RESEARCH

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Design and Performance of a Channel Reconstruction Project in a Coastal California Gravel-Bed Stream

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ABSTRACT / A 0.9 km-reach of Uvas Creek, California, was reconstructed as a sinuous, meandering channel in November 1995. In February 1996, this new channel washed out. We reviewed project documents to determine the basis for the project design and conducted our own historical geomorphological study to understand the processes operating in the catchment and project reach. The project was designed using a popular stream classification system, based on which the designers assumed that a "C4" channel (a meandering gravel-bed channel) would be stable at the site. Our historical geomorphological analysis showed that the reach had been braided historically, typical of streams draining the Franciscan Formation in the California Coast Ranges, with episodic flows and high sand and gravel transport. After the project washed out, Uvas Creek reestablished an irregular, braided sand-and-gravel channel, although the channel here was narrower than it had been historically, probably due to such factors as incision caused by gravel mining. Our study casts doubt on several assumptions common in many stream restoration projects: that channel stability is always an appropriate goal; that channel forms are determined by flows with return periods of about 1.5 years; that a channel classification system is an easy, appropriate basis for channel design; and that a new channel form can be imposed without addressing the processes that determine channel form.

Many stream restoration projects are undertaken in the United States, but the performance of these projects is rarely assessed. Postproject performance evaluations (e.g., Morris and Moses 1999) are needed so that we can learn from our collective experiences and thereby improve future project design (Kondolf 1995a). In one of the best examples of postproject appraisal to date, Smith (1997) documented the performance of a project on Deep Run, Maryland, where a 300-m-long reach was reconstructed with symmetrical meander bends and a narrower channel in 1995. By 1999, the project had failed, been repaired, and failed again. Smith (1997) concluded that one of the principal reasons for project failure was the reduction in hydraulic roughness on the floodplain due to clearing of riparian vegetation to permit channel realignment. This led to higher overbank flow velocities, which eroded chutes across meander necks.

In this study we examined a similar project in California, where an approximately 0.9-km-long, sinuous, meandering channel was constructed in a historically braided reach that had been disturbed by gravel mining. The project was completed in November 1995. In February 1996, during storm flows with a return period of 5–6 years, the stream abandoned the constructed channel. The purpose of this study was to determine the basis for the project design and to assess the reasons for the project's poor performance. Because our case study typifies a number of other similar channel reconstruction projects in California, which have similarly failed, our analysis and conclusions have implications for stream restoration beyond the case described here.

Although this project is typical of what are commonly termed "stream restoration" projects, we refer to it as a "stream reconstruction" project because the stream was not restored to a previous natural condition.

Site Description

The channel reconstruction project was located in the Uvas Creek Park Preserve in the city of Gilroy. The reach is alluvial, with an active channel (here used to refer to the open, unvegetated sand-and-gravel channel) typically 100–350 m wide historically, with a gradi-

KEY WORDS: Stream restoration; Channel classification; Fluvial geomorphology; Historical analysis; Episodic channels

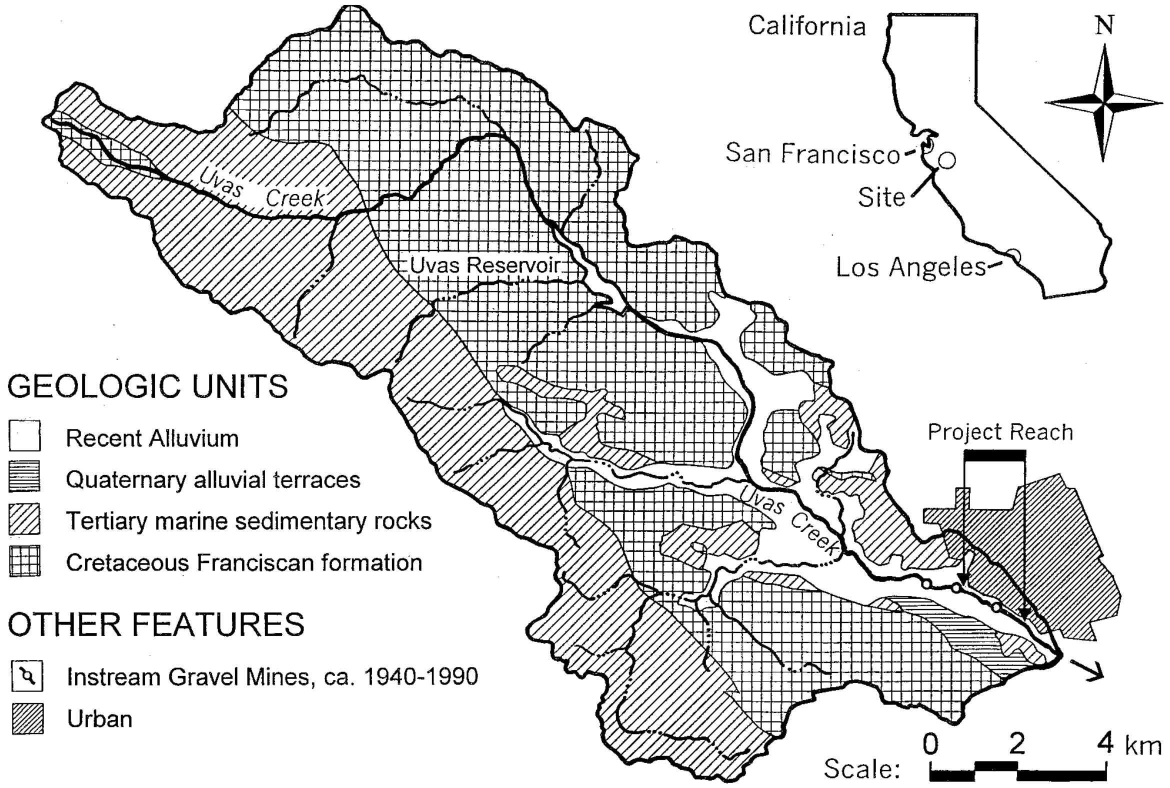

Figure 1. Basin, location, and generalized geologic map of Uvas Creek, showing the project reach in the city of Gilroy, California. Most of the basin is underlain by Cretaceous Franciscan formation and tertiary marine sedimentary rocks. Intensive gravel extraction has occurred within and upstream of the project reach.

ent of 0.17% to 0.3%, and median particle size of 20–26 mm.

Uvas Creek drains forested mountains in the Coast Ranges of California (elevations up to 1155 m) and alluvial valleys occupied by agriculture or suburban development, passing through the rapidly urbanizing city of Gilroy about 50 km south of San Jose (Figure 1). The climate is Mediterranean, with warm dry summers, and cool wet winters. Mean annual rainfall varies from 1140 mm in upper elevations to 560 mm near Gilroy. Over 93% of the rain falls from November through April, and runoff follows a similar pattern (Figure 2). Floods are highly variable from year to year, with annual peaks (at the project site) ranging over four orders of magnitude. Uvas Reservoir, constructed in 1957 with a capacity of 1.2×10^7 m^3, is about 12 km upstream and regulates runoff from 78 km^2 out of the total drainage area of 184 km^2 at Gilroy (at the project site). In the reach immediately downstream of Uvas Reservoir, the magnitude and frequency of floods has been considerably reduced: The 1.5-year return period flow was reduced from 60 m^3 sec predam to 27 m^3 sec^1 postdam (Kondolf and Matthews 1990). With distance downstream, the reservoir has less influence on flood magnitude. The alluvial aquifer is pumped for irrigation near the study reach (Norm Allen, City of Gilroy, personal communication, 1997), so the natural seasonal decline in flow in the summer and fall has probably been exacerbated. Reduced base flow and lowered water tables from groundwater pumping for agricultural and domestic use have been documented on other coastal streams in central California (e.g., Kondolf and others 1987). As a result, dry streambeds and lowered water tables in summer and fall limit riparian and aquatic habitat and impede fish passage into perennial reaches upstream.

