LOWER TUOLUMNE RIVER RESTORATION PLAN
SCOPING SUMMARY
and
PROPOSED WORKPLAN

Prepared for:

Lower Tuolumne River Settlement Agreement Technical Advisory Committee

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INTRODUCTION

Anadromous salmonid populations in the lower Tuolumne River require an adequate level of ecosystem health to achieve and sustain their potential productivity. Salmonids depend upon habitat formed and maintained by dynamic geomorphic processes, and restoring/maintaining these processes is crucial for restoring/maintaining naturally reproducing salmonid populations. If complete river ecosystem restoration is unlikely, or unfeasible, limiting factors must be identified for prioritizing restoration actions that best improve habitat conditions.

Dynamic channel processes are the primary forces that keep unregulated river ecosystems healthy and salmonid populations productive. Without these processes, prospects of sustaining a productive river ecosystem and salmonid habitat are greatly diminished. Restoration planning for a regulated river such as the lower Tuolumne River must begin by addressing several questions: What is a properly functioning river? Are these physical processes operable in the present-day mainstem Tuolumne River? If not, can all, or several, be restored? Which are the most important for improving salmonid habitat?

A comprehensive program for lower Tuolumne River ecosystem recovery requires an integrated evaluation of many biological and geomorphic watershed processes. Such an evaluation would gauge the river's restoration potential for salmonid habitat improvement, establish quantitative goals under realistic timelines, guide design and river-wide placement of future restoration projects, and estimate project costs.

In March 1996, we proposed to identify the most important processes/issues affecting channel morphology, riparian communities, and salmonid habitat. This overview would "weed out" minor or unimportant issues, allowing a more economic focus on strategies with the best restoration potential. Proposed tasks for this pilot investigation included:

1. Assess historic and contemporary geomorphic and hydrologic processes most important to river ecosystem restoration in the lower mainstem Tuolumne River;
2. Stage limited field reconnaissance to assess tributary and agricultural runoff inputs of fine sediment into the mainstem Tuolumne River and identify mainstem reaches potentially restricting bedload transport;
3. Review recent biological studies and hydrological data to evaluate factors potentially limiting salmonid productivity and riparian community development;
4. Prepare a scope of work for a detailed watershed analysis.

In this summary/proposal, we selectively present field and office evaluations, concentrating instead on conclusions and outlining future objectives and tasks.

Though originally conceived as a watershed analysis, our approach could be considered more as a river corridor analysis and restoration plan. We are not attempting to separate the river from its watershed; however, often the first hurdle for a proposed restoration project is to limit the project's scope without endangering its intent. An important objective for this preliminary assessment, therefore, was to determine if a successful salmonid habitat and river ecosystem restoration strategy could be limited to the river corridor. And if not, how far and how much of the surrounding watershed should be explicitly included in the plan.

BACKGROUND

Fluvial geomorphic processes are the physical underpinnings for determining the structure and function of river ecosystems (Ligon, Dietrich, and Trush 1995). The difficulty understanding how healthy biological systems function increases with a system's complexity as critical interactions among physical and biological components increase geometrically. Optimally, regulated rivers must be managed by mimicking natural geomorphic processes and budgets (sediment and flow) whenever and wherever possible as the most prudent strategy for preserving and promoting river ecosystem health.

Channel morphology is the channel dimension, shape, composition, and slope resulting from past and present-day fluvial geomorphic processes, as well as by human perturbation. Channel morphology for undisturbed mainstem alluvial rivers is maintained in "dynamic quasi-equilibrium," where the channel morphology and flow regime transport sediment at a rate roughly equal to the sediment supply. Sediment is transported through or temporarily stored within the channel (dynamic), but the channel morphology narrowly fluctuates over time (quasi-equilibrium). Any change to sediment supply or flow regime initiates an adjustment in channel morphology. While a dynamic quasi-equilibrium is not constant or universal among rivers, it provides a conceptual baseline from which to identify and quantify important physical processes and recommend reconstructed channel designs.

