200	121		0.03		0.28	0.75	29.0										0.15				
AR15	Stonehouse Road	0.54	940	1180	5800	2800	218	4	0.13	3.38	1.16	0.60	13.8	10			10		5	10		65	0.1		20		80
AR20	Highway 80	0.52	940	1295	5200	3295	360	4	0.13	3.38	1.09	0.60	12.0	5		20						75	0.119		35	5	60
AR25	Ophir Road	0.10	930	940	1161	503	45	3.5	0.11	2.86	0.43	0.60	10.0							100			0.084		15		85
AR30	Highway 80	0.49	835	1190	5600	2000	335	3.5	0.12	3.12	0.88	0.60	9.6	5						40		55	0.089		18		82
AR35	Highway 80	0.64	1350	1500	3800	2400	208	2	0.04	1.04	0.30	0.60	36.3	25	10		25	15			5	20	0.1				100
AR40	S.P.R.R.	0.56	1240	1380	3700	1300	200	3	0.07	1.82	0.43	0.60	25.0	12	12	12	12				45	7	0.094				100
AR45	Bean Road	0.60	1100	1340	5400	2300	235	3.5	0.11	2.86	0.89	0.60	6.8						30	30	30	10	0.07				100
AR50	Atwood Road	0.35	1215	1415	6866	4378	154	3	0.08	2.08	0.93	0.60	22.2	20		3				22	40	15	0.082				100
AR55	Atwood Road	0.27	1215	1420	5400	3562	200	3.5	0.09	2.34	0.86	0.60	31.0	30		5				15	20	30	0.088				100
AR60	Hidden Oaks Rd.	0.18	1100	1215	3984	2294	152	3.5	0.11	2.86	0.86	0.60	9.2							90	10		0.07				100
AR62	Mt . Vernon Rd.	0.64	1100	1240	5900	4000	125	3.5	0.11	2.86	1.22	0.60	9.2							90		10	0.07				100
AR65	Vada Ranch Rd.	0.63	1030	1100	3595	1657	103	3.5	0.12	3.12	0.87	0.60	7.2							65	35		0.078		7	8	85
AR70	Mt. Vernon Rd.	0.65	1040	1300	6300	3698	218	3.5	0.09	2.34	0.91	0.60	14.6	7					25	55	10	3	0.085		12		88
AR75	Bar Ranch Road	0.14	1020	1190	2800	1800	321	4	0.12	3.12	0.68	0.60	10.0							100			0.07		0.5		99.5
AR80	Millertown Road	0.59	835	1020	6571	4086	149	4	0.12	3.12	1.35	0.60	10.0							100			0.072		2		98
AR85	Highway 80	0.40	800	1080	4400	2800	336	3.5	0.12	3.12	0.91	0.60	6.0							50	50		0.071		1		99
DR5	Dutch Ravine	0.74	1100	1280	5137	3995	185	3.5	0.13	3.38	1.29	0.60	2.4							5	10	85	0.111		45		55
DR10	Dutch Ravine	0.27	980	1100	3085	1544	205	3.5	0.12	3.12	0.72	0.60	6.4						10	45	45		0.106		40		60
MR2	Mormon Ravine	0.10	895	1240	4400	2050	414	3.5	0.13	3.38	0.86	0.60	2.4							5	30	65	0.072		2		98
MR5	Mormon Ravine	0.35	920	1240	5398	3055	313	3.5	0.13	3.43	1.12	0.60	2.6							8		92	0.074			20	80
MR10	Mormon Ravine	0.10	835	920	2144	1439	209	3.5	0.11	2.86	0.57	0.60	10.0							100			0.077		3	20	77
MR15	Mormon Ravine	0.44	1005	1220	6548	4695	173	3.5	0.12	3.12	1.38	0.60	4.6							33	33	34	0.07			2	98
MR20	Mormon Ravine	0.19	1125	1240	2536	2083	239	3	0.10	2.60	0.61	0.60	5.3					25			65	10	0.081		12		88
MR25	Mormon Ravine	0.19	1040	1125	2660	1923	169	3	0.11	2.86	0.70	0.60	2.7					5			95		0.077			35	65

TABLE 2-7
FUTURE CONDITION SUBBASIN HYDROLOGIC DATA

BASIN ID	BASIN DESCRIPTION	Basin Area (Sq Mi)	Chan DElev (ft)	Basin UElev (ft)	Basin Length (ft)	Basin Centrd (ft)	Basin Slope (ft/mi)	Basin Type	Basin 'n'	Basin Ct	Basin Lag (hr)	Basin Cp	Imp Area (%)	Community Plan Land Use Conditions: Comm 0.90	HDR 0.60	MDR 0.30	LDR 0.20 (%)	RLDR 0.15	RR 0.10	RE 0.10	Ag 0.10	Open 0.02	Loss Rates (in/hr)	SCS Soil Classification: A:.48 A:.31	B:.25 B:.16	C:.16 C:.09	D:.12 D:.07
BR2	Bear River	0.30	940	1355	3390	2368	646.37	4	0.15	3.9	0.89	0.60	2.0								100		0.084		15		85
BR5	Bear River	0.26	1080	1380	3025	2349	523.64	4	0.15	3.9	0.88	0.60	2.0								100		0.075		5		95
BR10	Bear River	0.57	1100	1460	4446	2794	427.53	4	0.15	3.9	1.10	0.60	2.0								100		0.07		0.5		99.5
BR15	Bear River	0.31	1200	1360	1913	2348	441.61	4	0.15	3.9	0.78	0.60	2.0								100		0.07				100
BR20	Bear River	0.15	1250	1480	3000	1801	404.8	4	0.15	3.9	0.84	0.60	2.0								100		0.072		2		98
BR25	Bear River	0.33	1250	1415	3400	1662	256.24	3	0.15	3.9	0.92	0.60	2.0								100		0.072		2	0.5	97.5
BR30	Bear River	0.19	1310	1430	3000	2100	211.2	4	0.15	3.9	0.99	0.60	2.0								100		0.118		43	44	13
CL1	Clipper Creek	2.17	1760	1980	8100	3960	143.41	4	0.15	3.9	1.80	0.60	2.0									100	0.118		43	44	13
CL2	Clipper Creek	1.46	1560	1760	4270	4270	247.31	4	0.15	3.9	1.37	0.60	2.0									100	0.118		43	44	13
CL5	Clipper Creek	1.48	1230	1560	13400	8300	130.03	4	0.15	3.9	2.76	0.60	2.0									100	0.118		43	44	13
CL10	Clipper Creek	0.55	700	1230	4387	3256	637.88	4	0.15	3.9	1.08	0.60	2.8							10	90		0.09		20	8	72
AM5	American River	0.45	575	1570	3530	2618	1488.3	4	0.15	3.9	0.81	0.60	12.8	10						25	10	55	0.123		48	15	37
AM10	American River	0.54	600	1480	4166	2958	1115.3	4	0.14	3.64	0.87	0.60	5.0				10		5	10	55	20	0.091		13	18	69
AM15	American River	0.37	580	1560	4800	3400	1078	3.5	0.11	2.86	0.76	0.60	23.6	15		10	20		25			30	0.098		5		95
AM20	American River	0.14	530	1320	3800	2386	1097.7	3.5	0.11	2.86	0.62	0.60	7.0				10		40			50	0.113		40		60
AM25	American River	0.46	530	1500	6000	2850	853.6	3.5	0.08	2.08	0.58	0.60	13.7			5	40	5	30			20	0.114		20		80
AM30	American River	0.30	600	1380	4400	2576	936	3.5	0.09	2.34	0.56	0.60	14.9	5		15	15			20		45	0.114		25		75
AM35	American River	0.15	540	1355	2100	1325	2049.1	4	0.12	3.12	0.41	0.60	10.4			30					30	40	0.144		57	3	40
AM40	American River	0.15	500	1280	4000	2502	1029.6	4	0.08	2.08	0.47	0.60	24.4			80					20		0.123		10	1	89
AM45	American River	0.49	500	1320	3800	2049	1139.4	3.5	0.11	2.86	0.59	0.60	6.2			15					85		0.089		12		88
AM50	American River	0.17	560	1220	3600	2550	968	3.5	0.13	3.38	0.75	0.60	2.0									100	0.121	1	54		45
AM55	American River	0.14	500	1360	3400	2000	1335.5	3.5	0.13	3.38	0.65	0.60	2.0									100	0.113	1	45		54
AM60	American River	0.17	500	1120	2800	1610	1169.1	4	0.15	3.9	0.67	0.60	2.0									100	0.083		14		86
AM65	American River	0.24	490	1240	4095	2966	967.03	3.5	0.13	3.38	0.83	0.60	2.0								40	60	0.084		16		84
AM70	American River	0.32	480	1200	4400	1927	864	4	0.14	3.64	0.81	0.60	2.7					5			90	5	0.077		8		92
OC2	Bear River Canal	0.46	1695	1800	3730	3260	148.63	3.5	0.13	3.38	1.13	0.60	2.8							10		90	0.132		63	25	12
OC5	Irrig. Reservoir	0.37	1660	1880	4400	2600	264	3	0.11	2.86	0.85	0.60	2.8							10		90	0.097		10	90	
OC10	Sugar Pine Mtn.	0.53	1560	1660	4163	3603	126.83	4	0.15	3.9	1.43	0.60	2.8							10		90	0.09			100	
OC15	Halsey Forebay	0.32	1695	1765	4400	3800	84	3.5	0.11	2.86	1.16	0.60	8.4							80		20	0.115		35	65	
OC20	Christian Valley R.	0.39	1545	1680	4904	2582	145.35	3.5	0.1	2.6	0.88	0.60	9.6						10	85		5	0.095		7	93	
OC25	Christian Valley R	0.59	1475	1640	4200	1870	207.43	3.5	0.09	2.34	0.64	0.60	8.8						40	45	10	5	0.104		20	80	
OC30	Stanley Drive	0.59	1400	1475	2907	2007	136.22	3.5	0.11	2.86	0.76	0.60	7.2						45	20	30	5	0.096		15	60	25
OC35	Shirley Lane	0.17	1340	1400	3388	1489	93.506	3.5	0.11	2.86	0.77	0.60	6.0						45	5	20	30	0.097		30		70
OC40	Sunshine Mdw. Dr.	0.31	1495	1640	3583	2250	213.68	3.5	0.11	2.86	0.78	0.60	9.6							95		5	0.073			14	86
OC45	Kimo Way	0.17	1340	1495	1954	1054	418.83	3	0.09	2.34	0.37	0.60	9.2						15	75		10	0.07				100

TABLE 2-7 (continued)

														Community Plan Land Use Conditions										SCS Soil Classification			
BASIN ID	BASIN DESCRIPTION	Basin Area (Sq Mi)	Chan DElev (ft)	Basin UElev (ft)	Basin Length (ft)	Basin Centrd (ft)	Basin Slope (ft/mi)	Basin Type	Basin 'n'	Basin Ct	Basin Lag (hr)	Basin Cp	Imp Area (%)	Comm 0.90	HDR 0.60	MDR 0.30	LDR 0.20 (%)	RLDR 0.15	RR 0.10	RE 0.10	Ag 0.10	Open 0.02	Loss Rates (in/hr)	A:.48 A:.31	B:.25 B:.16	C:.16 C:.09	D:.12 D:.07
OC50	Stanley Drive	0.38	1300	1340	4252	2663	49.671	4	0.1	2.6	1.01	0.60	9.2						80	10	5	5	0.106		40		60
OC55	Gold Hill Canal	0.60	1340	1435	5280	3256	95	3.5	0.13	3.38	1.36	0.60	2.4							5	95		0.094		12	68	20
OC60	Lake Valley Drive	0.49	1300	1400	5200	3600	101.54	3.5	0.12	3.12	1.28	0.60	4.4							30	70		0.081		5	30	65
OC62	McElroy Drive	0.44	1320	2121	4200	2800	1007	3.5	0.12	3.12	0.75	0.60	8.4							80		20	0.081		5	30	65
OC65	Hwy 49 Bridge	0.32	1285	1300	2348	1978	33.731	3.5	0.13	3.38	1.05	0.60	2.0								95	5	0.084		15		85
OC70	Lone Star School	0.61	1320	1410	3038	1953	156.42	3	0.11	2.86	0.75	0.60	2.0								95	5	0.081		12		88
OC75	Hwy 49	0.70	1285	1360	6400	4200	61.875	3	0.11	2.86	1.43	0.60	2.0								95	5	0.084		7	40	53
OC80	Hwy 49	1.01	1160	1285	6617	4059	99.743	3.5	0.13	3.38	1.56	0.60	2.0								95	5	0.075		5		95
OC85	Lone Star Canal	0.33	1285	1460	4800	2300	192.5	3.5	0.13	3.38	1.05	0.60	2.0								100		0.071		1		99
OC90	Lone Star Spill	0.15	1160	1285	2300	1295	286.96	3.5	0.13	3.38	0.64	0.60	2.0								100		0.07				100
OC95	Lone Star Cmty	0.38	1050	1120	4211	2074	87.77	4	0.15	3.9	1.27	0.60	2.0								95	5	0.07				100
DC5	Hwy 80	0.68	1740	1970	6000	3512	202.4	4	0.13	3.38	1.28	0.60	4.6							33	33	34	0.087		0.5	84.5	15
DC10	Hwy 80	0.98	1600	1860	7335	3966	187.16	3.5	0.12	3.12	1.33	0.60	4.6							33	33	34	0.087			86	14
DC15	Christian Valley R.	0.48	1540	1820	4833	3469	305.9	4	0.14	3.64	1.20	0.60	4.4							30		70	0.096		12	75	13
DC20	Hwy 80	0.44	1540	1600	2776	2148	114.12	4	0.14	3.64	1.00	0.60	4.6							33	33	34	0.094		10	75	15
DC25	Dry Creek Road	0.47	1500	1600	3242	1587	162.86	3.5	0.12	3.12	0.77	0.60	5.2							40		60	0.128		60	20	20
DC30	Dry Creek Road	0.41	1420	1580	4200	2000	201.14	3.5	0.11	2.86	0.80	0.60	6.8							60		40	0.139		70	30	
DC35	Bowman Canal	0.62	1415	1700	5600	3950	268.71	3.5	0.1	2.6	0.96	0.60	9.6						8	87		5	0.135		67	25	8
DC40	Bell Road	0.57	1420	1600	5000	3800	190.08	3.5	0.11	2.86	1.06	0.60	12.4	5						75		20	0.119		45	25	30
DC45	Dry Creek Road	0.83	1335	1420	5620	3335	79.858	3.5	0.12	3.12	1.33	0.60	6.4							55		45	0.095		25	10	65
DC50	Gregg Way	0.27	1400	1645	3400	2138	380.47	3	0.1	2.6	0.63	0.60	10.0						50	50			0.139		70	30	
DC55	Black Oak Road	0.55	1335	1760	5200	2400	431.54	3.5	0.11	2.86	0.81	0.60	9.2							90		10	0.12		55		45
DC60	Dry Creek Road	0.32	1305	1490	4300	1300	227.16	3	0.09	2.34	0.56	0.60	9.2							90		10	0.074		4	2	94
DC65	Dry Creek Road	0.68	1260	1305	3301	1700	71.978	3.5	0.11	2.86	0.83	0.60	9.6							95		5	0.078		7	8	85
DC70	Dry Creek Road	0.24	1225	1470	3800	1653	340.42	3	0.07	1.82	0.43	0.60	18.6	10			10		40	35		5	0.081		1		99
DC75	Moss Rock Drive	0.28	1235	1360	3600	2188	183.33	3.5	0.11	2.86	0.80	0.60	10.0						5	95			0.07		0.5		99.5
DC80	Hwy 49	0.56	1200	1430	5200	950	233.54	3	0.07	1.82	0.42	0.60	23.1	15			15		30	35		5	0.086		0.5		99.5
DC85	Hwy 49	0.47	1180	1340	3600	2400	234.67	3.5	0.1	2.6	0.72	0.60	5.6							45	55		0.07				100
DC90	Joeger Road	0.69	1080	1180	6180	3472	85.437	3.5	0.1	2.6	1.14	0.60	5.6						5	40	50	5	0.07				100
DC95	Meadowbrook Dr.	0.29	1270	1410	5212	2777	141.83	3	0.06	1.56	0.55	0.60	16.1			20		50	25			5	0.08				100
DC100	Bell Road	0.94	1080	1270	5587	3365	179.56	3.5	0.11	2.86	1.07	0.60	9.6							95		5	0.07				100
DC105	Bell Road	0.44	1040	1080	3102	1618	68.085	3.5	0.13	3.38	0.96	0.60	2.0								100		0.084	6			94
RC5	S.P.R.R.	0.40	1500	1620	5400	2880	117.33	3	0.07	1.82	0.68	0.60	24.6	15			30			50		5	0.121		20	25	55
RC10	S.P.R.R.	0.21	1500	1600	4000	2800	132	3.5	0.11	2.86	0.95	0.60	19.7	10	2		15			63		10	0.127	1	39	5	55
RC15	S.P.R.R.	0.37	1450	1500	4629	2761	57.032	3	0.06	1.56	0.62	0.60	34.7	25			55			10		10	0.116		4	2	94
RC20	Bell Road	0.77	1450	1620	7000	2949	128.23	3	0.09	2.34	0.95	0.60	13.6	10						35		55	0.084		8	7	85

TABLE 2-7 (continued)

BASIN ID	BASIN DESCRIPTION	Basin Area (Sq Mi)	Chan DElev (ft)	Basin UElev (ft)	Basin Length (ft)	Basin Centrd (ft)	Basin Slope (ft/mi)	Basin Type	Basin 'n'	Basin Ct	Basin Lag (hr)	Basin Cp	Imp Area (%)	Community Plan Land Use Conditions (%): Comm 0.90	HDR 0.60	MDR 0.30	LDR 0.20	RLDR 0.15	RR 0.10	RE 0.10	Ag 0.10	Open 0.02	Loss Rates (in/hr)	SCS Soil Classification: A:.48 A:.31	B:.25 B:.16	C:.16 C:.09	D:.12 D:.07
RC25	Rock Creek Lake	0.47	1420	1485	3085	1360	111.25	1.5	0.06	1.56	0.38	0.60	32.9	10	35		10					45	0.099			5	95
RC30	Rock Creek Road	0.35	1330	1470	4550	2757	162.46	1	0.03	0.78	0.26	0.71	61.8	35	50							15	0.127		6	18	76
RC35	Hwy 49	0.41	1355	1390	3200	1800	57.75	1.5	0.02	0.52	0.16	0.77	73.5	65	20		15						0.12				100
RC40	Hwy 49	0.35	1330	1355	2823	2055	46.759	1	0.02	0.52	0.16	0.81	81.1	85	5	5						5	0.118				100
RC45	Hwy 49	0.47	1265	1330	3601	1599	95.307	2	0.04	1.04	0.29	0.60	40.2	20	15	40		5				20	0.108				100
RC50	Dry Creek Road	0.28	1215	1345	2800	1260	245.14	3	0.07	1.82	0.37	0.60	18.9	5	5		5	45	35			5	0.078				100
RC55	Joeger Road	0.21	1180	1215	2437	1854	75.831	3	0.07	1.82	0.49	0.60	10.1					10	85			5	0.07				100
DM5	Deadman's Gulch	0.63	1245	1360	3702	2403	164.02	3	0.08	2.08	0.62	0.60	10.4				5	5	45	40		5	0.073				100
DM10	Deadman's Gulch	0.36	1060	1245	2300	1874	424.7	3.5	0.11	2.86	0.57	0.60	9.6							95		5	0.093		25		75
AU1A	Auburn (CH2M)	1.57			8000	3400	174.2		0.035		0.30	0.75	37.0										0.15				
AU1B	Auburn (CH2M)	0.29			5000	2600	153.1		0.024		0.20	0.80	80.0										0.15				
AU2A	Auburn (CH2M)	1.66			6200	2200	121.4		0.028		0.20	0.75	65.0										0.15				
AR15	Stonehouse Road	0.54	940	1180	5800	2800	218.48	4	0.13	3.38	1.16	0.60	13.8	10			10		5	10		65	0.1		20		80
AR20	Highway 80	0.52	940	1295	5200	3295	360.46	4	0.13	3.38	1.09	0.60	12.0	5		20						75	0.119		35	5	60
AR25	Ophir Road	0.10	930	940	1161	503	45.478	3.5	0.11	2.86	0.43	0.60	10.0							100			0.084		15		85
AR30	Highway 80	0.49	835	1190	5600	2000	334.71	3.5	0.12	3.12	0.88	0.60	10.0							100			0.086		18		82
AR35	Highway 80	0.64	1350	1500	3800	2400	208.42	1.5	0.03	0.78	0.22	0.68	56.5	35	30		35						0.12				100
AR40	S.P.R.R.	0.56	1240	1380	3700	1300	199.78	2	0.04	1.04	0.24	0.60	34.1	12	13	35	10		30				0.105				100
AR45	Bean Road	0.60	1100	1340	5400	2300	234.67	2.5	0.08	2.08	0.65	0.60	11.5			5	5		40	50			0.075				100
AR50	Atwood Road	0.35	1215	1415	6866	4378	153.8	2	0.05	1.3	0.58	0.60	33.2	20	10	15			45			10	0.093				100
AR55	Atwood Road	0.27	1215	1420	5400	3562	200.44	2	0.04	1.04	0.38	0.60	22.1	10	5	25			15	10		5	0.069				100
AR60	Hidden Oaks Rd.	0.18	1100	1215	3984	2294	152.41	3.5	0.11	2.86	0.86	0.60	8.4							80		20	0.07				100
AR62	Mt . Vernon Rd.	0.64	1100	1240	5900	4000	125.29	3.5	0.11	2.86	1.22	0.60	9.2							90		10	0.07				100
AR65	Vada Ranch Rd.	0.63	1030	1100	3595	1657	102.81	3.5	0.11	2.86	0.80	0.60	9.6							95		5	0.078		7	8	85
AR70	Mt. Vernon Rd.	0.65	1040	1300	6300	3698	217.9	3	0.08	2.08	0.81	0.60	18.3	10				5	30	55			0.086		12		88
AR75	Bar Ranch Road	0.14	1020	1190	2800	1800	320.57	4	0.12	3.12	0.68	0.60	10.0							100			0.07		0.5		99.5
AR80	Millertown Road	0.59	835	1020	6571	4086	148.65	4	0.12	3.12	1.35	0.60	10.0							100			0.072		2		98
AR85	Highway 80	0.40	800	1080	4400	2800	336	2.5	0.06	1.56	0.46	0.60	40.5	35	5					60			0.091		1		99
DR5	Dutch Ravine	0.74	1100	1280	5137	3995	185.01	3.5	0.13	3.38	1.29	0.60	8.0						10	70			0.088		45		55
DR10	Dutch Ravine	0.27	980	1100	3085	1544	205.38	3.5	0.11	2.86	0.66	0.60	8.4						10	70		20	0.106		40		60
MR2	Mormon Ravine	0.10	895	1240	4400	2050	414	3.5	0.13	3.38	0.86	0.60	2.4							5	30	65	0.072		2		98
MR5	Mormon Ravine	0.35	920	1240	5398	3055	313	3.5	0.132	3.432	1.12	0.60	2.6							8		92	0.074			20	80
MR10	Mormon Ravine	0.10	835	920	2144	1439	209.33	3.5	0.11	2.86	0.57	0.60	10.0							100			0.077		3	20	77
MR15	Mormon Ravine	0.44	1005	1220	6548	4695	173.37	3.5	0.12	3.12	1.38	0.60	4.6							33	33	34	0.07			2	98
MR20	Mormon Ravine	0.19	1125	1240	2536	2083	239.43	3	0.1	2.6	0.61	0.60	5.3					25			65	10	0.081		12		88
MR25	Mormon Ravine	0.19	1040	1125	2660	1923	168.72	3	0.09	2.34	0.57	0.60	10.3					5		95			0.077			35	65

MODEL RESULTS

The model setups described above were used to make HEC-1 model runs for the major points of interest in the watershed, such as culverts, bridges, problem areas, and tributary confluences. The 2-, 10-, 25-, and 100-year peak flows for Present and Future conditions at each of these locations are listed in Table 2-8. Figures 1-6a to 1-6c indicate the locations for the peak flows listed in Table 2-8.

USE OF MODEL

The HEC-1 model input for the Auburn/Bowman Community has been set up with the goal of providing a tool for use in the future. Because of the storm centering method that was used to determine the precipitation for input into the HEC-1 model, there are a large number of input data files. Each of these input files represents the storm centering for a particular HEC-1 flow combination point. When runoff based on changed hydrologic parameters is wanted at a particular combination point in the watershed, it is necessary to modify the input file for that combination point and then run HEC-1 using the input file. Output from the HEC-1 model is then used as input to the FIXFORM program to change the formatting to be more easily readable.

Several FORTRAN programs were utilized as a part of this study to automate the modification of large numbers of input files, and to extract the wanted peak flows from the HEC-1 output files. The input modification program called MODSUB takes data from the hydrologic spreadsheet and inserts it into specified HEC-1 input files. CROSFLOW takes the output from specified HEC-1 output files and combines and interpolates it into flow output tables like Table 2-8. This combination and interpolation of flows, at points between combination points in the model, takes into account not only the magnitude of flows at each of the locations, but also the timing of the flood peaks being combined.

TABLE 2-8
PEAK FLOWS

CROSSING NUMBER	STREAM	CROSSING	DRAINAGE AREA (SQ. MI.)	2-YEAR		10-YEAR		25-YEAR		100-YEAR	
				PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)
1	ORR CREEK	INFLOW TO COON CR.	9.31	674	689	2180	2213	2931	2978	4176	4238
2		BELL RD.	9.29	673	688	2176	2209	2926	2972	4168	4230
3		TRIB. CONFLUENCE	8.93	643	658	2123	2157	2868	2915	4047	4112
4		TRIB. CONFLUENCE	7.44	571	582	1901	1936	2459	2504	3517	3578
5		HWY 49 (State)	6.13	477	488	1589	1623	2100	2141	2881	2936
6		TRIB. CONFLUENCE	5.81	511	522	1517	1550	2019	2060	2845	2902
7		W. STANLEY DR.	4.26	353	364	1092	1120	1464	1497	2031	2075
8		TRIB. CONFLUENCE	3.9	362	368	1063	1085	1410	1439	1916	1955
9		E. STANLEY DR.	3.36	306	310	917	935	1222	1247	1662	1692
10		COMBIE-OPHIR SIPHON	3.25	307	311	916	933	1194	1218	1631	1660
11		CHRISTIAN VALLEY RD.	2.66	265	271	823	838	1058	1077	1414	1435
12		TRIB. CONFLUENCE	2.07	254	267	646	667	835	862	1111	1144
13		STUDY BOUNDARY	1.15	151	161	368	387	469	492	624	653
14		TRIB. CONFLUENCE	0.78	114	124	248	264	316	335	420	444
15	ORR CK TRIB #1	LITTLE CREEK RD. (Private)	0.12	23	25	46	49	58	61	76	80
16	ORR CK TRIB #2	VIRGINIA WAY	0.48	69	69	194	194	250	250	334	334
17		KENNETH WY. (Private)	0.31	72	72	141	141	175	175	228	228
17	ORR CK TRIB #3	LONE STAR RD.	0.75	146	146	301	301	375	375	495	495
19	DRY CREEK	INFLOW TO COON CR	15.5	860	945	2787	2877	3844	3944	5575	5706
20		BELL RD.	15.32	848	932	2758	2847	3810	3908	5511	5638
21		TRIB. CONFLUENCE	15.06	831	915	2707	2800	3749	3832	5447	5555
22		ROCK CK. CONFLUENCE	13.14	660	729	2405	2464	3305	3355	4589	4675
23		HWY 49 (State)	8.38	431	461	1562	1630	2104	2195	2960	3100
24		TRIB. CONFLUENCE	7.82	399	428	1488	1550	1988	2082	2819	2938
25		BLUE GRASS RD.	7.3	368	391	1418	1476	1934	2012	2655	2759
26		BELOW DAM	6.62	392	411	1324	1366	1761	1814	2408	2483
27		INFLOW TO RES.	6.3	371	385	1291	1327	1704	1750	2323	2380
28		DRY CK. ROAD	5.48	334	343	1133	1151	1468	1485	1993	2017

TABLE 2-8 (continued)

CROSSING NUMBER	STREAM	CROSSING	DRAINAGE AREA (SQ. MI.)	2-YEAR		10-YEAR		25-YEAR		100-YEAR	
				PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)
29		TWIN PINES TR. (Private)	4.69	369	371	1056	1062	1379	1384	1877	1876
30		HAINES RD.	4.03	324	324	894	891	1171	1165	1589	1580
31		HALSEY AFTBAY OUTFLOW	3.05	298	298	750	748	955	951	1279	1275
32		BOWMAN RD.	2.82	288	289	702	702	898	898	1196	1195
33		LAKE ARTHUR RD.	2.58	262	264	649	652	831	834	1101	1104
34		LAKE ARTHUR RD.	1.81	178	178	407	407	525	525	695	696
35		BELOW LAKE ARTHUR	1.66	156	156	360	359	465	465	616	616
36	**DRY CK TRIB #1**	DRY CREEK RD.	0.1	19	20	38	40	48	51	64	67
37	**DRY CK TRIB #2**	DRY CREEK RD.	0.62	81	111	177	230	228	292	304	386
38	**DRY CK TRIB #3**	BLACK OAK RD.	0.35	100	104	203	208	256	261	338	344
39	**DRY CK TRIB #4**	DRY CREEK RD	0.1	22	30	44	56	55	70	72	92
40	**DRY CK TRIB #5**	JOEGER RD.	0.25	72	78	139	148	173	185	228	243
41	**DRY CK TRIB #6**	HOWE RD. (Private)	1.14	238	282	479	557	600	690	789	901
42		HUBBARD RD. (Private)	1.04	223	265	447	523	560	648	737	846
43		JOEGER RD.	0.29	46	77	96	149	120	186	158	244
44	**ROCK CREEK**	INFLOW TO DRY CREEK	4.29	386	457	1006	1229	1342	1711	1912	2424
45		JOEGER RD.	4.25	383	453	997	1217	1325	1688	1883	2387
46		SHERWOOD WY.	4.08	433	535	1019	1287	1312	1696	1773	2260
47		DRY CREEK RD.	3.8	381	478	922	1149	1195	1566	1596	2088
48		RICHARDSON RD.	3.78	381	478	922	1149	1195	1566	1596	2088
49		HWY 49 (State)	3.33	384	509	834	1045	1062	1380	1390	1861
50		ROCK CREEK RD.	2.24	394	396	466	499	603	641	772	812
51		ROCK CK LAKE OUTFLOW	2.22	400	400	464	497	601	641	769	809
52		ROCK CK LAKE INFLOW	2.22	370	421	898	1000	1104	1231	1435	1591
53		BELL RD.	0.98	134	159	284	322	359	404	472	532
54		NEW AIRPORT RD.	0.91	133	155	277	311	349	390	459	513
55		CRYSTAL SPRINGS RD.	0.85	131	152	271	302	342	379	449	498

TABLE 2-8 (continued)

CROSSING NUMBER	STREAM	CROSSING	DRAINAGE AREA (SQ. MI.)	2-YEAR		10-YEAR		25-YEAR		100-YEAR	
				PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)
56		TRIB. CONFLUENCE	0.61	123	136	247	265	309	332	406	435
57		CREEKVIEW CT.	0.19	36	37	73	74	92	93	122	122
58		RAILROAD	0.15	28	29	57	57	71	72	95	95
59	ROCK CK TRIB #1	RAILROAD	0.38	79	94	158	181	197	225	257	295
60	ROCK CK TRIB #2	NEW AIRPORT RD.	0.58	107	120	219	236	274	295	358	383
61		BELL RD.	0.31	57	64	117	126	146	157	191	204
62	ROCK CK TRIB #3	LOCKSLEY LN.	0.26	82	122	153	221	191	274	251	361
63	ROCK CK TRIB #4	ROCK CREEK RD.	0.66	174	246	385	527	499	708	669	976
64		BELL RD.	0.41	166	256	300	461	373	576	489	759
65	NORTH RAVINE	WISE RD.	5.25	591	646	1739	1862	2281	2459	3012	3241
66		WARREN WY. (Private)	5.1	578	632	1698	1823	2228	2408	2943	3176
67		CALNICK RD. (Private)	4.83	646	715	1701	1861	2207	2419	2908	3203
68		BELOW MILLERTOWN RD.	4.66	641	713	1674	1849	2176	2404	2863	3186
69		TRIB. CONFLUENCE	4.52	661	739	1654	1828	2126	2365	2792	3110
70		MILLERTOWN RD.	3.87	534	599	1395	1553	1805	2028	2373	2671
71		MT. VERNON RD.	3.24	523	600	1264	1473	1606	1928	2122	2549
72		HARRIS RD. (Private)	0.8	87	104	238	281	299	357	397	476
73		VISTA ROBLE RD. (Private)	0.62	126	177	247	333	306	413	401	541
74		ATWOOD RD.	0.35	32	42	62	80	77	99	100	129
75	N.RAV. TRIB #1	KEMPER RD. (Private)	0.23	46	61	89	115	110	142	144	187
76	N.RAV. TRIB #2	HIDDEN OAKS LN. (Private)	1.56	326	376	783	927	1017	1256	1372	1705
77		RAILROAD	0.64	203	259	375	478	470	618	648	842
78		HWY 49 (State)	0.35	112	142	206	263	259	340	356	463
79		PEAR RD. (Private)	0.28	87	119	164	219	204	273	268	360
80	N.RAV. TRIB #3	MILLERTOWN RD.	0.6	113	122	228	241	284	301	373	395
81		MT. VERNON RD.	0.36	69	75	139	147	173	184	228	241

TABLE 2-8 (continued)

CROSSING NUMBER	STREAM	CROSSING	DRAINAGE AREA (SQ. MI.)	2-YEAR		10-YEAR		25-YEAR		100-YEAR	
				PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)
82	**N.RAV. TRIB #4**	MILLERTOWN RD.	0.06	13	13	26	26	32	32	42	42
83		BAR RANCH RD. (Private)	0.04	10	10	20	20	24	24	32	32
84	**AUBURN RAVINE**	AUBURN RAVINE OUTFLOW	10.82	884	1047	3160	3406	4270	4589	6047	6411
85		N. RAVINE CONFLUENCE	10.42	856	1017	3042	3281	4060	4384	5835	6050
86		WISE RD.	4.68	968	1111	2366	2539	2993	3185	4300	4429
87		OPHIR RD.	4.58	948	1079	2326	2511	3033	3208	4217	4349
88		OPHIR RD.	4.23	934	1067	2233	2430	2901	3092	4034	4189
89		FORGOTTEN RD. (Abandoned)	3.54	1019	1192	2236	2440	2811	3038	3916	4088
90	**AUBURN R. TRIB**	I-80 (State)	0.49	75	75	161	161	202	202	271	271
91		RAILROAD	0.34	51	51	110	110	138	138	185	185
92	**DUTCH RAVINE**	RAILROAD	0.41	56	61	122	128	154	160	205	211
93		AUBURN-FOLSOM RD.	0.22	31	33	66	70	84	87	112	115
94	**MORMON RAVINE**	SHIRLAND RD.	0.04	6	6	14	14	17	17	22	22
95	**MORMON R. TRIB**	NO NAME RD	0.29	66	70	138	145	174	182	228	240
96		ANDREGG RD.	0.19	42	48	85	95	106	118	139	155
97	**AMER.R.TRIB #1**	HWY 49 (State)	0.32	78	78	155	155	194	194	257	257
98	**AMER.R.TRIB #2**	HWY 49 (State)	0.04	28	28	56	56	69	69	92	92
99	**DEADMAN CANYON**	JOEGER RD.	0.63	127	157	256	306	318	380	417	498
100		OAK CREEK CT.	0.19	38	47	77	92	95	114	125	149

SECTION 3
PROBLEM IDENTIFICATION

As discussed in Section 1, the watersheds in the study area are characterized by relatively steep slopes with moderate relief. Hence, flooding of structures (i.e. houses, buildings) in floodplains is much less severe in this area than in low-lying areas of western Placer County. However, most of the problems due to flooding in the Auburn/Bowman Community Plan area are associated with inadequate bridges and culverts which may be subject to damage by overtopping. Overtopping of these structures may also result in roads being damaged or closed, thus impeding traffic and restricting emergency access to an area. In addition, overtopping of bridges and culverts may result in potentially hazardous situations to traffic along roadways as vehicles may become stalled and swept downstream if severe overtopping occurs.

SUMMARY OF 1986 FLOODING PROBLEMS

The flood of February 1986 caused the most severe flooding damage to date in the Auburn/Bowman Community Plan area. As mentioned above, most of the flooding problems were due to inadequate bridges and culverts which resulted in overtopping of these structures. However at several locations in the study area flooding of structures did occur in the floodplains.

In order to identify the locations where flooding or overtopping has occurred, various departments were contacted within Placer County and interviews of staff members were conducted. The following is a list of departments contacted:

- Placer County Public Works Department
- Placer County Planning Department
- Placer County Office of Emergency Services

The following is a summary of the known existing problem areas due to flooding. It should be noted that this list may not be conclusive and does not include areas of local flooding not attributed to stream flow. It is also possible that more bridges and culverts were overtopped than are included in this list but do not pose a hazard or cause damage to the structure, and have not been reported to the County.

<u>Dry Creek Watershed</u>

Bowman Road Bridge at Dry Creek
Dry Creek Road adjacent to Dry Creek
Dry Creek Road and Haines Road at Dry Creek
Bell Road Bridge at Dry Creek
Blue Grass Road at Dry Creek
Twin Pines Trail at Dry Creek
Howe Road at Dry Creek Tributary
Hubbard Road at Dry Creek Tributary

Rock Creek Watershed

Sherwood Way at Rock Creek
Highway 49 Bridge at Rock Creek
Joeger Road at Rock Creek
Richardson Road at Rock Creek
Rock Creek Road at Rock Creek
New Airport Road at Rock Creek
New Airport Road at Rock Creek Tributary

Orr Creek Watershed

Christian Valley Road at Orr Creek
West Stanley Drive at Orr Creek
Lone Star Road at Orr Creek Tributary

North Ravine Watershed

Vada Ranch Road at North Ravine
Calnick Lane at North Ravine
Warren Way at North Ravine
Millertown Road at North Ravine
Mt. Vernon Road at North Ravine
Harris Road at North Ravine
Vista Roble Road at North Ravine
Kemper Road at North Ravine
Millertown Road at North Ravine Tributary
Mt. Vernon Road at North Ravine Tributary
Bar Ranch Road at North Ravine Tributary

Auburn Ravine Watershed

Stonehouse Road and Forgotten Road at Auburn Ravine

SUMMARY OF 100-YEAR STORM PROBLEMS

The following sections summarize the problems that were identified in the watershed based on HEC-1 and HEC-2 model runs using both the Base (present) and the Future Condition land use as described in Section 2.

For the purposes of this study, overtopping of culverts and bridges were determined using two methods.

1. Where HEC-2 model input data were available, the HEC-2 model and its associated bridge and culvert routines were used to determine the flow at which a bridge or culvert overtopped.
2. In stream reaches where the HEC-2 model was not developed, the Federal Highway Administration (FHWA) standard culvert formulas and nomographs were used to

determine the capacity of the bridge or culvert. Due to the relatively steep slopes throughout the study area, the structures were analyzed as inlet control structures.

After the bridge and culvert capacities were determined, they were compared against the 2-Year, 10-Year, 25-Year and 100-year flood flows (present and future conditions) at the same locations, given in Table 2-7. The capacity of the bridge or culvert was next subtracted from the flood flow and any remaining flow was entered in Table 3-1. It is important to note, however, that overtopping alone does not necessarily mean that damage will occur to the road surface or structure itself. It does mean that traffic on the roadway, and in particular emergency traffic, may be severely impeded and a serious safety hazard may exist.

The extent of the upstream floodplain that is affected by backwater from undersized culverts and bridges is hard to determine without detailed survey information indicating the elevation of the floodplain and dwellings and other buildings that may be in the floodplain. This detailed type of information was not collected as a part of this study and hence, was not possible to review in detail.

Existing Problems, Based on 1990 Land Use

Flooding problems that would occur in the watershed with the present base land use conditions and the 100-year design storm are classified as existing problems.

Bridges and Culverts - Overtopping and Backwater. Table 3-1 contains a listing of all bridges and culverts, with an indication next to those that have insufficient capacity to pass the design storms without going over the top of the roadway. The numbers in the table indicate the magnitude, in cfs, of the peak flow over the roadway at that location. A blank in the table indicates that the culvert or bridge has sufficient capacity to pass the flood.

The table indicates that over 70 percent of the bridges and culverts in the watershed are inadequate to pass the 100 year flood without overtopping under present land use conditions. Over 60 percent of the stream crossings are inadequate for even the 25-year flood.

Floodplain. The 100-year floodplains for Orr Creek, Rock Creek, Dry Creek and North Ravine were delineated on USGS 1:24,000 topographic maps based on flows developed from HEC-1 utilizing the 100-year design storm (with present land use conditions). The HEC-2 hydraulics model was then used in conjunction with the HEC-1 model to develop the water surface profiles and the associated floodplain for the 100-year flood. The water surface profiles for Orr Creek, Dry Creek, Rock Creek, and North Ravine are presented in Figures 3-1 to 3-4 respectively. The corresponding floodplains are delineated on Figures 3-5a to 3-5c. As shown on the figures, the floodplain for each of the streams is relatively narrow (average 200 to 300 feet wide) and the 100-year flood would probably impact few structures. However, the actual number of structures in the floodplain has not been identified.

