ADMINISTRATIVE DRAFT

Coarse Sediment Management Plan
Lewiston Dam to Grass Valley Creek
Trinity River, CA

Prepared For:

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1 INTRODUCTION

Prior to the construction of the Trinity River Division (TRD) of California's Central Valley Project, sediment was delivered to the Trinity River by a combination of hillslope and fluvial processes. Rainfall and runoff processes eroded and delivered sediment from hillslopes in the watershed to tributary channels, which transported their sediment load to the Trinity River. Climatic variations have caused this erosion and transport to fluctuate over moderate timescales (hundreds to thousands of years) but in general, sediment eroded from the watershed was transported out of the basin by the Trinity River such that watershed erosion and sediment delivery rates to the Trinity River were in balance with the fluvial transport and sediment export from the basin. This condition can be called a "dynamic quasi-equilibrium", where climatic fluctuations have shifted the balance between sediment supply to, and sediment export by, the Trinity River, but the overall trend of a balance between supply and export persisted. However, following completion of the TRD with the construction and operation of Trinity and Lewiston Dams, the sediment balance shifted. Trinity Dam traps all coarse sediment delivered from the watershed above the dam, and as a result, the coarse sediment balance below the dams has been significantly reduced.

The reduction in coarse sediment supply caused by the TRD has perpetuated downstream through the alluvial system. Below Lewiston Dam, the Trinity River channel has experienced adverse changes to channel processes and channel form, which in turn has affected the riverine habitat and biota. Contemporary understanding of river ecosystems recognizes that the underlying hydrology (water) and geology (e.g., sediment) are the primary governing variables of these systems; how water and sediment interact with vegetation and human influences result in the fluvial processes that define the channel form. Correspondingly, the resulting channel form defines aquatic and terrestrial habitat within the river corridor, which influences the biota that humans are usually interested in managing. If habitat along the river corridor is to be restored, the fluvial geomorphic processes responsible for forming and maintaining the alluvial features that help define the habitat must also be restored.

Recommendations in the Trinity River Mainstem Fishery Restoration Record of Decision (ROD) attempt to reverse the impacts to the river below Lewiston Dam by using a combination of high flow releases from Lewiston Dam, sediment management, and channel rehabilitation along the river corridor. The ROD adopts a restoration approach that re-establishes many of the attributes of the healthy pre-TRD channel (processes, morphology and habitat) as the foundation for fishery recovery. The recommended ROD high flow releases require large volumes of coarse sediment to be introduced into the river, which is a strategy originally recommended by the Trinity River Flow Evaluation Study (TRFES) (USFWS and HVT, 1999). Specifically, the TRFES presented a series of annual coarse sediment introduction recommendations. However, these recommendations are broad and general in scope. It is therefore the purpose of this report to present a coarse sediment management plan that provides specific details for implementing the intended coarse sediment management strategy.

This report presents a coarse sediment management plan and coarse sediment monitoring program for the Trinity River between Lewiston Dam and Grass Valley Creek, and is prepared as a guideline for supplementing sediment-depleted reaches below Trinity and Lewiston Dams. The conceptual foundation for this plan is based on: *1) restoring fluvial geomorphic processes to the Trinity River below Lewiston Dam, by 2) restoring adequate coarse sediment storage to the channel in which the river can restore its ability to create and maintain high quality aquatic habitat, and then 3) maintaining coarse sediment storage by a combination of mechanical coarse sediment introduction, tributary sediment management, and high flow releases.*

The coarse sediment management plan is developed in two phases. This report presents Phase I, which identifies potential coarse sediment addition locations, volumes and size ranges of sediment to be introduced, describes potential placement methods, and presents a monitoring program to evaluate the evolution of introduced sediments. Phase II, which will be completed at a later date, will focus on the potential use of dredge mine tailings as a source of spawning gravel for future additions to the river. Phase II includes identifying gravel source locations, prioritizing gravel source locations, estimating the volume of material at each location, determining possible mercury contamination, site access, materials moving and processing costs, stockpiling locations, and public relations.

The following sections of this report present the coarse sediment management strategy and the coarse sediment monitoring plan. Section 2 of this report describes the project background, defines "sediment" terms, prepares conceptual models, describes fluvial geomorphic links to biologic processes, and describes historic coarse sediment introductions within the project reach. Section 3 presents our strategy and objectives in developing the coarse sediment management plan. Sections 4, 5, and 6 represent the technical portion of this report: Section 4 describes coarse sediment introduction, including site identification, placement methods, and placement recommendations, Section 5 discusses tributary delta management, and Section 6 presents the coarse sediment management monitoring plan.

2 BACKGROUND

2.1 Definition of terms

In describing coarse sediment management, there are several potentially confusing terms used. Therefore, we define these terms as they are used in the context of this report.

Aggregate: A mass or body of rock particles.

Alternate bar sequence: An alternate bar sequence consists of two aggradational lobes, or point bars, opposite and longitudinally offset from one another, connected by a transverse bar. The low water channel meanders in a sinusoidal pattern between the point bars.

Bedload: The coarsest portion of the sediment load transported by a stream. It is intermittently transported by the stream and commonly composes the channel bed and banks. When the bed material load is mobilized, it travels along or very near the channel bottom, and typically comprises 5% – 15% of the stream's total sediment yield (excluding the dissolved component).

Coarse sediment: Sediment particle sizes 2 mm and larger. The coarse sediment size range can be subdivided into the specific size classes of gravel (2 mm to 64 mm), cobble (64 mm to 256 mm), and boulder (256 mm and larger) (Bunte and Abt, 2001). Size classes can be further modified into sizes between very fine and very coarse (gravel) or small to large (cobble and boulder). A coarse sediment size gradation chart is presented in Appendix A.

Coarse sediment introduction aggregate: Processed coarse sediment source aggregate, with particles of diameter between 0.3 inches (8 mm) and 6 inches (152 mm) used based on the ROD flow regime. If dredge tailings are used as a spawning gravel source, particle sizes less than 0.3 inches (8 mm) and greater than 6 inches (152 mm) diameter are removed. Coarse sediment introduction is not synonymous with spawning gravel introduction, although the particle size distribution contains the range of sizes greatly beneficial to spawning salmonids.

Coarse sediment introduction site: A location within the project reach, historically used or identified in this report as a suitable location for future coarse sediment introduction.

Coarse sediment sources: Sources of stockpiled, unprocessed aggregate with particle sizes ranging from silt to boulder. Within the project reach, these sources are typically composed of dredge tailings.

Fine sediment: Sediment particle sizes less than 2mm. The fine sediment size range can be subdivided into the specific size classes of sand (2.0 mm to 0.063 mm), silt (0.063 mm to 0.0039 mm), and clay (0.0039 mm and finer) (Bunte and Abt, 2001). Sand size classes can be further modified into sizes between very fine and very coarse.

Medial bar: A long, narrow deposit of sediment (predominately gravels and cobbles), developed mid-channel, and oriented parallel with the direction of streamflow with water conveyed on both sides of the bar during summer baseflows.

Point bar: One of a series of low, arcuate ridges of sediment (commonly sand and gravel) developed on the inside of growing meander by the addition of individual accretions accompanying migration of the channel along the outer bank.

Riparian Berm: Sand deposit along the low flow channel margin created as encroaching riparian vegetation slows water velocities during high flows and induces deposition of suspended fine sediments. Riparian berms are common in regulated rivers that continue to have a substantial fine sediment supply.

Spawning gravel introduction aggregate: Processes and washed coarse sediment source aggregate typically between 0.5 inches (13 mm) and 4 inch diameter. This coarse sediment management plan does not recommend spawning gravel introduction.

Suspended load: The finer portion of the sediment load transported by a stream. During transport, particles are suspended in the water column. Suspended sediments typically represent 85% – 95% of the stream's total sediment yield (excluding the dissolved component).

Transverse bar: Deposit of sediment (predominately gravels and cobbles) connecting two point bars within an alternate bar sequence. Riffles are nearly always transverse bars.

2.2 Fluvial geomorphic impacts

Trinity Dam traps all sediment delivered from the watershed above the dams. As a result, the only natural coarse sediment supply downstream of the dams comes from tributaries (e.g., Rush Creek and Grass Valley Creek in the project reach, and Indian Creek and Weaver Creek downstream). Because regulated flows downstream of the dams have been generally too small and too infrequent to distribute the coarse sediment supplied by the tributaries, large deltas have formed, which have caused backwater conditions upstream of the deltas and aggraded the mainstem channel. In conjunction with the tributary delta formation, the post-dam flow regime is incapable of moving larger pre-dam alluvial deposits (boulders). This combination of reduced flow and reduced coarse sediment supply generated a host of adverse geomorphic and biological impacts. Several studies, including the TRFES, Trinity River Flushing Flow Study (Wilcock et al. 1995), and the Trinity River Maintenance Flow Study (McBain and Trush 1997) have documented these specific impacts.

The TRFES summarizes the adverse changes to the Trinity River between Lewiston and the North Fork Trinity River, where changes were most severe. This summary illustrates that, in addition to blocking access to salmonid habitat beyond the dams, the following occurred:

- *Export of 90 percent of the average annual water yield into the Sacramento River basin;*
- *Extremely large floods decreased from 70,000 – 100,000 cubic feet per second (cfs) to 6,000 – 14,500 cfs;*
- *Elimination of large floods greater than 14,500 cfs and very few high flows greater than 6,000 cfs;*

- *Near elimination of baseflows exceeding 450 cfs at Lewiston;*
- *Annual flow variation that once varied from 25 cfs to over 100,000 cfs prior to the Trinity River Diversion was held constant at 150 to 450 cfs (with the infrequent exception of Safety of Dams releases, typically less than 6,000 cfs);*
- *Coarse sediment supply from the upper watershed was trapped by Trinity Dam.*

These changes in sediment and water supply caused physical changes to the channel, including:

- *Loss of coarse sediment supply and reduced high flow regime greatly reduced the dynamics of the Trinity River (e.g., channel migration, avulsion, bar formation);*
- *Gravel and cobble deposits used by spawning and rearing salmonids were not replenished by upstream sources, decreasing the amount and quality of these habitats;*
- *Reduced flow volume, magnitude, and duration in the mainstem Trinity River caused tributary sediments to accumulate at deltas at the confluence with the Trinity River. Coarse sediment remained at or immediately downstream of the tributary confluence, causing local aggradation, downstream steepening, and upstream backwater. These effects are most pronounced at Rush Creek, Grass Valley Creek, and Indian Creek confluences. Sand, however, was partially routed downstream, and accumulated in pools, spawning gravels, and along the channel margin as riparian berms;*
- *Constant low flows during the seed dispersal period for woody riparian vegetation provided ideal environmental conditions for good seed germination and initiation of seedlings. The lack of high flows prevented seedlings from being scoured away. Therefore, the plants were able to establish and mature along the low water channel margin, becoming impossible to remove with controlled flow releases from Trinity and Lewiston Dams;*
- *Establishment and maturation of the riparian community fossilized bar deposits, functionally removing an important source of alluvium to the mainstem Trinity River, and;*
- *The riparian berm functionally narrowed the channel width, increased depth, and increased average velocity for flows between 500 cfs and 5,000 cfs (where flows begin to spill over the berm).*

These are typical responses of a river to upstream flow and sediment regulated by a large storage reservoir (Collier et al. 1996). The results and conclusions presented in the TRFES was incorporated into the Trinity River Mainstem Fishery Restoration Environmental Impact Statement / Report (CH2MHill 2000), and the Secretary of the Interior adopted the management recommendations of the TRFES in the ROD, which was signed by former Secretary Bruce Babbitt in December 2000.

The ROD “recognizes that restoration and perpetual maintenance of the Trinity River’s fishery resources require rehabilitating the river itself, restoring the attributes that produce a healthy, functioning alluvial river system”. As such, one of the primary components of the ROD is increasing the high flow regime to the Trinity River downstream of Lewiston Dam. Because restoring fluvial geomorphic processes requires a coarse sediment supply in balance with the river’s flow regime, coarse sediment management is a required component to restore the river’s fluvial geomorphic processes and aquatic habitat components. McBain and Trush (1997) developed the Attributes of Alluvial River Ecosystems, which were incorporated into the TRFES as well as the Environmental Impact Statement / Report. These attributes are guiding principles for the Trinity River Restoration Program brochure and are summarized as follows:

Attribute 1. Channel morphology and habitat is spatially complex.

Attribute 2. Flow regime and water temperatures variable over a year, and between years.

Attribute 3. The gravel-bed surface is frequently mobilized.

Attribute 4. The gravel-bed surface is periodically scoured and redeposited.

Attribute 5. Fine and coarse sediment supply from the watershed is balanced by river transport.

Attribute 6. The channel periodically migrates or avulses across the floodway.

Attribute 7. The river has a floodplain that is frequently inundated.

Attribute 8. Very large floods occur on an infrequent basis that re-organizes the channel and riparian vegetation.

Attribute 9. Riparian vegetation is self-sustaining, and is spatially and structurally diverse.

Attribute 10. The water table adjacent to the river is often connected to the river.

Restoring these attributes will begin the restoration process. Because many of these attributes require a combination of high flow management and coarse sediment management (i.e., Attributes #1, 3, 4, 5, 6, 7, and 8), coarse sediment management is a mandatory restoration approach. If coarse sediment supplies and fluvial geomorphic processes can be restored within the project reach to rebuild bars and other alluvial features, these reaches could provide substantially improved habitats for anadromous salmonids. The introduced gravel could also eventually route downstream of the project reach to the lower alluvial reaches, potentially providing uninterrupted bedload transport continuity from Lewiston Dam to possibly reaches below Weaver Creek. However, the limits of the project reach for this plan only extend from Lewiston Dam downstream to Grass Valley Creek. The project limits were not extended further downstream because: 1) Coarse sediment introduction is needed most in the reaches closest to Lewiston Dam, 2) Reaches downstream of Indian Creek have adequate coarse sediment supply from tributaries, and 3) Reaches between Lewiston and Grass Valley Creek are easiest to manage (e.g., land ownership, access). For these three reasons, we are focusing on the reach from Lewiston Dam to Grass Valley Creek first.

2.3 Project Location and Reach Delineation

This coarse sediment management plan focuses on the reach beginning at Lewiston Dam, located at river mile (RM) 112.0, and extending 8 miles downstream to the confluence of Grass Valley Creek (RM 104.0) (Figure 1). We delineated two separate reaches based on our conceptual model of coarse sediment storage and transport capacity (see Section 2.4). The reach delineation is as follows: Reach 1: Lewiston Dam to Rush Creek confluence, and; Reach 2: Rush Creek confluence to Grass Valley Creek confluence. These delineations are discussed below and are shown in Figure 2.

<u>Reach 1: Lewiston Dam to Rush Creek confluence (RM 112.0 to 107.6)</u>

Reach 1 begins at Lewiston Dam and extends 4.4 miles downstream to the confluence of Rush Creek. Natural coarse sediment supply to this reach comes primarily from Deadwood Creek (RM 110.8) and Hoadley Gulch (RM 109.9). Deadwood Creek has a relatively small in drainage area (DA = 8.9 mi^2) and contributes less sediment than the major tributaries (e.g., Rush Creek, DA = 22.7 mi^2), and as a result, delta formation at its confluence with the mainstem channel is minor. Other natural coarse sediment enters the channel in Reach 1 resulting from hillslope processes (e.g., landslides, rock fall)

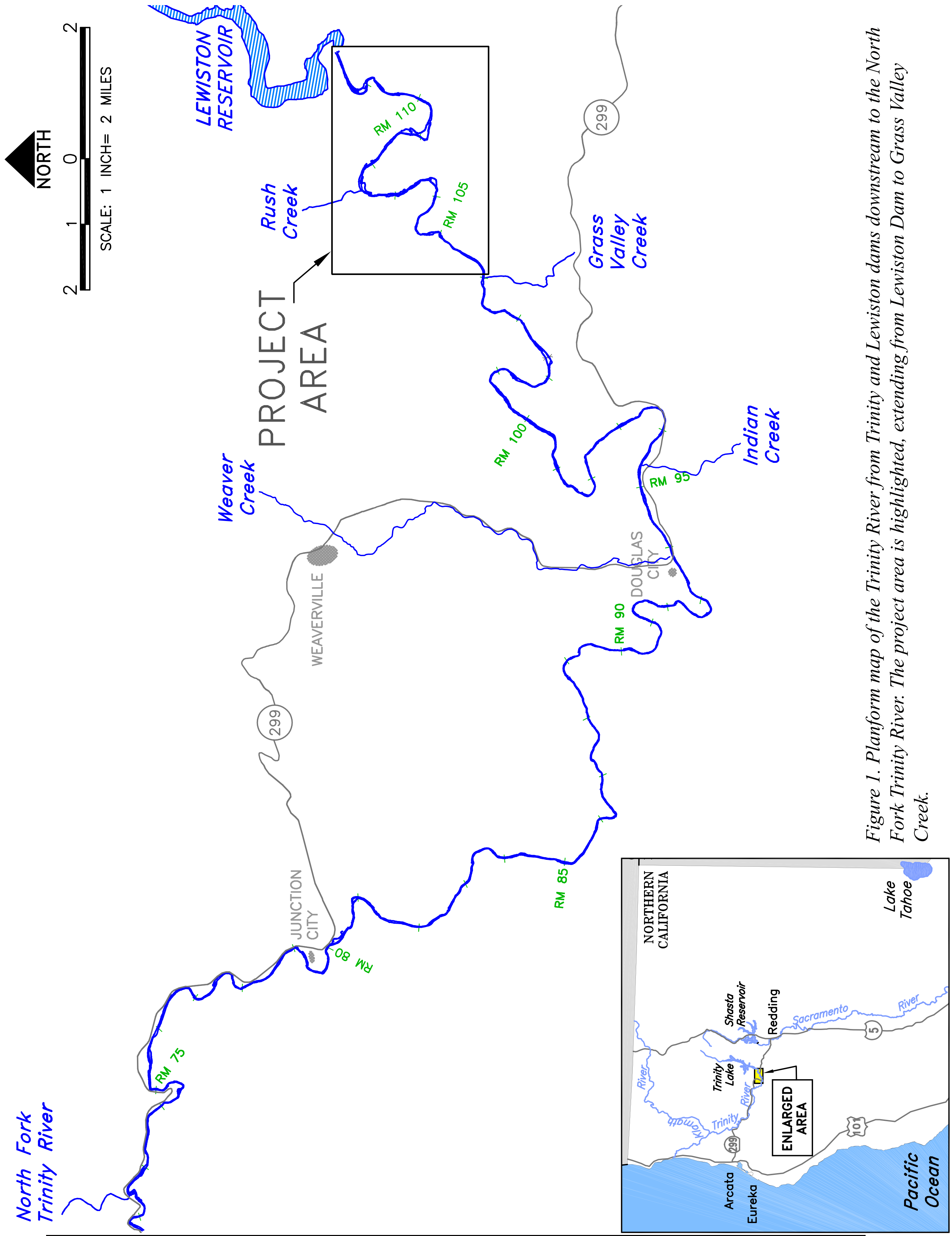


Figure 1. Planform map of the Trinity River from Trinity and Lewiston dams downstream to the North Fork Trinity River. The project area is highlighted, extending from Lewiston Dam to Grass Valley Creek.

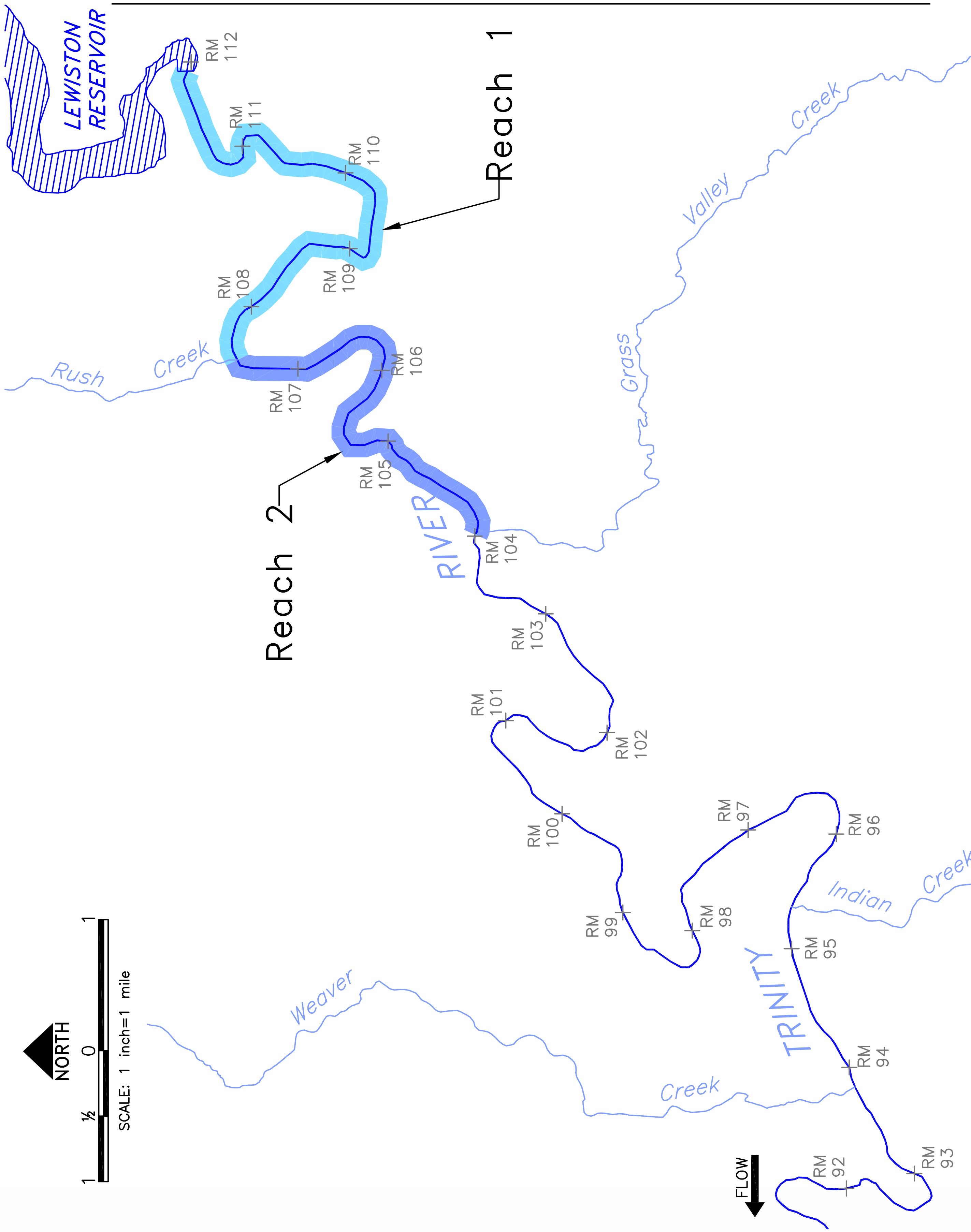


Figure 2. Planform map of the project area Lewiston Dam to Weaver Creek showing geomorphic reach delineations.

and fluvial processes (e.g., bank erosion). Bank erosion occurs mainly at the Cemetery Hole (RM 109.45), and the overall sediment supply at this location is relatively minor. Coarse sediment has also been supplied to this reach from previous coarse sediment introduction programs (see Section 2.5). Sediment routing in Reach 1 is limited by sediment supply, sediment type (coarse versus fine), regulated flow releases below Lewiston Dam, and the backwater formed by the Rush Creek delta.

Reach 2: Rush Creek confluence to Grass Valley Creek confluence (RM 107.6 to 104.0)

Reach 2 begins at the Rush Creek confluence and extends 3.6 miles downstream to the Grass Valley Creek confluence. Reach 2 is similar to Reach 1; the mainstem channel exhibits similar hydraulic and geomorphic characteristics, and sediment transport is limited by sediment supply, sediment type (coarse versus fine), regulated flow releases below Lewiston Dam, and the backwater formed by the remnant Grass Valley Creek delta. Natural sediment supply in Reach 2 comes primarily from Rush Creek, and to a minor extent from Dark Gulch (RM 106.1). Other natural coarse sediment sources include hillslope processes and fluvial processes. Similar to Reach 1, but not as extensive, coarse sediment has been supplied to this reach from previous coarse sediment introduction programs (see Section 2.5).

2.4 Conceptual Models

The natural characteristics of a river ecosystem are created and maintained by geomorphic and hydrologic processes that result from energy and material interactions between flowing water and sediment supply, and from secondary influences of riparian vegetation. Correspondingly, the channel morphology provides aquatic and terrestrial habitat within the river corridor, and thus influences the abundance and distribution of riverine biota. These interactions can be conceptualized using a generalized hierarchical model of river ecosystems that incorporates the following elements: SUPPLY, PROCESSES, FORM, HABITAT, and BIOTA (Figure 3)

The primary natural components of SUPPLY are water and sediment, with some influence by large wood. Changes to the input variables (SUPPLY) in this conceptual system usually cascade down to the biota, but this cascading effect is usually not adequately considered before the change is imposed on the system. The primary natural components of the PROCESSES tier are sediment transport, sediment deposition, channel migration, channel avulsion, nutrient exchange, and surface water-groundwater exchange. In turn, these channel and floodplain features provide the physical location and suitable conditions that define habitat for aquatic organisms, including native fish species. Channel morphology is thus a critical linkage between fluvial processes and the native biota that use the river corridor.

The Trinity River exhibits a dynamic gradient of habitat types over the project reach. Salmonids, their habitats, and other aquatic flora and fauna are distributed in relatively predictable ways along that gradient, according to their specific life history requirements. Hence, describing the historic and contemporary fluvial geomorphic processes that form and maintain alluvial rivers is important for assessing related ecological impacts. The following sections describe the general fluvial processes that form and maintain alluvial rivers (SUPPLY, PROCESS, and FORM) and the biological requirements (HABITAT and BIOTA) that are linked to the fluvial processes focusing on the Trinity River project reach.

2.4.1 Fluvial Processes

An alluvial river requires a coarse sediment supply to function properly. The Trinity River historically transported its sediment load from its headwaters and tributary streams downstream to the Klamath River, forming a continuous link in sediment supply and downstream yield. Coarse and fine sediment budgets were maintained by an approximate balance in sediment inputs (supply), storage, and downstream transport which in turn maintained the natural channel morphology (Figure 4).

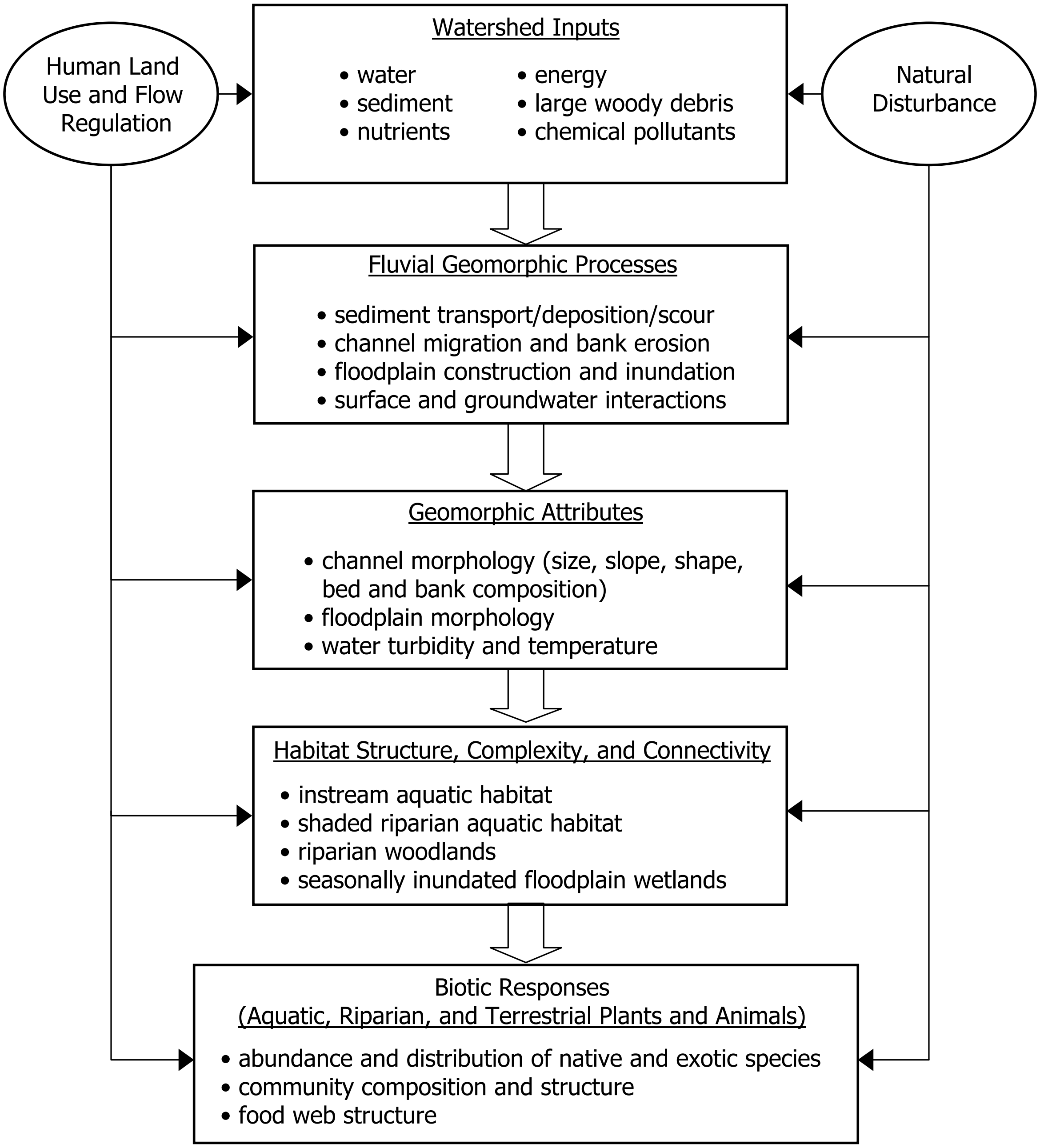


Figure 3. A simplified conceptual model of the physical and ecological linkages in an alluvial river system.

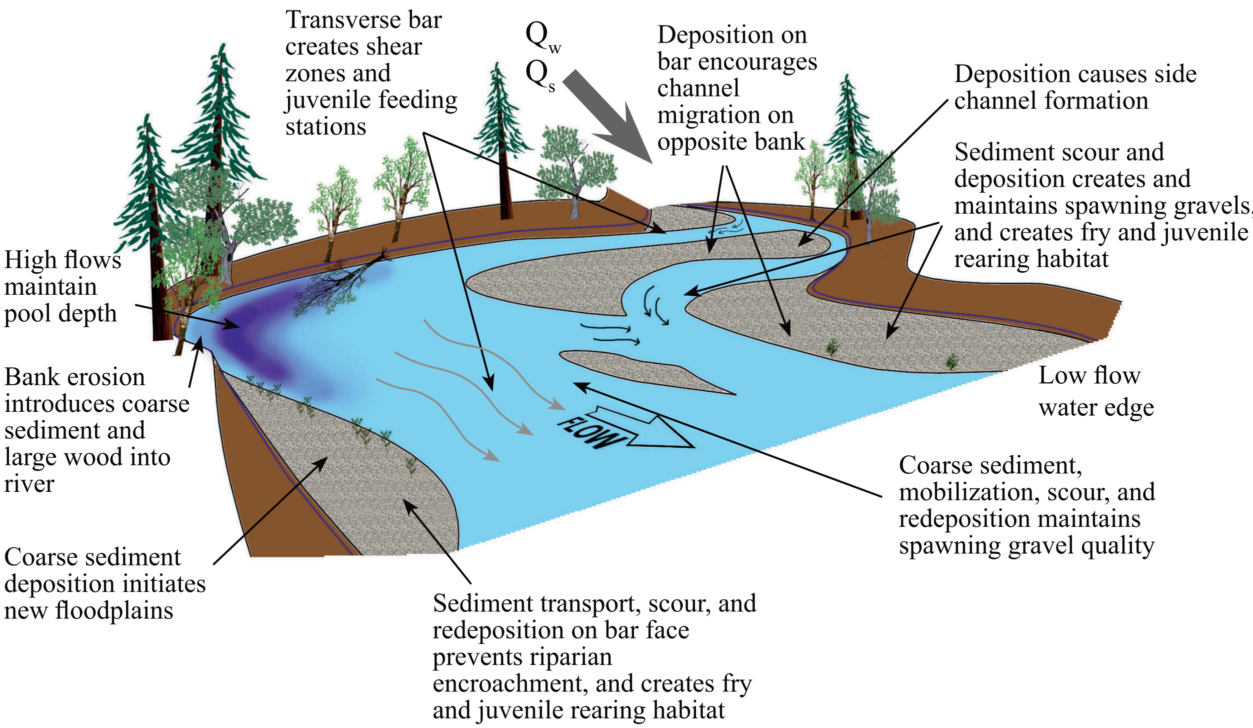


Figure 4. Comparative illustration (top) and photograph (bottom) of the Trinity River channel illustrating the dependency of channel processes and morphology on coarse sediment supply.

Figure 3 presented a broad conceptual model illustrating the cascading effect of water and sediment supply on the biota. If one were to focus on only the relationship between water and sediment supply to sediment transport and channel morphology, then a more specific conceptual model is needed. Lane (1955) provided a simple formula to illustrate the way in which rivers balance slope, sediment particle size, sediment transport, and streamflow to maintain a dynamic equilibrium:

$$Q_w * S \alpha Q_s * D_{50}$$

where: Q_w = stream discharge, S = stream slope, Q_s = sediment discharge , and D_{50} = median streambed grain size. In other words, the product of flow times slope is proportional to the product of sediment discharge times particle size. When one variable changes (e.g., flow), there is a corresponding change in the other variables (e.g., sediment discharge and/or particle size). This equation is graphically portrayed in Figure 5.

A balance in the sediment transport capacity provided by the high flow regime with sediment supplied from the watershed over time and distance results in a dynamic quasi-equilibrium, in which sediment is mobilized, transported, and deposited. The channel migrates (dynamic), but the size and shape of the channel remain similar (equilibrium) (Schumm 1977). While this presentation of the quasi-dynamic equilibrium concept of sediment supply and transport is considerably simplified, it is useful as a quantifiable objective for assessing and restoring fluvial processes. It also helps predict channel response to altered flow and sediment regimes. Trinity and Lewiston dams, and to a lesser extent, land management activities (e.g., road building) and natural disturbances (e.g., fire), have caused sediment imbalances in the channel through the project reach. For example, the reduced magnitude, duration, and frequency of high flows imposed by the TRD has allowed tributary sediments to accumulate at several deltas. Coarse bed material remained at or near the deltas, aggrading Rush Creek, Grass Valley Creek, and Indian Creek deltas. Sand, however, was partially routed downstream, and accumulated in pools, spawning gravels, and along the channel margin as riparian berm (e.g., DWR 1970).

The combination of accumulated fine sediment from reduced flood flows and the elimination of coarse sediment supply by the dams have degraded the alluvial features that provide salmonid habitat. Figure 6 shows a cross-sectional view of a typical alluvial channel. Without coarse sediment supply, the patch of coarse sediment shown in Section “A” (part 1) is scoured during high flows (part 2) but is not replenished (part 3). Over time, this repeated process generates a host of adverse alluvial impacts including:

- Decreased bed surface elevation;
- Bed surface coarsening as finer particles are winnowed out (armoring), resulting in 1) increased thresholds for bed mobilization, scour, and transport, and 2) reduced spawning habitat, potentially increasing juvenile overwintering and fry rearing habitat;
- Reduced channel dynamics;
- Reduced coarse sediment storage;
- Little to no change in bed surface fine sediment storage but possible increase in subsurface fine sediment storage.