The catchment is underlain primarily by the Franciscan Formation, which consists of mesozoic sandstones, cherts, metavolcanics, and other subduction-zone lithologies (Figure 1). These lithologies are noted

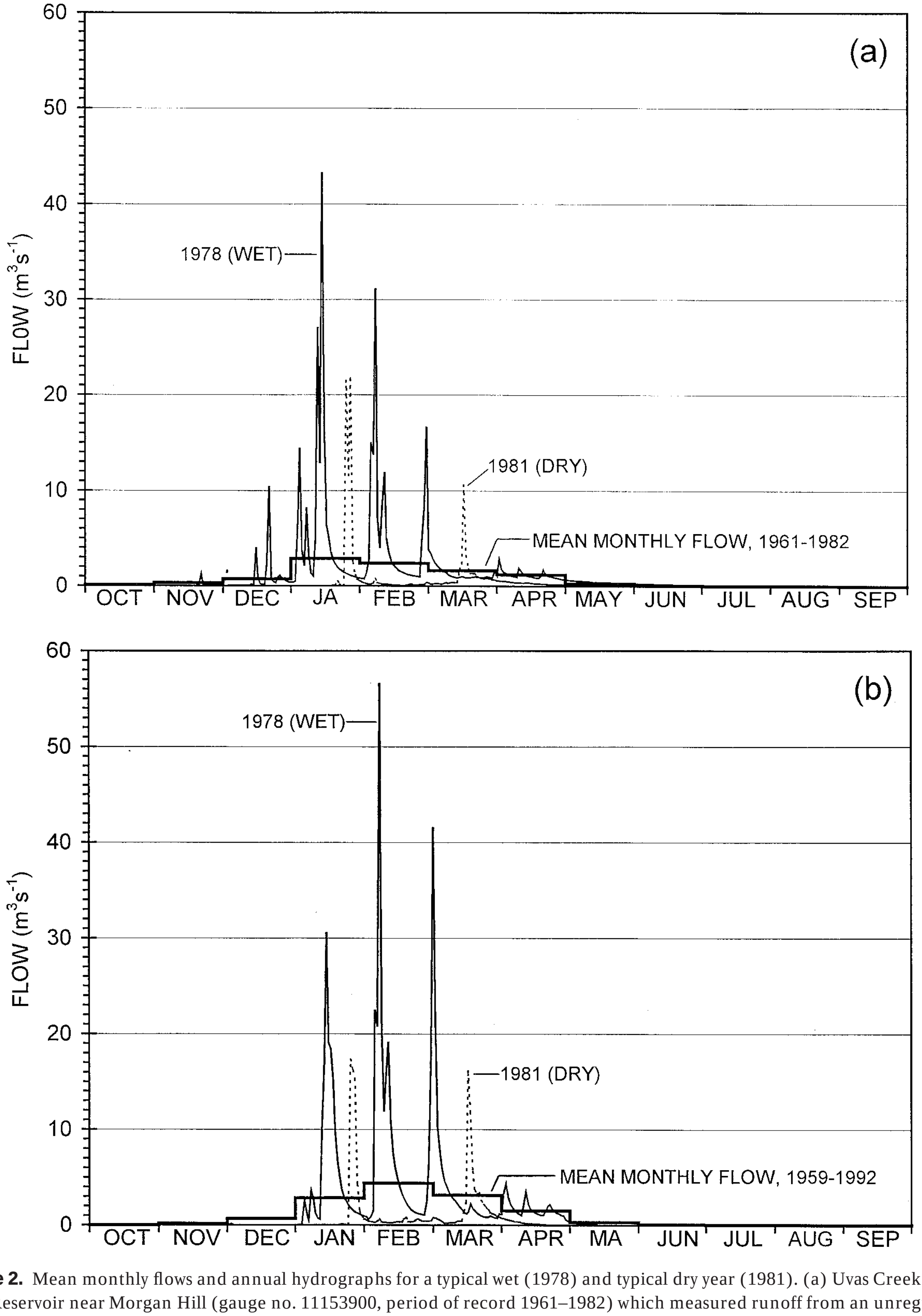

Figure 2. Mean monthly flows and annual hydrographs for a typical wet (1978) and typical dry year (1981). (a) Uvas Creek above Uvas Reservoir near Morgan Hill (gauge no. 11153900, period of record 1961–1982) which measured runoff from an unregulated and largely unurbanized 54 km^2 catchment, and (b) Uvas Creek near Gilroy (gauge no. 11154200, period of record 1959–1992), which measured runoff from a 184-km^2 catchment with mixed land uses. (*Source:* published records of the US Geological Survey.)

for high sediment yields: 130–500 $m^3\ km^{-2}\ year^{-1}$ indicated by reservoir sedimentation rates in the Coast Ranges (Kondolf and Matthews 1993), including high yields of sand and gravel. The high bedload sediment supply and highly variable flow regime are reflected in broad, shallow, commonly braided, sand-and-gravel-bedded channels typical of streams draining Franciscan catchments in the Coast Ranges of California (Hecht 1994).

Gravels of Franciscan chert and sandstone are durable and make excellent construction aggregate, so gravel-bedded stream channels in Franciscan terrain have been extensively mined. Three instream gravel mines operated in and immediately upstream of the project reach between 1940 and 1990 (Figure 1). Unfortunately, the amounts extracted were not recorded, as the state did not collect such production data prior to the 1990s (Mike Sandecki, California Division of Mines and Geology, personal communication 1997).

Uvas Creek historically supported a healthy run of steelhead trout (*Oncorhynchus mykiss*), an anadromous salmonid that migrated to headwater reaches to spawn and rear. Uvas Reservoir now blocks access to much of this formerly important steelhead habitat, and seasonally low flows (exacerbated by groundwater withdrawal) limit rearing habitat and migration.

Methods

We reviewed project documents to determine how the reconstructed channel was designed. In particular, we looked for how project objectives were identified and the rationale for the form and dimensions of the channel that was designed for the reach. We reviewed the following documents: (1) the 1992 master plan for Uvas Creek Park Preserve (the "Master Plan"); (2) the creek restoration plan (the "Project Plan"), prepared in 1993; (3) the channel design drawing, prepared in 1993; (4) the Public Notice of Application (US ACE 1994) and (5) permit (US ACE 1995) under the Clean Water Act Sec. 404 (33 U.S.C. 1344); (6) various correspondence about the project from 1993–1997 among the city, consultants, and regulatory agencies; and (7) notes from an April 1996 postmortem technical meeting.