TABLE 3-1
BRIDGE AND CULVERT OVERTOPPING TABLE

CROSSING NUMBER	STREAM	CROSSING	CROSSING CAPACITY (CFS)	2-YEAR		10-YEAR		25-YEAR		100-YEAR	
				PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)
2	**ORR CREEK**	BELL RD.	5291								
5		HWY 49 (State)	3107								
7		W. STANLEY DR.	1800							231	275
9		E. STANLEY DR.	1800								
11		CHRISTIAN VALLEY RD.	210	55	61	613	628	848	867	1204	1225
15	**ORR CK TRIB #1**	LITTLE CREEK RD. (Private)	45			1	4	13	16	31	35
16	**ORR CK TRIB #2**	VIRGINIA WAY	110			84	84	140	140	224	224
17		KENNETH WY. (Private)	210							18	18
18	**ORR CK TRIB #3**	LONE STAR RD.	35	111	111	266	266	340	340	460	460
20	**DRY CREEK**	BELL RD.	2917					893	991	2594	2721
23		HWY 49 (State)	8125								
25		BLUE GRASS RD.	1800					134	212	855	959
28		DRY CK. ROAD	2312								
29		TWIN PINES TR. (Private)	200	169	171	856	862	1179	1184	1677	1676
30		HAINES RD.	1100					71	65	489	480
32		BOWMAN RD.	600			102	102	298	298	596	595
33		LAKE ARTHUR RD.	1040							61	64
34		LAKE ARTHUR RD.	1100								
36	**DRY CK TRIB #1**	DRY CREEK RD.	15	4	5	23	25	33	36	49	52
37	**DRY CK TRIB #2**	DRY CREEK RD.	220				10	8	72	84	166
38	**DRY CK TRIB #3**	BLACK OAK RD.	110			93	98	146	151	228	234
39	**DRY CK TRIB #4**	DRY CREEK RD	100								

TABLE 3-1 (continue)

CROSSING NUMBER	STREAM	CROSSING	CROSSING CAPACITY (CFS)	2-YEAR PRESENT (CFS)	2-YEAR FUTURE (CFS)	10-YEAR PRESENT (CFS)	10-YEAR FUTURE (CFS)	25-YEAR PRESENT (CFS)	25-YEAR FUTURE (CFS)	100-YEAR PRESENT (CFS)	100-YEAR FUTURE (CFS)
40	**DRY CK TRIB #5**	JOEGER RD.	2625								
41	**DRY CK TRIB #6**	HOWE RD. (Private)	100	138	182	379	457	500	590	689	801
42		HUBBARD RD. (Private)	700							37	146
43		JOEGER RD.	45	1	32	51	104	75	141	113	199
45	**ROCK CREEK**	JOEGER RD.	3860								
46		SHERWOOD WY.	977			42	310	335	719	796	1283
47		DRY CREEK RD.	2387								
48		RICHARDSON RD.	696			226	453	499	870	900	1392
49		HWY 49 (State)	1368						12	22	493
50		ROCK CREEK RD.	290	104	106	176	209	313	351	482	522
53		BELL RD.	1346								
54		NEW AIRPORT RD.	405							54	108
55		CRYSTAL SPRINGS RD.	602								
57		CREEKVIEW CT.	450								
60	**ROCK CK TRIB #2**	NEW AIRPORT RD.	25	82	95	194	211	249	270	333	358
61		BELL RD.	185							6	19
62	**ROCK CK TRIB #3**	LOCKSLEY LN.	30	52	92	123	191	161	244	221	331
63	**ROCK CK TRIB #4**	ROCK CREEK RD.	105	69	141	280	422	394	603	564	871
64		BELL RD.									
65	**NORTH RAVINE**	WISE RD.	3730								
66		WARREN WY. (Private)	2327						81	616	849
67		CALNICK RD. (Private)	1800				61	407	619	1108	1403
70		MILLERTOWN RD.	1172			223	381	633	856	1201	1499
71		MT. VERNON RD.	2169								380
72		HARRIS RD. (Private)	90		14	148	191	209	267	307	386
73		VISTA ROBLE RD. (Private)	228			19	105	78	185	173	313
74		ATWOOD RD.	135								

TABLE 3-1 (continue)

CROSSING NUMBER	STREAM	CROSSING	CROSSING CAPACITY (CFS)	2-YEAR		10-YEAR		25-YEAR		100-YEAR	
				PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)	PRESENT (CFS)	FUTURE (CFS)
75	**N.RAV. TRIB #1**	KEMPER RD. (Private)	8	38	53	81	107	102	134	136	179
76	**N.RAV. TRIB #2**	HIDDEN OAKS LN. (Private)									
78		HWY 49 (State)	144			62	119	115	196	212	319
79		PEAR RD. (Private)	2	85	117	162	217	202	271	266	358
80	**N.RAV. TRIB #3**	MILLERTOWN RD.	60	53	62	168	181	224	241	313	335
81		MT. VERNON RD.	100			39	47	73	84	128	141
82	**N.RAV. TRIB #4**	MILLERTOWN RD.	7	6	6	19	19	25	25	35	35
83		BAR RANCH RD. (Private)	5	5	5	15	15	19	19	27	27
85	**AUBURN RAVINE**	N. RAVINE CONFLUENCE									
86		WISE RD.	2400				139	593	785	1900	2029
87		OPHIR RD.	3600							617	749
88		OPHIR RD.	6000								
89		FORGOTTEN RD. (Abandoned)	1000	19	192	1236	1440	1811	2038	2916	3088
93	**DUTCH RAVINE**	AUBURN-FOLSOM RD.	175								
94	**MORMON RAVINE**	SHIRLAND RD.	65								
95	**MORMON R. TRIB**	NO NAME RD	18	48	52	120	127	156	164	210	222
96		ANDREGG RD.	35	7	13	50	60	71	83	104	120
97	**AMER.R.TRIB #1**	HWY 49 (State)	120			35	35	74	74	137	137
98	**AMER.R.TRIB #2**	HWY 49 (State)	25	3	3	31	31	44	44	67	67
99	**DEADMAN CANYON**	JOEGER RD.	270				36	48	110	147	228
100		OAK CREEK CT.	300								

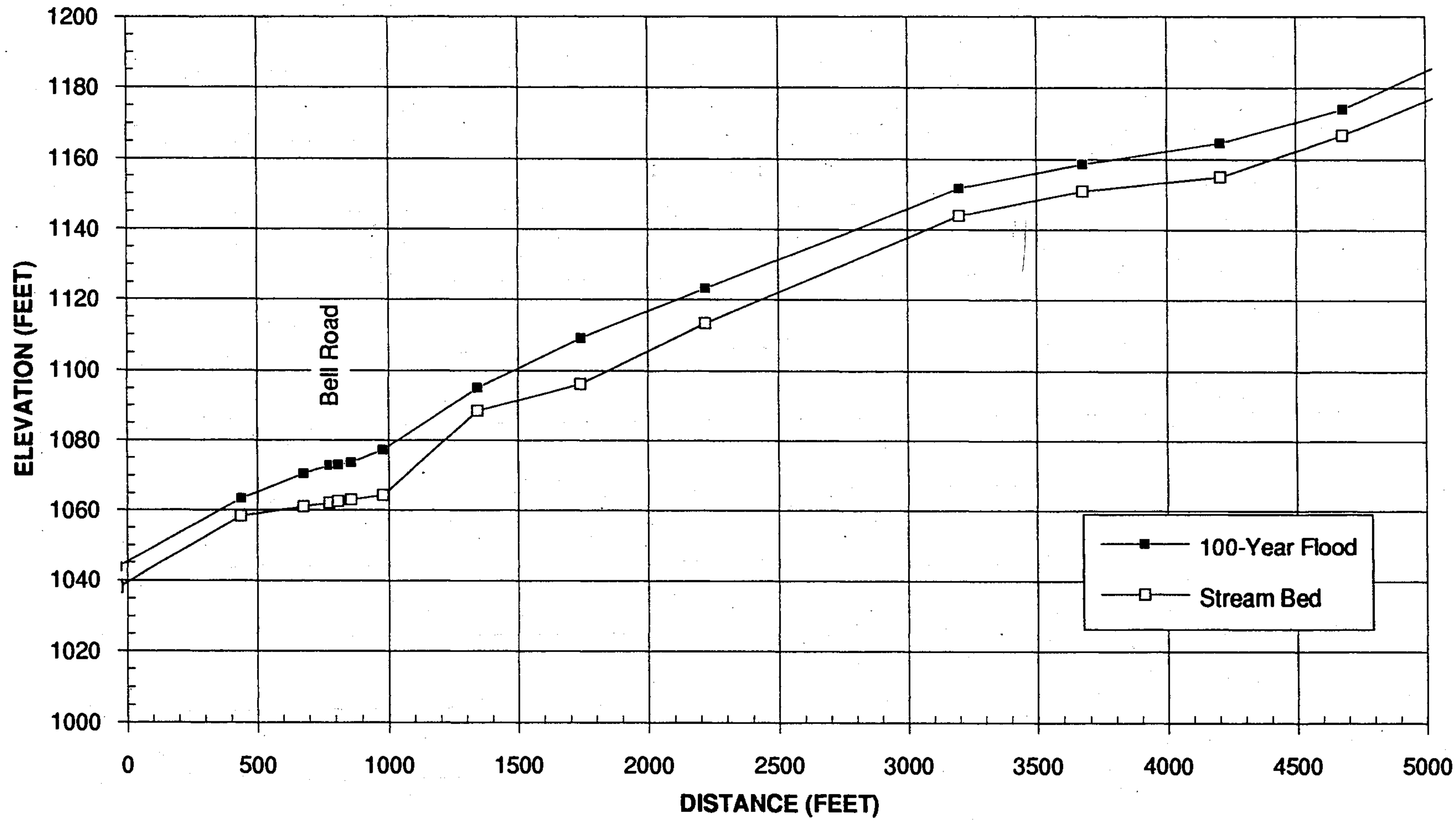


FIGURE 3-1
ORR CREEK 100-YEAR FLOOD PROFILE

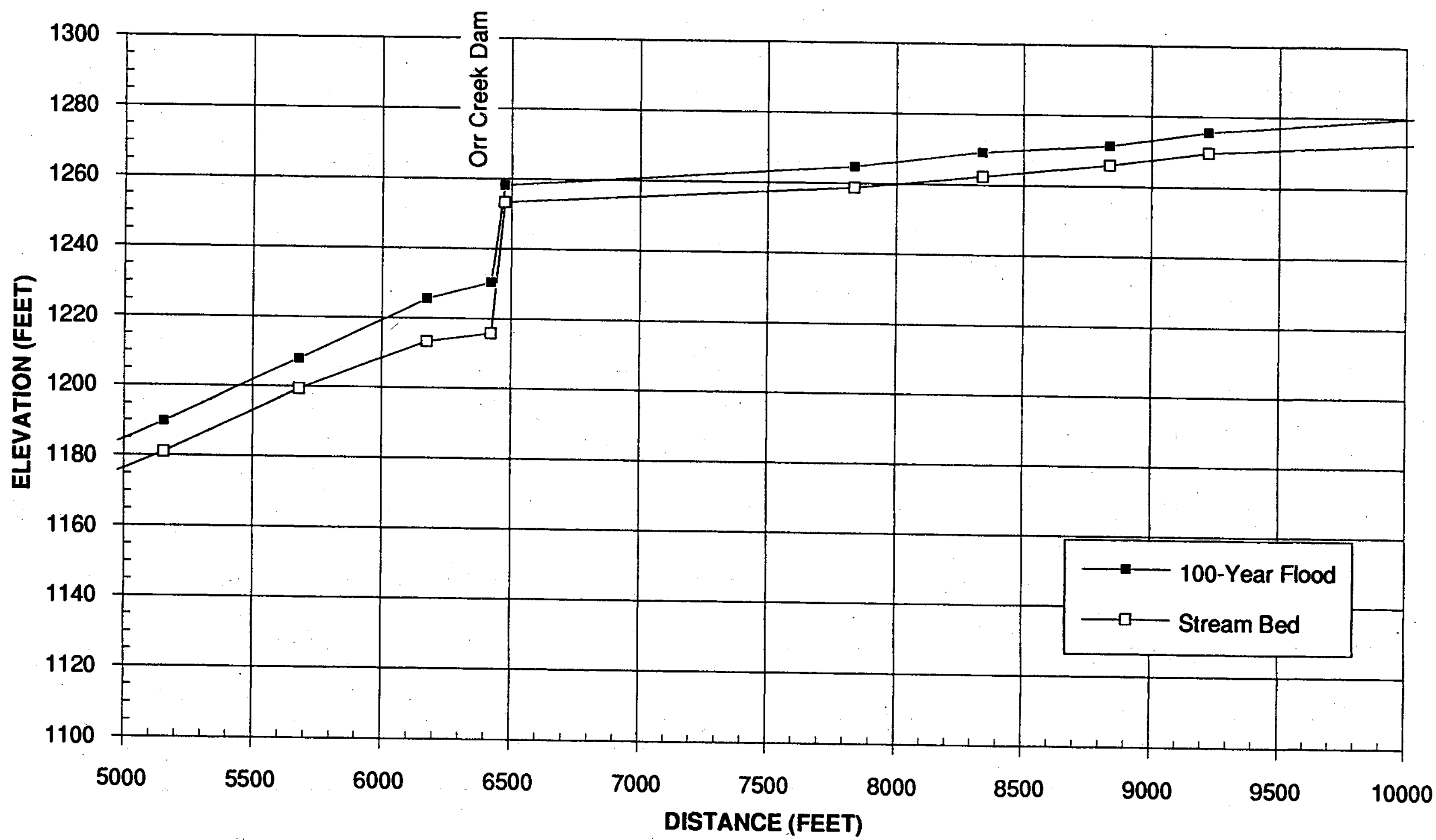
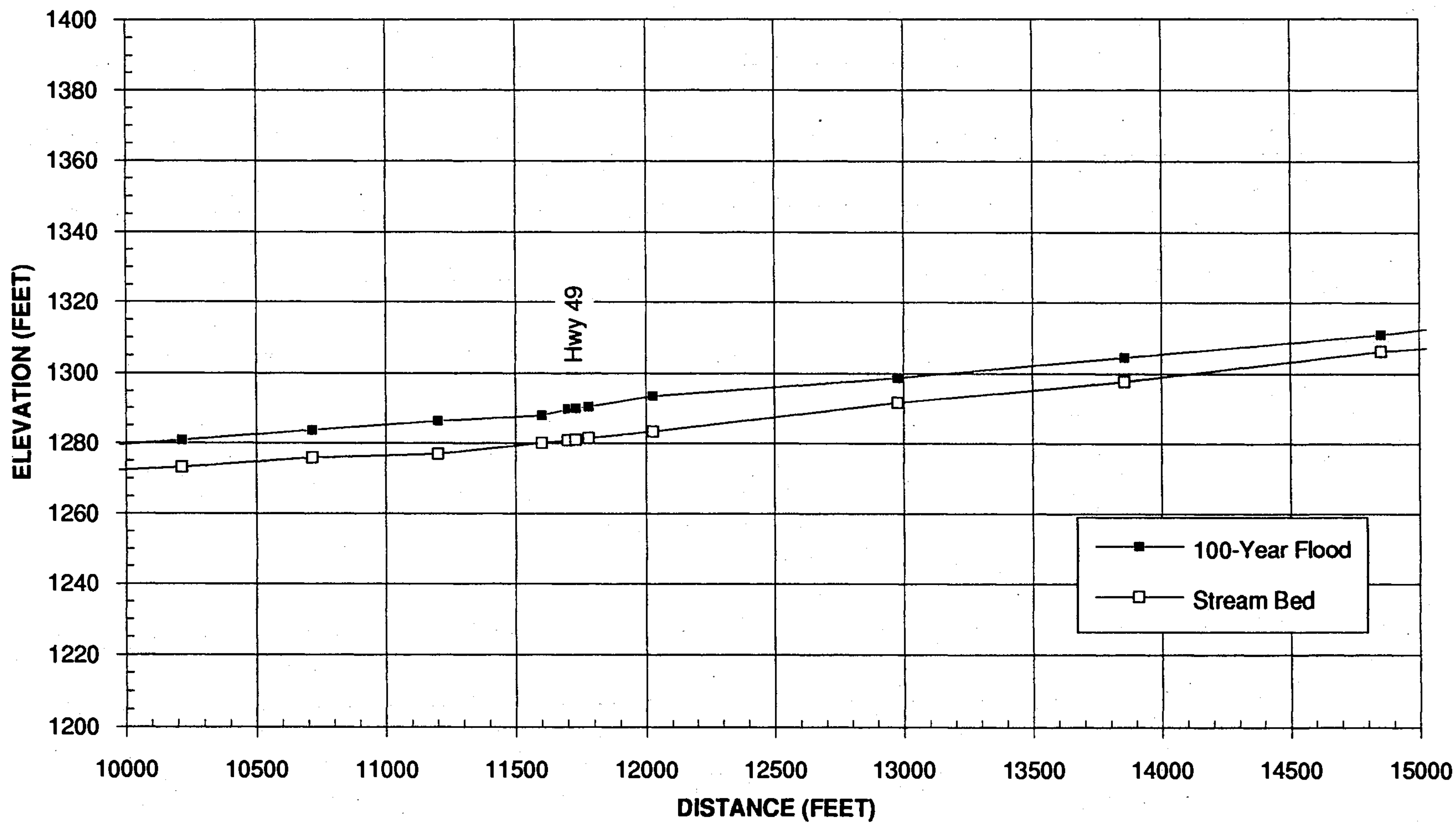


FIGURE 3-1 (continued)



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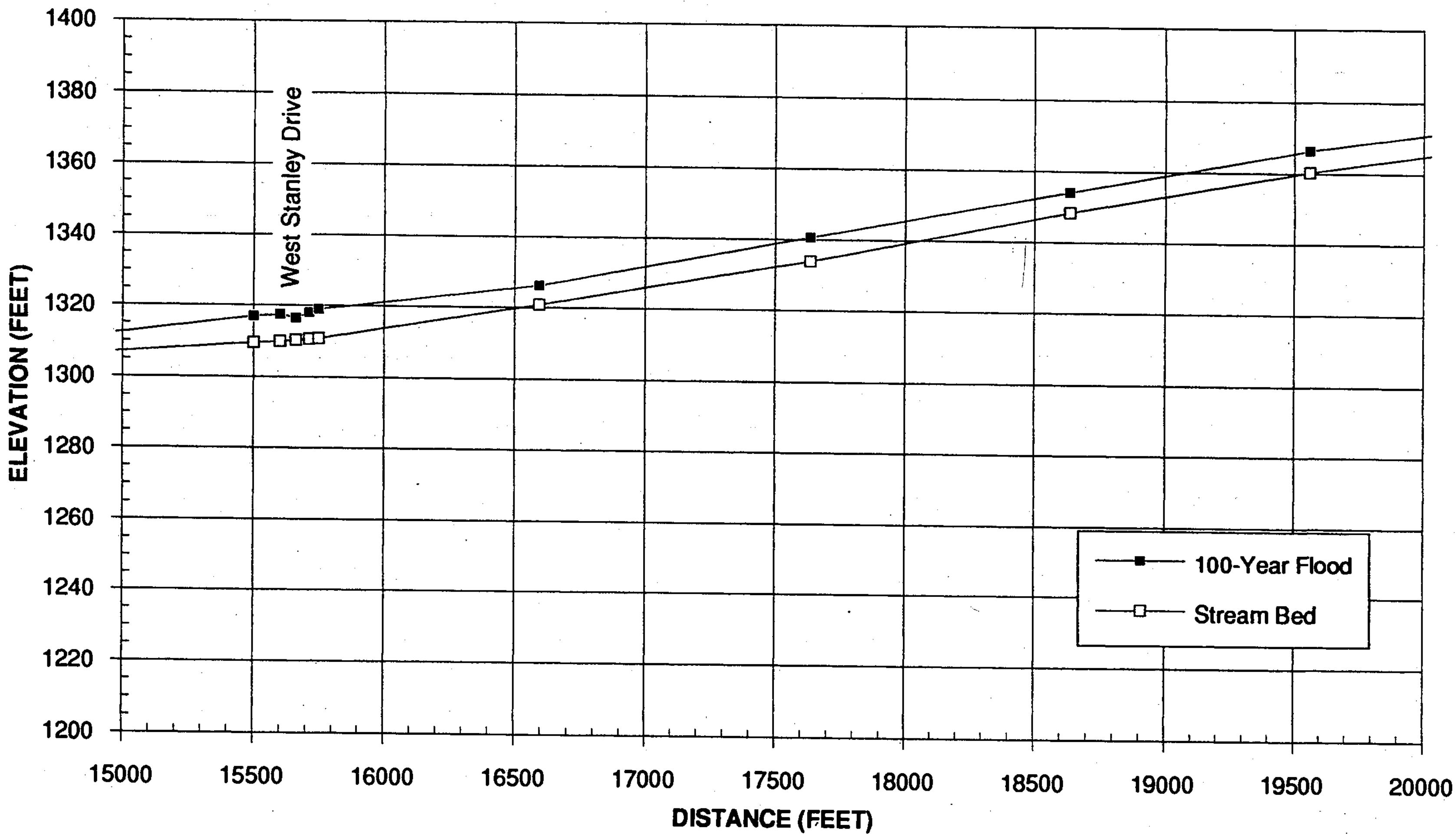


FIGURE 3-1 (continued)

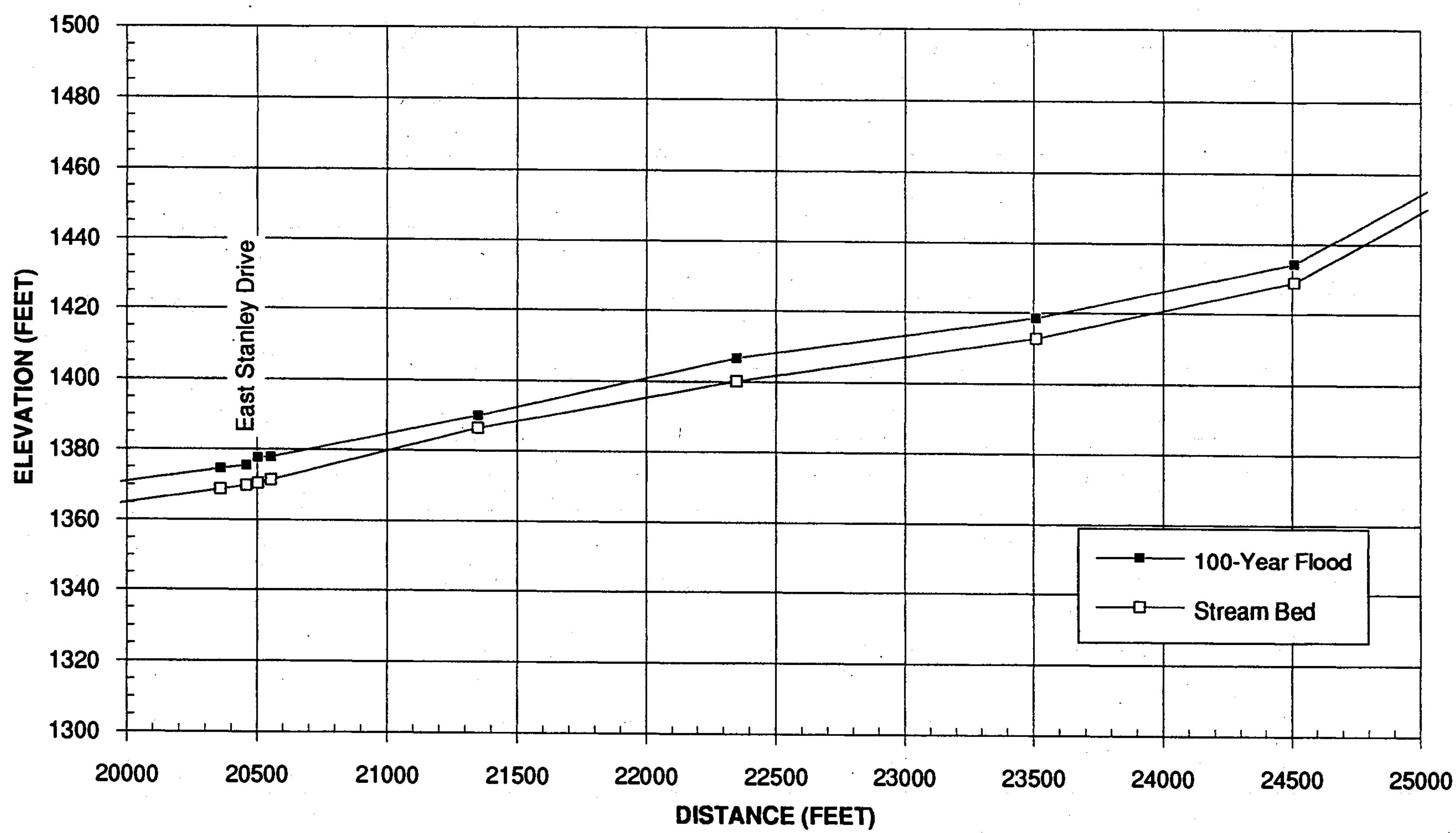


FIGURE 3-1 (continued)

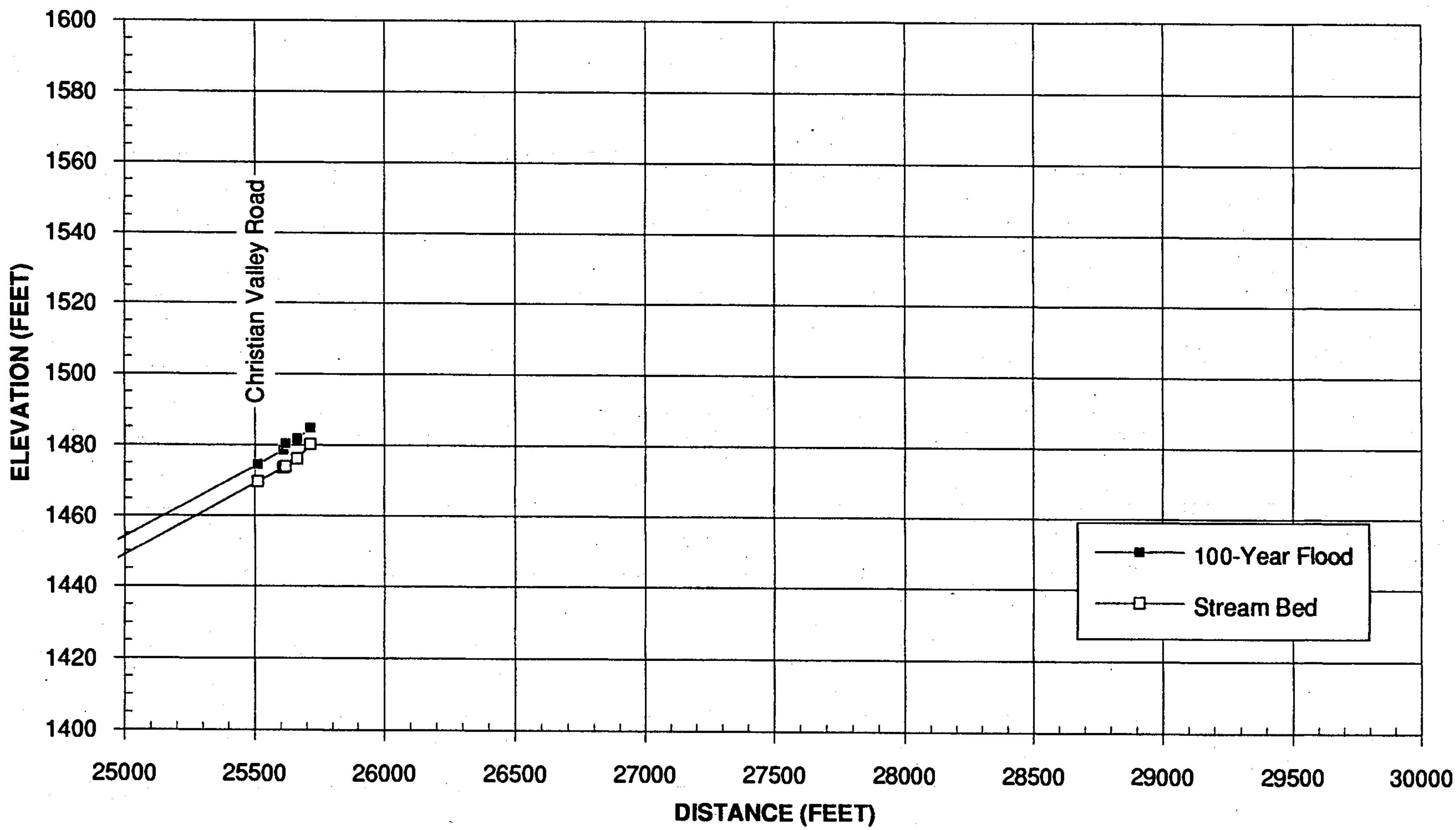


FIGURE 3-1 (continued)

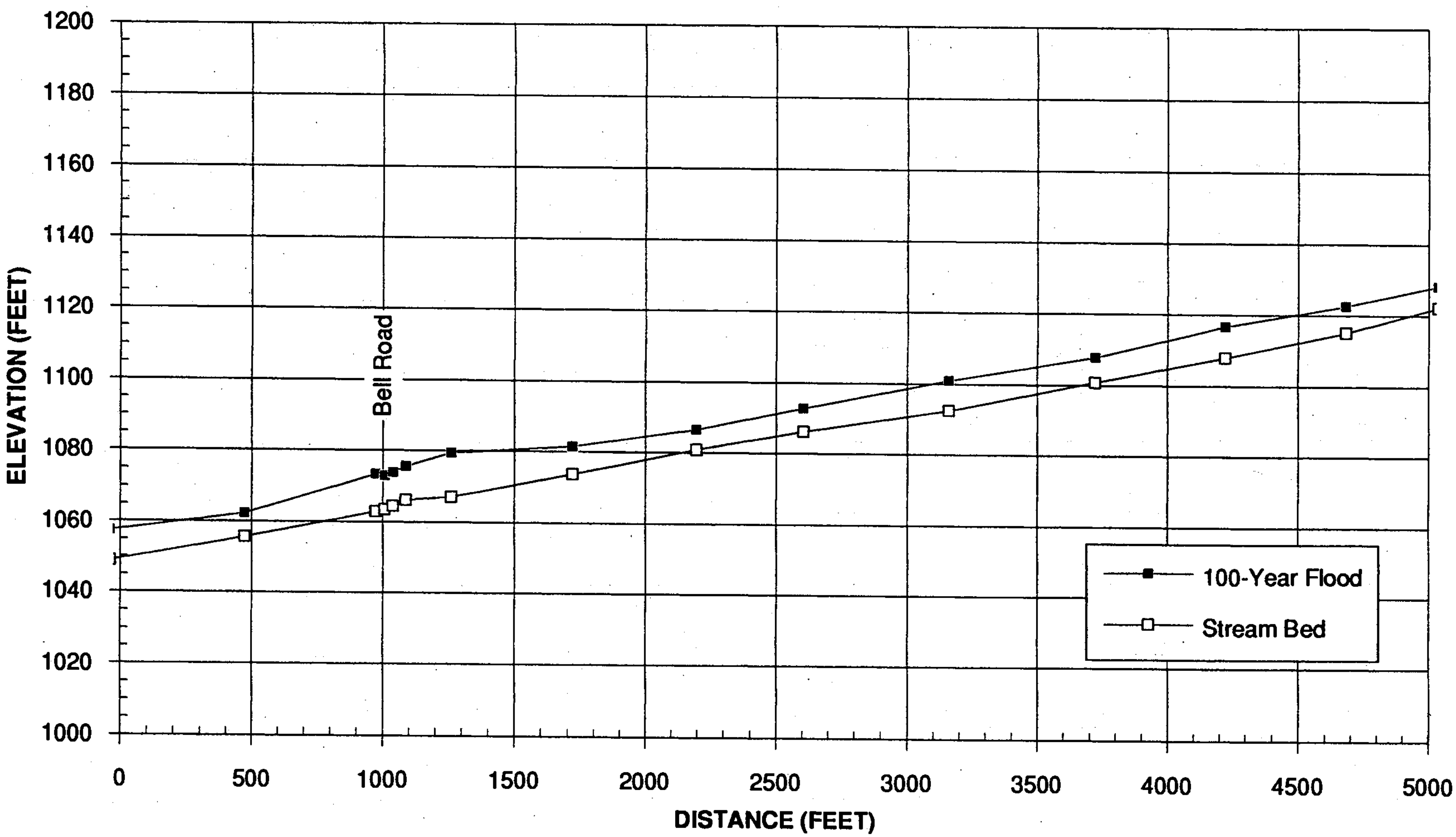


FIGURE 3-2
DRY CREEK 100-YEAR FLOOD PROFILE

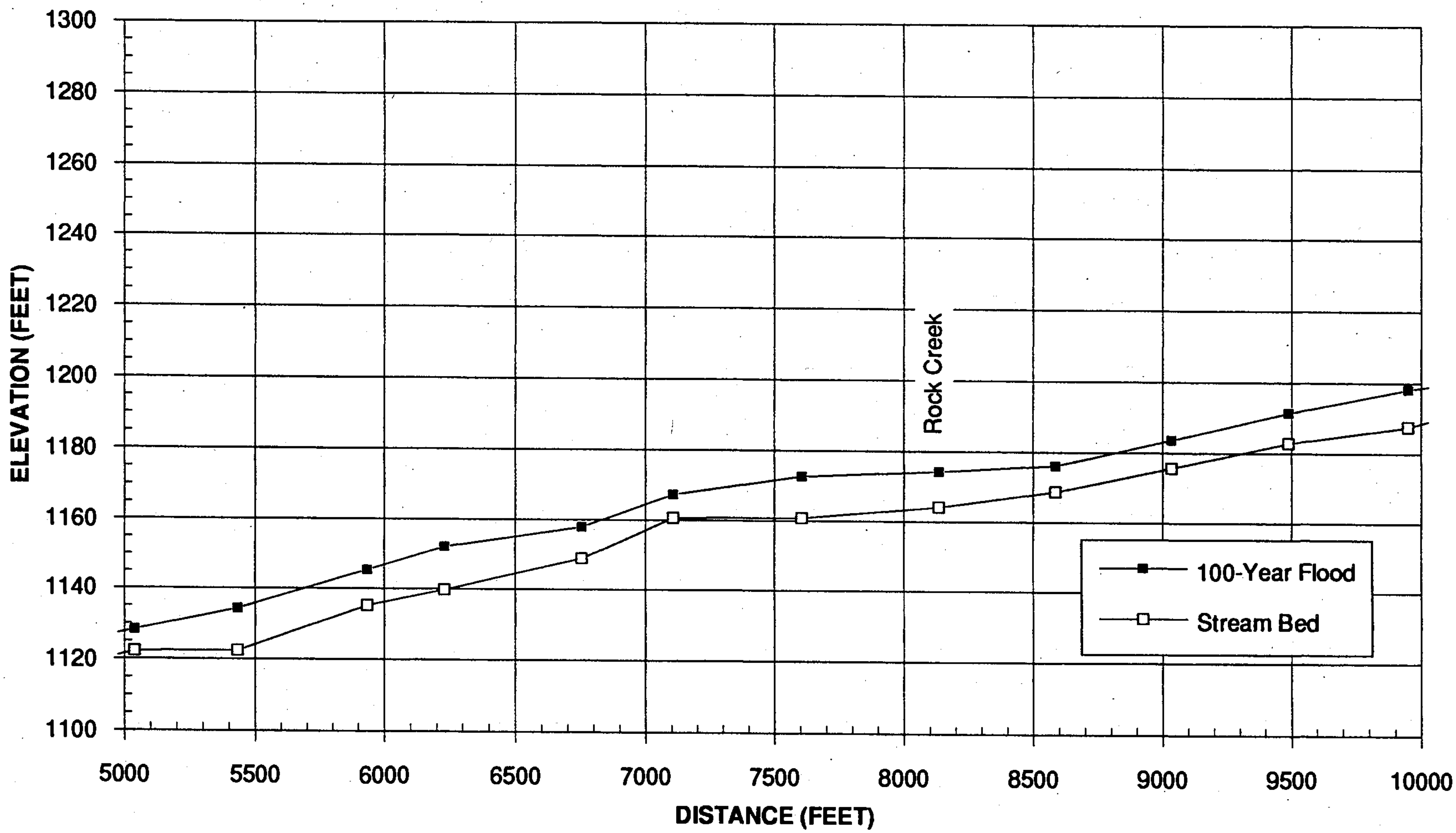


FIGURE 3-2 (continued)

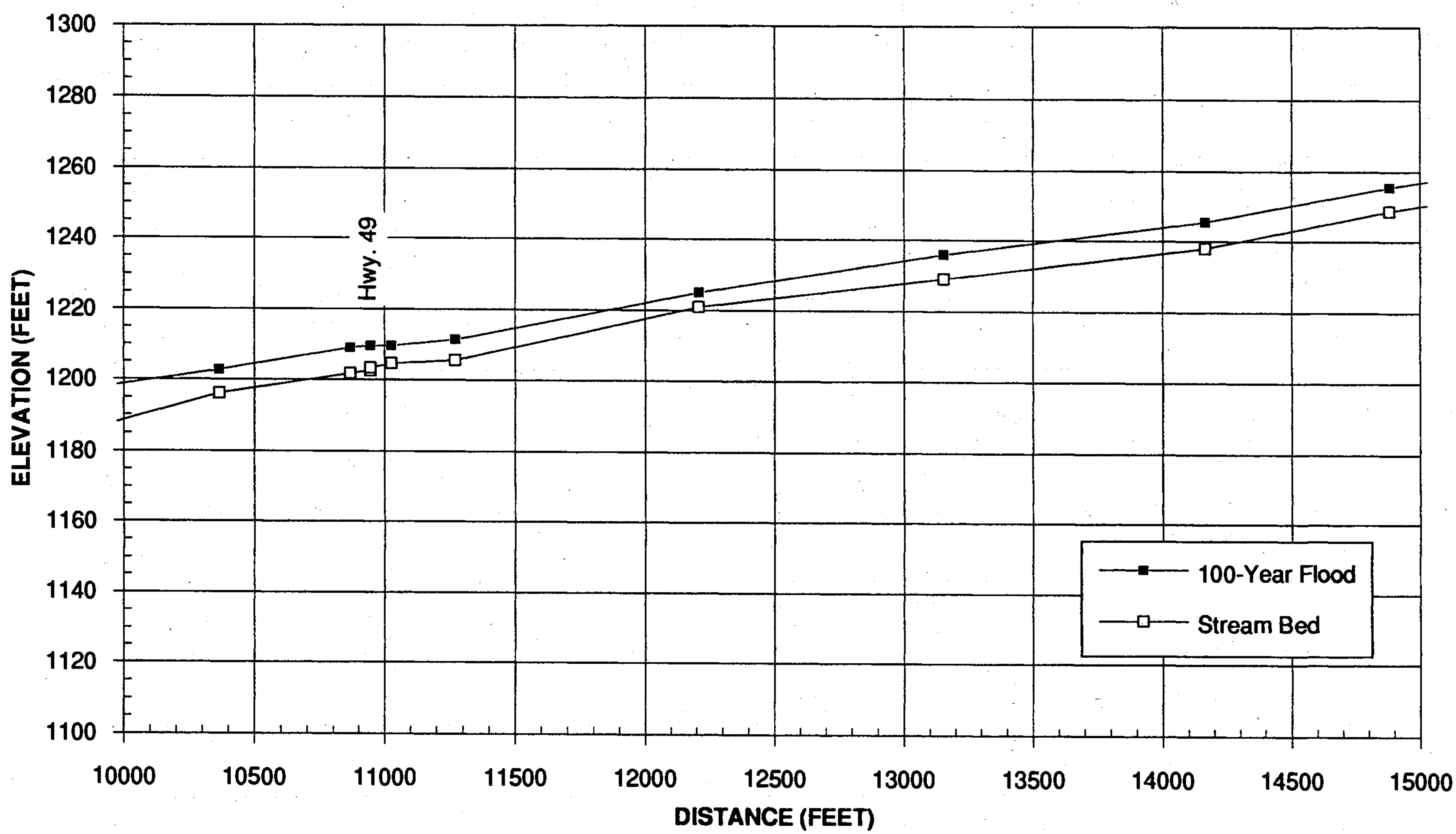
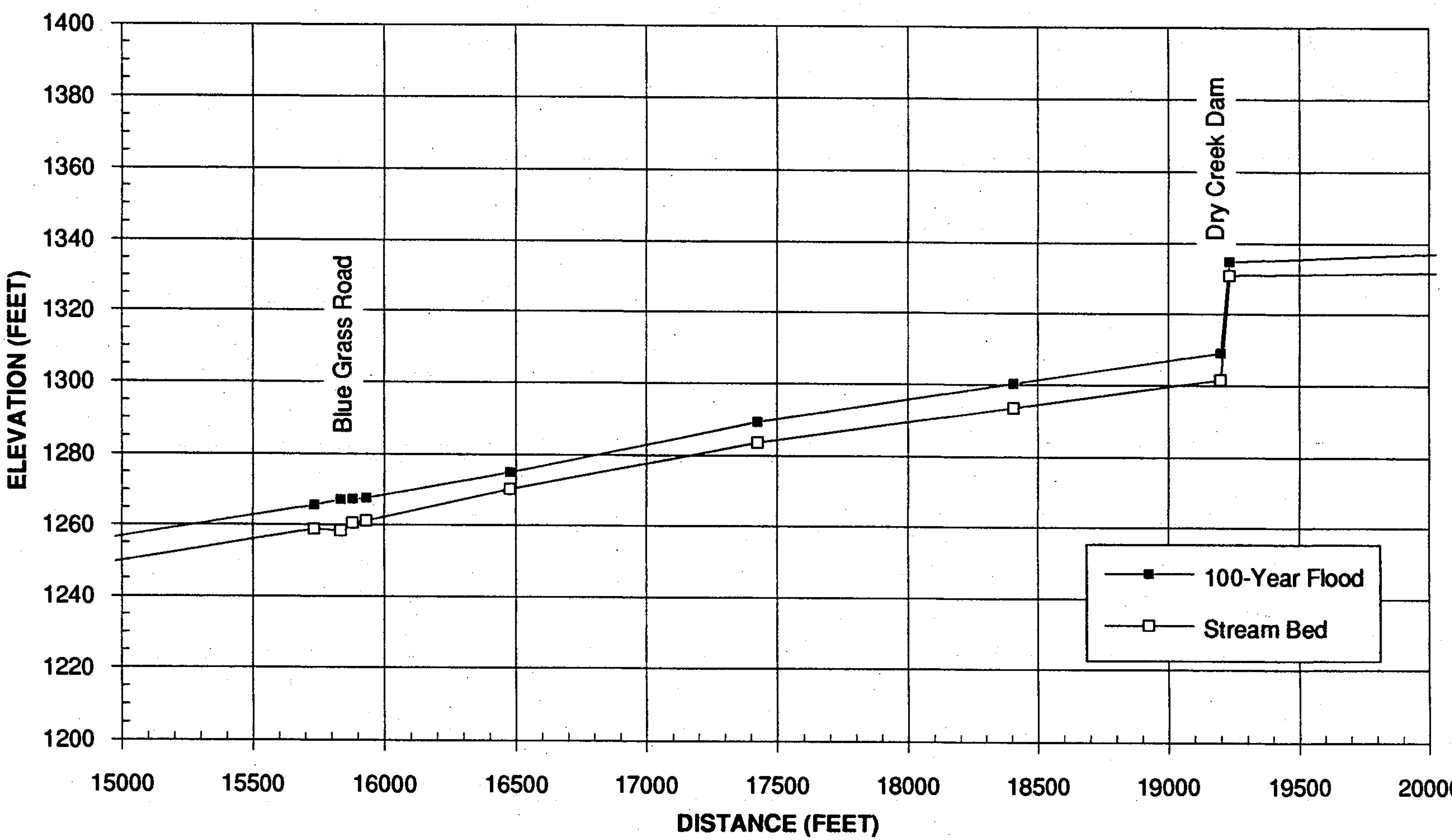


FIGURE 3-2 (continued)



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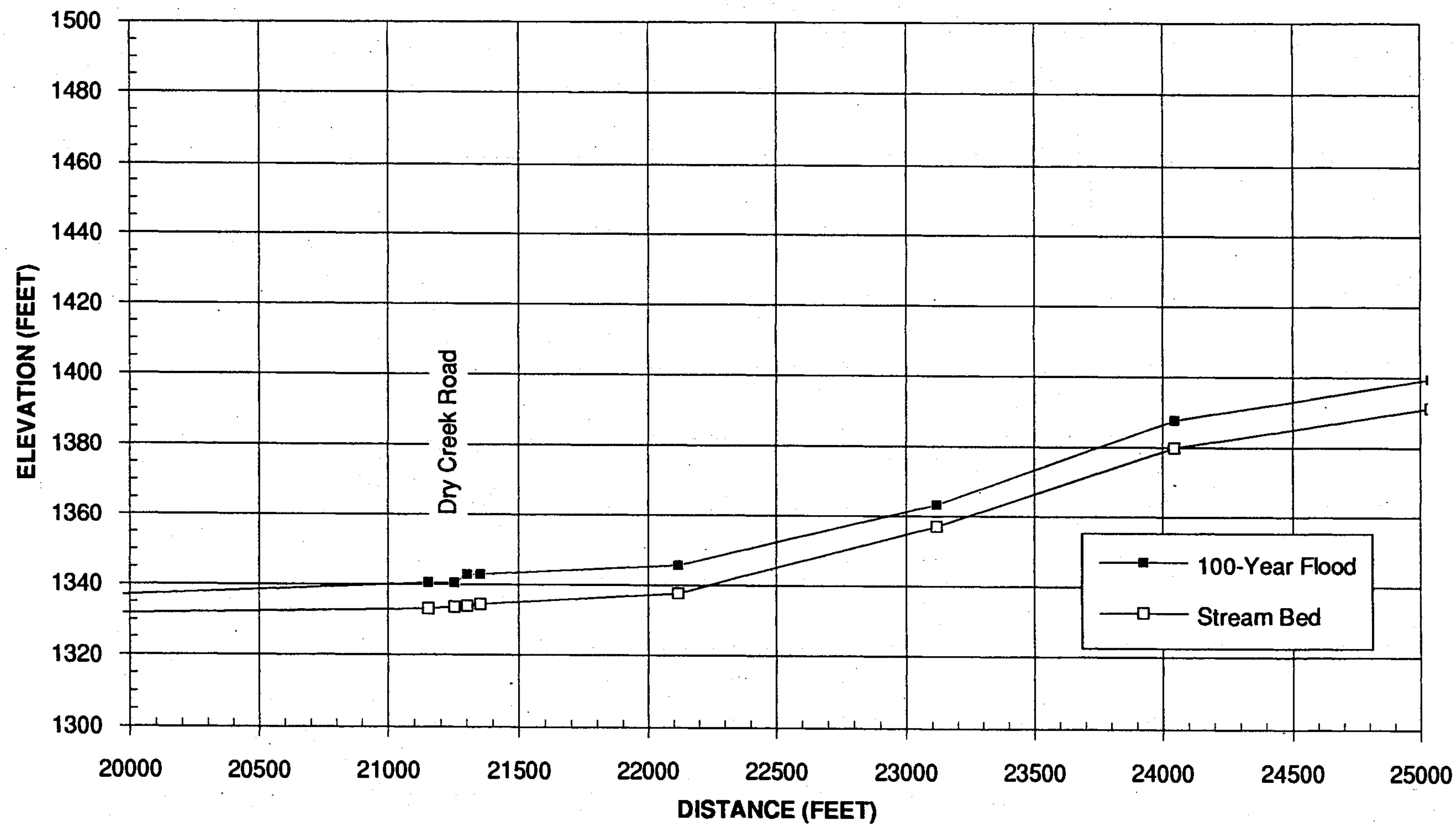

