APPENDIX A - DRAFT TECHNICAL MEMORANDUM

TO: CKB ENVIRONMENTAL CONSULTING

FROM: GEOSYNTEC CONSULTANTS

SUBJECT: **GEOMORPHIC ASSESSMENT OF LAGUNA CREEK**
TASK 3.2.3; TECHNICAL MEMORANDUM #3

DATE: JULY 14, 2006

A geomorphic assessment is a critical step toward understanding the hydrologic and geomorphic processes that influence creek channel stability within an urbanizing watershed. The studies conducted by William-Lettis & Associates (2005) and the geomorphic field work conducted by Geosyntec Consultants (Geosyntec) (described herein) provide the foundation for evaluating the following:

- the sensitivity of the channels to changes in watershed hydrologic processes (i.e., hydromodification);
- how past development and other watershed activities have affected channel form and stability; and
- how this information can be used to plan future development and manage stormwater runoff to achieve better outcomes for the Laguna Creek and its beneficial uses.

This memorandum summarizes Geosyntec's assessment of Laguna Creek from its headwaters near Grant Line Road downstream to Highway 99. This assessment is mostly qualitative as it summarizes our field observations. Throughout this memorandum, the term "Upper Laguna Creek" refers to the drainage area and creek system upstream from the intersection of Waterman Road and Bond Road. "Lower Laguna Creek" refers to that portion downstream from this same intersection to Highway 99.

Geosyntec surveyed nine sites on Laguna Creek and one each on Elder Creek and Morrison Creek, from May 30 to June 2, 2006. Geosyntec staff walked much of the entire creek length and collected information regarding reach-wide conditions. Geosyntec staff revisited the WLA sites to verify observations and compile a common data set.

A photo essay is provided to accompany the description of each reach of Laguna Creek. The following PowerPoint files contain the photos illustrating the features described in this summary:

- Laguna Creek near Grant Line Rd.ppt
- Kite Creek.ppt
- Frye Creek.ppt
- LC above Eagles Nest.ppt
- LC below Waterman-Bond.ppt
- WLA Sites 2-3.ppt
- WLA Sites 4-8.ppt
- WLA Sites 9-11.ppt
- WLA Sites 12-15, 19-20.ppt

Background

The erodibility of stream banks is one of the most difficult aspects of assessing stream channel destabilization as a result of changes to watershed hydrology caused by urbanization. Channel failures can be caused by several factors, including:

- shear erosion and undercutting;
- slumping during fast declining flood flows;
- water forced into banks from obstructions, such as large woody debris;
- collapse of bank material and vegetation by weight of over steepened banks; and
- lost vegetation that previously provided bank protection.

The ability of a stream bank to resist erosion depends on:

- soil materials
- bank stratigraphy
- vegetation density and root strength,
- amount of clay or cementing of the soil particles
- bank height and bank slope.

The nature and extent of a channel's response to hydrologic changes depends upon the erosion resistance of boundary materials (the soils along the channel bottom and banks) and the type and density of vegetation. Stream channels bounded by compacted silts and clays are more resistant to erosion and respond more slowly to hydrologic changes than channels bound by loosely consolidated sands and gravels.

Watershed soils are highly diverse and are linked to large-scale geologic features. The geologic material of Laguna Creek consists of ancient alluvial deposits formed by an ancestral American River (WLA 2005). These deposits have been weathered, cemented, and modified to form the current soil horizons and indurated sub-layers. These soils and their duripan layers have a strong influence on the observed landscape and channel morphology.

Boundary material influences both the erodibility of banks and vegetation assemblages, which in-turn provide resistance to bank erosion. Stream banks that are more resistant to erosion tend to form deeper and narrower channels, while banks that are less resistant tend to form wider and shallower channels. Channels with erosion-resistant beds (bottoms), such as duripan, and less resistant bank materials will respond to increased flows by widening and planform adjustment (shifting meander) as opposed to incising (down cutting). This is the expected mechanism for adjustment as Laguna Creek responds to the forces of hydromodification.

Work Conducted

Field work consisted of collecting qualitative and quantitative information at multiple cross-sections along Upper Laguna Creek and vicinity. Data collected at these cross-sections were used to develop a field-based understanding of the stream conditions. The data is used first as input parameters for the stability assessment and, second, to interpret and evaluate the results of the stability assessment.

Geosyntec conducted geomorphic surveys of Upper Laguna Creek in 2006 between May 30 and June 2 and again on June 26. Exhibit A provides an example data sheet used for the geomorphic assessment. This survey was combined with data collected by William-Lettis & Associates (2005) to develop a spatially complete survey of Upper Laguna Creek. The unusually high rainfall and runoff events of the winter of 2005/2006 revealed vulnerabilities of the creek system that might not otherwise have been apparent.

Field data collected included:

- Topographic survey of cross-section and longitudinal slope data which consisted of elevation and station measurements at eleven (11) cross-section locations. These data were supplemented by William-Lettis' twenty (20) cross-sections. A longitudinal profile was collected at each section extending a few hundred feet both upstream and downstream from each section.
- Geomorphic assessment focused on identifying the channels potential susceptibility to hydromodification and erosion, which consisted of observations of sediment supply and transport, and channel boundary material properties, including:
    - bed and bank materials
    - vegetation characteristics
    - evidence of excessive channel erosion
    - overall channel stability.
- Notes to describe excessive channel erosion, include:
    - the mechanism of failure;
    - whether the instability was localized or reach wide;
    - whether the channel activity was recent or historical, or anthropogenic;
    - whether artificial structures are present.

The paragraphs below briefly summarize the type and form of the information collected.

Parent Material & Soil Types

Parent material is defined as the underlying geologic formations and associated soils that make up the channel boundary. The reader should refer to William-Lettis (2005) for a complete description of the geologic formation. Figure A-1 shows the distribution of soil types within the Laguna Creek watershed and vicinity. These data were used with other information to help:

- Layout the study area and determine where individual cross sections should be located;
- Identify channel boundary materials;
- Understand the fluvial geomorphic and erosion characteristics observed in the field.

Cross - Sectional Survey

Cross-sections were located throughout the watershed to obtain a spatially representative data set. Factors considered in selecting locations included: tributary area, changes in flow, soil type, existing development, likelihood of future development, suspected problem reach, stable reach, conservation easement and physical access.

Elevations were measured at breaks in slope, channel thalweg (deepest point in the cross-section), water surface (where wet), bankfull indicators, and other geomorphic surfaces where present. Cross-sectional surveys provided data on bank height and slope, channel width and depth, and longitudinal slope for stability calculations.

Elevation and station survey data were collected using a Nikon DTM/NPL-302 Series total station from Tripod Data Systems.