We compiled annual peak flows for the U.S. Geological Survey stream gauge *Uvas Creek near Gilroy* (no. 11154200), located at the downstream end of the project reach, and conducted a flood frequency analysis (Dunne and Leopold 1978). The gauge began operation in 1959, after construction of Uvas Reservoir, and was discontinued in 1992. For comparison, we also plotted the 1996 peak flow (the year the design channel washed out) as estimated by the Santa Clara Valley Water District (Jim Wong, personal communication 1997) on the flood frequency curve.

To understand change in bed width and elevation, we compared current conditions with historical conditions. In July 1997 we inspected the project reach and portions of the stream upstream and downstream, documented evidence of flood scour, recent deposition, channel change, and vegetation establishment. In October–November 1998, we surveyed with Justine (1998) a 1.8-km longitudinal profile and compared it to a profile surveyed in 1984 by the U.S. Army Corps of Engineers (US ACE) and to the profile shown on project design documents. We also surveyed a cross section, on which we identified remnants of the 1939 channel bed from features that appeared on aerial photographs from 1939–1997.

To provide an initial basis for understanding channel processes in the reach, we assembled 1:24,000-scale topographic and geologic maps covering the watershed, outlined the drainage basin, identified land uses, inferred potential effects on runoff and sediment yield, and considered potential implications for channel changes. We located and analyzed historical information, including maps back to 1876 and aerial photographs from 1939, 1956, 1980, 1993, and 1997. We measured channel widths and meander wavelengths from these and mapped channels appearing in 1939, 1993, and 1997 photography. The constructed channel was not captured in aerial photography before it failed, so we superimposed the design channel on the map generated from the preproject (1993) aerial photographs. We also reviewed ground photographs of the channel back to 1894 and reoccupied the camera position for a photograph taken in 1894.

Results: Project Document Review

Objectives of the Reconstruction Project

The 1992 Master Plan called for channel reconstruction to "establish a more stable and natural channel" after the creeks's alteration by gravel mining. The Project Plan (p. 2) stated, "The project goal is to restore stability and habitat to the channel. Channel stability will be accomplished by re-creating the stable hydraulic geometry relationships (width, depth, velocity as a function of discharge) to the channel. This will require major grading to restore proper floodplain elevations and belt width." Although the terms *re-create* and *restore* imply a reference historical channel condition, no historical geomorphological analysis was undertaken to determine a suitable restoration goal. The U.S. Army

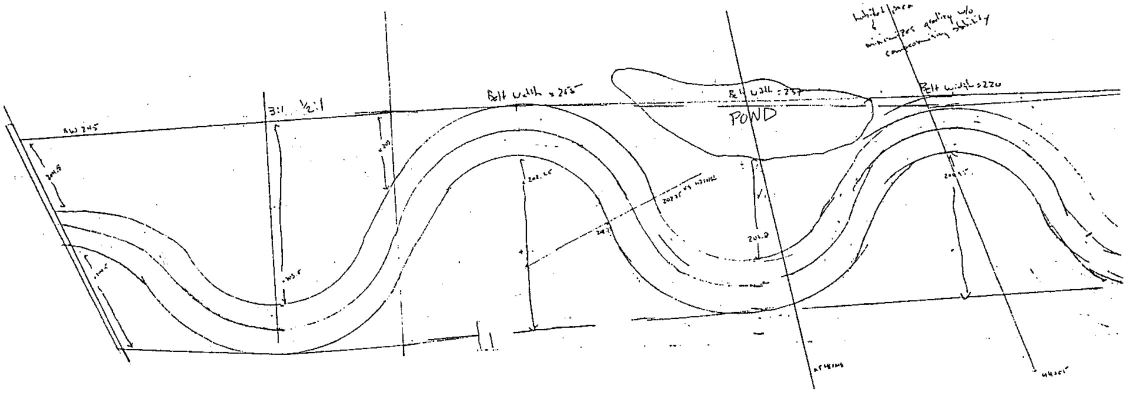

Figure 3. Detail (of upper 365-m portion) of design drawing for the Uvas Creek channel reconstruction project. This drawing was evidently the basis for construction drawings. Although neither orientation nor scale was indicated, the left edge of the drawing is immediately downstream of the Santa Teresa Boulevard Bridge, the upstream end of the project reach.

Corps of Engineers permit (USACE 1995, p. 1) stated the project objectives as to "improve steelhead [trout] migration and enhance fisheries spawning habitat." The documents did not present evidence that the objective of stabilizing the channel was feasible, or that better fish habitat would result from the planned stabilization.

Basis for Design

The basis for the project design was not clearly stated in the restoration plan, but it was evidently based on the belief that "the channel was once a stable C4 channel" (Project Plan, p. 1). "C4" is the alpha-numeric designation for a channel type described as "a slightly entrenched, meandering, gravel-dominated, riffle-pool channel with a well-developed floodplain" in the stream classification system of Rosgen (1996). Apparently, the design approach was to determine, using the stream classification system (and measures of slope, grain size, and other channel characteristics), the type of channel that should be stable in the reach. Referring to a C4 channel, the plan (p. 17) stated, "This is the stable channel type for this site. This is what existed prior to human disturbances."

The Project Plan presented no evidence to support the assertion that Uvas Creek formerly was a C4 channel, but stated (p 1–2) that the effects of "levee construction, gravel mining, and ill-fated flood control efforts" were "to convert the stable C4 channel to F4 and G4c channels," and that this would ultimately lead to "a braided condition (D4 channel)." The Project Plan continued in this manner, referring to various channel types in the Rosgen classification system and ultimately concluding that converting the existing forms to a C4 channel was an appropriate design. The alpha-numeric designations refer to other stream types in the Rosgen classification system: F4 is "a gravel dominated, entrenched, meandering channel, deeply incised in gentle terrain," G4 is "deeply incised in depositional material primarily comprised [*sic*] of an unconsolidated, heterogeneous mixture of gravel, some small cobble, and sand," and D4 are "braided streams, found within broad alluvial valleys and on alluvial fans consisting of coarse depositional materials formed in moderately steep terrain" (Rosgen 1996). Neither the Project Plan nor the U.S. ACE permit documents articulated reasons to expect a "C4 stream type" to be "more stable and natural" for Uvas Creek (US ACE 1995, p. 1).

The Project Plan included 12 tables of channel characteristics for 11 locations along the existing channel and one showing design dimensions chosen for the restoration project, but did not articulate how the latter was derived from the former. The Project Plan described bankfull discharge as 12.6 $m^3 sec^{-1}$, identifying it as the flow with a return period of 1.25 years ($Q_{1.25}$). Bankfull discharge is defined as the flow that just fills the banks, at the point where overflow begins onto the floodplain (Wolman and Leopold 1957).

