CHAPTER 5: STREAM SEDIMENT

Introduction

This chapter discusses stream sedimentation and erosion processes in the ERP planning area and characterizes existing conditions found in the primary watershed reaches. Sediment and erosion management issues and their negative and positive effects on the watersheds are also included in the following discussion.

Stream Erosion and Sedimentation Processes

The complex interaction of streams and the surrounding landscape can be characterized to a large extent by describing the erosion and sedimentation that occurs both within the watershed and within the stream itself. The input and movement of sediments from the watershed and the instream erosion and deposition of sediments helps determine many stream habitat features such as channel depth, shape, substrate, flow patterns, dissolved oxygen concentrations, adjacent vegetation, and aquatic communities.

Instream sediments come from two sources: runoff from surrounding areas and erosion of sediments from the channel itself. Relative surface erosion hazard potential within the ERP planning area is identified in Figure 5-1. The sediment content of runoff depends on:

- Rate and duration of precipitation Erosion is generally highest when soils have been saturated and precipitation is high.
- Slope or gradient Steep slopes generate high velocity and high-energy runoff, resulting in more rapid erosion.
- Soil texture and structure- Fine, loosely compacted silt soils erode more rapidly than dense clays, cobbles, or, absent concentrated flow, sandy soils.
- Vegetative cover Surface vegetation reduces the direct impact of precipitation and reduces the velocity of runoff over the soil. Root structures and organic matter also bind soil particles together. Vegetated areas are thus generally more stable than areas without vegetation. Soils exposed by recent construction are particularly susceptible to erosion.
- Slope length and flow concentration

Erosion within the streambed itself is also affected by these factors. For example, loss of vegetation along the stream bank will result in higher rates of erosion.

Once sediments enter the stream, they are suspended in the water column or deposited as bedload and carried downstream either immediately or at some time in the future. The quantity and type of sediments suspended in the water column depends on (a) the energy of the flow and (b) the density and size of the particle. Higher velocity flows carry larger and heavier sediments. Since stream energy is related to the steepness (gradient) of the stream, coarser sediment particles are generally deposited in upstream areas and finer sediments are carried further downstream and deposited where water velocities decline.

Insert fig. 5-1

Under natural conditions, there is a dynamic range of runoff, erosion, sediment movement, and sediment deposition conditions within each watershed. The aquatic species within the watershed are adapted to survive within this range of conditions. When human activity alters these conditions, the sediment regime within the watershed may create conditions that adversely affect the ability of native aquatic species to survive in the system. For example, runoff from urban areas may be more rapid than runoff from naturally vegetated areas, thus increasing the peak flows in the stream, which in turn increases channel erosion. At the same time, construction and land use activities in the watershed may increase the amount of sediment entering the stream, which in turn increases sediment deposition.

Objectives of the Sediment Analysis

This evaluation of streams and channels for the ERP is intended to:

- Enhance understanding of the watershed and channel processes that control the channel conditions throughout the study area;
- Identify channel segments in the study area that are changing due to present watershed conditions; and
- Predict in what manner the channel segments may change in the future, considering future watershed development and land management patterns.

This analysis of watershed and stream sedimentation can then be used as part of the overall analysis of how and to what degree channel conditions influence the present and potential future status of key biological resources. Based on this analysis of present and potential future problems, ERP project recommendations can be made. A conceptual model of the interaction of the stream and its watershed can be developed from an understanding of:

- Channel forming processes and channel conditions within specific channel segments;
- The interaction of channel segments at the watershed scale based on routing and channel storage of stream flow and sediment; and
- The combined effects of these two elements and changes in watershed and channel network conditions over time.

The conceptual basis for this evaluation is described in Appendix A and is outlined briefly below.

Conceptual Basis for Watershed and Stream Sedimentation Analysis

The system applied in this watershed evaluation is a modification of a classification approach proposed by Montgomery and Buffington (1993, 1997, 1998), a system that relates erosion/deposition processes in individual channel segments to watershed gradient (hill slope) and sediment erosion, transport, and deposition in the watershed.

Stream Order

The evaluation begins by classifying all of the streams in the Auburn Ravine and Coon Creek watershed by order (Strahler 1957). Stream orders begin with 0, which designates an upper watershed drainage that is flowing only during or immediately after precipitation and is not designated a blueline stream on 7.5' USGS quad maps. Order 1 streams are indicated as blueline streams on USGS quad maps and collect flows from these intermittent drainages and/or groundwater (springs), and may flow year round or intermittently. Order 2 streams collect flows from Order 1 streams, with Order numbers increasing until the river drains to the ocean. Stream ordering is the most basic organizational framework used to categorize stream processes and channel - floodplain interactions, which change in relatively predictable ways from upstream to downstream.

Channel Confinement Class

The second approach to classification is to characterize each stream segment according to its susceptibility to bank modification due to changing stream flow and/or sediment regimes; that is, how well the channel is confined within its banks. Channels are generally classified as confined, semi-confined, unconfined, and levee-confined. These classifications are often related to stream order and position in the watershed. For purposes of more precise definition, these general classifications are modified by where they occur within the watershed. Channels are thus defined in terms of channel confinement area and then classed by the level of confinement. With reference to the numerical designations on Figure 5-2, the specific confinement areas are:

- High confinement (I) flows are generally contained in the defined channel by steep hillsides and bedrock formations:
- Moderate confinement (II) flows are contained within the channel by moderate hills and bedrock, with some sections of channel where flows may overflow banks;
- Dynamic confinement (III) bank overflow and bank erosion are more common and bank erosion may be high;
- Translational (IV) bank erosion is limited by hard sediments but high flows will cause flooding due to the relatively flat surrounding lands;
- Basin (V) crossing an alluvial basin, the channel overflows regularly, often due to backwater conditions, creating seasonal ponding (most of these areas are now controlled by levees); and
- Overbank (VI) flooding occurs over a wide flat floodplain.

Fig 5-2

Channel Confinement Sub-Class

Each of these confinement areas is explained in detail in Appendix A. In field evaluation, each of these classifications may be sub-classified for a given stream section, by designating the estimated level of confinement:

- Confined (C)
- Semi-confined (SC)
- Unconfined (UC)
- Levee-confined (LC)

For example, an individual stream reach may therefore be described as Levee Confined (indicated on Figure 5-2 as LC). This indicates that the particular reach has been modified by levees and is now confined to the leveed channel.

Channel Bedform Type

Streams may be classified by their in-channel and channel bed shapes and features, such as bedrock drops, rapids, riffles, and pools. These features are related to basic sediment routing and channel form relationships and to channel confinement. Bedform provides important information on sediment routing processes and the basic structure of aquatic habitat of various channel reaches. Auburn Ravine and Coon Creek have a number of bedform types, each of which is characterized by different sediment regimes, and each of which presents a different set of restoration problems and opportunities. The major types are:

- Colluvium (C) 0-order drainages along hillsides, not blueline streams;
- Bedrock (BR) Narrow steep channels in upstream areas, with hard rock bottoms and sides; these segments may include short segments of bedrock-forced channel, defined as low gradient channels confined by hard rocky channel walls, resulting in confined flows carrying high sediment loads through the channel section;
- Cascades (CA) Steep channels dominated by large boulders, creating complex flows and sediment regimes;
- Plane Bed (PB) Moderate gradient, cobble substrate stream sections, often between upstream and cascade sections;
- Pool-Riffle (PR) Complex stream sections with a variety of bed materials and gradients in unconfined channels, often resulting in rapidly changing channel configurations; and
- Dune-Ripple (DR) Confined channel in terraced areas, with moderate to flat gradient and constant movement of fine sediment and high sediment mobilization in high flows.

Bedform classifications add information to the understanding of each reach analyzed. For example, combined with the Channel Confinement Class, an individual stream reach

may be characterized as within general area of Dynamic Confinement, Semi-Confined, with Dune-Ripple characteristics. On Figure 5-2, this designation would read: SC/DR.