Longitudinal Slope

A longitudinal profile was surveyed at each cross-section to measure the local slope for stability calculations to be conducted later. Profile measurements were collected up to one hundred feet on each side of the section. Elevation points were collected along the thalweg and waters edge (where present) and at similar topographic bed features, such as at the top of riffle segments (where identifiable).

Data for an overall longitudinal profile for the Upper Laguna Creek was not collected, but was obtained from existing information.

Bed and Bank Material Properties

Bed and bank material properties (as well as vegetation type and density) define the channels susceptibility to the forces of flowing water. For the bed, the geomorphic assessment data includes: observed bed forms, bed mobility, material type and size, and if any armoring exists. For the bank, the geomorphic assessment data includes material type and stratigraphy, an ASCE type classification listed in Table 2-1 in Appendix C, observed mechanisms of failure (if any), and an overall stability rating. Notes were collected on whether any observed problems are localized or reach wide, recently active or historical.

Vegetation Type and Density

Vegetation influences channel processes and is, in turn, influenced by these same processes. Stream channel destabilization is often attributed to a loss of woody vegetation, especially if more vegetation was present prior to urbanization. Dense vegetation adds roughness and slows flow velocity, reduces shear stresses on stream banks and adds soil cohesion through root structure. Large woody debris (LWD) also adds roughness and slows flow velocity, with the added benefit of creating habitat. Vegetation data collected included: type and density of the plants, density and depth of the rooting mass, and whether or not woody debris was present to improve channel stability and habitat value.

Laguna Creek Watershed Divisions

The properties of the channel bed and bank vary along the length of the creek, as do the magnitude and duration of flows which act upon them. G*eomorphic reaches* characterize the form and properties of the creek based on the longitudinal variation in these features. Within a geomorphic reach, broadly-similar influences (whether vegetation, geology, topography, level of upstream development or some combination therein) affect channel form and processes in a similar manner. Sometimes it is useful to recognize sub-reaches or segments within a reach.

Figure A-2 shows the watershed and illustrates the divisions used and discussed herein. The geomorphic reach division used in this report follows the approach used by William-Lettis, which is largely based on geologic land forms, soil types and the resulting land slopes.

Five sub-reaches were defined by William-Lettis (2005):

<u>Reach 1</u> extends from the upper headwaters east of Grant Line Road downstream to about Jackson Road (Highway 16). Reach 1 has an average slope of 0.0036 ft/ft and is steeper than the other reaches. This reach is underlain by the Arroyo Seco Gravel formation and is characterized by hilly topography and moderate relief. This formation is believed to be an ancient terrace of the ancestral American River. Upper Laguna Creek flows in a narrow valley, which runs along the terrace and cuts into these ancient deposits. Exposed creek banks and beds contain gravel and cobble originating from these deposits, which act as armoring of the creek bed in some places. The downstream end roughly coincides with the transition to the Riverbank formation. Soil types formed on this material are primarily the Redding and Red Bluff series.

<u>Reach 2</u> extends from Jackson Road to Excelsior Road and has an average slope of 0.0010 ft/ft. This reach is further sub-divided into two sub-reaches. The first is the upstream portion that flows across a broad alluvial plain underlain by the Riverbank formation. About two-thirds of the way down Reach 2 the creek crosses onto Arroyo Seco Gravel again, which continues down to Excelsior Road. Soil types formed on Riverbank formation deposits are the San Joaquin soil series and its associates.

<u>Reach 3</u> extends from Excelsior Road to a point slightly downstream from Vineyard Road and has an average slope of 0.0024 ft/ft. In this reach, Upper Laguna Creek flows down the

western escarpment of the ancient terrace and onto a broad alluvial plain underlain by the Riverbank formation. The Riverbank formation is a more recent deposit of the ancestral American River that occurred a few hundred-thousand years ago. As the channel passes from the upper terrace to the lower terrace, it flows across the Fair Oaks Gravel and onto the Riverbank formation, which likely contributes to the mixed and irregular channel conditions observed in the field.

Reach 4 extends from slightly downstream from Vineyard Road to the intersection of Waterman and Bond. This section has an average slope of 0.0007 ft/ft. This area is underlain by Riverbank formation and Holocene alluvium. This reach is characterized by flow across broad, low-relief alluvial plains within San Joaquin soils. The channel flows up against the eastern margin of the Elk Grove Outlier of the Arroyo Seco Gravel, which is a north trending ridge between Gerber and Elk Grove Blvd. This outlier turns Laguna Creek in a southerly direction before it wraps around the southern tip and flows west again.

Reach 5 extends from the intersection at Waterman and Bond to Highway 99. This section has an average slope of 0.0005 ft/ft and is the shallowest reach of the study area. Most of Reach5 has been modified for flood control purposes. This reach appears to be stable. One of the known problems is the buildup of emergent wetland plants upstream from Camden Park. The buildup of emergent plants increases roughness and affects the channels capacity to carry flood flows.

Soil Types

Redding Soils: Redding soils (and associated Red Bluff soils) are located on the older *high terraces* along the eastern edge of the Central Valley, California. In the Laguna Creek watershed, these soils originate from the older alluvium (Arroyo Seco Gravel) that is a deposit of coarse material (gravel and some cobble) inter-mixed in a consolidated sandy clay matrix. Redding soils are generally classified as a *gravelly loam*. Other classifications include sandy loam, cobbly loam, gravelly clay loam, cobbly sandy loam, cobbly clay loam, or sandy clay loam. According to the USDA SCS soils data, surface infiltration rates range from 0.60 to 2.0 inches/hour. As a class “D” soil type, these soils are well- or moderately-well drained with very slow to slow permeability. Depth to duripan is 20 to 40 inches and ranges in clay content from 35 to 60 percent. Percolation rates of the duripan range from 0.00 to 0.06 inches/hour.

The land surface is a mound-intermound (hummocky) landscape. Vernal pools are common in the intermound areas with slopes of 0 to 3 percent. Soils are usually dry from June until September and are moist during most of the rest of the year. Vegetation cover is a complex of annual grasses and native and non-native forbs. It is used primarily for rangeland and dry land farm production of small grains. A few areas have been used for irrigated pasture.

Red Bluff Soils: Red Bluff soils generally coincide with the Redding soil series along the older high terrace in the Central Valley. Red Bluff soils are also classified as a *gravelly loam*. Soil texture ranges from a gravelly loam to a clay loam. As a class “C” soil type, these soils are well drained with moderately slow permeability. Surface infiltration rates range from 0.60 to 2.0

inches/hour. This series lacks a duripan. Percolation rates of the lower horizons range from 0.20 to 0.60 inches/hour.

Vegetation consists of blue oak, live oak and a complex of annual grasses and forbs. In lower rainfall areas, oaks and brush are absent. Small grains and pasture are grown where dry farmed. Row crops, pasture and a few orchards are grown under irrigation.