The channel design drawing (undated but evidently from September 1993) did not include a scale, but its scale could be inferred from notations of meander dimensions (Figure 3). The drawing shows regular meander bends with a wavelength of 140 (± 20) m and amplitude of 72 (± 5) m. These dimensions were not

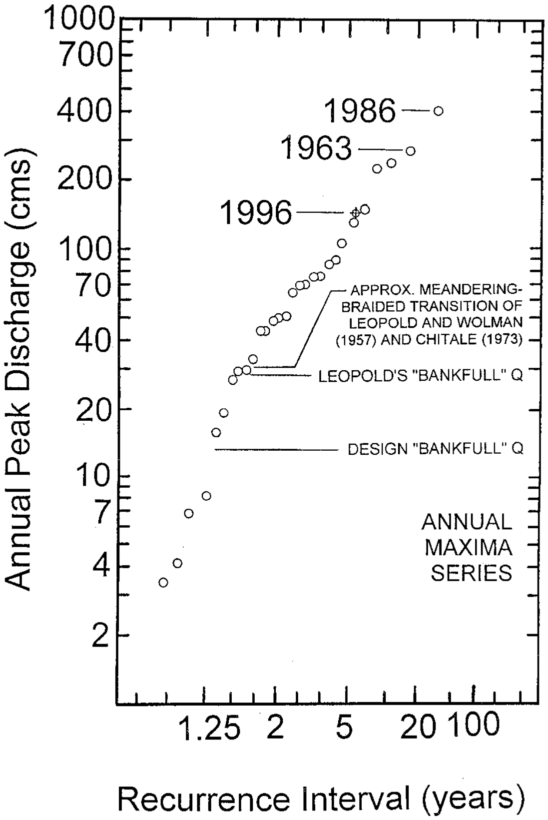

Figure 4. Empirical flood-frequency analysis (annual maxima) for the gauge, Uvas Creek near Gilroy. The period of record was 1959–1992, but there were no data for 1977 and 1988, and we did not plot the lowest two annual peaks of 0.04 m^3 sec^{-1} in 1976 and 0.08 m^3 sec^{-1} in 1961 to simplify scaling the plot. Also shown for comparison is the peak flow in 1996, estimated at 140 m^3 sec^{-1} by the Santa Clara Valley Water District. (*Source:* published records of the US Geological Survey.)

consistent with the wavelength of 235 m and amplitude of 84 m given in the Project Plan for an "idealized (post-restoration) cross-section." The design drawing evidently was the basis for the final AutoCAD grading plan that guided channel reconstruction. However, neither postproject surveys nor aerial photos were made to document the as-built channel dimensions.

Results: Hydrology and Field Surveys

Annual peak flows on Uvas Creek at Gilroy from 1959–1992 ranged from 0.04 m^3 sec^{-1} to over 400 m^3 sec^{-1}. The February 1996 flow that washed out the project was estimated by the Santa Clara Valley Water District at 140 m^3 sec^{-1}; this flow has a return period of 5–6 years on our flood frequency analysis (Figure 4). Our analysis also indicated that $Q_{1.25}$ is 16 m^3 sec^{-1}, not the 12.6 m^3 sec^{-1} indicated in the Project Plan. Leopold (unpublished data in the Water Resources Center Archives, University of California, Berkeley) listed bankfull discharge as 28.3 m^3 sec^{-1} for the same gauge, defining bankfull discharge as the flow with a 1.5-year return period ($Q_{1.5}$).

Field observations along Uvas Creek in July 1997 showed some scour at the toe of revetments along designed meander bends, but the revetments (and banks immediately up- and downstream) were not damaged. Uvas Creek simply abandoned the design channel and adopted a course through the constructed floodplain (Figure 5). Deposition occurred throughout the project reach, with revetments at the third meander bend (in a downstream direction) completely buried.

The longitudinal profile of the channel shows little differences in bed elevation between 1984 and 1998, although the 1984 profile (US ACE 1984) was not as detailed as our 1998 survey, so it was not capable of picking up the irregularities in the bed shown on the 1998 profile (Justine 1998)(Figure 6). The design channel averaged about 0.5 m lower than the surveyed bed elevation in 1984 and 1998. Channel gradient ranged between 0.17% and 0.3%. The cross section we surveyed about 900 m downstream of the Santa Teresa Road bridge shows the active channel was narrower in 1998 than in 1939 and indicated that the current channel is incised about 2 m below the remnants of the 1939 channel bed (Justine 1998)(Figure 7).

Using Leopold's value for bankfull discharge of 28 m^3 sec^{-1} and the observed slope of about 0.002–0.003, Uvas Creek plots at the transition between braided and meandering channels proposed by Leopold and Wolman (1957), slightly below the transition (in the meandering range) on the plot of Chitale (1973), and far below the cloud of gravel bed river points in Kellerhals (1982) scatter diagram of proglacial Canadian rivers. Of course, these plots are gross simplifications, but the transition values of Leopold and Wolman (1957) and Chitale (1973) imply that a meandering channel here might be metastable at best and prone to braiding at higher flows.

Results: Historical Geomorphological Analysis

The Santa Clara County Atlas (1:32,400 scale) (Thompson & Crest 1876), though probably schematic in its depiction of channel planform, shows Uvas Creek