Predominant Bed Material

The final level of channel analysis involves classification of the sediment sizes in each reach to provide greater detail on the character of the sediment being moved through the stream system. In general, larger size materials (bounders, cobbles, and coarse gravels and sands) are found in upper reaches and finer sediments (gravels, sands, and clays) tend to be found in lower reaches. Predominant bed materials found within the ERP watersheds are shown on Figure 5-2. The classifications used in this analysis are:

- (Si) Silt (less than 0.0002 inches [< 0.0625 mm])
- (Sa) Sand (0.002 0.08 inches [0.0625-2.0 mm]
- (Gr) Gravel (0.08 2.5 inches [2.0-64.0 mm] (includes pebbles)
- (Co) Cobble (2.5 10 inches [64.0-256.0 mm])
- (Bl) Boulder (greater than 10 inches [> 256.0 mm])
- (Br) Bedrock

Analyzing Sediment Regimes using these Classification Systems

By evaluating stream systems in terms of these four elements, it is possible to better understand how sediment is generated, transported, and deposited as it moves from upstream watershed areas through the streams and rivers of the system. Some general patterns of sediment movement in streams and rivers are:

- As stream gradient flattens, larger sediments are deposited first, with the finest sediments settling out of the stream in downstream reaches where stream gradient is generally flatter;
- Channel confinement, size, and shape generally change from upstream to downstream; the width of the floodplain adjacent to the channel tends to increase downstream; and
- Channel characteristics change in response to changes in factors such as flow, increased or decreased sediment input, and the condition of the adjacent riparian zone.

Watershed processes, which may lead to a change in channel forming regimes within any channel segment may include:

- Progressive changes in climate;
- Changes in land uses; and
- Changes to channel segments upstream that may alter the pattern of channel forming stream flows and/or sediment regime in downstream stream segments.

The results of changes in these factors are measured primarily in terms of changes to the bedform of the channel, such as:

- Narrowing or widening,
- Deepening or filling in,
- Straightening or becoming more sinuous, and/or
- Increased or decreased overbank flow (flooding).

These changes in the form of the stream reflect changes in the interaction of the stream system with its watershed. Understanding them is therefore a means to understand the past, present, and potential future impacts of changes within the watershed.

Characterization Of Primary Channel Segments In The Watersheds

Channel Conditions of Mainstem Segments

The mainstem reaches of Auburn Ravine and Coon Creek are located at the downstream portion of the watershed, in the relatively flat alluvial plain. Issues of concern in these reaches include:

- Bank erosion and land losses,
- Community and social infrastructure issues such as potential flooding and associated damage to structures,
- Aquatic and adjacent riparian habitat supporting both resident species and migratory fish.

Cross Canal

The Cross Canal is the outlet channel for the entire Auburn Ravine and Coon Creek watershed. It is a 5.5 mile long engineered drainage canal system connecting the East Side Canal to the Sacramento River at Verona. The Cross Canal collects flows from the north and south arms of the East Side Canal. The East Side Canal intercepts flows from a number of streams that previously drained across the floodplain of the Bear, Feather, and Sacramento Rivers. The streams of the Auburn Ravine and Coon Creek watershed are captured by the north arm of the East Side Canal include Coon Creek, Markham Ravine, Auburn Ravine, and King Slough. The south arm of the East Side Canal captures flows from Curry Creek, Pleasant Grove Creek, and several minor unnamed local streams. Because the Cross Canal channel is engineered, the interaction between the channel bed, banks, and floodplain areas is controlled by levees and associated structures.

During periods of low flow in the downstream leveed reach, the Cross Canal within the levees is a mix of open connected ponds and marsh habitat areas, with relatively sparser riparian trees in many areas. Dredging to provide materials for levee construction has formed deeper ponds. In any given segment of the Cross Canal, these ponds may cover from one-half the channel width to the full channel width, with water surface elevations

controlled by the river stage on the Sacramento River. Unponded areas are maintained as bare ground or grass.

In the upstream reach, a narrow steeper-gradient channel flows through a well-developed riparian habitat. This low flow channel varies in width from 10 ft to 30 ft, and velocities in the low flow channel vary accordingly. The banks of the low flow channel are sometimes controlled by placed rubble or stabilized by the roots of adjacent, dense riparian trees. The stream banks are stable. This narrow channel occupies only a small percentage of the canal floor cross-section.

Because of its very low gradient, extensive areas of ponds, and the backwater influences from the Sacramento River during floodflow events, flow velocities are often quite low and sediments entering this reach fall out of suspension. The Cross Canal is an area of net sediment buildup (sediment sink).

The connected-pool structure of the low flow channel in the downstream reach, created by excavation for levee material does not reflect natural conditions. The pools may harbor non-native warm water fish (bass) and amphibians (bullfrogs) that would adversely impact native aquatic species. Lack of tules and/or shaded riparian vegetation in some areas may also create unfavorable conditions for native species, particularly salmonids.

East Side Canal

The East Side Canal is the north arm of the canal system extending from an abandoned Sacramento Northern Railroad crossing upstream 4.5 miles to a point where the canal system cuts off the lower channel of Coon Creek. At this point, the East Side channel extends the levee system eastward on Coon Creek for approximately 200 feet. The location of these levees confines Coon Creek and does not allow interaction with the adjacent landscape through hydraulic or channel forming processes. Conversely, flows that would have naturally flowed into the creek pond at the intersection of the East Side Canal and Coon Creek (the same is true for Auburn Ravine and Markham Ravine). Small, private built levees extend upstream. Since channel capacity has been lost, these levees do not generally restrict flows as the flows often overtop the banks and sheet flows southeast over the land. The canal has a wide flow area, about 200 ft., set between levees.

In the downstream 1.5 miles of the East Side Canal, the narrower low flow channel in the floor of the canal is stable due to resistant bank conditions (cohesive soils) and riparian tree root mass anchoring. In this low-flow channel, channel sections are narrow enough to have relatively high velocities and the banks are sharp, well defined, and stable. The narrower channel reaches have depths ranging from 2-4ft., have relatively high stream power, and are efficient at sediment transport.

The East Side Canal is located in the Basin channel confinement class (Figure 5-2), with notable overbank flooding, low velocities due to backwater influences, and the deposition

of fine-grained sediment during inundation. Wider channel sections indicate a history of sediment dredging and sediment deposition. These reaches may have multiple channels, extensive shallow areas, and a complex of marsh and riparian vegetation reestablishment. There are short reaches with wide excavated ponds without channel-like flow characteristics. Where stream channels and ponds do not occupy the entire drainage canal width, there are broad bare ground or grassy low terraces maintained for floodflow passage.

The upstream 3.0 miles of the East Side Canal is dominated by wide flow areas with very low water velocities, quiet pool and marsh areas, and a few slightly more narrow portions where higher velocities occur. The ponds in this reach tend to be very wide and shallow with bed materials comprised mostly of very fine cohesive clays and silts, and some fine sand. Stream channels are generally not well defined.

Similar to the Cross Canal, the East Side Canal area is a sediment sink for the watershed, due to generally very low gradients, extensive pond areas, and backwater influences from the Sacramento River during floodflow events.

Like the Cross Canal, the East Side Canal does not reflect historic aquatic conditions for this area of the watershed. In particular, the flat, sandy bottom, with little shaded riparian area, may create conditions unfavorable for native aquatic species.

Channel Conditions in Streams Above the East Side Canal

Coon Creek

The reach of Coon Creek described here includes the 33.3 river miles of channel between the East Side Canal and Dry Creek Dam. Elevations range from 34 ft at River Mile (RM) 10.0 (as measured from the Sacramento River) to about 1315 ft at RM 43.3 (see Figure 5-2). Average channel gradient is 38.5 ft/mi (0.7%). From downstream to upstream, this reach of Coon Creek includes five channel confinement classes: Levee Confined (Basin), Translational, Dynamic Confinement, Highly Confined, and Moderately Confined (Figure 5-2).

RM 10.0 - 20.2

The downstream reach of Coon Creek at the East Side Canal is levee confined, with a channel gradient of about 3.3 ft/mi (0.06%). The water surface generally covers the inter-levee area, except in areas with riparian-forested steep banks and very narrow inconsistent terrace deposits. About 400 yards upstream, the levees appear to end and the channel meanders across the floodplain and is bounded by a narrow strip of riparian vegetation. The streambed is flat floored with minor sand bars exposed only when flows are extremely low. The flow area of the channel is typically 15-20 ft across and 2-4 ft deep. The bed is mostly fine sand and silt. Peak winter flows occasionally deposit small isolated areas of fine sands along the banks. This channel reach was not fully

investigated in the field due to limited access, but those observations made did not reveal any signs of notable bank erosion or channel instability.

Increased sand loading has reduced the aquatic habitat quality through decreased inchannel morphological variability, increased barriers to anadromous fish migration during periods of low flows, and reduced channel floodflow capacity leading to greater flood potential and increased risk to the levee system. Narrowed areas of riparian habitat and reduced channel dynamics are also a concern.