San Joaquin Soils: San Joaquin soils are formed on *lower terraces* located on eastern side of the Central Valley. These soils have been formed from the younger alluvium of the Riverbank formation and consist of semi-consolidated granitic sands and silts. San Joaquin soils are generally classified as a *loam*. Other textures include sandy loam, silt loam, and fine sandy loam. As a class "D" soil type it is well- to moderately-well drained with slow permeability. Surface infiltration rates range from 0.60 to 2.0 inches/hour. Depth to the duripan ranges from 20 to 40 inches. Percolation rates of the duripan range from 0.00 to 0.06 inches/hour. According to the NRCS data, below the duripan (~60 inches) percolation rates increase to 0.20 to 0.60 inches/hour in a stratified sandy loam soil type. Soils are suitable to a wide range of crops, livestock grazing and uses; including small grains, irrigated pasture and rice; vineyards, fruit and nut crops.

Fiddyment Soils: Fiddyment soils are located on low terraces and hill slopes along the eastside of the Sacramento Valley. These soils are generally classified as a *fine sandy loam*. Its texture ranges from a fine sandy loam, silt loam, to clay loam, indurated to weathered bedrock. The soils were formed from weathered material of the Laguna Formation creating a weakly consolidated siltstone and sandstone soil matrix. As a class "D" soil, it is well drained and very slow permeability. Surface infiltration rates range from 0.60 to 2.0 inches/hour. Depth to the duripan (claypan) ranges from 20 to 40 inches, below which is the weathered Laguna Formation. Percolation rates of the duripan range from 0.00 to 0.06 inches/hour. According to the NRCS data, deep percolation rates increase to 0.20 to 0.60 inches/hour below the duripan.

Typical vegetation consists of annual grasses, native and non-native forbs and a few scattered oaks. These soils are used for rangeland and non-irrigated grain crops. Some areas are used for irrigated pasture.

Hicksville Soils: Hicksville soils are located on *low stream terraces*, adjacent to flood plains or low stream drainage ways and hill slopes. These soils (and the associated Hedge series) are found along the channel margin throughout most of Upper Laguna Creek. The soils were formed in alluvium derived from mixed sources of re-worked local primary soils. These soils form most of the channel bank materials and are an important factor when evaluating long-term stability.

Hicksville soils are generally classified as a *loam*. Texture ranges from a gravelly loam, to loam, to clay loams, to a sandy clay loam. As a class "B/C" soil, they are moderately well drained and has moderately slow permeability. According to NRCS data, surface infiltration rates range from 0.60 to 2.0 inches/hour and decrease to 0.20 to 0.60 inches/hour at depth. The soils are flooded occasionally for very brief periods during high intensity storms. A water table occurs at depths of 60 to 72 inches for short periods in December through April.

Typical vegetation is native and non-native annual grasses and forbs. A few areas are used for irrigated hay and pasture and irrigated row and orchard crops.

Hedge Soils: Hedge soils are located on *low terraces* commonly adjacent to channels, flood plains or low stream drainage ways. Texture ranges from a loam, sandy loam to clay loams. As a class "C/D" soil, it is moderately well drained and has a slow to moderately slow permeability. Surface infiltration rates range from 0.60 to 2.0 inches/hour, decreasing to 0.00 to 0.06 inches/hour in the duripan. Depth to the duripan ranges from 20 to 40 inches, which has a weakly silica cemented structure. A water table forms above the duripan in winter and early spring months. Below the duripan is a sandy loam layer with reported percolation rates of 0.60 to 2.0 inches/hour.

Vegetation is mainly annual grasses and native and non-native forbs. These soils are mainly used for rangeland and non-irrigated cropland. A few areas are used for irrigated pasture and crops.

Results

Laguna Creek is a *second order stream* of the Central Valley originating locally in the foothills of the Sierra Nevada. Laguna Creek is cut into both old and young alluvium deposited by an ancestral American River several hundred-thousand years to a million years ago. Laguna Creek essentially drains the land surface of an ancient terrace. The creek flows south-west along the older terrace deposits (Arroyo Seco & Fair Oaks Gravel Formations), eventually crossing the western facing escarpment of the terrace and dropping onto the younger formation (Riverbank), before flowing to Morrison Creek, and on to the Stone Lakes/Beach Lake complex and/or the Sacramento River, depending on flow volumes and where they are discharged.

The geomorphic character of Laguna Creek is highly influenced by these ancient deposits and the soils originating from these deposits, which is different than a river or stream formed in its own alluvium. The channel boundary material consists of a combination of stratified soil and hardpan, locally derived alluvium, and exposed outcrops of parent material.

Today the creek is mainly a single threaded meandering channel with moderate to high width to depth (W/D) ratios (except where channelized), low to moderate sinuosity and low gradient. Historically (and small portions today), with its broad valley plains and gentle relief, the creek occupied multiple channels along floodplains forming seasonal wetlands and valley swales. Because the creek is cut into ancient American River deposits, the channel boundary material is primarily made up of these ancient deposits. More recent alluvium is interspersed throughout the creek system having been eroded, transported and re-deposited along the creek banks over time.

Bed and bank materials are primarily classified as a loam with varying amounts of gravel, sand and clays. The bed is vertically constrained in places by periodic outcrops of hardpan, bedrock, and cobble; and is frequently well vegetated. It is not known if this material exists under the entire length of creek and overlain by a shallow depth of loose bed material; or it is not clear if shallow bed incision between these outcrops will results in bank failures. It is possible that the creek banks are near a threshold of failure and an additional 6 to 12 inches of incision could initiate bank slumping and other types of failure. Hardpan and cemented bank material laterally constrain the creek in some places, but overall there is sufficient evidence of weak bank material (recent alluvium), potential lateral channel movement and adjustment. Hardpan and cemented soils are resilient, but have varying degrees of hardness and are not completely free from erosion. Hardpan layers can erode or dissolve, albeit at a relatively slow rate.

Figure A-3 presents a map illustrating the creeks current level of stability.

Reach 1; Cross-Sections 1 to 4, near Grant Line Road.

Reach 1 near Grant Line Road characterizes the headwater segments of Laguna Creek. The channel at cross sections 1 and 2 drain 780 acres and 559 acres, respectively. The channel at cross section 3 and 4 drains 1339 acres of the headwater watershed. Reach 1 was mostly dry when surveyed. A small number of meander bend pools still contained a shallow depth of water. Most all had an abundance of small frogs. The average channel gradient is 0.0036 ft/ft (WLA, 2005), which, based on our experience, is a low to moderate slope when addressing stream power and the erosion and sediment transport processes. The longitudinal slopes measured at individual cross sections were as high as 1% (0.010).