These impacts can be contrasted with Section “B”, which shows the same coarse sediment patch but <u>with</u> a coarse sediment supply. During high flows, the sediment patch is scoured (part 1) and then replenished with sediment from upstream sources (part 2), resulting in no net change in bed surface elevation (part 3). Over time, this process promotes a healthy alluvial river by:

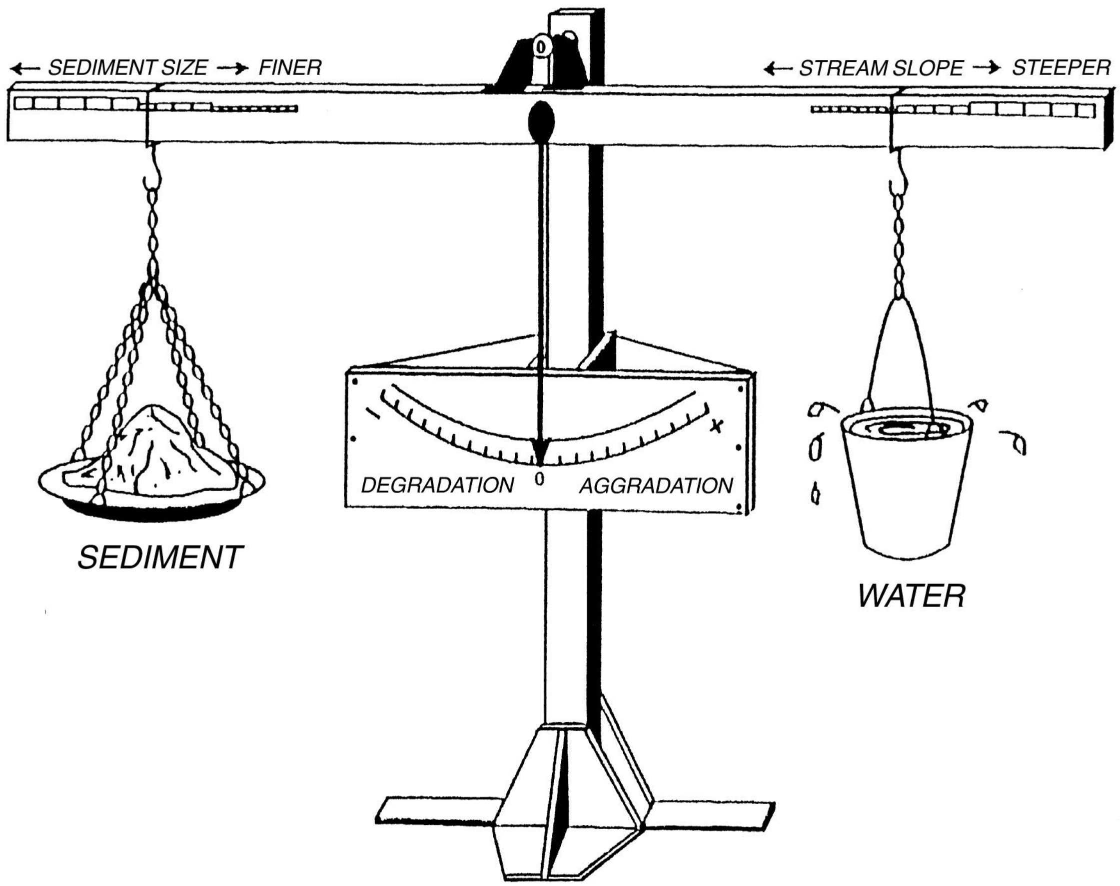


Figure 5. Conceptual flow-sediment balance necessary for channel equilibrium, and channel response to disequilibrium (from Lane, 1955).

- Maintaining the bed elevation;
- Maintaining bed particle size distributions and thereby: 1) preserving relative thresholds for bed mobilization, scour, and transport, and 2) maintaining alluvial features and the habitats they create;
- Preserving channel dynamics;
- Maintaining coarse sediment storage;
- Maintaining a balance with the fine sediment component of the sediment load.

Cumulative effects resulting from sediment imbalances can also be viewed on a reach-wide scale, and on the Trinity River include the following:

Mainstem channel:

- Reduced coarse sediment storage available to the river at most locations between Lewiston Dam and the North Fork Trinity River;
- Reduction in flows allowed riparian encroachment to fossilize bars along the low flow channel, simplifying the channel morphology, confining the channel, disconnecting the Trinity River from its floodplain, and increasing shear stress (via confinement) during infrequent high flows;

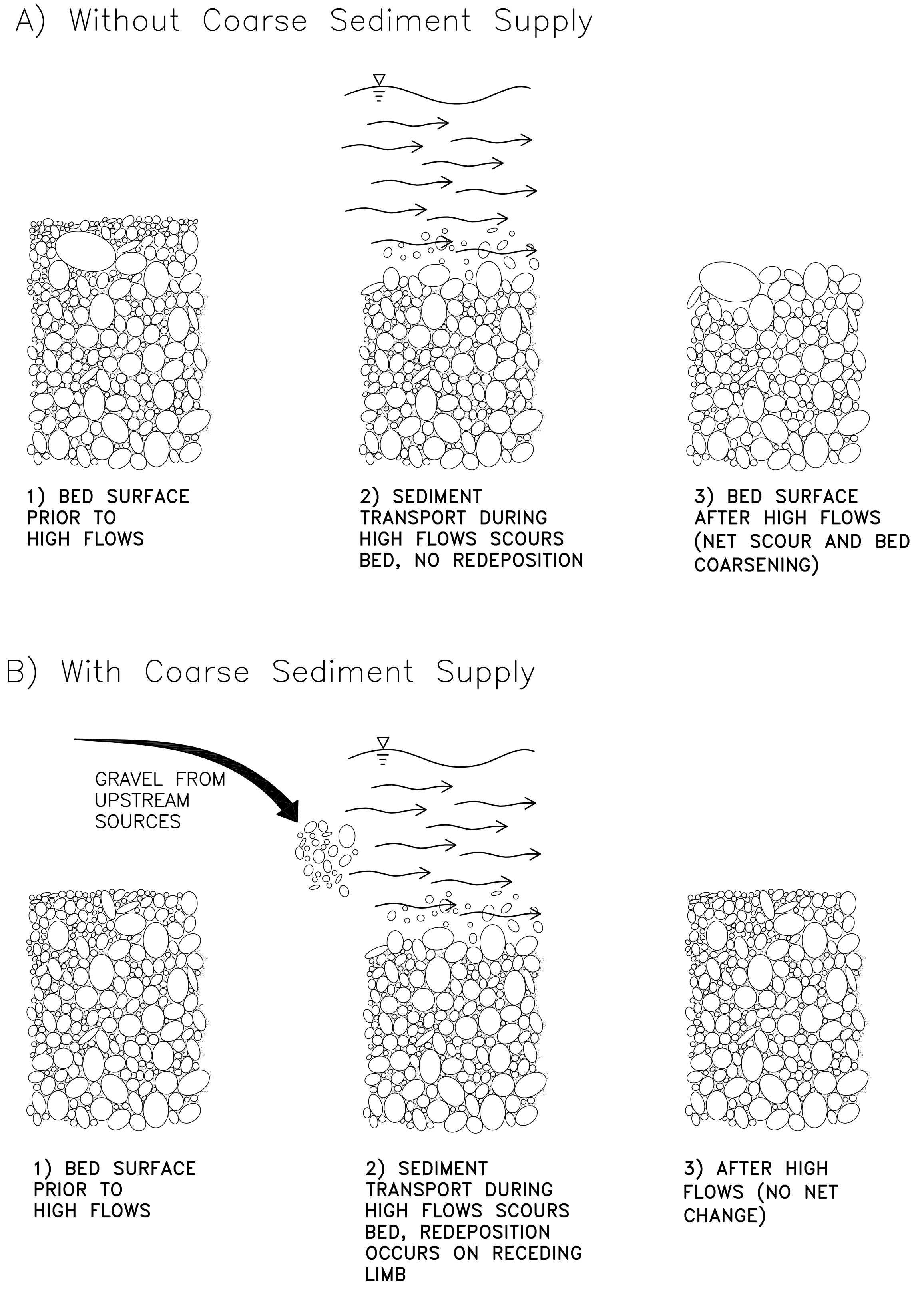


Figure 6. Conceptual diagram illustrating the effects of sediment imbalances resulting from a reduction in coarse sediment supply (section "A") compared to a balanced sediment budget and naturally functioning alluvial channel (section "B").

- Loss of upstream sediment supply caused local downcutting and bed coarsening in reaches without bedrock control;
- Reduced coarse sediment supply, reduced high flow regime, and riparian encroachment virtually eliminated channel migration and avulsion processes. Channel migration and avulsion was a critical process for preventing riparian encroachment, causing large wood input, and creating complex aquatic habitats.

Tributary deltas:

- Reduced flow regime (and potentially increased sediment yield from tributaries) allowed coarse sediment delivered by Rush, Grass Valley, and Indian Creek to accumulate locally;
- Inability of mainstem to distribute this coarse sediment downstream reduced the ability of the river to rejuvenate alluvial deposits downstream during infrequent high flow releases, further reducing coarse sediment storage in downstream reaches;
- Aggradation of over 10 feet in certain locations, causing flooding impacts (particularly downstream of Indian Creek);
- Aggradation at tributary deltas, caused by large backwater upstream on the mainstem Trinity River, eliminating the ability of the reach to route coarse sediment through the tributary delta.

To illustrate the evolution of the coarse sediment balance in the project reach, we have developed conceptual models for both pre-TRD (assumed unimpaired) and contemporary (regulated) sediment storage and routing conditions from Lewiston Dam downstream to Weaver Creek (RM 93.8) (Figure 7). Under these assumed unimpaired conditions, all sediment derived from the upper watershed and tributaries was eventually routed downstream through the project reach (Figure 7, Section A). Each reach adjusted its slope, width, and particle size to transport sediment at a rate equal to upstream supply, and is illustrated in Figure 7 by the relatively uniform thickness of the sediment “block”. Most importantly, sediment stored as alluvial features (gravel bars, pool tails, etc.) provided the distinct habitat features utilized by anadromous salmonids.

Section “B” of Figure 7 illustrates coarse sediment storage and routing resulting from the impacts of the TRD. The lack of sediment supply from the upper watershed, combined with infrequent, moderate magnitude floods capable of transporting coarse sediment supplied by tributaries, has resulted in the slow attrition of alluvial storage features (gravel bars, channel banks), progressive degradation of the channel (e.g., downcutting of the bed), coarsening/armoring of the bed surface, and the steady loss of salmonid habitat.

2.4.2 Biological Links to Fluvial Processes

Alluvial rivers are generally considered biodiversity hotspots as a result of high rates of energy and nutrient input, storage, and transport (Tietje et al. 1991, Stanford et al. 1996, Williams et al. 1999). Expansive floodplains with nutrient-rich soils, shallow groundwater, and high annual variability in both streamflow and temperature regimes contribute to a high biodiversity. Within alluvial reaches, the river’s planform morphology and channel geometry governs its habitat structure; alternating point bars and associated riffles and pools are the primary geomorphic units of alluvial rivers, and represent a key habitat template for all freshwater life stages of anadromous salmonids, as well as for other river biota.

The prevalent morphological feature within the bankfull channel of alluvial rivers is the alternate bar sequence. An alternate bar sequence consists of two aggradational lobes, or point bars, opposite and

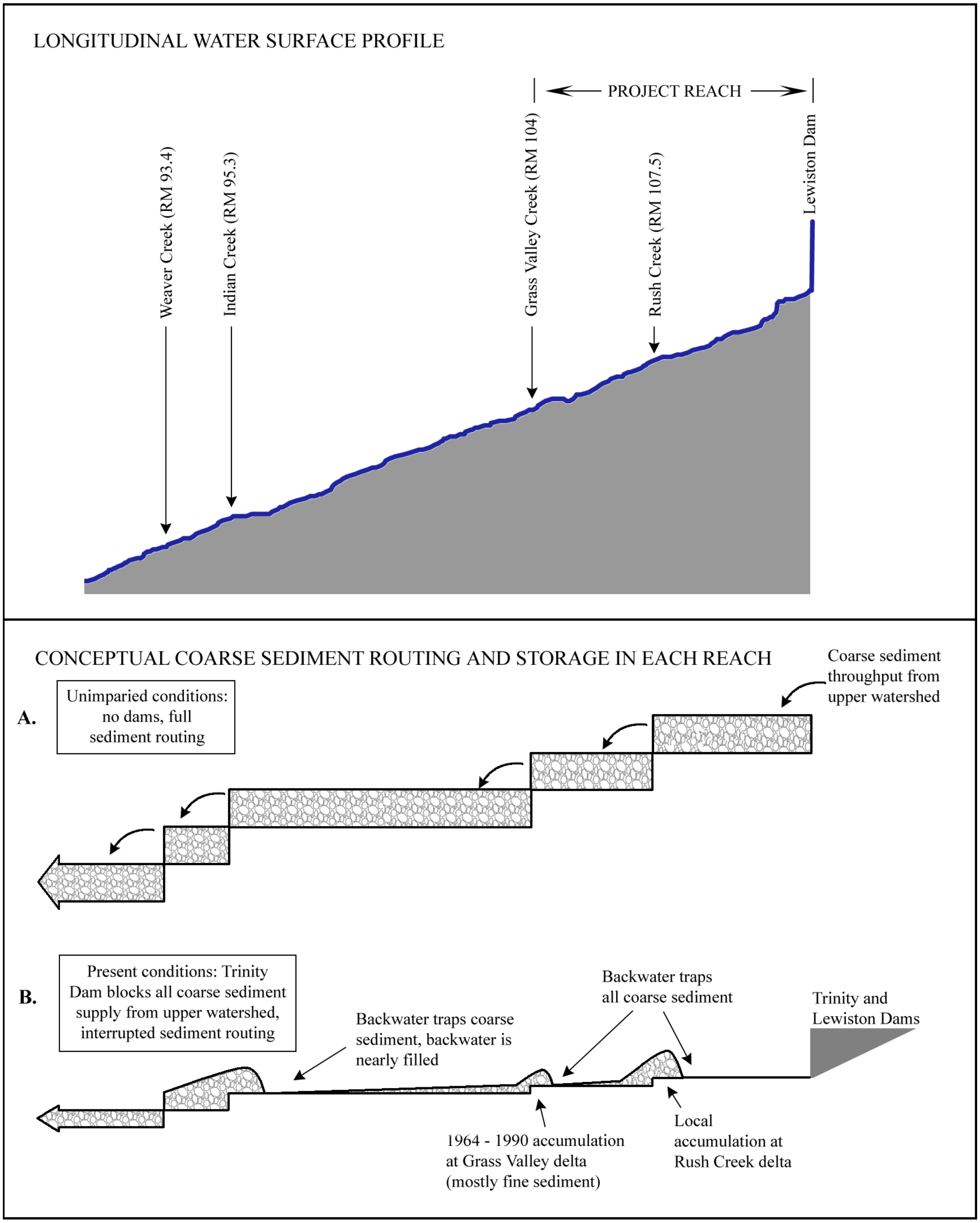


Figure 7. Conceptual model of historical and existing coarse sediment storage and routing from Lewiston Dam to Weaver Creek. Section "A" shows unimpaired conditions and full sediment routing prior to the construction of Trinity and Lewiston dams. Section "B" shows contemporary coarse sediment storage and routing conditions resulting from coarse sediment blockage by Trinity Dam.

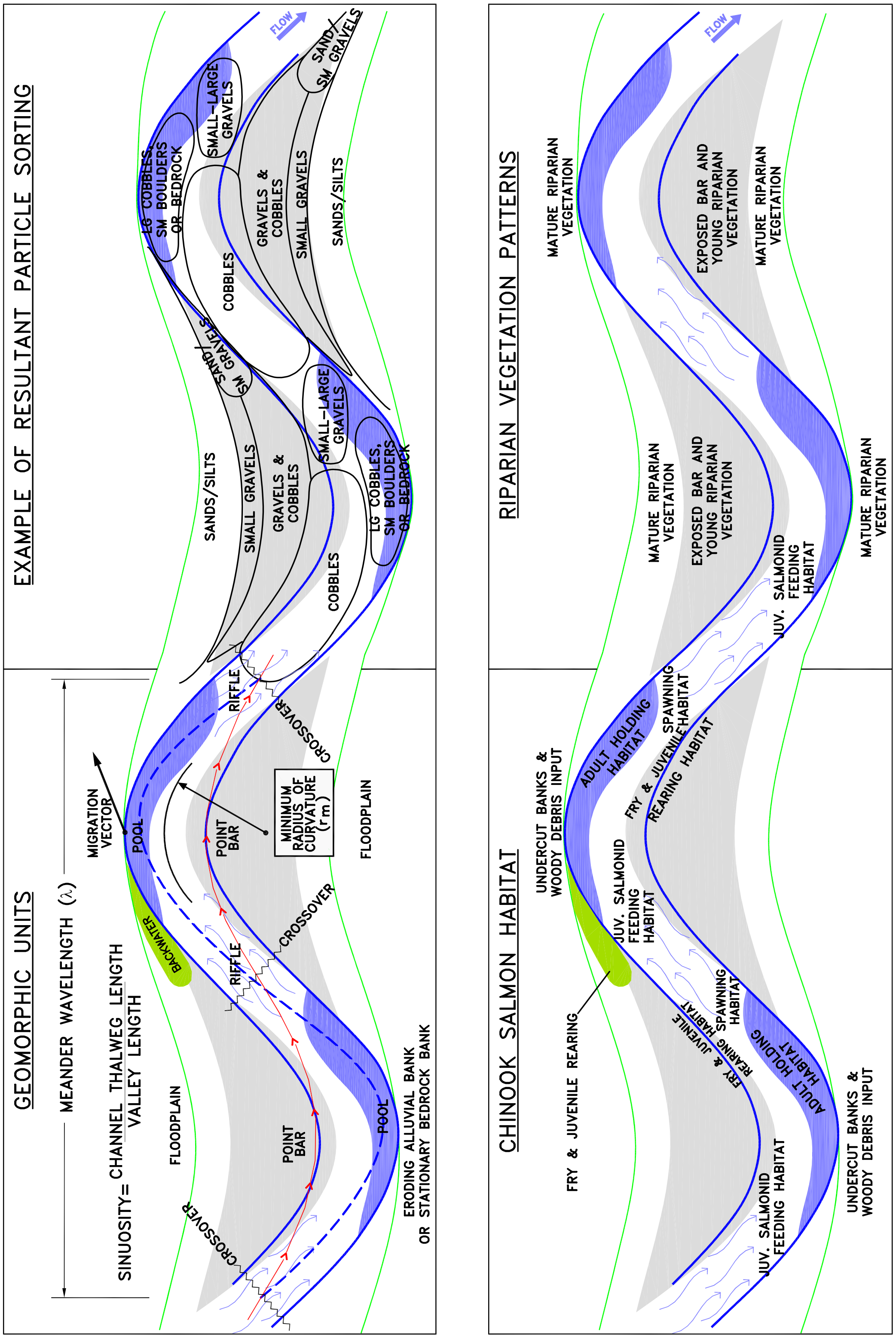
longitudinally offset from one another, connected by a transverse bar (Figure 8). The point bars are located adjacent the deep scour pool on the outside of the meander bend, and water flowing across the transverse bar forms a riffle, hence the traditional pool-riffle sequence. On a broader scale, two alternate bars form a complete channel meander commonly having a wavelength roughly equaling 9 to 11 bankfull channel widths (Leopold et al. 1964).

During low flows the channel meanders though the alternating point bars, but during high flows the bars become submerged and the flow pattern straightens. During these periods of high energy, bedload is transported primarily across the face of these alternating point bars rather than along the thalweg (the deepest portion of channel). In unregulated alluvial rivers, alternate bar surfaces mobilize frequently but the overall bar morphology and elevation are preserved between moderate floods. This attests to the channel form remaining relatively constant as sediment passes through the system, where sediment that is mobilized downstream during periods of high flow is later replenished by sediment deposited from upstream sources.

In addition to its persistence, the alternate bar sequence forms distinct, topographic and hydraulic environments that are extremely important to aquatic organisms, particularly as habitat for anadromous salmonids (Figure 8 and Table 1). For example, at typical baseflows (the lowest seasonal flows of the year), an alternate bar sequence provides adult holding areas, preferred spawning substrates, early-emergence slack water, and winter/summer juvenile rearing habitats. As the initial stages of flow increases (above baseflows) the different micro-habitats remain available, but in differing proportions and locations; suitable spawning habitat in pool tails migrates downstream deeper into the riffle and laterally up the bar face. Similarly, fry and juvenile rearing habitat along the shallow margins of point bars also migrates laterally onto the bar surface, and then onto the floodplain. The floodplain thus provides refugia (and highly productive habitat) for juvenile salmonids during high flow events.

Table 1. Geomorphic units, general particle sizes, and salmonid habitat components of alluvial channel features.

ALLUVIAL CHANNEL FEATURES UTILIZED BY SALMONIDS		
Geomorphic unit	***General particle size***	***Habitat component***
Point bar	Ranges from cobble and gravel near channel to small gravel and sand near floodplain transition.	Fry and juvenile rearing along channel margin
Riffle	Small to large cobble	Juvenile feeding, juvenile overwintering, spawning
Pool (scour hole)	Boulder and large cobble	Adult holding, summer juvenile rearing
Pool tail	Coarse to fine gravel	Spawning, egg incubation, juvenile feeding
Backwater	Fine gravel to sand	Winter and spring fry and juvenile rearing
Floodplain	Sand to silt	Fry and juvenile refugia during winter and spring floods
Side Channels	Gravel to cobbles	Adult spawning, fry and juvenile rearing



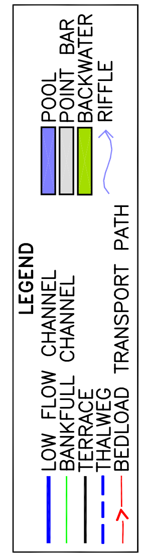


Figure 8. Conceptual alternate bar unit showing relationship of bar units to particle diversity, salmonid habitat, and riparian vegetation.

Creation and maintenance of alluvial features and the alternate bar morphology (and thus many of the critical habitat components) depends integrally on the supply, storage, transport, and deposition of coarse sediments within alluvial reaches. High quality salmonid spawning habitat, for example, requires a well-sorted distribution of gravel and small cobbles, frequent mobilization from winter floods to flush fine sediments, and a channel bed morphology that creates suitable hydraulic conditions for spawning and egg incubation. The highest quality rearing habitat for salmonid fry is often found along the shallow, slow velocity margins of alternate bars, where coarse sediments provide interstitial hiding places, productive invertebrate (food) habitat, and access to high flow refugia on top of lateral bars. As another example to link salmonid productivity and gravel supply, we portray the life history of fall-run chinook salmon, and correlate how coarse sediment supply satisfies habitat needs for each life history stage (Figure 9).

2.5 Coarse Sediment Introduction History

Recognizing the importance of coarse sediment to salmonid habitat and the sediment-depleted reach of the Trinity River below Lewiston Dam, several past efforts have been undertaken to improve coarse sediment supply and storage to the Trinity River. The U.S. Bureau of Reclamation (USBR), California Department of Water Resources (DWR), and U.S. Forest Service (USFS) have previously implemented short-term coarse sediment introduction projects on the Trinity River. These introduction efforts, including the year, location, and lead agency are presented in Appendix B.

Although these coarse sediment introduction efforts were successful in temporarily shifting the balance in sediment transport capacity, they were small-scale and short-term, and thereby only provided a temporary shift toward equilibrium conditions. Because the volumes of coarse sediment added were not spatially extensive nor was the sediment always annually replenished, the introductions did not achieve the continuous balance between transport and supply a longer-term sediment introduction program would offer. For example, some coarse sediment introductions were not followed by annual replenishments, and other additions were never fully mobilized from the introduction site (Loren Everest, personal communication, April 3, 2002). To best restore the sediment balance between supply and transport, a more comprehensive long-term coarse sediment introduction program will help restore a healthy alluvial river system and provide diverse and complex habitat for all life stages of salmonids. Therefore, this coarse sediment management plan is developed from both a fluvial geomorphic (SUPPLY – PROCESS) and a biologic (FORM – HABITAT – BOITA) perspective.

3 COARSE SEDIMENT MANAGEMENT PLAN

3.1 Strategy

The flow and sediment management recommendations presented in the TRFES outline both a short-term and a long-term strategy for coarse sediment introductions within the project reach. The short-term strategy was to rapidly (over the period of a few years) replenish coarse sediment storage in the reach between Lewiston Dam and Grass Valley Creek, with the effects possibly extending to reaches further downstream (e.g., Indian Creek), that was scaled to the future flow regime. The long-term strategy was to maintain storage by periodically introducing coarse sediment at a rate equal to transport by the yearly flow release schedule. This two-stage approach is designed to restore the sediment balance by first providing coarse sediment supply to the mainstem channel to increase coarse sediment storage, and then provide annual replenishments scaled to the flow release schedule. This strategy was adopted by the ROD and is also adopted in developing this coarse sediment management plan.

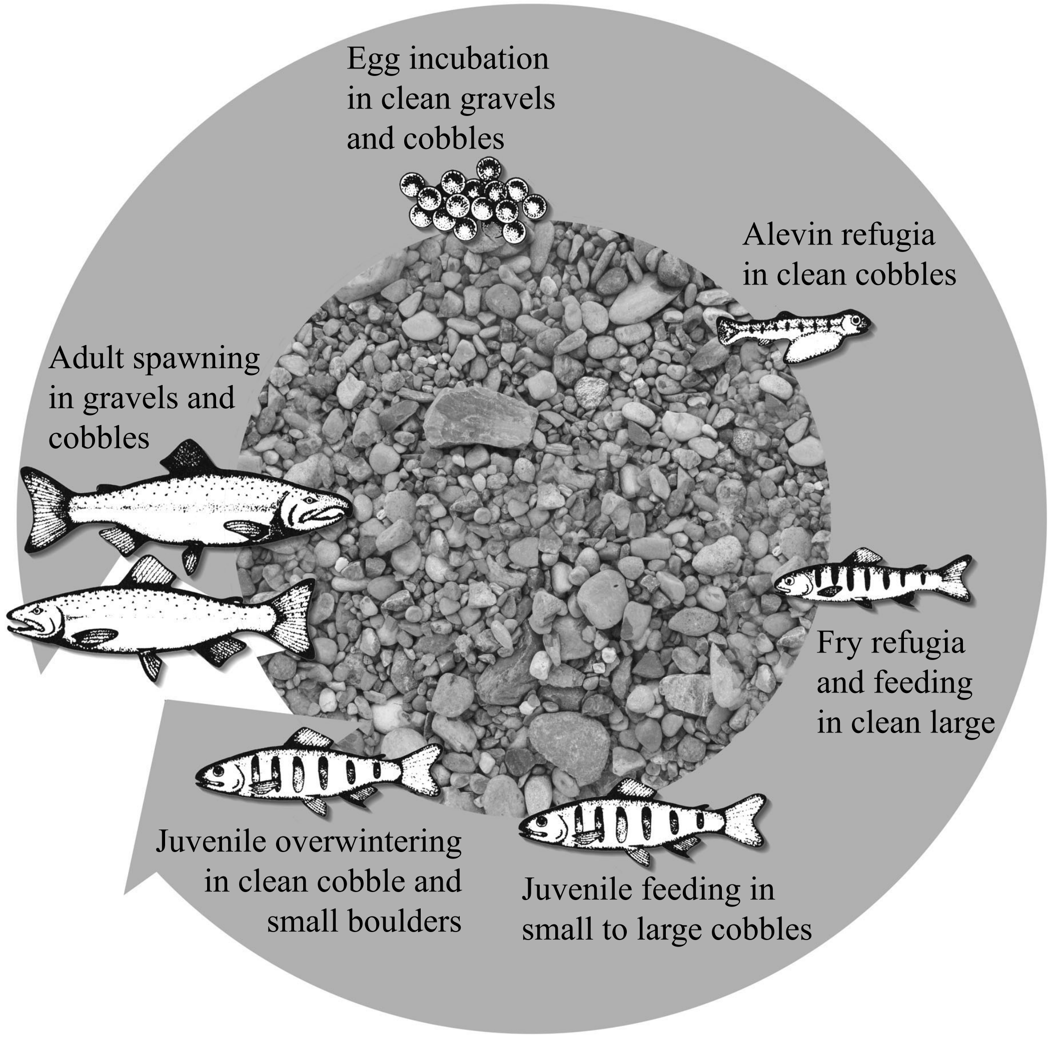


Figure 9. General habitats provided by coarse sediments for fall-run chinook salmon life-stages.

3.1.1 Short-term strategy

The short-term strategy of the TRFES recommended adding coarse sediment to the channel at two historic coarse sediment introduction sites: the reach adjacent to the fish hatchery (approximately RM 111.5) and the reach where the USGS cableway is located (approximately RM 110.2). For this coarse sediment management plan, we have identified several other potential short-term coarse sediment introduction locations in addition to the two TRFES recommended sites (the new coarse sediment management plan introduction sites are presented in Section 4). Coarse sediment additions at short-term sites should take place during the first year of gravel management. This strategy adds large volumes of coarse sediment (e.g., 1,000 yd^3) at multiple introduction sites in Reaches 1 and 2, thereby increasing the overall coarse sediment storage in the mainstem channel. This multiple-site strategy allows for a spatially extensive supply of coarse sediment to the project reach over a short period, opposed to using a single site that would require more time to distribute the same volume of coarse sediment over the same area (Figure 10).

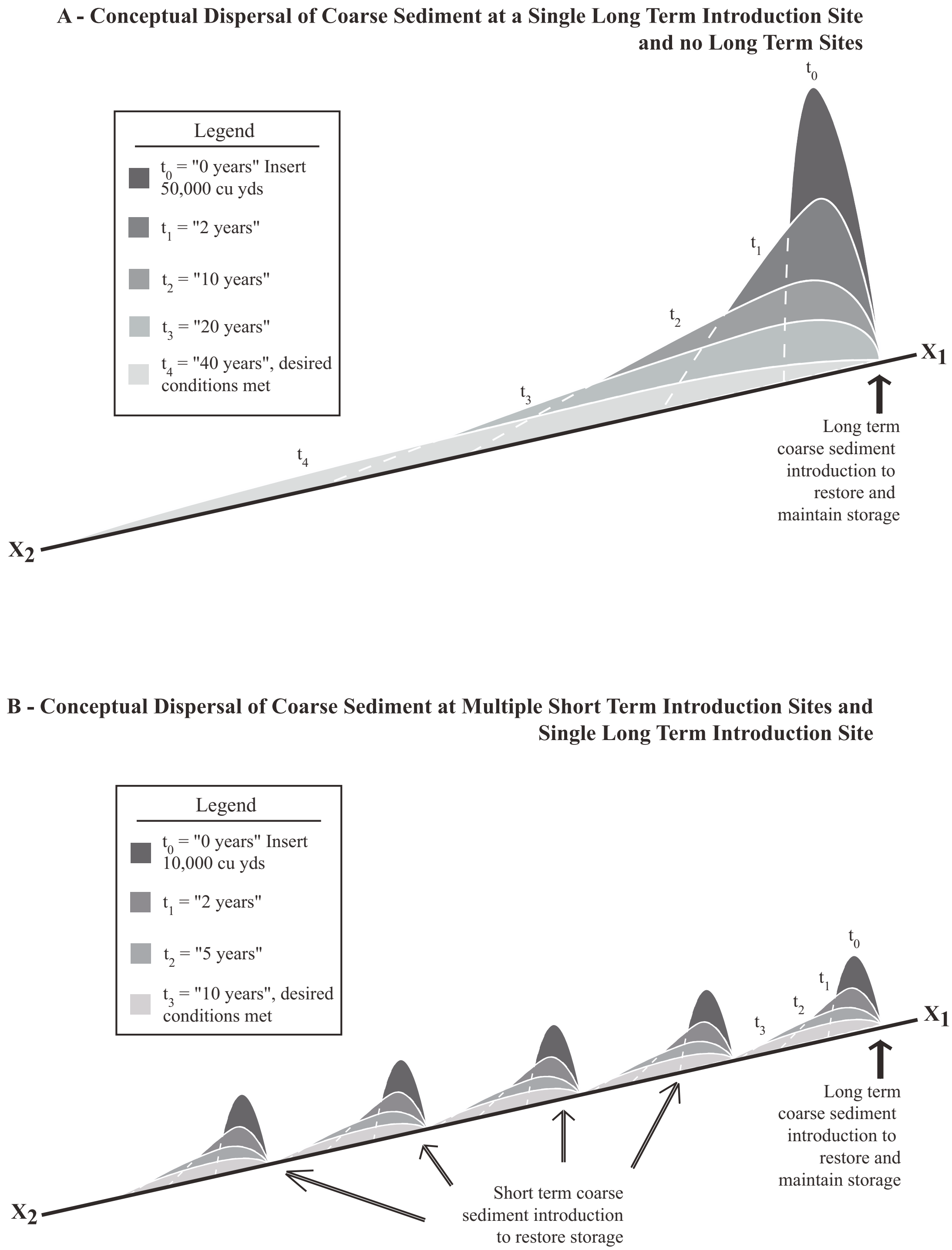


Figure 10. Conceptual diagram of sediment dispersal showing a large volume coarse sediment introduction at one location (Section A) versus smaller volume coarse sediment introductions at multiple locations (Section B). Section A illustrates the dispersal of a single sediment pulse at times (t) t0 through t4 from points X1 to X2 along the channel, where Section B illustrates the dispersal of the same volume using multiple sediment pulses through the same reach from times t0 through t3. Note that the time scale is arbitrary; numbers in quotations (e.g., "2 years") represent hypothetical periods to illustrate relative dispersal times. Using a hypothetical introduction volume of 50,000 yd3, desired conditions (coarse sediment dispersal through the reach) are met sooner using the multiple site approach.

In addition to increasing overall coarse sediment storage, the short-term strategy provides immediate benefits to salmonids by allowing geomorphic processes of bed scour, transport, and redeposition as natural alluvial features to occur on a more frequent basis, while simultaneously providing high quality salmonid spawning and rearing habitat available for immediate use. This strategy will allow the channel to begin reconstructing alluvial features by redistributing sediments downstream of each introduction site. Sediment deposited as alluvial features on the bed and banks will increase coarse sediment quantity in the channel (increasing overall storage) and improve spawning and rearing habitat quality by reducing the concentration of fine sediment presently in the channel.

3.1.2 Long-term strategy

Following coarse sediment introduction at the short-term sites, annual replenishments of coarse sediment will be needed to maintain the balance between transport and supply within the project reach. Annual replenishment at all short-term coarse sediment introduction sites would best maintain equilibrium sediment conditions but would cause repeated mechanical disturbance at these sites. Based on this, the TRFES recommended annual replenishment only in the reach near Lewiston Dam. As such, the majority of short-term sites should be retired following the first year of coarse sediment introduction, with the exception of two sites in the reach near Lewiston Dam that will continue to receive coarse sediment supply as part of a long-term introduction program (Figure 10, Section “B”).

In addition to the annual coarse sediment replenishment in the Lewiston Dam reach, the long-term coarse sediment management strategy includes dispersal of sediments accumulated at tributary deltas. Dispersal of the coarse sediments aggrading the channel at tributary deltas is intended to eliminate the backwater that has caused local aggradation upstream and route the tributary coarse sediments to downstream reaches. As a result of the backwater, coarse sediment transport from reaches upstream of the deltas has become further interrupted in each reach. By removing the deltas, the aggraded sections will be lowered, thereby increasing the hydraulic gradient and facilitating sediment routing through the tributary delta. A detailed discussion of tributary delta management is presented in Section 5.

3.2 Purpose and Objectives

To develop a coarse sediment management plan for the project reach, we first needed to identify the objectives of coarse sediment management. By identifying these objectives, we can establish the linkage between adding the necessary specificity to the sediment management recommendations presented in the TRFES and ROD, and developing a specific plan to implement the management objectives. Therefore, we have identified the following objectives of coarse sediment management in the project reach:

1. ***Increase coarse sediment storage*** by adding coarse sediment at discrete locations to the channel and banks;
2. ***Maintain coarse sediment storage*** with annual coarse sediment replenishment;
3. ***Mobilize, scour, and redeposit coarse sediment*** to provide coarse sediment cleansing (i.e., removing interstitial fine sediment) and remove young riparian vegetation;
4. ***Route coarse sediment downstream*** where it will deposit as an alluvial feature;
5. ***Improve the quantity and quality of salmonid spawning and rearing habitat*** by creating new and enhancing existing alluvial features, and;
6. ***Improve sediment transport model predictions*** for coarse sediment introduction requirements.