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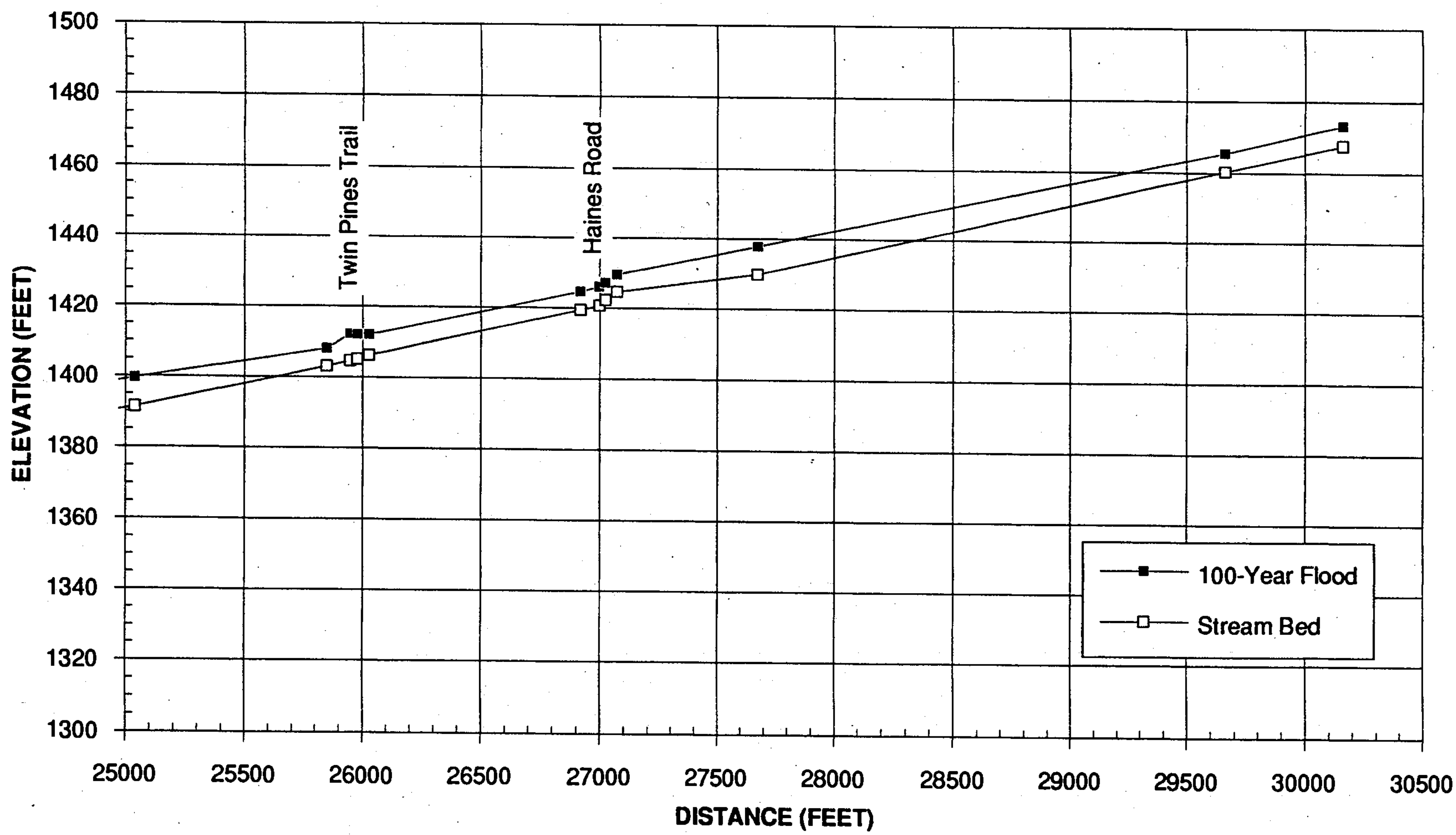

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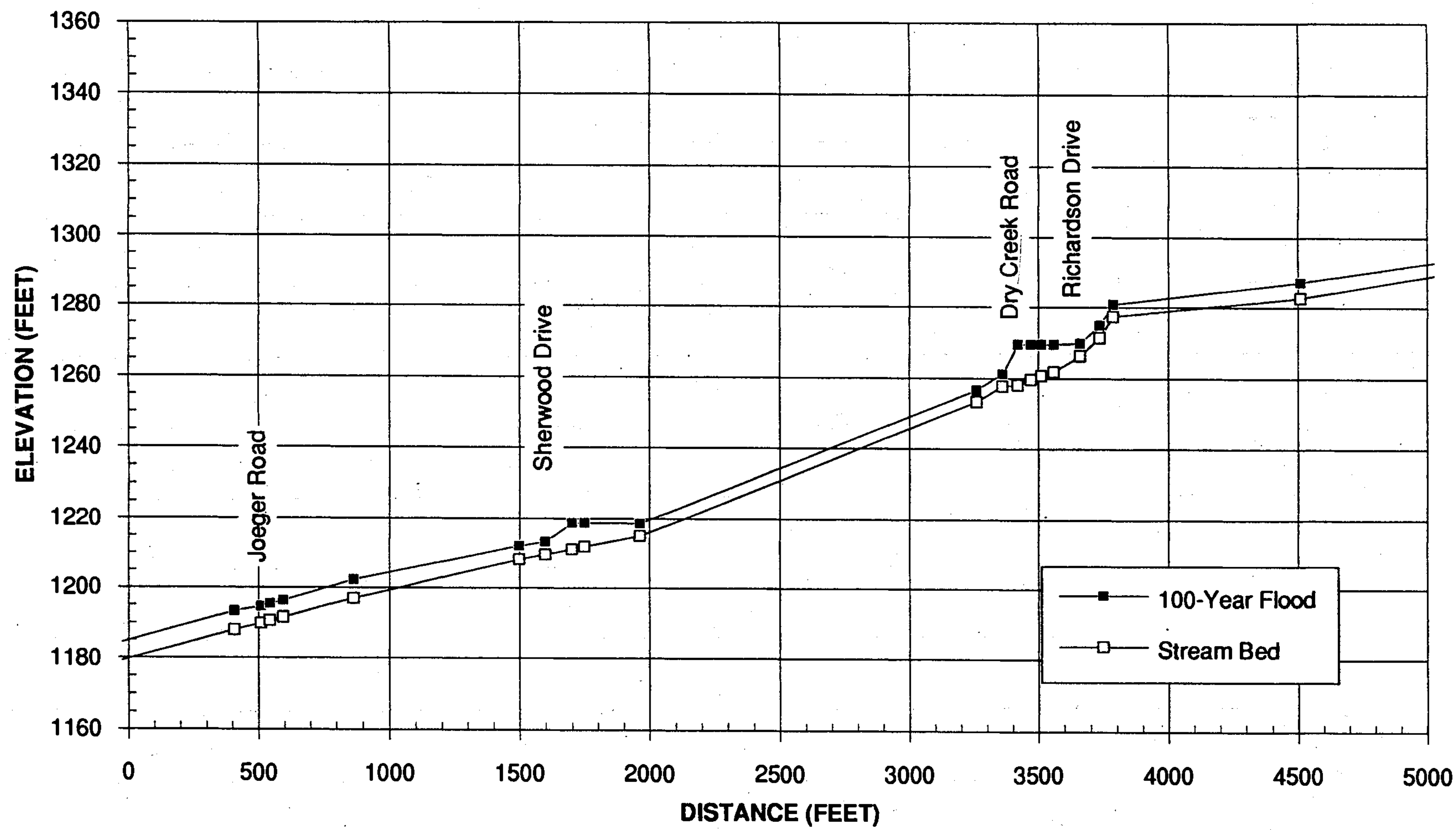


FIGURE 3-3
ROCK CREEK 100-YEAR FLOOD PROFILE

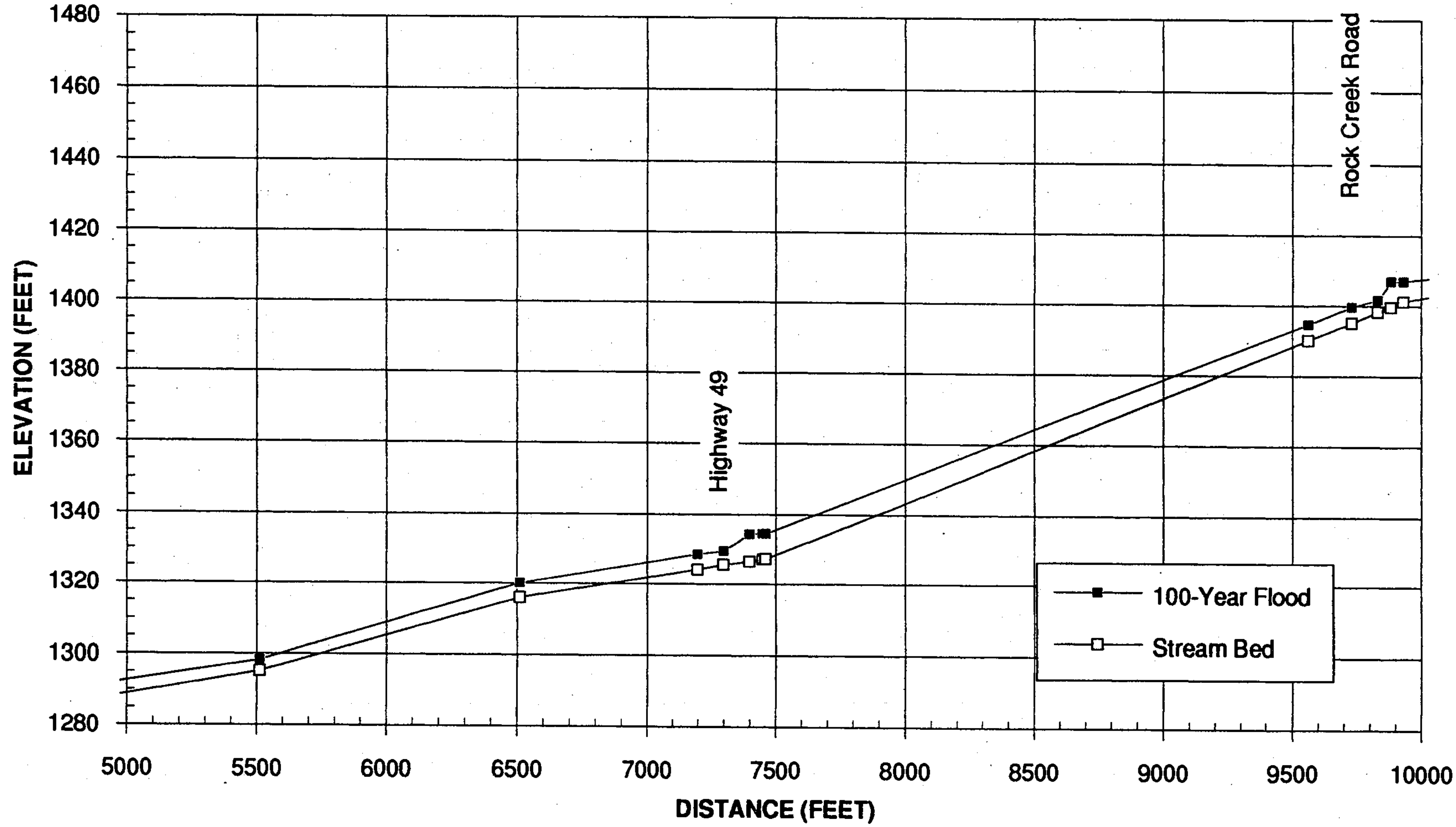


FIGURE 3-3 (continued)

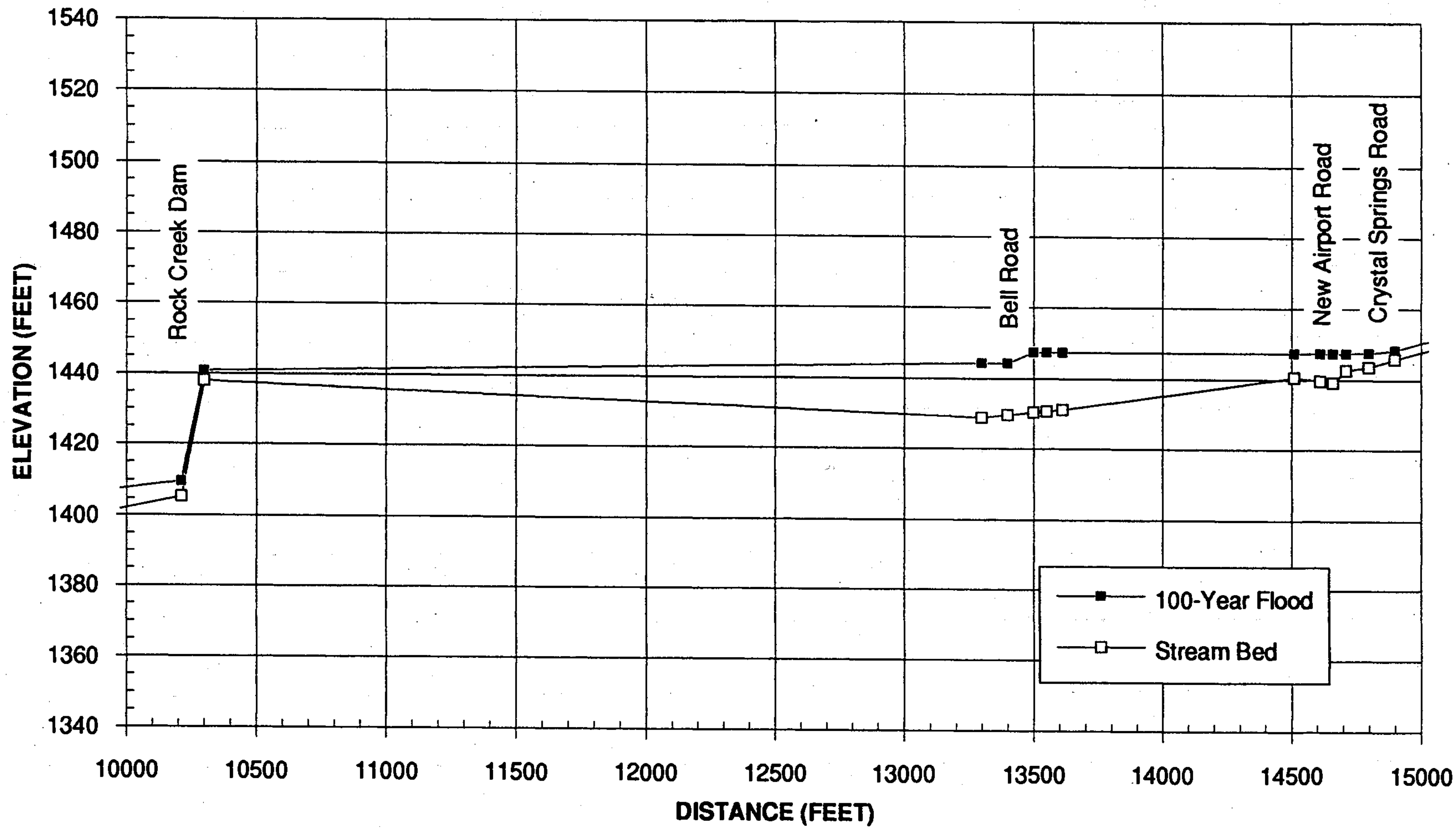


FIGURE 3-3 (continued)

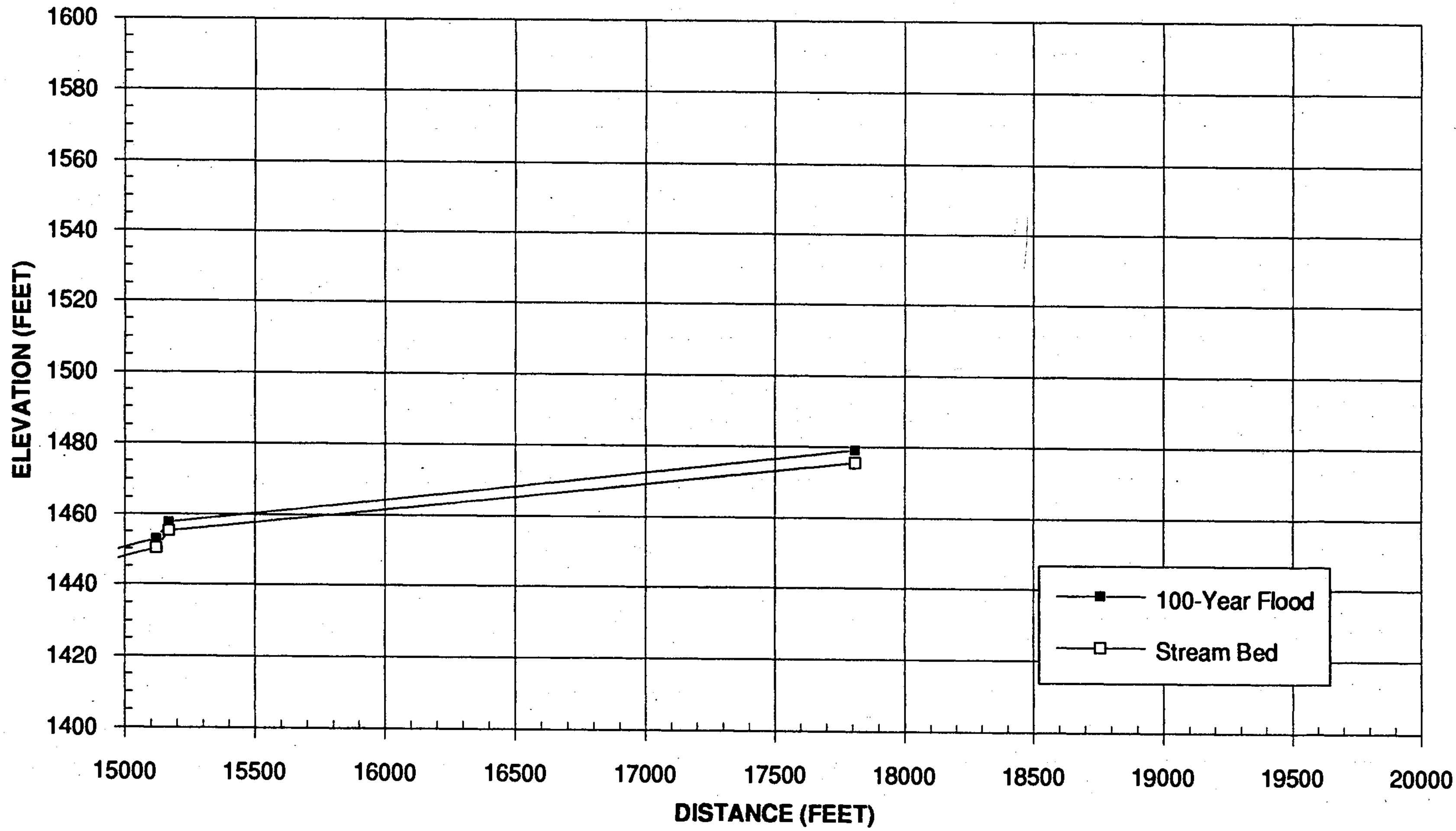


FIGURE 3-3 (continued)

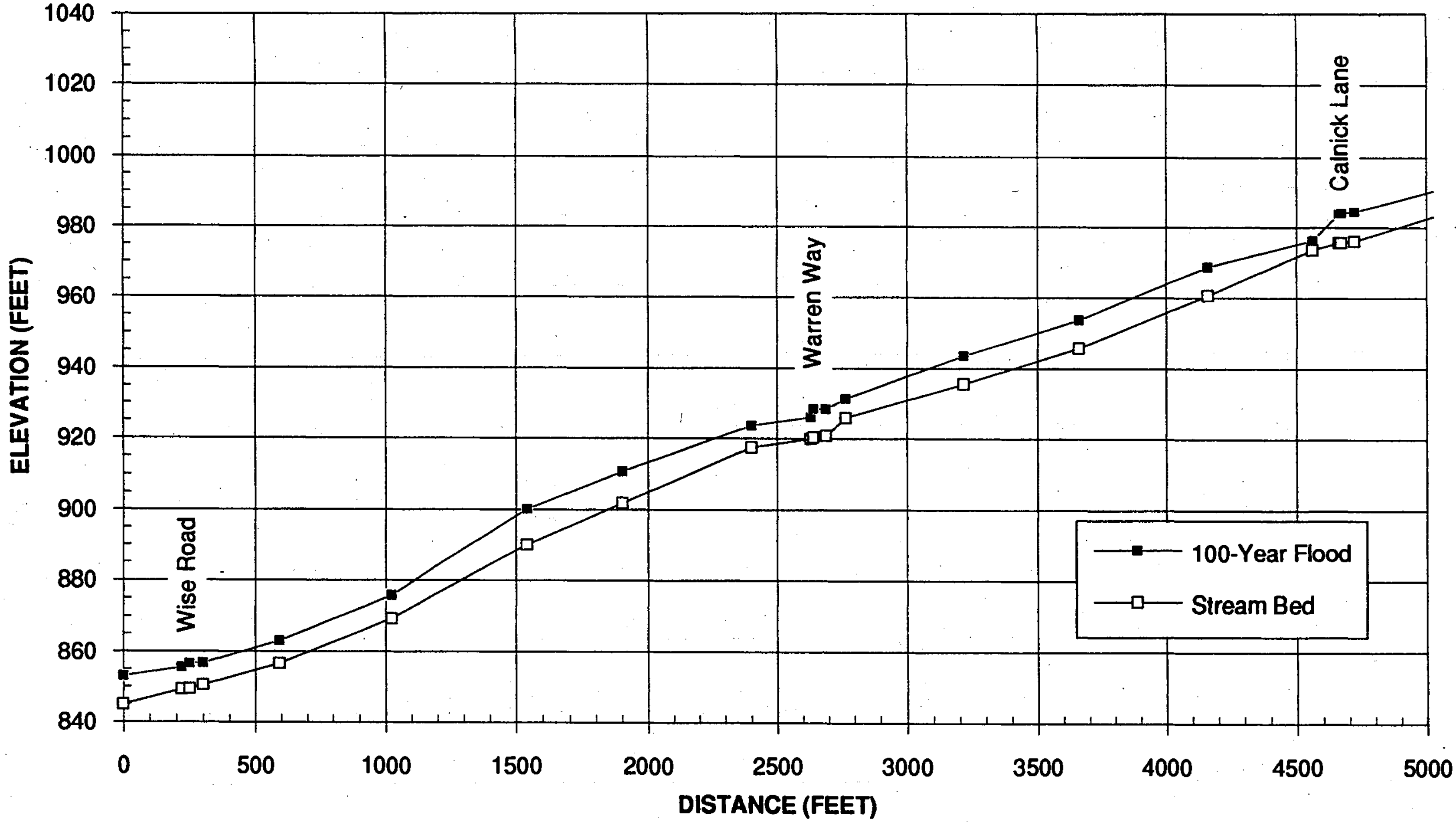


FIGURE 3-4
NORTH RAVINE 100-YEAR FLOOD PROFILE

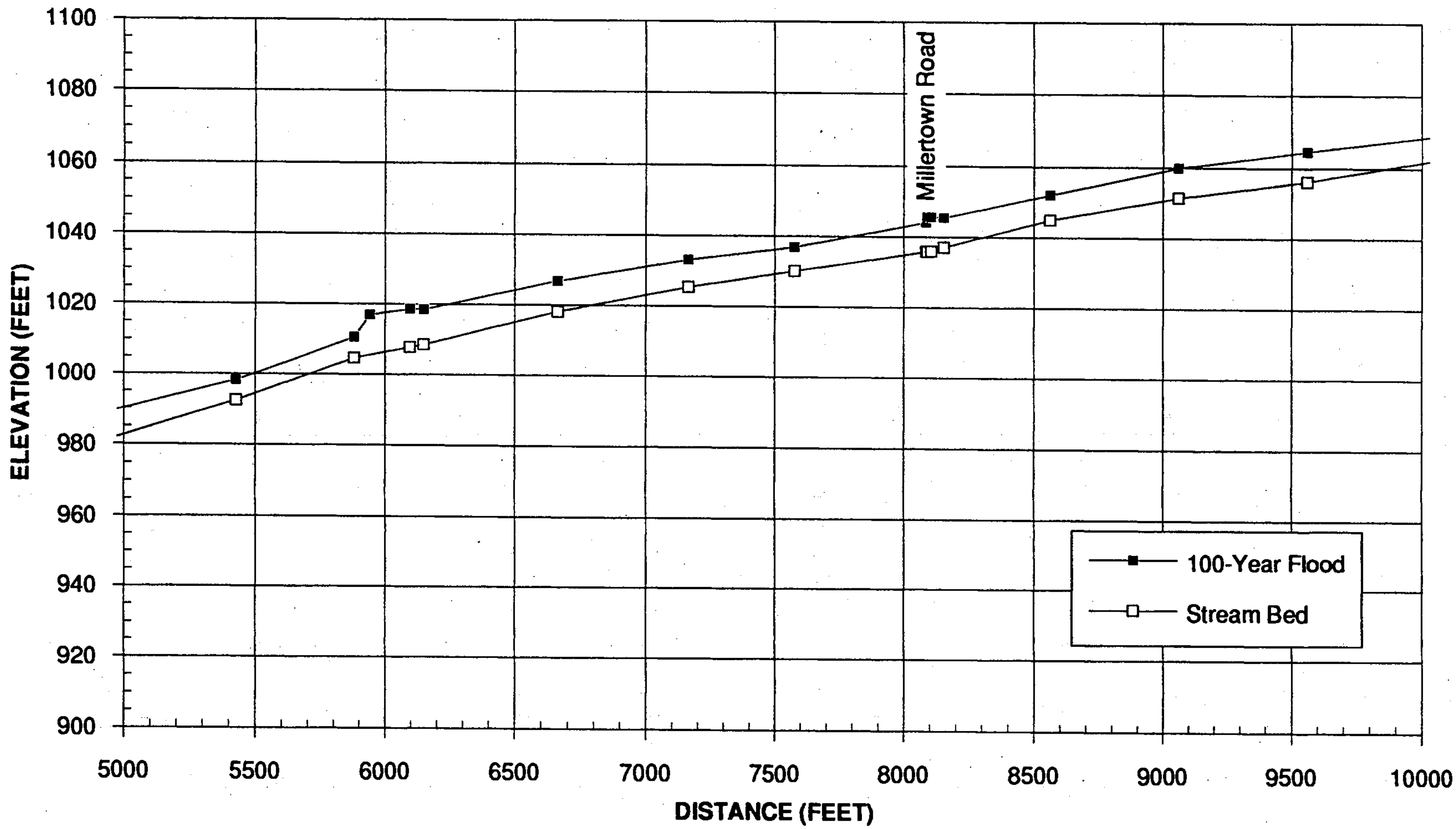


FIGURE 3-4 (continued)

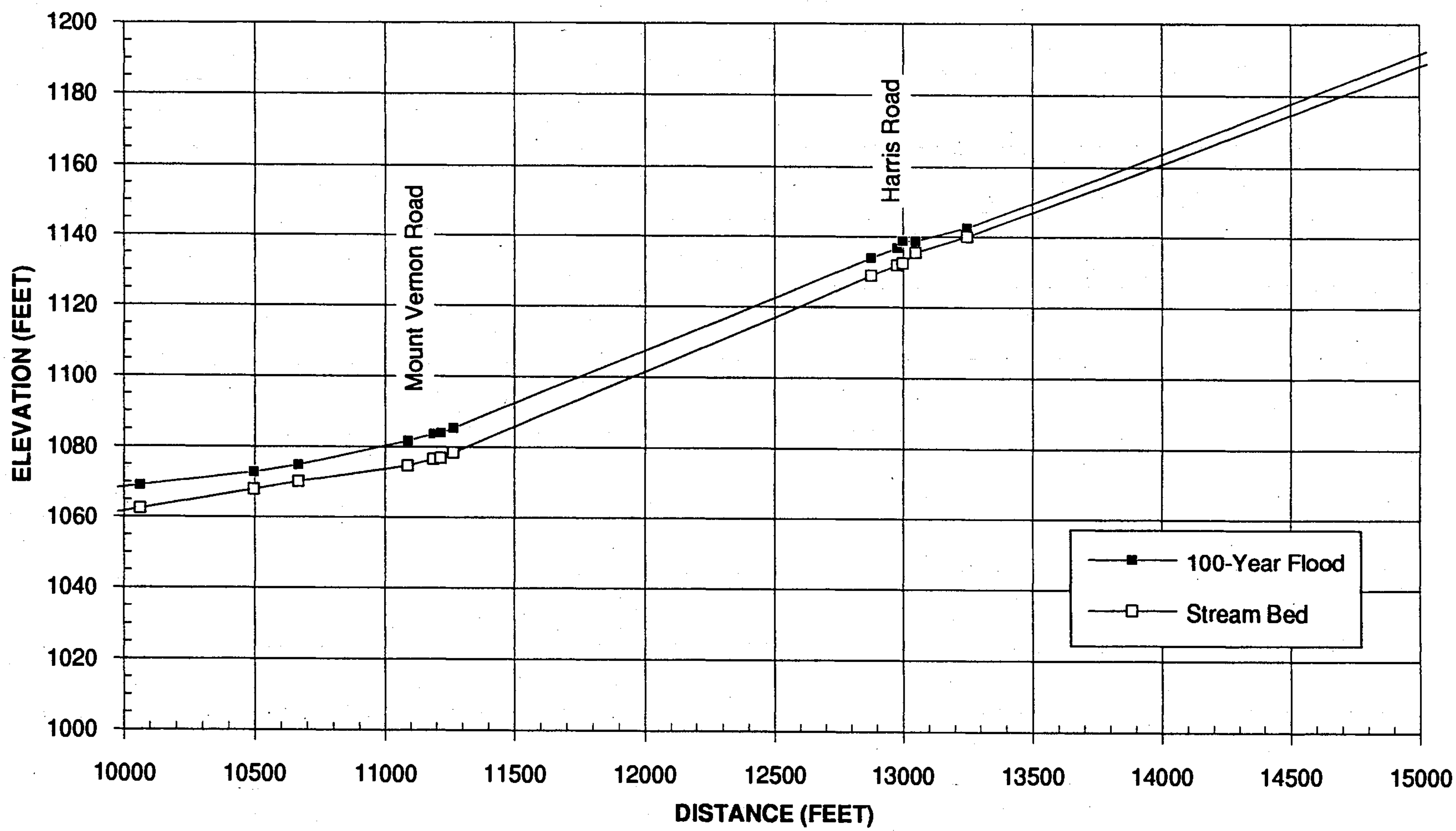


FIGURE 3-4 (continued)

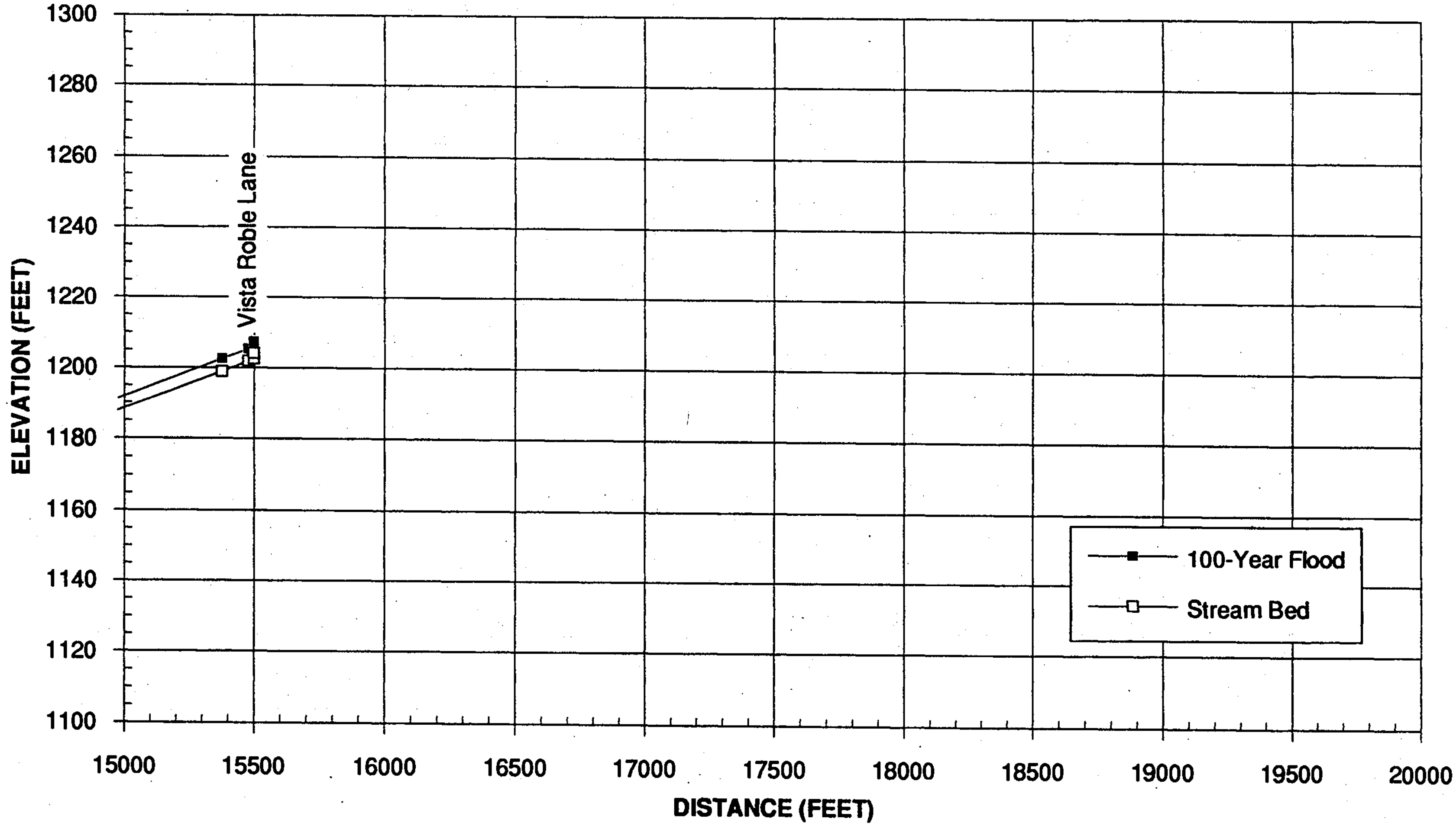


FIGURE 3-4 (continued)

Future Problems, Based on General Plan Land Use

Land use changes in the watershed from the 1990 base conditions to the Future Conditions cause a five percent overall increase in the impervious area, from around 9 percent of the watershed in 1990 to about 14 percent for Future Conditions. This increase in impervious area, combined with the other changes described in Section 2, accounts for an average overall increase in all the tributaries of around six percent in the 100-year peak flows. The range in flow increases for each individual watershed, however, is from 2 percent to 22 percent, depending on the size of the watershed, and the amount of development that is projected to take place in that watershed. The net result of this peak flow increase is that the problems in areas with existing problems are made worse, and there are some areas without existing problems that may experience problems based on the Future Conditions' flows.

Bridges and Culverts - Overtopping and Backwater. Table 3-1 also contains a listing of the locations and magnitude of culvert and bridge overtopping in the watershed under Future land use conditions. As indicated in Table 3-1 over 70 percent of the bridges and culverts will overtop during the 100-year flood under Future land use conditions and over 60 percent will overtop during the 25-year flood. Backwater from overtopping bridges and culverts will increase slightly due to the increase in flood flows due to Future Conditions. The backwater increase will probably not be directly proportional to the increased flood flows because the length of the overflow section usually increases with increasing depth of flow over the roadway.

Floodplain. The areas where the increase in flood flows from Base to Future land use conditions causes additional problems do not change significantly from those already impacted by the 100-year flood with present land use conditions. Additional structures may be impacted, but they will most probably be located near those that are already at risk with present land use conditions.

Erosion Potential

Except where roadway embankments were eroded by flood waters flowing over the roads during the February 1986 flood, the streams in the Auburn/Bowman Community have not shown a serious erosion potential in the past. Dense vegetation, in and along the majority of the channels and floodplains in the watershed, reduces flow velocities and erosion potential significantly. This slowing in flow velocity, in addition to the fact that flood flows are normally of fairly short duration, would seem to indicate that erosion of stream banks should not be a serious problem.

Erosion protection may be required, however, in areas where channel improvements are constructed because of the higher velocities that are incident with those improvements. Erosion protection will also be required in the stilling basin area downstream of the outlets from local detention basins. This erosion protection can take many forms but will usually be rock riprap, gabions, grassing, or some other type of channel lining.

SECTION 4
WATER QUALITY

INTRODUCTION

Not only are the impacts of flooding a concern for this study, but also the water quality impacts from stormwater runoff in the study area. Water quality degradation from stormwater runoff is primarily the result of runoff carrying pollutants from the land surface (i.e. streets, parking lots, pastures) to the receiving waters (i.e. streams and lakes). This type of pollution is termed "non-point source" pollution due to the fact that the pollutants are typically spread out over the land surface area (as opposed to point source pollution which refers to a specific managed source of pollution such as an industrial or wastewater treatment plant outfall to a stream). Non-point source pollution is of specific concern in the Auburn/Bowman Community Plan area not only because of the potential water quality impacts on streams, but also because of potential impacts on the numerous reservoirs and canals in the study area. In addition, the changing land uses (i.e. conversion of agricultural land to residential) in the study area may also have an adverse impact on future water quality due to increased pollutant loads.

This purpose of this section is to review the impacts stormwater runoff has on the water quality of the streams, canals, and reservoirs in the study area. Both existing conditions and future conditions are considered. However, data on the water quality of the surface waters in the study area is relatively sparse and much of the analysis presented below is based on other studies such as the Nationwide Urban Runoff Program (NURP) implemented by the Environmental Protection Agency.

Streams

As discussed in previous sections, the primary streams in the study area are Orr Creek, Dry Creek, Rock Creek, North Ravine and Auburn Ravine. The watersheds of these five streams comprise over 75% of the Auburn/Bowman Community Plan area with the remaining portions of the study area draining to the Bear River, American River (North Fork), and other smaller stream systems. The water quality in all of these streams is of concern for wildlife and fisheries as well as for other downstream uses. Stormwater runoff from rural and urban areas may contain excessive levels of pollutants (i.e. pesticides, herbicides, hydrocarbons, etc.) that are toxic to fisheries and other aquatic life in the streams. In addition, the water drained from the Auburn/Bowman Community Plan area eventually reaches the Sacramento River which is a primary source of water for the City of Sacramento as well as for the Sacramento - San Joaquin Delta which has numerous water uses (water supply, recreation, fisheries and wildlife habitats).

Reservoirs

The potential impacts of stormwater runoff on the reservoirs in the study area is also of concern. Reservoirs in the study area include Halsey Forebay and Afterbay, Orr Creek Reservoir, Dry Creek Reservoir, Wise Forebay, and Rock Creek Lake. These reservoirs are primarily used as regulating points for the numerous canals in the study area. However, Rock Creek Lake is also a primary source of municipal water for the North Auburn Water Treatment Plant located adjacent to the lake. The watershed upstream of Rock Creek Lake is undergoing significant urbanization, and therefore the impacts of stormwater runoff from recent and planned developments are of special concern.

In addition to potential pollutants such as metals, hydrocarbons and pesticides, pollutants in the form of soluble nutrients (nitrogen and phosphorous) may also have a significant impact on the water quality of reservoirs in the study area. Excessive nutrient loading may promote eutrophication (algae blooms) in these reservoirs which can have an adverse impact on both the aquatic habitat as well as the overall water quality. Algae blooms often lead to anoxic conditions which can impact fisheries and many of the aquatic organisms. In addition anoxic conditions can promote the release of soluble metals from bottom sediments and under these conditions, metals such as iron, manganese, and mercury may enter the water column at toxic levels.

Canals

Stormwater runoff may also enter directly into the canals in the study area. As discussed in previous sections, most of the canals in the Auburn/Bowman Community Plan area are not encased and therefore, have the potential for intercepting and transporting stormwater runoff and the associated pollutants. Hence, as with streams and reservoirs, any contaminant in the stormwater runoff has the potential for entering the canal system. Due to the fact that the canals lack the pollutant removal mechanisms of natural streams and that the canal water is used for domestic purposes (as well as agricultural), the quality of canal water is critical from a public health standpoint.

NATIONWIDE URBAN RUNOFF PROGRAM

The Environmental Protection Agency conducted the Nationwide Urban Runoff Program (NURP) with the purpose of investigating the extent to which urban runoff was causing water quality problems in receiving waters. A secondary purpose of the program was to test the effectiveness of various measures (i.e. infiltration basins) on reducing the amount of pollutants carried to receiving waters. The program was conducted from 1978 to 1983 in urban locations throughout the country and the results from the study are the basis for the National Pollution Discharge Elimination System (NPDES) program which is administered by the EPA. This program presently requires that both industries and municipalities (with populations exceeding 100,000) obtain permits for the discharge of stormwater runoff to receiving waters. The application for these permits requires identification of existing storm drainage facilities, characterization of existing stormwater quality, and the development of a detailed Stormwater Management Program.

The results from the NURP study may not be directly applicable to the study area due to the fact that the program covered different urban areas in different parts of the country. However, results from the program do provide a general indication of the types of pollutants and their impacts on water quality of runoff in urban areas such as the urbanized areas of the Auburn/Bowman

Community Plan area. The following discussion on potential pollutants and their sources in the study area is largely based on results from the NURP study as well other studies in urban and rural areas.

POTENTIAL SOURCES OF POLLUTANTS

Water quality degradation from non-point source pollutants is primarily the result of stormwater runoff carrying pollutants from the land surface to the receiving waters. The types of pollutants that may be transported to the receiving waters are dependent on the land use and the associated land use activities. In the Auburn/Bowman Community Plan area the specific land uses that may contribute to non-point source pollution are:

- Urban/Commercial Land Uses,
- Rural/Agricultural Land Uses, and
- Construction Sites.

In recent years much focus has been placed on runoff from urban and industrial areas. As mentioned above, the EPA's NPDES program currently requires that cities of 100,000 or more obtain NPDES permits for discharging stormwater into streams or rivers. It is anticipated that in the near future discharge permits will be required for smaller cities and urban areas as well. In addition to urban areas, rural and agricultural areas may also contribute to non-point source pollution through various farming and livestock management practices. Construction activities may also contribute to stormwater runoff pollution by increasing the potential for erosion as well as adding construction debris into the stormwater runoff. The following lists the potential sources of pollutants from the above mentioned land use activities:

- Urban/Commercial Land Uses
    - Automobiles
        Tires
        Oil leaks
        Brake linings
        Catalytic converters
    - Chemicals (improper use and disposal)
        Pesticides
        Fertilizers
        Herbicides
        Paints, Paint Thinners, Solvents
        Petroleum chemicals
    - Erosion of unprotected surfaces
    - Structural surfaces
        Street pavement
        Galvanized pipes
        Roofing materials
        Wood preservatives
    - Solid Waste
        Litter and debris

    Vegetative matter
    Pet droppings
- Rural/Agricultural Land Uses
  - Chemicals (improper use and disposal)
    Pesticides
    Fertilizers
    Herbicides
  - Erosion
    Farming activities
    Overgrazing of pastures
    Streamside erosion from livestock
  - Animal Waste
  - Septic Tanks
    Improper design and maintenance
- Construction Sites
  - Erosion
    Removal of vegetation
    Disturbing land surfaces
  - Construction Debris
  - Construction Chemicals
    Paints
    Solvents
    Waterproofing compounds
    Petroleum products (gasoline, oil, and grease)

POTENTIAL POLLUTANTS

The following pollutants most commonly associated with nonpoint source pollution in urban and rural areas are sediment and suspended solids, nutrients, oxygen demand (organic matter), oil and grease, trace metals, toxic chemicals and bacteria. Each of these pollutants is discussed in greater detail below.