River Ecosystem Health Criteria

Any collective measure of river ecosystem health must first incorporate the fluvial geomorphic processes that create and maintain a dynamic river morphology, and second, the plant/animal community responses dependent on these processes. The following principles of physical and biological health for alluvial river ecosystems guided our preliminary assessment of river ecosystem health and consideration of restoration strategies for the lower Tuolumne River:

PRINCIPLE #1
No single segment of channelbed provides optimum habitat for all species. Only by providing the necessarily wide range of physical environments can diverse

and productive biological communities be maintained. Spatial diversity must be incorporated into any investigation designed to identify and evaluate the significance of fluvial processes on river ecosystem integrity;

PRINCIPLE #2

Seasonal and annual flow regimes are broadly predictable, but specific flow magnitudes, timing, durations, and frequencies are as unpredictable as natural runoff patterns produced by storms and droughts. This temporal "predictable unpredictability" is the foundation for dynamic river ecosystems and must be preserved;

PRINCIPLE #3

River reaches export sediment at a rate equal to upstream sediment input. The amount and mode of sediment storage for a given river reach should exhibit minimal fluctuation when averaged over many years, maintaining a channel morphology in dynamic quasi-equilibrium;

PRINCIPLE #4

The dominant particle size of alluvial, and many partially-alluvial, channelbed surfaces are mobilized by common floods, often labeled the bankfull discharge, once annually as a long-term average;

PRINCIPLE #5

The active channelbed should be periodically scoured deeper than the surface layer by floods exceeding 3 to 5 year annual maximum flood recurrences. These floods, larger than bankfull discharge, are also necessary to deposit finer sediment on the floodplain and lower terraces.

PRINCIPLE #6

The channel should migrate at rates and wavelengths consistent for rivers in watersheds with similar annual flow regimes, valley slopes and confinement, and sediment supply and caliber (i.e., with regional geomorphic and hydrologic similarity);

PRINCIPLE #7

Floodplains are inundated once annually (as a long-term average) by common floods exceeding bankfull stage. Lower terraces are inundated less frequently, with their expected inundation frequencies dependent on norms established from regionally similar river channels;

PRINCIPLE #8

Woody riparian plant establishment and mortality are consistent with each species life history strategy, culminating in early successional population structures and species diversities (canopy and understory) characteristic of self-sustaining riparian communities in unregulated rivers regionally;

PRINCIPLE #9

Seasonal water quality characteristics, especially water temperature and suspended sediment concentrations, should be similar to undisturbed rivers regionally.

Given past human-induced influences within the Tuolumne River corridor, not all criteria may apply and/or be feasible to restore regardless of effort and funding. A goal of this scoping project was to identify important physical and biological processes that appear to be functioning properly for an alluvial river, as well as constraints on ecological processes not occurring and/or considered limiting to salmonid productivity. Restoration potential also was considered.

Alluvial Channel Morphology and Salmonid Habitat

The basic building block for alluvial rivers is a depositional feature called the alternate bar. It is comprised of an aggradational lobe and scour hole (Figure 1). More commonly, an alternate bar is identified as the riffle-pool sequence, with the exposed portion of aggradational lobe adjacent to the pool considered the "point bar" and the scour hole considered the "pool". A "riffle" is simply water flowing down the face of the aggradational lobe. On a larger spatial scale, two bars form a complete channel meander with a wavelength roughly equaling 9 to 11 bankfull channel widths.

Rivers with dynamic alternate bar sequences exhibit:

1. Complex Habitat Diversity. Alternating point bars, with the thalweg passing from one bank to the other, provide the structural diversity creating a wide range of velocities and depths crucial to providing quality salmonid habitat. Diverse bar features, undercut banks, scoured pools, and velocity shear zones are integral to a meandering channel. Flows that preserve the dynamic nature of an alternate bar sequence also maintain the salmonid habitat that the alternate bar sequence provides.
2. Definable Channel Features. These include the active channel, bankfull channel, floodplain, and terraces, which should all be inundated at flow frequencies consistent with alluvial rivers regionally. Riparian vegetative communities should be occupying appropriate channel features, defined by physiological requirements of specific riparian species.