How each of these objectives will be achieved using the coarse sediment management plan strategy is discussed in the following sections.

3.2.1 Increasing and maintaining coarse sediment storage

Coarse sediment storage will increase as a result of adding coarse sediment to the channel. Using a variety of placement methods (Section 4.3) at selected introduction sites (Section 4.4), portions of the added coarse sediment may annually mobilize, route, and deposit downstream depending on the water year and corresponding flow releases from Lewiston Dam. Annual coarse sediment additions, coupled with increased high flow regime of the ROD, will therefore increase sediment storage and transport within and downstream of the project reach.

The coarse sediment budget for the project – that is, the balance of coarse sediment input, coarse sediment output, and changes in coarse sediment – can be conceptualized as:

$$I \pm O = \Delta S$$

where: I = coarse sediment input (supply), O = coarse sediment output (transport), and ΔS = change in coarse sediment storage (aggradation or degradation). Examples of each variable as they pertain to the project reach include: coarse sediment supply from tributaries and fluvial delivery from upper watershed (I); fluvial transport by the Trinity River (O); alluvial features such as gravel bars and floodplain deposits (S). These elements are portrayed graphically in Figure 11.

If we assume that the unimpaired sediment budget was balanced, the small changes in storage were reflective of a naturally quasi-dynamic river; small perturbations in sediment supply shifted the sediment balance from year to year, but over the long term, the overall trend was balanced [$I = O$, so $\Delta S \approx 0$]) (Figure 12, Section “A”). Following construction of the TRD, the coarse sediment supply from the upper watershed was eliminated, thereby decreasing mainstem coarse sediment storage ($O > I$) except for in the immediate areas of the major tributaries (Rush, Grass Valley, Indian creeks), where mainstem storage was locally increased ($I > O$). Section “B” of Figure 12 presents a conceptual diagram showing different phases of the Trinity River sediment budget for the project reach. Beginning with a balanced sediment budget

Through a combination of reduced flows and the augmented coarse sediment supply, the river could not adjust itself to a new configuration based on its new flow and sediment regime. This lack of ability to adjust generated a host of fluvial geomorphic and biological impacts (see Section 2.2) which, through restoring fluvial geomorphic processes by shifting and maintaining the sediment balance, should be partially mitigated by the flow and sediment management actions of the ROD (see Figure 7).

To maintain coarse sediment storage within the project reach, annual replenishments approximately equal to the volume transported by the previous high flows will be necessary. The volume to be added at each introduction site can be determined by documenting the volume transported from the previous addition. This can be accomplished by using topographic differencing methods, where the channel is surveyed before and following flows have transported the added gravel from the site. The area removed can then be converted to the volumetric quantity of gravel needed to replenish the site. These methods are further described in Section 6.

3.2.2 Sediment mobilization, scour, and routing

Because coarse sediment additions will be scaled to the ROD flow regime, coarse sediment mobility, scour, routing, and deposition will be achieved. Each coarse sediment introduction site must be hydraulically and geomorphically suitable for transporting and routing added sediments downstream.

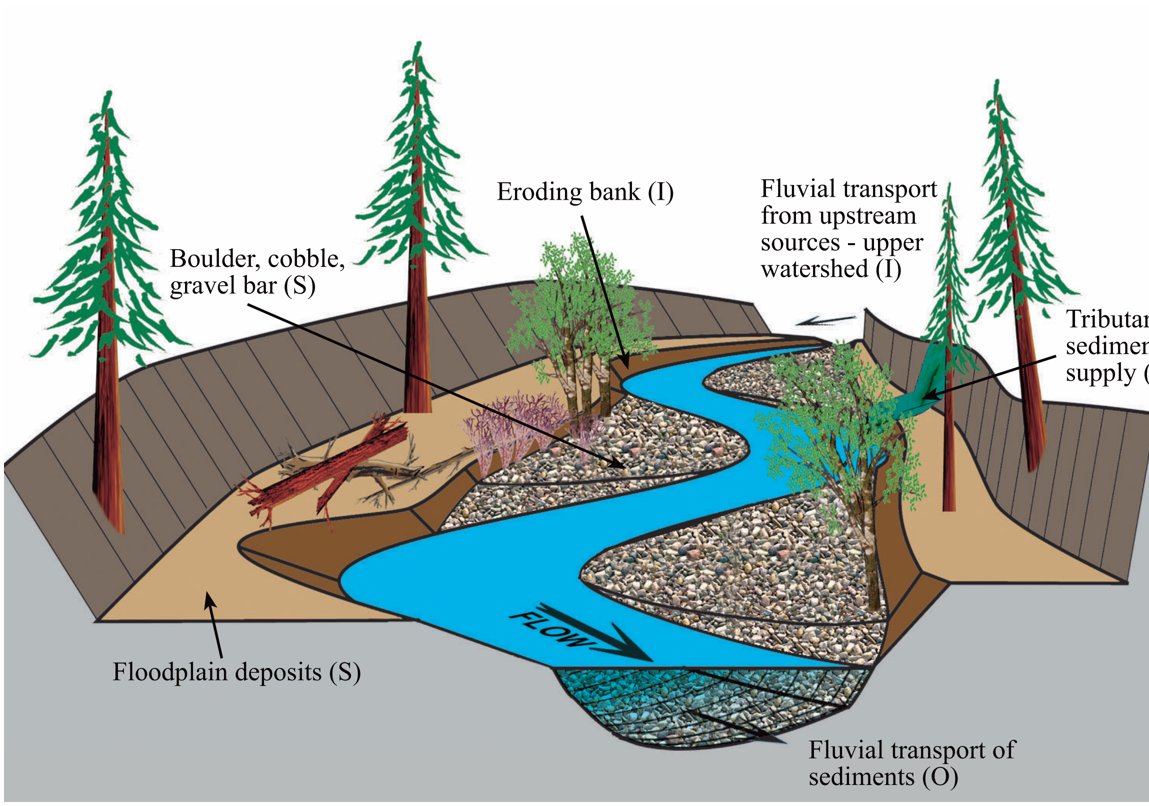


Figure 11. Conceptualized oblique cross-section of the Trinity River showing examples of sediment budget variables for sediment input (I), sediment output (O), and sediment storage (S).

Because each introduction site will have its own unique hydraulic and geomorphic characteristics (that is, each site will have unique hydraulic conditions), the factors governing sediment mobility must be understood.

Each coarse sediment addition to the mainstem Trinity River channel will occur as a relatively large volume (e.g., 1,000 yd^3) over a short period (e.g., 1 day). This input to the river channel is volumetrically and temporally similar to natural large sediment inputs such as those delivered by landslides or debris flows. These inputs, or "pulses", are defined as discrete supplies of a significant amount of sediment into a river that results in a transient topographic high on the bed (Cui et al. 2003).

Each pulse will generate a rapid minor adjustment of local channel dimensions and a local temporary shift in the sediment balance where supply temporarily exceeds transport (I > O, therefore S increases). These adjustments will shift the balance between the hydraulic driving forces that transport the sediment and the resisting forces provided by the sediment pulse itself. However, over time, the sediment pulse will propagate downstream through processes described as translation or dispersion (Lisle 1997), or as a combination of the two (Cui et al. 2003), resulting from the fluvial geomorphic processes of mobilization, scour, and deposition. As the pulse propagates downstream, the balance between supply and transport will re-equilibrate as the coarse sediments disperse as and deposit as alluvial features (objective 3).

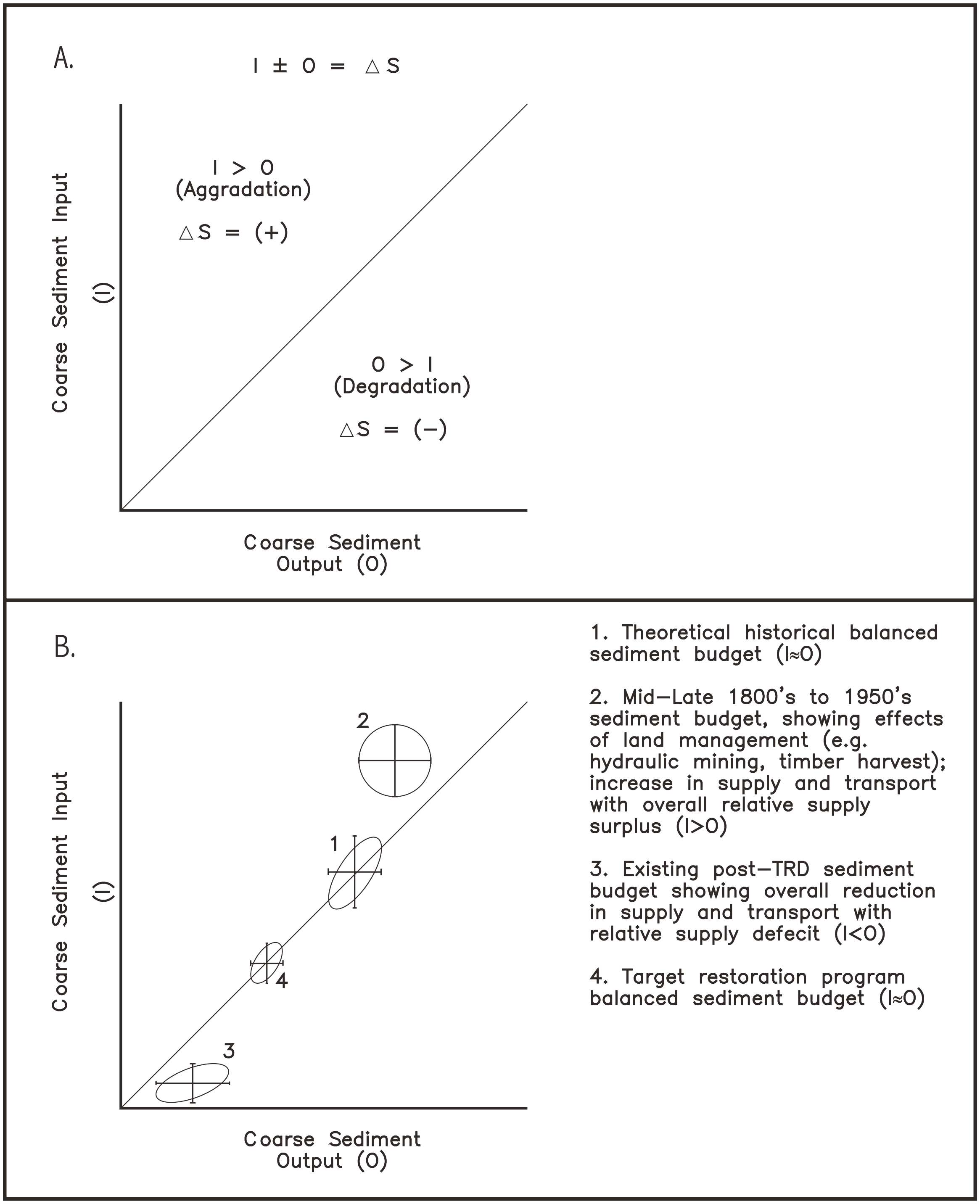


Figure 12. Section A: Conceptual graph showing channel aggradation ($I>O$), degradation ($O>I$), and equilibrium ($I=O$) conditions based on the ratio of sediment input to output. Although small perturbations in sediment supply shifted the sediment balance from year to year, the overall trend remained balanced [$I = O$, so $\Delta S \approx 0$]). Section B: Conceptual graph showing different phases of the Trinity River below Lewiston sediment budget. Circles with bars illustrate the theoretical fluctuations in coarse sediment inputs and outputs. Each circle shows a deviation from the balanced condition (Field 1), from aggradation ($I > O$) caused by instream and near-channel gold mining (Field 2); to degradation ($O > I$) caused by construction of trinity and Lewiston dams (Field 3); to a theoretically restored condition ($I \approx O$) resulting from successful coarse sediment management (Field 4).

3.2.3 Improving the quantity and quality of salmonid spawning and rearing habitat

Coarse sediment storage will increase as a result of adding coarse sediment to the channel. Combined with the ROD flows, the coarse sediment additions will mobilize, scour, and route downstream, and redeposit as alluvial features. These alluvial features will provide the complex habitats needed for salmonids, including spawning gravel. The quality of salmonid spawning and rearing habitat should increase, as the coarse sediment introduced to the channel will be virtually devoid of fine sediment. Fluvial transport of remaining fine sediments in the channel should further decrease fine sediment storage in the mainstem Trinity River channel, increasing the longevity of introduced coarse sediments (reduced fine sediment infiltration risk).

3.2.4 Improving sediment transport model predictions

In 1996 and 1997, the Hoopa Valley Tribe (HVT) Fisheries Department collected sediment transport data on the mainstem Trinity River at the Lewiston cableway (RM 110.2) and the Limekiln Gulch cableway (RM 98.5), and on Deadwood Creek, Rush Creek, Grass Valley Creek, and Indian Creek (USFWS and HVT 1999). The bedload transport data at the mainstem stations were used to develop a rating curve relating flow release and coarse sediment transport (i.e., if Lewiston Dam releases "X" cfs, then coarse sediment transport in the mainstem Trinity River is "Y" tons/day). The TRFES adopts the initial objective of releasing a yearly flow magnitude and duration to transport the volume of coarse sediment delivered annually by Rush Creek (confluence at RM 108.5), and the magnitude and volume of flow releases are based on assuming that these rating curves can be applied to sediment transport conditions at the Rush Creek Delta. Because the hydraulic conditions at the two cableway locations are different than those at the Rush Creek delta (and other locations on the mainstem Trinity River), a sediment transport and routing model was developed by the USBR Technical Service Center River Hydraulics and Sedimentation Group. The sediment transport model extends between Lewiston Dam (RM 112) and the Salt Flat Bridge (RM 107), and from a location just upstream of Indian Creek (RM 95.7) to the Weaver Creek confluence (RM 93.8). The sediment transport model uses the following information: (1) topographic and particle size data collected by the HVT, (2) measured bedload transport and mobility data collected by the HVT and Graham Matthews and Associates (GMA), and (3) tributary delta topographic changes with different high flow hydrographs. Since 1996, the HVT and GMA collected bedload data on the mainstem Trinity River at the Lewiston cableway (RM 110.2) and the Limekiln Gulch cableway (RM 98.5), and on Deadwood Creek, Rush Creek, Grass Valley Creek, and Indian Creek. These measurements provide a basis for understanding mobility thresholds and the relationships between bedload transport and discharge on the mainstem Trinity River and tributaries closest to Lewiston Dam. They will also be useful for calibrating the sediment transport relationships in the model to improve predictive accuracy.

The hydraulic model component of the sediment transport model has been calibrated to 2002 Trinity River flow releases (6,000 cfs) from a series of surveyed water surface elevations, and will be an important tool in predicting long-term gravel introduction volumes. The model is intended to be used for the following purposes: (1) predict the annual flow magnitude and duration needed to route the volume of coarse sediment delivered by Rush Creek for that year, and (2) based on this flow magnitude and duration, predict the volume of coarse sediment transported from the reach immediately downstream of Lewiston Dam. This latter volume will be used to develop the volume of coarse sediment needed to be mechanically added to the river on a yearly basis. Calibration benefits include: (1) continued bedload transport measurements at the Lewiston cable will provide calibration data for the sediment transport formula used in the model, (2) continued tributary delta topographic surveys will provide calibration data for the overall model (did the magnitude and duration of flow release transport the intended volume of sediment at Rush Creek delta), and (3) topographic monitoring in the reach immediately downstream of Lewiston Dam will provide calibration data for the model application used for coarse sediment augmentation.

4 COARSE SEDIMENT INTRODUCTION RECOMMENDATIONS

The primary considerations for adding coarse sediment to the Trinity River are placement location and particle sizes. Placement locations must consider the hydraulic suitability of the site to facilitate mobilization, scour, transport, and deposition. Although we have presented some general recommendations based on these concepts, implementing the coarse sediment management strategy requires more specific recommendations. This section provides additional specificity on the following topics:

- Coarse sediment size and composition;
- Potential coarse sediment sources;
- Potential coarse sediment placement methods;
- Potential coarse sediment introduction site identification and selection;
- Site-specific coarse sediment placement locations.

4.1 Size and composition

The primary purpose for introducing coarse sediment to the project reach is to re-establish geomorphic processes and alluvial features, which in turn provides high-quality habitat for all life stages of anadromous salmonids and other biota. Therefore, coarse sediment additions need to be of a size distribution that: 1) is mobilized and transported by the ROD flow regime, and 2) is of beneficial use to anadromous salmonids.

It should be noted that although coarse sediment additions will generate alluvial features that will be used in part by salmonids, the particle size distribution for coarse sediment introduction should not be solely driven by spawning gravel references. Considerable research has been conducted to describe suitable spawning gravel size compositions for spawning adult salmonids (e.g., Kondolf 2000; Kondolf and Wolman 1993; Bjornn and Reiser 1991). Although the coarse sediment introduction aggregate will contain a percentage of particles larger than some researchers have considered useable by spawning salmonids, spawning represents only one of several key life stages, whereas these larger particle sizes represent integral components to the structure of alluvial features that provide habitat for all life stages, as well as native non-salmonid biota.

4.1.1 Particle size distribution

Preliminary results from the USBR sediment transport modeling suggest that the largest particle diameter mobilized by the ROD flows is 6 inches, and previous field experiments at study sites within the project reach have shown that 6 inch diameter particles move at 6,000 cfs flows (USFWS and HVT, 1999). Because the largest magnitude ROD flows occur in extremely wet water years, the largest particle size added to the river should be readily mobilized by the extremely wet water year ROD release. Therefore, we recommend that the upper limit of coarse sediment particle size distributions not exceed 6 inches (152 mm).

The upper limit of the size distribution was selected based on fluvial geomorphic criteria. Using this same approach to select the lower limit of the distribution is slightly more ambiguous. Previous sediment transport sampling and modeling efforts on the Trinity River have used 8 mm as the cutoff for defining bedload and suspended load (McBain and Trush 1997; Wilcock et al. 1995). Although this provides one possible option, we also consider biologic criteria, primarily for salmonids, to select the lower limit of the distribution. Fine sediment can reduce gravel quality and thereby generate adverse effects such as reducing spawning gravel permeability (which can prevent intragravel flow from delivering oxygen to embryos and removing metabolic waste) and blocking fry emergence through intragravel pores (Kondolf 2000). With respect to these effects, fine sediment is defined by different researchers as ranging from 9.5 mm to 2 mm (Lutrick 2001). Therefore, considering both biologic and fluvial transport aspects of defining fine sediment, we recommend using 8 mm (0.3 inches) to provide a relatively conservative lower limit for coarse sediment introduction aggregate particle size distributions.

In addition to the upper and lower particle size limits, the intermediate sizes that define the particle size distribution (i.e., composition of the mixture) must also be considered. Although we recommend upper and lower size class limits of 6 inches (152 mm) and 0.3 inches (8 mm), respectively, this information alone is not sufficient to develop a general particle size distribution for the coarse sediment introduction aggregate. The distribution of naturally-occurring coarse fluvial sediments is rarely uniform; that is, the distribution of the intermediate sizes between the upper and lower limits of the distribution can vary significantly. Therefore, defining a "representative" particle size distribution characteristic of a typical stream bed is not possible. Because of this, we do not provide specific particle size gradation recommendations for the coarse sediment introduction aggregate. However, we recommend that to select a particle size distribution for the coarse sediment introduction aggregate, do not overly-coarsen or overly-fine the mixture. For example, do not create a mixture within the 0.3 to 6 inch size range, but contains a disproportionate coarse or fine component (such as 50 percent finer than 0.75 inches). A general guideline would be to avoid a distribution that has more than 25% of the entire sample weight within a single 1-inch size class (e.g., 3-4 inch class).

Assessing the effectiveness of coarse sediment addition requires monitoring substrate size before and after placement. As such, annual monitoring at each coarse sediment introduction site should be performed to assess the evolution of the sediments (i.e., their mobility) to document their mobilization from the site and make any necessary adjustments, such as fining the mixture, to ensure fluvial transport and deposition. Site-specific coarse sediment evaluation monitoring is discussed in Section 6.

4.2 Coarse Sediment Aggregate Sources

Presently, the primary source of coarse sediment to the Trinity River in the study reach are Deadwood Creek, Rush Creek, and Indian Creek (coarse sediment supply from Grass Valley Creek is low due to Hamilton Ponds capturing most sediment). As discussed in Section 2.2, the post-Trinity Dam flow regime has been insufficient to transport and route this coarse sediment from the deltas to downstream reaches. The ROD flows are intended to improve this routing, and reduce the need for introducing coarse sediment downstream of Rush Creek. Upstream of Rush Creek, a source will always be needed because there are no significant tributaries between Rush Creek and Lewiston Dam (the coarse sediment supply from Deadwood Creek is small). The ideal sources of this long-term coarse sediment are the large quantities of dredge tailings that are located at various points within the project reach (e.g., Gold Bar). In 2001, a cooperative effort between the Hoopa Valley Tribe and the Trinity County Resource Conservation District (TCRCD) delineated remaining dredge tailings along the Trinity River between Lewiston Dam and the North Fork Trinity River, estimated the quantity of these tailings, and conducted materials testing to estimate the proportion of raw tailings that would be useable for future coarse sediment introduction efforts. This results of this effort are discussed in more detail below.

4.2.1 Mapping and computations

To estimate the volume of dredge tailings available between Lewiston Dam and the North Fork Trinity River, the surficial extent of dredge tailings as observed on the 1997 orthorectified aerial photographs from DWR was digitized on-screen into AutoCAD Land Development Desktop as closed polygons outlining the dredge tailing boundaries. The coordinate system used for the DWR aerial photographs was retained (NAD 1983, California State Plane, Zone 1, Feet). The surface area (in square feet) was determined for each of these 62 polygons (Appendix D).

If dredge tailings were to be removed as a coarse sediment source, the limit of the removal surface should be at a distance above the low flow water surface such that the resulting surface can function as a functional floodplain and be revegetated. The floodplain should be designed at an elevation such that it is inundated by a 6,000 cfs flow event (approximately a 1.5 year flood under the ROD flow regime). Based on water surface elevation monitoring during high flows at bank rehabilitation sites, this elevation is approximately 5 feet above the summer baseflow (450 cfs) water surface elevation. Therefore, the depth of dredge tailing excavation was computed as the difference between the existing dredge elevation and the elevation that is 5 ft above the summer baseflow elevation (Figure 13).

The ground surface topography was estimated by DWR photogrammetry, and we needed to estimate an average elevation of the dredge tailing surface ("existing ground"). Rather than doing a volume computation in AutoCAD for all 62 polygons, we first measured the maximum elevation of dredge tailings, then applied an adjustment factor to the maximum elevation to estimate the average elevation. For four of the polygons (listed as "calibration plots" in the summary table in Appendix D), we used the DWR photogrammetry data to develop a 3-D topographical surface of the existing ground in AutoCAD. We then created a design ground surface that was 5 feet above the baseflow water surface elevation, and computed the volume between the two surfaces in AutoCAD. If we used 60% of the maximum tailing height (maximum elevation-design surface times 0.60), then our simple volume estimate reasonably approximated the volume estimate obtained from AutoCAD computations. We then multiplied the surface area of each tailing polygon by 60% of the maximum dredge tailing height (Figure 13) to estimate total volume of each dredge tailing polygon. All identified dredge tailing sites are shown on 1997 aerial photographs located in Appendix D. The photographs show each site identified by number and summarized in a table that precedes the photographs.

4.2.2 Materials testing

In 2000 – 2001, the Trinity County Resource Conservation District (RCD) sampled three locations within the project reach as a preliminary investigation to assess the aggregate quality at three prospective borrow sites. Two aggregate samples were collected in December 2000, one at Bucktail (approximately RM 105.5) and one at Gold Bar (approximately RM 106.5), and a third was collected in March 2001 at BLM property located off Goose Ranch Road (approximately RM 108.5). The samples were collected using a backhoe and placed into 5-gallon buckets, transported to a soils laboratory and then sieved for a size gradation analysis. The results of these analyses are presented in Table 2.

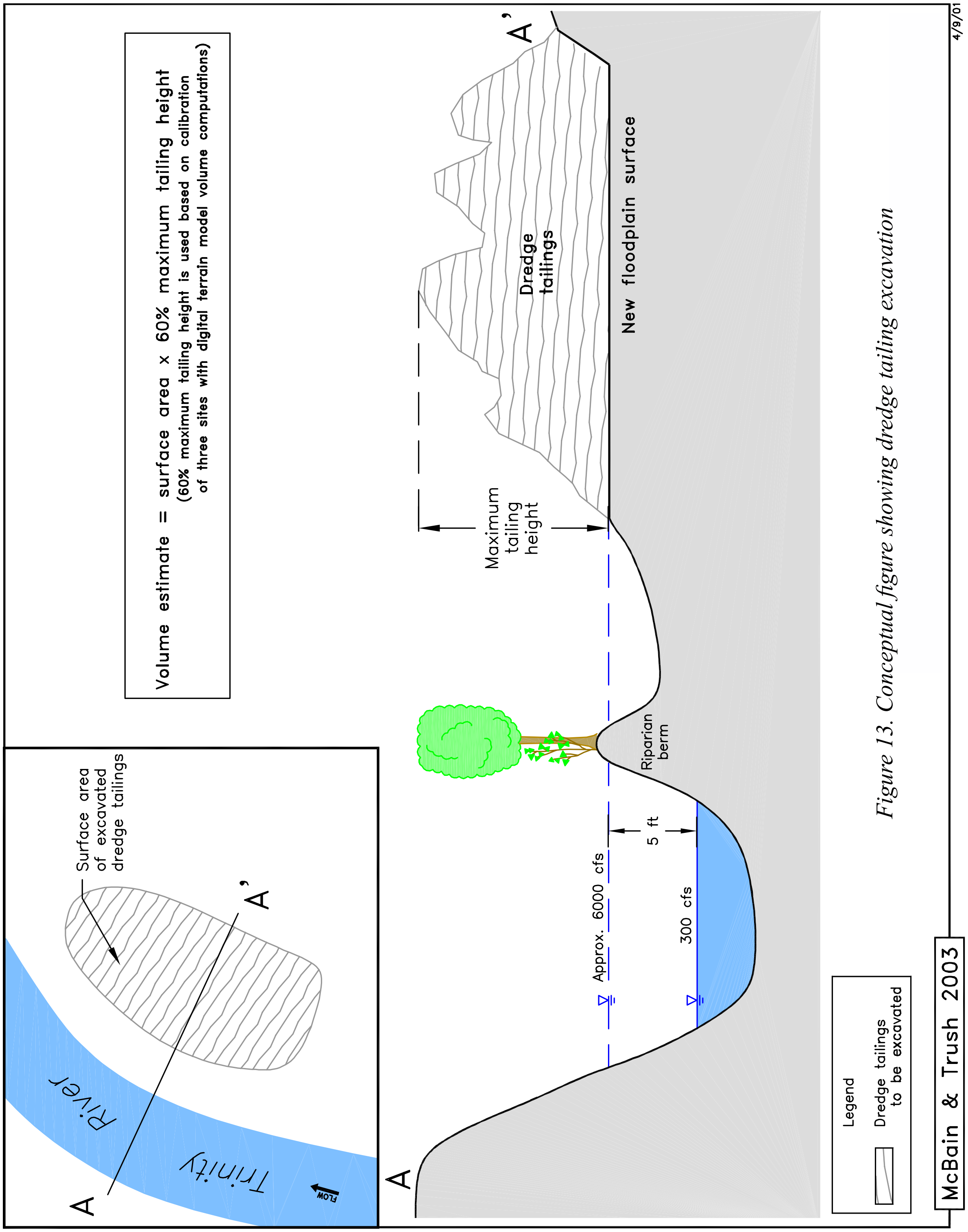


Figure 13. Conceptual figure showing dredge tailing excavation

Table 2. Summary of 2000 – 2002 materials testing at potential coarse sediment aggregate borrow sites.

<table>
<tr><th>Site</th><th>Date sampled</th><th>Approximate Location (RM)</th><th>Total sample collected (lb)</th><th>Sample weight processed for less than 6 inch fraction (lb)</th><th>Sieve screens used to define distribution (in)</th><th>Sieve screens used to define distribution (mm)</th></tr>
<tr><td>Bucktail</td><td>Dec. 15, 2000</td><td>105.5</td><td>450</td><td>450</td><td rowspan="2">6, 3, 0.5</td><td rowspan="2">152, 76, 13</td></tr>
<tr><td>Gold Bar</td><td>Dec. 15, 2000</td><td>106.5</td><td>450</td><td>450</td></tr>
<tr><td>Goose Ranch Rd.</td><td>Mar. 13, 2001</td><td>108.5</td><td>900 [1]</td><td>900</td><td>6, 3, 2, 1.5, 1.0, 0.75, 0.50, 0.38</td><td>152, 76, 51, 38, 25, 19, 13, 10</td></tr>
<tr><td>Jim Smith stockpile</td><td>Nov. 18, 2002</td><td>78.4</td><td>23,300</td><td>718</td><td rowspan="3">6, 5, 4, 3, 2, 1, 0.75, 0.5, 0.4, 0.18, 0.09, 0.04, 0.02, 0.01, 0.006, 0.003</td><td rowspan="3">152, 127, 101, 76, 51, 25, 19, 12.5, 9.5, 4.75, 2.36, 1.18, 0.60, 0.30, 0.15, 0.075</td></tr>
<tr><td>Indian Creek delta</td><td>Nov. 18, 2002</td><td>95.3</td><td>41,340</td><td>790</td></tr>
<tr><td>Rush Creek delta</td><td>Nov. 18, 2002</td><td>107.6</td><td>37,140</td><td>769</td></tr>
</table>

[1] Goose Ranch Rd. sample weight estimated based on weights reported from Bucktail and Gold Bar samples.

Upon reviewing these results, it appeared that the Bucktail and Gold Bar samples were not processed using enough sieves to accurately portray the particle size distribution at these sites. Figure 14 shows the particle size distribution for both sites and illustrates that the three screens used to sieve the sample yield too few data points on the distribution curve to accurately determine specific size parameters. In addition, it also appears that the sample volumes were too small to constitute a representative sample using the guidelines of Church and McLean (1987). First, volumetric samples need to be sufficiently large so that coarse particles are representatively included in the sample (Bunte and Abt 2001). Because large particles in small samples can account for a substantial portion of the total sample weight, Church and McLean (1987) suggests that the maximum particle size in the sample not constitute more than 1% of the total sample weight for particles up to 128 mm (5.0 in), and not more than 5% of the total sample weight for particles greater than 128 mm. For example, if the largest particle sampled is 6 inches, its corresponding weight is 10.8 lb (assuming spherical shape and density of 2.65 g/cm^3). Using the 5% sampling criterion yields a representative sample volume of approximately 1,030 lb, which illustrates that the preliminary samples may not be representative. Second, our observations of the aggregate stockpiles at the sampling locations noted cobbles and boulders much larger than 6 inches were also present. After discussing the sampling technique with John Condon of the Trinity County RCD, we determined that the samples collected did not include the full range of representative particles of the sampling sites (i.e., they were biased toward rocks 6 inches and smaller) and that new sampling would be needed.

In November 2002, McBain and Trush and the USBR performed additional sampling at three new sites with the objectives of 1) providing a better resolution in particle size distribution (more sieves to define the size distribution curve), and 2) collecting a significantly larger sample sizes that would yield representative particle size distributions. The sampling sites were located on the Indian Creek delta (RM 95.3), Rush Creek delta (RM 107.6), and at a large stockpile of dredge tailings at the Jim Smith site (RM 78.4). The Indian Creek and Rush Creek samples were collected in the deltas to represent the particle size distribution of sediment contributed by those streams to the Trinity River, which are to be used in the USBR sediment transport and routing modeling effort. The sample collected at the Jim Smith site is intended to represent the particle size distribution of dredge tailings,

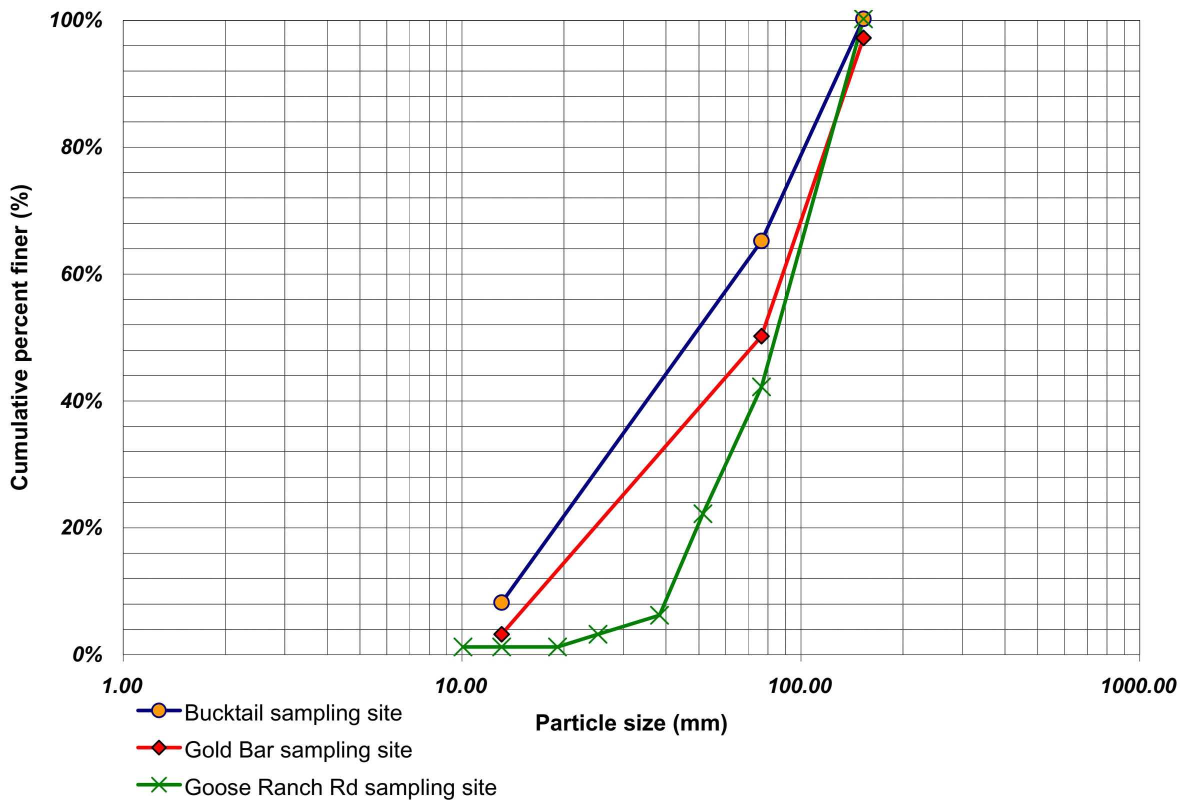


Figure 14. Particle size distribution curves generated from 2000 Bucktail, Gold Bar, and Goose Ranch Rd. samples

assuming that tailings would be used for the long-term coarse sediment source. Samples were excavated using a backhoe, collected in a dump truck, and transported to a gravel processing plant in Weaverville, CA where they were weighed and separated into populations larger than 6 inches and smaller than 6 inches. From the less than 6 inch population, we collected subsamples weighing approximately 750 lb each, which were later transported to a soils laboratory for a size gradation analysis. The results of our November 2002 sampling are also presented in Table 2 and are shown on Figure 15. Comparing Figure 15 with Figure 14 illustrates the greater resolution and portrayal of the particle size distribution provided by the 2002 sampling.