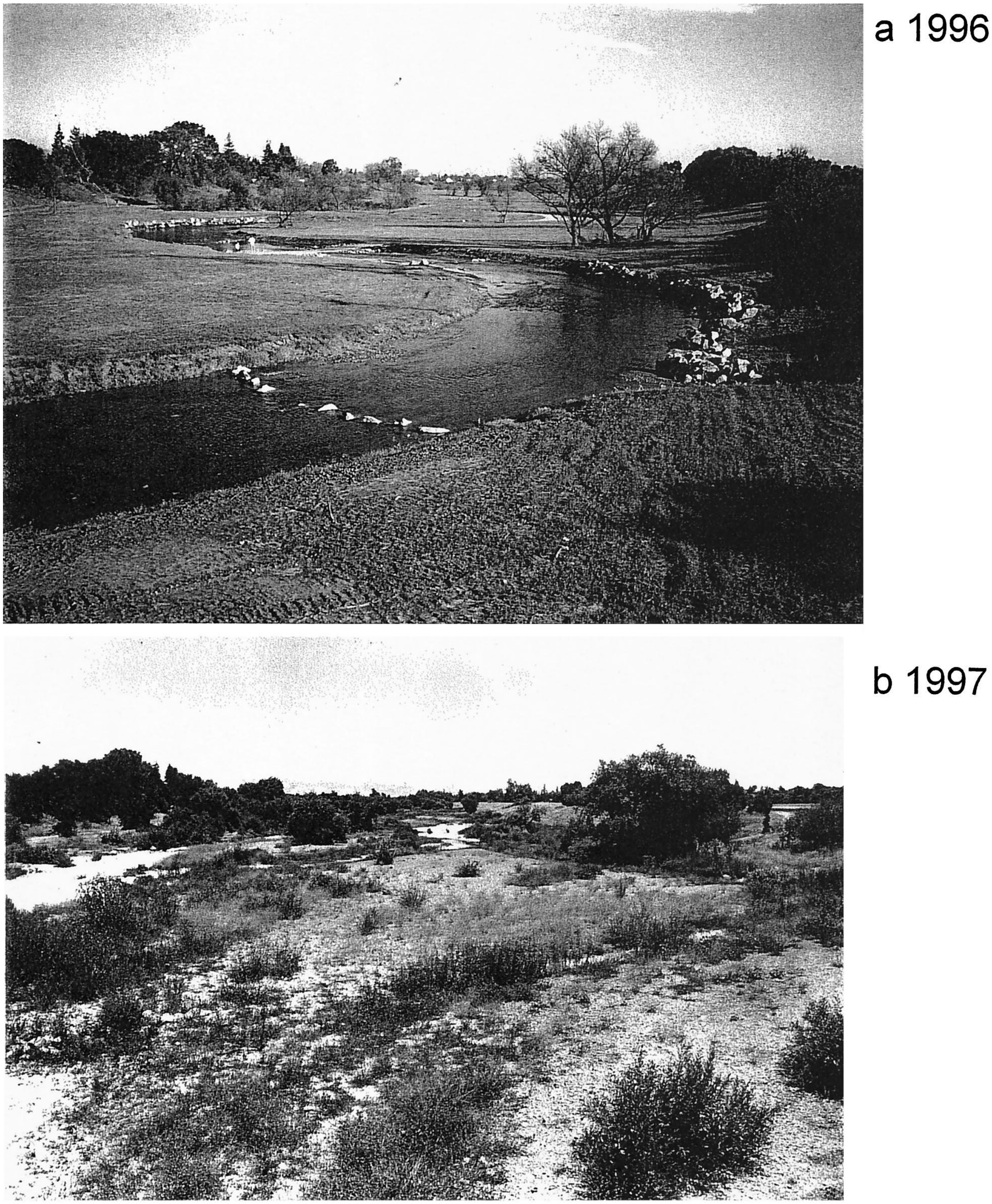

Figure 5. Photographs looking downstream from Santa Teresa Bridge at the channel of Uvas Creek. (a) in January 1996, about 2 months after construction of the channel reconstruction project, and (b) in June 1997, after the project had washed out. (1996 photograph courtesy of the City of Gilroy, 1997 photograph by Kondolf.)

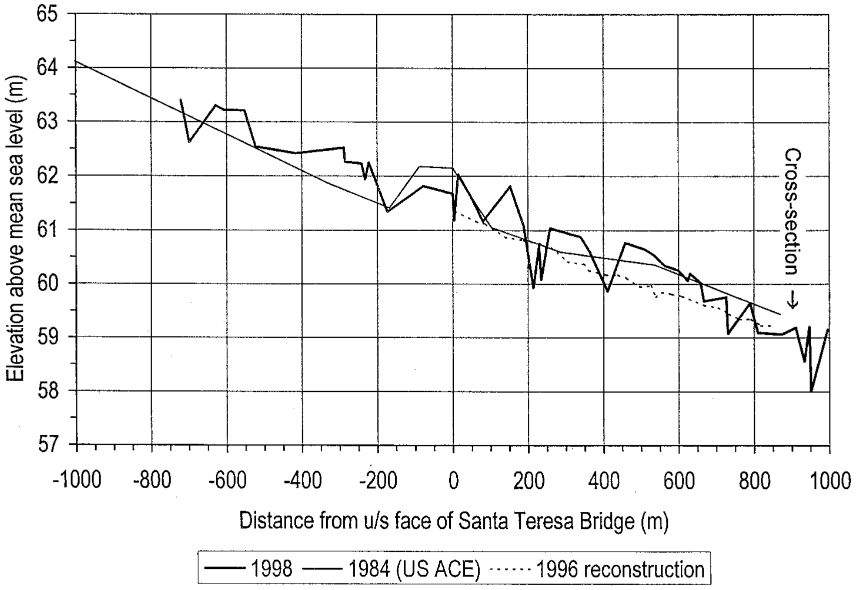

Figure 6. Longitudinal profile of Uvas Creek, near Santa Teresa Bridge. X axis is distance from bridge: negative values are distance upstream, positive values are downstream. The 1984 profile is from US ACE (1984), the 1998 profile is from Justine (1998), and the 1996 profile of the channel reconstruction project is taken from final AutoCAD construction drawing.

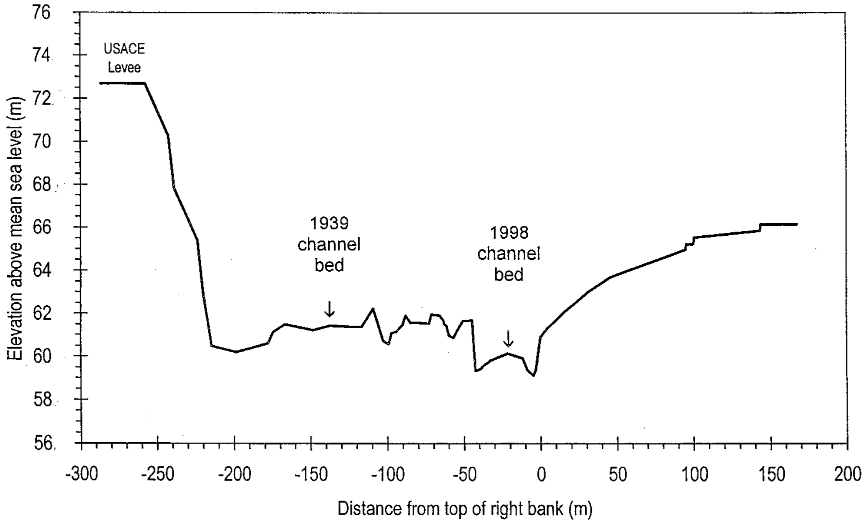

Figure 7. Cross-section surveyed in 1998 near the downstream end of the channel reconstruction project, 900 m downstream of Santa Teresa Bridge. About 2 m of incision since 1939 is inferred from comparison of sequential aerial photographs. Adapted from Justine (1998).

as a divided alluvial channel in the project reach (Figure 8). At Twin Bridges (now the Hecker Pass Highway bridge), 2.5 km upstream of the project reach, an 1894 photograph also shows a braided channel, a multiple channel pattern with bare gravel bars in between the channels. In 1997 this same view showed Uvas Creek had incised about 6 m within a single channel and narrowed (Figure 9). This is considerably more incision