Sediment

High concentrations of sediment are most often associated with construction activity where the natural land surface becomes disturbed. High concentration of suspended sediments in streams may cause increased turbidity, reduced light penetration, reduces spawning and other adverse effects to fisheries. In addition, sediment may be deposited in slower moving waters causing adverse effects to the benthic community and changes in the stream hydraulics.

Nutrients

Excessive levels of nutrients can occur in urban as well as rural agricultural runoff. In agricultural runoff the nutrient sources are typically fertilizers, animal waste, and other organic matter. In urban areas sources of nutrient are typically from urban landscaping, and gardens, lawns, golf courses, pet waste and litter. Excessive levels of nutrients (i.e. nitrogen and phosphorous) can lead to eutrophication (algae blooms) in downstream receiving water. The majority of the nutrients in urban runoff are in their soluble forms, which are readily utilized by algae, and therefore, aggravate the eutrophication process.

Oxygen Demand

Dissolved oxygen depletion in lakes or slow moving waters is a classic problem related to excessive pollutant loading of organic matter. The process of oxygen depletion is a result of decomposition of organic matter by microorganisms. The degree of potential dissolved oxygen (DO) depletion is measured by the biochemical oxygen demand (BOD) test that measures the amount of easily oxidized organic matter in the water. During storm events, runoff can capture and transport a wide variety of organic matter (i.e. lawn cuttings) that has accumulated on the land surface. BOD levels in receiving waters from urban areas may reach levels of 10 to 20 mg/l and in lakes or slow moving streams, this may result in anoxic conditions and be detrimental to aquatic life and the overall water quality. Schueler (1987) reports that the greatest export of organic matter comes from older, high density neighborhoods that have much vegetative growth and large populations of pets. Newer subdivisions with well maintained landscaping tend to have less organic matter loading from stormwater runoff.

Oil and Grease

The primary source of oil and grease (hydrocarbons) in urban runoff is the automobile. Oil leakage from crankcases as well as leakage of other lubricating agents are the major mechanisms by which automobiles release hydrocarbons to urban areas, Hydrocarbon levels are highest in runoff from parking lots, streets and service stations and somewhat less in residential areas. However, local problems may occur from illegal dumping of motor oil into storm drains or gutters. Hydrocarbons are lighter than water and when first captured by runoff, tend to form a film on the surface of the water. Due to the strong affinity hydrocarbons have for sediment, much of the hydrocarbons eventually adsorb to particles and settle out in slow moving waters. After deposition, the hydrocarbons may persist for a long period of time and have toxic impacts on the benthic organisms.

Trace Metals

Trace metals in urban runoff are of concern due to their potential long term toxic effects on aquatic life and the potential to contaminate drinking, water supplies. Sources of trace metals in urban runoff include automobiles, and surfaces such as roofs, galvanized pipes, etc. in which water may dissolve or leach out metals. The trace metals of primary concern are lead, cadmium, copper and zinc. The largest source of lead in urban runoff has been from leaded gasoline in automobiles. However, the phasing out of leaded gasoline has reduced the amount of lead introduced to the environment significantly (Schueler, 1987). In addition, as with hydrocarbons, a significant percentage of trace metals in urban runoff are attached to sediment, and hence the trace metals tend to accumulate in sediment deposits.

Toxic Chemicals

In most urban and rural areas there are relatively few sources of toxic chemicals that create a significant impact on the quality of the stormwater runoff. In most urban and residential areas the primary source of toxic pollutants is illegal disposal of household hazardous wastes such as waste oil, wood preservatives, paint thinner, and pesticides. Pesticides are also a primary source of toxic pollutants in agricultural area. The greatest source of toxic pollutants, is often industrial sites (existing or abandoned).

Bacteria

The NURP study conducted by the EPA found that coliform bacteria were present at high levels in urban runoff in most of the sites sampled. The coliform bacteria levels exceeded EPA water quality criteria for water contact sports during and immediately after storm events in most of the receiving waters even when a degree of dilution was provided by the receiving waters. Schueler (1987) reports that nearly every urban and suburban land use exports enough bacteria during storm events to violate health standards. Problems may be especially severe in areas that have combined or sanitary sewer overflows that export bacteria from human waste. Although the Auburn/Bowman Community Plan area is not served by a combined sewer system, improperly designed or maintained septic tanks in rural areas may be a significant source of bacteria in receiving water (as well as livestock and other farm animals).

EXISTING WATER QUALITY

Data on the existing water quality of streams, canals and reservoirs in the study area is sparse. As part of this study, a wide variety of agencies were contacted in an effort to obtain water quality data. These agencies included NID, PG&E, PCWA, City of Auburn and various agencies within Placer County (Public Works Department, Flood Control District, Environmental Health Department). The lack of any existing or previous DWR or USGS gages on streams in the study area precluded the contacting of state or federal agencies for water quality data. From this investigation, two sets of existing water quality data were obtained: (1) data from Placer County's monitoring program at its wastewater treatment plant on Rock Creek and, (2) data from a discontinued water quality monitoring program of Auburn Ravine conducted by the City of Auburn.

The State Water Quality Control Board requires that the wastewater treatment plant operated by Placer County monitor the receiving water both upstream and downstream of the effluent discharge sites. Grab samples are taken on a weekly basis on Rock Creek and Dry Creek and the samples are analyzed for the following constituents:

- Dissolved oxygen
- Turbidity
- pH

- Temperature

The weekly measurements for December 1990 to December 1991 have been plotted and are presented in Figures 4-1 to 4-8.

It should be noted that the sampling program at the treatment plant is conducted primarily to assess the impact the effluent discharge may have on the receiving waters. Hence, constituents which are analyzed are not particularly beneficial in assessing water quality impacts from stormwater runoff. However, from discussions with the officials at Placer County and as evident by the plots, the pH of Rock Creek (upstream of the discharge) averages approximately 8 to 8.5 whereas the pH of Dry Creek (upstream of the confluence with Rock Creek) averages approximately 7.5. The higher pH levels in Rock Creek are attributed to pollution in the runoff from the more heavily urbanized and commercial areas in the lower Rock Creek watershed (conversation with Warren Tellefson, Placer County).

The turbidity of the sampled stream waters also provides an indication of water quality impacts from non-point sources. In Dry Creek the turbidity levels are much higher in the month of March, when heavy rainfall occurred in the area. However, the measurements in Rock Creek at the same time period do not indicate higher turbidity levels. The increased turbidity levels in Dry Creek may be due to increased erosion from construction activities or other land disturbances in the Dry Creek watershed. At the same time, the lower Rock Creek watershed is already heavily urbanized and there may have been little construction or other activity to disturb the soils in the watershed.

Data on water quality of Auburn Ravine was also obtained from the City of Auburn. The purpose of the study was to assess the impacts, if any, of non-point source pollutants on the stream. On October 16, 1990 the City sampled Auburn Ravine at nine different locations within the city limits. Grab samples were obtained and analyses were performed for a wide variety of pollutants including trace metals, volatile organic priority pollutants, and chlorinated pesticides and PCB's. With the exception of methylene chloride (an organic pollutant), no priority pollutants or pesticides were detected at any of the stream sampling locations. However, these samples were taken during a dry period and the results may not be truly representative of stormwater runoff quality. Due to funding problems and the fact that pollutants were not detected in high enough concentrations to warrant further study, the monitoring program was discontinued.

FUTURE WATER QUALITY

Future changes in the water quality of the streams, canals and reservoirs in the Auburn/Bowman Community Plan area will largely be governed by the changing land use conditions. As discussed earlier, the types and extent of non-point source pollution is largely dictated by land use activities. Hence, any changes in the land uses (especially urbanization) of any given watershed in the study area has the potential for altering the water quality through stormwater runoff.

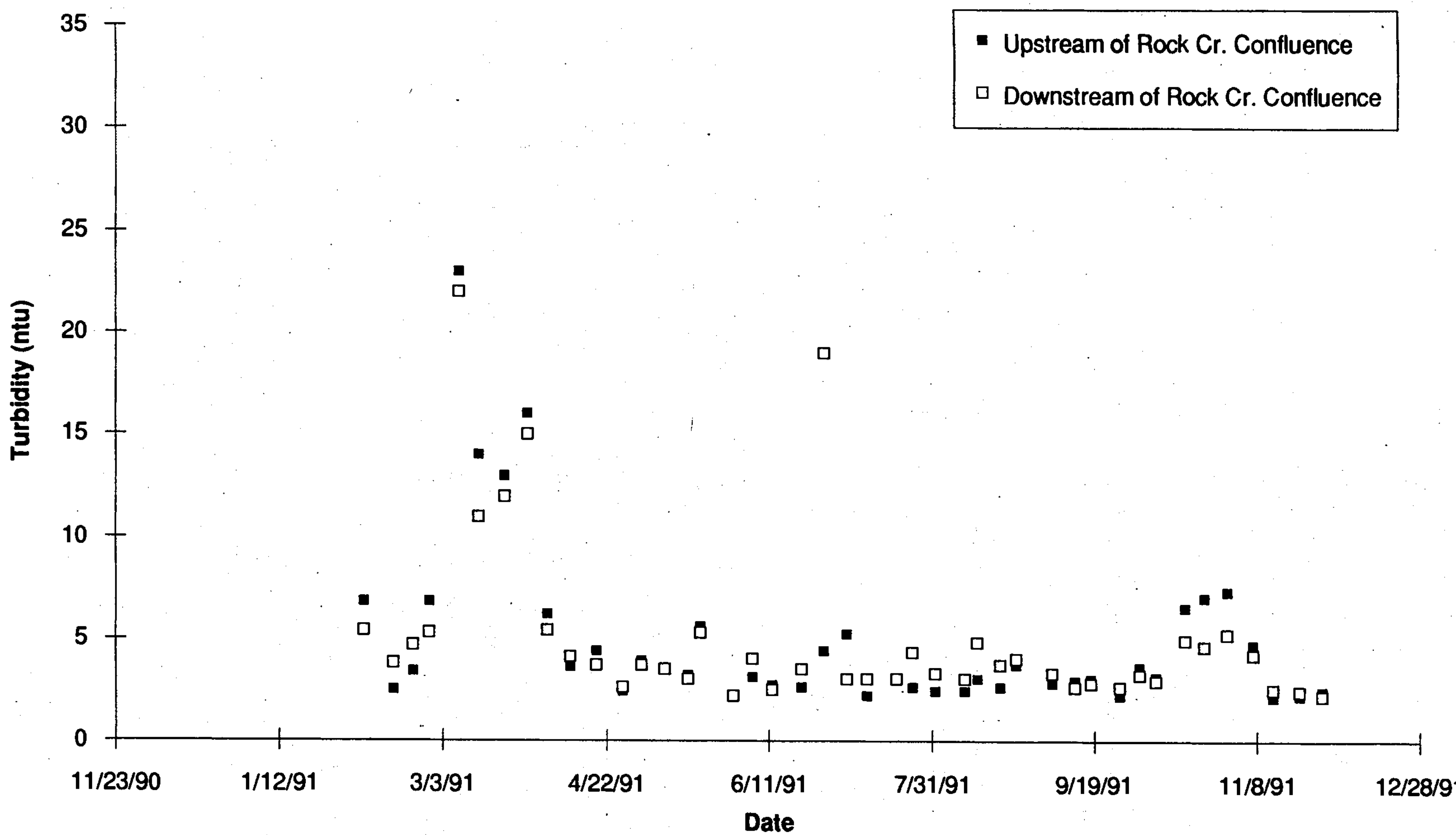


FIGURE 4-1
DRY CREEK TURBIDITY

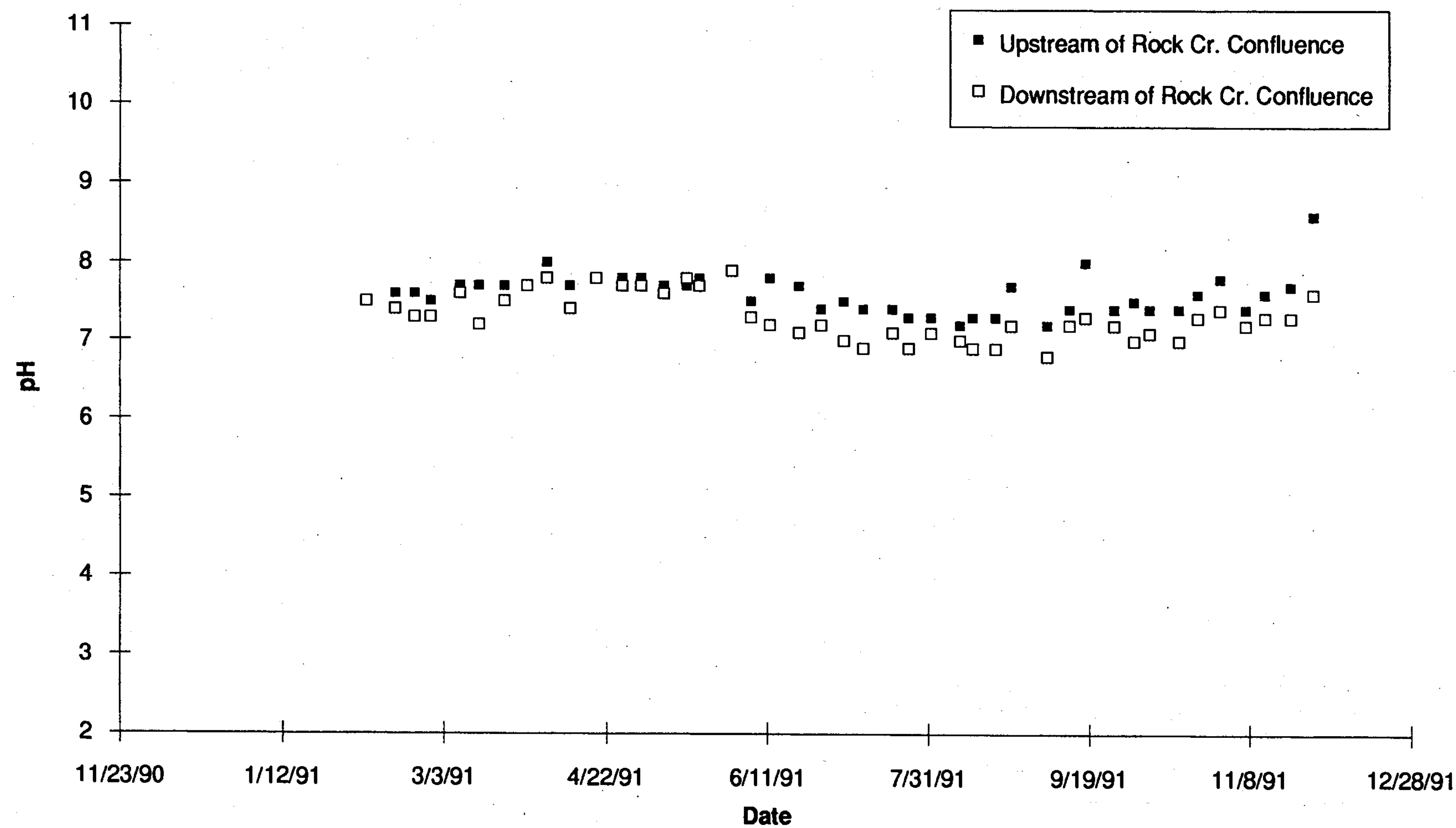


FIGURE 4-2
DRY CREEK PH

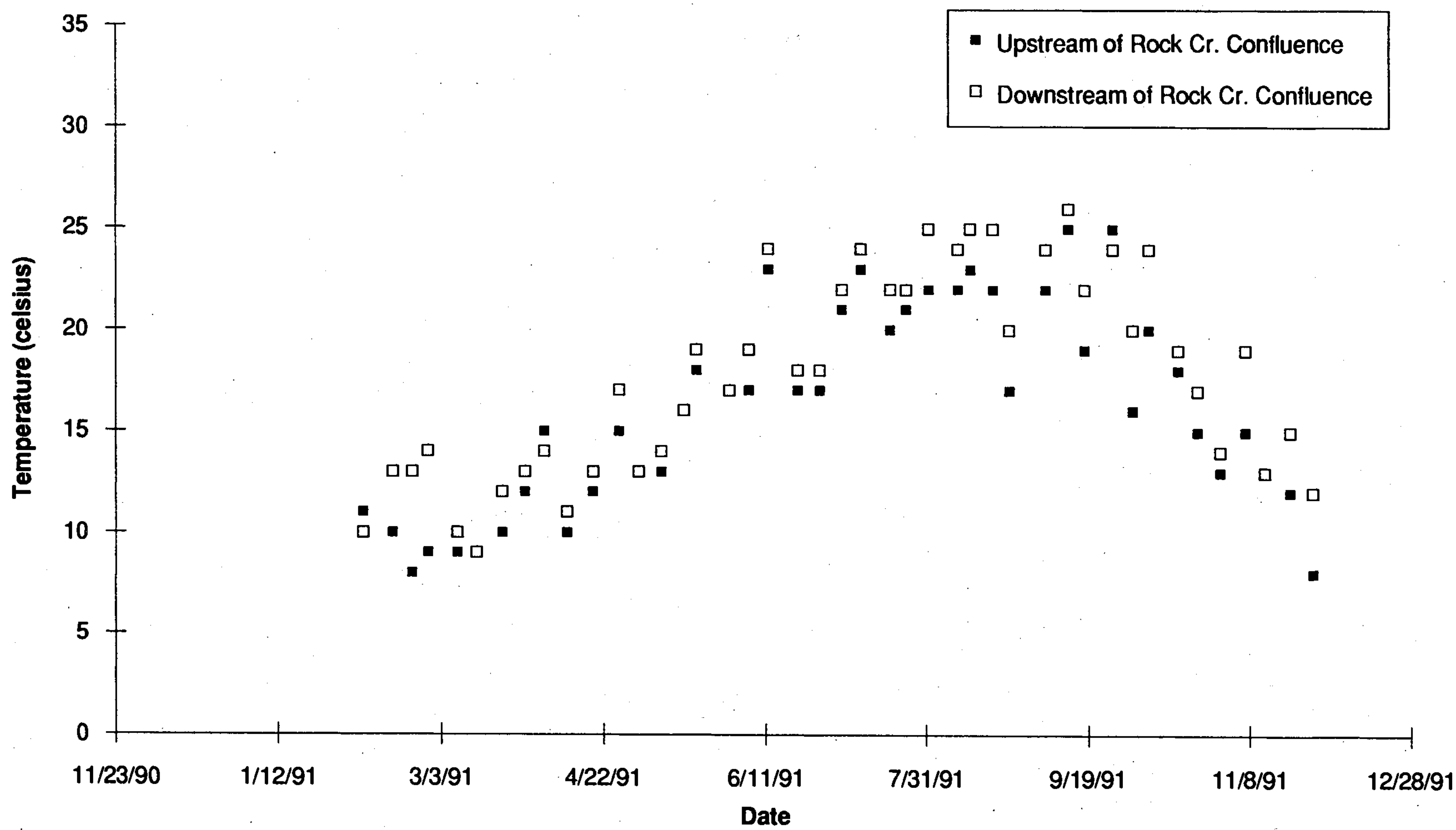


FIGURE 4-3
DRY CREEK TEMPERATURE

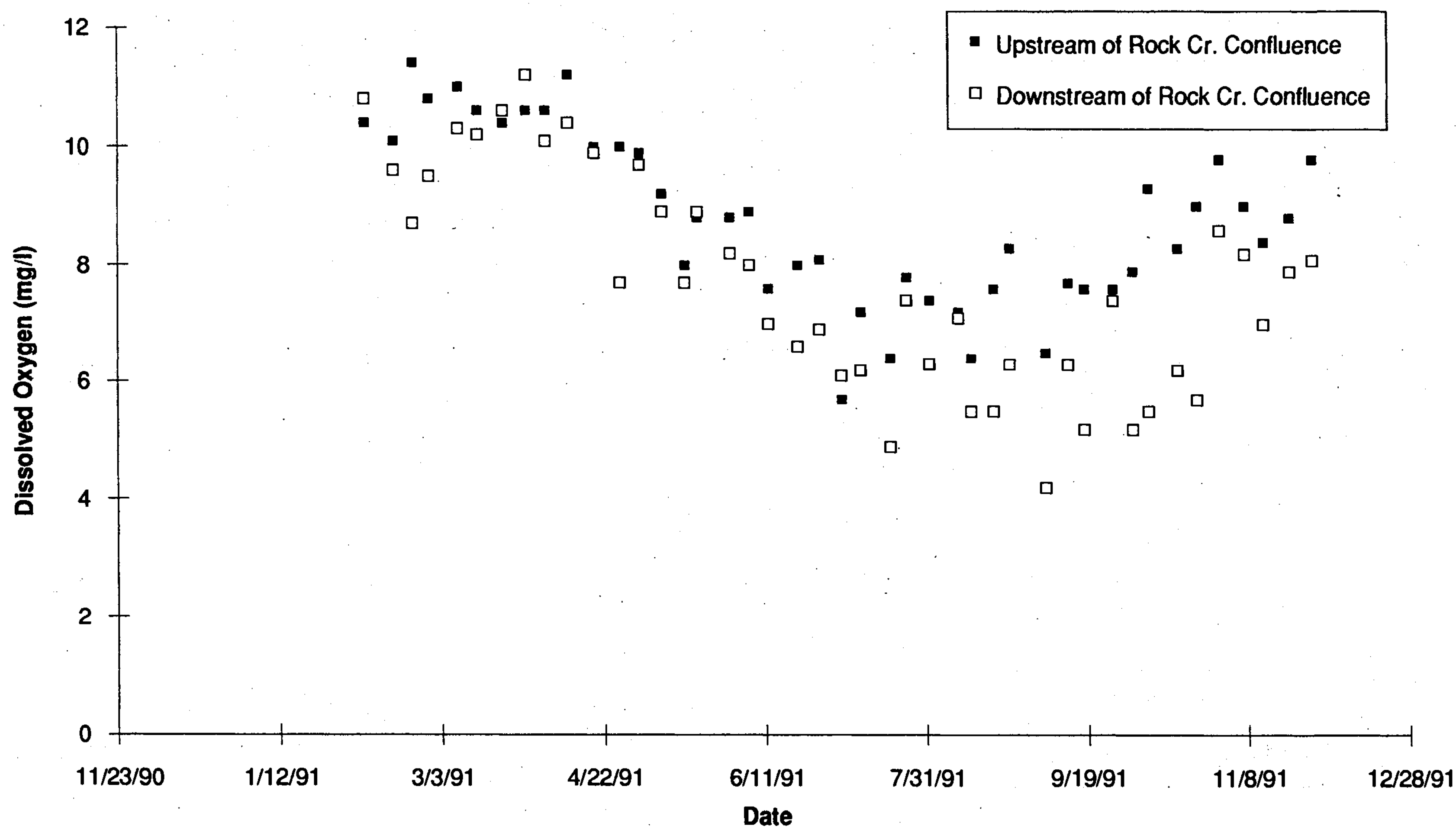


FIGURE 4-4
DRY CREEK DISSOLVED OXYGEN

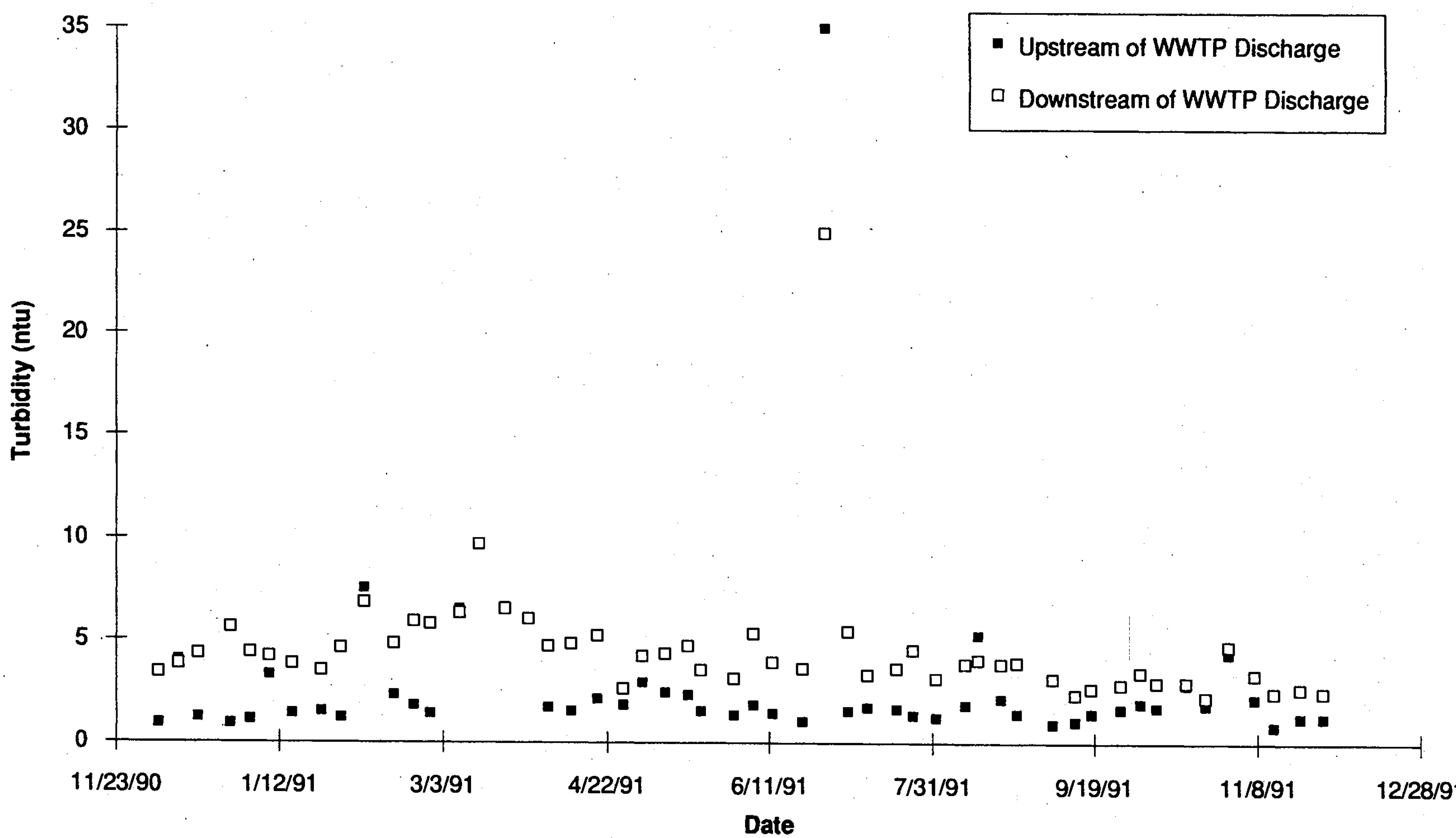


FIGURE 4-5
ROCK CREEK - TURBIDITY

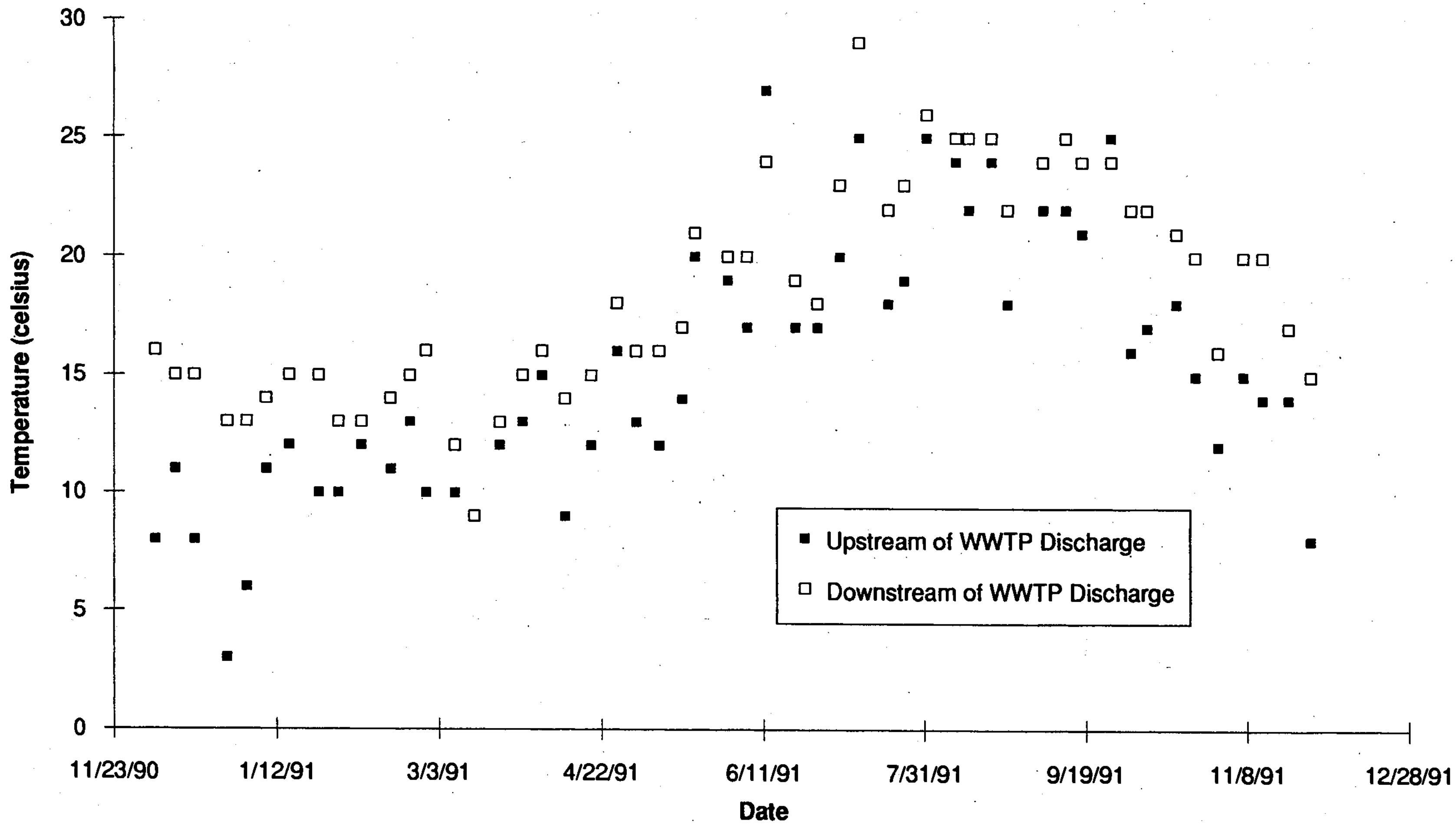


FIGURE 4-6
ROCK CREEK - TEMPERATURE

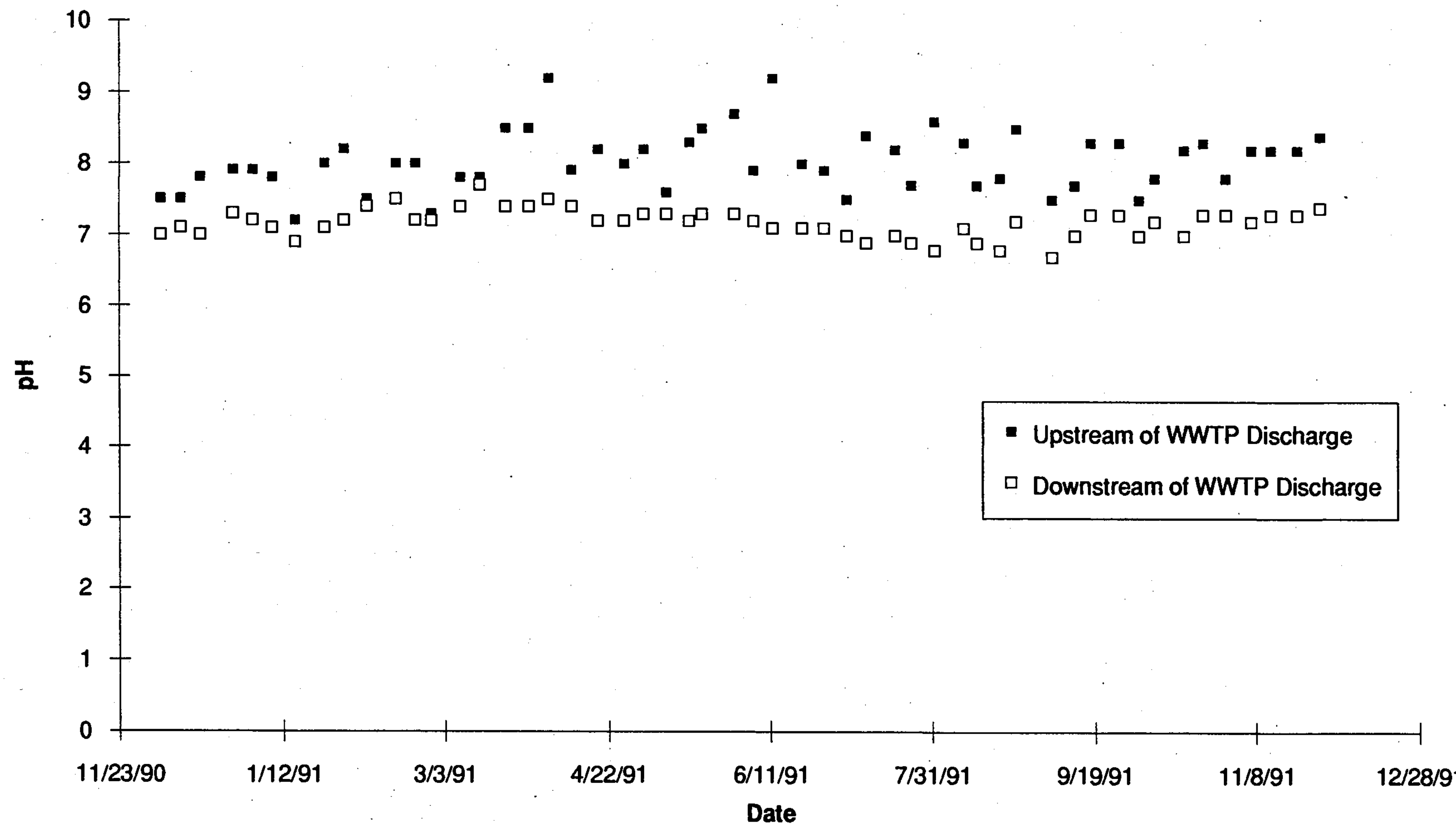


FIGURE 4-7
ROCK CREEK - PH

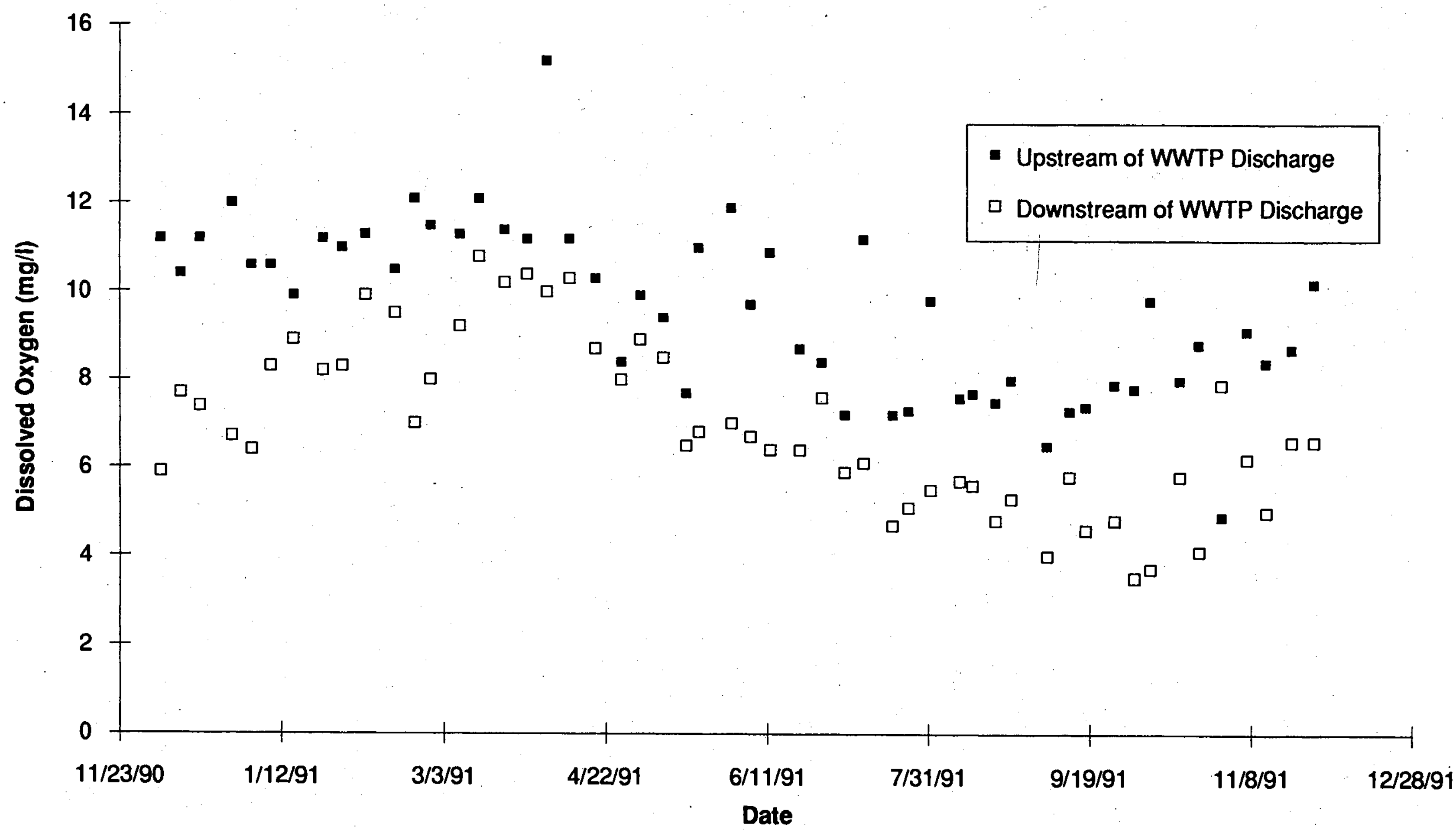


FIGURE 4-8
ROCK CREEK - DISSOLVED OXYGEN

Estimation of Non-Point Source Pollutant Loads

There are numerous methods available for estimating pollutant loads from non-point sources, however, most of these methods have been developed for urban areas. These methods range from simplified manual methods which estimate average pollutant loads over a given year to much more sophisticated and complex computer models that require extensive input data. The various manual methods available for evaluating non-point source pollutant loads include the Unit Load Method, the Preliminary Screening Procedure, Concentration Times Flow Method, and the Simple Method.

In the Auburn/Bowman Community Plan area, the primary present and future land uses are rural residential and agricultural with only limited urban development. All of the methods of estimating pollutant loads mentioned above are generally applicable to urban areas and are based largely on studies conducted in urban and metropolitan environments such as the NURP study. Hence, specific data on pollutant loading in rural environments is sparse and therefore, the methods of estimating non-point source pollutant loads mentioned above are not directly applicable in estimating changes in regional pollutant loads in the study area.

NURP Study Results for Developed and Undeveloped Areas

As part of the Nationwide Urban Runoff Program, over 300 runoff events were monitored in the Washington DC. area. These monitoring locations included newer suburban areas, older urban areas, and undeveloped areas (forested land). The average flow weighted concentrations for a variety of pollutants sampled as a part of the study as well as the National NURP average for all of the NURP study sites are presented in Table 4-1. The values reported in this table provide an indication on how much pollutant export may increase as a result of urbanization. It is interesting to note that older urban areas have a significantly higher pollutant export rate than newer suburban areas. In addition, the concentration levels of all pollutants increased when urbanization occurred.

Land Use Changes and Potential Water Quality Impacts

As presented in Table 4-2, the overall land use changes from the present (Base Conditions) to Future Conditions are limited. With the exception of the commercial development along the Highway 49 corridor, the present land use conditions are primarily rural residential, agricultural, and open space. With a few exceptions, the future land use changes throughout the study area primarily involve the conversion of agricultural land and open space to rural lots. However, the amount and type of land use changes vary with the different watersheds in the study area. The following is a brief summary of land use changes and the potential water quality impacts in each of the major watersheds in the study area. It should be noted that the assessments of water quality impacts presented below are general and are based solely on the changes between present and future land use conditions. In addition, to water quality impacts from future conditions, as the specific areas are developed there is increased potential sediment loading associated with construction activities.

TABLE 4-1
NURP STUDY RESULTS

POLLUTANT	UNDEVELOPED AREAS (mg/l)	NEW SUBURBAN NURP SITES (mg/l)	OLDER URBAN AREAS (mg/l)	NATIONAL NURP STUDY AVERAGE (mg/l)
PHOSPHORUS				
Total	0.15	0.26	1.08	0.46
Ortho	0.02	0.12	0.26	--
Soluble	0.04	0.16	--	0.16
Organic	0.11	0.1	0.82	0.13
NITROGEN				
Total	0.78	2	13.6	3.31
Nitrate	0.17	0.48	8.9	0.96
Ammonia	0.07	0.26	1.1	--
Organic	0.54	1.25	--	--
TKN	0.61	1.51	7.2	2.35
COD	>40.0	35.6	163	90.8
BOD (5-day)	--	5.1	--	11.9
METALS				
Zinc	--	0.037	0.397	0.176
Lead	--	0.018	0.389	0.18
Copper	--	--	0.105	0.047

AVERAGE FLOW-WEIGHTED CONCENTRATIONS OF POLLUTANTS
FROM METROPOLITAN WASHINGTON NURP STUDY (1980-1981)

TABLE 4-2
OVERALL LAND USE CHANGES

WATERSHED	WATERSHED IN STUDY AREA (sq. mi.)	COMMERCIAL & INDUSTRIAL		RESIDENTIAL (less than one acre)		RURAL (1 - 4.6 acres)		AGRICULTURAL (4.6 - 20 acres)		OPEN SPACE	
		Present (sq. mi.)	Future (sq. mi.)	Present (sq. mi.)	Future (sq. mi.)	Present (sq. mi.)	Future (sq. mi.)	Present (sq. mi.)	Future (sq. mi.)	Present (sq. mi.)	Future (sq. mi.)
ORR CREEK	8.1	0.0	0.0	0.0	0.0	2.3	2.8	4.2	4.5	1.6	0.8
DRY CREEK	9.2	0.1	0.1	0.1	0.2	3.9	6.3	2.0	0.9	3.1	1.6
ROCK CREEK	4.3	0.4	1.1	0.6	1.2	0.9	1.1	0.2	0.0	2.2	0.9
AUBURN/NORTH RAVINE	6.3	0.5	0.6	0.5	1.0	2.6	3.3	1.1	0.0	0.8	0.4
BEAR RIVER	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	2.0	1.2	0.0
AMERICAN RIVER	2.9	0.1	0.1	0.3	0.4	0.3	0.5	1.2	1.1	1.1	0.9
DEADMAN CANYON	0.9	0.0	0.0	0.0	0.0	0.5	0.9	0.4	0.0	0.1	0.0
DUTCH RAVINE	0.3	0.0	0.0	0.0	0.0	0.2	0.2	0.1	0.0	0.0	0.1
MORMON RAVINE	0.8	0.0	0.0	0.0	0.0	0.3	0.4	0.4	0.2	0.2	0.2

Orr Creek and Dry Creek Watersheds. The present land use in the Orr Creek and Dry Creek watersheds is primarily rural residential, agricultural, and open space. There is, however, a small amount of residential and commercial development in the Dry Creek watershed near the Highway 49 corridor. The future land use conditions in these watersheds calls for the conversion of approximately 25% of the existing open space and agricultural land to rural estates and rural residences. Only a small amount of land (one tenth of a square mile in the Dry Creek watershed) is designated for residential development and there is no future commercial development in this area.