Within the Lower Tuolumne River corridor, complex alternate bars once dominated mainstem channel morphology. Extensive point bars sorted diverse substrate compositions and produced variable flow velocity distributions to support high-quality mainstem salmonid habitat. Frequent bed mobilization of the alternate bars' active channel probably kept pools deep and spawning gravel composition free of extensive sand accumulation. The remains of historic point bars still expose a wide variety of particle sizes, testament to the ability of pre-project floods to transport, sort, and shape large cobble alternate bars.

SCOPING PROJECT FINDINGS

We compared our set of alluvial criteria to field evidence, with the overall objective of identifying key channel morphologies and fluvial processes that should be considered in developing mainstem restoration strategies.

Mainstem Sediment Dynamics

Coarse bedload supply (gravel-sized and larger) to the pre-dam alluvial mainstem channel was almost totally derived above LaGrange Dam. Re-working coarse alluvium stored in the mainstem floodplain and terraces below LaGrange (but originally supplied from upstream), as the river meandered across its floodway, was the only major coarse alluvium source downstream of the dam site. The larger of downstream intermittent tributaries inspected showed little or no evidence of significant coarse sediment supply; only Gasburg Creek near LaGrange (RM 50.3) provides a potentially significant bedload supply to the mainstem channel downstream of LaGrange Dam. Since dams trap sediments derived from the upper watershed, today's coarse bedload sources include only minor mainstem channelbank erosion and a few small tributary deltas. Bank erosion and active channel migration was not evident during a 5,300 cfs release; however, the 8,500 cfs event in WY95 did erode banks along several short reaches excessively confined by levees.

To develop a basinwide perspective of sediment dynamics, historic and contemporary, a sediment budget is often constructed. Sediment budgets first quantify the caliber and quantity of sediment entering the river from tributaries and eroding mainstem banks, and second, determine the caliber and quantity of sediment stored and transported through the mainstem channel. A substantial imbalance between supply and transport (given the potential error of the estimates) will indicate either oversupply relative to transport capabilities (channel aggradation and braiding) or undersupply (bed coarsening and channel degradation). Either usually forewarns impacts to the river ecosystem and a downward trend in anadromous fish habitat. Given the large margin of error in sediment budgets and high cost of constructing one, one goal of this scoping project was to determine if a sediment budget is necessary to develop restoration strategies for the lower Tuolumne River ecosystem and anadromous salmonid habitat.

In April 1996, we examined the mainstem channel morphology for physical clues of either under- or over-supply of sediment. In moderately over-supplied channels, storage of finer bedload (e.g., sand) is obvious in slack water areas (e.g., pool bottoms during low flows and on floodplain/low terrace surfaces) and in interstices of coarser rifflebed substrates. In grossly oversupplied channels, pools fill with finer sediments, and in extreme cases, riffle surfaces become saturated with sand. Significant sand storage in the bottoms of deep mainstem Tuolumne River pools and on floodplains/low terraces was not obvious. The most significant sand storage component is in the subsurface, with its particle size distribution considerably finer than the channelbed surface particle size distribution. As a simple qualitative comparison against "baseline" conditions, we inspected pre-1850 gravel deposits within the Santa Fe Aggregate mine pit (RM 36) and observed a large percentage of sand in the substrate, suggesting the pre-European Tuolumne River already had a large sand component in the bed material.

On 26 March 1996, we placed over 2,000 orange-painted tracers (representing the median particle size of the channelbed as well as spawnable gravel sizes) into the mainstem channel prior to a 5,300 cfs release to assess bedload mobility. We placed approximately 350 tracers at each of the following channel locations: under the Geer Road Bridge near Fox Grove Park (RM 26), at the Santa Fe Aggregates conveyor bridge (RM 36.2), at the head of the replaced gravel riffle at the Santa Fe Aggregates site (RM 36.7), in riffle 4B (RM 48.4), at the new LaGrange Bridge (RM 50.0), and at the old LaGrange Bridge (RM 50.5). Following this high flow, we observed little, if any, downstream tracer displacement at the assessment sites. This strongly suggests an important geomorphic threshold (Principle #4) will not be achieved by discharges less than approximately 5,300 cfs.