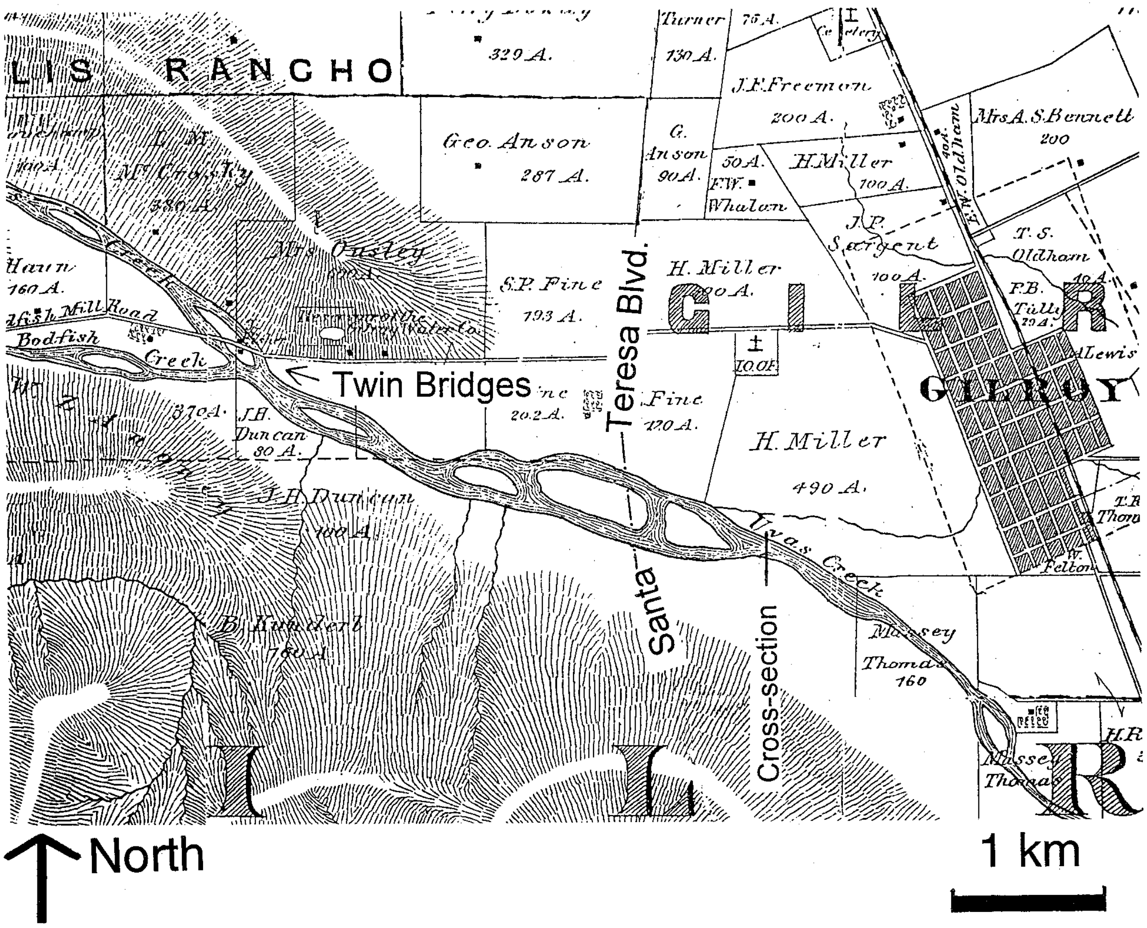

Figure 8. Uvas Creek near Gilroy as it appeared on a 1:32,400 scale map of 1876. Annotations have been added to show the location of Twin Bridges (Figure 9), and the Santa Teresa Boulevard Bridge at the upstream end of the 0.9-km project reach. Adapted from Thompson & Crest (1876).

than indicated by our cross-section near the downstream end of the project reach (Figure 7), which may be attributable to the greater concentration of gravel mining upstream of the project reach.

In the project reach, the width of the active channel measured from aerial photographs decreased about 70% between 1939 and 1993. The 1939 aerial photographs show a broad, unvegetated, braided channel between well-defined escarpments (Figure 10). Comparing 1939 and 1956 aerial photographs of Uvas Creek shows that the dominant (or low-flow) channel changed location within the active channel zone, although the braided form and width of the active channel remained similar. By 1993, the channel had incised and mostly adopted a single thread. In the project reach and for several hundred meters upstream, the effects of instream gravel mining were evident in aerial photographs of 1956, 1980, and 1993. Gravel mining reworked (and left pits in) the active channel, and obliterated the channel form. The low-flow channel was no longer confined between banks, but spread out as shallow flow over the disturbed bed of the unvegetated, active channel. The Master Plan cited this as causing seasonal obstruction of fish migration, and the channel reconstruction project was intended to correct this condition. The aerial photographs also show the exotic plant *Arundo donax* established in disturbed parts of the active channel. A flood control levee constructed by the U.S. Army Corps of Engineers on the left bank terrace, just outside the edge of the active channel, was visible

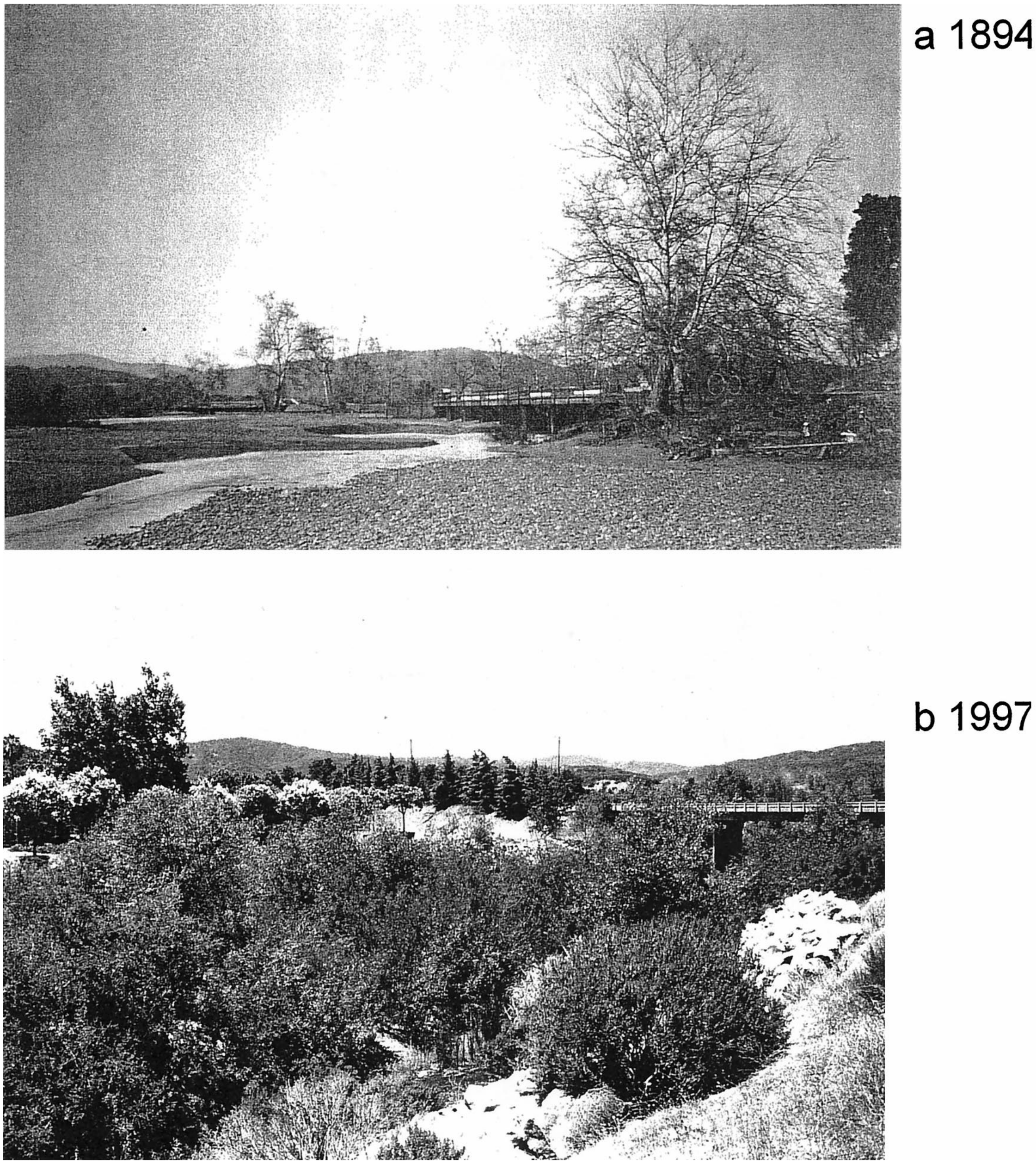

Figure 9. Photographs looking upstream towards the Hecker Pass Highway Bridge (formerly known as "Twin Bridges" crossing of Bodfish Mill Road). (a) in 1894, and (b) in June 1997. (1894 photograph is courtesy of Gilroy Historical Museum; 1997 photograph is by Kondolf.)

on the 1993 air photos. The 1993 channel did not evince clear multiple channels (probably because in the course of incision the stream had abandoned most secondary channels) and its course appeared to be strongly influenced by gravel mining extractions. The period 1987–1994 was dry, so no floods had occurred to rework the effects of instream gravel mining.