Due to the increase in rural residences in these watersheds there is the potential for increased pollutant loads of hydrocarbons from automobiles, nutrients from landscaping activities and other chemicals from pesticides and herbicides. In addition as open space and agricultural areas are converted to rural lots, there may be an increase in livestock and other ranch animals in these watersheds. This may increase the pollutant loads (i.e. bacteria) into the canals and streams from animal waste transported by stormwater runoff.

Rock Creek Watershed. The Rock Creek watershed presently has a wide variety of land uses. The lower watershed (below Rock Creek Lake) is primarily commercial (along the Highway 49 corridor) and residential whereas the upper watershed has larger amounts of open space along with limited residential and rural development. In addition, the Auburn Airport and associated business park are also located in the upper Rock Creek watershed. Future land use changes in the Rock Creek watershed include continued commercial development in the lower watershed and commercial and residential development in the upper areas of the watershed. Over 50% of the existing open space in the upper watershed will be developed.

The future development in the Rock Creek watershed has the potential for adverse impacts on the water quality of the canals, streams and Rock Creek Reservoir primarily from the urban and commercial land uses. The potential impacts include increased hydrocarbon levels from increased automobile traffic, increased nutrients from landscaping activities, bacteria from animal waste and increases in other pollutants associated with urban runoff.

Auburn Ravine/North Ravine Watershed. The present land use of the Auburn Ravine/North Ravine watershed (excluding the City of Auburn) is primarily rural residential and agricultural. There is limited commercial and residential development in the watershed, mostly in the areas adjacent to the Highway 49 corridor. Future land use changes in the area calls for conversion of all of the agricultural areas and a portion of the open space areas to rural lots. There is no planned changes to residential or commercial land uses in this area.

The future water quality impacts from land use changes in the Auburn/North Ravine watershed should similar to that of Orr Creek and Dry Creek watersheds. There may be increases in pollutant loads associated with the rural development (i.e. nutrients, hydrocarbons, bacteria).

Remaining Watersheds. The remaining watersheds in the Auburn/Bowman Community Plan area (Bear River, American River, Deadman Canyon, Dutch Ravine and Mormon Ravine) are presently all rural, agricultural and open space. Future land use changes in these areas are minimal with the primary changes being the conversion of a portion of the existing agricultural land and open space to rural lots. As with other watersheds in the study area, the future water quality impacts on the streams and canals will primarily result from the rural development and the associated pollutants (nutrients, hydrocarbons, bacteria, etc.).

BEST MANAGEMENT PRACTICES

Over the past two decades there has been growing emphasis placed on the quality impacts of stormwater runoff from developed or developing areas. Much emphasis has been placed on controlling, stormwater pollution at its source (before pollutants reach streams, river or lakes). These controls are called "Best Management Practices" (BMPs) and are a practice or combination of practices that can be feasibly implemented and are most effective in either controlling the pollutant directly at its source or removing the pollutants from the stormwater before they reach the receiving waters.

Numerous BMPs have been developed and implemented for use in commercial, urban, industrial, and agricultural areas as well as for construction sites. The general methods for stormwater management are (1) structural, and (2) non-structural. The structural methods consist of utilizing physical structures to remove pollutants from stormwater while the non-structural methods include land management techniques or direct source control.

The following is a list of the most common types of structural and non-structural BMPs.

Structural	Non-Structural
On-site Storage	Surface Sanitation
Infiltration	Direct Source Control
Overland Flow Modification	Vegetative Control
Street and Storm Sewer System	Land Use Control

Each of these methods for controlling stormwater pollution is discussed in greater detail below.

Structural BMPs

On-site Storage. The objective of on-site storage of runoff is either to prevent storm flow from reaching the drainage system or to change the timing of the runoff by controlling the release rate. Retention is the term for containment of runoff whereas detention is the term for delaying and controlling the runoff. Stormwater pollution may be reduced by on-site storage in several ways including: (1) settling out of particulate matter, (2) biological assimilation of some pollutants, and (3) decreased velocity of storm runoff, reducing the downstream erosion potential.

Infiltration. The concept of infiltration of stormwater involves capturing runoff from a storm and allowing it to percolate the runoff into the soil. This serves two purposes: (1) the total runoff and peak floods are reduced and (2) the "first flush" from storms can be percolated, thereby reducing the pollutant load from a storm event. Examples of infiltration BMPs are porous pavement, dry wells, infiltration basins (retention basins), and infiltration trenches.

Overland Flow Modification. Overland flow modification involves using such structures as dikes, berms, swales or silt fences to intercept runoff and divert it around an area which may be a large source of pollutants. These types of BMPs are commonly used in construction sites in order to prevent erosion from disturbed areas.

Street and Storm Sewer Systems. Street and storm sewer facilities are used in urban street systems to reduce pollutant discharges from stormwater runoff. These facilities consist of a wide variety of structures which include: (1) trapped catch basins, (2) vaults/tanks, (3) water quality inlets and, (4) sedimentation manholes. The primary pollutant removal mechanism in these facilities is sedimentation although modified facilities such as water quality inlet can provide limited removal of hydrocarbons.

Nonstructural BMPs

Surface Sanitation. The objective of surface sanitation practices is to remove the pollutants before they come in contact with rainfall or runoff. The primary methods of surface sanitation are street cleaning or street washing programs, but may also include other litter control programs such as frequent scheduled removal of litter from roadside swales, storm drain inlets and other areas where litter can accumulate and eventually enter the storm drain system.

Direct Source Control. Direct source controls are methods to reduce pollution from stormwater runoff through the reduction in the use and illegal disposal of pollutants such as toxic substances, fertilizers, pesticides, oil, gasoline and detergents. Specific methods include limiting operations by municipal agencies (tree spraying, weed control, fertilization of parks, etc.) and public awareness programs for individual homeowners on the use of chemicals and proper disposal methods.

Vegetation Control. Vegetation is an effective type of management practice for controlling erosion and removal of pollutants. Mulching and seeding is an effective method to control erosion on disturbed land in construction site. In addition, vegetation can also be utilized in urban and rural areas to control erosion, decrease runoff velocities, and enhance pollution removal through filtering of sediments.

Land Use Control. Land use controls are methods to control pollution by controlling the various land uses that may cause the pollution. Examples of land use controls include creating stream side "buffer zones" to limit livestock access to creeks in rural areas and to limit parking lots, buildings and other structures that may contribute to stormwater pollution near streams in urban areas.

The types of BMPs as well as specific BMPs that are most suitable for a specific area is dependent on many factors associated with the area of interest. Schueler (1987) suggested a series of screening tools that could be used to select the most appropriate BMPs for a particular site:

- Physical Suitability

- Stormwater Control Benefits
- Pollutant Removal Capability
- Environmental Amenities

Physical suitability refers to how applicable a site may be for a particular BMP. Physical factors that need to be considered when evaluating BMPs for a site include drainage area, soil type, slopes, land use, sediment input, and the potential for thermal enhancement (i.e., increasing the temperature of streams).

The drainage area and soil types are the two most significant factors in evaluating a site for potential BMPs. For instance, street and storm sewer system BMPs are designed for areas of one acre or less while detention basins are generally only feasible with watersheds exceeding 20 acres. Soil types are also a very important criteria in evaluating BMPs for a selected site. Any BMP that utilizes infiltration requires that the soil have an appropriately high infiltration rate. In the Auburn/Bowman area, the soil types are almost exclusively Hydrologic Soil Group 'D' or low infiltration soils. Hence, in most cases, the BMPs that rely on infiltration (i.e., porous pavement, infiltration trenches, infiltration basins) will not be appropriate for the study area.

The stormwater control benefits are also another criteria that can be used in evaluating the suitability of BMPs for a particular site. In developing areas, the objective of stormwater management is to reduce the post-development peak discharge of a given design storm to pre-development conditions. As an example, properly designed extended detention basins are excellent methods of peak discharge control. However, other BMPs such as street and storm sewer systems offer very little or no storm control benefits.

Another criteria that can be used in selecting a BMP is it's effectiveness in pollutant removal. The capability of a BMP to remove pollutants from stormwater is essentially dictated by: (1) the type of pollutant removal mechanism utilized (i.e., sedimentation, biological uptake, etc.), (2) the amount of runoff that us being treated, and (3) the types of pollutants in the stormwater. For instance particulate pollutants such as sediments can usually be easily removed through settling and filtering via such practices as extended detention ponds and filter strips. However, in order to remove soluble pollutants such as nutrients and some trace metals, biological treatment (uptake by bacteria, algae, aquatic plants, etc.) is required. The best methods for biological treatment are wet ponds, wetlands or marshes with a relatively long detention time.

Environmental amenities should also be considered when evaluating BMPs for a particular location. These amenities include both potential improvements to the natural habitat (i.e., erosion control, wildlife habitat creation) as well as benefits to the local community (i.e., aesthetics, recreational benefits).

In addition to the above four criteria that can be utilized in selecting BMPs for a given area, the initial costs of incorporating the BMP as well as annual maintenance costs should be considered when selecting BMPs.

There is an extensive amount of literature on Best Management Practices available through various government agencies as well as through numerous municipalities that have adopted BMPs in their Master Plans. For this study, reports on BMPs were obtained from the Soil Conservation Service, Environmental Protection Agency, Sacramento City and County, Clackamas County (Oregon), Clark County (Nevada), Washington Metropolitan Water Resources Planning Board and the High Sierra Resource Conservation District. These reports were reviewed for the management practices that would be applicable to the Auburn/Bowman Community Plan area and these BMPs are summarized below. It should be noted that the following is not a comprehensive list of BMPs - but rather a list of BMPs that are applicable to the land use conditions and the physical constraints of the study area. For instance, BMPs that utilize infiltration are not discussed below due to the fact that the soils in the study area are of relatively low permeability which renders infiltration practices unsuitable for the Auburn/Bowman area.

In addition, as previously discussed, the types and sources of pollutants in stormwater runoff are directly dependent on the specific land use types. Hence, the management practices incorporated for a certain area should take into account the land use and the associated source of pollutants. Accordingly, the BMPs presented below have been grouped into three categories based on the existing and future land uses in the study area: (1) Rural/Agricultural, (2) Urban/Commercial, and (3) Construction Sites.

RURAL AND AGRICULTURAL BMPS

Animal Waste Management

Animal waste management is a practice where animal wastes are temporarily held in waste storage structures until they can be utilized or safely disposed. This should be practiced in areas where large numbers of livestock congregate (i.e., feedlots, watering troughs) in order to remove animal waste before it is transported to streams via runoff. Typical storage units are constructed of reinforced concrete or coated steel. Wastes can also be stored in earthen ponds which intercept runoff from livestock areas. This practice is considered a good to excellent method of controlling nitrogen and phosphorus loading in corrals, stockpens, etc. A disadvantage to this method of waste control is the periodic need for the disposal of the wastes.

Type:	*Direct Source Control*
Area:	*Localized (Feedlots, Watering Troughs)*
Pollutant Removal:	*Nutrients (Phosphorous, Nitrogen)*
Stormwater Control Benefits:	*None*
Maintenance Required:	*Routine maintenance of storage structures and disposal of wastes*

Range and Pasture Management

The objective of range and pasture management is to prevent overgrazing caused by too many animals in a given area (overstocking). Overstocking may lead to (1) excessive erosion and subsequent sediments in streams, (2) soil compaction and an increase in runoff rates, and (3) added animal waste. Management practices include rotating animals between pastures, spreading water and mineral and feed supplements for better animal distribution, proper stocking rates, and grazing schedules.

Type:	*Land Use Control*
Area:	*Regional*
Pollutant Removal:	*Suspended Solids, Nutrients (Phosphorous, Nitrogen)*
Stormwater Control Benefits:	*Reduced runoff peak and delayed time of concentration due to increased vegetative cover*
Maintenance Required:	*None*

Streamside Management Zones

Consideration in streamside management include maintaining the natural vegetation along a stream and limiting livestock access to the stream. This has proven to be an effective method to reduce erosion along stream banks and in preventing animal waste from directly entering streams (nitrogen and phosphorous control). Fences need to be constructed to prevent livestock from entering the stream buffer zone (approximately 25 feet from the stream channel) and in disturbed areas, revegetation with grass, trees or shrubs should be established prior to winter runoff.

Type:	*Land Use Controls*
Area:	*Local and Regional(Along stream and river channels)*
Pollutant Removal:	*Erosion Control, Suspended Solids, Nutrients*
Stormwater Control Benefits:	*Minimal*
Maintenance Required:	*Minimal*

Agricultural Chemical Management

Pesticides, herbicides and fertilizers are commonly used in all types of agricultural activities for the control of pests, etc. Agricultural management considers factors such as how much chemical is enough to control a problem; the best method of applying the chemical, the appropriate time for application; the safe handling, storage and disposal of chemicals and their containers; pesticide leaching potential; and pesticide surface loss potential. Other considerations include using resistant crop varieties, optimizing crop planting time, and biological controls.

Type:	*Direct Source Control*
Area:	*Regional*
Pollutant Removal:	*Pesticides, Herbicides, Fertilizers, Toxic Chemicals*
Stormwater Control Benefits:	*None*
Maintenance Required:	*Minimal*

URBAN AND COMMERCIAL BMPS

Litter Control/Solid Waste Management

Spent containers from food and drink, cigarettes, newspapers, sidewalk sweepings, etc. all may contribute to street litter. Unless this material is prevented from reaching the street or is removed by street cleaning equipment, it is often found in storm water discharges. Enforcement of anti-litter laws, convenient location of sidewalk waste disposal containers, public education programs, and management of solid waste collection activity are some of the source control programs that may reduce the amount of solids loading from urban runoff.

Type:	*Surface Sanitation/Direct Source Control*
Area:	*Regional (Rural, Urban and Commercial Areas)*
Pollutant Removal:	*Solid Wastes*
Stormwater Control Benefits:	*None*
Maintenance Required:	*Continuing Public Education Programs, Frequent Solid Waste Collection*

Street Cleaning

Streets and parking lots can be cleaned by sweeping which removes large dust and dirt particles or by flushing which removes finer particles. Sweeping actually removes solids so pollutants do not reach the receiving waters. Flushing just moves the pollutants to the drainage system unless the drainage system is part of the sewer system, in which case the pollutants will be treated as wastes in the sewer treatment plant. An advanced sweeping system (broom and vacuum combination) is the most efficient in removing both litter and the fine solids which broom sweeping alone cannot do.

Type:	*Surface Sanitation*
Area:	*Local (Urban and Commercial Streets and Parking Lots)*
Pollutant Removal:	*Solid Wastes, Sediments, Nutrients (from pet droppings, lawn cuttings, etc.)*
Stormwater Control Benefits:	*None*
Maintenance Required:	*Frequent street cleaning, vehicle maintenance*

Minimize Directly Connected Impervious Areas

Directly connected impervious areas are defined as the impermeable areas that drain directly into an improved drainage system (i.e., paved gutter). The purpose of minimization of directly connected impervious areas is to delay the concentration of flows into the drainage system and maximize the opportunity for runoff to infiltrate. This is done by routing runoff from impervious areas to lawns, swales, etc. where infiltration may occur, thereby reducing the mass of pollutants transported to downstream waterways.

Type:	*Land Use Control*
Area:	*Local Developments*
Pollutant Removal:	*Trash, sediments*
Stormwater Control Benefits:	*Delays time of concentration and reduces runoff peak*
Maintenance Required:	*Periodic trash removal*

Grass-Lined or Vegetated Swales

A grass lined swale is a natural or man-made drainage way that is below (lower than) adjacent ground level, and is stabilized against erosion by suitable vegetation. The flow is normally wide and shallow and conveys runoff down the slope in the direction of the downstream storm drain facilities. The purpose of a swale is to intercept and convey runoff without causing damage by erosion. Swales control pollutants through several mechanisms including sedimentation, plant filtration, vegetative intake and percolation through the soil. Figure 4-9 illustrates the grass-lined or vegetated swale BMP concept.

Type:	*Overland Flow Modification, Vegetative Control*
Area:	*Local (Five acres or less)*
Pollutant Removal:	*Suspended Solids, Nutrients*
Stormwater Control Benefits:	*Delays time of concentration and reduces runoff peak*
Maintenance Required:	*Periodic mowing and disposal of trimmings, removal of sediments*

Public Education

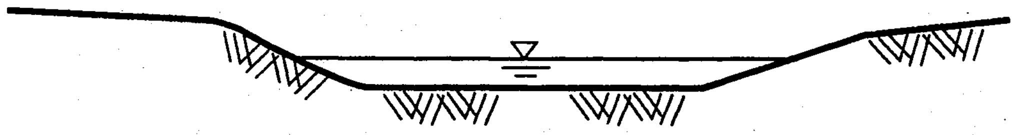
In addition to other public education efforts related to flood control planning, financing and public safety, a public education program dealing with storm water quality issues should also be developed. Topics of education could include:

- proper use and disposal of chemicals, hazardous wastes, and petroleum products,
- proper use and disposal of fertilizers and pesticides,
- effective housekeeping practices,
- litter and solid waste control,
- air pollution control,
- illegal dumping.

Public education efforts could be coordinated with other agencies with related objectives which have regular contact (e.g., billings) with the public. Examples include Placer County Water Agency, Nevada Irrigation District, Pacific Gas and Electric Company.

Type:	*Direct Source Control*
Area:	*Regional*
Pollutant Removal:	*Nutrients, Pesticides, Toxic Chemicals, Oil, Gasoline*
Stormwater Control Benefits:	*None*
Maintenance Required:	*Routine contact with public through mail, workshops, newspapers*

TOP VIEW



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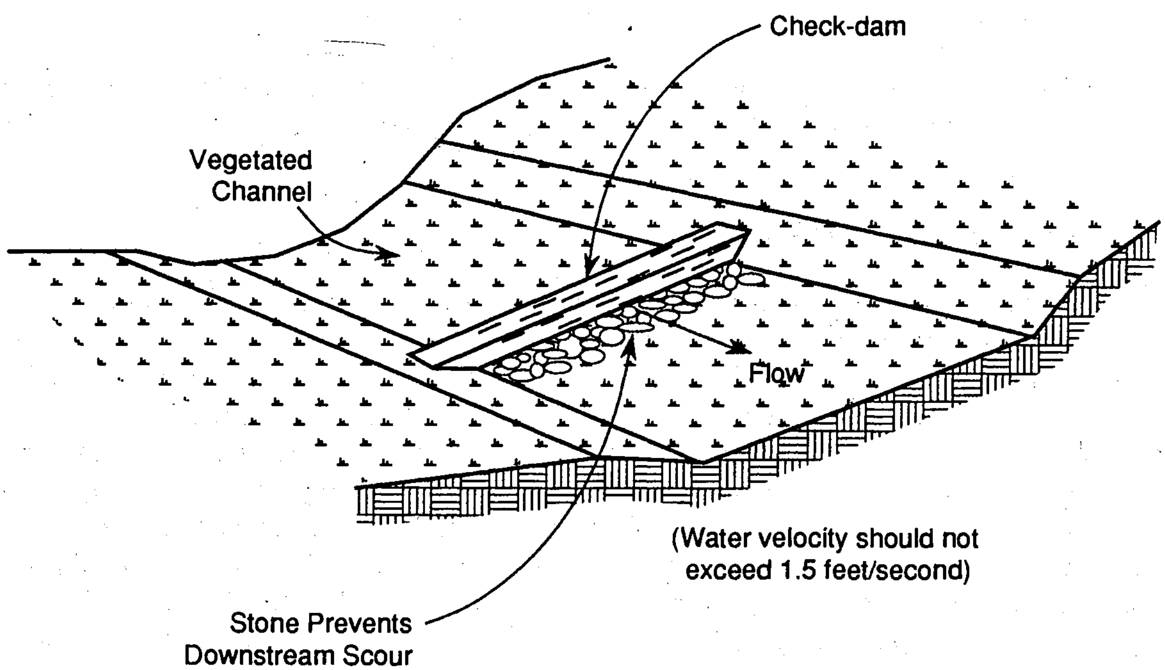


FIGURE 4-9
TYPICAL VEGETATED SWALE

Filter Strips

Filter strips are similar in many respects to grassed swales, except that they are designed only to accept overland sheet flow. Runoff from an adjacent impervious area must be evenly distributed across the filter strips. The purpose of filter strips are to intercept convey and/or infiltrate runoff without causing damage by erosion. As with grass swales, filter strips control, pollutants through several mechanisms including sedimentation, plant filtration, vegetative uptake and percolation through the soil. Filter strips can lower runoff velocity and increase watershed time of concentration, however, typically do not provide enough storage or infiltration to effectively reduce peak discharge for design storms. Figure 4-10 illustrates the operation of a filter strip BMP.

Type:	*Overland Flow Modification, Vegetative Control*
Area:	*Local (Five acres or less)*
Pollutant Removal:	*Suspended Solids, Nutrients*
Stormwater Control Benefits:	*Delays time of concentration and reduces runoff peak*
Maintenance Required:	*Routine mowing and proper disposal of clipping and removal of solids*

Dry Extended Detention Basins

Dry extended detention basins are modifications of the traditional detention basin designed specifically for flood control. The outlet is modified such that the detention times for regularly recurring runoff are "extended" to provide better pollutant removal efficiencies. Depending on the detention times, moderate to high removal efficiencies are possible for the particulate fraction of pollutants. However, the removal rates for soluble pollutants are low using dry extended detention, because dry extended detention basins for water quality control typically do not have a permanent pool and are normally dry. The primary difference between a dry extended basin for quality control versus one for quantity control is in the outlet structure, which is designed to release the regularly recurring runoff over an extended period of time. The minimum detention time for an extended detention basin should be 24 hours. Figure 4-11 shows a dry extended detention basin.

Type:	*On-site Storage*
Area:	*Fifteen acres or more*
Pollutant Removal:	*Suspended Solids, Heavy Metals,*
Stormwater Control Benefits:	*Delays time of concentration and reduces runoff peak*
Maintenance Required:	*Requires periodic sediment removal*

Wet Extended Detention Basins

A wet extended detention basin is a storage pond which normally contains a permanent pool of water. The term "extended" applies when the regularly recurring storm runoff is stored for a prolonged period of time before release. In addition to the sedimentation process to remove the particulate fraction of heavy metals, total solids, BOD, COD and the insoluble fraction of

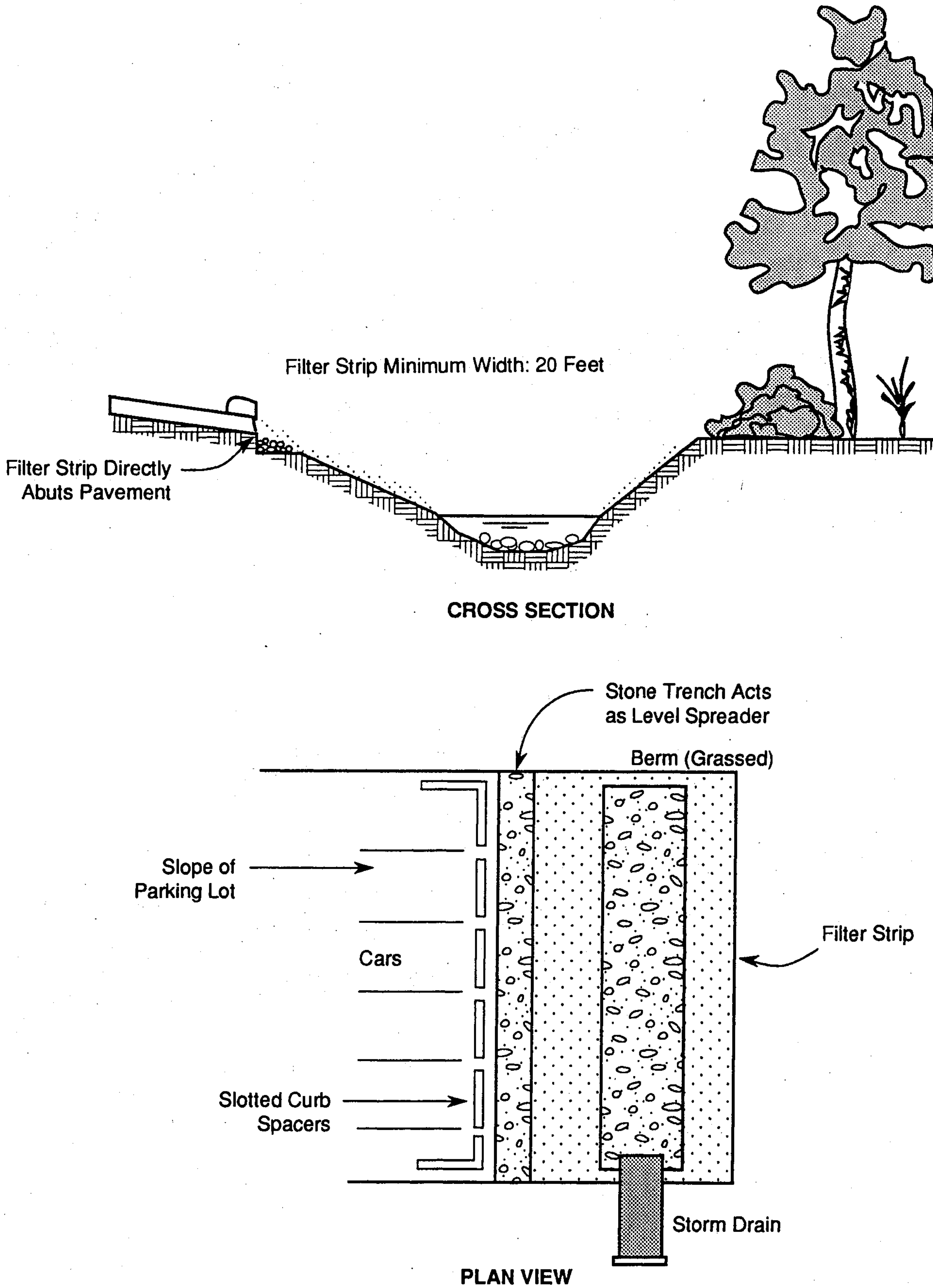
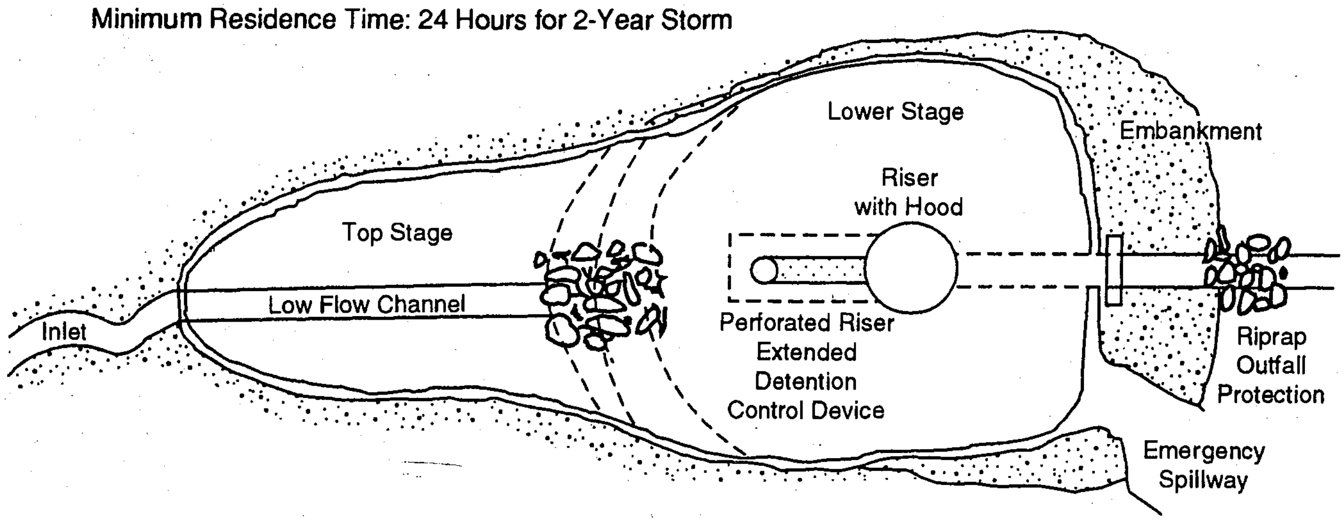


FIGURE 4-10
CONSTRUCTED VEGETATED FILTER STRIP



PLAN VIEW

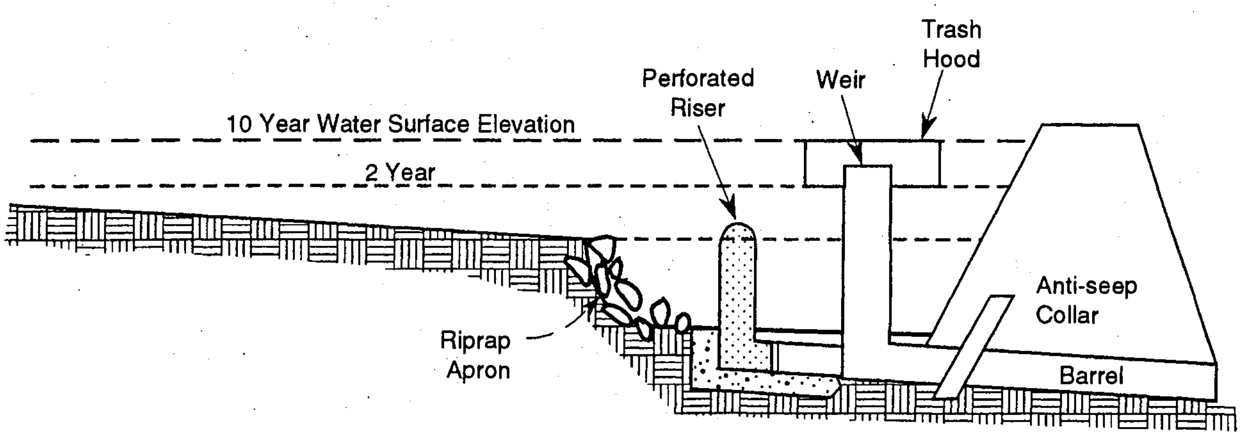


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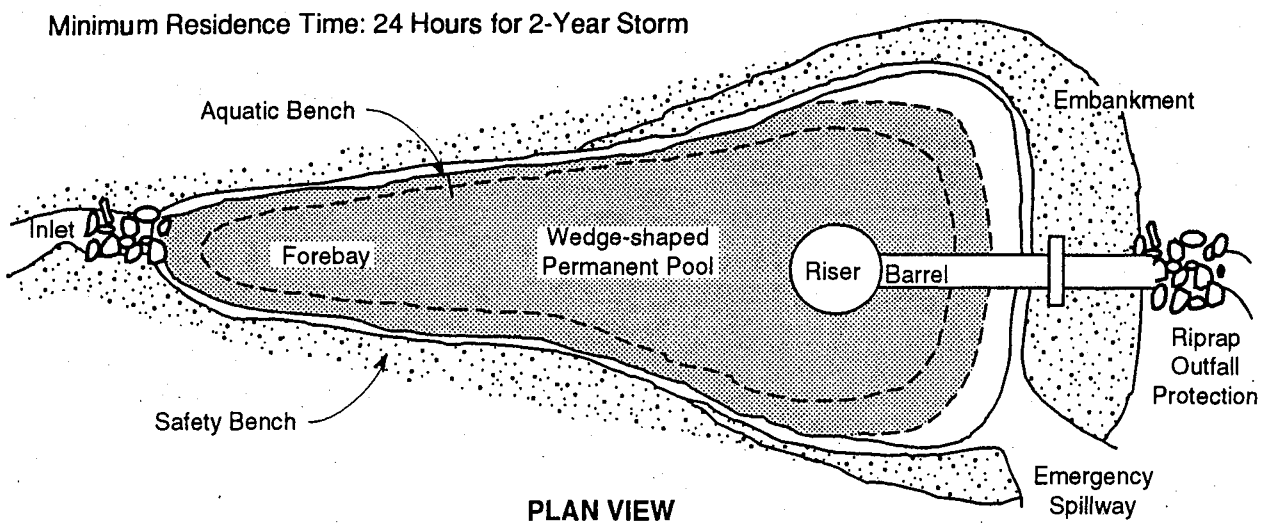
FIGURE 4-11
SCHEMATIC OF DRY EXTENDED DETENTION POND



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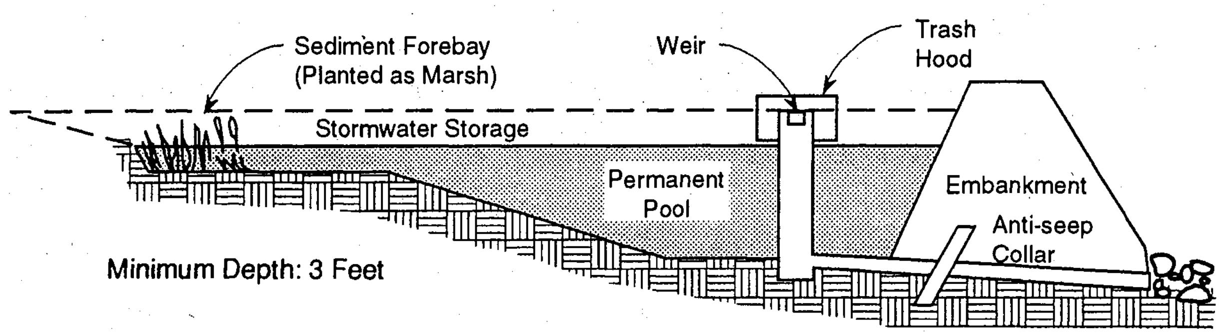


CROSS SECTION

FIGURE 4-12
SCHEMATIC OF WET EXTENDED DETENTION POND

nutrients (ortho-phosphorous and nitrate), wet detention ponds can achieve removal of dissolved nutrients through other physical/chemical and biological processes in the permanent pool. The removal of the soluble fraction of nutrients is by uptake of these nutrients by free-floating algae and wetland vegetation around the edge of the basin. If the runoff from an individual storm displaces all or part of the prior volume and the residual is retained until the next storm event, wet extended basins can be very effective in treating nutrients. The minimum detention time for an extended detention basin should be 24 hours. A typical wet extended detention basin installation is illustrated in Figure 4-12.

Type:	*On-site Storage*
Area:	*Fifteen acres or more*
Pollutant Removal:	*Suspended Solids, Heavy Metals, Nutrients*
Stormwater Control Benefits:	*Delays time of concentration and reduces runoff peak*
Maintenance Required:	*Requires periodic sediment removal and harvesting of vegetation, Maintenance of healthy pond, Insect Control*

Constructed Wetlands

Wetlands combine the functions of wet extended basins, infiltration basins and filter strips to provide enhancement for storm water runoff. Wetlands provide multiple benefits related to wildlife habitats and aesthetics and they can also be applied to a range of pollutant loading and hydraulic conditions. Constructed wetlands are used to provide water pollution abatement and recycling of nutrients in storm water runoff. Moderate to high removal efficiencies of BOD, TSS, and metals can also be achieved. The mechanism by which wetlands remove pollutants include a combination of sedimentation, adsorption, filtration, chemical precipitation, microbial interactions and uptake by vegetation. Negative impacts of wetlands include possible upstream and downstream habitat degradation, occasional nuisance problems (e.g., odor, algae, mosquitoes) and the eventual need for sediment removal. The minimum detention time for constructed wetlands should be two weeks. A combination sedimentation basin-constructed wetlands facility is illustrated in Figure 4-13.

Type:	*On-site Storage*
Area:	*Fifteen acres or more*
Pollutant Removal:	*Suspended Solids, Nutrients, Heavy Metals,*
Stormwater Control Benefits:	*Delays time of concentration and reduces runoff peak*
Maintenance Required:	*Requires periodic harvesting of wetland vegetation and removal of sediment deposits*

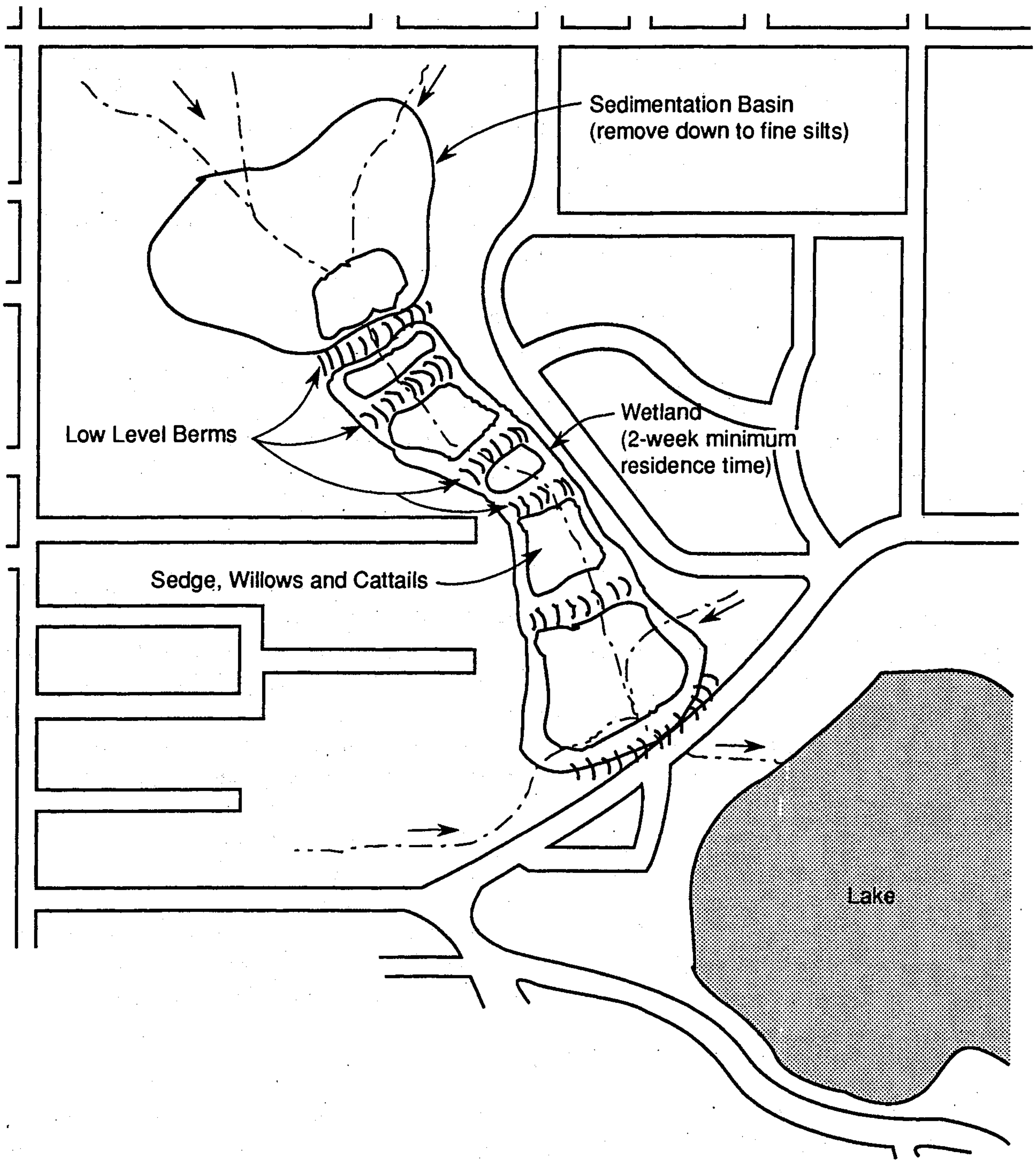


FIGURE 4-13
CONCEPTUAL SEDIMENTATION BASIN-WETLAND FACILITY

Trapped Catch Basins

Trapped catch basins are located between the curb and gutter and the storm drainage system. The main purpose of trapped catch basins are to collect large particles prior to their reaching the storm drainage system. The advantages of these basins are that they collect large sediment particles and prevent them from entering the storm drainage system. Disadvantage include the required periodic maintenance to remove accumulated sediment and the relatively small size of the basins which limits the effectiveness in settling out small particles. Installation costs are low when installed during the initial street construction, however, they are much higher for existing streets. A typical trapped catch basin is shown in Figure 4-14.

Type:	*Street and Storm Sewer System*
Area:	*One acre or less*
Pollutant Removal:	*Large Sediment Particles, Floatable Debris*
Stormwater Control Benefits:	*Minimal due to relatively small size of catch basin*
Maintenance Required:	*Periodic maintenance to remove accumulated sediments and debris*

Urban Landscaping

Urban landscaping refers to vegetation practices that can be used on development sites to improve water quality. These practices range from using simple storage depressions in a residential yard to grass-lined swales around commercial facilities. The main focus of urban landscaping is to use natural site characteristics in combination with vegetation practices and infiltration to improve runoff water quality. Vegetation should be selected which will establish itself and survive on the site. Ground slopes should be minimized in order to control erosion , especially through flower beds and gardens. Figure 4-15 is an illustration of recommended urban landscaping practices.

Type:	*Vegetation Control, Land Use Control*
Area:	*Local (residential or commercial lots)*
Pollutant Removal::	*Suspended Solids, Nutrients*
Stormwater Control Benefits:	*Delays time of concentration and reduces runoff peak*
Maintenance Required:	*Routine landscaping maintenance (mowing lawns, trimming shrubs, etc.) and proper disposal of cuttings*

Water Quality Inlets (Oil/Grit Separators)

The objective of water quality inlets is to remove sediment and floating hydrocarbons (oil and grease) and floatable debris from stormwater before they are transported to the main drainage system. Water quality inlets (also referred to as oil/grit separators) are used in conjunction with storm drainage systems, typically in areas with high pollution due to automobiles (parking lots, gas stations, etc.). A typical water quality inlet consists of several underground chambers in which runoff from a parking area is drained to. As the water moves through the chambers, sediment and debris are captured, along with the floating hydrocarbons. Soluble pollutants, however, pass through water quality inlets with essentially no removal occurring. In addition, individual inlets

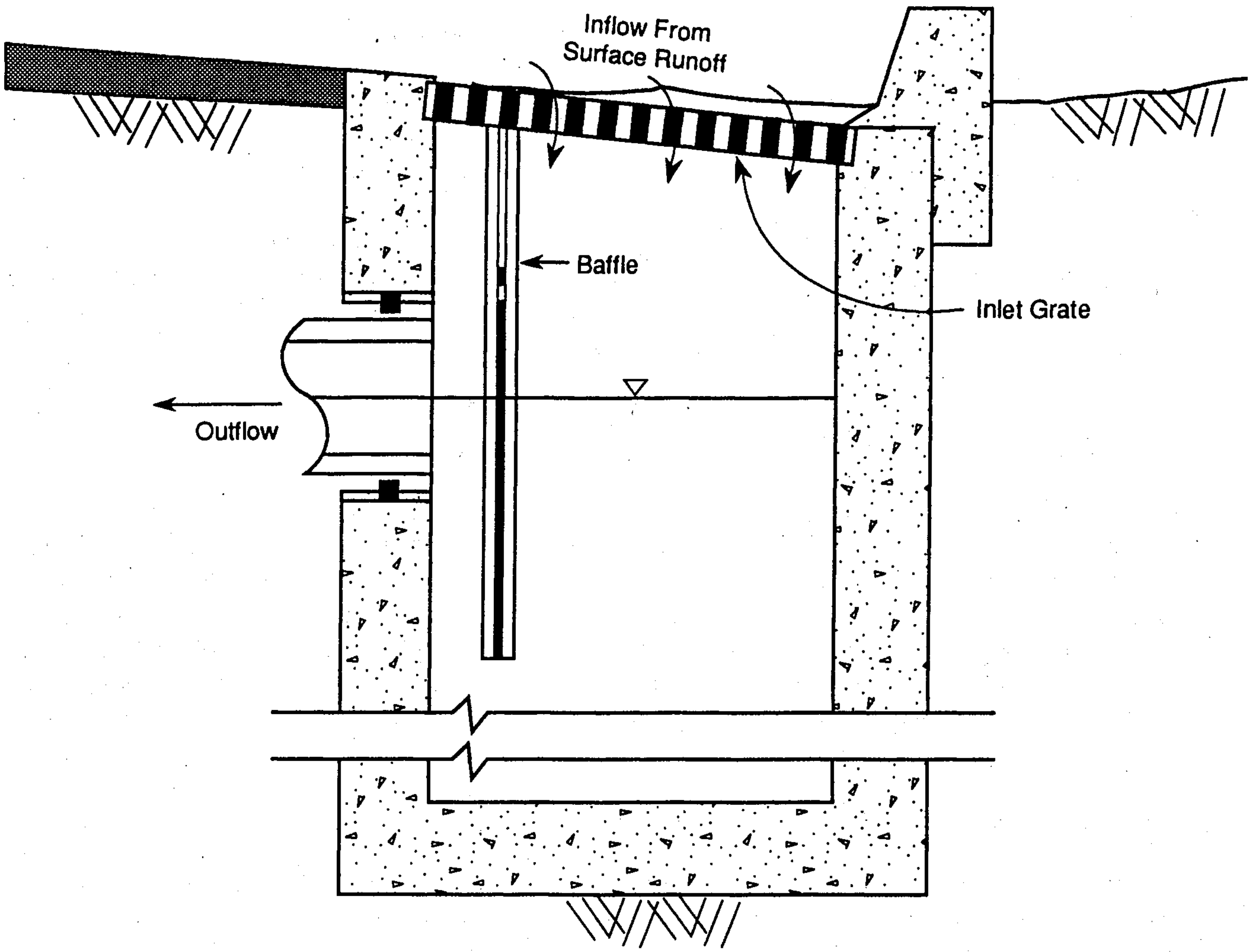


FIGURE 4-14
TYPICAL TRAPPED CATCH BASIN

should be used to serve relatively small areas (less than one acre) and due to their small holding size, inlets normally store only a small fraction of the water quality design storm event. Figure 4-16 illustrates the water quality inlet concept.