4.2.3 Quantity estimates

From the 2002 sampling results, we selected the Jim Smith sample as representative of the dredge tailings within the project reach (dredge tailings to be used for future long-term coarse sediment sources). We applied the criteria of removing fine sediments less than 0.3 inch and coarse sediments greater than 6 inch diameter to the Jim Smith dredge tailing sample (Figure 15). Based on the frequency distribution presented in Figure 15, we computed the fraction of sample between 8 mm (0.3 in) and 156 mm (6 in) to be 74.8%, and also plotted the new distribution of coarse sediment assuming the finer and coarser particles are screened out. Using the raw tailings volume estimates shown in Appendix D, we multiplied the total raw tailings volume by 74.8% to give predictable useable gravel volumes within the project reach. Table 3 presents these volumes summarized on a reach-wide basis,

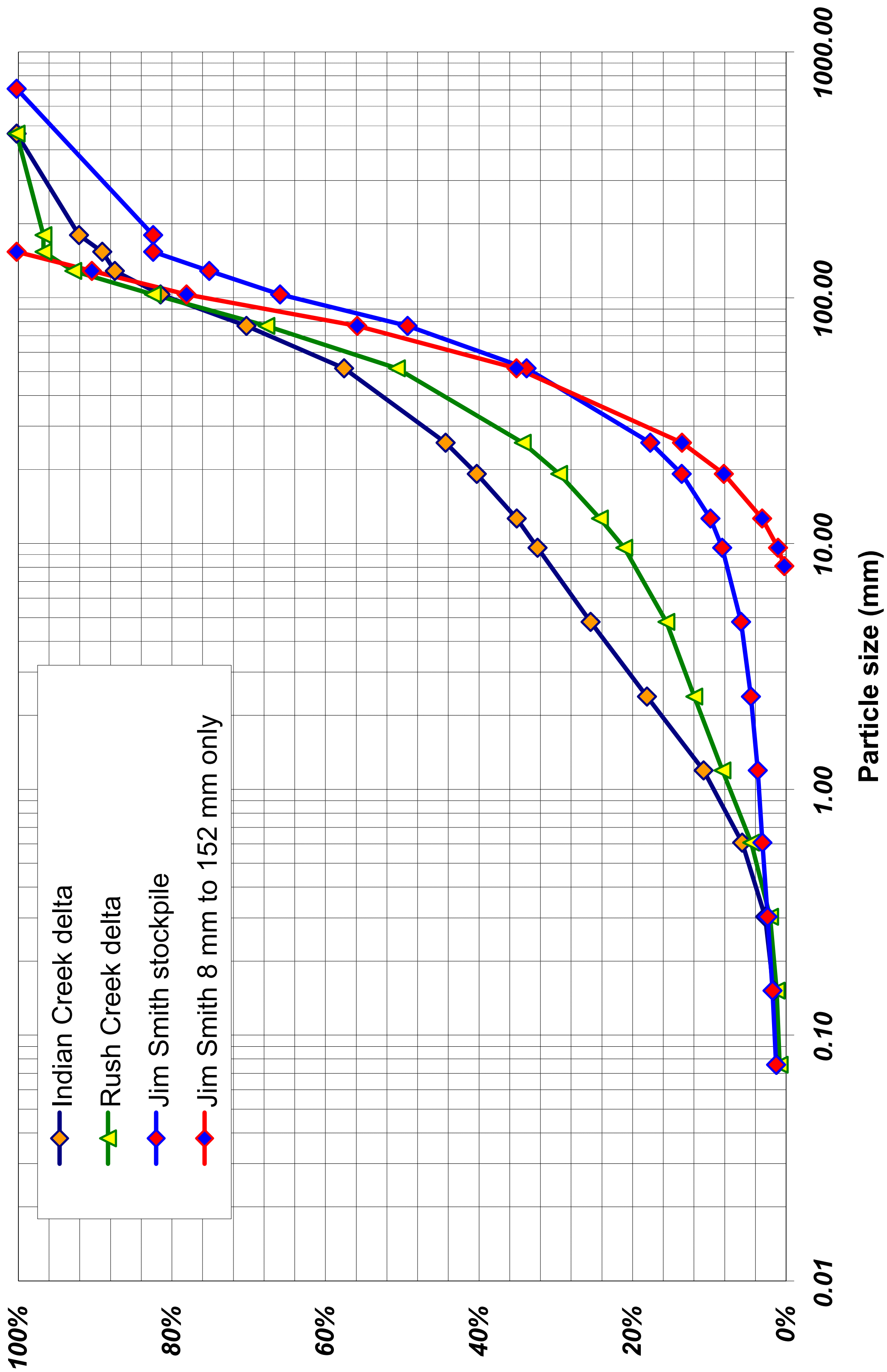


Figure 15. Particle size distribution curves generated from 2002 Indian Creek delta, Rush Creek delta, and Jim Smith stockpile samples

and a table that itemizes each site individually is presented in Appendix D. Based on the results, the Gold Bar site (Appendix D, site ID #5) appears very good due to large volume stored onsite and its proximity to Lewiston Dam. The next highest priority sites are at RM 108.8 where dredge tailings remain on BLM property on the south bank of the river (site ID # 1 and #2). These sites are close to recommended introductions sites, but are smaller volume than the Gold Bar site. The majority of coarse sediment sources are downstream of Dutch Creek (RM 86) in the wider alluvial valley near Junction City, but using these sources at recommended introduction sites would require hauling them over Oregon Mountain (costly) and through Weaverville (traffic and public safety impacts). Coarse sediment used from sites upstream of Dutton Creek (RM 89) would not need to be hauled over Oregon Mountain or through Weaverville; thus, sites upstream of Dutton Creek should be prioritized for the long-term coarse sediment augmentation effort. Dredge tailings at all locations can be used for gravel augmentation for local bank rehabilitation sites, as needed for the particular design for each site.

Table 3. Summarized reach-wide distribution of the estimated useable percentage of dredge tailings for introduction to the Trinity River. See Appendix D for a complete listing of the individual sites and their dimensions.

Reach	***Location (RM)***	***Number of identified potential source sites***	***Estimated volume of useable dredge tailings (yd^3)***
Lewiston Dam to Rush Creek	112.0 – 107.6	2 (sites 1, 2)	49,368
Rush Creek to Grass Valley Creek	107.6 – 104.0	8 (sites 3 – 10)	406,388
Grass Valley Creek to Indian Creek	104.0 – 95.3	0	0
Indian Creek to Browns Creek	95.3 – 87.8	15 (sites 11 – 25)	215,237
Browns Creek to Sheridan Creek	87.8 – 81.9	12 (sites 26 – 37)	247,887 [1]
Sheridan Creek to Pear Tree Gulch	81.9 – 73.1	25 (sites 38 – 62)	3,206,369 [1]
Total		**62**	**4,125,250**

[1] Low estimate. Aerial and volumetric estimates could not be made for some of the identified sites because of a lack of topographic data.

To make the project cost effective, aggregate should be processed as simply as possible. This can be accomplished by onsite processing (grizzly/Screen All) that mechanically screens out particle sizes greater than 6 inches (152 mm) and less than 0.3 inches (8 mm). This approach reduces aggregate costs and greatly reduces transportation (hauling) costs compared to purchasing processed aggregate from offsite sources and transporting it to each introduction site. However, the screening process is noisy and may be impossible in many locations based on permitting needs and potential impacts to neighbors.

The Jim Smith particle size distribution, with particles finer than 0.3 inch and coarser than 6 inch removed (Figure 15), was compared to the recommended criteria of each 1-inch size class containing no more than 25% of the total sample volume (Table 4). The Jim Smith dredge tailings appear to satisfy these criteria, although there is uncertainty how representative the Jim Smith dredge tailings are compared to all the other potential dredge tailing source sites listed in Appendix D. Based on our field review, the surficial texture of the Jim Smith dredge tailings appears to be similar to other tailings in the study reach, although we did not perform a quantitative comparison. Regardless, this sample gives us a reasonable estimate of the particle size distribution of the dredge tailings for planning purposes.

Table 4. Comparison of the Jim Smith dredge tailing particle size distribution to the criteria of no more than 25% of the total sample is contained in any1-inch size class category.

Particle size (mm)	Percent of total sample	Pass/Fail criteria
6-5 inches	9.8 %	Pass
5-4 inches	12.3 %	Pass
4-3 inches	22.2 %	Pass
3-2 inches	20.8 %	Pass
2-1 inches	21.5 %	Pass
1-0.3 inches	13.3 %	Pass

4.3 Coarse Sediment Placement Methods

The method used to introduce coarse sediment to the channel depends on the introduction site morphology and the short- and long-term objectives of the site. Each coarse sediment introduction site is selected based on its initial suitability, however because each site has its own somewhat unique hydraulic and geomorphic setting, objectives can be best achieved if the sediments are placed in the channel in a manner consistent with the existing channel topography and/or hydraulic setting. The following sections recommend four coarse sediment introduction methods, each having unique and common benefits and limitations.

4.3.1 Indirect Placement: High flow recruitment stockpile [Method 1]

A high flow recruitment pile places a quantity of sediment at or near the channel margin where it is available for downstream transport by high flows (Figure 16). The primary advantage to this method of sediment introduction is the relatively low cost and fewer environmental compliance requirements to implement annual introduction. Placing a recruitment stockpile minimizes additional costs, such as on-site transportation once the sediment has been delivered to the site, additional permitting costs for conducting in-channel work, vegetation removal for access, and others. In addition, this method reduces the risk of collateral environmental impacts of having heavy equipment working in the low-flow channel.

The main limitation to this introduction method is that it is indirect, so that in the absence of controlled high flow releases from Lewiston Dam, a lengthy period of time may pass before a high flow release mobilizes and redeposits the sediment downstream. Additionally, flows exceeding bed mobility thresholds generally occur during events of short duration (days), followed by long periods in which bedload transport thresholds are not exceeded (months or years). Coarse sediments dumped on the bank may therefore sit immobile for a period of time before being transported and redeposited downstream. Although the recruitment stockpile method provides some benefit in the long-term once it is distributed into the stream by high flows, it often does not maximize the benefits of coarse sediment introduction in the short-term, potentially requiring several years before mobilizing and providing usable salmonid habitat.

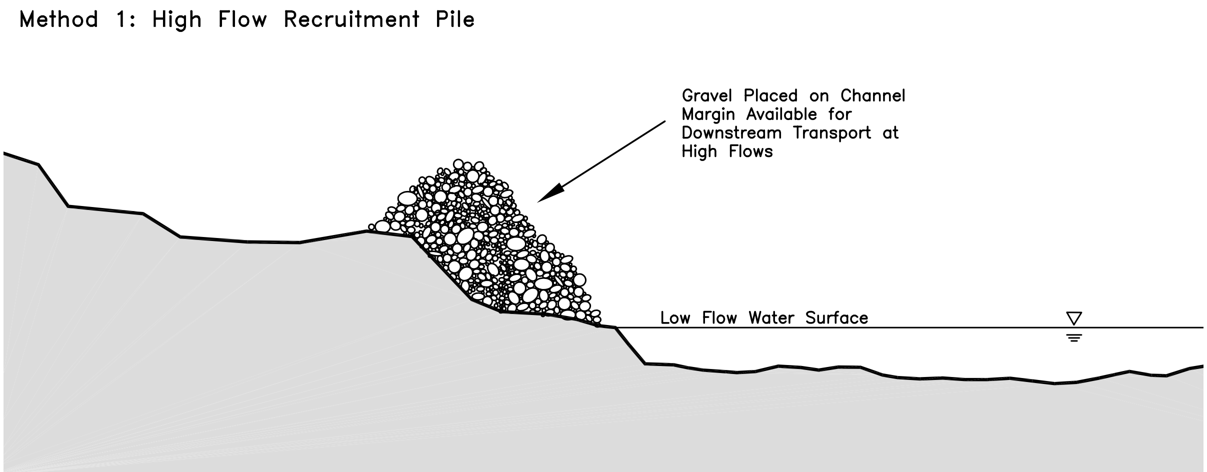


Figure 16. Method 1 for coarse sediment placement in Trinity River project reach: High flow recruitment pile.

4.3.2 Direct Placement: Riffle supplementation [Method 2]

A second method of coarse sediment introduction directly places sediments into the channel, raising the bottom of the channel with a layer of newly-introduced coarse sediment (Figure 17). This method requires some additional effort to transport, deposit, and distribute the coarse sediment within the low flow channel, and may require additional permitting hurdles and/or specialized equipment. This method assumes that the river will eventually transport and reshape the sediment into an alluvial morphology (e.g., building alternate bars, riffles, and pools) during high flow events, and provides the required coarse sediment supply directly in the channel.

The primary advantage of this method is the direct and timely re-supply of coarse sediments into the channel for potential immediate use by salmonids and other biota. Instead of requiring time for introduced sediment to route downstream to become incorporated into the channel bed, the coarse sediment storage in the channel is immediately replenished. Introduced coarse sediments thus have immediate benefit to salmonids and other biota.

4.3.3 Direct Placement: Contouring to mimic alluvial features [Method 3]

This method is similar to Method 2, but instead of and/or in addition to placing an even layer of sediment along the low flow channel bed, this method would contour the bed using the introduced coarse sediments to mimic natural alluvial features expressed at each site (Figure 17). For example, existing point bars and pool-tails would be supplemented, or new ones created, to mimic or enhance natural alluvial features. This would be accomplished using site-specific low-flow and bankfull channel dimensions measured at nearby bank rehabilitation sites that have re-adjusted their channel dimensions since 1991. This method has added benefits over Method 1 by immediately providing a more natural channel morphology that is usable by salmonids and other biota, instead of relying on future high flows to reshape the channel morphology.

Coarse sediment introduced as point bars could potentially be done in a way that prevents heavy equipment from entering the low-flow channel but will have to be evaluated at each site. Additionally,

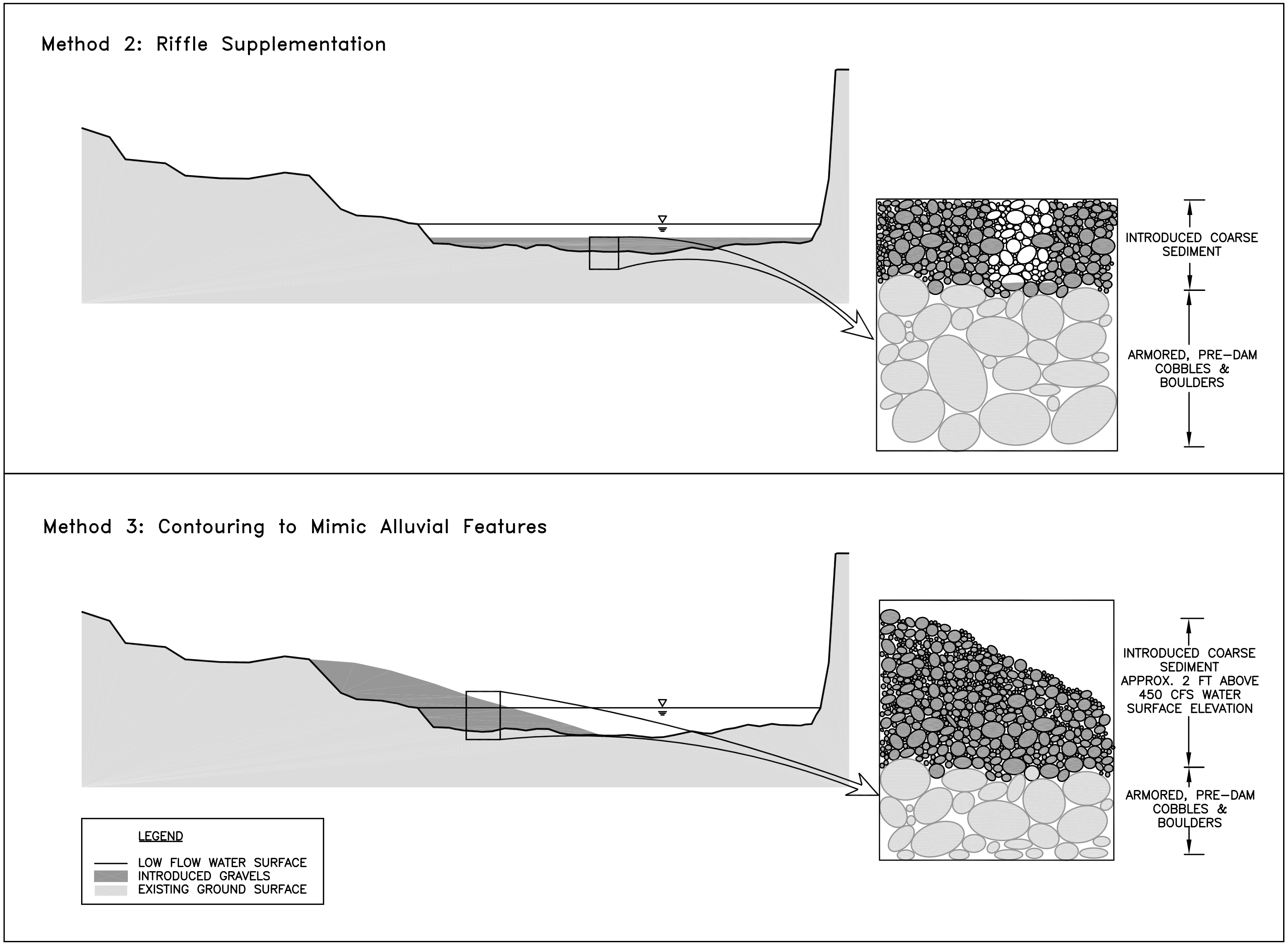


Figure 17. Methods 2 and 3 for coarse sediment placement in Trinity River project reach: Riffle supplementation and Contouring to mimic alluvial features

the volume of sediment introduced could be slightly exaggerated (oversupplied) because excess coarse sediment can be routed to downstream sites to improve storage. A final benefit is in the aesthetic appearance of the channel at these introduction sites, which would be designed to resemble a natural alluvial channel. This method, similar to Method 2, would also incur added transportation, field implementation, planning and permitting costs.

4.3.4 Direct Placement: High flow direct introduction [Method 4]

A fourth method of coarse sediment introduction directly places the coarse sediment into the channel during high flows, theoretically setting the sediment in transport as soon as it enters the channel (Figure 18). This method allows the river to transport and deposit the sediments downstream similar to a naturally-functioning alluvial channel. To introduce coarse sediment during high flows with the intent of immediate transport, these sediments would have to be introduced into the fast-moving portion of flow by one of several possible methods (e.g, dumping coarse sediments into the channel from a steep bank, or constructing an onsite delivery system such as a hopper and chute or a conveyor belt). Similar techniques have been used successfully on the Stanislaus River (Mesick, pers. comm.). One of the drawbacks is that coarse sediment can only be added to the channel during high flows, limiting the number of locations this method can be used at. Because of these constraints, this method is limited in applicability to sites or locations where large quantities of coarse sediment can be introduced during these hydraulic conditions, such as from bridges, down steep embankments, or at sites that have room for equipment and machinery. In addition, this method would incur transportation, field implementation and planning costs.

This method provides benefit to salmonids as soon as the flow recedes and the sediments deposit on an existing or create a new alluvial feature. In addition, background turbidity will be greater during high flows, which will allow the high flow introduction to generate a smaller impact on water quality.

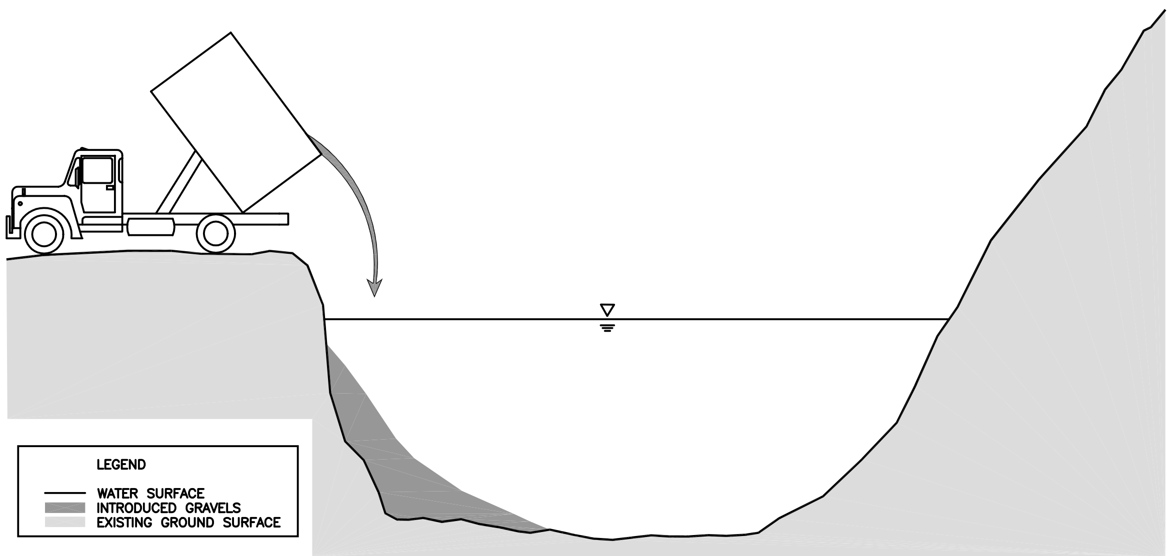
4.4 Coarse sediment introduction site identification and selection

Sites selected for coarse sediment aggregate introduction consist of both historic coarse sediment introduction sites, located in the near-vicinity of Lewiston Dam, and new sites, located between Lewiston Dam and Grass Valley Creek. The historic sites were chosen based on their proximity to Lewiston Dam and because coarse sediment has been introduced successfully the past (thereby providing some understanding of how the channel locally responds to coarse sediment introductions). New coarse sediment introduction sites were chosen by establishing a site selection criterion structured to first identify potential coarse sediment introduction sites from aerial photographs, followed by a field reconnaissance.

4.4.1 Historical introduction sites

The TRFES identified two sites requiring immediate coarse sediment supplementation: a 1,500 foot reach immediately downstream of Lewiston Dam (approximately RM 112.0 to RM 111.5), and a 750-foot reach immediately upstream of the USGS cableway (approximately RM 110.2) (USFWS and HVT, 1999). Historically, both of these sites, as well as other areas immediately up- and downstream, have received coarse sediment additions (see Appendix B). However, the coarse sediment introductions at these sites were short-term and only provided a temporary shift toward a balanced sediment budget. The TRFES outlined a strategy for future coarse sediment additions at these sites by restoring roughly 2 feet of bed elevation at each site. This strategy requires approximately 10,000 yd^3 of properly graded coarse sediment to be added at the Lewiston Dam site, and approximately 6,000 yd^3 to be added at the USGS cableway site. The TRFES also identified a third site, located at

Method 4: High Flow Direct Introduction



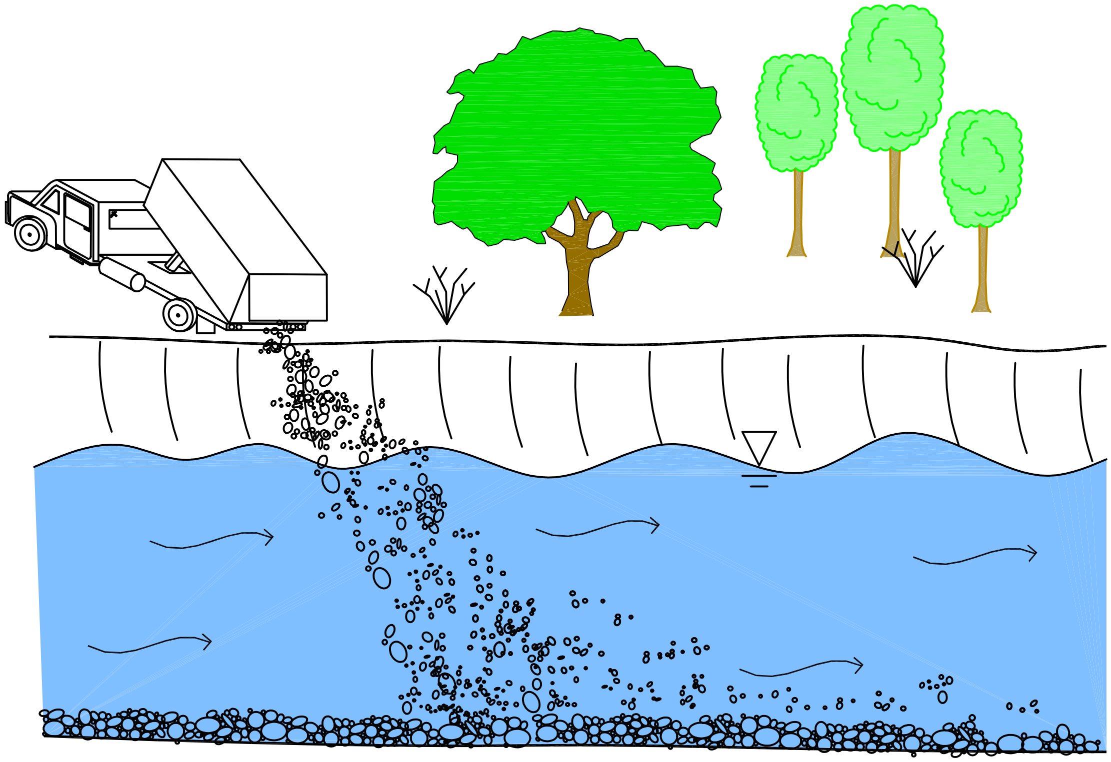


Figure 18. Method 4 for coarse sediment placement in Trinity River project reach: High flow direct introduction. Although the illustration shows direct dumping into the channel during a high flow, other methods are possible including constructing an onsite delivery system such a hopper and chute or a conveyor belt.

the USGS gaging station (RM 110.9), for annual high-flow coarse sediment introductions (Method 4). This location was used for coarse sediment introductions in 2000, where approximately 2,000 yd^3 was inserted using Method 1. Following this introduction, a 1,200 cfs flow event then transported the pile and partially filled the pool downstream. Based on this result, Method 4 is recommended at this site.

In the TRFES, the above historical introduction sites are characterized as short-term and/or long-term. The report recommends that the short-term introduction sites add coarse sediment to rebuild the bed and banks in depositional reaches of the channel, where the long-term sites focus on adding coarse sediment to the channel during the annual peak flow so that the sediment in entrained as soon as it is introduced. Because the hydraulics at the long-term sites facilitate instant transport during a high flow introduction, annual replenishments can be made at this location without local aggradation of the channel. Theoretically, after the short-term introduction sites (historical and new introduction sites) have received their initial coarse sediment supply, the long-term site will provide a source for the annual replenishment needed to replace the volume transported (Figure 10). It is likely that replenishment from upstream will happen to some degree, but some annual replenishment via direct placement at the short-term sites may also be required; this will be evaluated with a monitoring program (Section 6).

4.4.2 New introduction sites

We identified potential new short-term coarse sediment introduction sites by first reviewing 1997 and 2000 aerial photographs of the project reach. Criteria used to evaluate potential sites in the project reach from these photographs included:

- Site size
- Site access (feasibility)
- Reach morphology (e.g., meander bend, etc.)
- Reach gradient (from 1997 photogrammetry).

We then compared the potential sites to 1997 aerial photographs that included 2000 and 2001 redd mapping performed by the USFWS. This review allowed us to see where recent spawning areas have been delineated to potentially incorporate coarse sediment introduction sites in areas not presently being used by spawning adults due to inadequate coarse sediment storage in the channel.

After identifying potential coarse sediment introduction sites in the office, we conducted a reconnaissance-level field investigation on August 15, 2002. The purpose of this field investigation was to: 1) visually assess the extent of the existing coarse sediment storage and condition of alluvial features at the selected introduction sites, 2) identify other sites that were not readily apparent from the aerial photographs, and 3) estimate volumes of coarse sediment introduction needed at selected introduction sites to replenish in-channel storage, rearing habitat, and spawning habitat. In total, we identified 28 potential short-term coarse sediment introduction sites. Maps of the project study reach showing potential coarse sediment introduction sites are presented in Appendix C.

At each identified site, we evaluated the local setting to first determine if the site was suitable for coarse sediment introduction. This was done by visually evaluating the hydraulic and geomorphic characteristics of the channel, best evidenced by the presence and type of alluvial deposit (coarse sediment storage). The type of alluvial deposit (e.g., point bar) allowed us to understand the present sediment routing and depositional characteristics, and visualize how these might be enhanced via the supplementation of existing or the creation of new alluvial features (Figure 19). This evaluation also allowed us to determine the suitability and feasibility of each site for sediment introduction. After verifying the suitability of each site, we ranked the sites in order of prioritization (High or Low).

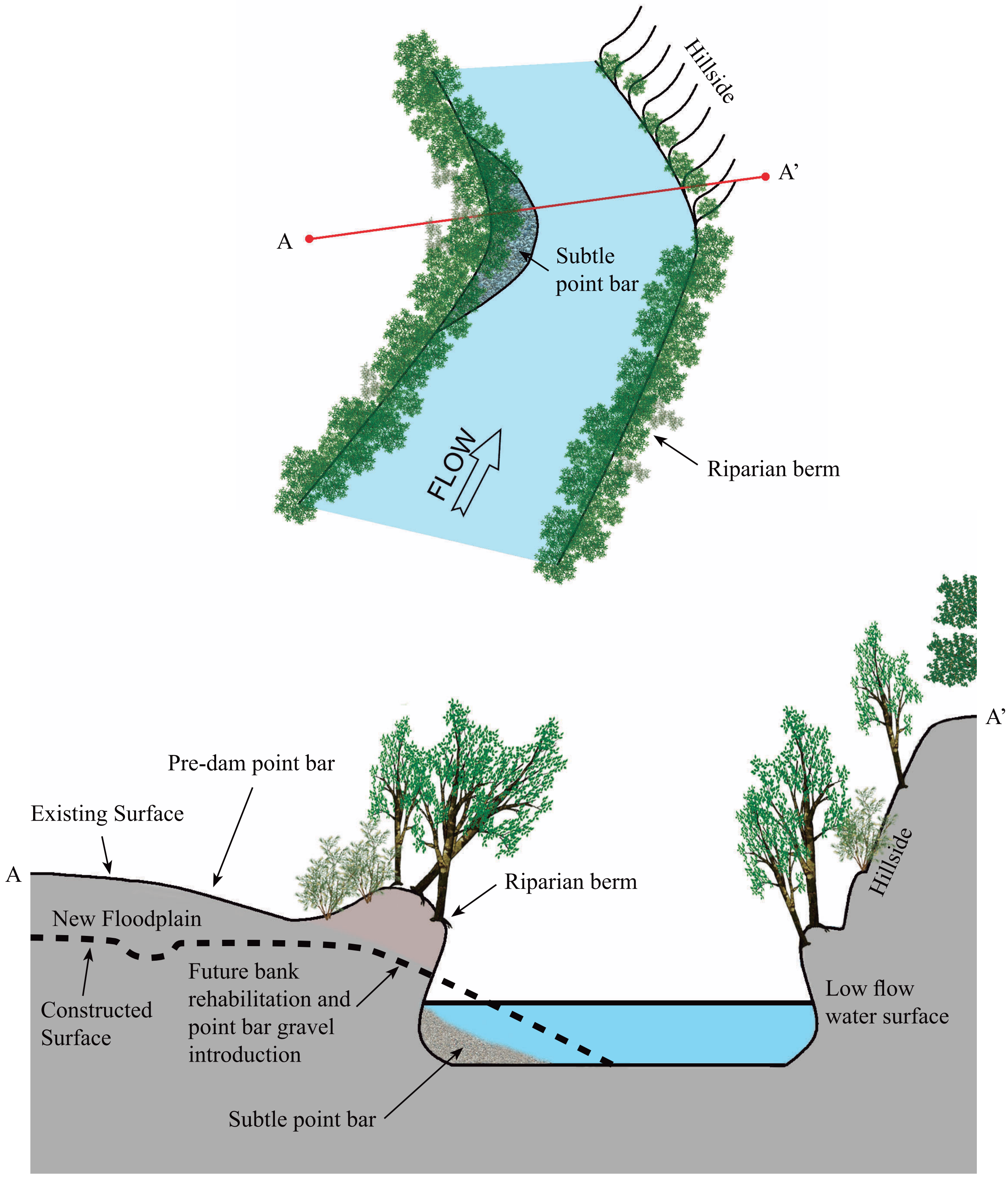


Figure 19. Typical channel morphology in the project reach, showing oblique planform and cross-sectional view of a potential coarse sediment introduction site. Using a combination of coarse sediment introduction and bank rehabilitation, the riparian berm would be removed (bank rehabilitation) and the point bar would be enhanced.

This ranking is based on a combination of the site's hydraulic and geomorphic feasibility (where mobilization and routing potential is high and where introduced sediments can provide the most immediate benefit for salmonids and other biota [High]), land ownership (public [High] vs. private [Low]), and coincidence with existing bank rehabilitation sites (High). Of the 28 potential coarse sediment introduction sites we identified, we classified 10 as high priority (6 sites in Reach 1 and 4 sites in Reach 2).

We mapped the limits of each potential introduction site on laminated 1997 aerial photographs, and then measured the dimensions at each site (e.g., length, width, and average water depth). To estimate the rough volume of coarse sediment to be added at each site, we estimated the average depth of coarse sediment to be introduced by adding an additional two feet to our measured average water depth in order to project the constructed surface onto the channel bank (discharge during our field visit was approximately 470 cfs). We then multiplied this depth by the surface area to estimate volume. Volume estimates at some sites were made using the aerial photographs to delineate the length and width of the feature, and the average coarse sediment depth was determined using existing cross section survey data. Because our measurements were made at the reconnaissance level, pre-project surveys will need to be completed to provide a more realistic volume estimate (see Section 6).

Table 5 presents a summary of the 28 identified coarse sediment introduction sites. This summary includes information about each site including the site location by river mile (the river mile locations delineate the downstream end of each site), the estimated volume of coarse sediment introduction aggregate needed, coarse sediment introduction priority, land ownership, and a general description of the type of feature to be constructed.

4.5 Site-specific placement recommendations

Each of the identified high-priority sites will serve as a short-term coarse sediment aggregate introduction site. Of the 10 high-priority short-term sites we identified, 6 are located in Reach 1 and 4 are located in Reach 2. Combined, these sites could introduce up to 19,600 yd^3 of coarse sediment introduction aggregate to the project reach (11,200 yd^3 and 8,400 yd^3 for Reaches 1 and 2, respectively). In addition to the coarse sediment introduction locations we identified, the TRFES presents additional short-term as well as two long-term study sites which are adopted for this plan. Below we present coarse sediment placement recommendations for the high priority (short-term) and long-term sites in the project reach.

4.5.1 Short-term, high-priority sites

All short-term, high-priority sites are also bank rehabilitation sites (except RM 108.84). Because of this, we recommend that all coarse sediment introduction work be coordinated with bank rehabilitation efforts.

<u>Reach 1</u>

- RM 111.50: The historical introduction site at RM 111.50 refers to the 1,500 reach of river located immediately downstream of Lewiston Dam, as described in the TRFES (Lewiston Dam Coarse Sediment Introduction Location). Per the recommendations in the TRFES, coarse sediments totaling up to 10,000 yd^3 should be added to the channel to raise the bed elevation by 2 ft in this reach. To accomplish this, we recommend using a combination of <u>Methods 1 – 3</u> to add coarse sediment to the channel by enhancing the right bank bar and riffle (<u>Methods 2 and 3</u>), while also placing a high flow stockpile (<u>Method 1</u>) that, if not recruited by the river, can be used for subsequent annual replenishment. For this approach, we recommend coarse sediment placements occur prior to high flow events.