RM 20.2 - 24.3

This segment is an unconfined channel within a Dynamic Confinement stream channel confinement class. The active channel is typically about 15 to 30+ ft wide with active banks ranging from 5 to 15 ft high and a gradient of about 8.3 ft/mi (0.16%). The bank material is recent alluvium and tends to have extensive zones of finer clays and silts which are somewhat cohesive and hold very steep bank slopes. The presence of this fine alluvium and the steep but relatively stable banks create deeply incised split-channel reaches and islands with high surface elevation. This formation is unique in the Auburn Ravine and Coon Creek watershed. The alluvial surface that contains the channel of this segment lowers in elevation relative to the channel bed in a downstream direction to the degree that extensive overbank flooding occurs in the downstream portions of this segment.

There is evidence of long-term and continuous channel migration, including scattered short reaches of active and severe bank erosion, secondary channel erosion and formation, and abandonment and infilling of older channels. Active bank erosion and undercutting of rooted alders along the channel margin create deeper scour holes and pools with high velocities and cover. These can range to 3-4 ft deep and lateral undercutting within the root masses of 1-2 ft.

In places, there are overbank surfaces 6-10 ft above the low flow channel in which 4-5 ft of sand deposition has occurred during the life-span of the adjacent larger valley oaks (3+ft diameter at breast height (DBH)) which are likely to be over 100 years in age. This situation indicates that there was a short period of significant overbank deposition of sand during the last 100 - 200 years, perhaps dating to the mining period in the watershed upstream or to presently increased floodflow elevations.

The bed material gradually transitions from fine gravels, pebbles and sand upstream to pebbles, and sand downstream. This material is highly mobile during floodflow events and the sand is mobile at lower flows. Therefore while the channel is unconfined and can adjust its width to allow for in-channel hydraulic variability and pool-riffle bedforms, the mobile sand and small pebbles tend to fill in deeper pools, reducing in-channel bedform variability during the lower flow periods. In reaches where steep cohesive banks exist, channel widths are semi-confined and the in-channel hydraulic variation is limited by an undersized channel width. Bedforms tend toward plane-bed even though the bed material is relatively fine. The harder banks and undercut areas tend to create deeper scour holes.

Short sections of severe bank erosion can induce small-scale hydraulic variability resulting in small-scale increased sinuosity and pool-riffle development. This can induce aggravated bank erosion short distances downstream.

In spite of the variability of erosion and deposition processes in this segment, channel erosion, bank scour, and bank retreat predominate. This may be associated with increased flood flow energies resulting from development in the watershed, which causes more rapid runoff and thus more frequent periods of high flow.

Within the constraints of the levees, increased sand loading and on-going bank erosion have decreased variability of the channel's form by filling in pools and filling in the spaces between coarse materials with sands. Bank erosion is resulting in loss of riparian habitat that provides shade for the channel. Erosion is widening the low-flow channel. The channel therefore lacks habitat diversity, in particular areas of deep-water ponding, and this may create unfavorable conditions for adult anadromous fish spawning migration during periods of low flows. Because shade from riparian areas is reduced and the channel bottom is a relatively uniform sandy substrate, juvenile salmonids would also find only limited rearing habitat during emigration to the sea, and could be exposed to increased predation.

RM 24.3-30.7

This channel segment has a well-defined active channel cut into both recent (younger) alluvial deposits and riverbank terraces. Harder (older) riverbank formations are adjacent to the active channel in various reaches. The channel is mostly confined but occasionally there are wide channel reaches with unconfined channel dynamics. The tighter more confined channel in the upstream portion of this reach has a gradient of about 13.9 ft/mi (0.26%). The riverbank (younger) terrace surface is about 10-12 ft above the channel bed and does not show prominent evidence of overbank deposition. In the incised channel within the younger riverbank formation, where the space is available, a series of three lower terraces of sedimentary deposits occur (2 ft, 5 ft, and 7 ft above the low flow water surface). The higher surfaces are relatively old and well vegetated with trees. These surfaces may correlate to the overbank terrace depositions noted in the downstream segment.

Where the channel reaches are semi-confined, the channel cross section is nearly rectangular, with near vertical banks and a nearly flat channel floor. The channel bottom is typically of pool-riffle bedforms with sand and pebbles in the pools and gravel to cobble and very small boulders in riffles. There are some isolated cascade bedforms where very small boulders are concentrated, partially anchored by alders. There are also isolated sections with bedrock channel inverts. Scour pools can occur adjacent to resistant banks and along undercut alder tree root masses that can range to 3-4 ft deep. Where unconfined, the channel is wide and shallow with a predominance of gravel and small cobble materials.

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This reach is characterized by active erosion of both the channel bed and adjacent banks. Areas with alders that anchor bed material are being progressively eroded, resulting in loss of surface anchoring and allowing coarse material to be eroded and transported downstream from the section. The lower in-channel terraces show prominent evidence of scour and, where exposed, bedrock surfaces are stripped to a point of resistant competence. There is on going and extensive bank erosion and bank channel widening in areas where infrastructure has been placed and banks consist of softer decomposed granite. Sediment deposition was noted only in channel sections where substantial bank retreat and lateral channel realignment have provided sites of lower hydraulic energies.

Increased channel scour is causing loss of riparian habitat and tree root binding along portions of the active channel. There is loss of riparian shading for the channel as a result. Channel scour is resulting in land losses.

RM 30.7 - 39.6

This confined channel segment crosses a region of moderate-grade and hard rock substrate (diabase intruded metamorphic geology), which resists erosion. The channel flows along the bottom of the ravines formed by the adjacent hills and there is little floodplain flow. The overall gradient of this segment is about 97.1 ft/mi (1.8%). There are scattered reaches controlled by resistant low terrace features instead of hill slopes. These features are basically constructed by long-term channel process and appear to be unaffected by the major streamflow events of the present watershed runoff regime.

The bedforms of this channel segment are largely controlled by bedrock of the bed and banks. Short, relatively low (2-4 ft.) bedrock drops create upstream sediment accumulation of cobbles and small boulders that form cascade and plane-bed bedforms. Downstream of the bedrock drops, large pools (25 ft by 40+ feet by 2-4 feet deep) are found. The pools temporarily store sediments, typically grading from pebble to small cobble and, usually near the downstream end of the pools, cobble and small boulders. The upstream ends of these pools often have deeper plunge-pool features.

Channel margins are essentially stable. There are reaches with narrow banks of sediment deposits. Some of these banks are composed of fine sand and smaller particles that can form banks to 2 ft above the pool water surface elevation. In many locations roots of mid-aged trees show evidence of relatively recent bank retreat of several feet. Other depositional units are long low terraces, which are adjacent to the low flow channel along reaches up to several hundred feet in length. They are very stable, composed of coarse material and well vegetated. These terraces structure long wide pools that range 30 ft x 200+ ft and 2-4 ft deep; rooted riparian trees providing lineal aquatic habitat cover generally line them. The downstream ends of these long pools often are the glides of coarse material riffle drops.

The riffles and short plane-bed reaches are strongly controlled by riparian vegetation. Riffles tend to be relatively steep and can range from 15-40 ft long. In riffle drops rooted trees anchor much of the bed material limiting the cross-section of active sediment

mobilization. Often these riffle drops show signs of a recent trend toward over-abundant incoming sediment with out-of-active channel deposition of cobble and small boulder materials. Plane-bed reaches can be 10-40 ft long and are steep coarse bed (gravel and cobble) features, but channel margins are constrained by riparian forest, which reduces bank erosion.

Although this channel segment is generally stable and the banks are resistant to changes in stream flow and/or sediment regimes, field evidence indicated that general channel scour and enlargement processes are underway. Changes observed include aggradation of coarse material in the glide and crest of riffle drops due to increased scour of pool sections, isolated areas of bed degradation and loss of riparian-root anchored coarse bed material, and bank erosion of fine material depositional units. These changes could either be due to progressive watershed changes to the stream flow and/or sediment regimes and the initiation of general bedform adjustments or to recent major flood events near the higher end of general channel thresholds of stability. These observations are in correlation with general bed scour and/or channel enlargement in downstream Coon Creek channel segments.

Increased channel scour is causing losses of riparian sites, vegetation, and cover. These are presently only minor in extent but may become pervasive.