General Stability: These segments of Reach 1 are stable, although active, with high W/D ratios, and a vegetated channel bed along much of its length. The reach is active, with evidence of shear erosion, scour pools, and slumping mostly associated with the outer banks of meander bends. With the exception of minor cattle impacts, these observed erosion indicators appear to be part of the natural geomorphic processes and would not be a concern. Although conditions vary along the channel, channel banks are generally low in height and well vegetated. Vertical cutbanks on the outer bend of meander pools are on the order of 3 to 5 feet.

Erosion Processes: Bank slumping and, to a lesser degree, shear erosion are present. Minor slumping along meander bends is producing an irregular bank configuration (blocky) that is an indication of the semi-consolidated bank character. Minor bank collapse from cattle hooves was also observed, although it did not appear to be wide spread. The slumped bank material is often not far removed from the location of failure suggesting that the capacity to transport sediment is low. Shear erosion is observed at meander bends and is natural.

Sediment Supply & Transport: Coarse sediment supply and transport appear to be low as there are no substantial unconsolidated depositional features within the channel (e.g., bars). Given the low quantities of in-stream deposits and the vegetated low relief landscape, sediment supply appears low and supply limited. The majority of coarse sediment within the channel appears to be derived from stream bank material deposited by the ancestral American River. Point bar features are rare and where present are covered with grasses and not likely mobilized except maybe under extreme events. Two to three point bars of sand and gravel deposits were observed in the segment near cross section 3 and 4.

Bed Form & Material: The generalized bed form might be characterized as a pool/run series. The cross over between pools tends to be long uniform channels. The bed is fixed and vegetated and consists of the locally derived compacted and cemented soils. Gravel is embedded in both the bed and bank material. An armor layer of cobble covers the bed in places. Scour pools are formed at meander bends and the transition from run to pool is often a knickpoint or drop. Coarse material is often found in the bottom of scour pools with sand deposits occasionally found on the inside of meander bends.

Bank Form & Material: Vertical cutbanks along meander bends can be 3 to 5 feet in height, and are generally blocky in structure. Between meander bends, the banks are low in height, shallow sloped and well vegetated. Bank material consists of a semi-consolidated silty-sandy matrix with embedded gravel and cobble. It is hard when dry and medium soft when moist. Moist material can be formed into a ball but breaks apart easily when attempting to form a ribbon. The material feels grainy and is low in clay content. Material characteristics are consistent with the description of soil type and parent material in this area.

Vegetation: The surrounding landuse is mostly pasture with moderately dense grasses and forbs. Although vegetation is continuous it has a moderate density in that some exposed soil can be seen between plants. Vegetation also grows along most of the bed, including the armor layers. Rooting depth of grasses along the banks is shallow (<6-inches); therefore, vegetation does not appear to play a significant role in bank and channel stability.

Reach 1; Cross-sections 5 on Kite Creek, upstream from Jaeger Road.

Cross section 5 is located upstream from Jaeger Road and the channel drains 1020 acres. This segment of creek is in good condition. Downstream from Jaeger Road the creek has been channelized and straightened. A culvert road crossing is acting as grade control and preventing impacts from downstream from extending upstream into this segment.

General Stability: Similarly to cross-sections 1 to 4, this segment is stable, active, with high W/D ratios and a vegetated channel bed. Banks are generally low in height and shallow sloped between meander bends, with deeper scour pools and taller vertical banks formed at bends. This tributary shows a greater amount of cattle impacts such as trampled banks and compacted bed, with evidence that cattle are using the creek bed as a trail. The reach is active as evidenced by slumping bank material along the outer banks of meander bends. With the exception of some cattle impacts, these observed erosion indicators are believed to be part of the natural processes.

Erosion Processes: Bank slumping is present along the outer banks of meander bends. Slumping is producing a blocky irregular bank configuration that is an indication of the semi-consolidated bank character. Shear erosion is present at meander bends. This segment shows more cattle impacts and bank trampling than that observed at cross-sections 1 to 4. Downstream from Jaeger Road, where the creek has been channelized; exposed hardpan is being eroded near the discharge from the road culverts. The hardpan appears to have been originally deposited in layers. The top layer is being eroded and exposing the lower layer.

Sediment Supply & Transport: Coarse sediment supply and transport are low as there are no substantial depositional features within the channel (e.g., bars). The majority of coarse sediment within the channel is derived from stream banks. Where present, point bars are covered with grasses and are not likely to be mobilized except maybe under extreme events. One point bar of sand deposits was observed in this segment of reach 1.

Bed Form & Material: The generalized bed form may be characterized as a pool/run series. The cross over between pools tends to be long uniform channels. The bed consists mostly of the surrounding parent materials overlain by a thin layer of sands with minor amounts of gravel. The bed is vegetated and is not armored with gravel or cobble as seen along Laguna Creek. Scour pools are present at bends, but do not have the same run-drop-pool structure as seen previously, and may be due to the absence of armoring.

Bank Form & Material: Bank material consists of a cemented silty-sandy matrix that is hard when dry and soft when moist. This section is located in the Hedge/Hicksville soil series and does not contain the embedded gravel present in the first 4 sections. Moist material can be formed into a ball but breaks apart easily when attempting to form a ribbon. The material is grainy and appears to be low in clay content. Material characteristics are consistent with the description of soil type and parent material in this area. An outcrop of sandstone/siltstone was observed on the outer bank of one meander bend.

Vegetation: The surrounding land use is mostly pasture with a moderate density of grasses and forbs. Although vegetation is continuous it appears to have a moderate density in that some exposed soil can be seen between plants. Vegetation also grows along most of the bed. Rooting depth of grasses along the banks is shallow (<6-inches) with a density of <15%; therefore vegetation does not appear to play a significant role in bank stability.

Reach 1; downstream from Blodgett Reservoir.

Although no cross sections were located in this segment of Reach 1, Geosyntec inspected this segment in February 2007. This segment of Laguna Creek is one of the two most heavily damaged and unstable portions of Laguna Creek (in addition to the segment downstream from Jaeger Road). Historically, the channel was re-aligned and straightened to direct reservoir discharges away from farm land to the south of the creek. Bank failures, head cutting and incision occurs along this segment for several thousand feet downstream from the reservoir. Eventually, the impacted channel gives way to shallow swale like channel features that appear to be stable again. Creek flow eventually disappears in the swale like segment.

Reach 2 - Cross-sections 6 & 7, upstream from Eagles Nest Road.

Reach 2 is the first segment (from the top of the watershed) that had flowing water. It also has a greater abundance of wildlife. The average channel gradient is 0.0010 ft/ft (WLA, 2005), which is a shallow slope when addressing stream power and erosion/transport processes. Stream flow was quiescent during the survey and water temperature was 75 degrees in the sun.

This segment of Reach 2 was historically channelized and straightened for agricultural purposes (WLA 2005). The channel is deeper with a medium width to depth ratio, but is currently well vegetated and stable.