Type:	*Street and Storm Sewer Control*
Area:	*Localized urban areas with storm drainage systems (parking lots, industrial areas, high vehicle use areas with drainage area less than one acre)*
Pollutant Removal::	*Sediments, Suspended Solids, Hydrocarbons, Floatable Debris*
Stormwater Control Benefits:	*Very limited due to small holding capacity of chambers*
Maintenance Required:	*Accumulated sediment should be removed at least twice a year and trash racks should be inspected and cleaned periodically.*

CONSTRUCTION SITE BMPS

Regulations covering the issuance of an NPDES Construction Permit are currently in the review process in the State of California. Tentatively, these regulations will require NPDES Construction Permits for all construction activities where soil disturbance exceeds five acres. As part of the permit, the owner will be required to define the construction BMPs that will be implemented on the construction site to prevent erosion and to remove sediment from the stormwater and other construction water leaving the site. An appropriate combination of the BMPs described in this subsection of the report would most likely provide the protection required by the NPDES Construction Permit.

Dike and Berm Controls

Dike and berm controls can be used to control erosion by diverting runoff from exposed slopes. They can be placed across the top of short slopes or at intervals along longer slopes in order to reduce slope length. the primary dike and berm control structures are diversion dikes and check dams. Each of these is discussed in greater detail below:

- Diversion Dike. A diversion dike is a temporary ridge of compacted soil immediately above cut or fill slopes and built with adequate height to divert drainage away from the unprotected slope. Diversion dikes are also used to direct sediment laden runoff from a disturbed area to a sediment trapping facility. A typical diversion dike facility is illustrated in Figure 4-17.
- Interceptor Dike. An interceptor dike is a temporary ridge of compacted soil, located across disturbed areas or right-of-ways. The purpose of the interceptor dike is to shorten the length of exposed slopes by intercepting storm runoff and diverting it to a stabilized outlet or sediment trapping device.

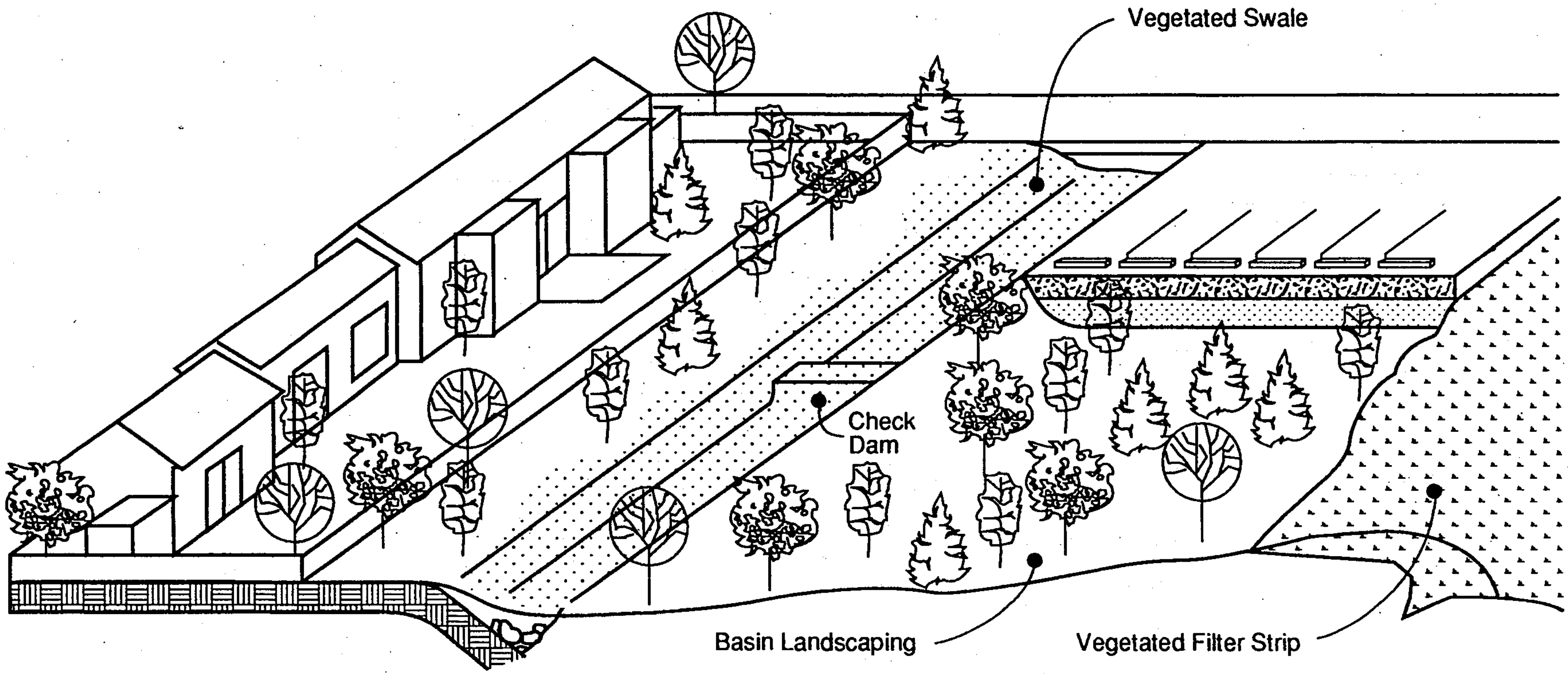


FIGURE 4-15
URBAN LANDSCAPING PRACTICES

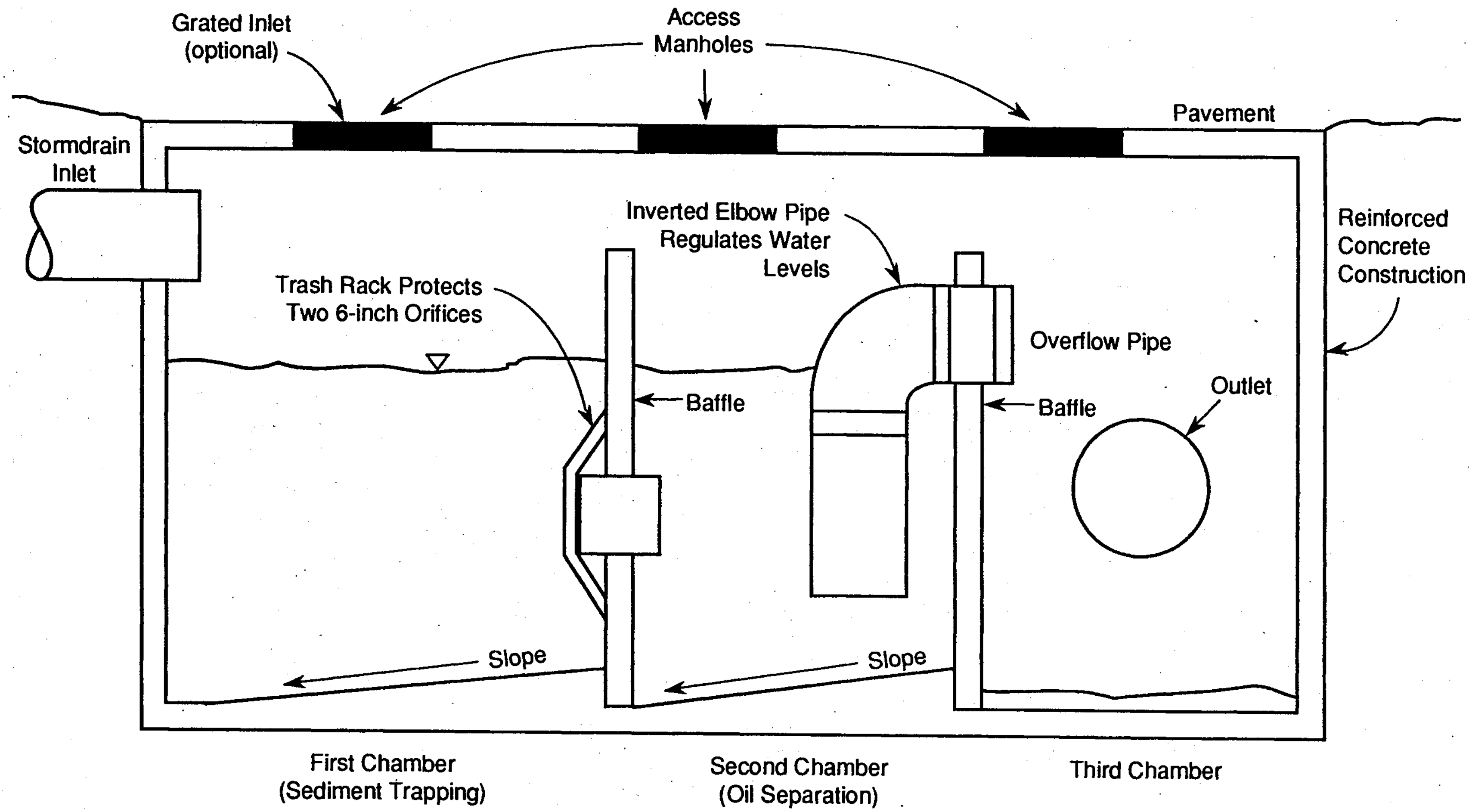


FIGURE 4-16
WATER QUALITY INLET BASIC DESIGN CRITERIA

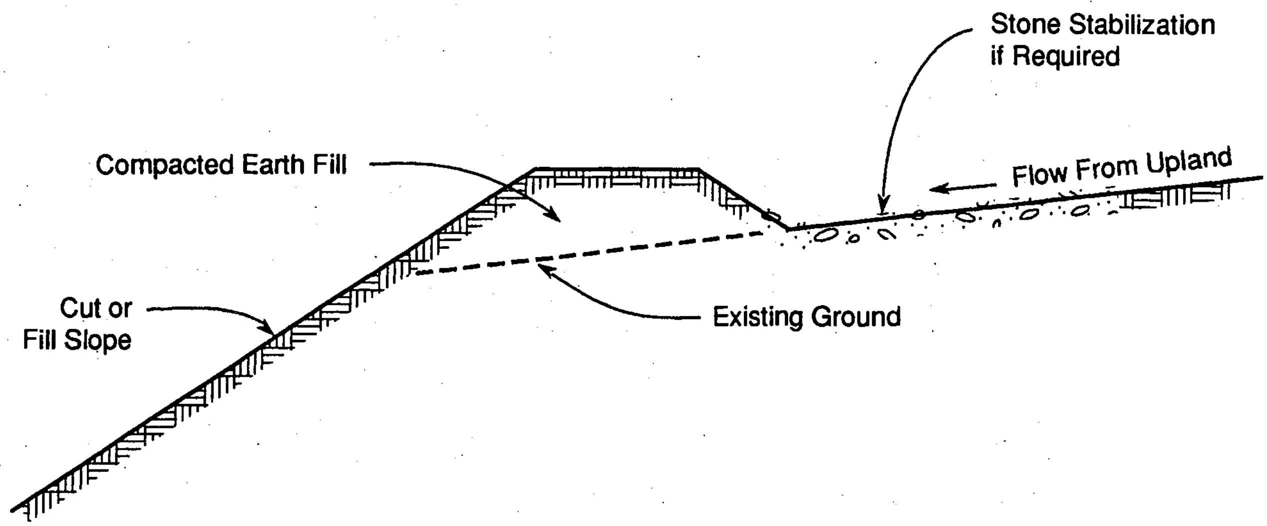
- Perimeter Dike. A perimeter dike is a temporary ridge of compacted soil located along the perimeter of the disturbed area. The propose of the perimeter dike is to prevent off-site storm runoff from entering the site and also to prevent on-site storm runoff to leave the site.
- Straw Bale Dike Structures. A straw bale dike structure is a temporary barrier constructed with straw bales at the base of a slope. The purpose of the dike is to intercept and detain small amounts of sediment from unprotected areas. A straw bale dike installation is shown in Figure 4-18.
- Check Dams. Check dams are small temporary dams constructed across a swale or drainage ditch with the purpose of reducing the velocity of storm water flows. This will reduce the erosion potential of the runoff and also trap small amounts of sediment.

Type:	*Overland Flow Modification*
Area:	*Localized Construction Sites*
Pollutant Removal:	*Sediments, Suspended Solids, Erosion Control*
Stormwater Control Benefits:	*Very limited, designed to divert runoff, not reduce or delay runoff*
Maintenance Required:	*Requires occasional to frequent inspection and maintenance*

Ditch and Swale Controls

Ditch and swale controls are similar to dikes and berms in that they can be used to reduce erosion and sedimentation by diverting runoff from the face of an exposed or disturbed slope. Depending on the volume and velocity of runoff, ditches and swales can be natural earth, vegetatively stabilized or rip rap lined channels, interceptor swales, perimeter swales and grass-lined channels.

- Diversion Channel. A diversion channel is a vegetation or rip rap-lined drainage way that is used to intercept and convey runoff to stable outlets at low velocities. Diversion channels can be utilized where runoff from up slope areas has the potential for endangering property or causing erosion. The diversion channel concept is shown in Figure 4-19.
- Interceptor Swale. An interceptor swale is a temporary drainage way excavated across disturbed areas. The purpose of the interceptor swale is to shorten the length of exposed slopes in order to reduce erosion potential on the slopes.
- Perimeter Swale. A perimeter swale is a temporary excavated drainage way located along the perimeter of the site. The purpose of the perimeter swale is to prevent off-site storm runoff from entering the site and also to prevent storm runoff containing high quantities of sediment from leaving the site.
- Grass-Lined Channels. A grass lined channel is a permanent drainage way that is used to intercept and convey runoff without causing excessive erosion. The channel is normally wide and shallow and carries runoff down the slope.



CROSS SECTION
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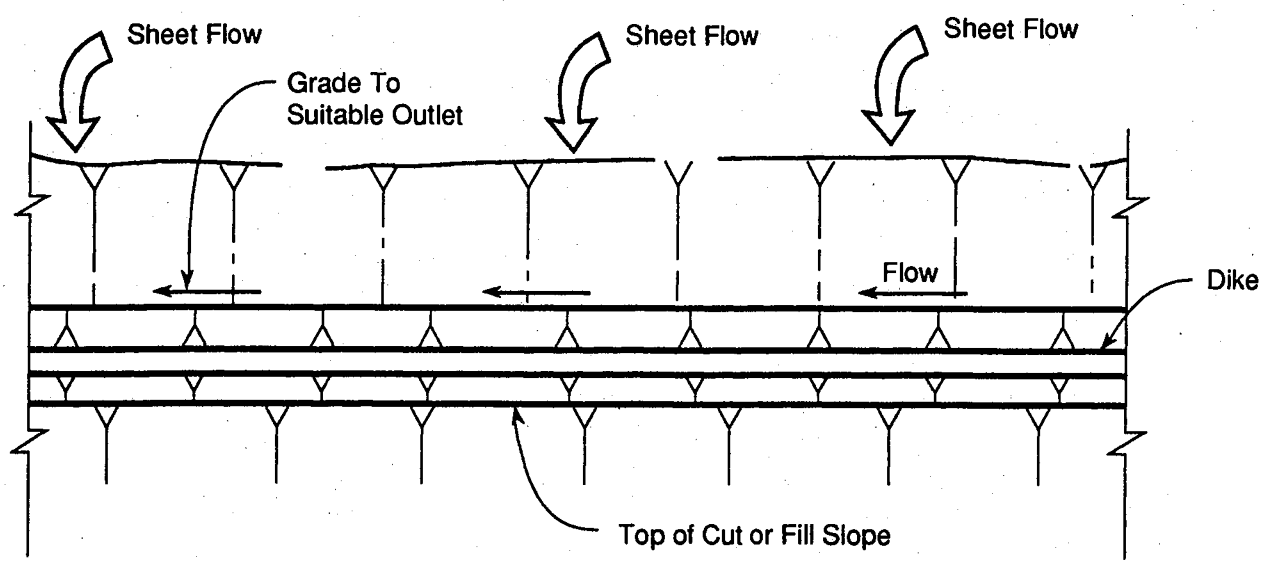
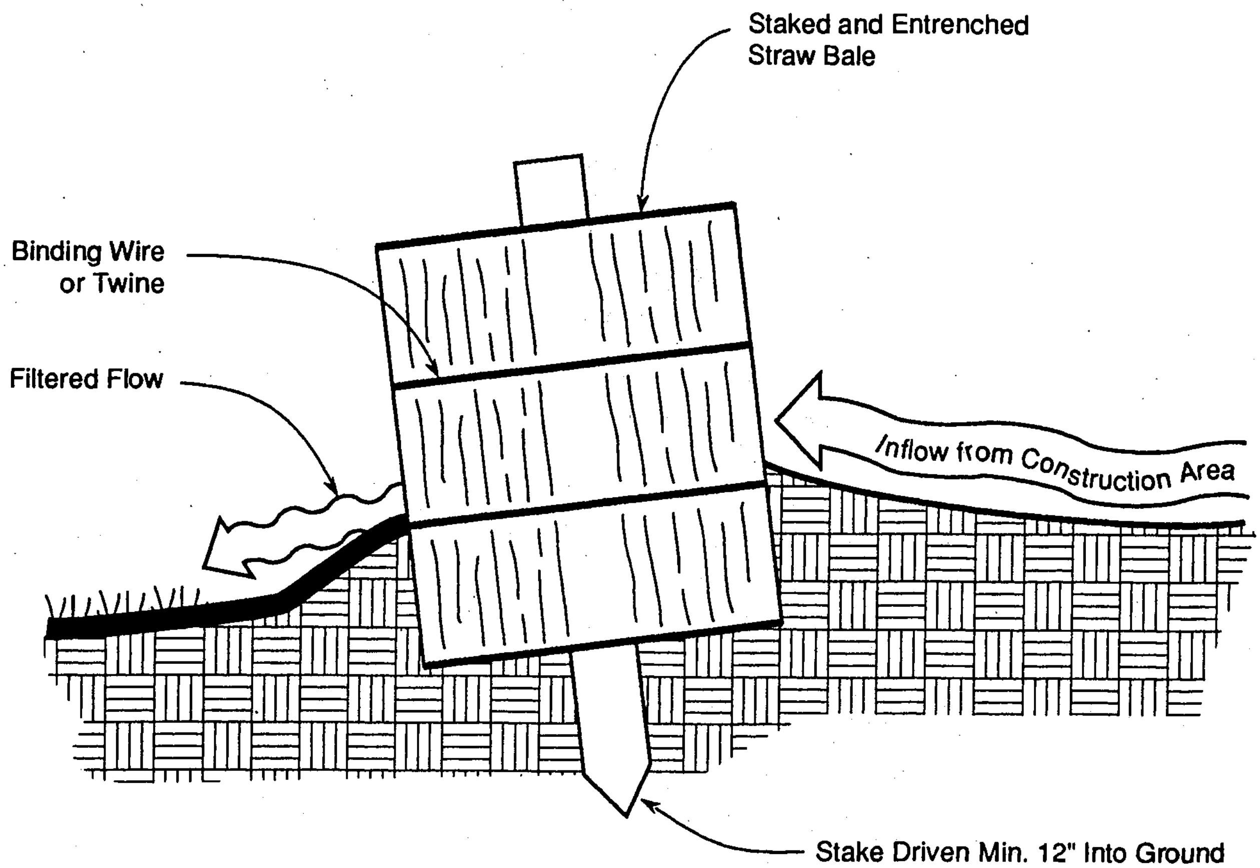


PLAN VIEW
(No Scale)

FIGURE 4-17
TYPICAL DIVERSION DIKE



Not to Scale

FIGURE 4-18
STRAW BALE DIKE

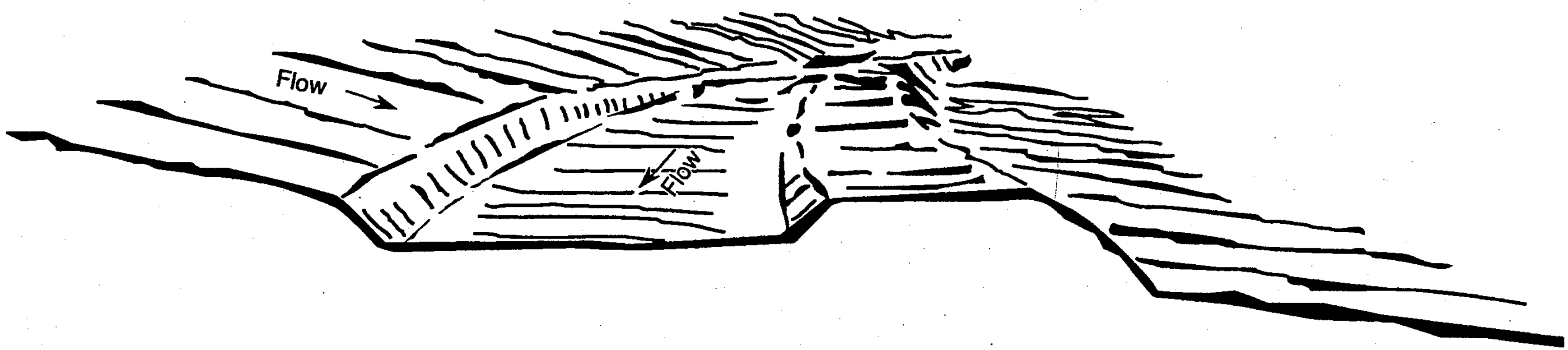


FIGURE 4-19
DIVERSION CHANNEL

Type: *Overland Flow Modification*
Area: *Localized Construction Sites*
Pollutant Removal: *Sediments, Suspended Solids, Erosion Control*
Stormwater Control Benefits: *Very limited, designed to divert runoff, not reduce or delay runoff*
Maintenance Required: *Requires occasional to frequent inspection and maintenance*

Sediment Collection

Collection controls such as fences and barriers, sediment traps and basins, and inlet protection measures are utilized to collect sediment from runoff before it leaves the site. These controls are discussed in greater detail below.

- Fences and Barriers. The purpose of fences and barriers is to intercept and detain water-borne sediment and also to decrease the velocity of sheet flows and low-level channel floods. The silt fence is a temporary linear filter barrier constructed of synthetic filter fabric utilizing a wire fence for support. The filter barrier is constructed of stakes and burlap material.
- Sediment Basin. A sediment basin is an area created by a temporary barrier or dam and utilized to capture sediment-laden runoff and to trap and retain the sediment. Sediment basins are generally utilized downstream of construction activities and are used to prevent sedimentation and water quality problems downstream of the project site.
- Sediment Trap. A sediment trap in a small temporary basin formed by excavation and is used to intercept and trap sediment-laden runoff and retain the sediment. Sediment traps are typically much smaller than sediment basins.

Type: *On-site Storage*
Area: *Localized Construction Sites*
Pollutant Removal: *Sediments, Suspended Solids, Construction Debris*
Stormwater Control Benefits: *Delays time of concentration and reduces peak flows*
Maintenance Required: *Minimal, requires occasional inspection and maintenance*

Land Grading Controls

Land grading practices, such as surface roughening, scarification, or creation of grooved slopes can improve the vegetative cover, reduce runoff velocity and erosion potential, increase infiltration and provide for sediment trapping. Land grading controls consist of reshaping existing topography in order to maximize the erosion control and establishment of vegetative cover. Common measures include terraces, serrated cuts, diversion swales and scarification.

Type: *Overland Flow Modification*
Area: *Localized Construction Sites*
Pollutant Removal: *Suspended Solids, Erosion Control*
Stormwater Control Benefits: *Delays time of concentration and reduces peak flows*
Maintenance Required: *Minimal to none, this is a temporary protective measure*

Vegetation and Mulching Controls

Temporary vegetation and mulching are measures that can provide temporary soil stabilization and thereby greatly aid in protecting exposed sites from erosion and downstream areas from sedimentation. It is typically desirable to provide a vegetative cover of rapid-growing and resilient native plants and grasses. Application of organic mulches such as rice hulls, corn stalks, or straw can provide immediate protection to unstabilized slopes during winter months or periods of construction delays. Mulches also enhance vegetative establishment by conserving moisture and moderating soil temperatures.

Type:	*Vegetation Control*
Area:	*Localized Construction Sites*
Pollutant Removal:	*Suspended Solids, Erosion Control*
Stormwater Control Benefits:	*Delays time of concentration and reduces peak flows*
Maintenance Required:	*Minimal*

Structure Slope Stabilization

The structural control measures included in this section; paved chutes, pipe slope drains, and rip rap and gabions, are primarily used for temporary or permanent slope protection. Paved chutes and pipe slope drains are typically implemented to convey concentrated storm runoff down steep slopes without causing rill (small rivulets), gully, or channel erosion. These methods can be valuable in protecting exposed slopes until permanent drainage structures are installed as is commonly encountered when construction is delayed prior to the establishment of final grade. chutes and drains can be designed for a particular storm event using established hydraulic methods.

Rip rap (loose stones, cobbles, or boulders) and gabions (wire enclosed rip rap) are used at soil-water interfaces where soil, water turbulence, and/or velocity and vegetative cover conditions are conducive to soil erosion under normal design flow conditions. Rip rap aids in slowing runoff velocity and in controlling erosion damage to otherwise unstable slopes and is typically a permanent control measure.

Type:	*Overland Flow Modification*
Area:	*Local Construction Sites*
Pollutant Removal:	*Erosion Control*
Stormwater Control Benefits:	*Chutes and Drains may decrease time of concentration and increase peak flows. Rip rap and gabions may increase concentration time and decrease runoff peaks*
Maintenance Required:	*Minimal.*

Litter Control/Solid Waste Management

Spent material from construction activities such as empty containers, wrappings, etc. all may contribute to construction litter. Unless this material is cleaned up and contained, it is often found in storm water discharges. Convenient location of waste disposal containers, education programs, and the enforcement and management of solid waste collection activity are some of the source control programs that may reduce the amount of solids loading from construction runoff.

Type:	*Surface Sanitation/Direct Source Control*
Area:	*Local Construction Sites*
Pollutant Removal:	*Solid Wastes, Construction Debris*
Stormwater Control Benefits:	*None*
Maintenance Required:	*Frequent Solid Waste Collection*

SECTION 5
MANAGEMENT OPTIONS AND ALTERNATIVES

In general, flood control approaches can be divided into two classes: structural and nonstructural. Structural approaches are those involving the traditional capital improvement projects such as channels improvements, floodwalls, bridge and culvert replacement, regional detention basins, levees, etc. In contrast, nonstructural approaches attempt to minimize flood damage and losses through a variety of planning and administrative procedures which are less capital intensive. Included in this category are floodplain management, on-site detention, and flood warning systems. Local or on-site detention is classified as a nonstructural alternative because it takes the form of an administrative policy or ordinance requiring local detention by developers.

The various structural and nonstructural alternatives considered as part of the Auburn/Bowman Drainage study, along with evaluation criteria, are discussed in the following sections. The evaluation sections include a discussion of the environmental impacts of the proposed alternatives.

STRUCTURAL ALTERNATIVES

The various types of structural alternatives considered as part of the study include; bridge and culvert replacements, regional detention basins, channel improvements, levees and floodwalls, and various structural methods to protect Rock Creek Reservoir. Each of these types of structural alternatives are discussed in the following sections.

Regional Detention Basins

Regional detention basins typically consist of a 15 to 35 foot high dams, capable of storing 50 to 500 acre-feet of stormwater, and are usually constructed on the larger tributaries of a given watershed. A flow-through outlet in the dam is designed to reduce flood flows by restricting the peak flow that will pass through the outlet. The flood flows that exceed the capacity of the outlet are designed to be stored in the basin and released over a period of time after the peak of the storm has passed. A regional detention basin can be designed to reduce flood flows for any given flood return period, but normally the basin will be designed to control 25- to 100-year flood flows.

Selection Criteria The first step in the selection process for the regional detention basin sites was determining the need for regional detention on the major streams in the study area. The second step in the screening process was to determine if there were suitable locations for a regional detention basin in the area where it is needed. This includes the determination of whether the land is currently undeveloped and whether the topography and layout of the site are suitable to support a regional detention basin.

As discussed in earlier sections, the impact of future land use on the flood peaks will be minimal and hence, within the study area there is not a need for regional detention inside the study area to mitigate changes in future flows. In addition, the reservoirs in the study area (Rock Creek Reservoir, Dry Creek Reservoir, Halsey Forebay, Orr Creek Reservoir) already act as detention basins (to varying degrees). Lake Arthur and Lake Theodore (located on Dry Creek upstream of the study area) also act partially as detention basins for the Dry Creek watershed.

Even when regional detention is not recommended inside the study area, regional detention outside the study area may be suggested in order to mitigate increased volumes of stormwater runoff that may occur as a result of development in the Auburn/Bowman Community Plan Area.

Bridge and Culvert Replacement

Bridge and culvert replacement is required when the capacity of a bridge or culvert is inadequate to pass a specified flow and as a result causes floodwaters to either backup into adjacent structures, or overtop the bridge or culvert. Maintenance of the existing flood storage in the floodplain was an important aspect that was considered when determining the required size and configuration of replacement bridges and culverts. Removal of existing flood storage upstream of culverts could increase flood flows downstream of the area where the storage is removed. For this reason, the replacement bridges and culverts were designed conceptually so as not to be overtopped by the 100-year flood flows while at the same time maintaining as much of the existing flood storage above the crossing as possible. This design concept will keep the impacts of the culvert or bridge improvement to a minimum, while at the same time solving the problems caused by inadequate bridge or culvert capacity.

Selection Criteria There are approximately 30 bridges and culverts in the Auburn/Bowman Community Plan area which do not have adequate capacity to pass the 100-year flows (excluding private road crossings and State Highways). However, not all of these bridges and culverts are recommended for replacement. Some of the crossings in the rural areas have been designed as low flow crossings and as such would not be damaged from high flows. In addition, other crossings were built in such a way within the floodplain that it would not be feasible to pass the 100-year flows without significant channel improvements and modifications (in addition to the replacement of the crossing).

Evaluation Of Bridge and Culvert Replacement. The required capacity for each of the replacements was taken from the 100-year peak flow tabulation in Table 3-1 and a replacement or addition was designed for each of the locations as shown on Table 5-1. Table 3-1 indicates the overtopping flows for each crossing and each return period. A major design criteria used in determining the replacement sizes for the bridges and culverts was that the bridge or culvert pass the peak flow such that the flood waters are just below the road surface. This design criteria will result in the smallest possible reduction in storage upstream of the bridge or culvert, while at the same time providing adequate capacity to pass the 100-year peak flows. Maintenance of existing upstream storage capacity as culverts are improved will help prevent increases in downstream

TABLE 5-1
BRIDGE AND CULVERT REPLACEMENT*

ITEM NO.	X-ING NO.	DESCRIPTION	EXISTING	MODIFICATION	ADD	REPLACE
1	7	Orr Creek @ W. Stanley Dr.	3 - 8' CMP	1 ea. CMP 5.5'	X	
2	11	Orr Creek @ Christian Valley Rd.	3 - 3.5' CMP	4 ea. CMPA's 6.3' x 9.3'		X
3	15	Orr Creek Trib. @ Black Oak Rd.	1 - 3' CMP	1 ea. CMP 3'	X	
4	16	Orr Creek Trib. @ Virginia Way	1 - 4' CMP	1 ea. CMPA 4.8' x 6.9'	X	
5	17	Orr Creek Trib. @ Kenneth Way	3 - 3' CMP	1 ea. CMP 1.5'	X	
6	18	Orr Creek Trib. @ Lone Star Rd.	1 - 3' x4' CMPA	3 ea. CMPA's 5.6' x 7.9'		X
7	20	Dry Creek @ Bell Road	1 - 9'x15' Bridge	Bridge Modification to 10.4' x 25'		X
8	25	Dry Creek @ Blue Grass Rd.	3 - 8' CMP	1 ea. CMPA 8' x 12.7	X	
9	29	Dry Creek @ Twin Pines Trail	4 - 3' CMP	4 ea. CMPA's 7.4' x 11.6'		X
10	30	Dry Creek @ Haines Rd.	1 - 5' x 25' Bridge	Bridge Modification to 6.7' x 28'		X
11	32	Dry Creek @ Bowman Rd.	1 - (4.7'x14'). 1 - (5.7'x14') RCB	2 ea. RCB 5.2' x 14'.		X
12	36	Dry Creek Trib. @ Dry Creek Rd.	1 - 2' CMP	3 ea. CMPA's 2.0' x 2.9'	X	
13	37	Dry Creek Trib. @ Dry Creek Rd.	1 - 3.5' x 10' Bridge	Bridge Modification to 3.5' x 17'		X
14	38	Dry Creek Trib. @ Black Oak Rd.	1- 4' CMP	1 ea. CMPA 4.9' x 6.8'	X	
15	41	Dry Creek Trib. @ Howe Rd.	2 - 3' CMP	3 ea. CMPA's 5.9' x 8.6'		X
16	42	Dry Creek Trib. @ Hubbard Rd.	1 - 5' x 20' Bridge	Bridge Modification to 5' x 24.2'		X
17	43	Rock Creek @ Joeger Rd.	1 - 2' CMP	1 ea. CMPA 3.6' x 5.3'	X	
18	46	Rock Creek @ Sherwood Way	2 - 6.5' x 10' CMPA	2 ea. CMPA's 6.6' x 9.8'	X	
19	48	Rock Creek @ Richardson Rd.	2 - 8' CMP	2 ea. CMPA's 8.3' x 12.8'	X	
20	49	Rock Creek @ HWY 49	3 - 5.5' x 12' RCB	1 ea. Box Culvert 5.5' x 6.2'	X	
21	50	Rock Creek @ Rock Creek Rd.	2 - 5' CMP	2 ea. CMPA's 5.6' x 7.8'	X	
22	54	Rock Creek @ New Airport Rd.	3 - 4' x 5.5' CMPA	1 ea. CMPA 3.6' x 5.3'	X	
23	60	Rock Creek Trib. @ New Airport Rd.	1 - 2' CMP	3 ea. CMPA's 3.6' x 5.3'	X	
24	61	Rock Creek Trib. @ Bell Rd.	1 - 5' CMP	1 ea. CMPA 1.5' x 2'	X	
25	62	Rock Creek Trib. @ Locksley Lane	1 - 2' CMP	1 ea. CMPA 3.9' x 5.9'	X	
26	63	Rock Creek Trib. @ Rock Creek Rd.	1 - 4' CMP	3 ea. CMPA's 5.6' x 7.9'	X	
27	66	North Ravine @ Warren Way	1 - 6' x 25' Bridge	Bridge Modification to 6' x 34'		X
28	67	North Ravine @ Calnick Rd.	1 - 5.5' x 18' Bridge	Bridge Modification to 8' x 22'		X
29	70	North Ravine @ Millertown Rd.	1 - 5' x 20' Bridge	Bridge Modification to 9' x 25'		X
30	71	North Ravine @ Mt. Vernon Rd.	1 - 7' x 20' Bridge	Bridge Modification to 7' x 24'		X
31	72	North Ravine @ Harris Rd.	1 - 4' CMP	3 ea. CMPA's 3.9' x 5.9'	X	
32	73	North Ravine @ Vista Roble Rd.	1 - 3' x 12' Bridge	Bridge Modification to 3' x 29'		X
33	75	North Ravine Trib. @ Kemper Rd.	1 - 1.5' CMP	4 ea. CMPA's 3.2' x 4.8'		X
34	78	North Ravine Trib. @ HWY 49	1 - 4' x 3' RCB	1 ea. CMPA 4.9' x 6.8'	X	
35	79	North Ravine Trib. @ Pear Rd.	1 - 1' CMP	4 ea. CMPA's 5.6' x 7.9'		X
36	80	North Ravine Trib. @ Millertown Rd.	1 - 3' x 4' CMPA	3 ea. CMPA's 3.9' x 5.9'		X
37	81	North Ravine Trib. @ Mt. Vernon Rd.	1 - 4.5' CMPA	1 ea. CMPA 4.6' x 6.1'	X	
38	82	North Ravine Trib. @ Millertown Rd.	1 - 1.5' CMP	3 ea. CMPA's 1.7' x 2.3'		X
39	83	North Ravine Trib. @ Bar Ranch Rd.	1 - 1' CMP	1 ea. CMPA 2' x 2.9'	X	
40	86	Auburn Ravine @ Wise Rd.	1 - 12' x 20' Bridge	Bridge Modification to 12' x 37'		X
41	87	Auburn Ravine @ Ophir Rd.	3 - 6' x 10' RCB	1 ea. Box Culvert 6' x 6.3'	X	
42	89	Auburn Ravine @ Forgotten Rd.	2 - 8' CMP	3 ea. CMPA's 9.1' x 14.8'	X	
43	95	Mormon Ravine Trib. @ No Name Rd.	1 - 2' CMP	4 ea. CMPA's 3.2' x 4.8'		X
44	96	Mormon Ravine Trib. @ Andregg Rd.	1 - 2' CMP, 1 - 3' CMP	2 ea. CMPA's 3.9' x 5.9'	X	
45	97	American River Trib. @ HWY 49	1 - 4' CMP	1 ea. CMP 4'		X
46	98	American River Trib. @ HWY 49	1 - 2' CMP	1 ea. CMPA 2.8' x 4.1'	X	
47	99	Deadman Canyon @ Joeger Rd.	1 - 5.5' x 7.7' Bridge	3 ea. CMPA's 4.9' x 6.8'		X

* This list includes all deficient bridges and culverts in the study area.

flow that would occur if the storage was lost. As was discussed previously, the natural storage in the watershed is an important factor in reducing the peak runoff from a given storm event.

Environmental Impacts of Bridge and Culvert Replacement. Environmental impacts of bridge and culvert replacement will occur as a result of the construction process. These impacts may include:

- Erosion of exposed areas;
- Displacement of wildlife during the construction activities; and
- Short term sedimentation in the stream during construction.

The environmental impacts of the bridge or culvert after construction will be no different than those of the bridge or culvert being replaced or improved.

Channel Improvements, Levees, and Floodwalls

Due to the moderate to steep slopes within the Auburn/Bowman Community Plan area there are relatively few areas where stream channels have insufficient capacity to pass the 100-year flood flows. The Dry Creek channel adjacent to Dry Creek road was the only area identified in this study where the stream channel was inadequate to pass the 100-year flows without impacting existing structures (i.e. Dry Creek Road). Channel improvements, levees, and/or floodwalls may be the most practical structural measures of protecting Dry Creek Road, short of actually moving the road out of the floodplain.

The Placer County Stormwater Management Manual contains specific instructions on when channel improvements are appropriate. It states that channel improvements involving the straightening and enlargement of the stream channel are not permitted except as necessary to protect existing structures or improvements from flood damages. In conjunction with this work, the channel is also usually treated in some manner to insure that the improved channel will not erode. Treatment can include lining of the channel with rock rip rap, gabions, concrete, or grasses. In some instances where the required additional capacity is relatively small, it may not be necessary to enlarge or straighten the channel. In those cases it may be sufficient to simply maintain the channel and remove obstructions.

Where it is not possible to construct channel improvements, or where channel improvements alone will not provide adequate protection, it may also be necessary to build levees or floodwalls. A levee is an earthen berm built alongside the stream channel, preventing flood flows from overflowing out into portions of the floodplain containing buildings that are being protected. Floodwalls are typically constructed out of concrete or concrete block and perform the same function as levees, but are used where there is not enough room to construct a levee. Levees are required in place of floodwalls where the height of the protection must exceed about five feet.

Downstream impacts of channel improvement and levee projects may include increased erosion due to higher velocities coming out of the reach, and higher flood peaks caused by the reduction of storage volume in the improved reach of the channel. It is important to conduct detailed studies prior to construction of channel improvements or levees so that the exact nature of these impacts may be determined.

Selection Criteria. Environmental considerations make channel improvements, such as channel widening or clearing, the least desirable of the possible structural flood control alternatives. Channel widening and clearing can increase the flooding and erosion downstream of the channel improvement as described earlier. Channel improvements are used when no other feasible alternatives are available to solve the flooding problems at a particular location in the watershed. Levees and floodwalls may be used in conjunction with the channel improvements to reduce the amount of channel improvement that has to take place to obtain a given level of protection.

Locations in the watershed where the existing channel capacity is not sufficient to pass the 100-year flood, and the floodplain has been encroached upon are candidates for channel improvements and floodwalls. If, in addition, there are no upstream locations for detention facilities adequate to reduce the flood peaks to acceptable levels, then channel improvements may be the only feasible solution to the flooding problem.

Evaluation of Channel Improvements, Levees, and Floodwalls. As mentioned above, the Dry Creek channel adjacent to Dry Creek Road was the only area identified where the channel was inadequate to pass 100-year floods without the flooding of existing structures. Specifically, flooding has been known to occur on Dry Creek Road in the vicinity of Dry Creek Road bridge and Twin Pines Trail Bridge. Channel improvements to reduce this flooding were investigated using the HEC-2 hydraulic model. Both the 25-year and 100-year storm events were considered.

100-Year Storm Event. The most severe flooding of Dry Creek Road during flows associated with a 100-year storm occur at Dry Creek Road Bridge and further upstream at Twin Pines Trail Bridge. Significant channel improvements including channel excavation and bridge modifications would not be enough to lower the water surface elevations to below the roadway. Without channel modifications, Dry Creek Road in the vicinity of the Dry Creek Bridge is submerged by approximately three feet of water in the 100-year flood. Even with the significant improvements to the channel such as channel clearing and extensive channel excavation, the water surface elevation can only be lowered by around one foot. In the vicinity of Twin Pines Trail, improvements to the channel and culverts result in flooding being reduced from approximately a depth of two feet to just under one foot above the Dry Creek Road surface. Through these analyses it was determined that even with channel excavation exceeding 17,000 cubic yards, the channel could not be improved enough to prevent flooding of Dry Creek Road during the 100-year storm.

25-Year Storm Event. The most severe flooding for the 25-year event also occurs in the vicinity of Dry Creek Road Bridge and Twin Pines Trail Bridge. Channel modifications, including a combination of excavation and vegetative removal in the channel and floodplain were evaluated to be effective in eliminating flooding along Dry Creek Road for this storm event. A total of 6,600 cubic yards of excavation is required in addition to maintaining a clear channel and floodplain (i.e. removal of blackberries and other undergrowth in the channel and overbanks).

Environmental Impacts of Channel Improvements, Levees, and Floodwalls. Construction of channel improvements will have the most environmental impacts of any of the structural alternatives proposed as a part of this plan. Potential impacts to fish and riparian wildlife and vegetation are magnified due to the fact that the construction will take place in the stream channel for hundreds of feet. The potential construction impacts include:

- Erosion of unvegetated areas;
- Removal of trees and shrubs as required to construct the new stream channel;
- Displacement of wildlife during the construction activities;
- Displacement of the fish population and destruction of possible spawning beds along the channel improvement reach; and
- Short-term sedimentation in the stream during construction.

Post-construction impacts of the channel improvement can be mitigated by revegetation of the overbank areas and by provision of a meandering low-flow channel. This low-flow channel will provide pools and riffles for fish and riparian wildlife.

Construction impacts of levees or floodwalls may include:

- Erosion of unvegetated areas;
- Displacement of wildlife; and
- Removal of ground cover, trees, and shrubs along the levee or floodwall alignment.