- RM 110.19 (bank rehabilitation site D): The historical introduction site at RM 110.19 refers to the 750-foot reach immediately upstream of the USGS cableway, as described in the TRFES (Lewiston Cableway Coarse Sediment Introduction Location). Per the recommendations in the TRFES, coarse sediments totaling up to 6,000 yd^3 should be added to the channel to raise the bed elevation by 2 ft. To accomplish this, we recommend using of <u>Method 3.</u>
- RM 109.46 (bank rehabilitation site E): This reach of channel has aggraded, evidenced by a semi-uniform distribution of gravel across the width of channel, which becomes shallower and fines with distance downstream. We recommend using <u>Method 3</u> to add coarse sediments to the right bank to create a point bar that is approximately 1,175 ft long, with an average upstream width of 20 ft, and average downstream end width of 70 feet, and an overall average gravel depth of 4.5 ft (approximately 5,900 yd^3 total). A point bar at this location would likely encourage a thalweg to form toward the left bank, encouraging the channel to scour and facilitate alluvial deposition downstream.
- RM 109.07 (bank rehabilitation site F): A small right bank point bar presently occupies this site, located just downstream of a deep pool. Through coarse sediment introduction efforts in conjunction with bank rehabilitation (berm removal), a floodplain and larger right bank point bar can be created. We recommend that coarse sediment additions to this site should use <u>Method 3</u> to enhance the existing bar by placing approximately 500 yd^3 to enlarge the existing bar so it is approximately 145 ft long, 30 ft wide, with an average coarse sediment depth of 4 ft.
- RM 108.98 (bank rehabilitation sites G and H): This location can be considered a downstream continuation of the RM 109.07 site. Coarse sediment additions at this location can be placed to create a larger right bank point bar that is approximately 400 ft long and 30 ft wide, having an average coarse sediment placement depth of 5 ft (approximately 2,000 yd^3 total). The creation of this bar should be evaluated with the proposed plans for bank rehabilitation, and a smaller, intermediate bar (occupying portions of both this site and the RM 109.07 site) could be created. As with the RM 109.07 site, we recommend that coarse sediment additions to this site should use <u>Method 3.</u>
- RM 108.84: This site is bound between two boulder riffles. At this location, coarse sediment introduction can be used to create a left bank point bar, facilitating deposition and encourage the thalweg to form near the center to right half of the channel. Coupled with downstream construction at RM 108.78 (see following description), an alternate bar sequence can be created. We recommend using <u>Method 3</u> to construct the bar at this location that is approximately 295 ft long, 30 ft wide, and has a coarse sediment depth of 4.5 feet (approximately 1,100 yd^3 total).
- RM 108.78 (bank rehabilitation site I): Located just downstream of the RM 108.84 site, this site offers the ability to construct a right bank point bar to complete an alternate bar sequence (see RM 108.84 description above). We recommend using Method 3 to construct a right bank point bar that is approximately 250 ft long, 25 ft wide, and having a coarse sediment depth of approximately 3.5 feet (approximately 700 yd^3 total).
- RM 108.64 (bank rehabilitation site J): This site can be used to enhance an existing left bank point bar. This site is located approximately 75 feet upstream of a developing medial bar. Enhancing the existing subtle point bar at this location would have a similar effect as at the RM 108.84 and 109.46 point bars by encouraging a thalweg to form toward the opposite bank. This action would thereby facilitate deposition on the next downstream inside meander as well as facilitate deposition on the emerging medial bar. To enhance the existing bar at this

site, we recommend using Method 3 to create a bar that is approximately 275 ft long, 25 ft wide, and has a coarse sediment depth of 4.5 feet (approximately 1,000 yd^3 total).

Reach 2

- RM 106.45 (bank rehabilitation site N): This location consists of a developing right bank point bar, and we recommend enhancing this feature to increase its size and to encourage increased deposition downstream (potentially creating an alternate bar sequence). To enhance the existing bar at this site, we recommend using Method 3 to add coarse sediments to create a bar that is approximately 245 ft long. We recommend that the upstream 50 ft of the bar be approximately 15 ft wide and have a coarse sediment depth of 4.5 ft, and the downstream 195 ft be approximately 25 ft wide and have a coarse sediment depth of approximately3 ft (creating a feature with a total volume of approximately 800 yd^3).
- RM 104.82 (bank rehabilitation site S): Through coarse sediment introduction efforts in conjunction with bank rehabilitation (berm removal), a floodplain and larger left bank point bar can be created. We recommend that coarse sediment additions to this site should use Method 3 to enhance the existing bar by placing approximately 1,200 yd^3 to create a bar that is approximately 400 ft long, 20 ft wide, with an average coarse sediment depth of 5 ft.
- RM 104.45 (bank rehabilitation site T): This location contains a mid-channel aggradational lobe centered toward the left bank near the downstream portion of the site. Coarse sediment can be added to the left bank at this site to create a left bank point bar. By adding coarse sediment in conjunction with removing the riparian berm for bank rehabilitation (similar to the RM 104.82 site), a floodplain and larger left bank point bar can be created. To create the bar, we recommend using Method 3 to add approximately 2,000 yd^3 to create a bar that is approximately 400 ft long, 40 ft wide, and having a coarse sediment depth of 4.5 feet.
- RM 104.09 (bank rehabilitation site T): Located just downstream of the RM 104.46 site, this site offers the ability to construct a right bank point bar to complete an alternate bar sequence (see RM 104.45 description above). We recommend using Method 3 to construct a large right bank point bar that is approximately 1,225ft long, 30 ft wide, and having a coarse sediment depth of approximately 4.5 feet (approximately 4,400 yd^3 total). In addition, if this site is constructed in conjunction with the RM 104.45 site to create an alternate bar sequence, we recommend using Method 2 to supplement the riffle that connects the bars.

4.5.2 Long-term sites

The long-term supply reach is located in the immediate area downstream of Lewiston Dam and consists of introduction sites located only in Reach 1.

- RM 111.50: The historical introduction site at RM 111.50 refers to the 1,500 reach of river located immediately downstream of Lewiston Dam, as described in the TRFES (Lewiston Dam Coarse Sediment Introduction Location). Long-term introductions should take place near the upstream portion of this reach, near the Lewiston Dam tailrace at approximately RM 111.80. Per the recommendations in the TRFES, annual coarse sediment introduction volumes vary according to water year type (for volume estimates by water year type, see the TRFES, Table 8.10). Annual replenishment methods should be the same as those recommended for short-term introduction: add coarse sediment to the channel by enhancing the right bank bar and riffle (Methods 2 and 3), while also placing a high flow stockpile (Method 1) that, if not recruited by the river, can be used for subsequent annual replenishment. Using this approach, we recommend coarse sediment placements occur prior to high flow events.

In Wet or Extremely Wet water years, where the recommended introduction volumes are relatively large (compared to Normal, Dry, and Critically Dry water years; see the TRFES, Table 8.10), we recommend incorporating Method 4 to the above introduction strategy. Using Method 4, moderate to large volumes (potentially 40 to 60% of annual introduction needs) could be added during a single high flow event, thereby reducing the amount of coarse sediment introduction aggregate needed to be placed using Methods 1-3. For example, if 60% of the annual introduction needs can be introduced using Method 4, then the remaining 40% can be distributed throughout the site using a combination of Methods 1-3.

- RM 110.95: The historical introduction site at RM 110.95 is located at the USGS gaging station (Lewiston Gage Coarse Sediment Introduction Location). We recommend using this site in conjunction with the RM 111.50 site during Wet or Extremely Wet water years as an additional or alternative location to use Method 4 only. Per the recommendations in the TRFES, coarse sediments should be added annually at this site during the peak flow.

5 TRIBUTARY DELTA MANAGEMENT

The tributaries represent the only natural coarse sediment supply downstream of the dams. Because regulated flows downstream of the dams have been generally too small and too infrequent to distribute the tributary supply, large tributary deltas formed which reduced local water surface slopes and aggraded the mainstem channel, particularly at Rush, Grass Valley, and Indian creeks. At Grass Valley Creek, the Hamilton Ponds were constructed to trap fine sediment supply from the watershed. As a result, the adverse impacts generated at Rush and Indian creeks is no longer a problem at Grass Valley Creek. This portion of the coarse sediment management plan highlights the recommended strategy for re-establishing the sediment balance between tributary supply and mainstem transport. The accumulation of deltas not only causes local problems (e.g., backwater, bedload routing impedance, increase flooding of private property), it also reduces alluvial feature rejuvenation in downstream reaches (Figure 7, Section “B”). The ROD high flow regime, and potentially some mechanical manipulation of the deltas, will eventually reverse the negative impacts summarized in Section 2.4.1.

To help restore the balance in sediment supply and downstream yield, large tributary deltas need to be manipulated so the Trinity River can attain a more natural profile. Mechanical action may be needed to increase the hydraulic gradient through the delta and backwater area to facilitate downstream routing of the aggraded portion of channel at the deltas and restore coarse sediment routing through the delta. We prefer an approach that is self-maintaining rather than continual mechanical manipulation, and the ROD flow regime may be sufficient to do so. However, the delta area may need to be maintained to prevent it from re-forming.

5.1 Mechanical delta lowering

With the exception of Grass Valley Creek, all of the large tributary deltas on the Trinity River are composed of a range of coarse sediment size classes, including gravel, cobble, and boulder. Under the unimpaired flow regime, the Trinity River was able to mobilize and route all particle sizes delivered bythe tributaries. However, the post-TRD flow regime is insufficient to transport either the volume or size caliber of tributary derived coarse sediment, thereby causing aggradational deltas and associated backwater habitat upstream of the deltas. The ROD flow regime will greatly increase the sediment transport capacity of the mainstem, and have been developed with the objective of preventing future aggradation at the deltas, and ideally reverse some of the aggradation that has occurred there since completion of the TRD. However, some of the boulders delivered by the tributaries may still not be

Table 5. Summary of existing and new coarse sediment aggregate introduction sites. Surface area computed using AutoCAD. Bank rehabilitation sites and property ownership determined from USBR Restoration Site Work Area maps; land ownership is considered private if not otherwise labeled on the maps (e.g., BLM).

Reach	Approx. river mile location	Approx. length (ft)	Approx. width (ft²)	Estimated depth of sediment to be placed(ft)	Approx. surface area to be constructed / enhanced (ft²)	Estimated volume of coarse sediment to be added (yd³)	Associated with bank rehab site?	Sediment introduction priority	Property ownership	Description of recommended action
Historic introduction sites										
1	111.50	NA	NA	NA	NA	Per recommendations in 1999 Flow Evaluation Study	No	High	NA	Coarse sediment addition site at Fish Hatchery below Lewiston Dam
1	110.95						No	High	NA	Coarse sediment addition site at USGS gaging station
1	110.19						Yes (site D)	High	Private	Coarse sediment addition site at USGS cableway
New introduction sites										
1	111.05	1,500	30	7	43,300	11,200	Yes (A1)	Low	NA	Construct / enhance existing left bank point bar
1	110.42	685	20	7	12,900	3,300	Yes (site B & C)	Low	Private	Construct left bank point bar
1	109.95	420	30	5	11,000	2,100	Yes (site D)	Low	Private	Construct right bank point bar just upstream of Lewiston Bridge
1	109.87	40	180	4	7,200	1,100	No	Low	Private	Possibly fill gravel in behind boulder weir.
1	109.73	330	40	4.5	11,800	2,000	No	Low	Private	Enhance existing subtle right bank point bar
1	109.46	1,175	20 - 70	4	40,100	5,900	Yes (site E)	High	BLM	Construct narrow right bank bar; possibly connect to upstream right bank point bar (RM 109.73)
1	109.07	145	30	4	3,500	500	Yes (site F)	High	BLM	Enhance existing mall right bank point bar
1	108.98	400	30	5	10,600	2,000	Yes (sites G & H)	High	BLM	Construct right bank point bar
1	108.84	295	30	4.5	6,800	1,100	No	High	BLM	Construct left bank point bar, alternate bar sequence
1	108.78	250	25	3.5	5,100	700	Yes (site I)	High	BLM	Construct right bank point bar, alternate bar sequence
1	108.64	275	25	4.5	6,200	1,000	Yes (site J)	High	BLM / private	Enhance existing left bank point bar
1	108.50	325	45	4	9,900	1,500	No	Low	Private	Enhance existing left bank point bar
1	108.29	325	45	4	13,600	2,000	No	Low	Private	Construct right bank point bar
1	107.99	800	30 - 50	4	21,800	3,200	No	Low	Private	Construct right bank point bar with possible preserved side channel
1	107.56	1,970	60	6.5	126,400	30,400	No	Low	Private	Bank / bar construction along left edge of channel through present Rush Creek backwater area.
2	107.19	330	35	3	10,400	1,200	Yes (site L)	Low	Private	Enhance existing right bank point bar
2	106.86	190	20	4 - 7.5	7,600	1,600	Yes (site M)	Low	Private	Construct left bank point bar
2	106.78	200	20	5	3,600	700	No	Low	Private	Enhance existing subtle left bank point bar located between two side channel exits
2	106.45	50	15 - 25	3 - 4.5	5,500	800	Yes (site N)	High	Private	Enhance upstream end and construct downstream end of existing right bank point bar
2	106.32	NA	NA	NA	NA	NA	Yes (site O)	Low	Private	High flow coarse sediment direct placement location, across channel from bank rehab site O.
2	106.09	200	20	5	4,900	900	Yes (site P)	Low	Private	Construct right bank point bar at bank rehabilitation site
2	105.81	220	25	4.5	4,500	800	No	Low	Private	Construct right bank point bar at bank rehabilitation site
2	105.46	225	15	5	2,900	500	No	Low	Private	Construct bank point bar
2	105.28	215	35	5	5,200	1,000	Yes (site R)	Low	Private	Enhance existing left bank point bar
2	104.82	400	20	5	6,700	1,200	Yes (site S)	High	BLM / private?	Construct left bank point bar
2	104.63	325	20	6	5,600	1,200	No	Low	Private	Construct left bank point bar
2	104.45	400	40	4.5	13,700	2,000	Yes (site T)	High	BLM	Enhance existing left bank point bar, alternate bar sequence
2	104.09	1,225	30	4.5	26,400	4,400	Yes (Site T)	High	BLM, NPO	Construct right bank point bar, alternate bar sequence

transportable by the ROD flow regime, particularly at Rush Creek, Grass Valley Creek, and Indian Creek. Because the Hamilton Ponds now mitigate the delta problem at Grass Valley Creek, Rush Creek and Indian Creek are the largest potential aggradation problems within the study reach. For the Rush and Indian Creek deltas, some mechanical removal of the delta will likely be necessary before the ROD flows can be used to remove the annual supply of tributary sediments. Recent materials testing at the Rush Creek and Indian Creek deltas shows that the percentage of particles greater than 6 inches (the maximum size estimated to be easily moved by the ROD flow regime) is 4 % and 8% respectively. Some of the largest particles are over 18” diameter based on field observations. These larger particles may be sufficiently large that mechanical lowering of the upstream end of the deltas may be required in order to achieve the objective of preventing future aggradation and encouraging some degradation.

Lowering the deltas and preventing their reformation can be accomplished using a combination of mechanical and fluvial means. First, the deltas can be lowered mechanically, using heavy equipment to reduce the delta volume and contour the channel to a more natural profile. To minimize in-channel disturbance, mechanical delta removal can be performed using an excavator operated from the channel bank. Although the excavation will generate some localized disturbance, it will provide the fastest means for restoring the sediment balance and facilitating transport of upstream gravels stored in the channel. This can be accomplished by first removing the delta, which will increase the channel slope (and hydraulic gradient) through the reach (Figure 20, step 1). The increase in hydraulic gradient is designed to facilitate the transport and downstream routing of the sediments stored upstream of the delta and return the channel to a more uniform gradient (Figure 20, step 2). An auxiliary benefit to this method is that coarse sediments that are removed from the delta can be screened for the appropriate size fraction and recycled at nearby gravel introduction sites. This lowering and contouring should create a hydraulic setting that will allow the ROD flows to transport tributary supply from the delta area and prevent future aggradation (Figure 20, step 3).

5.2 Delta maintenance

Although the tributaries will continue to supply the mainstem channel with coarse sediment, delta removal and the resulting increase in the local hydraulic gradient should facilitate downstream routing of the tributary sediment supply and prevent future large deltas from re-forming (Figure 20, step 3). However, because tributary sediment supply and mainstem transport are not directly proportional (that is, the annual tributary sediment supply is not balanced with the flow regime below the TRD), it is possible that small deltas will continue to form at the tributary confluence. If the magnitude of high flows in the ROD flow regime is sufficient, the deltas should be prevented from growing to large and re-creating adverse hydraulic conditions (e.g., upstream backwater). Because delta removal will create a new balance between tributary supply and mainstem transport, the delta areas will have to be monitored in order to document the alluvial processes at each tributary confluence. Specifically, an adaptive management program designed to monitor the delta area and channel gradient through the reach should be developed to evaluate whether the magnitude and duration of flows are sufficient to prevent future delta aggradation, and to evaluate whether additional mechanical maintenance programs are necessary. This monitoring program can be used to document trends in aggradation and allow for mitigation in case tributary sediment supply exceeds mainstem transport (e.g., additional mechanical removal).

Tributary sediment supply has been monitored at the major tributaries to the mainstem Trinity River. Monitoring has included bedload and suspended sediment sampling, delta topographic surveys, and conceptual sediment budgeting (McBain and Trush, 1997). Sediment supply at Deadwood Creek and Grass Valley Creek has been monitored since water year (WY) 1995 and at Rush Creek and Indian

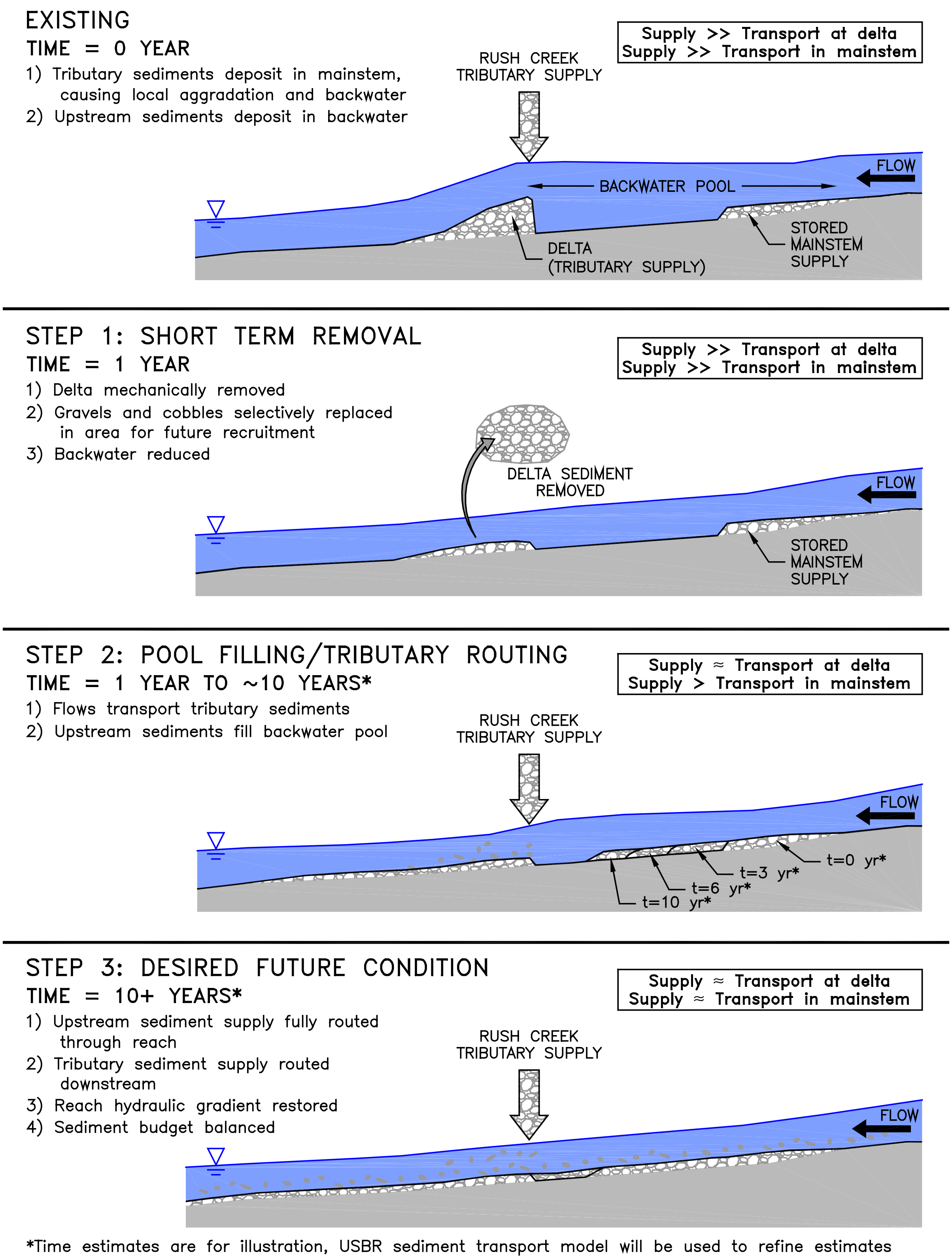


Figure 20. Conceptual model of mechanical tributary delta lowering and flow maintenance.

Creek since WY 1997. Monitoring at each of these tributaries has continued through WY 2002. The data compiled from these tributaries has been used to quantify the annual volumes of sediment supplied to the mainstem Trinity River and to develop relationships between tributary streamflow and sediment volumes (i.e., rating curves). Although these data have been used to develop conceptual sediment budgets, they will also be an important monitoring component to develop the magnitude and duration of annual high flow releases, as well as to evaluate the effectiveness of the ROD flow regime.

6 COARSE SEDIMENT MANAGEMENT MONITORING PLAN

A monitoring plan for coarse sediment management must evaluate whether the objectives of coarse sediment management are achieved. In Section 3.2 we presented the following objectives for coarse sediment management in the project reach:

1. ***Increase coarse sediment storage*** by adding coarse sediment at discrete locations to the channel and banks;
2. ***Maintain coarse sediment storage*** with annual coarse sediment replenishment;
3. ***Mobilize, scour, and redeposit coarse sediment*** to provide coarse sediment cleansing (i.e., removing interstitial fine sediment) and remove young riparian vegetation;
4. ***Route coarse sediment downstream*** where it will deposit as an alluvial feature;
5. ***Improve the quantity and quality of salmonid spawning and rearing habitat*** by creating new and enhancing existing alluvial features, and;
6. ***Improve sediment transport model predictions*** for coarse sediment introduction requirements.

The two-stage approach proposed for introducing coarse sediment at identified sites, based on the ROD flow regime, will first provide coarse sediment supply to the mainstem channel (short-term strategy), and then provide annual replenishments scaled to the flow release schedule (long-term strategy). Because ROD flows will vary depending on the water year type, and because each site will differ hydraulically and geomorphically, coarse sediment introduction methods and volumes should be implemented within the context of a monitoring and adaptive management program designed to meet the above listed objectives.

The following section presents a monitoring plan that describes specific monitoring activities and techniques designed to evaluate the coarse sediment management objectives. These activities are grouped into the following four monitoring categories:

A. ***Monitor the placement method, storage, and morphological evolution of placed coarse sediments;***

B. ***Monitor the morphological evolution of large tributary deltas (e.g. Rush Creek and Indian Creek) and the downstream distribution of their coarse sediments;***

C. ***Estimate annual volumes of coarse sediment needed to maintain equilibrium conditions;***

D. ***Evaluate the benefit of introduced coarse sediments to salmonid spawning and rearing habitat quantity, quality, and use.***

The individual monitoring activities contained in each monitoring category will allow each objective, or a component of each objective, to be evaluated (results from more than one monitoring category may be required to fully evaluate each objective). The four categories are essential to an adaptive management and monitoring program for evaluating coarse sediment placement and evolution. Monitoring associated with sediment management should test hypotheses (not solely trends) designed to explain causative processes. For example, introduction of specified substrate size distributions should be linked to predicted (modeled and empirical) sediment transport thresholds, more frequent bedload mobilization, deposition as alluvial features, and increased relative use of different sediment sizes by anadromous salmonids.

Please note that many of the methods and techniques discussed in this monitoring plan are also presented in the U. S. Forest Service General Technical Report RM-245, Stream Channel Reference Sites: An Illustrated Guide to Field Technique (Harrelson et al. 1994). All monitoring personnel are encouraged to obtain Harrelson et al. (1994) as many of the following topics are discussed in greater detail than presented in this section. In addition, other fundamental techniques not discussed in this section are presented in Harrelson et al. (1994) that may prove beneficial for monitoring personnel (e.g., surveying, measuring discharge, characterizing bed and bank material). Copies of Harrelson et al. (1994) can be obtained from the U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80526.

6.1 Monitor coarse sediment placement method, storage, and morphological evolution

Because the coarse sediment introduction sites were chosen, in part, to facilitate the mobilization and downstream transport of the added sediment, it is necessary to monitor these sites in order to assess whether the intended geomorphic processes are occurring, and what changes need to be made if they are not (e.g., promoting or reducing sediment movement, increasing the volume of sediment to be added, or selecting additional sites for sediment introduction). Evaluations should be performed at the site-specific and at the reach-wide scale. Below we discuss monitoring techniques that can be used to perform these evaluations, including site establishment, planform mapping, volumetric estimates of sediments mobilized, and sediment mobility and scour dynamics.

6.1.1 Site-specific coarse sediment evaluation methods

Coarse sediment introduction sites must be evaluated to document changes in channel morphology caused by sediment introduction and transport. This evaluation should include cross section, thalweg profile, and topographic surveys. Monitoring at each introduction site will need to occur following the initial introduction program and then after coarse sediment transport thresholds have been exceeded.

6.1.1.1 Establishing the monitoring site

If the coarse sediment introduction site has not been set up for monitoring from previous project efforts (e.g., if the site is not associated with a bank rehabilitation site), certain fundamental tasks must be completed to ensure successful monitoring. First, a primary benchmark must be established. The primary site benchmark should be located far enough from the channel so that it is not inundated during high water and should be constructed out of durable materials such as small concrete pad containing an aluminum or brass benchmark cap (see Harrelson et al. 1994). After the benchmark is constructed, its elevation and coordinates will need to be established using a survey-grade Global Positioning System (GPS). This will provide reference coordinates from which all site surveys will be made.

Following installation of the benchmark, monumented cross sections will need to be established. The monumented cross section serves as the location for measuring physical channel characteristics, such as channel form (e.g., location, grade, and position), stream discharge, and particle size distributions. Because the cross section serves as the location from where hydraulic measurements and calculations are performed, its orientation is across the channel, perpendicular to the direction of flow. The measurements and calculations performed at a cross section are the basis for quantitatively describing changes in water width, depth, velocity and slope with increasing discharge, called at-a-station hydraulic geometry (Leopold 1994), and for developing long-term records of streamflow.

One of the primary purposes of establishing a cross section is to perform hydraulic calculations and document topographic change over time. To do this, install rebar (often referred to as "pins") along a transect that is perpendicular to flow. Drive each pin vertically into the ground to a depth where no more than about 4 inches is exposed above the ground surface. Install at least two 1/2-inch rebar pins on each side of the channel, one that is 2-3 ft above the summer low flow water surface (preferably within 20 feet of the low flow water edge), and one further back, at an elevation above the predicted peak flood stage. Rebar on opposite sides of the channel should be set at similar elevations such that a tape stretched between pins is reasonably horizontal. Place a plastic surveyor's rebar cap on each pin immediately after it is installed for identification and safety.

The exact location of each pin will be tied to the same coordinate system as the primary site benchmark. To do this, each pin should be initially surveyed in with a survey-grade GPS that is referenced to the primary benchmark at each site (this can be done at the same time the benchmark is surveyed. After the pins are installed, label them using the 1"-diameter aluminum tags. Tags should be wire-attached to each pin, and the following information is stamped onto the tag: cross section name (based on longitudinal stationing), date installed, and elevation of the top pf the pin referenced to the primary site benchmark.

Cross section monitoring is intended to document changes along a transect either perpendicular to flow (cross section) or along the length of the channel (longitudinal and thalweg profile). All channel surveying, including new and existing cross sections, and longitudinal profiles, should be re-surveyed on an annual basis and following high flow events capable of causing topographic (and therefore geomorphic) change. The channel cross section is measured by surveying the ground surface and channel topography along a tape stretched between the rebar pins, where the rebar pins serve as survey endpoints. First, attach the zero end of the tape to the left bank (facing downstream) rebar pin. Stretch the tape tight and level across the channel, and attach it to the right bank rebar pin. Record the distance between pins.

After beginning the survey by establishing elevation from the primary benchmark, begin the cross section survey at the left bank rebar (station zero) by surveying both the top of the rebar pin and then the ground surface. From this point, the survey progresses along the tape by recording ground surface elevations and significant topographic (breaks-in-slope), geomorphic (particle size or vegetation changes), and hydrologic features (water surface elevations and high water marks). First-time surveys should record ground surface elevations at 2-foot intervals, and then subsequent surveys can follow significant breaks caused by topographic changes, with spacing not exceeding 10 feet. Continue the survey across the channel to the right bank rebar pin. As with the left bank pin, survey both the ground surface at the base of the pin as well as the top of the pin. When finished, survey elevation of the primary benchmark to close the survey (do turning points if needed) and record closure error in the field notebook. If closure error is greater than 0.05 feet, repeat the turning point loop to remove the error.

Other tasks included in establishing a study site include establishing photopoints and preparing site sketch maps, and are presented in detail in Harrelson et al. (1994).

6.1.1.2 Planform mapping

Prior to the coarse sediment introduction efforts, each introduction site should be surveyed to document pre-project topography. This topography will provide details on the locations of key physical features such as the primary benchmark, cross section pins, and other prominent features.

In addition, site planform maps can also document "baseline" conditions for determining actual sediment volumes added to each site. The objectives of the initial planform site mapping program are to first survey the pre-project site topography, and then survey the post- introduction topography to document the as-built conditions and volume of sediment added. The mapping should be performed using a Total Station and referenced to the primary site benchmark.

Once the initial site planform mapping is completed, mapping should be again performed following transporting flows and/or the annual peak discharge. This mapping will constitute the first of a series of topographic surveys required to track the evolution of coarse sediment storage at the site. These surveys, in conjunction with the results from bed surface mobility and scour monitoring (see Section 6.1.1.4), will provide the data required to compute the annual volumes of coarse sediment mobilized from the site (see Section 6.3).

6.1.1.3 Monitoring streambed particle size distributions

To collect representative surface particle size information at a monitoring site, a sample of the streambed or floodplain substrate is collected and the distribution of particle size measured by number (e.g., pebble count) or by weight (e.g., sieve analysis). The pebble count technique is one of the most common due to its relative simplicity and is discussed in detail in Harrelson et al. (1994). Pebble counts are best suited for describing particle size distributions on the bed surface. If subsurface particle size distributions are desired (such as for measuring the percentage of fine sediment in spawning gravels), a sieve analysis is more appropriate. A detailed description of a sieve analysis, as well as several other sampling techniques, is discussed by Bunte and Abt (2001).

Monitoring bed surface particle size distributions should be performed at selected coarse sediment introduction sites to track the evolution of particle size distributions at the site. The results of this monitoring have many applications; for example, results can be used in conjunction with bed mobility monitoring to determine whether coarse sediment introduction aggregate mixtures are too fine or too coarse, with salmonid spawning habitat assessments as an index of gravel quality (see Section 6.4), or with monitoring at non-coarse sediment introduction sites to track the evolution of particle size distribution change with time (this can be included using an "Index Reach" approach described in Section 6.5).

6.1.1.4 Monitoring bed surface mobility, scour, and deposition

Marked rocks

Marked rocks sets are used to document channel bed surface mobility on alluvial features (e.g., point bars, medial bars, pool tails, etc.). A group that is comprised of several individual sets of particle size classes representative of the area to be monitored are painted a bright color, such as fluorescent orange, and placed at discrete locations in the channel along a monitoring cross section. Following a discrete high flow event, the cross section is revisited to document whether mobility of the marked rocks occurred, and if the marked rocks could be located downstream, how far they moved. The marked rocks are then re-set or replaced as initially installed for the next high flow event.

Commonly the channel bed surface will exhibit a mosaic of uniform substrate compositions. For example, a Trinity River point bar will likely be composed of gravels and cobbles, whereas the floodplain would likely eventually be composed of sand and silt. In this case, the bar and floodplain can be considered separate distinct size populations, or facies. Because each facies will yield its own unique particle size distribution, each must be sampled separately in order to collect representative particle size information. Because it is possible for more than one facies to be present at a monitoring cross section, it is best to split the marked rock sets into no more than two separate populations according to the major facies changes (e.g., channel facies and bar facies).

Using the statistical particle size distribution from field sampling (e.g., pebble count), collect D_{84}, D_{50}, and D_{31} particle sizes (particle sizes in a cumulative distribution for which 84, 50, and 31 percent are finer, respectively) and paint them a distinguishable color. When the paint has dried, group the rocks into individual sets consisting of each size parameter and placed the sets at approximately two foot intervals on a cross section: place the D_{84} on the cross section, the D_{50} one foot upstream of the D_{84}, and the D_{31} one foot upstream of the D_{50} (Figure 21). This placement scheme prevents artificial shielding of the smaller marked rocks by the larger ones. Set each marked rock on the bed surface so that its exposure mimics that of the surrounding rocks. To do this, place each marked rock on the bed surface by removing a similar sized rock from the bed and setting the marked rock in its place. This placement scheme allows the marked rocks to reasonably maintain natural bed surface conditions and avoid unnatural over- or under-exposure. If large boulders or other obstructions prevent placing certain rocks in their desired location, place the rock as close as possible to the originally intended spot.

Following a high flow (capable of exceeding transport thresholds), revisit each marked rock set and note which, if any, marked rocks move. Rocks can be assumed to have moved if they are farther than two feet from the original cross section location; distances less than two feet can be considered hydraulic stabilization. Marked rocks relocated downstream should be measured for their particle size and their travel distance recorded. If direction of movement is desired, individual rocks can be labeled so this parameter can be tracked.

The marked rocks sets are used to empirically document channel bed surface mobility. The goal of marked rocks monitoring is to document bed surface mobility resulting from several high flow events so that the results bracket the range of peak flows that generate between 0% and 100% mobility of each size class of marked rock. Theoretically, enough monitoring events will provide sufficient data points to capture this flow range

<u>*Scour cores*</u>

Scour cores are used to document channel bed scour and redeposition on alluvial features (e.g., point bars, medial bars, riffles, pool tails). To measure this, a core of channel bed substrate is removed and backfilled with brightly painted, uniform size “tracer gravels” that are smaller than the surrounding bed materials (an alternative to painting gravels is to use a homogeneous, unique color lithology, such as quartzite or dolomite). When discharge increases and scours the surrounding bed, the tracer gravels also become entrained and are transported downstream. Following high flows capable of causing scour, the scour core location is revisited to document, via survey control, scour and redeposition depths. Typically two to three scour cores are installed at a site where scour is to be measured.

Scour cores are commonly placed on a cross section to provide precise stationing and easiest to install on exposed bars. The installation procedure is as follows: survey the elevation of the bed surface (referenced to a site primary benchmark). Next, manually work a McNeil sampler (or similar device) approximately 1.5 feet into the bed, and place the excavated substrate in a 5-gallon bucket for disposal away from the scour core. Best results are obtained by iterations of working the sampler a few inches into the bed, excavating some substrate, and repeating the process until the excavation is roughly 1.5 feet deep. Once the target depth is reached, survey the elevation of the bottom of the core, then backfill the core to roughly the original bed elevation with the tracer gravels. After backfilling the core, remove the McNeil sampler, smooth the surface of the tracer gravels with your hand, and survey the elevation of the top of the tracer gravels (see Figure 22 steps 1 through 5).

During a high flow event that scours the bed, the tracer gravels will became entrained and transported away from the scour core. To document scour and redeposition depths following a scouring event,

Figure 21. Photograph of typical tracer gravel placement along a cross section.