General Stability: Although this segment was historically channelized; today it is physically stable, contains many plant species and has fish, frogs and other aquatic organisms. Channel activity is low with little exposed bank soils or persistent bank failures[1]. Being channelized, this segment has a smaller W/D ratio then Reach 1. Vegetation is dense and extends all the way down to the water's edge. Hardpan is exposed at cross section 7.

Erosion Processes: With the exception of one small length of exposed soil (~10 feet), no other erosion or recent physical activity was observed at Cross-sections 6 and 7. Banks are well vegetated and emergent wetland plant species are present within the channel.

Sediment Supply & Transport: Coarse sediment supply and transport are very low and the only depositional feature is the soft silty bed. Transport, if any, must primarily be in the form of suspended material and wash load. Bed load transport is essentially zero.

Bed Form & Material: The form of this segment might be classified as a glide, a slow-moving pool with little surface turbulence, or simply as a dammed pool. Both large woody debris and at least one Beaver dam are present in this segment. The channel has marsh-like qualities, such as a soft silty bed and aquatic plants. The silty bed overlies hardpan, which is exposed at section 7. Hand-sized pieces of this material are friable when separated from the mass, suggesting a low hardness. The exposed underside of the broken piece of hardpan seemed to dissolve in water.

Bank Form & Material: Bank material consists of a silty-loam, clay-loam matrix, is medium stiff when dry and soft when moist. This section is located in the San Joaquin soil series. The bank toe material has an increase in clay content and can be formed into a ribbon about ¼ inches in diameter before breaking apart. Material characteristics are consistent with the description of soil type and parent material in this area.

Vegetation: The surrounding landuse is mostly pasture, agriculture and rural residential. Vegetation includes trees, shrubs, vines, forbs, grasses and emergent wetland plants. Vegetation is continuous and dense, much denser than observed in Reach 1. Root density and strength is believed to be high. Bank vegetation extends all the way down to the waters edge, with cattails and other aquatic plants in the water. Large woody debris is present downstream from Cross-section 7.

Reach 2; WLA Cross-sections 1 to 3, upstream from Excelsior Road.

General Stability: This sub-reach is stable, with high W/D ratios, shallow bank heights and slopes, and flood flows have frequent access to floodplains. High flow channels on the floodplain exist and contain gravel and cobble armoring. The channel alternates between large pools without emergent vegetation and swale like segments with observed vegetation on the channel bed.

Erosion Processes: A small amount of bank slumping was observed along the active channel where banks are vertical and consist of soft loams. Although some grazing impacts were seen, bank slumping is believe not to be related to cattle. No other erosion was observed.

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[1] A small length (~10 feet) of bank erosion is present locally, but this feature is infrequent.

Sediment Supply & Transport: Coarse sediment supply and transport are very low and the only depositional feature is the soft silty bed; grass covered and swale-like in places. The only source of coarse material is from the stream banks. The surrounding landscape is low gradient, well vegetated pasture with little signs of surface erosion and source material to Laguna Creek. Sediment transport appears very low and must primarily be in form of suspended material and wash load. Bed load transport is essentially zero.

Bed Form & Material: This segment might be classified as a pool/riffle or simply a pool. Other portions of this segment have a *swale* form with shallow flows and vegetation covering the bed. High flow channels that are dry have cobbles embedded in the bed.

Bank Form & Material: This section is located in a spatially variable mix of the Redding, Fiddyment and Hedge soils. Textures range from gravelly-loam to sandy-loam to clay-loam. The low bank height and high W/D ratios suggest a weak bank structure with low resistance to the forces of flowing water.

Vegetation: The surrounding landuse is mostly pasture and conservation easement. Vegetation includes forbs, grasses, and emergent aquatic plants. Vegetation is continuous and dense. Bank vegetation extends all the way to the water's edge. Emergent wetland plants are present in some shallow segments.

Reach 3; WLA Cross-sections 4 to 9, upstream from Vineyard Road.

This reach flows down the escarpment on the western face of a terrace of the ancestral American River. The average channel gradient is 0.0024 ft/ft (WLA, 2005), which is steeper than all other reaches except Reach 1. The lower segment has a medium W/D ratio compared to the upper portion, which has wider pools formed upstream from the hardpan. The narrowing generally coincides with changing soil types from Redding to San Joaquin soil complexes.

General Stability: The upper segment of this reach of Laguna Creek is generally stable. The lower segment of this reach is much less stable and has floodplain scour and channel incision. The channel flows along the interface of two soil types and geologic formations that likely contribute to the mixed irregular channel conditions within the reach (see Figure A-1). This reach has also undergone channel modification as part of a mitigation/enhancement project. The purpose and year are not known at this time. High flow seasonal wetlands or floodplain pools were created. A large scour hole (~4-feet deep) and headcut exists on the right bank, which is cutting a secondary channel across the floodplain.

Erosion Processes: This reach of Laguna Creek has floodplain scour and channel incision. Because the bed is armored with exposed hardpan, the incision may be halted or progressing at a slow rate. The exposed hardpan in this segment appears harder than that observed upstream. Two elevated stormwater outfalls and deeper low flow channel exist on the segment near WLA sections 7 and 8, suggesting that the stream has incised approximately 12 to 15-inches since the outfalls were constructed. The year of construction is not yet known, but the structure looks fairly recent. The incision could potentially be a result of downstream impacts and/or dissolution of the hardpan. The incision observed through this reach may be a result of eroding a thin layer of loose bed material exposing hardpan or suggests that the hardpan may not be as resilient to the effects of urbanization as one might think.

A higher elevation broad secondary channel exists on the right floodplain adjacent to the current narrower low flow channel, which is deeper by about 18 inches. This broader secondary channel resembles the natural channel geometry present in the upstream conservation area.

In addition to the elevated culverts, a large scour hole and headcut exists on the right bank between WLA section 6 and 7. This scour hole/headcut is cutting a channel through the floodplain, creating what will become a secondary channel. During high flow events, flow on the floodplain spills over this headcut causing erosion and scour. This headcut is active and migrating upstream. Sometime in the near future, a new second channel will be formed.

Sediment Supply & Transport: As with the entire system, coarse sediment supply and transport appear to be very low and the only source of coarse material is derived locally from stream banks. There is little loose unconsolidated sand and gravel deposits within the channel, although more than observed upstream, which is likely due to the increased bank erosion. Gravel that is observed on the bed is embedded into hardpan and is difficult to remove by hand.

Bed Form & Material: This segment might be classified as a pool/riffle or simply a pool formed by hardpan acting as grade control. The bed is armored with gravel and small cobble embedded in hardpan. It was difficult to dislodge a pebble by hand. WLA (2005) reports the median grain size to be 20 to 30 mm; i.e., coarse gravel. Hardpan is exposed in many places and is acting as grade control forming pools upstream. A dry high flow pool on the left floodplain near WLA section 6 has a gravel and cobble bed likely originating from the parent material. Outcrops of hard cemented hardpan with embedded gravel can be seen in the upper portion of this segment.