RM 39.6 - 43.3

Most of this channel segment is generally less confined by hill slopes than the foregoing segment in that it crosses lower grade metamorphic rocks and the regional fault zone. The rate of channel network erosion and downcutting is arrested by the harder downstream geologic units and the segment has a gradient of about 68.7 ft/mi (1.30%). With slightly reduced channel downcutting, the rates of hill slope erosion and slope retreat create generally more separation between hill slopes and channel margins. The moderately confined stream system classification reflects the situation in which channel margins are a mix of hill slopes and coarse low terrace features.

Bedrock features are often exposed in scattered locations along the channel, which imparts a strong control on bed processes; most importantly, limiting bed downcutting. These bedform features and bed materials generally result in wide shallow channels with considerable in-channel roughness resulting from the large bed materials. Reaches of bedrock control create generally small, low gradient drops of 2-5 ft high and lengths in the range of 20 ft. The bedrock areas can have riparian trees rooted to bedrock fractures and anchored coarse material on the bedrock surface. The bedrock reaches generally are low gradient, dominated by fine sediments. These reaches can have well defined channels within fine sediment banks rooted by riparian trees and herbaceous vegetation. Flow area is generally relatively narrow (3-5 ft) and deep (1-2 ft) with higher stream velocities and considerable in-channel hydraulic variability induced by small-scale sinuosity and bank roughness. The channel sections are generally too narrow to develop substantial in-channel temporary sediment storage.

Other channel reaches are plane-bed and poorly formed pool-riffles. They are generally wide (10-20 ft) and shallow (3-5 ft) relative to the top of bank, and have a high bed roughness because of the larger cobble bed material. In these reaches adjacent floodplains of variable widths and length exist, often composed of coarse transported material. These wide channel reaches are controlled by reduced hill slope confinement and by bedrock bed controls either as a shallow feature under the channel bed or as a downstream grade control exposure. These floodplain features are generally composed of coarse material but can be subjected to channel modifications from shifting stream flow and/or sediment regimes.

These upstream reaches of Coon Creek do not appear to be significantly altered from the conditions, which would be expected in the upper watershed.

Doty Ravine

The reach of Doty Ravine described here includes the 11.6 miles of channel between its confluence with Coon Creek and the upstream end of a rapid/riffle channel reach at about elevation 667 ft. Elevations range from 104 ft at RM 0.0 (Coon Creek) to 667 ft at RM 11.6. Average gradient is 48.5 ft/mi (0.92%). Doty Ravine is characterized as a Dynamic channel confinement class through most of the lower portion, and is Highly Confined at the upstream end (Figure 5-2).

RM 0.0 - 10.0

This segment is an unconfined channel, within the Dynamic channel confinement class, and is typically about 10 to 25+ ft wide with active banks up to about 3 ft high. Adjacent terraces and floodplain deposits are from 3 to 8+ ft higher than the low flow channel. The overall channel gradient is about 29.1 ft/mi (0.55%), ranging from about 14.9 ft/mi (0.28%) in the downstream end to about 43.9 ft/mi (0.83%) in the upstream end. The channel in this segment generally consists of pool-riffles with gravel and limited small cobble material deposited in small, attached bars forming the riffles and shallow/wide scour pools. In occasional locations, small bodies of granitic bedrock control bedform and create very small bedrock drops.

From upstream to downstream, the channel gradually transforms from narrow, coarse-material riffles within higher, heavily vegetated terrace slopes to wider, fine-material riffles with low, unconsolidated banks. In the downstream portions, the riffles have semi-attached bars, diagonal bars, and medial bars, showing evidence of general channel sediment over-loading and trends toward changes in channel alignment. Below about RM 7.8 the channel is loaded with coarse sand, which is presently altering the aquatic habitat structure of the channel bed and in some shorter reaches, completely transforming the channel to dune-ripple or bedrock-forced configurations. Channel reaches above about RM 8.5 show no evidence of elevated sand loading, suggesting that sediments are being generated below this point, but access to the reach of Doty Ravine between RM 7.8 and 8.5 was not available to the field crew and the source of the sand load was not identified.

Channel banks are generally recent alluvium; mainly composed of coarse sand, fine sand, and lenses of pebble and gravel material. Downstream of RM 5.0, these recent alluvial terraces are inset within terraces of Riverbank (younger) formation. Upstream of RM 5.0, they are mostly within terrace surfaces of the low relief deeply weathered granitic terrain. The channel margins are typically coarse near vertical banks composed of coarse non-cohesive material, often with heavy vegetation cover. These channel types are very sensitive to channel pattern derangement, degradation, and reconstruction in accommodation of changing watershed or channel segment changes in stream flow and/or sediment regimes.

In various locations elevated rates of bank erosion were observed, but even with the elevated rates of coarse sand transport, there are presently no known locations where the channel is generally changing form. But the isolated locations of bank erosion and the various bedforms observed indicate an over-loaded sediment regime, which may have the potential to destabilize the channel segment, resulting in changes in channel form.

At present, key-resource degradation includes: land losses to landowners, infrastructure facilities at risk including bridges and other in-channel structures, and aquatic habitat quality, particularly in the downstream 7.8 miles. Increased sand loading and minor bank erosion has reduced the aquatic habitat qualities through decreased in-channel morphological variability, infilling of pools and embedding of coarse materials by coarse sand, reduced fish habitat conditions, and difficult anadromous migration during periods of low flows. Bank erosion is resulting in short-term loss of riparian habitat quality and on-going land losses. Infrastructure is at risk due to increased flooding, which may require more frequent maintenance of bridges, culverts, and water diversion structures.

RM 10.0 - 11.6

This channel segment is within the granitic bedrock Highly Confined channel confinement class. When unweathered granitic material is exposed, this geologic unit is resistant to erosion. This segment has an overall gradient of about 170 ft/mi (3.2%). Most of the segment was inaccessible to the field crew, but conditions may be inferred from short reaches observed and channel conditions implied by segment gradient and apparent available in-channel materials as observed upstream. In this segment, the expected bedforms would include bedrock, cascade, plane-bed, and short and compressed pool-riffle. These bedforms, in conjunction with the potential bed materials of bedrock, boulder, cobble, and gravel, are likely to result in high quality aquatic habitat structure and banks relatively resistant to bank erosion.

Although fieldwork was limited, this segment was not found to have significant problems related to key resources.

Auburn Ravine

The reach of Auburn Ravine described here includes the 27.6 miles of channel between its confluence with the East Side Canal (about 7.8 miles above the Sacramento River) and the downstream end of the I-80 box culvert, west of Auburn. Elevations range from about 30 ft at RM 0.0 to about 1100 ft at RM 27.6. Average gradient is 38.8 ft/mi (0.73%). From downstream to upstream, this reach of Auburn Ravine traverses four channel confinement classes, including in upstream order; Basin, Translational, Dynamic Confinement, and Highly Confined (Figure 5-2).

RM 0.0 - 2.5

This segment of Auburn Ravine, within the Basin channel confinement class, is confined by levees. The present channel has a gradient of about 6.0 ft/mi (0.11%), which is a steeper gradient than expected because this segment has been straightened (shortened) to accommodate agricultural land uses and it is contained within the constructed levees. The low flow area of the channel is typically 15-20 ft across and 2-4 ft deep and, except for some steep riparian forested banks, occupies most of the inter-levee area. The bed is flat; minor sand bars attached to the banks are exposed only during extremely low flows. The levees fully contain flow at all volumes, up to their design flow.

The channel bed is mostly coarse sand, but peak winter flows occasionally deposit finer sands along the banks in isolated areas. There is significant, in-channel, short-term sediment storage. The seasonal placement of irrigation diversion dams provides pools within which thick deposits (2-4 ft) of coarse sand develop due to constant sediment input from upstream. During the winter season, when the diversion structures are removed, higher flows move much of the stored sediment downstream. Thinner beds of coarse sand from upstream areas then replace these deposits.

Increased sand loading and narrow levee confinement have altered the aquatic habitat in this segment, creating an area with little habitat variation, few areas of riparian shading, and a relatively uniform sandy bed. These qualities may adversely affect adult salmonid migration, juvenile salmonid rearing and survival, and habitat for other native aquatic species. The sedimentation regime also reduces channel capacity, resulting in an increased risk of flooding.

RM 2.5 - 7.1

This channel segment crosses both Basin and Translational channel confinement classes. This reach is confined primarily by resistant Riverbank (younger) materials, though there are reaches where low levees have been installed to protect agricultural fields from inundation. However, the levees are not a significant factor in channel confinement compared to the local geology, which controls the banks of the active channel. The segment has a gradient of about 5.9 ft/mi (0.11%).