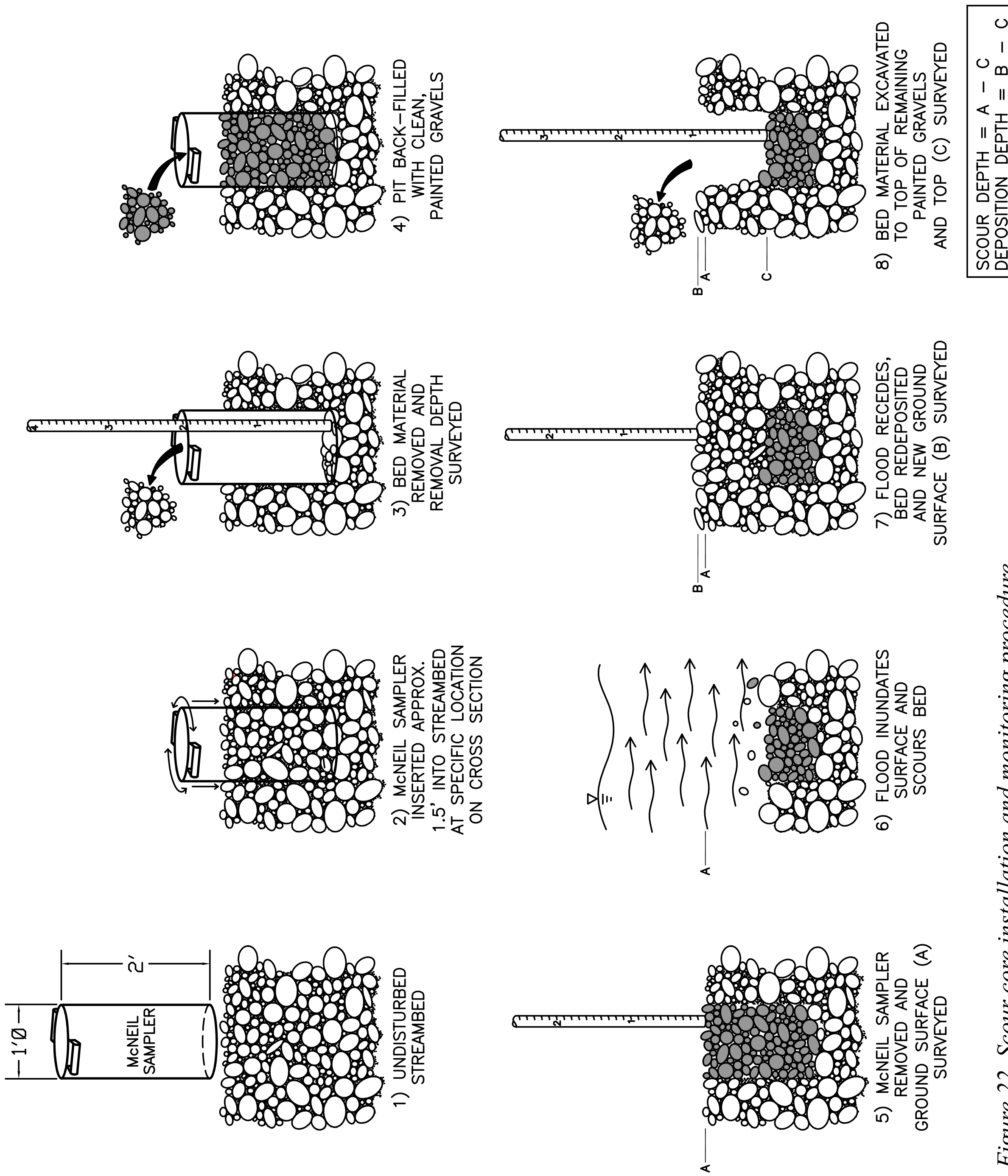


Figure 22. Scour core installation and monitoring procedure.

reoccupy the scour core location by stringing a tape across the cross section. Once the tape is strung, locate the precise station the core was installed, and survey the bed surface elevation. Using the McNeil sampler, carefully re-excavate the core until the tops of the tracer gravels are found. It is important to re-excavate slowly, so the surface of the tracer gravels is not disturbed; if the excavation extends into the tracer gravels, an inaccurately large scour and redeposition depth will be recorded. Once the surface of the tracer gravels is exposed, survey their elevation. Differences in surveyed bed elevations and surface tracer gravel elevations will effectively document scour and redeposition depths (Figure 22, steps 6 through 8).

6.1.2 Reach-wide sediment evolution evaluations

6.2.1.1 Planform mapping

In addition to the site-specific planform mapping, coarse sediment evolution should be monitored throughout the project reach. Because sediments that have mobilized from the introduction sites will route downstream and deposit on existing, or as new, alluvial features, the occurrence and formation of these features, such as point bars, pools, riffles, etc. should be documented by reach-long planform mapping. Alluvial features not associated with coarse sediment introduction sites should be identified in the field and plotted on low-altitude (e.g., 1:12,000) aerial photographs. These maps will help identify coarse sediment storage sites and document their evolution (morphologically and/or spatially) as a function of time and flow. At minimum, these maps should simply be mapping the surficial extent of alluvial deposition (bars) during summer baseflow periods. As bank rehabilitation sites are implemented, coarse sediment is introduced, and high flows are released to distribute tributary derived sediments, the number and aerial extent of exposed gravel/cobble bars should increase with time. The mapping should document whether this expected alluvial response is being achieved (and where it is occurring). Additional detail could be added with topographical data, but the expense may not justify this expanded effort based on the information it provides.

6.2 Monitor morphological evolution of tributary deltas and downstream distribution of their coarse sediments

Tributary delta evolution can be monitored using a combination of several previously described techniques specifically applied to the tributary delta setting. Tributary deltas are self-supplying coarse sediment introduction sites. However, unlike at the mechanical introduction sites, coarse sediment supply to the tributary deltas is unregulated, and the volume contributed by the tributaries is dependent on winter storm events. Tributary contribution of coarse sediment is an integral part of the overall coarse sediment management plan, and high flow releases are designed to transport this coarse sediment downstream at the same rate of delivery from the tributaries. Therefore, future monitoring of coarse sediment delivered by the tributaries should continue in the future. The most important tributaries are Deadwood Creek (RM 110.8) and Rush Creek (RM 107.5) because of their proximity to Lewiston Dam and the importance of their coarse sediment contribution to the Trinity River. Historical monitoring has included: (1) bedload transport sampling during tributary high flow events to predict overall coarse sediment delivery to the Trinity River, and (2) topographic surveys of the tributary deltas before and after distinct storm events, as well as at the end of the high flow season, to develop another estimate of coarse sediment delivery to the Trinity River. Hamilton Ponds near the mouth of Grass Valley Creek (RM 104.0) should also be continued to track sediment yield from Grass Valley Creek, but because Hamilton Ponds trap nearly all coarse sediment from reaching the Trinity River, this monitoring is not that useful to the Coarse Sediment Management Plan. Indian Creek (RM 95.2) has been topographically monitored in the past for storm-specific events, but because it is further downstream, the cumulative flows increase sediment transport capacity in the mainstem

Trinity River compared to upstream deltas. Therefore, the volume estimates using this method at Indian Creek are not as accurate as upstream deltas because the mainstem transports much of the sediment delivered by Indian Creek to downstream reaches.

The volumetric estimates of sediment delivery will be important for yearly flow management, as the sediment routing model developed by the USBR Technical Service Center will be used as a tool to develop the magnitude and duration of annual high flow releases. The monitoring information will also allow calibration of the sediment model, which should greatly improve the predictive capability of the model. Empirical sediment transport rating curves relating flow to the annual sediment transport rate developed from field measurements should be compared with predicted (modeled) results. Empirical sediment transport data should be collected at the USGS Lewiston gaging station cableway to calibrate the sediment transport formula used in the model, and delta topography and gravel introduction site topography should be collected before and after each high flow release to evaluate the overall performance of the sediment transport model. High flow water surface elevations should be surveyed at the sediment modeling cross sections to improve hydraulic model calibration. The sediment transport model was used to develop the flow magnitude and duration needed to accomplish a desired volume change at the tributary delta, then the flow is released, and topographic monitoring will allow comparison of predicted versus observed results. Additional calibration of the hydraulic model and sediment transport function could theoretically improve future predictive accuracy of the sediment transport model.

6.3 Estimate annual volumes of coarse sediment needed to maintain equilibrium conditions

Achieving the project objective of maintaining a balanced coarse sediment budget (maintaining equilibrium conditions) will require developing methods for estimating annual coarse sediment replenishment needs. Annual coarse sediment volumes required to resupply the mobilized portion of each introduction site can be computed using the integrated results from the site planform maps, representative cross sections, and coarse sediment routing model (Section 6.1.1). Planform mapping surveys should be conducted following each sediment introduction effort at each site, then again following the annual high flows that mobilize sediment from the site. The planform maps generated at each site provide ground surface topographic data that can, using topographic differencing, provide the net volume of sediment mobilized from each site. Topographic differencing is a technique where the pre- and post-sediment mobilization site planform maps can be superimposed to calculate the volumetric difference between the two surfaces, thereby providing the volume required to replenish each site back to its pre-mobilized surface elevation.

In addition to estimating the volume of coarse sediment required to resupply each site, estimates of the net volume of sediment mobilized from the site should be made. The topographic differencing method described above will only provide an estimate of the volume of sediment required to replenish the site surface to its pre-transport surface. This method only captures a portion of the volume of sediment transported from the site, because it does not capture the depth to which the site scoured before being redeposited with sediment from upstream sources. To estimate the full volume of sediment transported from each site, scour depths recorded by the scour cores will need to be extrapolated to a representative depth for the site. Once this depth has been estimated, it should be added to the volume obtained from the topographic differencing to yield an estimate of the total volume of sediment transported from the site.

6.4 Evaluate the benefit of introduced coarse sediments to salmonid spawning and rearing habitat quantity, quality, and use

Linking management actions (e.g., sediment augmentation) to projected benefits (e.g., improved spawning habitat) is the holy grail of resource management. Monitoring is the first step in this linkage. Ideally, biological monitoring should be implemented within the context of a comprehensive monitoring plan that is designed to evaluate the individual and combined effects of alternative restoration strategies and projects, as well as annual trend monitoring. For example, monitoring designed to assess sediment augmentation sites should be coordinated with monitoring at bank rehabilitation sites. This strategy can reduce monitoring costs as well as improve the overall quality of data collected. Developing a comprehensive monitoring plan is beyond the scope of this document. Instead we suggest a broad framework for a comprehensive monitoring plan and provide monitoring recommendations that focus specifically on coarse sediment augmentation.

Obviously not all sites along the river can be monitored for all parameters. We therefore recommend a strategy that combines an assessment of river-wide trends in salmonid population dynamics and habitat availability with focused monitoring at selected "index reaches" (see Section 6.5). This strategy balances broad-scale assessments of population and habitat trends with site-specific information that is assumed to be representative of river-wide conditions. For example, the total number of salmon that return to spawn (adult escapement) obviously must be estimated within the context of the entire river, whereas measuring spawning gravel quality (permeability, percentage of fine sediment) at every spawning site is unnecessary.

Because a fundamental goal of coarse sediment management is to increase sediment storage as a strategy to increase and maintain spawning gravel availability, monitoring spawning gravel availability and spawning dynamics is a critically important component to the adaptive management process. At some level two important parameters of spawning gravel – capacity and productivity –should be evaluated. Capacity is simply the amount of habitat in a given area (density), whereas productivity refers to the quality of the gravels (Mobrand et al. 1997), which determines survival-to-emergence of incubating embryos. Both these monitoring components are relatively common and have established methodologies for their implementation. Finally, in addition to evaluating the capacity and productivity of spawning gravels, we recommend establishing a quantitative relationship between streamflow and spawning habitat availability. This relationship can be used as an important piece of evidence in evaluating whether spawning habitat is limiting production for a given adult escapement. This relationship can also be used to apply variable flows during the spring-run and fall-run Chinook spawning periods to distribute the two runs into different areas of the channel (laterally and longitudinally), thereby reducing superimposition mortality of incubating eggs (later fish spawning on already constructed redds, killing the earlier spawned eggs and thereby reducing fry production).

6.4.1 River-wide monitoring

We recommend the following monitoring elements be included as part of a more comprehensive river-wide biological monitoring program:

- Estimate spawning escapement for each species of anadromous salmonids (spring-run, fall-run, coho? steelhead?), either by weekly carcass counts or by trapping and counting adults passing a downstream weir.

- Quantify spawning habitat availability for each species of anadromous salmonids by mapping spawning habitat area at each riffle onto the 2001 orthorectified aerial photographs (scale: 1”=100’); spawning habitat should be identified using depth, velocity, substrate, and other criteria developed within the Trinity River; each mapping event should occur at a single flow, but a range of flows should be assessed to develop a flow vs. habitat relationship.

- Document spawning distribution by weekly redd counts of the number of redds per individual riffle or spawning site, and by redd mapping to document the relative distribution of redds within riffles; this assessment should be conducted at a relatively coarse scale that will reveal river-wide trends in spawner distribution, but may not accurately reveal the extent of redd superimposition or other finer-scale parameters within individual spawning sites.

- Measure smolt outmigration by rotary screw trapping or other method, to quantify annual trends in smolt production, survival, migration timing, and fish condition (size and weight).

6.5 Index Reach Monitoring

Complementary to the broader-scale river-wide monitoring, we are presenting the concept of “Index Reach Monitoring”. This concept is borne from the potential monitoring challenges of quantifying and qualifying the benefits of coarse sediment introduction to salmonid spawning. In addition to this habitat monitoring component, the index reach concept can be adopted for the other monitoring components presented in this chapter, such as reach wide sediment evolution evaluations (Section 6.1.2) and estimating annual volumes of coarse sediment needed to maintain equilibrium (Section 6.3).

If this monitoring strategy is adopted, we recommend establishing several index reaches within the overall project reach. Index reaches will allow for more focused monitoring to provide an assessment of specific restoration components as well as the cumulative benefits of several different restoration elements. For example, coarse sediment augmentation implemented in conjunction with bank rehabilitation sites can be monitored within an index reach that would include several biological parameters.

We recommend that at least 4 index reaches should be established (2 per geomorphic reach), each approximately 1,000 ft in length and containing one or more short-term coarse sediment introduction sites. Using the habitat monitoring component of the monitoring plan (Section 6.4) as an example, we recommend the following elements be considered for monitoring at index reaches:

- Quantify fry and juvenile rearing habitat availability and use, comparing bank rehabilitation and gravel bar augmentation sites to unrestored bank margins with well-developed riparian berms or depleted sediment conditions.
- Quantify spawning habitat availability and use by mapping all redds at individual riffles during the entire spawning season, total station survey equipment should be used to precisely locate individual redds; index spawning sites should be mapped each year to reveal temporal changes in spawning densities.
- Quantify spawning habitat quality using permeability techniques, bulk sampling to quantify particle size distribution and the percentage of fine sediments in spawning gravels, and/or redd-capping (of natural or artificially constructed redds) to estimate survival-to-emergence of salmonid eggs.

- Assess habitat complexity by mapping habitat layers onto the 2001 orthorectified aerial photos, including meso-habitat units (pool-riffle-run), physical elements such as sediment particle facies, large and medium woody debris components, overhead and instream vegetative cover, undercut banks, large boulder and bedrock cover elements, velocity shear zones, and micro-habitat elements including spawning and rearing habitat; this information can be synthesized using a multi-metric index (Karr and Chu 1999).
- Quantify invertebrate taxonomic richness, abundance, and production using standardized methodologies similar to the Rapid Bio-assessment Protocol (RBP) developed by California Department of Fish and Game (Barbour et al. 1999)
- Evaluate changes in herpetofauna habitat availability and habitat use, taxonomic richness and abundance.

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APPENDICES

APPENDIX A

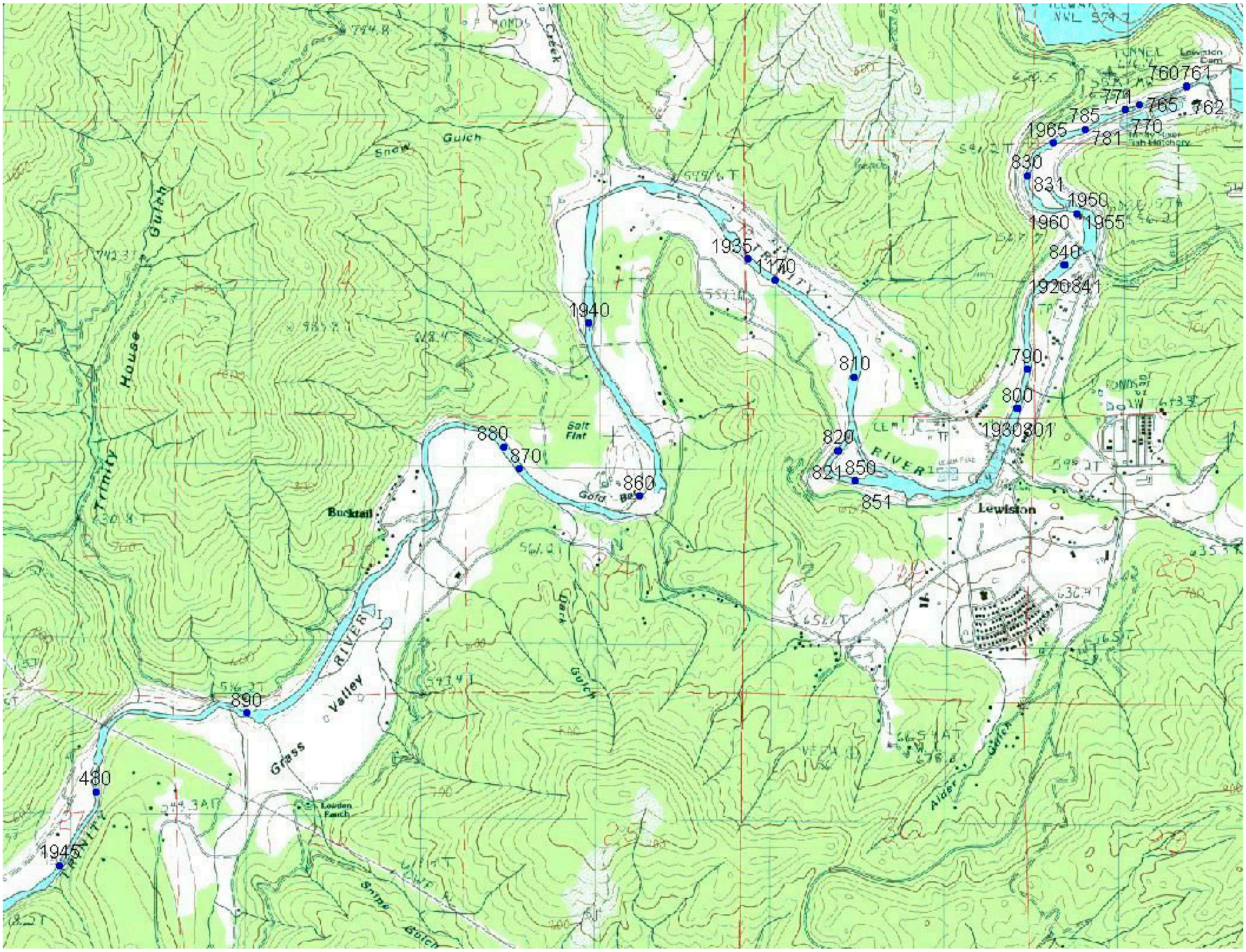
Particle size class		Particle size (mm)	Particle size (in)
		4,096	161.2
	Very large	2,896	114
		2,048	80.6
	Large	1,448	57
Boulder		1,024	40.3
	Medium	724	28.5
		512	20.1
	Small	362	14.2
		256	10.1
	Large	181	7.1
Cobble		128	5
	Small	90.5	3.6
		64	2.5
	Very coarse	45.3	1.8
		32	1.2
	Coarse	22.6	0.9
		16	0.6
Gravel	Medium	11.3	0.4
		8	0.3
	Fine	5.66	0.2
		4	0.16
	Very fine	2.83	0.11
		2	0.08

Coarse sediment size gradation chart showing particle size class descriptions and sizes. Particle sizes less than 2mm are classified as sand (2.0 mm to 0.063 mm), silt (0.063 mm to 0.0039 mm), or clay (0.0039 mm and finer) (Bunte and Abt, 2001).

APPENDIX B

Year	*Location (river mile)*	*Map location point no.*	*Implementing agency*	*Volume*	*Coarse sediment introduction project description*
1976	111.8	760	USBR	NA	Riffle construction
1976	111.5	770	USBR	NA	Riffle construction
1976	111.4	785	USBR	NA	Riffle construction
1976	110.2	790	USBR	NA	Riffle construction
1976	110.1	800	USBR	NA	Riffle construction
1976	108.8	810	USBR	NA	Riffle construction
1976	109.1	820	USBR	NA	Riffle construction
1977	111.2	830	USBR	NA	Riffle construction
1977	110.7	840	USBR	NA	Riffle construction
1977	109.3	850	USBR	NA	Riffle construction
1977	107.2	860	USBR	NA	Riffle construction
1977	105.7	870	USBR	NA	Riffle construction
1977	105.6	880	USBR	NA	Riffle construction
1977	104.0	890	USBR	NA	Riffle construction
1983	111.8	761	DWR	2,400 yd^3	Spawning gravel placement / riffle repair
1983	111.4	781	DWR	NA	Spawning gravel placement / riffle repair
1983	110.2	791	DWR	NA	Spawning gravel placement / riffle repair
1983	110.1	801	DWR	NA	Spawning gravel placement / riffle repair
1983	109.1	821	DWR	NA	Spawning gravel placement / riffle repair
1983	111.2	831	DWR	NA	Spawning gravel placement / riffle repair
1983	110.7	841	DWR	400 yd^3	Spawning gravel placement / riffle repair
1983	109.3	851	DWR	NA	Spawning gravel placement / riffle repair
1984	111.8	762	DWR	775 yd^3	Spawning gravel placement / riffle rehabilitation
1984	111.5	771	DWR	126 yd^3	Spawning gravel placement / riffle rehabilitation
1984	111.4	780	DWR	860 yd^3	Spawning gravel placement / riffle rehabilitation
1986	111.5	765	NA	NA	Spawning gravel placement
1989	110.1	1930	USBR	400 yd^3	Spawning gravel placement
1989	110.7	1920	USBR	900 yd^3	Spawning gravel placement
1989	110.2	1925	USBR	500 yd^3	Spawning gravel placement
1989	108.1	1935	USBR	200 yd^3	Spawning gravel placement
1989	107.0	1940	USBR	200 yd^3	Spawning gravel placement
1989	111.5	1915	USBR	1,175 yd^3	Spawning gravel placement
1998	110.8	1950	USBR	1,000 tons	Spawning gravel placement
1998	111.3	1965	USFS	800 yd^3	Spawning gravel placement
1999	110.8	1955	USBR	1,000 tons	Spawning gravel injection
2000	110.8	1960	USBR	2,000 tons	Spawning gravel injection

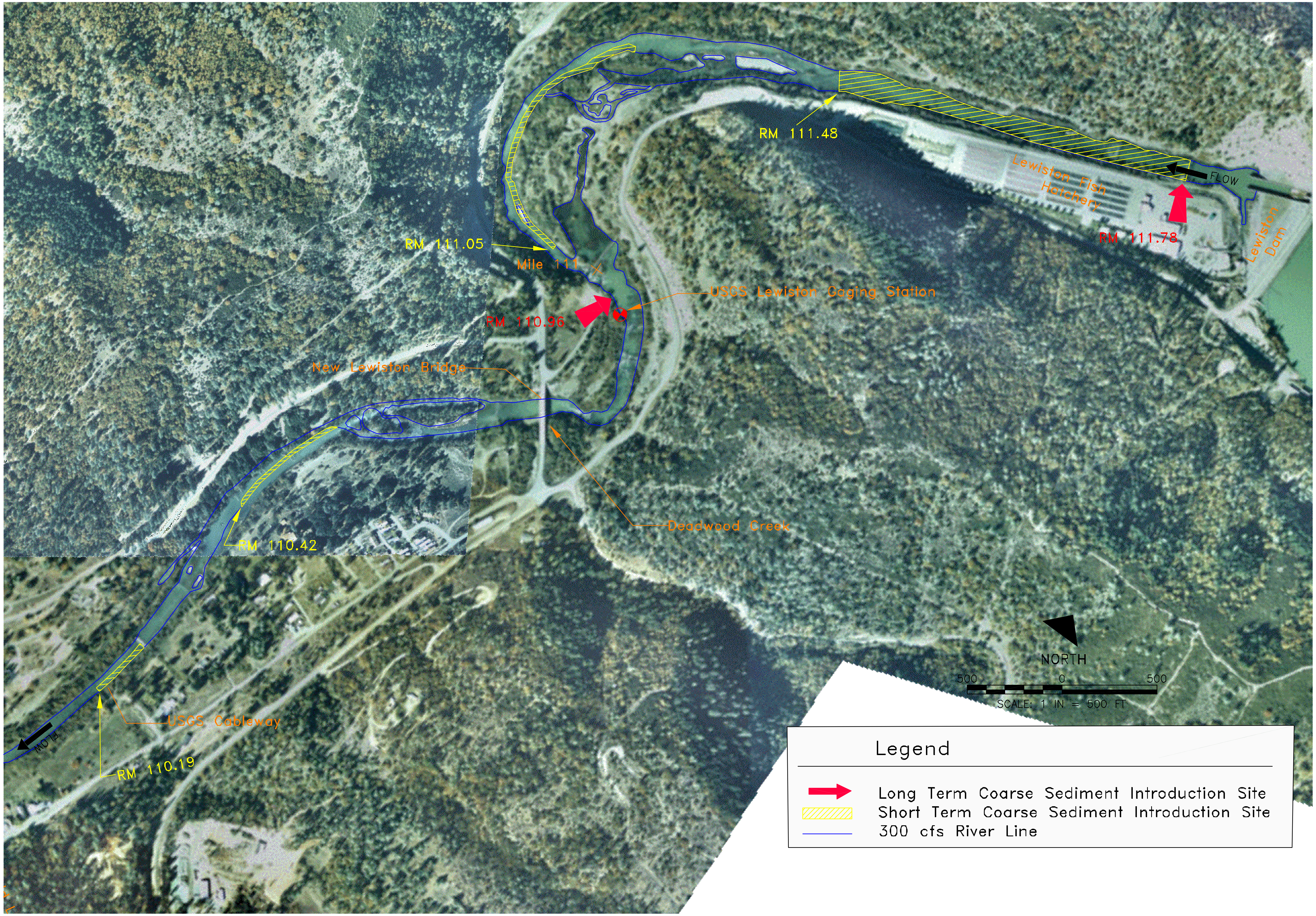
Historic coarse sediment introduction efforts within the project reach, 1976 to present. Information provided by J. Elko, California Department of Water Resources.



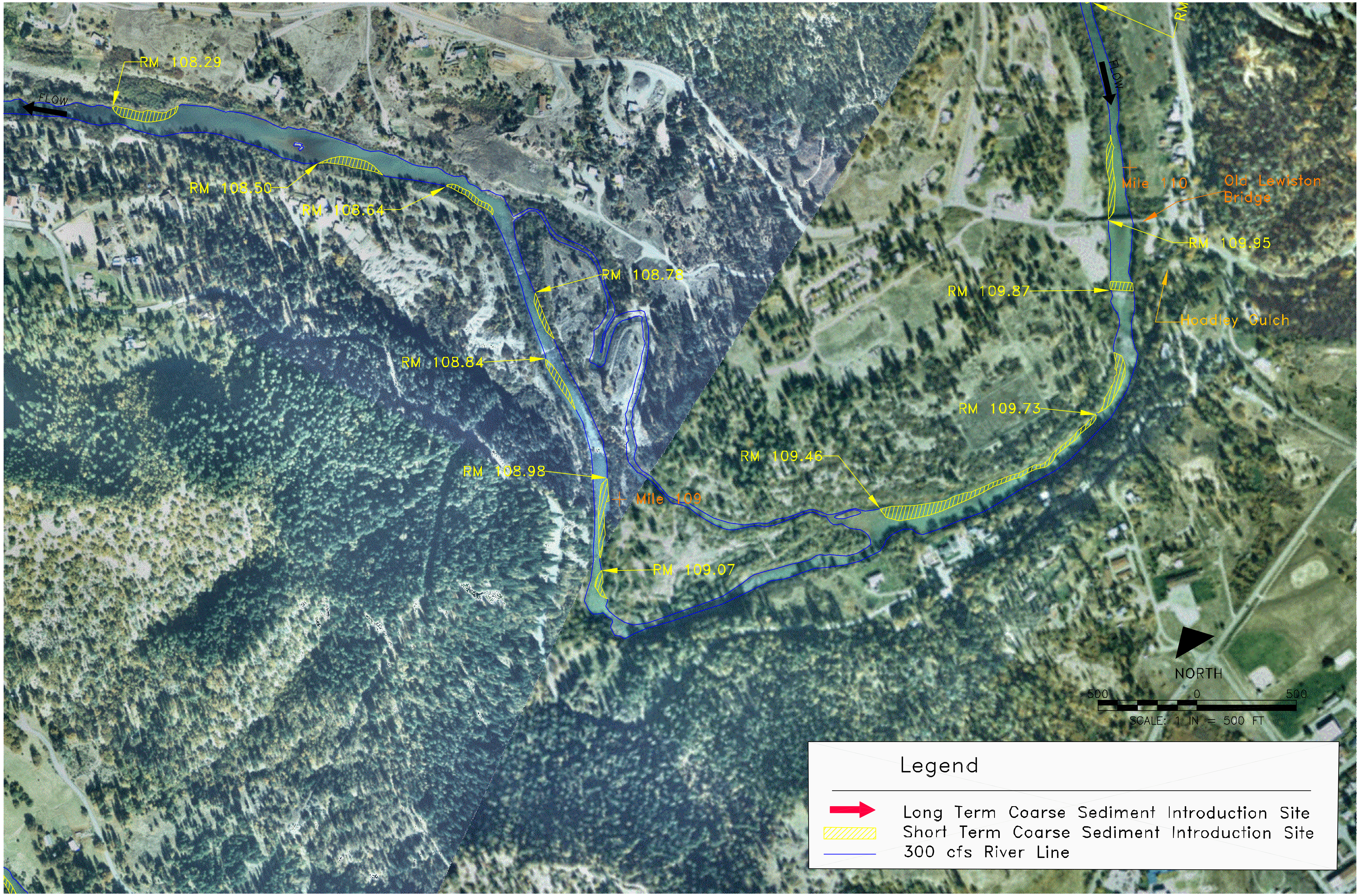
Historic coarse sediment introduction sites. Numbered locations on this map correspond with map location point numbers listed in previous table. Map provided by J. Elko, California Department of Water Resources.

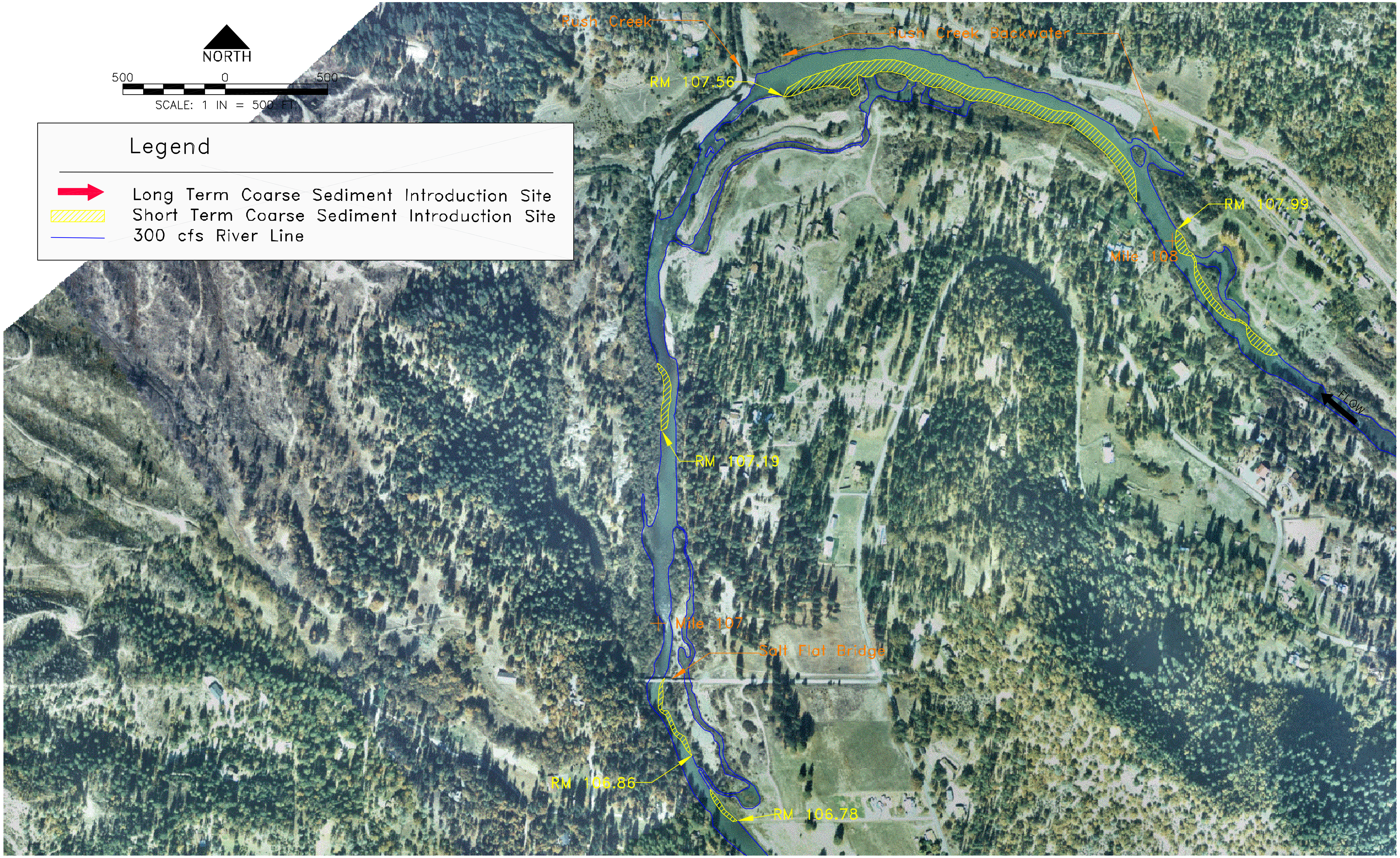
APPENDIX C

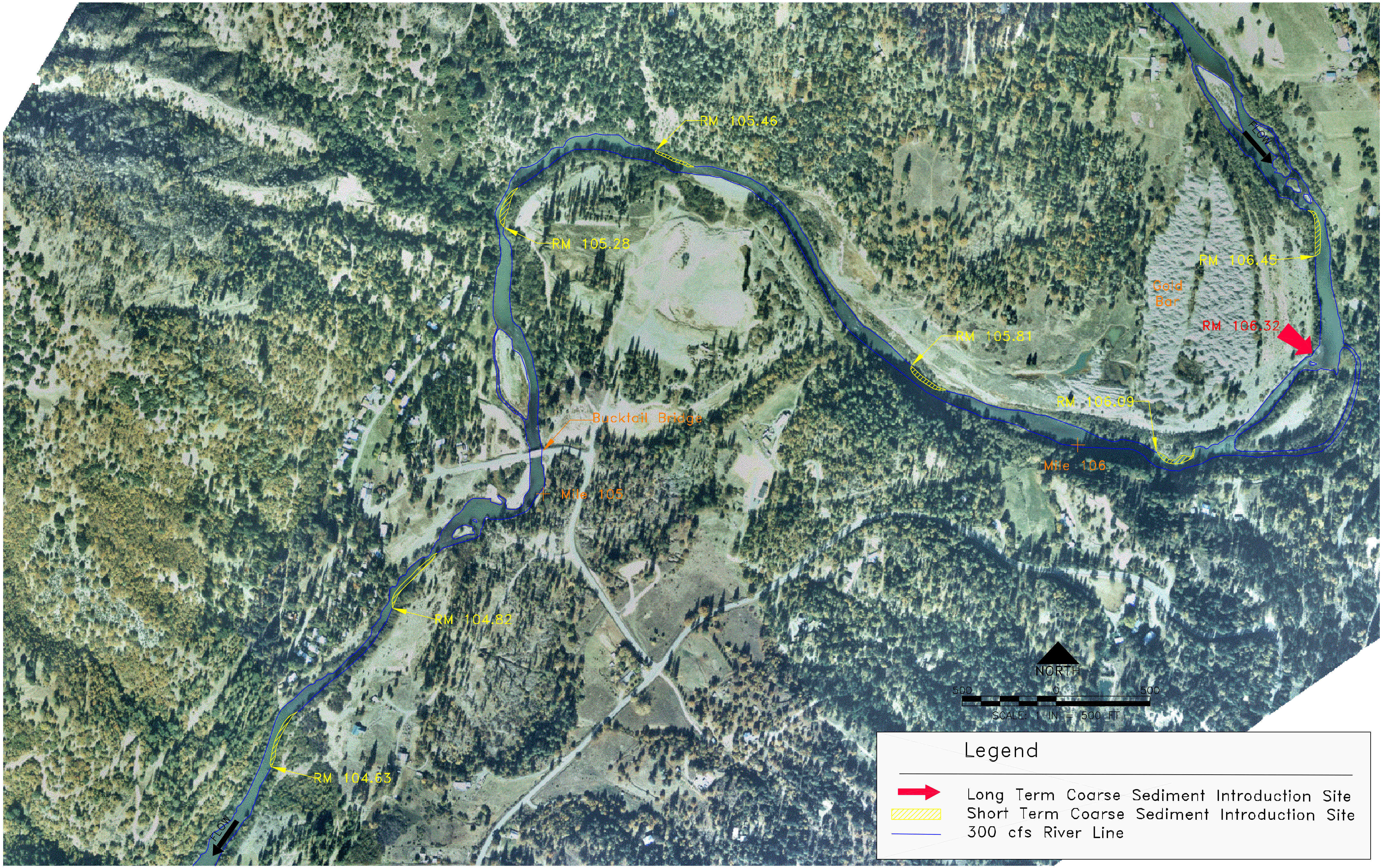
11x17 maps of the project reach showing all identified potential intro sites (see Section 4.4.2)