When the 1995 channel reconstruction is superimposed on the 1993 photo and contrasted with the channel planform mapped from sequential aerial

Figure 10. Aerial photographs of Uvas Creek below the present location of Santa Teresa Boulevard Bridge in 1939 and 1997.

photographs of 1939, 1993, and 1997, the project's design meanders are starkly inconsistent with the planform of Uvas Creek upstream and downstream of the project, and historically in the project reach (Figure 11). In 1996, the planform of Uvas Creek reverted to a mostly braided form similar to its premining historical condition, although the active channel was narrower and more of it was confined to

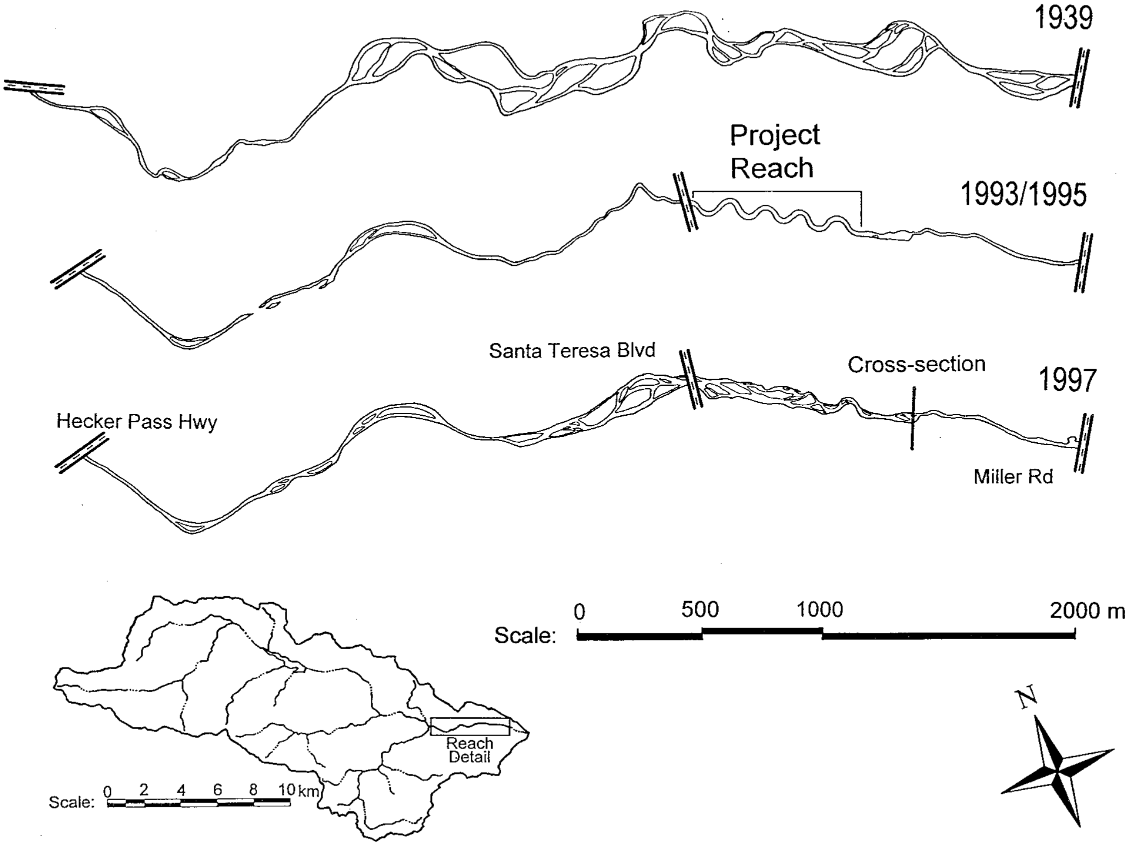

Figure 11. Active channel planform of Uvas Creek from Hecker Pass Highway to Miller Road, in 1939, 1993/1995, and 1997, as mapped from aerial photographs. Because the project survived only 3 months after construction, it was not captured in aerial photography, so we superimposed the design channel (constructed in 1995) onto the map of the channel based on 1993 aerial photographs.

a single thread upstream and downstream of the project reach.

Discussion

Implications of Historical Geomorphic Analysis for Restoration

Broad, unstable sand-and-gravel channels are typical in unregulated streams draining the California Coast Ranges, reflecting their sediment supply, episodic flows, and virtually constant adjustment to high flows or intervening droughts. Historical maps and aerial photographs show that Uvas Creek had such a broad, treeless, braided channel between well-defined escarpments. However, the project plan was based on the assumption that a meandering C4 channel type formerly existed in Uvas Creek and that such a channel would be stable. Neither the Project Plan nor the U.S. ACE permit documents acknowledged that Uvas Creek was formerly braided at the site, nor that braiding was typical for streams in the region.

The Project Plan presented no historical geomorphological analysis of former channel conditions, nor analysis of changes in the channel and catchment and their probable effects on channel process and form. The notion that the channel could be made stable by bulldozing certain dimensions dictated by a classification system was evidently accepted by agencies and reviewers involved in approving the project. The first suggestion in the project documents that there may be no stable form for this reach was in notes from the postmortem technical meeting to discuss reasons for project failure.

As noted by Sear (1994), many so-called geomorphically based restoration projects are designed using channel dimensions drawn from regression relations or other “cookbook” approaches, but without doing “real geomorphology.” The latter involves analysis of geomorphic processes at a watershed scale and over longer time scales, and could involve reach-level calculation of shear stresses at various flows, and so on (Kondolf 2000).

Geomorphic reasoning would suggest that the processes that formed and maintained a braided channel historically would tend to re-create a similar channel as soon as flows occurred that were adequate to transport sediment and thus rearrange the bed from its postmining or postproject condition. The tendency to reestablish a braided channel would be limited by channel incision and consequent narrowing. Thus, while the post-1996 channel resembled the 1939 channel in being braided, mostly unvegetated sand and gravel, the active channel had narrowed and incised, likely the result of instream gravel mining, upstream impoundment, land use changes in the catchment, and encroachment of agriculture and other human uses into the former active channel. For example, in the reach directly below Uvas Reservoir, the active channel narrowed 16–48% between 1953 and 1990 in response to dam construction (Kondolf and Matthews 1990). In the project reach, about 12 km downstream, effects of the dam are less because most of the drainage area lies downstream of the dam.