5-17

The active channel is from 10-20 ft wide and about 50% of the banks have irregular erosional/depositional surfaces vegetated with narrow bands of riparian forest. Peak winter flows occasionally deposit isolated patches of finer sands. The streambed is flat, with minor sandbars attached to the banks and exposed only when flows are low.

The bedrock confinement tightly constrains the hydraulic energies and there are long channel reaches in which there are relatively high velocities but little hydraulic variability. However, the relatively high average gradient and rapid flow generates small-scale bank erosion, channel sinuosity, and hydraulic variability in short channel reaches. The bed consists of mostly coarse sand and the bedforms are mostly duneripple, with some attached bars. The segment is a reach of significant, in-channel, short-term sediment storage. Overall, there is little opportunity for the channel to change shape and size to accommodate longer-term changes in stream flow and/or sediment regimes.

Increased sand loading in the narrow channel has altered aquatic habitat by decreasing inchannel structural variability. The channel has little habitat variation, few areas of riparian shading, and a relatively uniform sandy bed. These qualities may adversely affect adult salmonid migration, juvenile salmonid rearing and survival, and habitat for other native aquatic species. The sedimentation regime also reduces channel capacity, resulting in an increased risk of flooding.

RM 7.1 - 12.8

This segment is an unconfined channel within the Dynamic Confinement channel confinement class. The active channel is typically about 10 to 25+ ft wide with active banks ranging about 5 - 8+ ft high. Channel gradient is about 8.1 ft/mi (0.15%). The bank material is mostly recent alluvium, mainly composed of coarse sand, inset within a corridor of Riverbank (younger) formation. The channel margins are mostly within the recent alluvium but occasionally the channel margin is the resistant riverbank material. The downstream reach below Moore Road is dominated by a double set of depositional terraces, the lower of which has a backslope surface, an outboard secondary flood-overflow channel, and evidence of surface scour, all indications of that it has developed as a result of active flood flow and related sediment deposit. In the reach above Moore Road, the alluvial surfaces are more complex, with several sets of inset surfaces indicating periods of general channel enlargement followed by net bank deposition.

This channel segment is strongly rectangular-shaped with near vertical banks and a flat floor loaded with coarse sand. The vertical banks are a result of riparian tree root-anchoring and resistant banks. The relatively high gradient and confinement of the channel result in relatively high hydraulic energy and low in-channel hydraulic variability. The bedform is primarily dune-ripples composed of thick (2-3 ft) coarse sand material. This material is under active transport at most flows. At peak flows most of the bed material is probably in active transport with flows scouring the in-channel sand material to the bedrock floor of the channel. Little overbank deposition of this coarse material appears to occur during the typical flood flows. Following flood flows, the

coarse sand imported from upstream sources is redeposited in the bed and continued sand sediment input occurs during low flow periods.

Under present circumstances the channel banks are mostly stable and confined by riparian tree root masses, but the segment is considered unconfined because most exposed bank material is highly erosive and changes in stream flow and/or sediment regimes, or removal of the binding root masses, could lead to unstable conditions, resulting in new channel patterns and bedforms.

Compared to the probable natural channel condition, increased sand loading in a narrow channel has decreased in-channel structural variability, with potentially adverse impacts on habitat for anadromous salmonids and other native aquatic species. Sand loading has reduced channel capacity, leading to greater potential for flooding and damage to infrastructure such as bridges and water diversion structures.

RM 12.8 - 18.5

This segment is an unconfined channel within the Dynamic Confinement channel confinement class. The active channel is typically about 15 to 30-40 ft wide with active banks ranging from about 5 to 15 ft high. It has a gradient of about 19.6 ft/mi (0.37%). The bank material is mostly recent alluvium and tends to be coarse and unconsolidated, including coarse sand, pebbles, and small lenses of gravel. The bank is occasionally the resistant Riverbank (older) formation.

Three elevated coarse-grained terraces are a prominent feature of this segment, ranging from 3-4 ft to 15+ ft above the channel. The channel gradient is steeper than the terrace surfaces so the relative elevation differences between a specific terrace surface and the channel increases downstream. Many of these surfaces have backslopes and outboard secondary flood-overflow channels, or fluted surfaces, all indicating active, or recently active, depositional construction. They are typically well vegetated with mature riparian trees, and the lack of significant over bank sediment deposits on the higher surfaces indicates that only the mid and lower terrace surfaces are currently actively receiving significant sediment deposits from flood flows.

Pool-riffle forms, with some limited area of dune-ripple where narrow confined channels exist, dominate this segment. The sediment of the bed ranges from coarse sand, pebbles, and gravel (with some limited amount of small cobble) in the upstream end to coarse sand and pebbles downstream. Coarse sand is currently loaded throughout the channel segment and has filled the spaces of the coarser and steeper riffle drops. In some reaches the coarse sand loads the channel to 2-3 ft deep in a uniform, dune-ripple bed.

In the upstream portion, above SR 65, many of the pool-riffle bedforms have medial bars, diagonal bars, semi-attached bars, and attached bars with downstream dune forms. All of these features indicate that this channel reach is presently experiencing excess sediment loads. This reach also has scattered but repetitious locations of hydraulic impingement on high terrace banks with induced bank erosion and aggravated local hydraulic complexity.

The increased flow impingement appears to be a very recent process; all of these sites show evidence of very fresh and active erosion and bank retreat.

This increased hydraulic bank impingement appears to be caused by a change in the stream flow and the sediment regimes. Changes in the stream flow regime may include increased flow energies with both more frequent peak flows and greater flows for a given level of precipitation. The change in the sediment regime may include the growth in the length of riffle drop forms. These changes may combine to induce a trend toward increased wave length and amplitude of in-channel hydraulic meandering during higher stream flows. Changes in the hydraulic wave length result in high energy flow attacking channel banks that would otherwise have been isolated from such flows. Locations of bank retreat have active bank failures characterized as about 40 ft long, 10 ft high, and 2-10 ft of retreat. All of the locations of bank retreat show evidence of high rates of present retreat, relatively recent initiation of retreat processes, and little evidence of stabilization and reconstruction of sites of previous of bank retreat.

Bank failure locations have also led to the loss of large trees, which then fall into the channel, causing additional hydraulic backwater, local bed aggradation, and aggravated hydraulic impingement on the banks where bank retreat is active. Bank erosion then introduces additional sediment to the channel, which aggravates the trend in overloaded sediment in downstream reaches.

Downstream of SR 65, the channel is being significantly changed by this recent cycle of channel downcutting and incision and/or the cycle of heavy sediment loading and channel aggradation and widening. Before 1986, this channel reach was relatively straight and confined within well-vegetated banks. Since 1986 this reach has been undergoing substantial bank retreat, channel aggradation, the release of very high volumes of sediment from the eroding banks, and the introduction of very large trees to the channel. The channel has responded by a doubling or tripling in channel width and the development of a meandering channel pattern. The meandering channel pattern is unstable with high rates of sediment transport, ongoing channel widening and wave length development, and areas of over-loaded sediment and short-term deposition. These are adjustment features associated with channels with high flows, high sediment loads, low channel (no) confinement, and low gradient.

While the cause of these changes in channel form is not fully known, the channel is clearly degrading. This will eventually be followed by general aggradation and reconstruction, but the reconstructed channel will likely have a steeper gradient, small, more confined channel banks, and an inset set of lower floodplain surfaces. At present it appears that the channel will continue to degrade and that the degradation will migrate both upstream and downstream before the phase of general channel aggradation and reconstruction will occur. This degradation process has introduced elevated amounts of sand sediment to downstream reaches and segments. This is likely to be the case for some time.

Causes of this change in channel stability are not clear but could be related to a change in segment stream flow and sediment regimes. Because this segment is within a Dynamic Confinement channel confinement class, this process, once initiated, has generated a process of feedback. Bank failures in one reach have created conditions, which have generated bank and channel changes in both adjacent upstream and downstream reaches. It is also possible, but less likely so, that the placement of the Joiner Parkway Bridge and the filling of most of the floodplain caused increased stream power at the bridge cross-section or at an upstream location causing the initiation of incision. Field evidence indicates that the process of channel derangement is progressing upstream faster than downstream but this could be a result of local bank failures.

Just downstream of SR 65, there is a short section of concrete box channel that serves as a stream gauge. This structure appears to have elevated the upstream bed and this has trapped sediments in this upstream reach, resulting in net channel aggradation for several hundred yards through the SR 65 and railroad bridge sections. The accumulation of inchannel sediment has reduced the channel flow capacity and has induced depositional meandering leading to bank erosion and bank retreat.