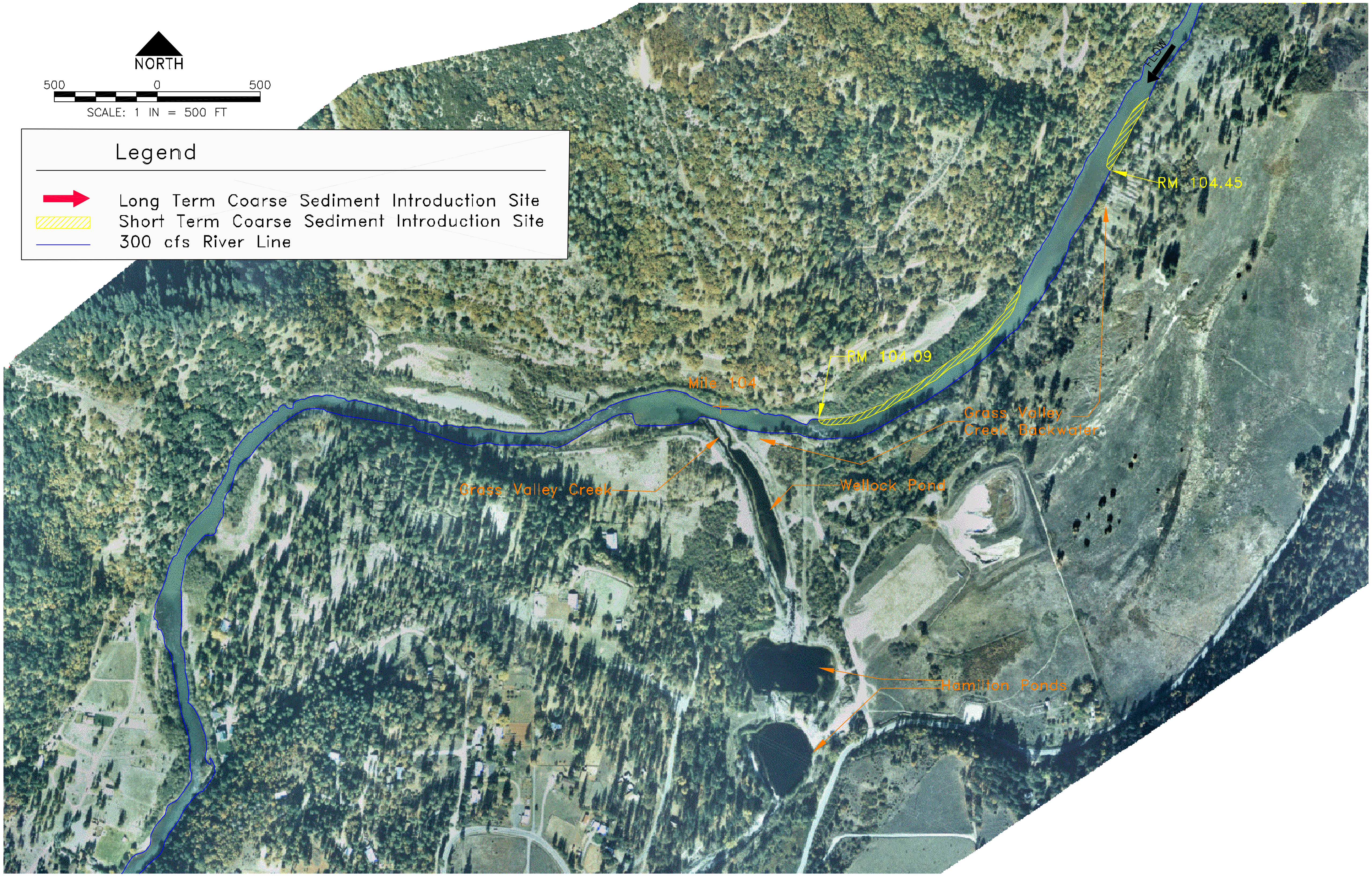


RM 111.48
FLOW
Lewiston Fish Hatchery
RM 111.78
Lewiston Dam
RM 111.05
Mile 111
USGS Lewiston Gaging Station
RM 110.96
New Lewiston Bridge
Deadwood Creek
RM 110.42
NORTH
500
0
500
SCALE: 1 IN = 500 FT
USGS Cableway
FLOW
RM 110.19
Legend
Long Term Coarse Sediment Introduction Site
Short Term Coarse Sediment Introduction Site
300 cfs River Line


FLOW
RM 108.29
RM 108.50
RM 108.64
RM 108.78
RM 108.84
RM 108.98
Mile 109
RM 109.07
RM 109.46
RM 109.73
RM 109.87
RM 109.95
Mile 110
Old Lewiston Bridge
Hoadley Gulch
FLOW
NORTH
500 0 500
SCALE: 1 IN = 500 FT
Legend
Long Term Coarse Sediment Introduction Site
Short Term Coarse Sediment Introduction Site
300 cfs River Line


NORTH
500
0
500
SCALE: 1 IN = 500 FT
Legend
Long Term Coarse Sediment Introduction Site
Short Term Coarse Sediment Introduction Site
300 cfs River Line
Rush Creek
Rush Creek Backwater
RM 107.56
RM 107.99
Mile 108
FLOW
RM 107.19
Mile 107
Salt Flat Bridge
RM 106.86
RM 106.78


RM 105.46
RM 105.28
RM 106.45
Gold Bar
RM 106.32
RM 105.81
RM 106.09
Bucktail Bridge
Mile 106
Mile 105
RM 104.82
RM 104.63
FLOW
FLOW
NORTH
500 0 500
SCALE: 1" IN = 500 FT
Legend
Long Term Coarse Sediment Introduction Site
Short Term Coarse Sediment Introduction Site
300 cfs River Line


NORTH
500
0
500
SCALE: 1 IN = 500 FT
Legend
Long Term Coarse Sediment Introduction Site
Short Term Coarse Sediment Introduction Site
300 cfs River Line
FLOW
RM 104.45
RM 104.09
Mile 104
Grass Valley Creek Backwater
Grass Valley Creek
Wellock Pond
Hamilton Ponds

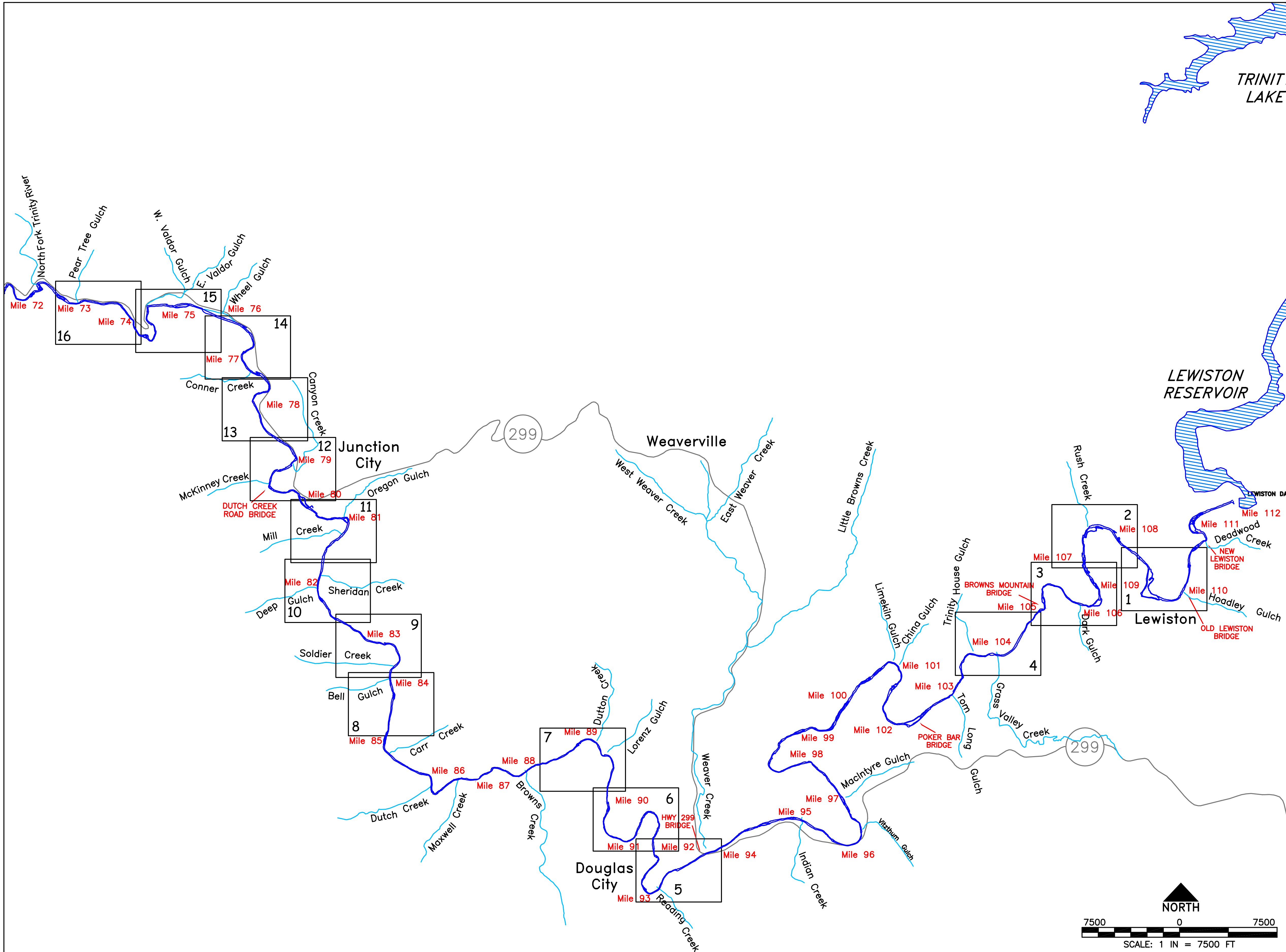
APPENDIX D

Appendix D. Table listing all identified locations of potential coarse sediment sources (dredge tailings) and estimated useable volumes of gravel based on Jim Smith gradation results. Then insert the 1997 aerial photographs showing locations of potential coarse sediment sources (dredge tailings).

2000 TRINITY RIVER DREDGER TAILING VOLUMES

ID#	SURFACE AREA (SQ FT)	SURFACE AREA (AC)	APPROX. RIVER ELEV (FT)	APPROX. BASE ELEV (FT)	APPROX. TAILING ELEV (FT)	TAILING HEIGHT (FT)*	EST. TAILING VOLUME (CU YD)	USABLE PERCENTAGE OF TOTAL VOLUME (CU YD)	NOTES
1	40,445	0.93	1790	1795	1814	19	17,000	12,716	
2	104,547	2.40	1788	1793	1814	21	49,000	36,652	
3	30,311	0.70	1778	1783	1790	7	4,700	3,516	
4	17,377	0.40	1776	1781	1790	9	3,500	2,618	
5	577,511	13.26	1764	1769	1792	23	295,000	220,660	
6	64,881	1.49	1762	1767	1782	15	22,000	16,456	
7	543,967	12.49	1754	1759	1774	15	181,000	135,388	CALIBRATION PLOT
8	77,311	1.77	1746	1751	1768	17	29,000	21,692	
9	9,211	0.21	1742	1747	1762	15	3,100	2,319	
10	14,985	0.34	1742	1747	1762	15	5,000	3,740	CALIBRATION PLOT
11	26,697	0.61	1608	1613	1628	15	8,900	6,657	
12	93,182	2.14	1600	1605	1634	29	60,000	44,880	CALIBRATION PLOT
13	3,497	0.08	1600	1605	1616	11	900	673	
14	28,942	0.66	1598	1603	1622	19	12,000	8,976	
15	127,116	2.92	1596	1601	1624	23	65,000	48,620	
16	5,838	0.13	1592	1597	1620	23	3,000	2,244	
17	70,153	1.61	1590	1595	1624	29	45,000	33,660	
18	4,237	0.10	1590	1595	1612	17	1,600	1,197	
19	662	0.02	1590	1595	1612	17	250	187	
20	36,360	0.83	1590	1595	1616	21	17,000	12,716	
21	5,257	0.12	1588	1593	1618	25	2,900	2,169	
22	4,384	0.10	1586	1591	1614	23	2,200	1,646	
23	35,076	0.81	1584	1589	1610	21	16,000	11,968	
24	42,772	0.98	1560	1565	1580	15	14,000	10,472	
25	102,331	2.35	1558	1563	1580	17	39,000	29,172	
26	39,412	0.90	1498	1503	1522	19	17,000	12,716	
27	15,437	0.35	1496	1501	1518	17	5,800	4,338	
28	17,483	0.40	1496	1501	1522	21	8,200	6,134	
29	295,891	6.79	1488	1493	1522	29	191,000	142,868	
30	105,938	2.43	1486	1491	1522	31	73,000	54,604	
31	53,104	1.22	1486	1491	1516	25	30,000	22,440	
32	15,200	0.35	1486	1491	1510	19	6,400	4,787	
33	119,680	2.75	1484	1489				0	**NO TOPOGRAPHY**
34	674,599	15.49	1484	1489				0	**NO TOPOGRAPHY**
35	328,746	7.55	1474	1479				0	**NO TOPOGRAPHY**
36	7,885	0.18	1474	1479				0	**NO TOPOGRAPHY**
37	16,337	0.38	1474	1479				0	**NO TOPOGRAPHY**
38	4,807	0.11	1474	1479	1494	15	1,600	1,197	
39	362,355	8.32	1472	1477				0	**NO TOPOGRAPHY**
40	23,334	0.54	1474	1479	1502	23	12,000	8,976	
41	7,328	0.17	1472	1477	1490	13	2,000	1,496	
42	21,773	0.50	1470	1475				0	**NO TOPOGRAPHY**
43	542,014	12.44	1470	1475				0	**NO TOPOGRAPHY**
44	22,141	0.51	1470	1475				0	**NO TOPOGRAPHY**
45	15,569	0.36	1470	1475				0	**NO TOPOGRAPHY**
46	1,076,387	24.71	1460	1465	1498	33	789,000	590,172	
47	451,694	10.37	1454	1459	1492	33	331,000	247,588	
48	65,836	1.51	1452	1457	1490	33	48,000	35,904	
49	701,844	16.11	1444	1449	1480	31	483,000	361,284	CALIBRATION PLOT
50	7,586	0.17	1444	1449	1466	17	2,900	2,169	
51	473,251	10.86	1436	1441	1478	37	389,000	290,972	
52	926,906	21.28	1432	1437	1468	31	639,000	477,972	
53	254,536	5.84	1428	1433	1480	47	266,000	198,968	
54	4,095	0.09	1428	1433	1434	1	90	67	
55	81,380	1.87	1428	1433	1468	35	63,000	47,124	
56	24,892	0.57	1420	1425	1460	35	19,000	14,212	
57	102,397	2.35	1420	1425	1448	23	52,000	38,896	
58	289,779	6.65	1412	1417	1454	37	238,000	178,024	
59	22,922	0.53	1408	1413	1434	21	11,000	8,228	
60	973,460	22.35	1404	1409	1440	31	671,000	501,908	
61	424,121	9.74	1388	1393	1412	19	179,000	133,892	
62	367,271	8.43	1374	1379	1390	11	90,000	67,320	
TOTAL	**11,004,439**	**252.63**					**5,515,040**	**4,125,250**	

*Assumes that bedrock does not limit excavation depth- shallow bedrock will significantly decrease volume estimates



TRINITY RIVER DREDGER TAILING INVENTORY

INDEX SHEET
RM 69.6–112

NORTH
SCALE: 1 IN = 48,000 FT

LEGEND

- HWY 299
- Trinity River
- Tributaries
- Sheet Locations
- River Miles (Mile 72)

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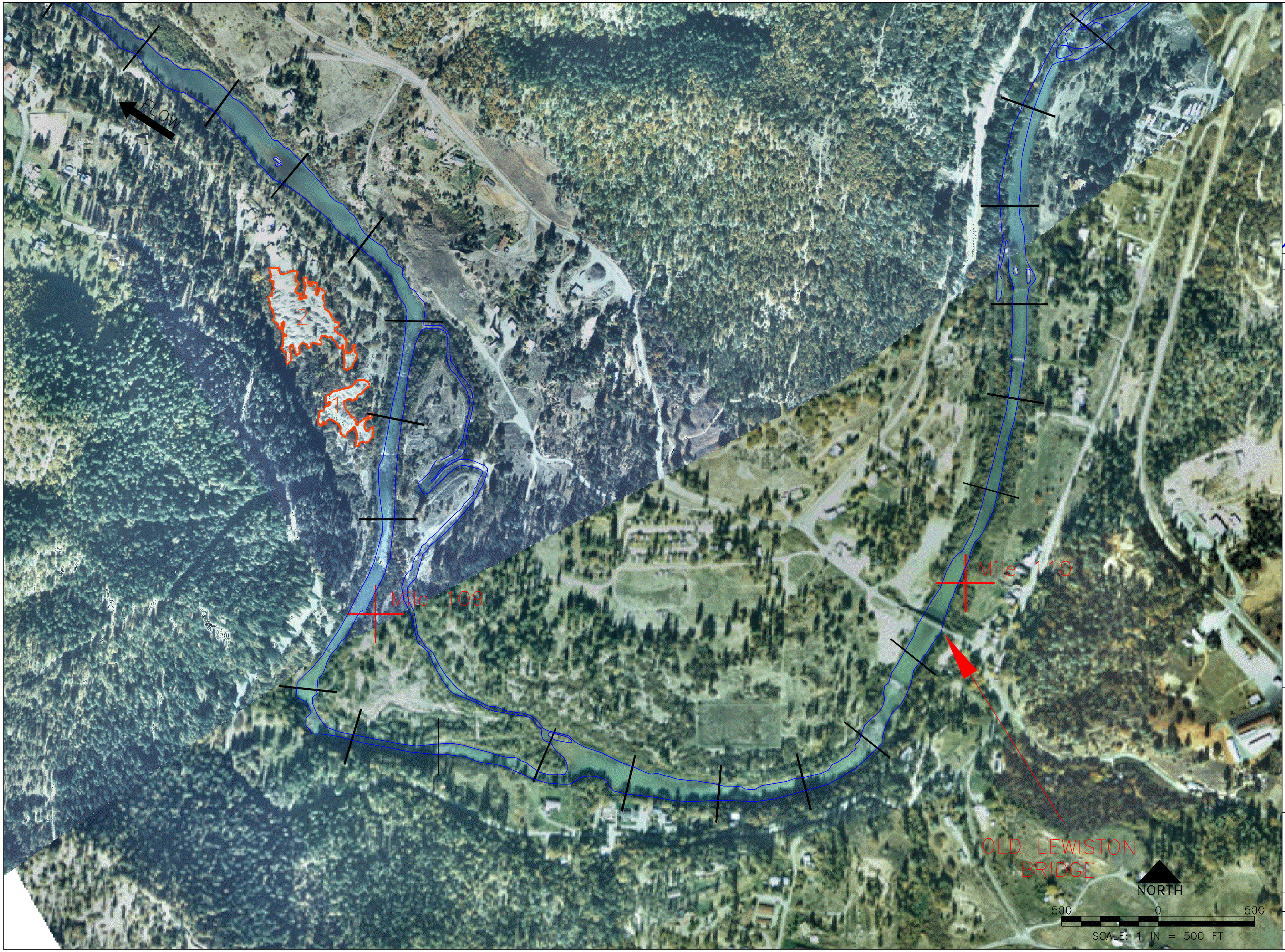
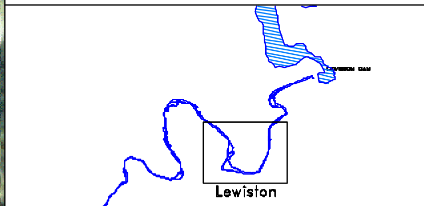


TRINITY RIVER DREDGER TAILING INVENTORY



SHEET 1
RM 108.2–110.6

LEGEND

Trinity River
River Miles
RM 10ths
Tailing Site

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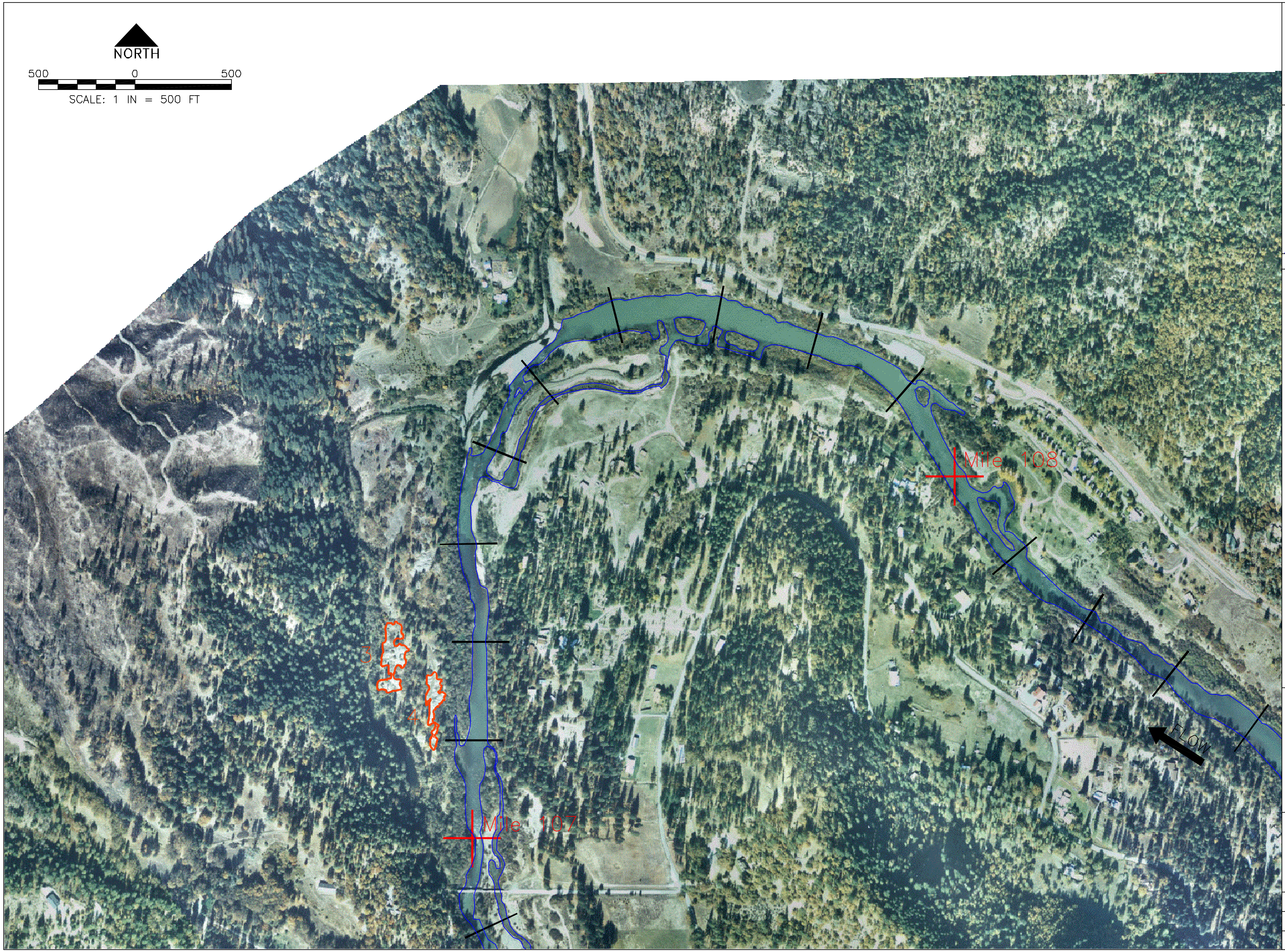
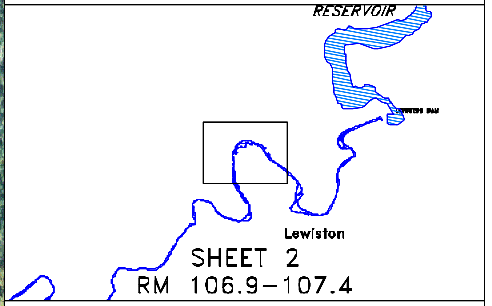


TRINITY RIVER DREDGER TAILING INVENTORY



LEGEND

Trinity River
Mile 72 River Miles
RM 10ths
12 Tailing Site

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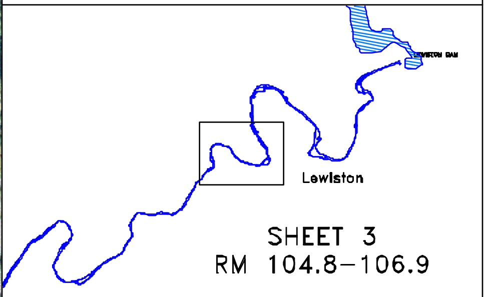

SHEET 3
RM 104.8–106.9

LEGEND

Trinity River
Mile 72 River Miles
RM 10ths
12 Tailing Site

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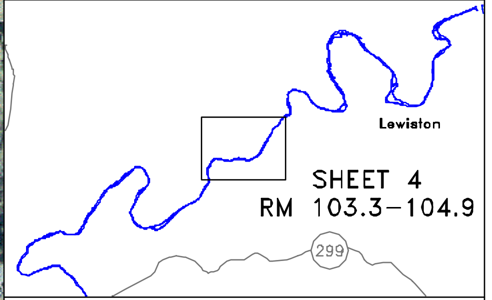
TRINITY RIVER DREDGER TAILING INVENTORY



LEGEND

Trinity River
Mile 72 River Miles
RM 10ths
12 Tailing Site

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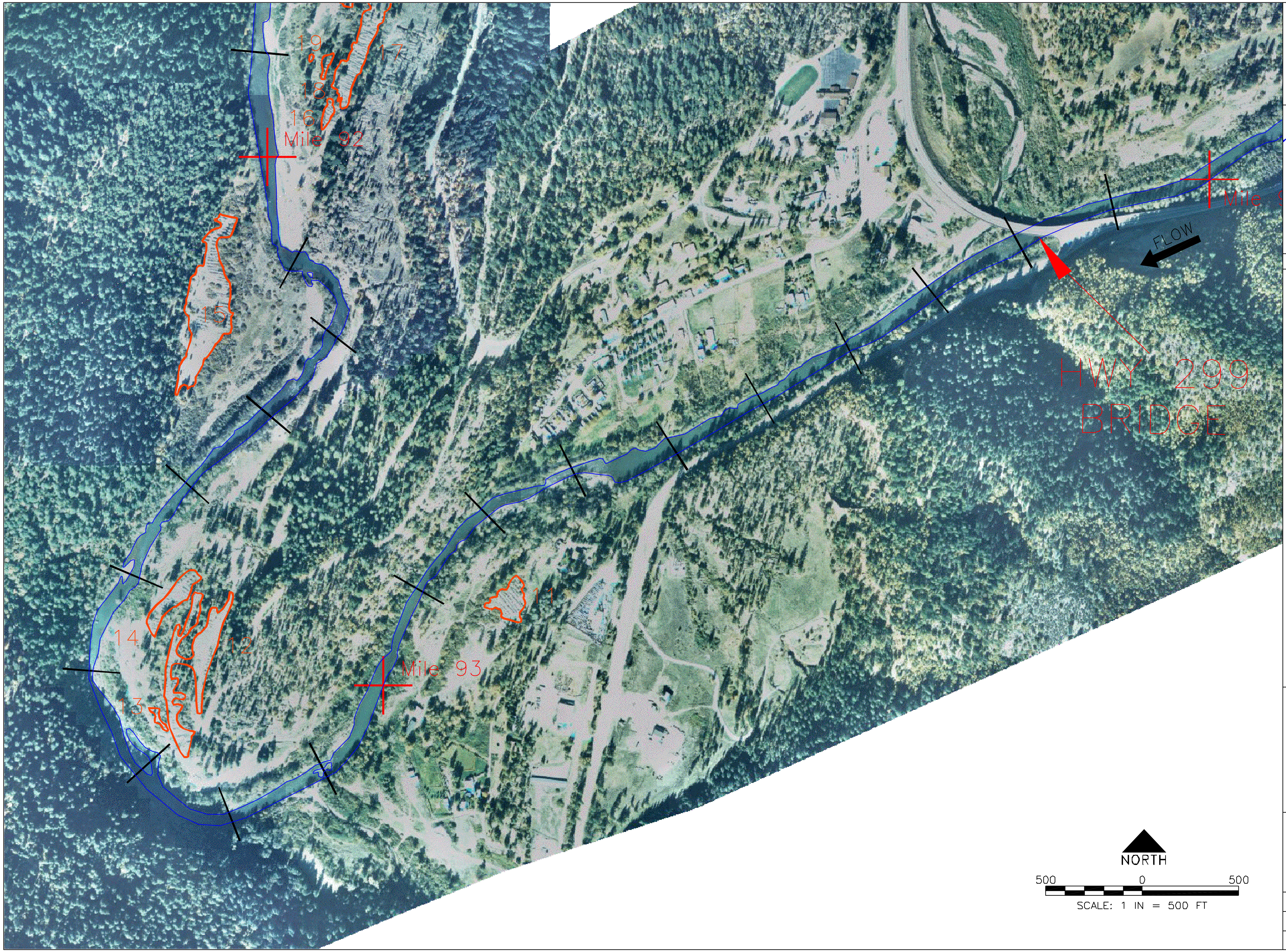
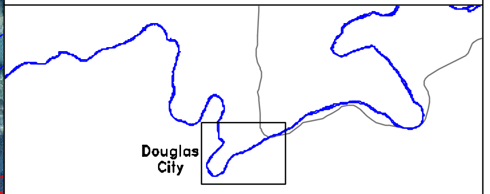


TRINITY RIVER DREDGER TAILING INVENTORY



SHEET 5
RM 91.9-94

LEGEND

Trinity River
Mile 72 River Miles
RM 10ths
12 Tailing Site

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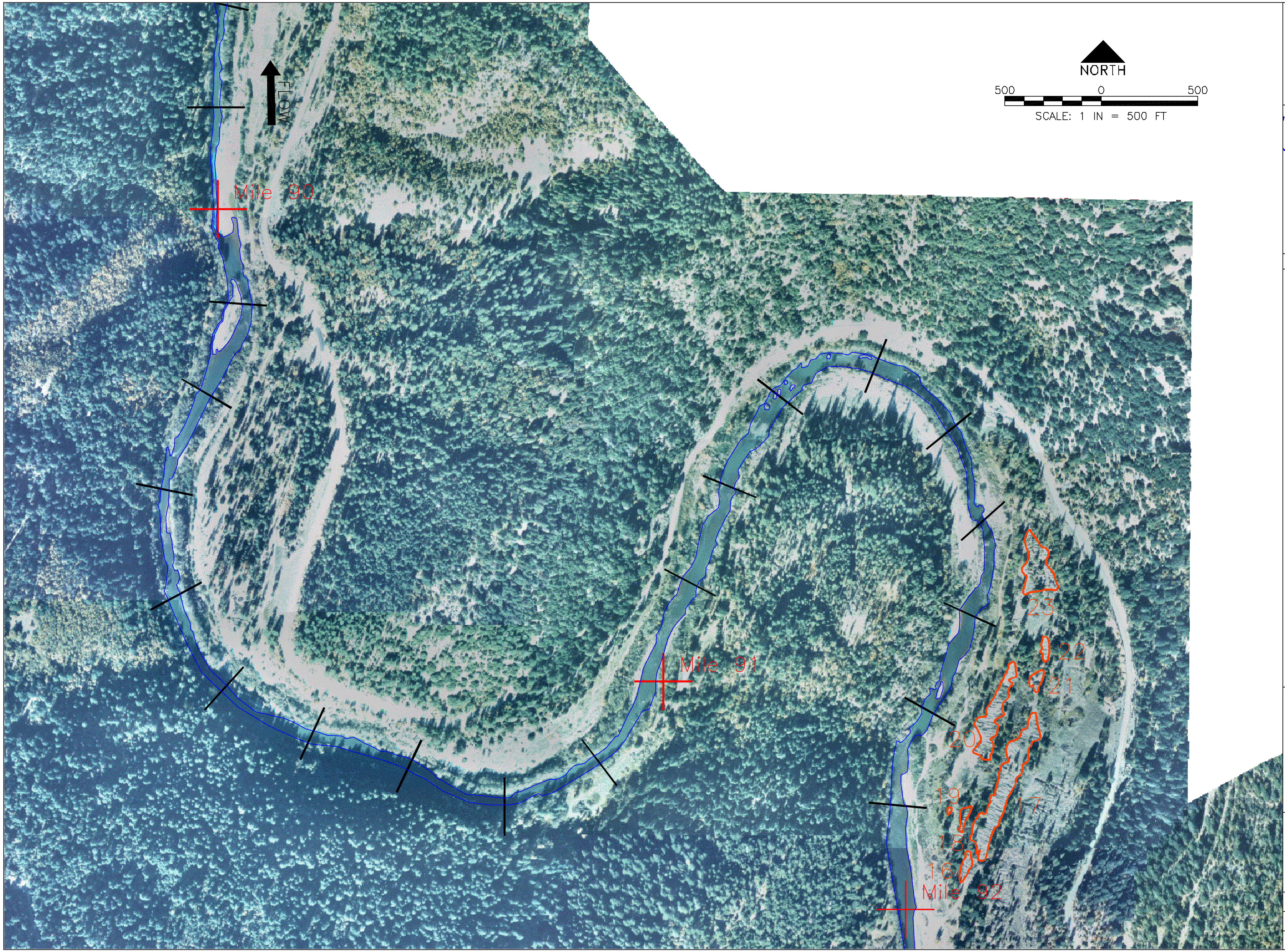
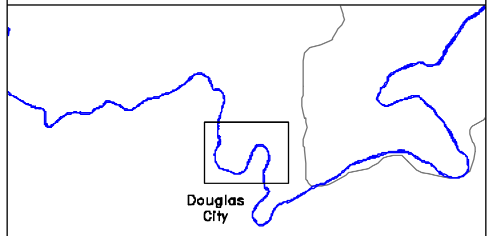