On 11 April 1996, we inspected the Gasburg Creek delta, which was composed mostly of finer coarse bedload and sand. The well-developed sand delta did not extend into the mainstem channel beyond the willow fringe indicating : 1) the long term bedload contribution was insignificant, and 2) mainstem bedload transport had probably occurred during the 8,500 cfs release in 1995. Our tracer gravels at Old LaGrange Bridge documented no bedload transport during the 5,300 cfs release. Without frequent mobilization of the mainstem channelbed surface, the long residency time for fine sediments originating from this tributary will have a prolonged negative effect on anadromous fish spawning/egg incubation habitat.

Alternate bars at the Santa Fe Aggregate channel restoration site, while subtly expressed as constructed in 1993, adjusted and developed during the 8,500 cfs release. Though the bedload source for this development was probably local, bar formation demonstrated that bedload can be transported by contemporary high flows. The thalweg also assumed a more sinuous pattern at the Sante Fe Aggregate site, indicative of alternate bar development.

Several critical questions that may need addressing remain:

1. Could a channel morphology, particularly near the dam site, be designed to transport gravel-sized alluvium (originally placed in the active channel as spawning habitat) over a relatively immobile planform morphology composed of a framework of cobbles and small boulders?

2. What are the potential ecological effects of washload-sized sediment (silts and finer) inputs from tributaries?

3. What is the size class distribution of agricultural sediment runoff entering mainstem salmonid spawning reaches? If sediment runoff is primarily washload size, impacts to spawning habitat are probably minimal. If agricultural sediment runoff has a significant sand component (or larger), the mainstem channelbed surface should be sufficiently mobile to prevent excessive sand residency and accumulation in the subsurface.

4. What are potential impacts of sediments originating from Peaslee Creek watershed activities?

Channel Hydraulics

We benchmarked water surface slopes at many sites between LaGrange and Fox Grove Park during the 5,300 cfs release. Due to continuing high water conditions, water surface slopes have only been surveyed near the Sante Fe Aggregate Waterford Plant (river mile 34.6 to 37.7) because we could easily survey along good road access along the river edge. These slopes varied from 0.0006 to 0.0016. These slope measurements, combined with the tracer gravel experiments and cross sections, will allow us to back-calculate hydraulic parameters (such as Manning's *n*) and evaluate the predictive capability of several bed mobility models. These data and modeling approaches can help design channels that transport bedload during channel forming flows with reasonable confidence. Additional work is necessary because many flood stage markers can only be accessed and surveyed at low flows.

Floodplain Dynamics

An objective of several previous channel reconstruction projects was to create a functional floodplain, where flows greater than 4,000 to 5,000 cfs began inundating the floodplain and depositing fine sediment. We observed that 5,300 cfs was inundating constructed floodplain surfaces (e.g., on the Santa Fe Aggregate site), but due to the clear water dam release and limited surficial storage of fine sediment in the channel, minimal fine sediment deposited on these designed floodplains. In some cases, fine sediment placed on the floodplain was eroded. This suggests two processes: 1) a larger clear water release would mobilize the bed surface, exposing finer grain sizes for transport and potential deposition on floodplain surfaces, and 2) timing moderate-sized dam releases with naturally generated tributary high flows to place the tributary fine sediments onto the floodplains.