Rock Creek Reservoir Protection

The water quality of Rock Creek Reservoir is of concern due to the fact that the reservoir is the primary source of water for the North Auburn Water Treatment Plant (operated by NID) as well as for the lower Wise Canal and Fiddler Green Canal. The water in these canals is ultimately used for agricultural and municipal purposes. Hence, protection of the water quality in Rock Creek Reservoir from potential pollutants carried in stormwater runoff is of utmost importance.

The watershed of the reservoir is composed of approximately 1400 acres with three tributaries entering from the southeast (Rock Creek), the east, and the north. These tributaries to Rock Creek Lake are all intermittent. The current land use in the watershed includes Auburn Airport and business park to the north, open space to the east, and a combination of open space, rural residential, and urban developments to the southeast. The watershed is undergoing significant urbanization and therefore, the potential exists for degradation of water quality in the reservoir due to stormwater runoff from recent and planned developments. As discussed in previous sections, urban runoff has the potential of transporting a variety of pollutants to receiving waters including petroleum contaminants and trace metals from streets and paved surfaces as well as pesticides and fertilizers from lawns and gardens.

In addition to the implementation of Best Management Practices in new developments in the upper Rock Creek Watershed, there are various structural methods that may be used to protect the reservoir from urban runoff pollutants. These methods include: (1) construction of a bypass channel paralleling the reservoir such that runoff from the tributaries would be intercepted and diverted around the lake with a discharge to Rock Creek below the reservoir; (2) construction of sedimentation basins at each of the three tributaries entering the reservoir such that particulates and solids in the stormwater runoff could be settled out before entering the reservoir; (3) use of vegetation in the reservoir to remove pollutants; and (4) construction of wetlands upstream of the reservoir or around the reservoir which could provide treatment of the runoff before entering the reservoir. Each of these options is discussed in greater detail below

Bypass Channel. The concept of a bypass channel is to intercept and divert runoff before it enters the reservoir. The bypass channel would be constructed parallel to the reservoir shoreline starting from where Rock Creek enters the reservoir (near Bell Road) and continuing along the northeastern side of the reservoir such that the runoff would be diverted to a point downstream of the existing dam and outlet structure on Rock Creek. The channel could be constructed for various levels of protection for the reservoir. For example, it could be constructed with a capacity to divert and carry only the smaller storm runoff with excess runoff spilling into the reservoir, or it could be constructed with a much larger channel and outlet structure such that all runoff including that of a 100-year storm is diverted around the reservoir. However, in designing the channel with a smaller capacity, the "first flush" which typically contains the most contaminants would be diverted around the reservoir while the larger flows (which generally are of better water quality) would spill into the reservoir.

While the water quality in Rock Creek Reservoir will be protected by the bypass channel, Rock Creek below the dam will suffer some adverse water quality impacts as a result of the operation of the bypass channel. The first flush flows that would otherwise have been diluted in the lake will instead be dumped directly into Rock Creek below the dam. These flows may or may not be diluted, depending on the current releases from the dam.

Sedimentation Basins. The idea behind the use of a sedimentation basins to treat urban runoff is to detain runoff from storm events in a basin such that suspended solids have the time to settle out before the runoff leaves the basin. When properly designed and maintained, sedimentation basins can be an effective tool in removing a large percentage of suspended solids from stormwater runoff. In addition, since hydrocarbons as well as certain trace metals have an affinity for suspended solids, many of these contaminants can be removed from urban runoff by use of sedimentation basins. In the Rock Creek watershed, sedimentation basins could be constructed on each of the three tributaries of Rock Creek which enter the reservoir. The basins can be designed for a specific storm event as well as removal efficiency of suspended solids through the basin size, geometry and outlet structure. For instance, a larger basin may be able to detain runoff for a longer period of time and hence, have a higher efficiency in the removal of suspended solids. Factors to be considered when designing sedimentation basins are the land availability for the basins, and particle size and removal efficiency desired.

Vegetative Removal of Pollutants. Methods are available that would utilize free floating and rooted submersed plants to consume nutrients and to accumulate trace metals. Through careful management of the appropriate aquatic vegetation, nutrient levels from stormwater runoff in Rock Creek Reservoir could be kept below critical levels, resulting in overall water quality improvement. A system of this type would use the dilution and sedimentation capacity of the Rock Creek Reservoir as an integral part of the treatment scheme, with the aquatic vegetation providing for the removal of trace metals and nutrients. Once the nutrients and trace metals have been consumed by the aquatic plants, the plants are harvested and removed, thus removing the pollutants and insuring that the lake will not require dredging to remove polluted sediments. This type of treatment would have the fewest negative impacts on Rock Creek downstream of the lake and could still provide the required water quality in the lake.

Constructed Wetlands. Constructed wetlands treat urban runoff by routing the runoff through an artificially created wetland area which can provide treatment of the runoff prior to discharging the runoff to the receiving waters. The use of wetlands in treating effluent from wastewater treatment plants is well documented and recent studies indicate that wetlands may also be an effective way to treat urban runoff. The primary method of treatment that wetlands provide are the biological assimilation of certain pollutants such as nutrients and certain soluble metals as well as sedimentation. In the Rock Creek watershed potential sites for constructed wetlands include Rock Creek upstream of Bell Road (13 acre parcel owned by PG&E) and around the eastern and northern shore of Rock Creek Reservoir (the same location as the bypass channel described above). Runoff from the upstream watersheds could be diverted through these wetlands prior to discharging into Rock Creek lake. Factors that need to be considered in utilizing constructed wetlands to treat urban runoff include upstream watershed size and runoff quantities, sources of water to maintain the wetlands environment, types of contaminants to be treated, and suitable sites for the wetlands construction.

Selection Criteria. Each of the above methods of protecting Rock Creek Reservoir were evaluated based on the relative effectiveness, environmental considerations, and suitable sites for the required structures. In addition combinations of the above methods were also considered as potential alternatives. For instance, a combination of sedimentation basins (to be used as pre-treatment to settle out solids) and wetlands (for more advanced treatment) were considered.

Bypass Channel. The bypass channel was considered to be a viable option in that it would route flows around the lake and hence, prevent at least the "first flush" from entering the lake. The land where the bypass channel could be constructed is owned by PG&E and would require their approval for construction of the channel. In addition, the modification of the natural channels and the diversion of flows to a point downstream of the lake would also require the approval of various state and federal agencies including the Fish and Wildlife Service as well as the Army Corps of Engineers.

Sedimentation Basins. Sedimentation basins were also considered to be a viable option in the treatment of the urban runoff in Rock Creek. As mentioned earlier, sedimentation basins can be an effective method of removing suspended solids and other pollutants from stormwater runoff. There are potential locations for sedimentation basins at each of the three tributaries to Rock Creek Reservoir before they enter the reservoir. On the northern tributary there is ample undeveloped land that could be used for a sedimentation basin on the Rock Creek Reservoir property owned by PG&E. This property is presently leased as pasture land by PG&E and would require their approval for the construction of a sedimentation basin. The area which serves as the watershed of the eastern tributary (to the east of New Airport Road) is zoned as open space in the proposed General Plan and it is possible that a golf course (private or municipal) will be built there (Dean Prigmore, Placer County Planning Department). Hence, a sedimentation basin could be incorporated into the golf course design. At Rock Creek itself, there is a potential location for a sedimentation basin on the creek upstream of Bell Road. This property is presently undeveloped and owned by PG&E and hence, would require the approval of PG&E for construction of such a basin.

Vegetative Removal of Pollutants. With the proper use of submersed vegetation for pollutant removal, Rock Creek Reservoir has the potential to provide water quality treatment for all the stormwater from the upper Rock Creek watershed. The size of the lake would provide adequate retention time for uptake of nutrients and trace metals by the floating and rooted aquatic plants. Two main problems exist with this technology. First, it is proprietary and would require sole-source installation and maintenance of the project. Second, it will not prevent the pollutants from entering the lake, but will instead remove the pollutants (nutrients and trace metals) after they have entered the lake. If the primary concern, as stated by the Rock Creek Reservoir Technical Advisory Committee, is preventing pollutants from entering the lake in the first place, this method of pollution control is not acceptable.

Constructed Wetlands. Potential sites around the perimeter of the reservoir as well as upstream of Bell Road on Rock Creek were evaluated for sites for constructed wetlands to treat runoff prior to discharge into Rock Creek Reservoir. However due to the large sizes of the upstream watersheds, the wetlands concept was not considered to be an effective method in treating the urban runoff. For runoff from the two-year design storm, the maximum detention time that the wetlands could be designed for is approximately 30 minutes with velocities of approximately 1-2 feet per second. However, for biological treatment of the runoff, the recommended detention time is on the order of two weeks (with a velocity of 0.01 feet per second). Hence, while it is possible to construct wetlands in these areas (as a mitigation measure, for instance), the wetlands would not serve as an effective method of treating stormwater prior to entering the lake.

NONSTRUCTURAL ALTERNATIVES

Local or On-site Stormwater Detention

Even though local or on-site stormwater detention involves the construction of detention structures to detain stormwater, it is classified as a nonstructural alternative because for the County it takes the form of an ordinance or policy requiring that developers provide appropriate local detention. Local detention is not part of the County's capital improvements program in which the structural alternatives would be placed.

Many rapidly growing communities have found that future drainage problems can be minimized by requiring new developments to provide on-site detention of stormwater so that the post-development runoff for specified design storms does not exceed the pre-development runoff for the same storms. The definition of local, or on-site detention is based on the size of the detention basin, the extent of the area it serves, and the design criteria used in its design. Local detention basins are typically designed to serve one or two projects by storing excess stormwater flows before they are allowed to leave the site.

Local or on-site detention if designed correctly will always be able to reduce the local, post-development flood flows downstream of the basin to pre-development levels. However, even though the local detention basins maintain the peak runoff from a developed area at the pre-development level, the peak flow is sustained for a longer period of time as the local detention basin releases the stormwater it has in storage. Without local detention, flood peaks from subbasins lower in the watershed would have receded before the arrival of all the upstream flood flows. With local detention however, the peak flows are maintained for a longer period of time than under natural conditions and these flows may begin to overlap at downstream points in the basin. The cumulative effect of these overlapping releases from all of the local detention basins in the watershed may reduce the effective flow reduction at downstream points. Modeling of the effects of local detention on downstream flood peaks is essential.

Floodplain Management

Floodplain management in the Auburn/Bowman Community Plan area involves two different aspects. The first is based on controlling building in the floodplain and the second is based on controlling the changes (other than buildings) that are made in the floodplain.

Controlling building in the floodplain is based on the assumption that it is better to keep people away from the water rather than keeping the water away from the people. Specific strategies can include establishment of designated floodplains and floodways within which new construction would be regulated or prevented (e.g., the National Flood Insurance Program); purchase of flood-prone land for use as parks or open space; and relocation of chronically flooded structures out of the floodplain.

The second element of floodplain management is involved with controlling what changes are made to the stream channels and floodplains. One of the basic guidelines included in many the general plans is that no floodplain clearing or channel improvements will be allowed along any stream. Especially singled out are streams that carry 10-year flows greater than 200 cfs as shown on Figure 2-4 These streams are designated as natural streams, are to be open channels, and are to remain in their natural state as much as possible.

Restricting the clearing of floodplains in the Auburn/Bowman Community Plan area will have a definite impact on the severity of flooding that occurs throughout the watershed. As discussed in Section 2, computer models developed as part of this study have shown that clearing of existing vegetation in channels and floodplains in the watershed would result in an increase in flood flows.

Implementation of floodplain management solutions requires the ability to regulate or influence land use through zoning or other measures. In the Auburn/Bowman Community Plan area, this ability belongs to Placer County.

Canal Protection

As discussed in previous sections there are numerous canals in the study area that supply water for both municipal and agricultural purposes. These canals are owned and operated by either Placer County Water Agency (PCWA), Nevada Irrigation District (NID), or Pacific Gas and Electric Company(PG&E). The canals range in size from small unlined ditches with capacities of less than five cubic feet per second (cfs) to the Wise Canal which has a capacity exceeding 500 cfs. The protection of these canals from surface runoff is of importance due to water quality concerns as well as the potential of canal damage due to flooding.

The various methods available for canal protection include: (1) land use controls, (2) canal encasement, and (3) structures such as interceptor ditches to prevent surface runoff from entering the canals.

Land Use Controls. Land use controls may be used to protect canals by preventing the building of structures such as roads, buildings or parking lots directly adjacent to an open canal. Structures such as these may cause an increase into the surface water runoff into the canals as well as an increase in pollutant loads entering the canals. Hence, by limiting commercial and urban development directly adjacent to the canals, the water quality and flooding impacts on the canals from development in the study area can be reduced.

Canal Encasement. Encasing all of the canals in the study area is perhaps the best method available to protect the canal water quality and to reduce the impact of flooding on the conveyance and spill structures. However, encasing all of the canals in the study area is not feasible due to the high costs. For example, the total costs for encasing all canals except the Wise Canal was estimated to be approximately $30 million. This estimate was based on utilizing reinforced concrete pipes sized to carry with the existing canal capacities at an average slope of 0.2%.

While canal encasement may not be a realistic option on a regional scale, it is a viable option for canal protection on a local scale. For instance, in areas where new development may impact an existing canal, the protection of the canal from the effects of the new development could be accomplished by encasing the canal in the area of the development. As new developments occur, the canals would be encased where protection is needed most. Also, the canals would not need to be encased in the rural areas where the impacts of the land use changes on the canals are minimal (i.e. conversion of agricultural land to rural estates). Current PCWA, NID, and PG&E policy requires that developers encase canals that border or cross new developments.

Interceptor Ditches, Diversion Structures. Another method available for localized protection of canals is to construct interceptor ditches or other diversion structures such that runoff from a developed area cannot flow into an open canal. The diverted runoff could be routed to a storm drain, or routed under or over the canal to an existing drainage. By requiring new developments to provide this localized protection, this option may also be an effective method in protecting canals from water quality problems associated with new development.

Monitoring Program

The primary purpose of implementing a flow and water quality monitoring program in the Auburn/Bowman Community Plan area is to determine the influence land use changes have on the quality and quantity of runoff (as well as timing of runoff). For instance, paved surfaces and storm sewers associated with urbanization may increase flood peaks downstream and the subsequent increased flood peaks may increase channel erosion as the channel capacity accommodates increased flows. In addition, increased flood peaks raise water levels and may flood structures and exceed design capacities of road crossings. Also, land clearing and construction activities may promote erosion and sedimentation which is detrimental to aquatic life. Pavement runoff from urbanized areas may also contain substances such as heavy metals and hydrocarbons which are toxic to aquatic life.

Data collected from a monitoring program can be used to determine if water quality or flood peak controls are required by state or federal regulatory programs such as the urban runoff program currently being administered by the EPA. As discussed earlier, flood peak controls typically consist of on-site controls such as detention basins. Water quality controls consist of Best Management Practices (BMPs) which consist typically of constraints on system design, sedimentation ponds, or in some cases, treatment.

A baseline sampling program is necessary to determine existing water quality which may be already influenced by limited urbanization and agricultural activities. An ongoing program would allow assessing the magnitude of potential changes in flood peaks and water quality as urban development occurs.

Three levels of potential monitoring are shown in Tables 5-2 and 5-3, and the suggested locations for the monitoring stations are shown in Figure 5-1. The level I program consists of placement of crest and staff gages at seven locations with water quality sampling three times per year (dry conditions, wet conditions and during the first major storm event of a season). This limited program would provide baseline water quality data during normal flow conditions but would be unlikely to allow assessment of water quality changes during flood events. Crest gage data over a period of at least twenty years would allow determination of land development influence on peak flows.

TABLE 5-2
WATER QUANTITY MONITORING ALTERNATIVES

ALTERNATIVE	METHOD	FREQUENCY	LOCATIONS	FIELD MEASUREMENTS	LAB MEASUREMENTS
Level I	Crest and Staff Gages	3 Times/Year (1) Dry (2) Wet (3) 1st Storm	Dry Creek @ Mouth (Bell Road) Orr Creek @ Mouth (Bell Road) Dry Creek @ Twin Pines Trail Rock Creek @ Mouth (Joeger Road) Rock Creek @ Reservoir (Bell Road) Rock Creek Reservoir North Ravine @ Mouth (Wise Road)	Stream Levels	N/A
Level II	ALERT Precipitation & Stream Level Stations	Continuous (automated)	Dry Creek @ Mouth (Bell Road) Orr Creek @ Mouth (Bell Road) Halsey Forebay (Precip. only) Rock Creek @ Mouth (Joeger Road) Rock Creek @ Reservoir (Bell Road) Rock Creek Reservoir (Staff Gage Only) North Ravine @ Mouth (Wise Road)	Precipitation & Stream Levels	N/A

TABLE 5-3
WATER QUALITY MONITORING ALTERNATIVES

ALTERNATIVE	METHOD	FREQUENCY	LOCATIONS	FIELD MEASUREMENTS	LAB MEASUREMENTS
Level I	Grab Samples	3 Times/Year (1) Dry (2) Wet (3) 1st Storm	Dry Creek @ Mouth (Bell Road) Orr Creek @ Mouth (Bell Road) Dry Creek @ Twin Pines Trail Rock Creek @ Mouth (Joeger Road) Rock Creek @ Reservoir (Bell Road) Rock Creek Reservoir North Ravine @ Mouth (Wise Road)	Temperature Conductivity pH Dissolved Oxygen	BOD Oil & Grease Nutrients Suspended Solids Selected Metals
Level II	Automatic Samplers	3 Storms/Year	Dry Creek @ Mouth (Bell Road) Orr Creek @ Mouth (Bell Road) Rock Creek @ Mouth (Joeger Road) Rock Creek @ Reservoir (Bell Road) Rock Creek Reservoir (Grab Samples) North Ravine @ Mouth (Wise Road)	Temperature Conductivity	BOD Oil & Grease Nutrients Suspended Solids Selected Metals
Level III	Grab Samples & Automatic Samplers	3 Storms/Year	Dry Creek @ Mouth (Bell Road) Orr Creek @ Mouth (Bell Road) Rock Creek @ Mouth (Joeger Road) Rock Creek @ Reservoir (Bell Road) Rock Creek Reservoir (Grab Samples) North Ravine @ Mouth (Wise Road)	Temperature Conductivity pH Dissolved Oxygen	BOD Oil & Grease Nutrients Suspended Solids Selected Metals & Full Range of Pollutants recommended by County and EPA

The seven locations were selected to provide data for all the watersheds in the study area. The four downstream locations on Orr Creek, Dry Creek, Rock Creek and North Ravine provide baseline data on flows and water quality data in the watersheds. Rock Creek at Bell Road isolates the influence of urbanization on water quality in upper Rock Creek upstream of Rock Creek Reservoir (where significant urbanization is expected to occur over the next two decades). The Rock Creek Reservoir sampling site allows for the measurement of accumulated pollutants in the reservoir itself.

The Level II program consists of ALERT water level sensors and precipitation gages at each of the seven locations. The National Weather Service and the California Department of Water Resources jointly coordinate the ALERT radio telemetered system. ALERT is made up of precipitation gages, water level sensors, and weather stations that are owned and operated by local jurisdictions. The ALERT systems consist of remote stations in the watershed, linked using line-of-sight radio telemetry to communicate with one or more base stations. The remote sites consist of an enclosure containing a water level sensor and/or a tipping bucket precipitation gage and radio telemetry equipment. Base stations have a receiver and decoder that is connected to a computer that manages the data from the remote stations.

Software is available for the base station that will allow it to predict downstream flood flows based on rainfall and measured stream water levels. Due to the small size of the study area and the fact that it is located in the upper end of the Coon Creek and Auburn Ravine watersheds, the flood warning times based on streamflow predictions will be very short in the study area. The flood flow predictions will be of great benefit farther downstream in the Coon Creek and Auburn Ravine watersheds where they can be used be emergency operations for determining evacuation requirements due to impending flooding.

In addition to the automated ALERT flow and precipitation gages, automatic water quality samplers would also be installed at each location. These samplers could be programmed to obtain samples throughout a storm event. Since water levels would also be recorded, the first flush of pollutants from paved surfaces by the early rainfall in a storm or the first storms of the season can be determined. Field and laboratory measurements for this level of monitoring are limited to the parameters most likely to change as the result of land development. The ALERT data of detailed flow and precipitation would allow better calibration of the HEC-1 runoff models and increase confidence in the performance of proposed runoff controls and BMPs.

The Level III monitoring program consists of Level I and II with additional laboratory measurements of the full range of potential water quality pollutants mandated by the state and federal agencies. These laboratory measurements are designed to detect all pollutants due to agricultural, urban and industrial activities. Agency review of this water quality data may lead to eventual National Pollution Discharge Elimination System (NPDES) permits.

SECTION 6
RECOMMENDED IMPROVEMENTS AND POLICIES

This section presents a summary of the recommended improvements and policies for the Auburn/Bowman Hydrology Study. Cost estimates for implementation of the recommended improvements and policies are included at the end of the section. All aspects of the recommendations, both structural and nonstructural, have been designed to work together to provide increased flood control and water quality protection throughout the Auburn/Bowman Community Plan area.

STRUCTURAL IMPROVEMENT RECOMMENDATIONS

The following paragraphs describe the structural improvements that should be implemented as part of the Auburn/Bowman Community Plan Hydrology study. Figures 6-1a to 6-1c indicate the location of each of the proposed structural improvements. The individual structural improvements have been designed to be implemented independently of other improvements because of uncertainties about the timing of construction of proposed improvements.

Regional Detention Basins

Regional detention basins are not recommended inside the study area for two reasons, 1) a lack of adequate sites for regional detention in the study area, and 2) because the peak flows resulting from development can be mitigated in the study area through the use of local, on-site detention for new development.

Regional detention basins have been recommended outside the study area for the Coon Creek and Auburn Ravine watersheds (CH2M-Hill, 1992). These regional detention basins would function to reduce both the peak flow rate and the volume of flows entering the lower reaches of these two streams. Even though peak flow rates leaving the study area can be mitigated through the use of local, on-site detention basins, the increase in volume of runoff due to development can't be mitigated in the same way. The recommendation from the previous study (CH2M, 1992) was to construct large regional detention basins that will hold the increased volume until flooding has begun to recede in the lower stream reaches and then release the held stormwater at low rates.

Bridge And Culvert Replacement

As described in Section 3, approximately 70% percent of the bridges and culverts in the Auburn/Bowman Community Plan study area are inadequate to pass the 100-year flood without overtopping. However, not all of these bridges and culverts are recommended for replacement. Some of the crossings in rural areas have been designed as low flow crossings and as such would not be damaged from high flows. In addition, other crossings were built in such a way within the floodplain that it would not be feasible to pass the 100-year flows without significant channel improvements and modifications (in addition to replacement of the crossing). Table 5-1 contains a description of each of the inadequate bridges and culverts and the improvements that would be required to allow passage of the 100-year flow. The locations of the recommended bridge and culvert replacements are shown as circles with numbers on Figures 6-1a to 6-1c.

Channel Improvements

A local channel improvement project is recommended for Dry Creek from Dry Creek Road bridge upstream to Twin Pines Trail bridge to provide 25-year protection for the road. The Dry Creek channel in this area (adjacent to Dry Creek Road) was the only channel identified in this study where the stream channel was inadequate to pass the 25 and 100-year flows without impacting existing structures (i.e. Dry Creek Road). A hydraulic analysis of this stream reach indicated that it was not feasible to provide 100-year protection of the road without significant channel excavation and clearing. However, 25-year protection can be provided through a combination of moderate channel excavation and the maintenance of a clear channel and floodplain (i.e. removal of blackberries and other undergrowth in the channel and overbanks).

Rock Creek Reservoir Protection

The various structural methods considered for protection of Rock Creek Reservoir include a bypass channel around the reservoir, sedimentation basins upstream of the reservoir, vegetative removal of pollutants in the reservoir, and constructed wetlands upstream of the reservoir. Both the bypass channel and sedimentation basins are considered to be viable methods of protecting the water quality in the reservoir from pollutants associated with urban runoff. The vegetative removal of pollutants was not chosen because although it might be effective in pollutant removal, it does not prevent the pollutants from entering the reservoir in the first place. Due to site constraints and the large size of the upstream watersheds, constructed wetlands were not considered to be an effective method in treating the runoff and subsequently, protecting the reservoir water quality.

In order to protect the reservoir from pollutants associated with stormwater runoff and at the same time maintain the downstream water quality of Rock Creek, it is recommended that both a bypass channel and sedimentation basins be constructed. The bypass channel will provide protection for the reservoir by routing runoff around the reservoir while the sedimentation basins will provide a degree of treatment of this runoff by settling out solids prior to discharge into the bypass channel.

Bypass Channel The bypass channel should be constructed such that it intercepts flows from the three primary tributaries to Rock Creek Reservoir and diverts the flows to Rock Creek downstream of the reservoir. At a minimum, the channel should be constructed to have a capacity to divert the 2-year storm runoff downstream of the reservoir such that the "first flush" of a storm event would be diverted around the reservoir. Spill structures should be constructed along the channel so that flows greater than the 2-year runoff will spill into the reservoir.

The bypass channel will impact Rock Creek below the dam because rather than passing diluted flows through the dam outlet works to the stream, the "first flush" would bypass the reservoir and go directly to the stream. Some dilution may occur in the stream depending on the current reservoir releases. The sedimentation basins are recommended to help mitigate the impacts of the bypass channel on Rock Creek below the dam by removing the majority of the sediment load and any of the pollutants that are adsorbed onto the sediments, as described below.

Sedimentation Basins The idea behind the use of sedimentation basins to treat urban runoff is to detain runoff from storm events in a basin such that suspended solids (and the associated pollutants) have the time to settle out before the runoff leaves the basin. In the Rock Creek watershed, sedimentation basins should be constructed on each of the three tributaries of Rock Creek which enter the reservoir. This includes the construction of two sedimentation basins on property owned by Pacific Gas and Electric (PG&E) on the northern tributary and on Rock Creek upstream of Bell Road. In addition, a sedimentation basin should be constructed on the eastern tributary (east of New Airport Road). A golf course has been proposed for that property, and a sedimentation basin should be incorporated into the design of the golf course if it is built.

NONSTRUCTURAL POLICY RECOMMENDATIONS

The following paragraphs describe the recommended nonstructural policies for the Auburn/Bowman Community Plan area.

Local, On-site Detention Basins

All new developments located in the shaded areas of the Auburn/Bowman Community Plan area on Figure 6-2, should be required to provide local, on-site detention of stormwater flows except where it is determined by the County Engineer that local detention is either not required or not practical. There are some locations in the watershed where HEC-1 model studies have indicated that travel time and other timing consideration cause local detention to increase downstream flood flows over existing conditions. These subbasins are left unshaded on the map, along with other subbasins where local detention caused no net decrease in regional flood flows, or where future development based on the Community Plan would cause no or minimal increase in stormwater flows downstream. It would not be cost effective to require local detention in those subbasins except for cases where local detention can solve a local flooding problem.

Local, on-site detention should be designed to control the peak flow leaving the property as a result of the 10-, 25, and 100-year storms, such that there is no net increase in stormwater peak flows due to development. The design to accomplish this detention should be approved by the County Engineer.

Only in those situations where the County Engineer determines that topography or other factors will limit the effectiveness of local detention for a particular development, the developer should make an in-lieu payment to the County. The payment should be based on the size and land use of the development. The developer could also be required to provide adequate land for an off-site detention basin. This in-lieu payment could be used by the County to defray the costs of increasing downstream regional detention storage to handle the undetained flows from that development.

Floodplain Management

Floodplain Mapping Floodplain mapping is essential to provide direction for the Placer County Planning Department as land is developed along the streams in the Auburn/Bowman Community Plan area. As part of this study the 100-year floodplains (for Future flows) were delineated for Orr Creek, Dry Creek, Rock Creek and North Ravine and are presented in .Figures 3-1 to 3-4. However, it will be necessary to update this mapping on a scheduled basis to account for changes in land use or other factors. It is recommended that the floodplain mapping be checked every two years, and where changes affecting flood flows are found to be significant the floodplain mapping should be checked and redone if needed.

Channel and Floodplain Clearing The stream channels and floodplains in many parts of the Auburn/Bowman Community Plan area are densely vegetated with trees, bushes, blackberries, vines, and bamboo. The model studies conducted for this study have demonstrated that removal of this vegetation, which acts as a natural flow retarding system, will increase the flood flows in the channels.

It is recommended that floodplain management and grading ordinances and policies be enacted as part of the Community Plan where such ordinances and policies are not already in place. These ordinances should restrict the removal of riparian vegetation from the channels and floodplains of the major streams in the study area. Clearing would be allowed in those exceptional cases where other considerations, such as health and safety, or potential damage to structures, require removal of the vegetation. Reduction of vegetative cover would also be allowed where increases in vegetation in the future change the channel and floodplain flow characteristics sufficiently to place existing structures in danger from flooding. In that case, clearing would only be allowed to return floodplain and channel to the approximate conditions existing at the time of the adoption of these recommendations.

Major streams, for the purpose of these ordinances, are defined as those streams carrying more than 200 cfs in the 10-year flood. The locations of all streams in the watershed that meet these criteria are indicated on the map in Figure 2-1.

Canal Protection

As discussed in earlier sections, there are numerous canals in the study area that may be subject to water quality degradation through the interception of stormwater runoff. As development of lands adjacent to these open canals occurs, the likelihood for increased pollutant levels increases. In addition to the potential impacts on canal water quality, urbanization may also result in increased flows into the canals from surface water runoff. These increased flows may cause damage to the canals by overtopping, erosion, or other structural damages to the canals or spill structures on the canals.

In order to protect the canals from increased water quality degradation and increased flows as a result of new developments, it is recommended that the canal protection measures discussed below be implemented. The purpose of these canal protection measures is to prevent any future increase in pollutant loading or interception of stormwater runoff from occurring as a result of new development in the study area.

Land Use Controls A zoning ordinance should be implemented which limits the development of commercial, industrial, institutional and multi-family residential developments directly upstream of an open canal. The ordinance should state that a 100-foot setback is required from the uphill bank of a canal, with a 50-foot setback required from the downhill bank of a canal.

Drainage Controls To the extent practical, no development uphill of an open canal should be allowed to let storm drainage enter a canal through a storm drainage collection system.

Canal Encasement Canals should be encased in new residential developments with lot sizes of two acres or less and in new residential subdivisions where roads are constructed within 100 feet of a canal. In addition, canals should be encased in new residential developments with lot sizes of three acres or less if the canal carries the raw water supply for a downstream water treatment plant. Canals should also be encased in commercial, industrial, institutional and multi-family residential developments.

The size and types of pipes used to encase the pipes and the installation procedure should be approved by the County Engineer and the responsible canal agency.

Canal Fencing Fencing should be required for canals which are not required to be encased but which are within residential developments with lot sizes of five acres or less. The requirement for fencing along open canals in other developments should be determined on a case by case basis depending on the location and size of buildings, parking lots, roads and other improvements, the canal size and downstream water use, and the presence or use of hazardous or toxic materials.

The location of the fences as well as their design and construction should be approved by the County Engineer as well as the responsible canal agency.

Best Management Practices

As described in previous sections, Best Management Practices (BMPs) can be effective methods in removing pollutants from stormwater runoff (i.e. oil/grit separators, detention/sedimentation ponds) as well as in controlling the pollutants at their source (i.e. street cleaning, public education). A list of BMPs applicable to the Auburn/Bowman Community Plan area is presented in Section Four. This list is not exhaustive, however, it does present the most common BMPs in use in other rural and urban areas as well as at construction sites.

In order to provide water quality protection of the streams, canals, and reservoirs in the study area, it is recommended that all new developments be required to implement appropriate BMPs such that the net increase in pollutant loads from the development is minimized. The specific BMPs and their design should be approved by the County Engineer prior to development of a site.

Monitoring Program

It is recommended that the County implement the Level II monitoring program (as described in Section Five) in the Auburn/Bowman Community Plan area. This level of monitoring includes seven ALERT stations for stream level and precipitation monitoring in addition to automatic water quality samplers at each of the seven locations. This monitoring program is designed to provide monitoring data (flow and water quality) throughout the Auburn/Bowman Community Plan area in order to determine the influence changing land use conditions have on the quantity and quality of storm water runoff.

The seven locations were selected to provide data for all of the primary watersheds in the study area including Orr Creek, Dry Creek, Rock Creek and North Ravine. In addition, two extra monitoring stations: Rock Creek at Bell Road and Rock Creek Reservoir (water quality monitoring only) will provide additional data on the Rock Creek Reservoir and the upper Rock Creek watershed (where significant development is anticipated over the next twenty years). This automated monitoring program is designed to sample several times over a given storm event such that the first flush of a storm event can be monitored. In addition, this program can be upgraded to monitor for all EPA priority pollutants (Level III monitoring). However, this would require that grab samples be taken in the field as the automated samplers do not have the capacity to obtain the large samples required for the analysis of all priority pollutants.

The monitoring stations would tie into the ALERT system operated by Placer County Flood Control and Water Conservation District. Data transmitted from the stations would be collected on a computer in the District offices. Precipitation and streamflow data would be used to prepare timely predictions of flood flows in the Coon Creek and Auburn Ravine watershed. One shortcoming of these predictions is that the response times in the upper ends of the watersheds which comprise the Auburn/Bowman Community Plan study area will be very short and thus will provide limited flood warning benefits. Response times and flooding predictions for the lower Coon Creek and Auburn Ravine watersheds will be greatly enhanced by the monitoring system proposed for the study area.

IMPACTS OF THE RECOMMENDED POLICIES AND IMPROVEMENTS

The overall goal of the above recommended policies and improvements is to reduce the impact of flooding in the study area as well as water quality degradation in the streams, canals and reservoirs from stormwater runoff. As discussed above, the recommendations include local detention, bridge and culvert replacement, channel improvement, Rock Creek Reservoir protection, floodplain management, canal protection, and implementation of Best Management Practices and a regional monitoring program. The potential impacts of these policies and improvements on the flood hydrology and water quality in the study area are discussed below.

Local, On-Site Detention

The overall goal in local, on-site detention is to reduce the local, post-development peak flood flows downstream of the given watershed to pre-development levels. As discussed above, local or on-site detention is only recommended for new developments in those areas that are shaded in Figure 6-2. The results of the implementation of local detention are presented in Table 6-1. The table contains peak flow information for the 100-year flood for existing and future conditions, with and without local detention.

As is evident by the table, the most significant mitigation produced by local detention occurs in the Rock Creek and North Ravine watersheds. In the Rock Creek watershed the 100-year peak flow increases by approximately 22% (1796 cfs to 2205 cfs) with the change from existing to future land use conditions. However, with the implementation of local detention in the watershed, the 100-year peak flows for future conditions are reduced to 1879 cfs (less than a 5% increase in flows over present conditions). In the North Ravine watershed the future 100-year peak flow (without local detention is approximately 3241 cfs, or an 8% increase over present conditions. With the implementation of local detention in the recommended areas, the future 100-year flow is reduced to within 1% of present conditions.

In the Orr Creek and Dry Creek watersheds the 100-year future peak flows (without local detention) do not significantly increase from present peak flows (an increase of less than 3% in each watershed). However, with the limited local detention that is recommended in each of the watersheds, the 100-year future peak flows can be reduced to the present levels in the Orr Creek watershed and within 2% of the present levels in the Dry Creek watershed.

Bridge and Culvert Replacement

The bridges and culverts for which improvements or replacements are recommended is listed in Table 5-1. The improvements to these crossings will result in better access throughout the study area during a major storm event as well as safer crossings with less potential for injury, loss of life, or damage to the structures or other property from flood waters overtopping the crossings. In addition, maintenance of the existing flood storage in the floodplain was an important aspect that was considered when determining the required size and configuration of replacement bridges and culverts. Removal of existing flood storage upstream of culverts could increase flood flows downstream of the area where the storage is removed. For this reason, the replacement bridges and culverts were designed conceptually so as not to be overtopped by the 100-year flood flows while at the same time maintaining as much of the existing flood storage above the crossing as possible. This design concept will keep the impacts of the culvert or bridge improvement to a minimum, while at the same time solving the problems caused by inadequate bridge or culvert capacity.

TABLE 6-1
RESULTS OF PLAN IMPLEMENTATION

CROSSING NUMBER	STREAM	CROSSING	DRAINAGE AREA (SQ. MI.)	100-YEAR PRESENT (CFS)	100-YEAR FUTURE (CFS)	100-YEAR WITH PLAN (LOCAL DETENTION) (CFS)
1	**ORR CREEK**	INFLOW TO COON CR.	9.31	4176	4238	4182
2		BELL RD.	9.29	4168	4230	4174
3		TRIB. CONFLUENCE	8.93	4047	4112	4047
4		TRIB. CONFLUENCE	7.44	3517	3578	3479
5		HWY 49 (State)	6.13	2881	2936	2843
6		TRIB. CONFLUENCE	5.81	2845	2902	2721
7		W. STANLEY DR.	4.26	2031	2075	1893
8		TRIB. CONFLUENCE	3.9	1916	1955	1769
9		E. STANLEY DR.	3.36	1662	1692	1508
10		COMBIE-OPHIR SIPHON	3.25	1631	1660	1467
11		CHRISTIAN VALLEY RD.	2.66	1414	1435	1238
12		TRIB. CONFLUENCE	2.07	1111	1144	906
13		STUDY BOUNDARY	1.15	624	653	481
14		TRIB. CONFLUENCE	0.78	420	444	305
15	**ORR CR TRIB #1**	LITTLE CREEK RD. (Private)	0.12	76	80	68
16	**ORR CR TRIB #2**	VIRGINIA WAY	0.48	334	334	323
17		KENNETH WY. (Private)	0.31	228	228	214
18	**ORR CR TRIB #3**	LONE STAR RD.	0.75	495	495	421
19	**DRY CREEK**	INFLOW TO COON CR	15.5	5575	5706	5692
20		BELL RD.	15.32	5511	5638	5625
21		TRIB. CONFLUENCE	15.06	5447	5555	5574
22		ROCK CR. CONFLUENCE	13.14	4589	4675	4749
23		HWY 49 (State)	8.38	2960	3100	2913
24		TRIB. CONFLUENCE	7.82	2819	2938	2760
25		BLUE GRASS RD.	7.3	2655	2759	2563
26		BELOW DAM	6.62	2408	2483	2321
27		INFLOW TO RES.	6.3	2323	2380	2238
28		DRY CR. ROAD	5.48	1993	2017	1930
29		TWIN PINES TR. (Private)	4.69	1877	1876	1807
30		HAINES RD.	4.03	1589	1580	1504
31		HALSEY AFTBAY OUTFLOW	3.05	1279	1275	1174
32		BOWMAN RD.	2.82	1196	1195	1090
33		LAKE ARTHUR RD.	2.58	1101	1104	998
34		LAKE ARTHUR RD.	1.81	695	696	616
35		BELOW LAKE ARTHUR	1.66	616	616	546

TABLE 6-1 (continued)

CROSSING NUMBER	STREAM	CROSSING	DRAINAGE AREA (SQ. MI.)	100-YEAR PRESENT (CFS)	100-YEAR FUTURE (CFS)	100-YEAR WITH PLAN (LOCAL DETENTION) (CFS)
39	**DRY CR TRIB #4**	DRY CREEK RD	0.1	72	92	92
40	**DRY CR TRIB #5**	JOEGER RD.	0.25	228	243	223
41	**DRY CR TRIB #6**	HOWE RD. (Private)	1.14	789	901	701
42		HUBBARD RD. (Private)	1.04	737	846	656
43		JOEGER RD.	0.29	158	244	226
44	**ROCK CREEK**	INFLOW TO DRY CREEK	4.29	1912	2424	2024
45		JOEGER RD.	4.25	1883	2387	1996
46		SHERWOOD WY.	4.08	1773	2260	1891
47		DRY CREEK RD.	3.8	1596	2088	1720
48		RICHARDSON RD.	3.78	1596	2088	1720
49		HWY 49 (State)	3.33	1390	1861	1440
50		ROCK CREEK RD.	2.24	772	812	784
51		ROCK CR LAKE OUTFLOW	2.22	769	809	781
52		ROCK CR LAKE INFLOW	2.22	1435	1591	1441
53		BELL RD.	0.98	472	532	481
54		NEW AIRPORT RD.	0.91	459	513	459
55		CRYSTAL SPRINGS RD.	0.85	449	498	442
56		TRIB. CONFLUENCE	0.61	406	435	369
57		CREEKVIEW CT.	0.19	122	122	103
58		RAILROAD	0.15	95	95	80
59	**ROCK CR TRIB #1**	RAILROAD	0.38	257	295	276
60	**ROCK CR TRIB #2**	NEW AIRPORT RD.	0.58	358	383	383
61		BELL RD.	0.31	191	204	204
62	**ROCK CR TRIB #3**	LOCKSLEY LANE.	0.26	251	361	251
63	**ROCK CR TRIB #4**	ROCK CREEK RD.	0.66	669	976	666
64		BELL RD.	0.41	489	759	759
65	**NORTH RAVINE**	WISE RD.	5.25	3012	3241	3042
66		WARREN WY. (Private)	5.1	2943	3176	2973
67		CALNICK RD. (Private)	4.83	2908	3203	2948
68		BELOW MILLERTOWN RD.	4.66	2863	3186	2908
69		TRIB. CONFLUENCE	4.52	2792	3110	2840
70		MILLERTOWN RD.	3.87	2373	2671	2403
71		MT. VERNON RD.	3.24	2122	2549	2108
72		HARRIS RD. (Private)	0.8	397	476	380

TABLE 6-1 (continued)

CROSSING NUMBER	STREAM	CROSSING	DRAINAGE AREA (SQ. MI.)	100-YEAR PRESENT (CFS)	100-YEAR FUTURE (CFS)	100-YEAR WITH PLAN (LOCAL DETENTION) (CFS)
73		VISTA ROBLE RD. (Private)	0.62	401	541	364
74		ATWOOD RD.	0.35	100	129	107
75	**N. RAV. TRIB #1**	KEMPER RD. (Private)	0.23	144	187	154
76	**N. RAV. TRIB #2**	HIDDEN OAKS LN. (Private)	1.56	1372	1705	1372
77		RAILROAD	0.64	648	842	649
78		HWY 49 (State)	0.35	356	463	357
79		PEAR RD. (Private)	0.28	268	360	360
80	**N.RAV. TRIB #3**	MILLERTOWN RD.	0.6	373	395	395
81		MT. VERNON RD.	0.36	228	241	241
82	**N.RAV. TRIB #4**	MILLERTOWN RD.	0.06	42	42	42
83		BAR RANCH RD. (Private)	0.04	32	32	32
84	**AUBURN RAVINE**	AUBURN RAVINE OUTFLOW	10.82	6047	6411	6015
85		N. RAVINE CONFLUENCE	10.42	5835	6050	5862
86		WISE RD.	4.68	4300	4429	4314
87		OPHIR RD.	4.58	4217	4349	4232
88		OPHIR RD.	4.23	4034	4189	4070
89		FORGOTTEN RD. (Abandoned)	3.54	3916	4088	3985
90	**AUBURN R. TRIB**	I-80 (State)	0.49	271	271	258
91		RAILROAD	0.34	185	185	177
92	**DUTCH RAVINE**	RAILROAD	0.41	205	211	211
93		AUBURN-FOLSOM RD.	0.22	112	115	115
94	**MORMON RAVINE**	SHIRLAND RD.	0.04	22	22	22
95	**MORMON R. TRIB**	NO NAME RD	0.29	228	240	240
96		ANDREGG RD.	0.19	139	155	155
97	**AMER. RIV. TRIB #1**	HWY 49 (State)	0.32	257	257	257
98	**AMER. RIV. TRIB #2**	HWY 49 (State)	0.04	92	92	92
99	**DEADMAN CANYON**	JOEGER RD.	0.63	417	498	498
100		OAK CREEK CT.	0.19	125	149	149

Stream Channel Improvements

Stream channel improvements are recommended for the Dry Creek stream channel in the vicinity of Dry Creek Road bridge and Twin Pines Trail bridge. A hydraulic analysis of this stream reach indicated that it was not feasible to provide 100-year protection for the road without significant channel excavation and clearing. However, 25-year protection should be provided through moderate channel excavation and the maintenance of a clear channel and floodplain.