TRINITY RIVER DREDGER TAILING INVENTORY



SHEET 6
RM 89.8–92

LEGEND

- Trinity River
- Mile 72 River Miles
- RM 10ths
- 12 Tailing Site

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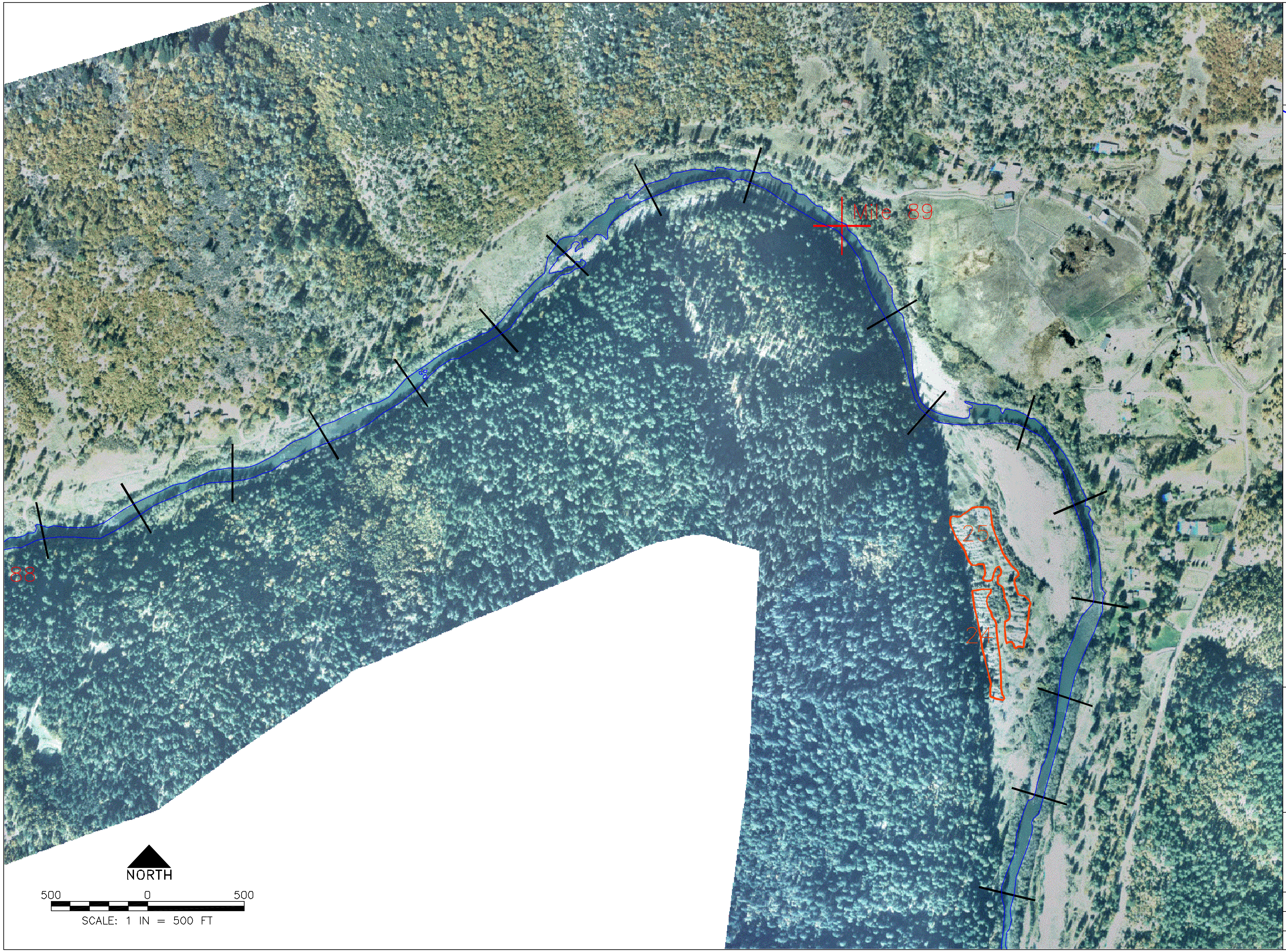
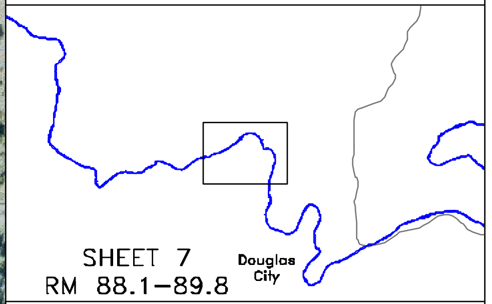


TRINITY RIVER DREDGER TAILING INVENTORY



LEGEND

- Trinity River
- River Miles
- RM 10ths
- Tailing Site

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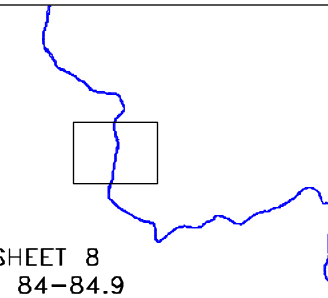
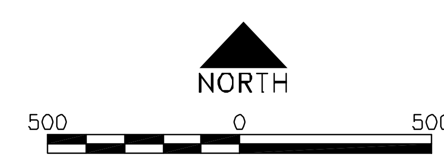
TRINITY RIVER DREDGER TAILING INVENTORY



SHEET 8
RM 84-84.9

LEGEND

Trinity River
Mile 72 River Miles
RM 10ths
12 Tailing Site



SCALE: 1 IN = 500 FT

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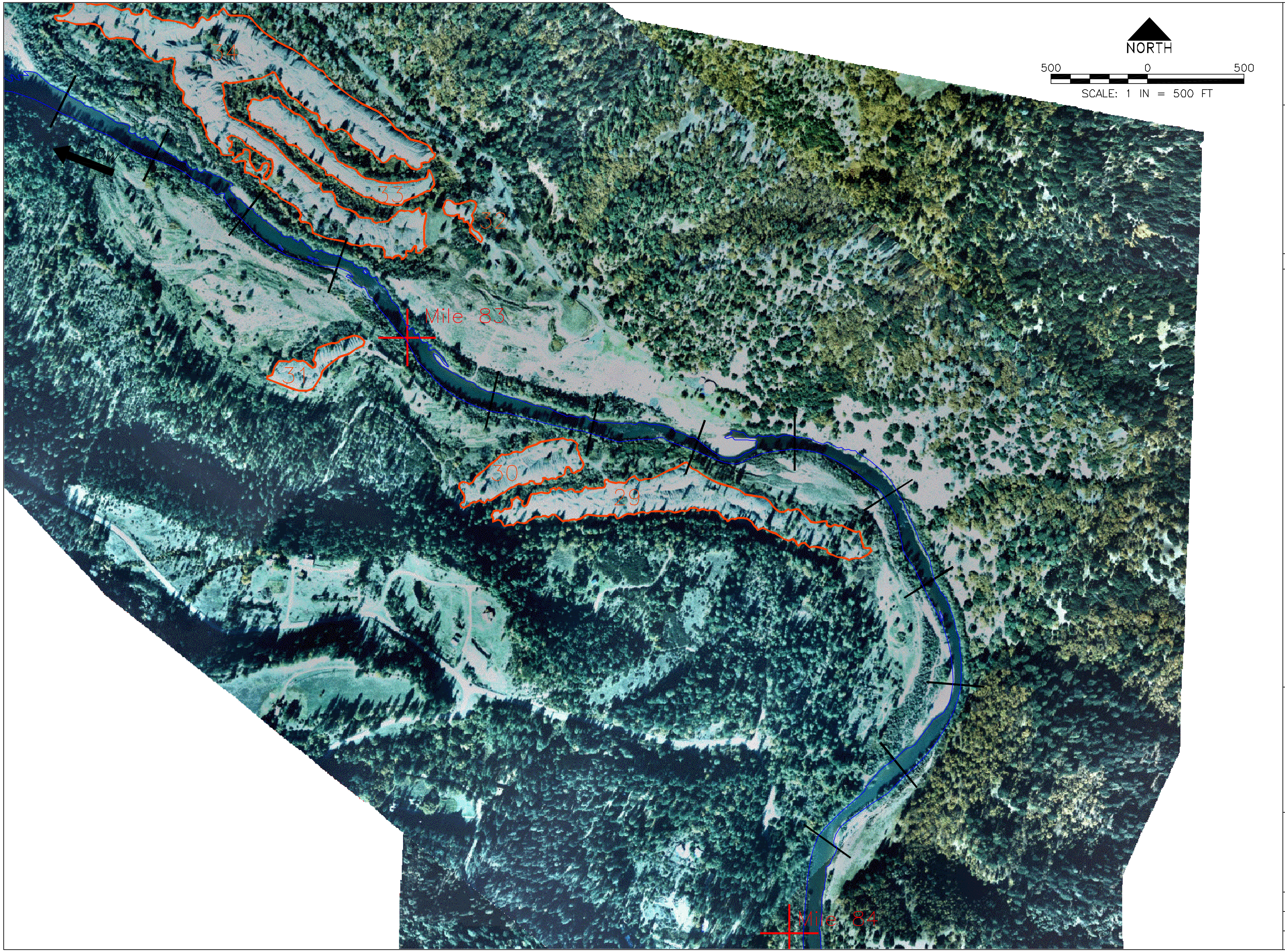
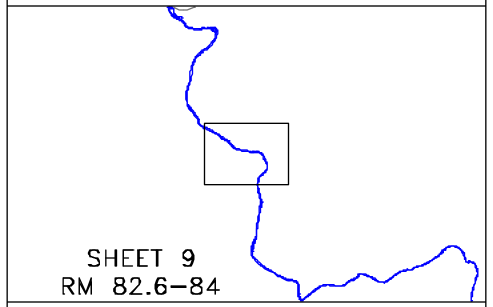


TRINITY RIVER DREDGER TAILING INVENTORY



LEGEND

Trinity River
Mile 72 River Miles
RM 10ths
12 Tailing Site

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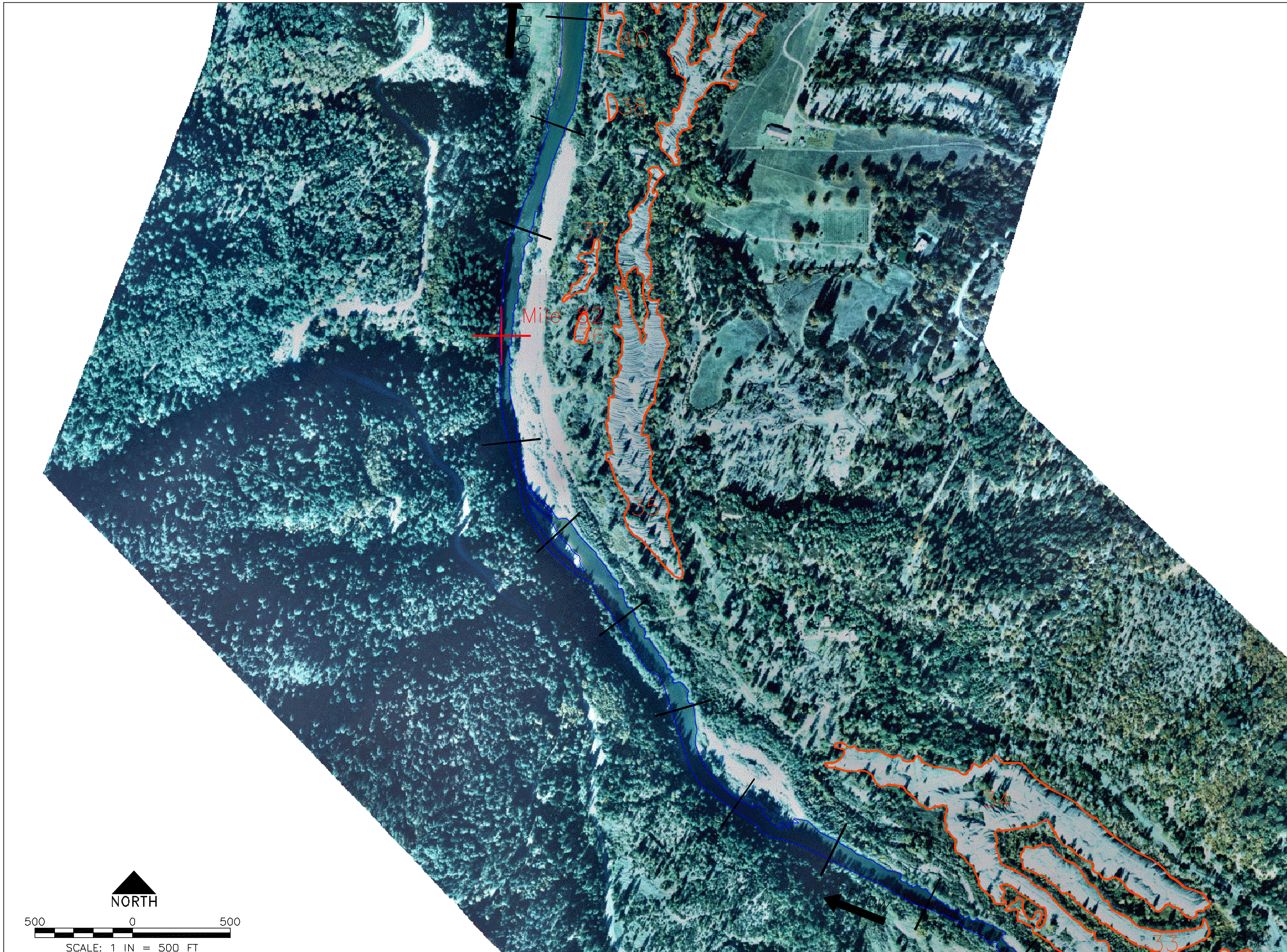
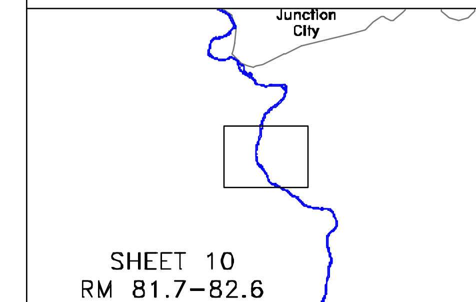
TRINITY RIVER DREDGER TAILING INVENTORY





LEGEND

- Trinity River
- River Miles
- RM 10ths
- Tailing Site

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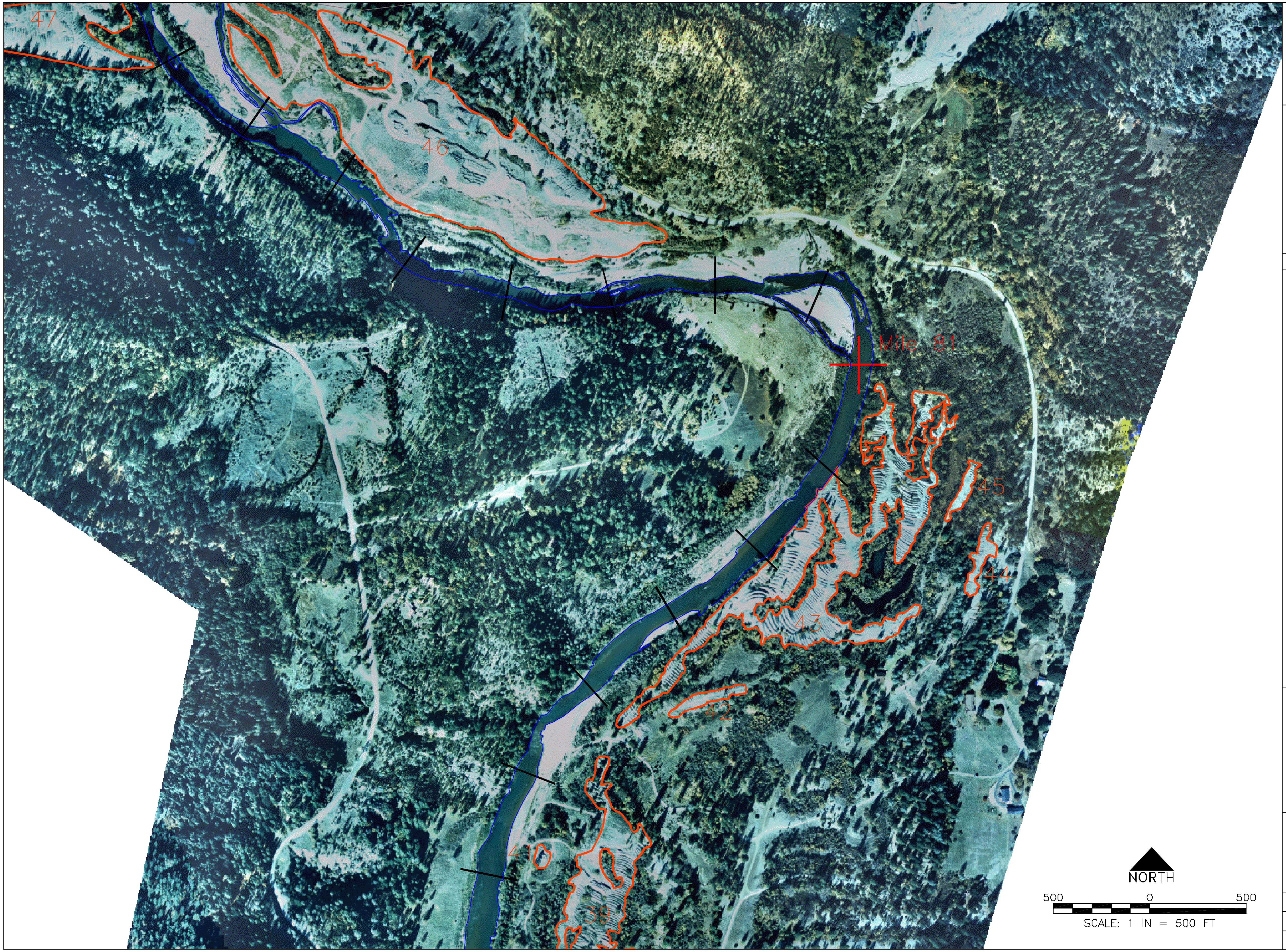
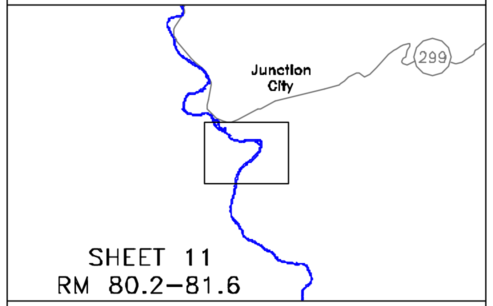


TRINITY RIVER DREDGER TAILING INVENTORY



SHEET 11
RM 80.2–81.6

LEGEND

- Trinity River
- River Miles
- RM 10ths
- Tailing Site

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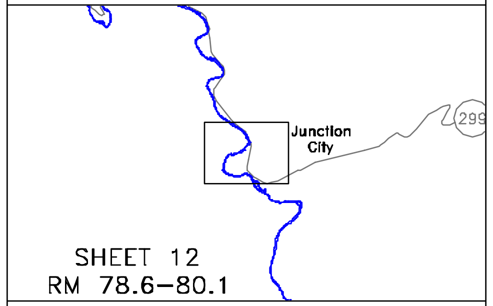
TRINITY RIVER DREDGER TAILING INVENTORY



LEGEND

Trinity River
Mile 72 River Miles
RM 10ths
12 Tailing Site

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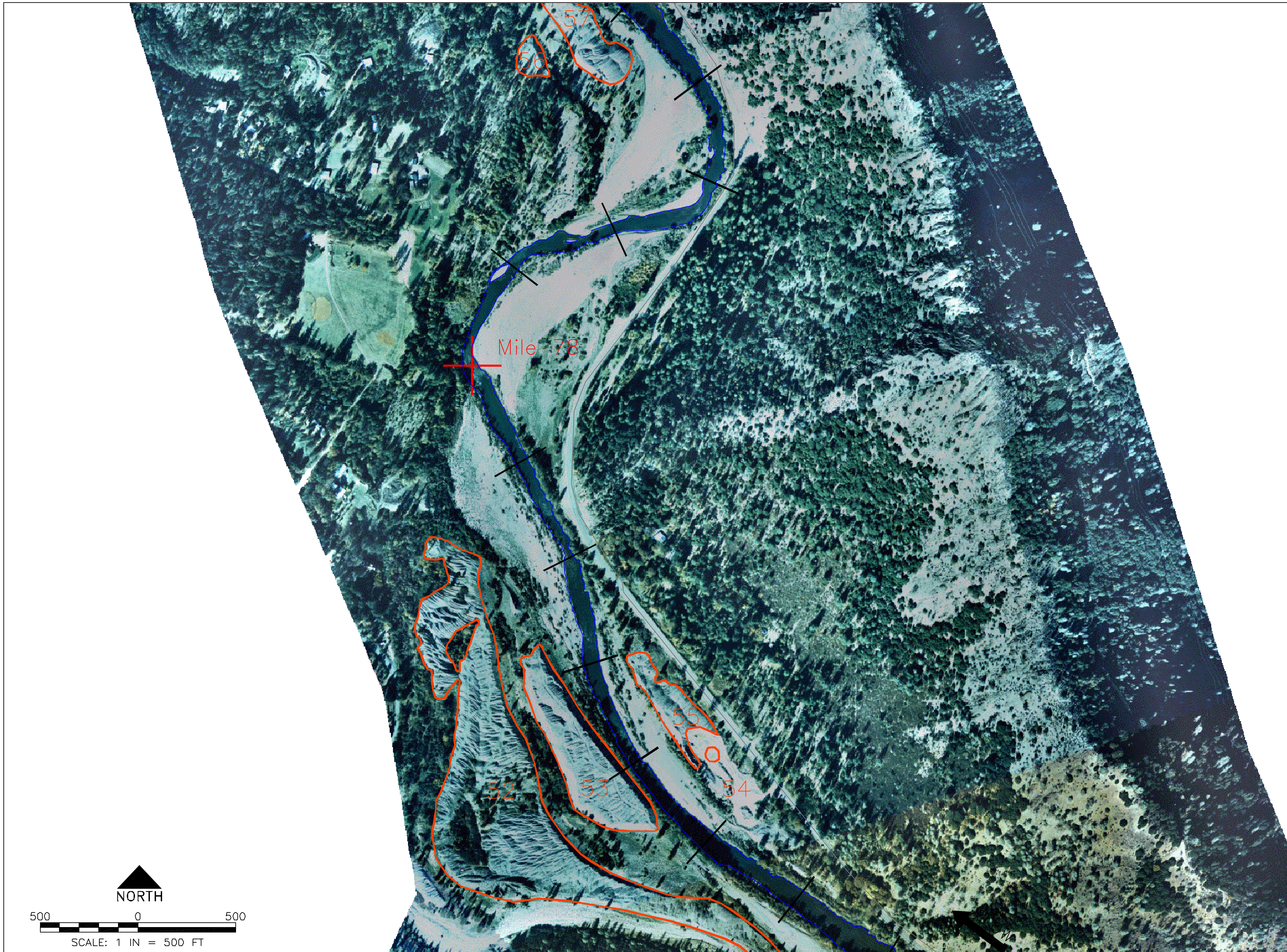
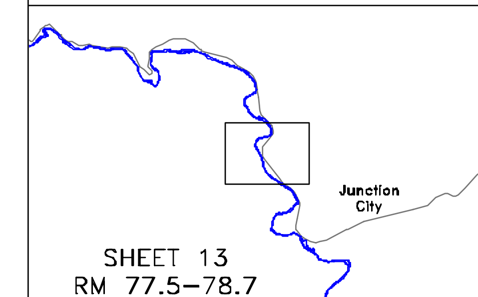


TRINITY RIVER DREDGER TAILING INVENTORY



SHEET 13
RM 77.5–78.7

LEGEND

Trinity River
Mile 72 River Miles
RM 10ths
12 Tailing Site

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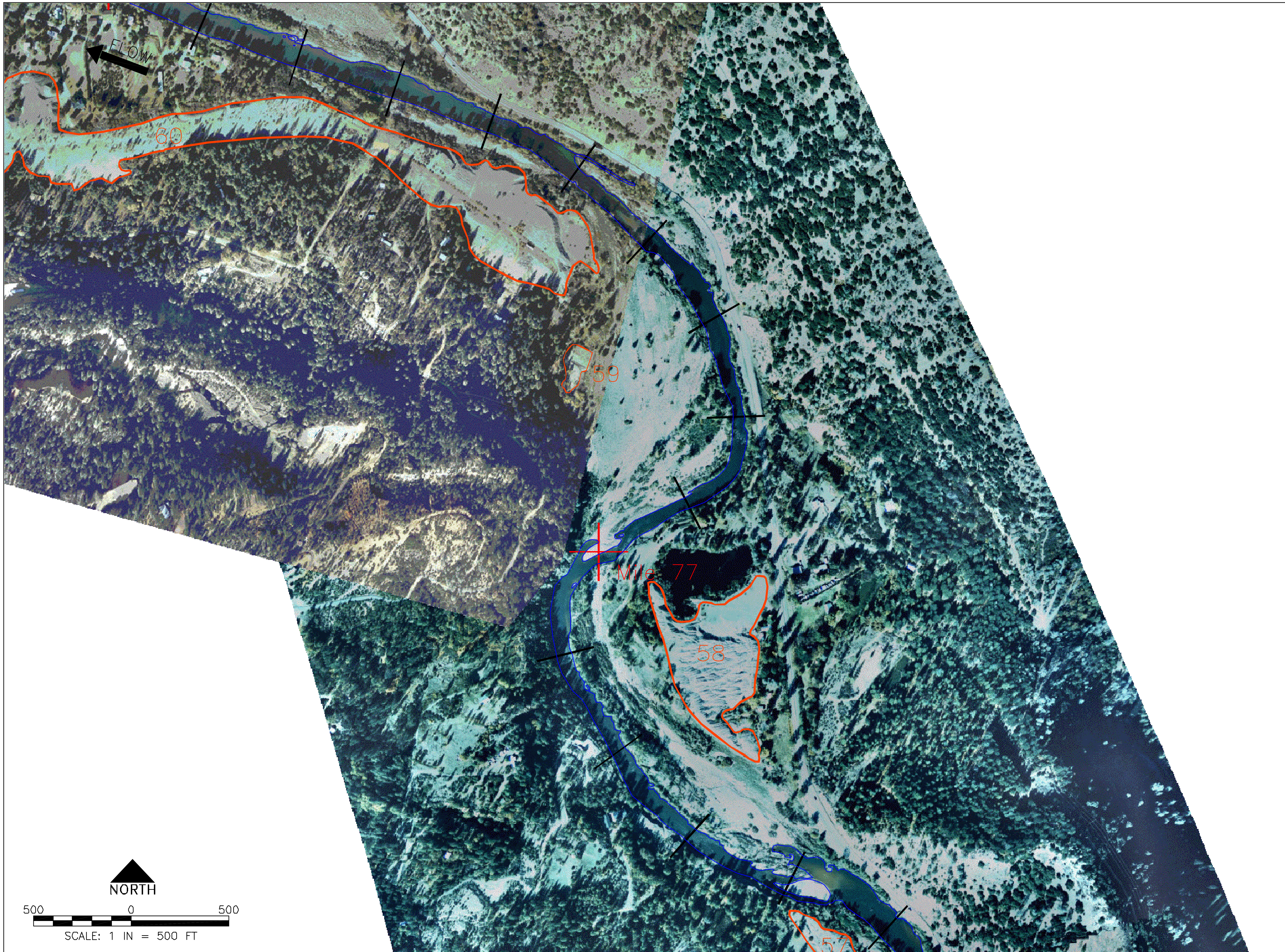
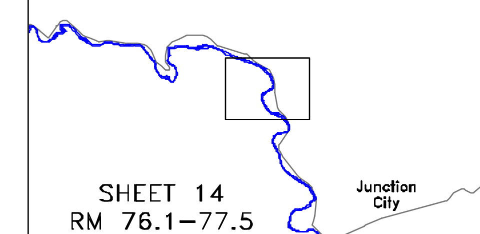


TRINITY RIVER DREDGER TAILING INVENTORY



LEGEND

- Trinity River
- Mile 72 River Miles
- RM 10ths
- 12 Tailing Site

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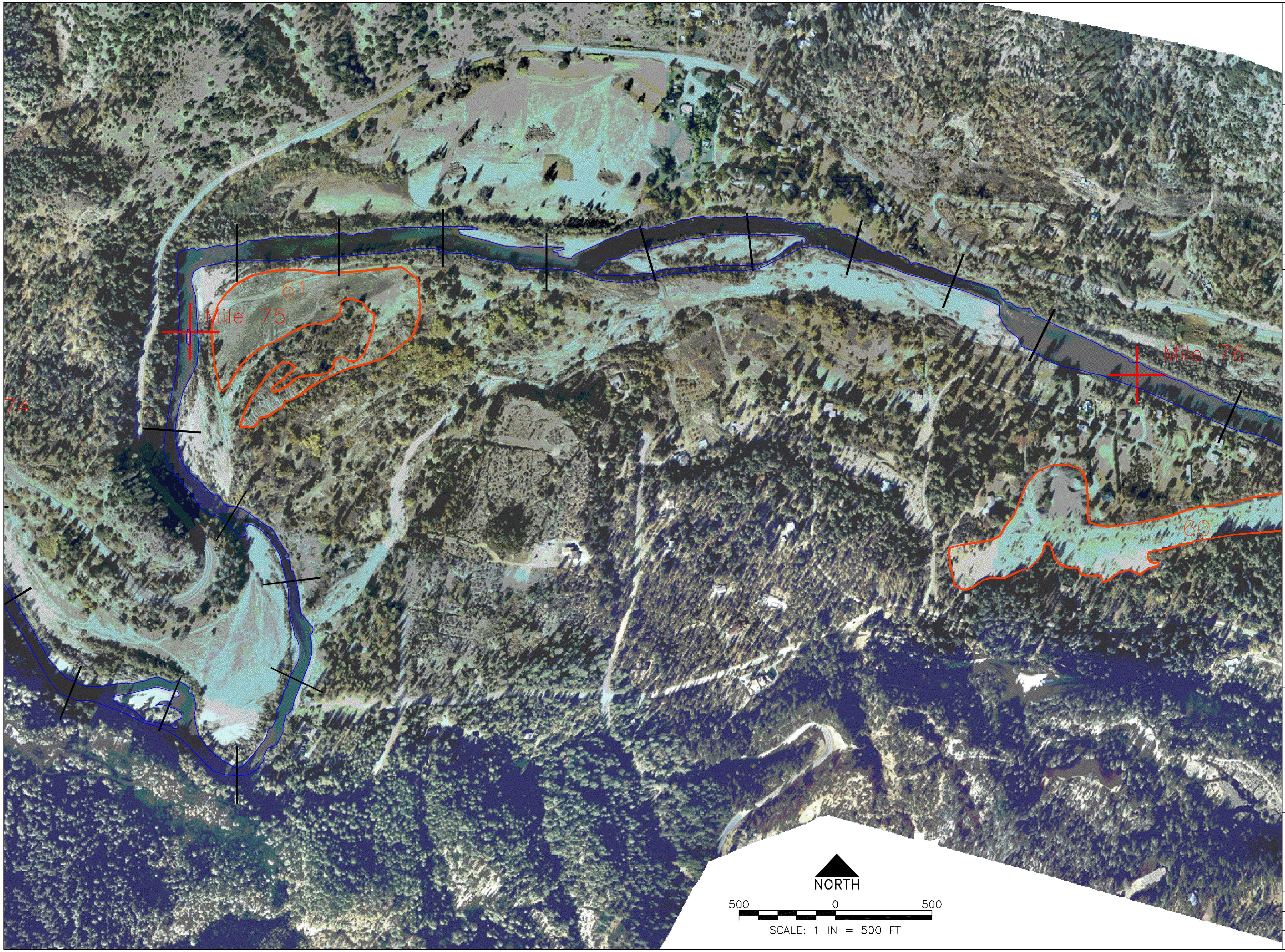

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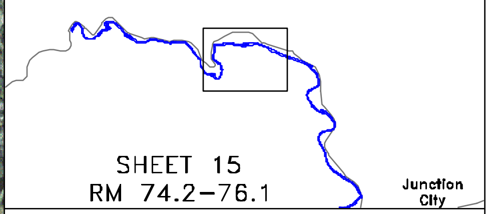

SHEET 15
RM 74.2–76.1

LEGEND

Trinity River
River Miles
RM 10ths
Tailing Site

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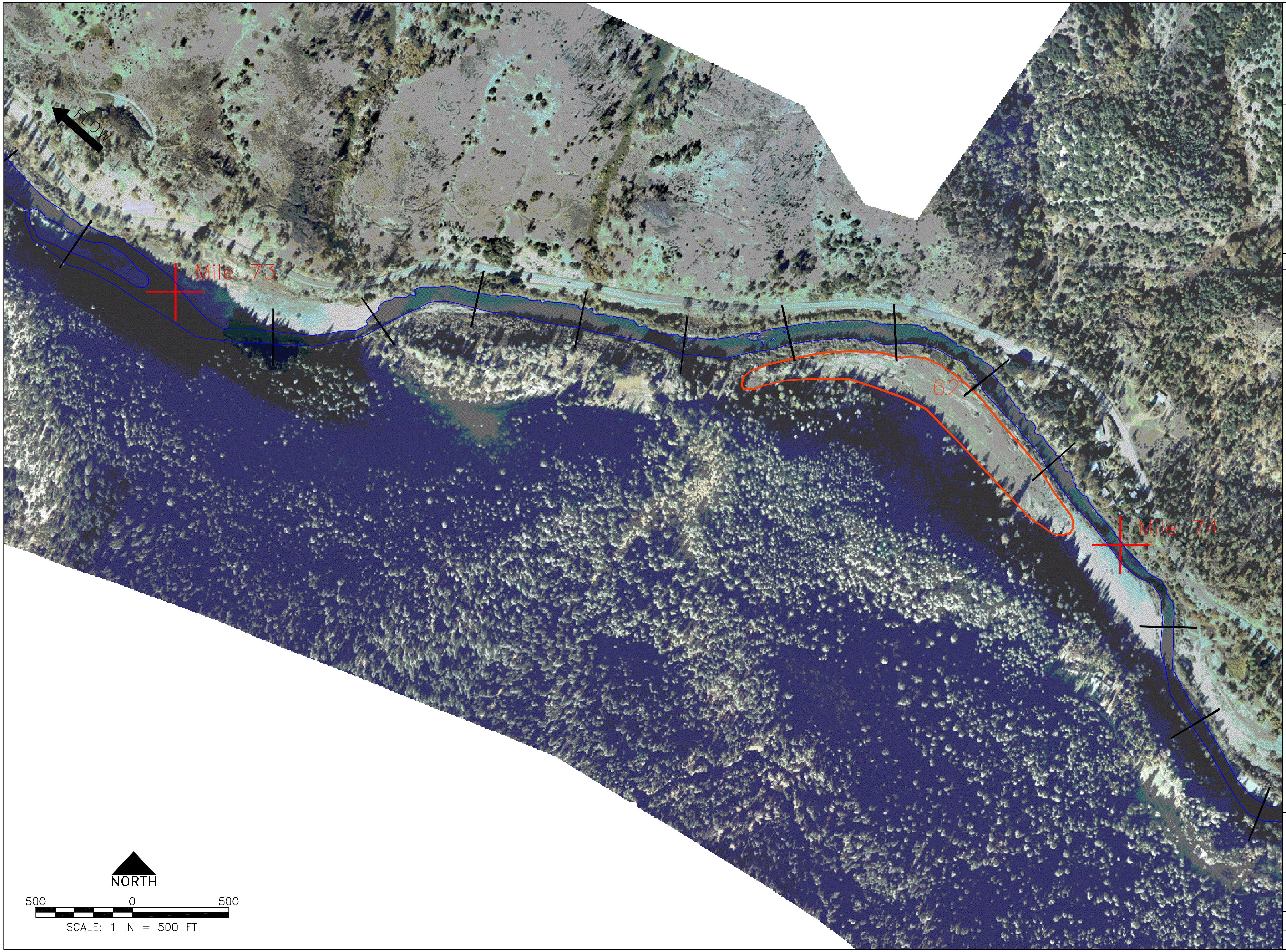
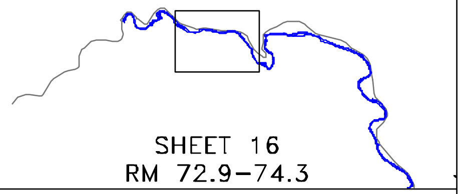


TRINITY RIVER DREDGER TAILING INVENTORY



SHEET 16
RM 72.9–74.3

LEGEND

- Trinity River
- Mile 72 River Miles
- RM 10ths
- 12 Tailing Site

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