Summary of Findings

Our assessment of mainstem alluvial "health" using the above criteria was generally not favorable, though not all criteria could be assessed equally during our field trips. Our qualitative field assessment indicated:

(1) the mainstem channel does not appear over-supplied with fine bedload (sands and finer); however, this is not to say that fine sediment are not having a detrimental effect on salmonid emergence success;

(2) the mainstem channel is not migrating; therefore, coarse sediment supply from bank erosion is minimal. Only tributary contributions, or intentional re-introductions of gravels, will serve as the future coarse bedload supply;

(3) although sand inputs probably do not exceed mainstem transport capabilities, the inability of the river's hydraulics to frequently mobilize the channelbed surface prohibits sand exposure and transport from the subsurface. This has encouraged considerable sand storage via infiltration that decreases salmonid emergence success and may give the appearance of excessive sand input;

(4) in many reaches, the mainstem channel cannot transport coarser bedload supplied by the bed itself, tributaries, and bank erosion, due to changes in channel morphology and/or from limited high flows;

(5) while a quantitative sediment budget is not warranted, identification and remediation of fine sediment input is a high priority. Reducing fine sediment input, primarily from agricultural runoff, and increasing the supply of spawning gravel by intentional re-introduction could become restoration priorities without requiring excessive sediment budget documentation;

(6) the strategic location of Gasburg Creek just upstream of considerable salmonid spawning and rearing habitat makes reducing its fine bedload inputs a high priority;

(7) peak flows approaching 10,000 cfs, or higher, may need to be more frequent to improve bedload transport, spawning substrate quality, and channelbed mobilization;

(8) historic large-scale channel alterations from gold dredging and in-channel aggregate mining, have created sediment traps that disrupt bedload transport;

(9) the floodway width continues to decrease as levees from terrace mining constricts the channel, and adjacent floodplain surfaces replaced by water-filled mining pits having maximum depths exceeding the river's thalweg depth;

(10) without frequent inundation on former floodplain and low terrace surfaces, regeneration of dynamic and diverse riparian communities (especially cottonwood dominated communities) is not occurring.

Following the field trips and preliminary analyses, our original uncertainty as to whether the entire watershed below LaGrange should be explicitly included in a proposed restoration plan seems clearer. With the few tributaries entering the mainstem below LaGrange and the relative confinement of the river, a river corridor plan can be developed independent of a comprehensive basinwide watershed analysis. Upstream dams and floodway encroachment are the primary variables to consider. Surface runoff from the many small tributaries and gullies of washload-sized sediment probably has significant biological effects, and reducing this sediment runoff should be a priority, but can be considered separately from a river corridor restoration plan.

PROPOSED SCOPE OF WORK

Tasks

1. Further define and evaluate alluvial health of the lower Tuolumne River. More completely identify contemporary geomorphic and riparian processes, how these relate to the ecosystem and anadromous salmonid habitat, and ways to improve these processes.

2. Contrast historic fluvial processes with present-day fluvial processes, identifying consequences of changing fluvial processes and river channel morphology as factors affecting river ecosystem integrity and limiting the salmonid fishery. This includes a historical hydrological analysis, anecdotal information (channel migration, gravel bar formation), and air photo analysis. Tasks include: Flow duration, flood frequency, and annual hydrograph evaluation at LaGrange, Hickman, and Modesto gaging stations, hydraulic geometry computations to relate inundation frequencies on specific channel surfaces with respect to the contemporary flow regime.

3. Estimate annual coarse bedload inputs (annual loads and particle size distributions) from Gasburg Creek and other tributaries as needed. Specifically identify mainstem channel reaches that prevent, or severely impede, coarse bedload transport throughout the mainstem.

4. Identify opportunities for achieving fluvial geomorphic thresholds using flow release prescriptions (e.g., using spring pulse flows and flood control releases during wet water years).

5. Identify restoration material needs and availability of sources. Determine (a)landowner willingness and/or concerns, (b)potential economic incentives, and (c)institutional constraints and/or opportunities.

6. Inventory, classify, and map existing riparian habitat in the lower Tuolumne River corridor. Assess uniqueness, ecological significance, and restoration potential. Identify and prioritize riparian preservation and restoration sites.

7. Recommend restoration strategies within the mainstem river corridor, and prioritize strategies with the best potential for restoring/protecting critical components of the Tuolumne River ecosystem and reduce limiting factors for the salmonid fishery.