This section of Dry Creek Road is in a rural area of the Auburn/Bowman Community and serves as the primary access road for residents and a local golf course to Highway 49 in the west and Bowman Road and Interstate 80 in the east. With the recommended improvements to the Dry Creek stream channel, the road will have complete access in major storms up to the 25-year event. In larger events such as the 100-year storm, up to two feet of flooding may occur on a short section of the road and the road in this area would need to be closed until floodwaters subsided. However, access to the area for local residents or emergency vehicles would still be possible either from the east (via Bowman Road and I-80) or from the west (via Highway 49).

Floodplain Management

It is recommended that floodplain management ordinances and policies be enacted in order to maintain the natural characteristics of the streams and floodplains in the study area. The stream channels and floodplains in the Auburn/Bowman Community Plan area are densely vegetated with trees, bushes, blackberries, vines and bamboo. The modeling analysis of the study area has demonstrated that removal of this vegetation, which acts as a natural flow retarding system, will increase the flood flows in the channels. Hence, by preventing the clearing or modifications of these stream channels and maintaining them in their present state, the channels will continue to serve as a form of storage for flood flows which reduce the flood peaks. In addition, by maintaining the natural conditions of the stream channels, the impact of continued growth in the study area on the aquatic habitat in and around the streams will be minimized.

It is also recommended that zoning ordinances or policies be enacted which prevent or limit new developments in the floodplains throughout the study area. Not only will this policy prevent any future structures from being flooded but it will also limit the impacts of floodplain encroachment. Encroachment of the floodplain by buildings, roads or other structures may result in higher flood levels as well as a wider floodplain which may endanger more structures and property which previously was not in the floodplain.

Best Management Practices

In order to minimize the impacts of changing land use conditions on the streams, canals and reservoirs in the study area, it is recommended that appropriate Best Management Practices (BMPs) be required for all new developments in the study area. Best Management Practices have proven to be effective methods of controlling pollutants carried in stormwater runoff in may rural and urban areas throughout the United States. However, quantifying the overall effectiveness BMPs have on treating or reducing the pollutant loads in stormwater runoff is difficult due to the many factors involved. These factors include the type of BMP implemented, type of pollutant to be removed, existing pollutant load, drainage area, magnitude of storm event and runoff, and specific design maintenance and method of implementation of the BMP.

The range of effectiveness of various structural BMPs was analyzed by Schueler (1987) and is presented in Table 6-2. These removal rates were obtained from field performance monitoring, laboratory experiments, modeling analysis, and theoretical considerations. It should be noted that the values presented in the table are for a range in designs of each BMP.

As is evident by the table, BMPs, when properly chosen and designed for a particular site, can be effective in removing a significant percentage of pollutants in stormwater runoff. Hence, in the Auburn/Bowman Community Plan area the impact of urbanization on the receiving waters can be minimized through the proper use of Best Management Practices.

Canal Protection

As described previously in this section, the overall goal of the recommended canal protection policy is to protect all canals in the study area from increased inflows and pollutant loads from stormwater runoff. The recommended policies include land use controls, and structural controls (canal encasement and fencing).

The effectiveness of the recommended policies will vary depending on the type of canal protection utilized. Canal encasement as recommended in residential, commercial and industrial developments is the most effective method to protect canals from stormwater runoff. Encasement will prevent any surface runoff from entering the canal, and hence, the canal would be completely protected from stormwater runoff and any associated pollutants.

Land use controls such as limiting development directly adjacent to canals, requiring that lots adjacent to a canal be larger than a certain minimum size, etc., may be an effective method in preventing in preventing runoff from a development from directly entering a canal. However, stormwater runoff from the undeveloped area directly adjacent to the canal may still enter the canal and transport such pollutants as litter and animal waste into the canals. In addition, during large storm events there may be the potential for stormwater runoff from upstream areas to overflow into the areas adjacent to the canal and into the canal itself.

Fencing of canals in rural areas (lot sizes of 2-5 acres) would prevent livestock and other animals from getting close to a canal. However, fencing would not prevent runoff (and the transported pollutants) from upstream areas from entering the canals. The increase in runoff from these rural areas (that were converted from agricultural land use or open space to rural lots) is not anticipated to be significant due to the relatively large lot sizes. However, the number of animals kept on these lots may increase, as many rural landowners may have cattle, horses or other farm animals such as pigs, chickens, etc. While fencing would keep the animals away from the canals, it would not prevent the stormwater runoff from carrying the pollutants associated with animal waste into the canals.

TABLE 6-2
EFFECTIVENESS OF STRUCTURAL BMPS

BEST MANAGEMENT PRACTICES (BMPs)	SUSPENDED SEDIMENT	TOTAL PHOSPHORUS	TOTAL NITROGEN	OXYGEN DEMAND	TRACE METALS	BACTERIA
EXTENDED DETENTION POND	60-100%	20-80%	20-60%	20-60%	40-80%	UNKNOWN
WET POND	60-100%	40-80%	20-60%	20-60%	40-80%	UNKNOWN
FILTER STRIP	20-100%	0-60%	0-80%	0-80%	20-100%	UNKNOWN
GRASSED SWALE	0-40%	0-40%	0-40%	0-40%	0-20%	UNKNOWN

Rock Creek Lake Protection

The recommended methods for protecting Rock Creek Reservoir from upstream runoff include construction of sedimentation basins upstream of the reservoir and the construction of a bypass channel to divert runoff to Rock Creek below the reservoir. As discussed in Sections Four and Five, the Rock Creek Watershed is undergoing extensive development and the potential exists for the degradation of water quality in the reservoir due to pollutants in the urban runoff. The pollutants of concern include oil and grease, trace metals, nutrients, and pesticides and herbicides.

The construction of sedimentation basins at the three tributaries just upstream of Rock Creek Reservoir will provide treatment of the runoff prior to the runoff entering the bypass channel. The conceptual design of the sedimentation basin is such that for a 2-year event the basins would remove approximately 70% of the suspended solids that are the size of very fine sand or larger. As discussed in Section 5, trace metals, nutrients and hydrocarbons (to a lesser degree) all have an affinity for suspended solids. Hence, not only would the sedimentation basins be efficient in removing suspended solids, but also other pollutants associated with urban runoff.

Construction of a bypass channel with a two-year peak flow capacity will divert downstream of the reservoir all of the runoff from small storm events and the initial runoff of larger storm events. Hence, the "first flush" when most pollutants are transported in runoff (either via the first storms of a season or the initial runoff from storms throughout the season) would be prevented from entering the reservoir. However, runoff from larger storms which exceed the 2-year peak flows would spill over the channel and into the reservoir. The amount of pollutants carried in these larger flows would be less due to the fact that most pollutants would be in the earlier smaller flows which would be treated by the sedimentation basins and diverted downstream of the reservoir.

COST ESTIMATES

One of the most important objectives for the Auburn/Bowman Hydrology study is to develop cost estimates for required flood control and water quality protection projects in the watershed. The purpose of this section is to present the cost estimates for the various recommended alternatives. Cost estimates are provided for both the structural and non-structural alternatives. Table 6-3 contains the cost estimates for the structural alternatives while Table 6-4 contains the cost estimates for the non-structural alternatives.

The following describes the criteria that were used in coming up with the cost estimates found in the table. Specifically, the cost factors for contingencies and engineering and administration will be discussed, followed by the structural alternatives cost criteria and then the non-structural alternatives criteria.

Construction Contingencies

The construction contingencies cost is added to the cost estimate to cover unforeseen problems that may occur during the construction of the alternatives defined in this study. These costs may also include contractor mobilization and planning. For this study, these costs have been estimated as 20 percent of the construction cost. Contingencies were added to all of the structural alternatives, but were not included in any of the non-structural alternatives except for the installation of the flood warning system.

Engineering and Administration

Engineering and administration is estimated to be 25 percent of the total construction cost. The engineering portion is 15 percent and is intended to cover all costs associated with the design engineering of the project. These costs include project level engineering studies, reports, preparation of final plans, specifications, contract documents, and engineering services during project construction. To cover those activities associated with the construction of the project that are not directly related to engineering, an administration/legal contingency of 10 percent has been included.

Environmental Analysis

Environmental analysis is estimated to be 10 percent of the total construction cost. This analysis includes wetland delineation and mitigation plans, environmental impact statements, and discussions with agencies such as Fish and Game and the EPA.

Structural Alternatives Cost Criteria

The following paragraphs present a brief discussion of the assumptions used in developing the unit costs for corrugated metal pipes, reinforced concrete box culverts, bridge construction, unlined channels, floodwalls, detention basin facilities, and land acquisition.

Corrugated Metal Pipes Corrugated metal pipes (CMP) and pipe arches (CMPA) are used where existing pipe culverts need to be replaced. Pipe cost estimates were obtained from the following sources:

- Contech Construction Products, Inc.
- Lee Saylor Construction Costs, 1991
- Means Heavy Construction Data, 1991
- Pipe suppliers

Pipe costs included the cost of imported bedding material for the pipes. The labor costs per linear foot of pipe installation were estimated using a typical cross section to determine the amount of material to be removed, and then estimating the time for a typical construction crew to install each foot of pipe. Pavement restoration costs assumed a 30 foot wide road with a width equal to the width of the required trench plus ten feet. The unit cost for road restoration is assumed to be $2.00 per square foot for materials and $2.00 per square foot for labor.

Reinforced Concrete Box Culverts Costs for reinforced concrete box culverts were developed in much the same way as for the corrugated metal pipes. Installation labor, imported materials, and pavement reconstruction were all determined the same as for CMPs.

Bridge Construction In order to estimate bridge replacement costs, local (Sacramento area) contractors were contacted. From information provided by these contractors, replacement costs were formulated on a square foot basis based on the type and size of bridge. These costs range from $57.00 per square foot to $95.00 per square foot. This includes traffic control; temporary supports; excavation of the new channel section at the bridge and upstream and downstream; construction of new abutment; and construction of a deck extension on the bridge.

Unlined Channels For this type of improvement, the unit cost for normal excavation was $5.00 per cubic yard which includes: equipment, labor, installation, and contractors overhead and profit. Excavated material was assumed to be trucked 3 miles one way for disposal.

Floodwalls Floodwalls were assumed to be constructed of reinforced concrete block with an average height of three feet above ground. The total cost per foot for floodwalls is $37.50 and includes material, equipment and labor to install the floodwall.

Land Acquisition For flood control alternatives such as detention facilities, channel improvement and floodwalls, it could be necessary to purchase land. Where project sites, especially detention basins, are located on public lands such as parks, it was assumed that there would be no significant cost associated with acquiring the use of the land. In the case of privately held land, it was assumed that the land would have to be purchased outright. It would be possible to invoke the right of condemnation to acquire a critical site, but the cost of this method of land acquisition was considered to be the same as for outright purchase.

Non-Structural Alternatives Cost Criteria

Floodplain Management Floodplain management, as defined for the Auburn/Bowman Community Plan Hydrology Study, involves two major aspects; floodplain mapping and enforcement of ordinances restricting the clearing of vegetation from major stream channels and floodplains.

Floodplain Mapping For cost estimation purposes, the proposed floodplain mapping was assumed to be done to FEMA standards. Estimated costs for floodplain mapping were obtained through discussions with FEMA and from recent experience in conducting FEMA floodplain mapping in Miners Ravine. The costs per mile are:

Surveying and Mapping	$7,000
Flood hydraulics	$3,000
Floodplain delineation and profile	$3,000
Miscellaneous and reports	$1,000
Total cost per mile	$14,000

Channel and Floodplain Clearing Enforcement of existing and future ordinances restricting the removal of vegetation from major stream channels and floodplains will require the services of one person full time to inspect all the major channels on an ongoing basis and report infractions of the ordinances. Without this level of support, substantial floodplain clearing will probably occur, with a resulting increase in flood flows.

TABLE 6-3
COST ESTIMATES, STRUCTURAL ALTERNATIVES

Item No.	Stream Cross. No.	Description	Estimated Construction Cost	Contingency at 20%	Engineering & Admin. at 25%	Environmental Analysis at 10%	Land Cost	Total Cost
		BRIDGE AND CULVERT REPLACEMENT						
1	7	Orr Creek at W. Stanley Dr.	$41,985	$8,397	$10,496	N/A	N/A	**$60,878**
2	16	Orr Creek Trib. #2 at Virginia Way	$10,829	$2,166	$2,707	N/A	N/A	**$15,702**
3	20	Dry Creek at Bell Road	$57,543	$11,509	$14,386	N/A	N/A	**$83,437**
4	30	Dry Creek at Haines Road	$67,088	$13,418	$16,772	N/A	N/A	**$97,278**
5	32	Dry Creek at Bowman Road	$164,976	$32,995	$41,244	N/A	N/A	**$239,215**
6	36	Dry Creek at Dry Creek Road	$11,349	$2,270	$2,837	N/A	N/A	**$16,456**
7	37	Dry Creek Trib. #2 at Dry Creek Road	$31,248	$6,250	$7,812	N/A	N/A	**$45,310**
8	38	Dry Creek Trib. #3 at Black Oak Road	$7,049	$1,410	$1,762	N/A	N/A	**$10,221**
9	43	Dry Creek Trib. #6 at Joeger Road	$7,049	$1,410	$1,762	N/A	N/A	**$10,221**
10	46	Rock Creek at Sherwood Way	$61,677	$12,335	$15,419	N/A	N/A	**$89,432**
11	48	Rock Creek at Richardson Road	$65,877	$13,175	$16,469	N/A	N/A	**$95,522**
12	50	Rock Creek at Rock Creek Road	$15,545	$3,109	$3,886	N/A	N/A	**$22,540**
13	54	Rock Creek at New Airport Road	$14,249	$2,850	$3,562	N/A	N/A	**$20,661**
14	60	Rock Creek Trib. #2 at New Airport Road	$20,167	$4,033	$5,042	N/A	N/A	**$29,242**
15	62	Rock Creek Trib. #3 at Locksley Lane	$7,769	$1,554	$1,942	N/A	N/A	**$11,265**
16	63	Rock Creek Trib. #4 at Rock Creek Road	$10,635	$2,127	$2,659	N/A	N/A	**$15,421**
17	70	North Ravine at Millertown Road	$83,163	$16,633	$20,791	N/A	N/A	**$120,586**
18	71	North Ravine at Mt. Vernon Road	$49,729	$9,946	$12,432	N/A	N/A	**$72,107**
19	80	North Ravine Trib. #3 at Millertown Road	$43,049	$8,610	$10,762	N/A	N/A	**$62,421**
20	81	North Ravine Trib. #3 at Mt. Vernon Road	$13,169	$2,634	$3,292	N/A	N/A	**$19,095**
21	82	North Ravine Trib. #4 at Millertown Road	$23,429	$4,686	$5,857	N/A	N/A	**$33,972**
22	86	Auburn Ravine at Wise Road	$116,310	$23,262	$29,078	N/A	N/A	**$168,650**
23	87	Auburn Ravine at Ophir Road	$18,000	$3,600	$4,500	N/A	N/A	**$26,100**
24	95	Mormon Ravine Trib. at No Name Road	$44,629	$8,926	$11,157	N/A	N/A	**$64,712**
25	96	Mormon Ravine Trib. at Andregg Road	$17,219	$3,444	$4,305	N/A	N/A	**$24,968**
26	99	Deadman Canyon at Joeger Road	$27,279	$5,456	$6,820	N/A	N/A	**$39,555**
		Total, Bridge and Culvert Replacement						**$1,494,966**
		ROCK CREEK RESERVOIR PROTECTION						
1	N/A	Rock Cr. Res. Bypass Channel and Sed. Basins	$488,414	$97,683	$122,103	$48,841	N/A	**$757,041**
		Total, Rock Creek Reservoir Protection						**$757,041**
		CHANNEL IMPROVEMENT, LEVEES, AND FLOODWALLS						
1	N/A	Dry Creek Road Channel and Floodplain	$56,200	$11,240	$14,050	N/A	N/A	**$81,490**
		Total, Channel Improvements, Levees, and Floodwalls						**$81,490**
		TOTAL, ALL STRUCTURAL IMPROVEMENTS						**$2,333,497**

TABLE 6-4
COST ESTIMATES, NON-STRUCTURAL ALTERNATIVES

Item No.	Description	Cost	Contingency at 25%	Engineering & Admin. at 20%	Land Cost	Total Cost
	FLOODPLAIN MAPPING - 30 MILES					
1	Surveying and Mapping	$210,000	$52,500	N/A	N/A	**$262,500**
2	Flood Hydraulics	$100,000	$25,000	N/A	N/A	**$125,000**
3	Floodplain Delineation and Profile	$100,000	$25,000	N/A	N/A	**$125,000**
4	Reports and Miscellaneous	$30,000	$7,500	N/A	N/A	**$37,500**
	Floodplain Mapping Total					**$550,000**
	REGIONAL FLOOD WARNING AND DATA ACQUISITION SYSTEM					
1	Streamgage/Precipitation station, complete	$8,000	$2,000	N/A	N/A	**$10,000**
2	Streamgage/Precipitation station, complete	$8,000	$2,000	N/A	N/A	**$10,000**
3	Streamgage/Precipitation station, complete	$8,000	$2,000	N/A	N/A	**$10,000**
4	Streamgage/Precipitation station, complete	$8,000	$2,000	N/A	N/A	**$10,000**
5	Streamgage/Precipitation station, complete	$8,000	$2,000	N/A	N/A	**$10,000**
6	Streamgage/Precipitation station, complete	$8,000	$2,000	N/A	N/A	**$10,000**
7	Water Quality Monitoring station, complete	$6,000	$1,500	N/A	N/A	**$7,500**
8	Water Quality Monitoring station, complete	$6,000	$1,500	N/A	N/A	**$7,500**
9	Water Quality Monitoring station, complete	$6,000	$1,500	N/A	N/A	**$7,500**
10	Water Quality Monitoring station, complete	$6,000	$1,500	N/A	N/A	**$7,500**
11	Water Quality Monitoring station, complete	$6,000	$1,500	N/A	N/A	**$7,500**
12	Annual Laboratory Analysis	$21,744	$5,436	N/A	N/A	**$27,180**
	Total, Regional Flood Warning and Data Acquisition System					**$124,680**
	TOTAL, ALL NON-STRUCTURAL IMPROVEMENTS					**$674,680**

Regional Flood Warning and Data Acquisition System The costs for acquiring and installing additional stations for the flood warning and water quality monitoring equipment were obtained through discussions with manufacturers. Approximate prices for monitoring equipment and installation are as follows:

Remote ALERT Station

Streamgage/precipitation station complete:	$4,500
Fittings:	$1,000
Installation:	$2,500
Total per site:	$8,000
Total for six stations	$48,000

Water Quality Samplers

Automated Water Quality Sampler:	$3,000
Installation (Material and Labor):	$3,000
Total per site:	$6,000
Total for five stations	$30,000

Water quality monitoring also has associated laboratory analysis costs. These costs have been estimated on a per sample basis as follows:

Laboratory Analyses(cost per sample):

BOD:	$75
Oil and Grease:	$70
Trace Metals (As, Pb, Cd, Cr, Cu, Ag, Hg)	$182
Phosphate:	$35
Nitrate:	$25
Settleable Solids:	$16
Total Coliform:	$50
Total per analysis	$453
Total Annual Lab Costs (5 stations with 3 storms per year and 3 samples per storm, plus 3 samples at Rock Creek Reservoir)	$21,744

Streamflow, precipitation, and water quality monitoring is an important, ongoing function. It was estimated that a technician would be required full-time for one-half of each year to service the flood warning and data acquisition system and to conduct other data collection activities such as stream gaging.

IMPLEMENTATION ROLE

Flood Control District/Placer County Department of Public Works

Either the Placer County Flood Control and Water Conservation District or the Placer County Department of Public Works will have the responsibility of administering the management plan developed as a result of this study. These responsibilities will include:

- Review of the design of proposed local, on-site detention facilities, determination of requirements for in-lieu fees, and inspection during construction of the local detention facilities;
- The maintenance and operation of the hydrologic computer models developed as part of this study;
- The maintenance and operation of the regional flood warning system;
- Administration of the floodplain mapping program including future conditions mapping and coordination with FEMA for needed map revisions;
- Coordination with developers and other jurisdictions to insure that development and general plans are consistent with the Hydrology Study;
- If appropriate, collection of fees and assessments; and
- Developing specific local flood control plans for areas where development is or will be occurring.

The Placer County Departments of Public Works and Environmental Health will be responsible for administering the water quality protection and enhancement strategies associated with new land development. The Environmental Review Committee (ERC) should be responsible for insuring that appropriate water quality protection and enhancement methodologies are described in the Environmental Document for the specific land development project. The Development Review Committee should be responsible for insuring that the proposed mitigation measures from the ERC are described and delivered to the hearing body as conditions of project approval. The project developer should be named as the entity responsible for insuring that the appropriate improvements are implemented in the project.

Placer County Placer County will be responsible for implementing assessments and fees in the Auburn/Bowman Community Plan Area.

SECTION 7
FUNDING PLAN

This chapter discusses what revenues are needed to construct, manage, and maintain the flood control system in the Auburn/Bowman area and how those revenues can be generated. The following subjects are covered:

- Definitions of terms as they are used in this section.
- Listing of the options available for funding and financing.
- Analysis of the costs of service for flood control.
- Proposed allocations of the costs by zone and between new development and all landowners
- A calculation of possible fees and charges to generate the needed revenues.

DEFINITIONS

- Funding -- The methods used to collect funds, e.g. taxes, fees, and assessments.
- Financing -- The methods used to address cash flow, e.g. bond financing or paying as you go.
- New Development -- Any land use change or construction that takes place after the funding procedures recommended in this plan are adopted.
- Cost of Service -- The revenues needed to provide a specific service, i.e. flood control.
- Zone -- A subdivision of the study area encompassing lands with similar flood control requirements and characteristics.

FUNDING ALTERNATIVES

Some of the funding and financing options available include the following:

Funding Options Applicable to All Landowners and to New Development

- Benefit Assessments, Utility Fees, Rates and Charges.
- General Funds.
- Sales Taxes
- Gas Taxes.
- State and Federal Grants.
- Grants from Local Agencies.
- County Service Area Charges.

Funding Options Applicable Primarily to New Development

- Development Charges or Connection Fees.
- Developer-provided Infrastructure.
- Mello-Roos Community Facilities District Assessments

Financing Options Applicable to All Landowners and to New Development

- Pay as You Go.
- State Revolving Fund.
- Revenue Bonds.
- Certificates of Participation.
- Assessment District Financing.

Financing Options Applicable Primarily to New Development

- Proposition 46 General Obligation Bonds
- Mello-Roos Community Facilities District Bonds.
- Marks-Roos Financing

The Dry Creek Watershed Flood Control Plan recently prepared for the Placer County Flood Control and Water Conservation District (JMM, 1992) contains a more detailed discussion of the funding and financing options that are available for flood control services. Please refer to that report for more detailed information about the funding and financing alternatives.

COST OF SERVICE ANALYSIS

For the purposes of this analysis, we have organized the costs related to providing flood control services into two major categories and have then subdivided those major categories into a number of smaller categories. The two major cost categories are "First Costs" and "Ongoing Costs". "First Costs" are costs that occur one time only. Principal among them are the capital costs to construct a new facility. "Ongoing Costs" are those costs that continue year after year. The most obvious "Ongoing Cost" is maintenance of the flood control facilities.

First Costs

The following paragraphs present a discussion of the various categories of first costs identified in this analysis.

Bridge and Culvert Replacements. Hydrologic analyses have shown that a large number of culverts and bridges are undersized for the 100-year design storm. Replacement or improvement of many of these bridges and culverts is recommended. The total cost of the recommended bridge and culvert improvements is $1,495,000.

Rock Creek Reservoir Protection. This is the cost to construct the sedimentation basins and bypass channel recommended to protect water quality in Rock Creek Reservoir. It is estimated to be $757,000.

Channel Improvement, Levees, and Floodwalls. This is the cost to improve one section of channel on Dry Creek where significant flooding damage occurs and bridge and culvert replacements would not solve the problem. The capital cost is estimated to be $81,500.

Regional Flood Mitigation. No regional detention basins are recommended within the study area. However, runoff from the Auburn/Bowman area into Auburn Ravine, Coon Creek, and their tributaries, will exacerbate existing, persistent flooding problems in western Placer County and eastern Sutter County. Therefore, participation of property owners in the Auburn/Bowman area in funding programs to mitigate regional impacts is likely. The Placer County Flood Control and Water Conservation District has estimated that a development fee of up to $2,700 per impervious acre may be needed to fund the regional flood mitigation. That amount has been included in this cost of service analysis.

Master Plan. This master plan has cost approximately $208,000 to prepare, including consultant fees and administrative time spent by County and Flood Control District staff.

Easement Purchase. Most of the proposed improvements are within road rights-of-way, so no easement purchase is needed. Notable exceptions are the segment of Dry Creek where channel improvements have been recommended, and the streamgage and monitoring stations. Easements will be needed in those areas. Easement costs are difficult to estimate because of the many factors involved. For this analysis, we have assumed easement costs of $7,500 per acre. The area involved in the Dry Creek Road channel improvements is about 23 acres. Each streamgage and monitoring station would require about ½ acre of easement or a total easement for all stations of around 3.5 acres. The total estimated easement cost would be $199,000.

Regional Flood Warning and Data Acquisition System. This plan recommends that a series of stream gaging and monitoring stations be installed to monitor rainfall, stream flow, and water quality. We estimate that capital costs for these stations will be $97,500 and ongoing operational costs will be $57,200 per year. The ongoing costs include laboratory analysis costs and labor costs for one person half time to maintain the stations and collect samples.

Floodplain Mapping. This plan recommends that floodplain mapping be extended and updated for the area. This needs to be done only once unless major stream improvements are made, since the increase in runoff from future development is not expected to significantly affect the floodplain boundaries. Thus it can be considered a "first cost". We estimate the cost of the recommended floodplain mapping to be $550,000.

Bond Sale Costs. If some form of debt financing is used to pay capital costs, there will be first costs associated with setting up that financing. We have assumed that all "first costs" allocated to all landowners would be debt financed and have estimated set up costs for the financing to be three percent of the amount financed. We have assumed that none of the costs allocated to new development would be debt financed. Interest costs associated with debt financing have been included in the capital recovery factor used to calculate the annual equivalent of first costs. The analysis assumed an interest rate of 8% and a term of 20 years.

NPDES Permitting Costs. Current federal regulations require that metropolitan areas obtain permits from the Regional Water Quality Control Board for stormwater discharges. This program has been in place a very short time so many of the details of the system are still being worked out.

When or whether the permit process will be extended to cover rural areas like the Auburn/Bowman area is still uncertain. If the process is extended to rural areas, it is not clear what changes will be made. Due to this uncertainty, it is not possible to develop even an approximate estimate of the costs associated with the permit process. Metropolitan areas that have obtained stormwater discharge permits have spent an average of about $300,000 each to develop the data needed for the permit application. Many have spent substantial amounts beyond that to implement BMPs to reduce the pollution caused by stormwater discharges. We cannot at this time say what the permit costs will be for the Auburn/Bowman area. We can say that there is a good chance permitting costs not shown here will come up in the future.

Ongoing Costs

The following paragraphs present a discussion of the various categories of ongoing costs identified in this analysis.

Administration. This includes the time spent by Placer County Public Works management and clerical staff associated with regional stormwater and flood control. The cost was estimated by taking the comparable cost estimated in the Dry Creek Watershed Flood Control Plan (JMM, 1992) and adjusting it based on the relative sizes of the study areas.

Insurance. This is an estimate of the cost of insuring the County against liability claims resulting from flood damages. The estimate was developed using an approach similar to that used for Administration costs.

Reserve. This is a recommended amount for unidentified flood control costs. The estimate was developed using an approach similar to that used for Administration costs.

Engineering. This item includes the time spent by the County and Flood Control and Water Conservation District engineers to coordinate flood control management in the area. The estimate was developed using an approach similar to that used for Administration costs.

Monitoring/Warning. These are the ongoing costs associated with operating the stream gaging stations and collecting and analyzing water quality samples. The water quality sampling is likely to be a requirement of the NPDES stormwater permit for the area. There is an estimate of $21,700 for laboratory analysis costs in Section 6. Operation of the stations is expected to require one person at half time. Thus, the total annual cost for the monitoring and warning is estimated to be $57,200.

There is a potential that ongoing costs, other than sampling and analysis, will be required as conditions for the NPDES permits. In some cases where NPDES permits have been obtained, sampling, analysis, and reporting costs have been the only ongoing costs. In other cases, agencies have paid significant amounts for BMPs. Since they are the only costs which can be defined at this time, sampling and analysis costs are the only ongoing NPDES permit compliance costs included here. The other potential costs are too uncertain at this time to be included in this cost of service analysis.

Maintenance - General. Regional flood control maintenance consists primarily of maintaining channels, bridges, and culverts. This analysis assumes that bridges and culverts will be maintained by County road crews, therefore, no costs are included here for bridge and culvert maintenance. The hydrologic investigations showed that extensive channel maintenance would increase flooding and recommended only limited channel maintenance concentrated in areas where clogged channels cause flooding of structures or roads. This item is for that limited channel maintenance.

Floodplain Enforcement. This cost item covers the cost of one person full time to enforce ordinances related to floodplain management.

Regional Flood Mitigation Maintenance. This is an estimate of this area's share of the ongoing operating and maintenance costs for regional flood mitigation measures planned to be located downstream of the study area.

COST ALLOCATIONS

Tables 7-1, 7-2, and 7-3 present a proposed allocation of flood control costs to six zones and a split of costs between new development and all landowners. The six zones are as follows:

- The Orr Creek Watershed
- The Dry Creek Watershed
- The Rock Creek Watershed
- The Auburn Ravine Watershed
- Other Areas outside the four listed watersheds. (These are primarily small watersheds draining into the Bear River or the American River)

Some costs not specific to any one zone are allocated to the entire Auburn/Bowman area.

Costs necessitated by new development should be funded by charges to new development, such as development fees. When improvements are necessitated by both new and existing development, an allocation of those costs must be made. All costs not necessitated by new development must be allocated to existing landowners.

The cost allocations proposed in Tables 7-1, 7-2, and 7-3 are based on the following assumptions:

- Costs for bridge and culvert improvements are to be allocated to the zone in which the crossing is located.
- Bridge and culvert improvement costs, channel improvement costs, and easement purchase costs are to be allocated to new development based on the proportion the increase in peak flow due to development will be of the total amount the flow at the crossing or channel section exceeds the current capacity.
- Rock Creek Reservoir protection costs are be allocated entirely to new development in the Rock Creek watershed since the project is necessitated by new development.
- Dry Creek channel improvement costs and easement purchase costs are to be allocated entirely to the Dry Creek Watershed.

TABLE 7-1
COST ALLOCATION
TO NEW AND EXISTING DEVELOPMENT BY ZONE

	Entire Auburn-Bowman Area			Orr Creek			Dry Creek		
Item No.	Total Flow Cost	New Dev Cost	Exist Dev Cost	Total Flow Cost	New Dev Cost	Exist Dev Cost	Total Flow Cost	New Dev Cost	Exist Dev Cost
	BRIDGE AND CULVERT REPLACEMENTS								
1				$60,878	$1,291	$59,587			
2				$15,702		$15,702			
3							$83,437	$1,879	$81,558
4							$97,278		$97,278
5							$239,215		$239,215
6							$16,456	$737	$15,719
7							$45,310	$9,625	$35,684
8							$10,221	$178	$10,043
9							$10,221	$3,603	$6,619
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
SUBTOTAL				$76,580	$1,291	$75,289	$502,138	$16,022	$486,115
	ROCK CREEK RESERVOIR PROTECTION								
	CHANNEL IMPROVEMENT, LEVEES, AND FLOODWALLS								
							$81,490	$17,446	$64,044
	REGIONAL FLOOD MITIGATION								
	$2,676,835	$2,676,835							
	MASTER PLAN								
	$208,000	$208,000							
	EASEMENT PURCHASE								
	$26,250		$26,250				$172,500	$172,500	
	REGIONAL FLOOD WARNING AND DATA ACQUISITION SYSTEM								
	$97,500		$97,500						
	FLOODPLAIN MAPPING								
	$550,000	$550,000							
TOTAL	$3,558,585	$3,434,835	$123,750	$76,580	$1,291	$75,289	$756,128	$205,968	$550,160
	TOTAL FIRST COSTS FOR ALL ZONES								
	$6,064,582	**$4,502,381**	**$1,562,200**						

TABLE 7-1 (continued)

	Rock Creek			Auburn Ravine			Other		
Item No.	Total Flow Cost	New Dev Cost	Exist Dev Cost	Total Flow Cost	New Dev Cost	Exist Dev Cost	Total Flow Cost	New Dev Cost	Exist Dev Cost
				BRIDGE AND CULVERT REPLACEMENTS					
1									
2									
3									
4									
5									
6									
7									
8									
9									
10	$89,432	$19,271	$70,160						
11	$95,522	$22,508	$73,014						
12	$22,540	$1,110	$21,430						
13	$20,661	$2,175	$18,486						
14	$29,242	$1,909	$27,333						
15	$11,265	$3,433	$7,832						
16	$15,421	$4,851	$10,570						
17				$120,586	$13,454	$107,133			
18				$72,107	$12,079	$60,028			
19				$62,421	$3,477	$58,944			
20				$19,095	$1,030	$18,065			
21				$33,972		$33,972			
22				$168,650	$4,912	$163,737			
23				$26,100	$792	$25,308			
24							$64,712	$3,236	$61,476
25							$24,968	$2,577	$22,390
26							$39,555	$6,434	$33,121
TOTAL	$284,083	$55,256	$228,826	$502,931	$35,744	$467,187	$129,234	$12,246	$116,988
	ROCK CREEK RESERVOIR PROTECTION								
	$757,041	$757,041							
TOTAL	$1,041,124	$812,298	$228,826	$502,931	$35,744	$467,187	$129,234	$12,246	$116,988

TABLE 7-2
SUMMARY OF COST ALLOCATIONS TO NEW DEVELOPMENT

Cost Element	Entire Watershed	Orr Creek	Dry Creek	Rock Creek	Auburn Rav.	Other
FIRST COSTS						
Bridges, Culverts, & Channels		$1,291	$16,022	$55,256	$35,744	$12,246
Reservoir Protection				$757,041		
Channel Improvements			$17,446			
Regional Detention	$2,676,835					
Master Plan	$208,000					
Easements			$172,500			
Monitoring System						
Floodplain Mapping	$550,000					
TOTAL REVENUE NEED	**$3,434,835**	**$1,291**	**$205,968**	**$812,298**	**$35,744**	**$12,246**

TABLE 7-3
SUMMARY OF COST ALLOCATIONS TO ALL LANDOWNERS

Cost Element	Entire Watershed	Orr Creek	Dry Creek	Rock Creek	Auburn Rav.	Other
ANNUAL EQUIVALENTS OF FIRST COSTS						
Bridges, Culverts, & Channels		$7,680	$49,584	$23,340	$47,653	$11,933
Reservoir Protection						
Channel Improvements			$6,533			
Regional Detention						
Master Plan						
Easements	$2,678					
Monitoring System	$9,945					
Floodplain Mapping						
Bond Sale Costs	$379	$230	$1,683	$700	$1,430	$358
ONGOING COSTS						
Administration	$19,000					
Insurance	$40,000					
Reserve	$10,000					
Engineering	$60,000					
Monitoring/Warning	$57,200					
Maintenance - General	$50,000					
Floodplain Enforcement	$50,000					
Detention Basin Maintenance	$5,000					
TOTAL ZONE REVENUE NEED	**$304,201**	**$7,910**	**$57,800**	**$24,040**	**$49,083**	**$12,291**
TOTAL REVENUE NEED	**$455,325**					
Cap. Recovery Factor	0.102					

- All other costs, including all ongoing costs, are to be allocated to the entire Auburn-Bowman area.
- Master planning costs are to be allocated entirely to new development.
- The regional flood warning, monitoring, and data acquisition costs are to be allocated to all landowners.
- Floodplain mapping costs are to be allocated entirely to new development.
- All ongoing costs are to be allocated to all landowners.

RATE STRUCTURE

There are many ways to implement a rate structure to collect the needed funds for flood control can be formulated. Tables 7-4, 7-5, 7-6, and 7-7 present a detailed development of one of those ways. The rate structure here is patterned after a similar rate structure proposed in the Dry Creek Watershed Flood Control Plan (JMM, 1992). The rate structure includes the following assumptions:

- Property owners will pay in proportion to each property's contribution to the total runoff in the area. Impervious area, a readily measurable parameter that is closely related to storm runoff, is the parameter used to quantify each parcel's contribution to runoff.
- All costs allocated to new development will be collected via development fees collected at the time building permits are issued.
- All costs allocated to existing development will be collected via a benefit assessment or user fee.
- Properties will be grouped into three user groups based on land use. The user groups will be commercial land, high density residential land, and single family residential land. Costs will be allocated to those user groups based on the impervious area in the user group.
- Billings to commercial land will be based on the property's gross acreage.
- Billings to residential land will be based on the number of dwelling units on the lot.

The gross acreage and impervious area estimates needed for the billing calculations were taken from data compiled for the hydrologic calculations. In the case of new development, these figures were the expected change in gross acreage or impervious area. The number of dwelling units in the two residential user groups was estimated using the following assumed number of dwelling units per acre:

Land Use Category	Assumed Number of Residences per Acre	User Group
High Density Residential	7	High Density Residential
Medium Density Residential	3	Single Family Residential
Low Density Residential	1.43	Single Family Residential
Rural Low Density Res.	0.667	Single Family Residential
Rural Residential	0.286	Single Family Residential
Rural Estates	0.08	Single Family Residential

TABLE 7-4
UNIT REVENUE NEEDS RELATED TO NEW DEVELOPMENT

Zone	Study Area Revenue Need (4)	Study Area Impervious Area Increase (Acres)(3)	Study Area Unit Cost (1)	Zone Specific Revenue Need (5)	Zone Impervious Area Increase (Acres)(3)	Zone Specific Unit Cost (1)	Zone Total Unit Cost (2)
Orr Creek	$3,434,835	843	$4,076	$1,291	24	$53	$4,129
Dry Creek	$3,434,835	843	$4,076	$205,968	136	$1,519	$5,595
Rock Creek	$3,434,835	843	$4,076	$812,298	420	$1,936	$6,012
Auburn Ravine	$3,434,835	843	$4,076	$35,744	206	$173	$4,249
Other	$3,434,835	843	$4,076	$12,246	57	$215	$4,291

NOTE:

1. Unit Cost refers to the cost per acre of impervious area increase.
2. Sum of the Study Area and Zone Specific Unit Costs
3. Impervious area estimate reduced to 85% of actual estimate to make the rates conservative to allow for estimating inaccuracies.
4. All first costs (i.e. capital costs) that are allocated to the entire study area.
5. All first costs (i.e., capital costs) for the specific zone only.

TABLE 7-5
UNIT ANNUAL REVENUE NEEDS RELATED TO ALL LANDOWNERS

Zone	Study Area Revenue Need (4)	Study Area Impervious Area (Acres)(3)	Study Area Unit Cost (1)	Zone Specific Revenue Need (5)	Zone Impervious Area (Acres) (3)	Zone Specific Unit Cost (1)	Zone Total Unit Cost (2)
Orr Creek	$304,201	1,630	$187	$7,910	187	$42	$229
Dry Creek	$304,201	1,630	$187	$57,800	328	$176	$363
Rock Creek	$304,201	1,630	$187	$24,040	443	$54	$241
Auburn Ravine	$304,201	1,630	$187	$49,083	472	$104	$291
Other	$304,201	1,630	$187	$12,291	201	$61	$248

NOTE:

1. Unit Cost refers to the cost per acre of impervious area .
2. Sum of the Study Area and Zone Specific Unit Costs
3. Impervious area estimate reduced to 85% of actual estimate to make the rates conservative to allow for estimating inaccuracies.
4. All annual costs (debt retirement plus ongoing costs) that are allocated to the entire study area.
5. All annual costs (debt retirement plus ongoing costs) for the specific zone only.

TABLE 7-6
RECOMMENDED DEVELOPMENT FEES

User Group	Impervious Area Increase in User Group (Acres)	Revenue Need Allocated to User Group	Billing Unit	No. Billing Units In User Group	Development Fee Per Unit
ORR CREEK					
SFR	28	$117,300	Dwelling Unit	34	$3,414
HDR	0	$0	Dwelling Unit	0	$0
Comm/Ind	0	$0	Gross Acres	0	$0
DRY CREEK					
SFR	139	$778,478	Dwelling Unit	301	$2,584
HDR	0	$0	Dwelling Unit	0	$0
Comm/Ind	20	$114,060	Gross Acres	23	$5,035
ROCK CREEK					
SFR	51	$307,543	Dwelling Unit	468	$658
HDR	64	$385,435	Dwelling Unit	748	$515
Comm/Ind	378	$2,274,815	Gross Acres	420	$5,411
AUBURN RAVINE					
SFR	84	$358,712	Dwelling Unit	634	$565
HDR	74	$316,118	Dwelling Unit	868	$364
Comm/Ind	84	$357,076	Gross Acres	93	$3,824
OTHER					
SFR	56	$242,210	Dwelling Unit	213	$1,137
HDR	0	$0	Dwelling Unit	0	$0
Comm/Ind	11	$45,172	Gross Acres	12	$3,862
TOTALS	991	$5,296,919			

TABLE 7-7
BILLING RATES FOR ALL LANDOWNERS
(Covers debt service on first costs allocated to all landowners plus all ongoing costs)

User Group	Impervious Area In User Group (Acres)	Revenue Need Allocated to User Group	Billing Unit	No. Billing Units In User Group	Annual Bill Per Unit
ORR CREEK					
SFR	220	$50,367	Dwelling Unit	230	$219
HDR	0	$0	Dwelling Unit	0	$0
Comm/Ind	0	$0	Gross Acres	0	$0
DRY CREEK					
SFR	327	$118,652	Dwelling Unit	363	$326
HDR	0	$0	Dwelling Unit	0	$0
Comm/Ind	59	$21,277	Gross Acres	65	$327
ROCK CREEK					
SFR	135	$32,496	Dwelling Unit	513	$63
HDR	138	$33,236	Dwelling Unit	1610	$21
Comm/Ind	248	$59,812	Gross Acres	276	$217
AUBURN RAVINE					
SFR	243	$70,535	Dwelling Unit	627	$112
HDR	49	$14,208	Dwelling Unit	570	$25
Comm/Ind	264	$76,611	Gross Acres	293	$262
OTHER					
SFR	188	$46,684	Dwelling Unit	465	$100
HDR	0	$0	Dwelling Unit	0	$0
Comm/Ind	48	$11,798	Gross Acres	53	$223
TOTALS	1918	$535,676			

There are a number of ways that the billings recommended in Tables 7-6 and 7-7 could be implemented. The most direct way to collect development fees would be for the County to enact them. Two available ways to enact the billing rates to all landowners would be for the Flood Control District to collect a benefit assessment or for the County Service Area to collect drainage maintenance fees in this area. Each of these implementation possibilities has its own set of legal requirements. For example, a majority vote in a public election would be needed before a benefit assessment could be implemented. Once an approach is selected, legal advice should be obtained on the specific implementation procedures.

IMPLEMENTATION

Implementation of the suggested funding plan will require a number of actions by several agencies. Some of the necessary actions and the roles of the key agencies are discussed here.

Roles

Placer County and the Placer County Flood Control and Water Conservation District are the primary agencies likely to be involved in implementing this plan. The County would probably be the one to implement development fees, since the District has no such authority. Either agency could implement the ongoing fees. As already noted, the actual steps needed to set up the various fees differ with each agency. Either agency could be given the lead in setting project priorities and in constructing the various improvements.

Portions of many of the drainage basins in this study area are inside the City of Auburn. Ongoing coordination with the City of Auburn is needed to insure that storm drainage management by the two neighboring entities remains compatible.

Schedule

The County Supervisors or the District Board, depending on which agency takes the lead, need to prioritize the improvements to determine which will be implemented first. Projects relying on development fees for funding should not be started until the funds from development fees are in the bank, since it is not possible to the speed at which development will occur. Projects relying on existing landowners could either be constructed immediately after enacting a funding mechanism by relying on bond financing, or they could be spread out over 20 years if construction is to be funded on a pay-as-you-go basis.

Review

Like all rate structures, the suggested flood control management rate structure should be reviewed periodically to be sure it is compatible with the current situation. Costs can change due to inflation, deviations from the plan, or changes in the expected development patterns. Annual rate structure reviews can avoid the need for drastic rate changes. In no case should rate structure reviews be more than five years apart.