Bank Form & Material: Because the creek flows along the interface between two soil types and geologic formations, two different bank characteristics are noted. The left bank (cemented San Joaquin soils) is more resistant than the soils on the right bank (Redding soils), which has steeper and taller banks (with exposed cutbanks) than those along the right bank. The right bank has shallower slopes and includes a majority of accessible floodplain area, scour pools and head cutting.

Vegetation: The surrounding landscape is buffer lands – outside the buffer lands is primarily residential. Vegetation consists primarily of grasses, with a few scattered trees and shrubs.

Reach 4; WLA Cross-sections 10 to 11, downstream from Vineyard Road.

This reach flows down the escarpment believed to be the western margin of a terrace of the ancestral American River. The average channel gradient is 0.0007 ft/ft (WLA, 2005), which is a shallow slope with respect to stream power and the erosion/transport processes. A ~6-foot diameter culvert discharges to the creek at Vineyard Road discharging stormwater from the Wildhalk sub-division built in recent years.

According to WLA (2005), the segment of reach 4 between Vineyard Road and Calvine Road has been dredged in the past that lowered the bed elevation and over steepened the channel banks, making them prone to slumping. Dredging in this reach has effectively disconnected the creek from its floodplain causing increased shear erosion of the creek bed and toes of banks during higher flows. Downstream from Calvine Road (cross section WLA 15), the stream channel broadens and shallows again and is generally more typical of the natural channel geometry.

General Stability: Downstream from Vineyard Road, Laguna Creek shows measurable increases in channel activity and instability, likely as result of the historical dredging. Field observations indicate the primary mode of failure is bank slumping and toe erosion. Slumping and toe erosion is observed throughout most of this segment. In two locations, trees have toppled into the channel from undermining of the bank.

This segment has been dredged to increase conveyance for flood flows, which created over steepened and tall stream banks. However, at the bottom of the dredged channel is a narrower and somewhat meandering sub-channel, small mid-channel islands (braiding?) and toppled trees that suggests recent hydraulic activity not related to dredging.

Erosion Processes: Bank slumping and toe erosion are observed throughout most of this segment. Field observations identified frequent slumps of bank material creating scarps along the top of the bank and an irregular bank condition. Slumping is a result of over steepened and tall banks, pore water pressure and rapid rise and fall of hydrographs. The height and steepness of these banks have exceeded the threshold of stability given the flashy nature of runoff in the Laguna Creek watershed. Several areas of exposed bank soil were also observed. Through long stretches of channel, vertical cut banks exist on both sides of the channel (including the inside of meander bends) and below slumps, suggesting scour of the toes of the banks and possible channel incision. Trees have also toppled into the channel from undermining of the banks. An elevated outfall is also observed near WLA Site 11, which suggests that the stream bed has deepened since construction of the outfall.

Sediment Supply & Transport: Although coarse sediment supply is low there is an increase in mobile bed material and in-channel deposits through this reach (silts, sands and gravel, bars and islands). The source of this material is likely from the failing stream banks as sediment is not likely being transported through Reach 2 or the upper portion of Reach 3. The capacity to transport sediment is likely higher through this reach due to the narrow entrenched channel form. On the other hand, the bed still contains silt and sand material, which would suggest a low transport potential.

Bed Form & Material: This segment might be classified as a pool/riffle or simply a pool. There is an increase in the quantity of mobile sands and gravels observed on the bed. The depth of this mobile layer is unknown, but it is probably thin given the nature of the Laguna Creek geology. WLA (2005) reports the median grain size to range from 10 to 20 mm, which is classified as medium gravel. Mid-channel deposits are present. Near Site 11, bedrock (hardpan?) is exposed along the bed and toes of banks (WLA 2005), which does not contain embedded gravels, but is formed from the granitic sands and silts of the Riverbank Formation. Fish redds are observed near Vineyard Road.

Bank Form & Material: According to WLA (2005), this segment was historically dredged and re-aligned, creating the narrow, deeper channel configuration. Steeper and taller banks are more susceptible to slumping and failure. The historical channel had a much wider and shallower form, i.e., larger W/D ratios, as observed from a historical channel segment still present. The historical channel can be seen in a few small places that haven't yet been plowed or graded.

Vegetation: The surrounding landscape is buffer lands, which is surrounded by residential and commercial areas. Vegetation includes trees, shrubs, vines, forbs, grasses and algae. Vegetation is continuous and fairly dense. Root density and strength is believed to be moderate. Bank vegetation extends all the way down to the water's edge. Root depth and density is low where exposed and observed at scarps.

Reach 4; WLA Cross-sections 12 to 15, downstream from Bradshaw Road.

General Stability: The overall stability of this segment is similar to that discussed above. Near WLA Site 12, the channel has the same small W/D ratios and observed bank slumping. In some areas the channel is a little wider, with shallower side slopes that appear stable. Near WLA Site 13, the bank material changes and is more resistant, having steeper and taller banks, and a blocky appearance. Hardpan is exposed on the bed and toes of banks in places. South of Calvine Road, the channel changes form from a narrow deep configuration to a wider, shallower one, which is more typical of the natural historical form.

Erosion Processes: Slumping and bank toe erosion is observed throughout most of this segment upstream from cross section WLA-13. Field observations identified frequent slumps of bank material creating a scarp along the top of bank. Several areas of exposed bank soil were also observed. Downstream from Calvine Road the frequency of erosion decreases.

Sediment Supply & Transport: Coarse sediment supply is low and the only source of material is from the eroding stream banks. Sediment transport capacity is low and primarily in the form of suspended material and wash load. Bed load transport is essentially zero.

Bed Form & Material: This segment might be classified as pool/riffle or simply a pool. WLA (2005) reports the median grain size around 10 mm, i.e., medium gravel. Hardpan is exposed in many places, which acts as grade control forming pools upstream. This hardpan does not have embedded gravels, but is formed from the granitic sands and silts of the Riverbank Formation.

Bank Form & Material: Bank material is beginning to show outcrops of a more resistant blocky material as well as hardpan. This material does not have the embedded gravel or cobble seen in upstream reaches; it consists of cemented sands and silts, which allow near vertical banks to form. Although the same exposed hardpan is present downstream from Calvine Road, Laguna Creek transitions from an entrenched channel to one that is much wider and shallower.

Vegetation: The surrounding landscape is buffer lands, which is surrounded by residential and commercial areas. Vegetation includes trees, shrubs, vines, forbs, grasses and algae. Vegetation is continuous and fairly dense. Root density and strength is believed to be moderate. Bank vegetation extends all the way down to the water's edge. Root depth and density is low where observed at scarps.