8. Locate potential restoration and preservation sites (using a GIS format already in place) and develop site-specific conceptual design, construction, volumetric, and regulatory considerations (e.g., zoning requirements, permitting timelines). Prepare channel dimension and riparian planting guidelines for all sites in general, and conceptual designs prepared for specific sites. Costs, benefits, and permitting issues associated with each restoration strategy would be prepared to compare recommended restoration strategies. This would be similar to plans already developed at several sites (e.g., SRP 9 and 10 at river miles 25-26).

9. Recommend monitoring philosophy and specific methodologies for determining how the implemented plan is accomplishing river ecosystem restoration and improving salmonid habitat.

PROPOSED PRODUCTS, TIMELINE, AND BUDGET

November, 1996
Status Report on High Priority Preservation and Restoration Sites Inventory and Preliminary Evaluation

Labor	$40,000
Equipment rental	$5,000
Travel expenses	$5,000
TOTAL	$50,000

A priority list of restoration sites and preservation sites, with ownership and estimated purchase/easement costs (and potential cost-sharing opportunities), including field classification and GIS mapping of riparian habitats.

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February, 1997
Evaluation of Source Materials for Restoration Resource

Labor	$11,000
Equipment rental	$2,000
Travel expenses	$2,000
TOTAL	$15,000

An inventory of mine tailings and other gravel sources within the Tuolumne River Corridor and selected outside sources (e.g., on the Merced River near Snelling). An analysis of the value of tailings from the private landowner and aggregate industry perspectives. Examine institutional constraints regarding purchase, cost-sharing, and/or donation of tailings for channel restoration. Estimate of transportation and permitting costs. Design of tailing areas adjacent to mainstem channel, once tailings removed, as potential floodplains.

March, 1997
Pilot Channel Restoration Designs

Labor	$4,000
Equipment rental	$500
Travel expenses	$500
TOTAL	$5,000

Four site-specific channel restoration designs were prepared by EA Engineering, with McBain and Trush in 1995 for potential Delta Pumping Plant funding. These designs require limited additional background and technical writing/drafting, as well as re-evaluation of construction costs given our proposed economic analysis of mine tailing availability. These completed designs could be used by agencies as construction bid documents for Summer '97 funding.

June, 1997
Mainstem Channel Bedload Transport Hydraulic Evaluation

Labor	$30,000
Equipment rental	$5,000
Travel expenses	$5,000
TOTAL	$40,000

Develop sediment transport model for mainstem. Estimate volume and particle size composition of major tributary inputs. Estimate coarse bedload input from channelbank scour. Bed mobility measurements and bedload monitoring results. Model mainstem to identify channelbed thresholds and channel reaches impeding coarse bedload transport.

June, 1997
Limiting Factor Analysis for Contemporary River Channel Dynamics and Anadromous Salmonid Populations

Labor	$20,000
TOTAL	$20,000

Identification and evaluation of geomorphic and hydrologic factors that directly or indirectly limit healthy river channel dynamics and/or salmonid populations. Comparison to past channel morphology and hydrology.

November, 1997
Restoration Site Identification, Design Recommendations, Cost Evaluation, and Implementation Constraints