Increased sand loading, bank erosion, and other changes in channel form have altered the aquatic habitat in this segment of Auburn Ravine. Excessive sedimentation has filled pools and embedded coarse materials in coarse sand. Bank erosion is removing riparian vegetation. There is less in channel capacity in some sections of this segment, increasing risks associated with flooding and damage to infrastructure.

RM 18.5 - 22.0

This segment is somewhat similar to the segment immediately downstream in that it is in a Dynamic Confinement channel confinement class with much of the channel margin composed of terraces of unconsolidated sediment deposits subject to dramatic bank erosion and bank retreat in response to changing stream flow and/or sediment regimes. It is classified as semi-confined because the erosion susceptible channel margins are separated by scattered bedrock exposures and some hill slope channel margins. The segment has a gradient of about 37.1 ft/mi (0.70%), notably steeper than the downstream segment, a different mix of bedforms, and coarser bed material.

The terraces susceptible to bank erosion and retreat can range from 6 to 12 ft above the channel bed and are composed of coarse and fine sized material. The bank slope of the channel/terrace interface can be nearly vertical and can be stable within a narrow range of thresholds, but when the thresholds are exceeded, significant bank retreat and land losses can occur very quickly.

From upstream to downstream, the channel transitions from primarily plane-beds to riffle-pool structure. The plane-beds are composed of gravel and cobble material and occasionally small boulders. The hydraulics, the bed material, and the bed material distribution in plane-bed channel indicated that there is intermediate in-channel sediment storage with bed mobilization occurring once every year or two and that changes in

sediment storage occur without significant changes in channel processes or bedform. The banks are stable, usually of coarser material than the channel bed imported and deposited during extreme event flood flows. These confining channel banks inhibit channel widening tendencies, which would otherwise provide for greater in-channel hydraulic variability and the development of pool-riffle bedforms. Limited field review of these bedforms did not identify sites of apparent instability.

The pool-riffle bedforms in this segment are limited to those reaches where unconfined banks provide the channel widths necessary for in-channel hydraulic variability during channel forming flows. These bedforms are not common, since resistant banks and bedrock exposures control most of the in-channel bed configuration of the segment. Where they are found, they are composed of gravel, small cobble, and pebbles.

Infrequent reaches of bedrock-forced channels may be composed of coarse sand, gravel and cobble. These reaches store sediment in the channel to varying degrees, but mostly for short duration. Banks are relatively resistant to erosion and channel pattern changes due to changes in stream flow and/sediment regimes. These channel reaches are incised within the general landscape ranging from 5-10 ft below the upper banks. Within the channel area, these reaches have complexes of contorted hydraulics during channel forming flows and have areas of deposition and erosion that may cycle over time as inchannel hydraulics change. Where not controlled by bedrock exposures, these channel reaches have erodible banks and bed areas; most of the channel banks are areas where riparian trees can and do root. Major flood flows are contained within the incised channel area, which can result is significant scour of surface materials and trees.

Downstream of the Dutch Ravine confluence, the bed of the Auburn Ravine is dominated by coarse sand. This material is pervasive in all channel reaches and bedforms except for steep pitches of short boulder rapids and coarse riffles. The material is in transport at nearly all flow magnitudes, which has served to fill in pools (particularly scour pools in the bedrock-forced channel reaches).

Overall field observations indicate a scouring and enlarging channel regime due to changes in stream flow and/or sediment regime changes. As with downstream segments of Auburn Ravine, the coarse sand loading of the channel is resulting in degraded channel forms and increased sediment transport and may be implicated as a contributing factor in aggravated bank erosion and retreat.

Increased sand loading, bank erosion, and other changes in channel form have altered the aquatic habitat in this segment of Auburn Ravine. Excessive sedimentation has filled pools and embedded cobbles and gravel in coarse sand. Bank erosion is removing riparian vegetation. There is less in-channel capacity in some sections of this segment, increasing risks associated with flooding and damage to infrastructure.

RM 22.0 - 27.6

This channel segment crosses an area of moderate-grade and hard rock (diabase intruded metamorphic geology). The channel is contained within hill slopes in most areas of the segment. The overall gradient of this segment is about 132.1 ft/mi (2.50%). There are several very prominent bedrock drops from 10-30 ft high, forming steep bedrock cascades. Along scattered locations of the segment there are also reaches of channel margin controlled by resistant low terrace features. These features appear to be unaffected by the major stream flow events of the present watershed runoff regime.

This channel segment is largely contained by bedrock of the bed and banks. Short, relatively low (2-4 ft.) bedrock drops create upstream sediment accumulation of cobbles and small boulders that form cascade and plane-bed bedforms. Downstream of the bedrock drops large pools can be found that range to about 25 ft. by 40+ft in size and to 2-4 ft deep. These pools temporarily capture sediment, from pebble to small cobble and, usually near the downstream end of the pools, cobble and small boulders. The upstream ends of these pools often have deeper plunge-pool features.

Channel margins are essentially stable due to the predominance of hill slope controls. There are reaches with narrow depositional banks. Some of these banks are composed of deposited fine sand and smaller particles and can form banks to 2 ft above the pool water surface elevation. In many locations these banks show signs of erosion and bank retreat. Roots of mid-aged trees show evidence of relatively recent bank retreat of several feet.

Riffles are present but uncommon and short (10-40 ft) plane-bed sections are strongly controlled by bedrock and riparian vegetation. Riffles tend to be relatively steep and can range from 15-40 ft long. In riffle drops, rooted trees anchor much of the bed material limiting the cross-section of active sediment mobilization. Plane-bed reaches are steep coarse bed (cobble and small boulders) but channel margins are constrained by riparian forest root binding of materials otherwise available for transport.

This channel segment is generally stable and the banks resistant to changes in stream flow and/or sediment regimes. The only field evidence of instability were locations of bank erosion and retreat of some low coarse material depositional terraces at which midaged riparian trees have 1-2 ft of roots exposed by bank undercutting. These changes could either be due to progressive watershed changes to the stream flow, and/or sediment regimes, and/or the initiation of channel enlargement, or to recent major floods.

Increased channel scour is causing losses of riparian sites, vegetation, and cover; presently this is only minor in extent. There are minor land losses of low terraces adjacent to developed housing sites.

Dutch Ravine

The reach of Dutch Ravine described here includes the 4.15 miles of channel between its confluence with Auburn Ravine (at about elevation 324 ft, about 21.3 miles above the

Auburn Ravine entrance to the East Side Canal and 29.1 miles above the Sacramento River) and the upstream end of an unlined channel reach at the Taylor Road culverts at about elevation 860 ft. The overall gradient is 131.5 ft/mi (2.49%). This reach of Dutch Ravine is within the Highly Confined channel confinement class.

The channel consists of mostly cascades, bedrock drops, and compressed riffles; bed materials are mostly bedrock or very coarse such as boulder and cobble. These conditions imply that the channel is primarily controlled by bedrock banks and bed controls and the movement of most bed materials occurs during the higher, least frequent flood flow events. While these channel bedforms often may have very small, well-developed pools, the channel segment has a very heavy load of coarse sand, which buries the in-channel coarser material bedforms. The coarse sand load infills coarser materials in cascades and other high velocity reaches while in pools and other lower velocity reaches up to 2 ft of coarse sand may overlie the coarser material bed. There is a notable downstream progression of increased coarse sand loading.

The banks of this segment are generally very stable, often well vegetated, and resistant to erosion. This condition makes the segment resistant to channel changes due to changed stream flow and/or sediment regimes. Elevated rates of sediment production from the contributing watershed are delivering greater rates of coarse sand to the channel; however, most of the consequences of this greater sediment load are limited to the channel bed in the form in sand burial and reduced aquatic habitat qualities.

Increased sand loading has reduced the aquatic habitat qualities through decreased inchannel morphological variability, infilling of pools and embedding of coarse materials by coarse sand, and reduced fish habitat conditions.

Management Concerns

Management issues related to erosion/sedimentation processes (Table 5-1) fall into several general categories. In the downstream reaches of the watersheds, leveed sections of the streams have been significantly altered from their natural condition and provide low habitat variability. In these reaches, net sediment build-up, combined with levee construction and maintenance, results in flat bottomed channels, often with little adjacent riparian vegetation.