Reach 5; Cross-Section 8, downstream from the intersection of Waterman and Bond.

The average channel gradient is 0.0005 ft/ft, which is a very shallow slope with respect to stream power and the erosion/transport processes. Stream flow was quiescent during the survey and water temperature was 78 degrees in the sun. Backwater ponding from the Camden Park lakes seem to extend up to the Southern Pacific Railroad crossing. This back water in combination with perennial flows is providing ideal conditions that support the growth of emergent wetland vegetation.

General Stability: This section is stable, contains riparian plants and has fish, frogs and other aquatic organism. The active channel appears to have frequent access to floodplains, with set-back levees on either side. Channel activity is low with little exposed bank soils or bank failures. Vegetation is dense and extends all the way down to the water's edge. Downstream about 1000 feet is a channel crossing, which acts as grade control.

Sediment Supply: Coarse sediment supply and transport are very low and the only depositional feature is the soft silty bed. Sediment transport capacity is low and must be in the form of suspended material and wash load.

Bed Form & Material: The form of this segment might be most simply classified as a pool. A rip-rapped culvert and trail crossing downstream acts as a grade control and flow control. The channel though this segment has a soft silty-clay bed. Water depth was 5 feet and more.

Bank Form & Material: Bank material along the active channel is soft silty-loam to clay-loam, and is part of the San Joaquin soil series. No bank failures were observed though this segment.

Vegetation: The surrounding landuse is mostly residential and commercial. Vegetation includes trees, shrubs, vines, forbs, grasses and aquatic plants. Vegetation is continuous and fairly dense. Root density and strength is believed to be moderate to high. Bank vegetation extends all the way down to the water's edge, but more exposed soil is observed within the active channel.

Discussion & Conclusions

On the basis of these field observations and previous work by WLA (2005), Laguna Creek is susceptible to the impacts of development and hydromodification. The creek system is dynamic, i.e., not stationary, and shows clear signs of recent geomorphic activity under the current hydrologic regime. If left unmanaged, increases in the magnitude and duration of stormwater discharges and volumes will intensify this activity and lead to unwanted channel impacts, bank failures and adjustment. Table A-1 provides a summary of the observed channel conditions.

The observed geomorphic activity includes bank slumping and toe scour, fallen trees, scour holes and incision, head cutting and secondary channel formation on floodplains. Much of the activity observed in Reach 1 and 2 is believed to result from natural processes not associated with urban development (except downstream from Blodgett Reservoir) or cattle grazing. Most of the observed channel activity is located along the outer bank of meander bends, where scour holes and steep vertical banks have been created. On the inside bank of meander bends and between bends channel bank heights are low, shallow and well vegetated. Cattle impacts do not appear to be significant. Only a small amount of bank trampling was observed and cattle trails sometimes pass in creek channels. An increase in activity occurs in Reach 3 and 4 downstream from Vineyard Road, which is downstream from the first major stormwater outfall. Some channel incision and floodplain scouring is observed just upstream from Vineyard Road. Two elevated outfalls are observed and suggest recent incision of up to 18 inches. The channel has been incised to expose hardpan throughout most of this reach. Hardpan is proving some control over further incision, but may not last forever. Several exposed hardpan knickpoints are observed in the lower portion of Reach 3 that may be subject to erosion and dissolution over time. According to WLA (2005) the upper segment of Reach 4 (downstream from Vineyard Road) was historically dredged for flood control purposes, effectively disconnecting the creek form its floodplain. The height and steepness of the creek banks have exceeded the materials threshold for stability and frequent bank slumps are observed. The dredging in Reach 4 has likely led to headcut migration upstream into Reach 3. The data from Reach 3 and 4 indicate that historical modifications to the creek (dredging and straightening) and watershed development have produced channel conditions and hydrologic regime with the power to cause bank failures, down riparian trees, create geomorphic adjustments. Further urban development and hydromodification will intensify and accelerate these processes. Reach 5 is stable, has little observed erosion activity, contains wildlife and creek flows have access to floodplains.

Laguna Creek does rest on hardpan of various forms and hardness, which slows or limits channel incision and provides some level of grade control. Hardpan layers are resilient, but they can erode, albeit at a slow rate. There are signs of incision downstream from Excelsior and Vineyard Road, which has cut down to hardpan and may be eroding or dissolving this hardpan. The incision could potentially be a result of downstream impacts migrating upstream in the form of headcuts. The incision observed through this reach may be a result of eroding a thin layer of loose bed material exposing hardpan or suggests that the hardpan may not be as resilient to the effects of urbanization as one might think. The banks consist primarily of the surface soils (silty, sandy and gravelly loams) and locally derived alluvium, which are less resistant to the forces of water than the exposed hardpan. Some bank material is soft and probably recent deposits, which is much less resistant than the bed. The bed can be armored with cobble derived from the parent material deposited by the ancestral American River. Cobble beds are observed in many places from the headwater streams down through Reach 4.

The effect of urbanization and hydromodification intensifies the erosion and sediment transport processes, leading to increased rates of erosion and channel adjustment. Bank slumping and shear erosion are two mechanisms of erosion that cause the observed channel failures. Bank slumping occurs when there is a precipitous rise and fall of stream flow hydrograph. When the bank soils are under water, they become saturated and heavy. When the water level rapidly drops, the banks collapse under their own weight, typically leaving an irregular bank surface. Shear erosion occurs from the forces of flowing water against the channel bank material, either by weight or momentum, typically leaving a smooth surface. Because bank material is believed to be less resistant than the bed, hydromodification will likely increase the rate of bank slumping and scour along the toes, which would result in channel widening. An increase in scour along the outer bank of a meander, could lead to an expansion of meander bends and planform adjustment. The bed is generally supported by frequent exposed hardpan or armored with cobble. However, it is not clear if the areas between these outcrops of hardpan will erode causing localized incision and bank failure. It is also not known if hardpan (especially the knickpoints) is subject to a slow rate of erosion or dissolution, which if so could give way some day initiating a rapid change in channel bed elevation, bank failure and widening, and potential loss of floodplain access and pool habitat.

The Laguna Creek watershed sediment supply appears to be very low naturally and the system appears to be supply limited. The landscape is fairly flat and hummocky, and consists mostly of rural residential and pasture with moderate to high density of grass cover. Vernal Pools and drainage swales are present over much of the landscape capturing and slowing the rate runoff. There is very little loose unconsolidated bed material or bar deposits in the channel. Point bars and channel beds are generally grass covered and are not mobilized very frequently. Loose bed material that is available for transport is thin and believed to have originated from bank erosion and failures. Where bank failures were observed, a deposit was not far from the failure location. Because of this condition, reduction in sediment supply does not appear to be a condition of concern for the Laguna Creek watershed. The morphology and potential for change is primarily a function of the surrounding channel materials controlling bank and bed conditions.