Labor	$70,000
Equipment rental	$2,000
Travel expenses	$8,000
TOTAL	$80,000

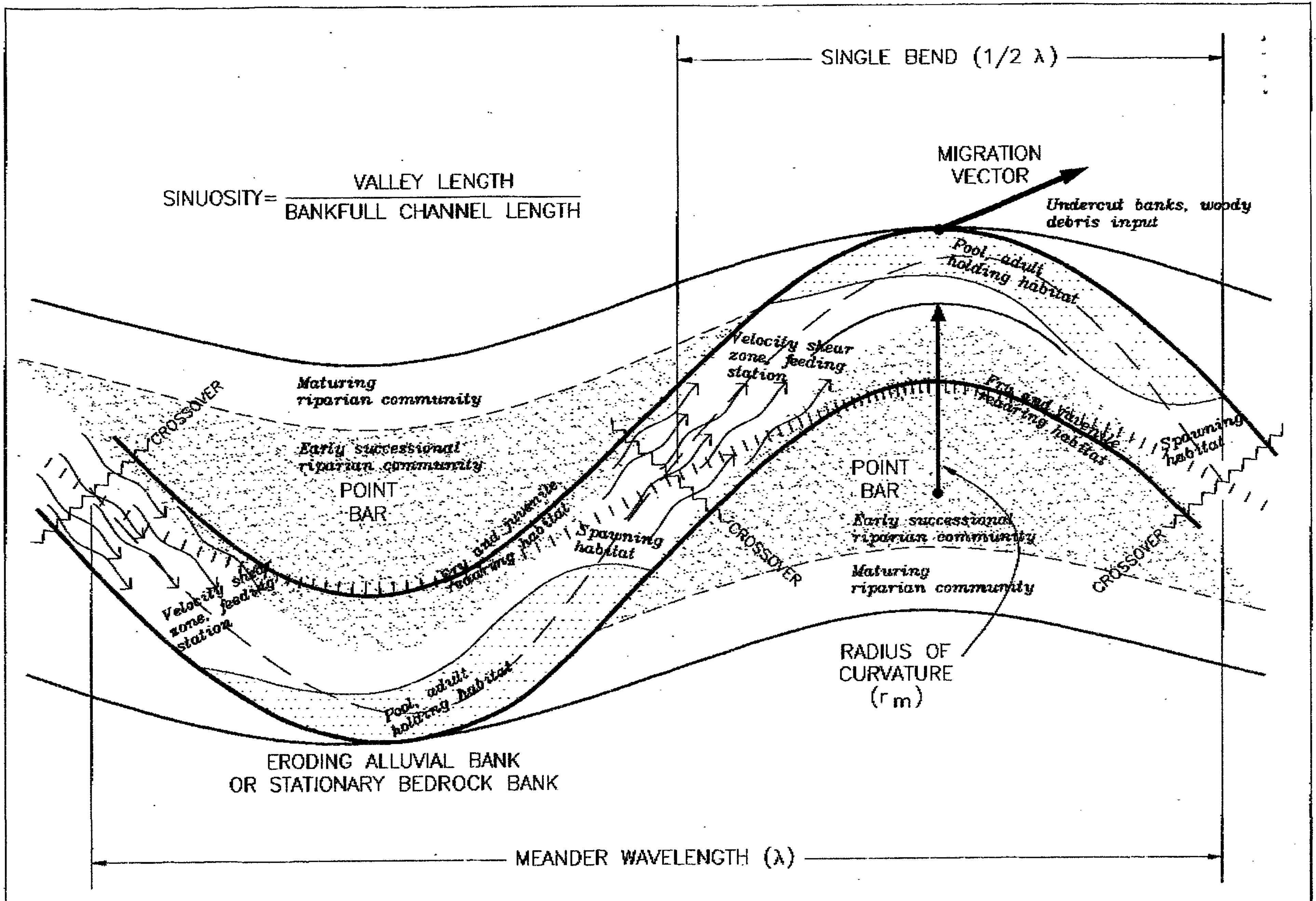
Development of site-specific pilot project designs of sufficient detail to be used as bid documents.

December, 1997
Final Report and Presentation on Restoration Plan Recommendations

Labor	$14,000
Production expenses	$1,000
TOTAL	$15,000

Release of final draft report.

GRAND TOTAL **$225,000**



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GEOMORPHIC FEATURES OF AN IDEALIZED ALTERNATE BAR SEQUENCE

PREPARED FOR:

DRAWN BY	RM	DATE	1/8/96
CHECKED BY	SM	REVISION	REV B

LEGEND

- LOW FLOW CHANNEL
- BANKFULL CHANNEL
- RIFFLE
- TERRACE
- THALWEG
- BEDLOAD TRANSPORT PATH
- DEEPER PORTION OF POOL