In upstream reaches, there is evidence of changes in sediment regimes, including finer sand and gravel accumulation in riffles and pools, as well as accumulation along stream banks. In other areas, there is evidence of significant new erosion, with loss of riparian vegetation adjacent to the channel.

Table 5-1. Resource Issues and Impacts Related to Sedimentation and Erosion

Management Issue	Negative Ecological and Social Impacts	Positive Ecological and Social Impacts	
	The Cross Canal		
SM 1. Pools have been excavated inside of the levees.	SMN 1.1. Provides habitat for exotic and undesirable warm-water fish species. SMN 1.2. Provides conditions undesirable for emigrating juvenile salmonids (elevated water temperature and greater potential of stranding as water surface elevations decline).	SMP 1.1. May provide habitat for splittail, a listed fish species.	
SM 2. Lack of riparian vegetation along channel.	SMN 2.1. Increased water temperature and loss of shading and visual cover for aquatic species.	SMP 2.1. Given the relatively narrow distance between levees, provides for improved hydraulics in the flood control channel.	
SM 3. Timing of the opening of flood management weirs (Fremont and Sacramento Weirs) on the Sacramento River creates a backwater effect up the channel, resulting in increased flooding frequency and water depth of floods.	SMN 3.1. Backwatering causes increased sediment deposition in the Cross Canal and upstream which adversely impacts aquatic habitats. SMN 3.2. Backwatering can cause direct mortality to less mobile wildlife species and drown certain riparian plant species. SMN 3.3. Backwatering reduces the downstream flow migratory cues for juvenile salmonids possibly delaying emigration and increasing mortality.	SMP 3.1. Current operations management minimizes the number of times and days the Yolo Bypass is flooded providing flood protection for the Sacramento metropolitan area.	
The East Side Canal			
SM 4. Flat, sandy bottom and lack of adjacent riparian vegetation.	SMN 4.1. Poor habitat conditions for salmonids and potential for exotic warm-water species to proliferate, thus increasing potential	SMP 4.1. Provides enhanced floodwater flowage rates.	

Table 5-1. Resource Issues and Impacts Related to Sedimentation and Erosion

Management Issue	Negative Ecological and Social Impacts	Positive Ecological and Social Impacts
	mortality to juvenile salmonids.	
SM 5. Timing of the opening of flood management weirs (Fremont and Sacramento Weirs) on the Sacramento River creates a backwater effect up the channel, resulting in	SMN 5.1. Backwatering causes increased sediment deposition in the Cross Canal and upstream which adversely impacts aquatic habitats. SMN 5.2. Backwatering can cause direct mortality to less mobile wildlife species and drown certain riparian plant species. SMN 5.3. Backwatering reduces the	SMP 5.1. Current operations management minimizes the number of times and days the Yolo Bypass is flooded.
increased flooding frequency and water depth of floods.	downstream flow migratory cues for juvenile salmonids possibly delaying emigration and increasing mortality.	
	Coon Creek: RM 10.0-20.2	
SM 6. Sediment levels and general lack of sediment transport reduces instream aquatic habitat quality and diversity.	SMN 6.1. High sediment levels results in a reduction in potential habitat quantity and quality for native resident species. SMN 6.2. High sediment levels reduce the migration (adults) and emigration (juveniles) potential for salmonids by creating a flat, sandy bottomed channel with no thalwag or associated pools for resting. This problem is particularly acute at lower flow levels.	SMP 6.1. None identified.
SM 7. Sediment levels and general lack of sediment transport reduces channel floodflow capacity.	SMN 7.1. High sediment levels in the channel reduce the channel's capacity to transport floodflows, resulting in increased frequency of flooding on adjacent lands. SMN 7.2. Increased frequency of flooding and higher water surface	SMP 7.1. Increased flood frequency may benefit some riparian plant species.

Table 5-1. Resource Issues and Impacts Related to Sedimentation and Erosion

Management Issue	Negative Ecological and Social Impacts	Positive Ecological and Social Impacts
	elevations can increase the incidence and magnitude of fish stranding on adjacent lands.	
	SMN 7.3. Increased flood frequency and water surface elevations may increase the risk to existing levees in the downstream reach of this segment.	
SM 8. Riparian vegetation in this segment is reduced or absent along the stream channel in some locations.	SMN 8.1. Reduced riparian vegetation can result in increased water temperature, decreased bank stability, and an overall reduction in aquatic habitat quantity and quality.	SMP 8.1. None identified.
	Coon Creek: RM 20.2 - 24.3	
SM 9. Erosion of banks and loss of riparian habitat.	SMN 9.1. Reduced riparian vegetation can result in increased water temperature, decreased bank stability, and an overall reduction in aquatic habitat quantity and quality.	SMP 9.1. Increased flood frequency may benefit some riparian plant species.
	SMN 9.2. High sediment levels, caused by erosion results in a reduction in potential habitat quantity and quality for native resident species. SMN 9.3. High sediment levels reduce the migration (adults) and emigration (juveniles) potential for salmonids by creating a flat, sandy bottomed channel with no thalwag or associated pools for resting. This problem is particularly acute at lower flow levels.	
	SMN 9.4. High sediment levels in the channel reduce the channel's	

Table 5-1. Resource Issues and Impacts Related to Sedimentation and Erosion

Management Issue	Negative Ecological and Social Impacts	Positive Ecological and Social Impacts
	capacity to transport floodflows, resulting in increased frequency of flooding on adjacent lands.	
SM 10. This channel segment is widening and filling with sediment.	SMN 10.1. Channel widening portends even greater channel instability and loss of aquatic habitats. The widening process can accelerate bank erosion, sediment deposition, and loss of riparian vegetation.	SMP 10.1. Increased flood frequency may benefit some riparian plant species.
	SMN 10.2. High sediment levels reduce the migration (adults) and emigration (juveniles) potential for salmonids by creating a flat, sandy bottomed channel with no thalwag or associated pools for resting. This problem is particularly acute at lower flow levels.	
	Coon Creek: RM 24.2 - 30.7	
SM 11. Bank scour and loss of riparian vegetation.	SMN 11.1. Reduced riparian vegetation can result in increased water temperature, decreased bank stability, and an overall reduction in aquatic habitat quantity and quality.	SMP 11.1. None identified.
	SMN 11.2. High sediment levels, caused by erosion results in a reduction in potential habitat quantity and quality for native resident species.	
	SMN 11.3. High sediment levels reduce the migration (adults) and emigration (juveniles) potential for salmonids by creating a flat, sandy bottomed channel with no thalwag	

Table 5-1. Resource Issues and Impacts Related to Sedimentation and Erosion

Management Issue	Negative Ecological and Social Impacts	Positive Ecological and Social Impacts
	or associated pools for resting. This problem is particularly acute at lower flow levels.	
	Coon Creek: RM 30.7 - 39.6	
SM 12. There is minor scour, bank erosion, and loss of riparian vegetation.	SMN 12.1. Reduced riparian vegetation can result in increased water temperature, decreased bank stability, and an overall reduction in aquatic habitat quantity and quality.	SMP 12.1. None identified.
(Coon Creek RM 39.6 - 43.3: No problen	ns detected
	Doty Ravine: RM 0.0 - 10.0	
SM 13. Increased sedimentation downstream of RM 7.8, with no major sediment sources identified above RM 8.5.	SMN 13.1. High sediment levels, caused by erosion results in a reduction in potential habitat quantity and quality for native resident species. SMN 13.2. High sediment levels reduce the migration (adults) and emigration (juveniles) potential for salmonids by creating a flat, sandy bottomed channel with no thalwag or associated pools for resting. This problem is particularly acute at lower flow levels.	SMP 13.1. None identified.
SM 14. Extensive livestock damage to stream banks and riparian vegetation downstream of approximately Gladding Road.	SMN 14.1. Grazing practices have resulted in significant negative impacts to the channel banks and a general loss of riparian vegetation, resulting in deteriorated aquatic habitat quantity and quality, loss of stream bank stability, increased sediment delivery to the channel, and loss of riparian habitat for wildlife species.	SMP 14.1. None identified.