Vegetation (grasses) does not appear to play a significant role in channel stability. Although the vegetation cover reduces erosion at the land surface, the depth and density of rooting structure is insufficient to provide resistance to erosion along the banks. An exception is the segment of Reach 2 just upstream and downstream from Eagles Nest Road, where dense riparian vegetation is providing stability and better habitat structure. Vegetation is also providing benefits in Reach 5 downstream from Waterman and Bond.

Throughout most of the study area, Laguna Creek can generally be described as one having a wide, shallow channel. Low bank heights and high W/D ratios typical of Laguna Creek suggest that the bank structure is weak relative to the resilience of the bed creating the tendency toward wider shallow channel configurations. With the periodically exposed hardpan and armored beds, increases in the volume and duration of stormwater runoff will likely lead to widening and bank failure in the short term rather than deepening of the channel. In the long-term, erosion of the hardpan and knickpoints could lead to further channel incision and sudden channel failures.

Table A-1. Summary of Cross Section Channel Features

Reach	Location	Soil Type	Reach Slope	W/D Ratio	Sediment Supply	Vegetation Density	Observed Stability
Reach 1	G.S. XS-1	Redding Gravelly Loam	0.0036	High	Low	Low	Stable
	G.S. XS-2			High	Low	Low	Stable
	G.S. XS-3			High	Low	Low	Stable
	G.S. XS-4			High	Low	Low	Stable
Reach 2	G.S. XS-5	Hedge & San Joaquin Loam	0.0010	High	Low	Low	Stable
	G.S. XS-9			High	Low	Low	Stable
	G.S. XS-6			Low	Low	High	Meta-Stable
	G.S. XS-7			Low	Low	High	Meta-Stable
	WLA Site 1			High	Low	High	Stable
	WLA Site 2			High	Low	High	Stable
Reach 3	WLA Site 4	Redding Gravelly Loam	0.0024	High	Low	Med	Meta-Stable
	WLA Site 6			Med	Low	Med	Meta-Stable
	WLA Site 7			Med	Low	Med	*Unstable*
	WLA Site 8			Med	Low	Med	*Unstable*
Reach 4	WLA Site 10	Hedge & San Joaquin Loam	0.0007	Low	Low	Med	*Unstable*
	WLA Site 12			Low	Low	Med	*Unstable*
	WLA Site 13			Low	Low	Med	*Unstable*
	WLA Site 15			Med	Low	Med	Stable
Reach 4	WLA Site 16	Hicksville Loam	0.0007	Med	Low	Med	Stable
	WLA Site 17			Med	Low	Med	Stable
	WLA Site 18			Med	Low	Med	Meta-Stable
	G.S. XS-8			High	Low	Med	Meta-Stable
	WLA Site 19	*Trib.1*		Low	Low	Low	*Unstable*
	WLA Site 20	*Trib.1*		Low	Low	Low	*Unstable*

Figure A-1. Map of Laguna Creek Illustrating the NRCS Soil Types

Figure A-2. Map of Laguna Creek Illustrating the Sub-Watersheds, Stream Reaches, and Cross-Section Locations

Figure A-3. Map of Laguna Creek Illustrating the Current Level of Channel Stability

EXHIBIT A

CHANNEL STABILITY FIELD SHEET

OBS.________ DATE______________

WEATHER CONDITIONS: Rainy Cloudy Sunny Windy TEMPERATURE___________?F

WATERSHED __________________________________ CREEK ____

REACH LOCATION ____

SURROUNDING LAND USE ____

REACH STABILITY

SEDIMENT SUPPLY: Very High High Moderate Low Very Low

DEPOSITION FEATURES: None Point Bars Mid Bars Side Bars Tributary Bars Braiding

IS REACH CURRENTLY: Aggrading Incising Widening Stable NA (see remarks)

DEPTH: Aggrading: _________ft Incising: _______ft Age: ____________years

EVIDENCE: Bridge Abutments Outfalls Pipelines Tree Roots Cutbanks

Other ____

HEADCUTS / NICKPOINTS: Bedrock Hardpan Grade Control Tree Roots Other

DEPTH: Drop: _____________ft Distance: _________ft Age: ____________years

HISTORICAL or ACTIVE:____

POSSIBLE CAUSATION:____

REMARKS ____

ARTIFICIAL STRUCTURES

BED TYPE: Drop Structure Grade Control Rip-Rap Biotechnical

Other ____

Drop: _______________ft Distance: ________________ft Age: ____________years

UPSTREAM BED SLOPE: ________________ft/ft

BANK TYPE: Sack Concrete Rip-Rap Gabions Biotechnical Re-Vegetation

Other ____

Bank Cover: _____________% Distance: ________________ft Age: ____________years

BED MATERIAL PROPERTIES:

BED FORMS: Colluvial Cascade Step/Pool Plane Bed Riffle/Pool Dune/Ripple Chutes/Run

BED MOBILITY: Mobile Fixed MOBILE LAYER DEPTH: ______________ft

MATERIAL: Clay Silt Sand Gravel Cobble Boulder MORPHOLOGY: Graded Armored Shingled

EMBEDDEDNESS (%): <10 <25 <50 <75 <100 PERCENT FINES: ______________%

GRAIN SIZE (mm): Wolman Pebble Count

<2	<4	<8	<16	<24	<32	<45	<64	<96	<128	<192	<256	>256

FIXED BED MATERIAL: Bedrock Hardpan Clay Concrete Other ______________

REMARKS ____

____

BANK PROPERTIES:

SIDE: LEFT or RIGHT BANKFULL DEPTH____ft HEIGHT: _____ ft ANGLE:_______ (°)

MATERIAL TYPE: Clay Silt Sand Loam Compacted Consolidated Unconsolidated

STRATIGRAPHY: Homogeneous Layered WEAK LAYER: Clay Silt Sand Loam Mixed (gravel)

ASCE INDEX: ❑Fine Sand ❑Sandy Loam ❑Silty Loam ❑Alluvial Silts ❑Firm Loam
❑Soft Clay ❑Stiff Clay ❑Shales/Hardpan/Bedrock

BANK FAILURE: YES NO STABILITY RATING: Actively eroding Eroded yet stable Stable

Other ____

FAILURE MECHANISM: Shear erosion Slumping Under Cutting Piping Lost Vegetation

Other ____

REMARKS ____

____

VEGETATION PROPERTIES:

VEGETATION TYPE: Trees Shrubs Grasses Vines Forbs Bare Soil Other ________

VEGETATION DENSITY: Continuous Scattered Low Moderate High None

ROOTS DENSITY (%): <5 <15 <30 <55 <80 <100 ROOT DEPTH: ____________ft

DEBRIS BLOCKAGES: None Infrequent Moderate Extensive Dominant

REMARKS ____

____

SKETCHES