It could be argued that the reduced sediment supply from the dam, along with the sediment deficit created by gravel mining, flashier runoff from recently urbanized areas, and constriction of flood flows by levees, might induce a channel shift from braided to meandering. That is, the current flow and sediment transport regime might no longer support the braided channels of former times. However no such suggestion was articulated in any of the project documents, and the post-flood channel of 1996 reflected braiding, albeit restricted to a narrower zone than formerly.

Channel Stability as a Project Goal

The project goal of establishing “a more stable and natural channel” raises some issues. First, if, as indicated in the design documents, the constructed channel form was expected to be inherently stable, it is unclear why revetments would be needed on the outsides of meander bends.

Second, a considerable body of scientific literature has demonstrated that the dynamic migration of meandering channels is responsible for much of their habitat value, as the processes of bed scour, bank erosion, and point bar deposition maintain undercut banks and clean gravels and create fresh surfaces for colonization of riparian vegetation. This literature also indicates that arresting meander migration leads to decreased habitat value (e.g., Ward and Stanford 1995, Johnson 1992). Thus, creating a meander sequence that is “stable” (i.e., “frozen in place”) precludes the ecological benefits of a dynamically migrating channel. In urban areas, there are often constraints that prevent us from allowing channels to migrate freely, but, ironically, the Uvas Creek Park Preserve was one area that could accommodate some channel migration, given that there were no structures right along the banks and relatively few infrastructure constraints.

Third, the relations between bankfull channel width and meander dimensions used in this (and many other channel reconstruction projects) are based on values generally drawn from beautifully developed meanders (the classic forms that draw researchers), which are typically also the meanders that are migrating actively (and thus maintaining the ideal forms). It is unclear why geometries from actively migrating meanders would be used to design meanders that were expected to be static.

The Bankfull Flow Concept in Project Design

Our flood frequency analysis and the unpublished data of Leopold (both reported above) suggest that the $Q_{1.25}$ given in the Project Plan was too low. This may have contributed to the project failure. However, the Project Plan’s assumption that a channel designed with bankfull flow equal to $Q_{1.25}$ would provide stability is questionable because it does not consider the site’s geomorphic context. The notion of the 1.5-year flow as bankfull or channel-forming discharge is based on research in humid-climate and snowmelt streams (Wolman and Leopold 1957). However, the return periods associated with the bankfull form actually observed in nature vary widely (Williams 1978). In semi-arid settings, with their episodic flow regimes, channels are more influenced by less frequent flows (Wolman and Gerson 1978, Hecht 1994). Typical of streams in the Coast Ranges of central California, Uvas Creek can be considered an episodic channel, as evidenced by its extreme range of discharge.

Failure of Classification-Based Projects

Projects to construct meandering C4 channels based on the Rosgen classification scheme have been built and similarly failed on other channels in the northern California in recent years, including Jamison, Wolf, and Greenhorn Creeks in the Sierra Nevada and Cuneo and Mattole Canyon Creeks in the Coast Ranges. In each case the design channel washed out or filled with sediment, and the channel reverted to essentially preproject conditions. Objective postproject appraisals have not been published for any of these projects, but their similar histories makes it likely that their failure was also a consequence attempting to impose inappropriate channel forms.

In correspondence prior to construction, one of two consultants responsible for the Uvas Creek channel design raised concerns that the project would not be stable because final construction drawings showed changes from the original design: fewer rock weirs, and revetments at meander bends not extending as far upstream and downstream as originally called for. However, when viewed in the larger temporal and spatial context (e.g., Figure 11), we see no geomorphic reasons to expect the meandering channel to have been stable in this reach even if built precisely as originally designed. The revetments and grade controls were not eroded; they were buried in sediment or abandoned by the channel as it cut through the constructed "floodplain," which was largely unvegetated, and thus had a low frictional resistance, probably high overbank flow velocities, and thus greater likelihood of chute erosion across meander bends, as observed on the Deep Run project by Smith (1997).

The question can be posed whether the Uvas Creek channel might have survived a 6-year flood (such as 1996) if it had been preceded by several dry years without flood scour, during which vegetation could have established. We think this unlikely given that groundwater drawdown from pumping would be greatest in dry years, likely desiccating the bars and constructed floodplain on which riparian seedlings might attempt to establish. Moreover, a 6-year flood (such as 1996) has roughly a 15% chance of occurring in any year, so it is reasonable to expect a channel reconstruction project be designed to withstand such a flow within the first year.

Conclusion

This case study illustrates dangers of a prescriptive approach to stream restoration design and casts doubt on several assumptions that are unfortunately common in stream restoration projects. First, the channel reconstruction project was probably not addressing the primary factors limiting steelhead trout on Uvas Creek: providing fish access to the best habitat upstream of Uvas Dam, and the lowered water tables and dry stream bed that result from groundwater pumping. To address these problems would require reexamining existing infrastructure and water use patterns, a complicated and politically charged task, far more difficult than reconstructing a reach of channel. Simply reconstructing a more desirable channel (even if successful), however, would not address these fundamental factors limiting fish populations.

Second, the geomorphic basis of the reconstruction project design was flawed. It is not always appropriate or feasible to design for "stability" of channel banks, as some channels are inherently mobile even when channel form is stable. Channel forms are not always determined by flows with return periods of about 1.5 years, and the concept of bankfull or channel-forming discharge is of limited utility when applied to streams with episodic flow regimes. The notion that appropriate channel designs can be readily picked from a classification system, while understandably appealing to the manager or nongeomorphologist, is not supported by sound analysis and understanding of geomorphic processes.

The notion that streams can be "restored" by imposing new channel forms without addressing the processes that determine alluvial channel form, and without appreciating system evolution and watershed context, is inconsistent with basic geomorphic principles (Kondolf 1995b). After all, channel processes create and maintain channel form, so if a certain desired channel form (e.g., a "C4" meandering channel) is not observed on a reach, or at least observed to be trending towards this desired channel form, it implies that current channel processes do not support such a form. A classification-based approach could conceivably be successful where watershed processes were largely undisturbed but the channel destabilized (e.g., by removal of bank vegetation). In such cases, however, it is not entirely clear what is gained by describing the channel with a classification system instead of simply using the "carbon copy" approach (Brookes and Shields 1996) of rebuilding the predisturbance channel form based on historical information or a nearby, undisturbed reference reach.

In cases where human actions have directly altered the channel but watershed processes (e.g., runoff, sediment yield, and their temporal patterns) are undisturbed, fluvial geomorphic processes would tend to drive the channel back to a predisturbance channel form even without channel reconstruction. On dynamic, high-energy systems with adequate sediment load, the channel is likely to "restore itself" quickly—after one or several competent floods. On low-energy streams, self-recovery might require decades or centuries, and thus channel reconstruction is more warranted. A geomorphic analysis of Uvas Creek would have shown it to be an episodic, high-energy system, and thus that channel reconstruction was an option of questionable merit.

In cases where runoff and sediment load have changed, restoration channel design will involve predicting channel form and dimensions suitable for the altered conditions. At least in theory, the classification-bankfull approach might be one way to obtain insights into channel design, but there is no evidence that this potential has been met in the experience on Uvas Creek and similar projects in California.

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