Table 5-1. Resource Issues and Impacts Related to Sedimentation and Erosion

Management Issue	Negative Ecological and Social Impacts	Positive Ecological and Social Impacts
	Doty Ravine: RM 10.0 - 11.6	i
SM 15. Minor erosion and loss of riparian habitat on banks. No significant problems identified, however, more extensive surveys needed.	SMN 15.1. Reduced riparian vegetation can result in increased water temperature, decreased bank stability, and an overall reduction in aquatic habitat quantity and quality.	SMP 15.1. None identified.
	Auburn Ravine: RM 0.0 - 2.5	5
SM 16. Sediment levels and general lack of sediment transport reduces instream aquatic habitat quality and diversity.	SMN 16.1. High sediment levels result in a reduction in potential habitat quantity and quality for native resident species. SMN 16.2. High sediment levels reduce the migration (adults) and emigration (juveniles) potential for salmonids by creating a flat, sandy bottomed channel with no thalwag or associated pools for resting. This problem is particularly acute at lower flow levels.	SMP 16.1. None identified.
SM 17. Sediment levels and general lack of sediment transport reduces channel floodflow capacity.	SMN 17.1. High sediment levels in the channel reduce the channel's capacity to transport floodflows, resulting in increased frequency of flooding on adjacent lands. SMN 17.2. Increased frequency of flooding and higher water surface elevations can increase the incidence and magnitude of fish	SMP 17.1. Increased flood frequency may benefit some riparian plant species.

Table 5-1. Resource Issues and Impacts Related to Sedimentation and Erosion

Management Issue	Negative Ecological and Social Impacts	Positive Ecological and Social Impacts
	stranding on adjacent lands. SMN 17.3. Increased flood frequency and water surface elevations may increase the risk to existing levees in the downstream reach of this segment.	
SM 18. Riparian vegetation in this segment is reduced or absent along the stream channel in some locations.	SMN 18.1. Reduced riparian vegetation can result in increased water temperature, decreased bank stability, and an overall reduction in aquatic habitat quantity and quality.	SMP 18.1. None identified.
	Auburn Ravine: RM 2.5-7.1	
SM 19. Sediment levels and general lack of sediment transport reduces instream aquatic habitat quality and diversity.	SMN 19.1. High sediment levels results in a reduction in potential habitat quantity and quality for native resident species. SMN 19.2. High sediment levels reduce the migration (adults) and emigration (juveniles) potential for salmonids by creating a flat, sandy bottomed channel with no thalwag or associated pools for resting. This problem is particularly acute at lower flow levels.	SMP 19.1. None identified.
SM 20. Sediment levels and general lack of sediment transport reduces channel floodflow capacity.	SMN 20.1. High sediment levels in the channel reduce the channel's capacity to transport floodflows, resulting in increased frequency of flooding on adjacent lands. SMN 20.2. Increased frequency of flooding and higher water surface elevations can increase the incidence and magnitude of fish	SMP 20.1. Increased flood frequency may benefit some riparian plant species.

Table 5-1. Resource Issues and Impacts Related to Sedimentation and Erosion

Management Issue	Negative Ecological and Social Impacts	Positive Ecological and Social Impacts
	stranding on adjacent lands. SMN 20.3. Increased flood frequency and water surface elevations may increase the risk to existing levees.	
SM 21. Riparian vegetation in this segment is reduced or absent along the stream channel in some locations.	SMN 21.1. Reduced riparian vegetation can result in increased water temperature, decreased bank stability, and an overall reduction in aquatic habitat quantity and quality.	SMP 21.1. None identified.
	Auburn Ravine: RM 7.1-12.8	3
SM 22. Sediment levels and general lack of sediment transport reduces instream aquatic habitat quality and diversity.	SMN 22.1. High sediment levels results in a reduction in potential habitat quantity and quality for native resident species. SMN 22.2. High sediment levels reduce the migration (adults) and emigration (juveniles) potential for salmonids by creating a flat, sandy bottomed channel with no thalwag or associated pools for resting. This problem is particularly acute at lower flow levels.	SMP 22.1. None identified.
SM 23. Sediment levels and general lack of sediment transport reduces channel floodflow capacity.	SMN 23.1. High sediment levels in the channel reduce the channel's capacity to transport floodflows, resulting in increased frequency of flooding on adjacent lands. SMN 23.2. Increased frequency of flooding and higher water surface elevations can increase the incidence and magnitude of fish stranding on adjacent lands.	SMP 23.1. Increased flood frequency may benefit some riparian plant species.

Table 5-1. Resource Issues and Impacts Related to Sedimentation and Erosion

Management Issue	Negative Ecological and Social Impacts	Positive Ecological and Social Impacts
	SMN 23.3. Increased flood frequency and water surface elevations may increase the risk to existing levees.	
	Auburn Ravine: RM 12.8 18.	.5
SM 24. Sediment levels and general lack of sediment transport reduces instream aquatic habitat quality and diversity.	SMN 24.1. High sediment levels results in a reduction in potential habitat quantity and quality for native resident species. SMN 24.2. High sediment levels reduce the migration (adults) and emigration (juveniles) potential for salmonids by creating a flat, sandy bottomed channel with no thalwag or associated pools for resting. This problem is particularly acute at lower flow levels. SMN 24.3. Bank erosion contributes high levels of sediment and reduces the amount of riparian vegetation.	SMP 24.1. None identified.
SM 25. Sediment levels and general lack of sediment transport reduces channel floodflow capacity.	SMN 25.1. High sediment levels in the channel reduce the channel's capacity to transport floodflows, resulting in increased frequency of flooding on adjacent lands. SMN 25.2. Increased frequency of flooding and higher water surface elevations can increase the incidence and magnitude of fish stranding on adjacent lands.	SMP 25.1. Increased flood frequency may benefit some riparian plant species.
SM 26. Riparian vegetation in this segment is reduced or absent along the	SMN 26.1. Reduced riparian vegetation can result in increased water temperature, decreased bank stability, and an overall reduction in	SMP 26.1. None identified.

Table 5-1. Resource Issues and Impacts Related to Sedimentation and Erosion

Management Issue	Negative Ecological and Social Impacts	Positive Ecological and Social Impacts
stream channel in some locations.	aquatic habitat quantity and quality.	
SM 27. The NID gaging station structure has altered sediment deposition patterns upstream of the structure and has induced depositional meandering, leading to bank erosion and bank retreat.	SMN 27.1. This elevation control point has caused sediment to be deposited in pools and riffles suitable for anadromous salmonids to spawn and rear in. This situation decreases habitat quality and quantity and overall stream productivity.	SMP 27.1. Continuation of the existing situation results in lower operational costs to NID.
	Auburn Ravine: RM 18.5 - 22	.0
SM 28. Sediment levels and general lack of sediment transport reduces instream aquatic habitat quality and diversity.	SMN 28.1. High sediment levels results in a reduction in potential habitat quantity and quality for native resident species.	SMP 28.1. None identified.
SM 29. Bank erosion is reducing riparian vegetation.	SMN 29.1. Bank erosion contributes high levels of sediment and reduces the amount of riparian vegetation.	SMP 29.1. None identified.
Auburn Ravine: RM 22.0 - 27.6		
SM 30. Increased channel scour is causing minor loss of riparian vegetation.	SMN 30.1. Bank erosion contributes high levels of sediment and reduces the amount of riparian vegetation.	SMP 30.1. None identified.
Dutch Ravine		
SM 31. Increased	SMN 31.1. Since this is a relatively	SMP 31.1. None identified.

Table 5-1. Resource Issues and Impacts Related to Sedimentation and Erosion

Management	Negative Ecological and Social	Positive Ecological and
Issue	Impacts	Social Impacts
sedimentation is filling in pools and riffles.	small tributary watershed to Auburn Ravine, the concern is that adjacent land use practices and possibly natural geology are contributing greater than expected sediment quantities to Auburn Ravine downstream.	

Summary of Findings

Changes in water management (flood control) and adjacent land use have had both positive and negative impacts on stream erosion and sedimentation regimes in the ERP watershed, with varying levels of biological and ecological consequences. These, in general, include:

- In the lower watershed, levee construction and maintenance have somewhat constrained the channel and have resulted in a more uniform channel cross-section and bed materials (mostly sands and silts). Levee areas often have less variety of riparian vegetation than would have occurred under natural conditions. However, levees provide significant economic and social benefits.
- There is a zone of altered erosion/sedimentation between the East Side Canal and the upstream portions of the watershed. In these reaches, bank erosion is common, with loss of adjacent riparian vegetation. Sediments from runoff and from localized bank erosion are altering the bedforms of the streams filling in pools and riffles and creating a more uniform sandy bed composition. There is loss of channel bank stability in some reaches. This may be a result of adjacent land use (such as grazing and infrastructure and residential/commercial development).
- In general, conditions in the upper watershed are relatively stable. The mostly-confined channels in the upper watershed have flow and erosion characteristics such as would be expected under normal natural conditions.