ORANGE COUNTY
OC PublicWorks
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JUN 07 2011

CITY OF LAKE FOREST
DEVELOPMENT SERVICES DEPT

NCL 11-012

June 1, 2011

Ms. Carrie Tai, AICP
Senior Planner
City of Lake Forest, Development Services Department
25550 Commercentre Drive, Suite 100
Lake Forest, California 92630

SUBJECT: Notice of Preparation of a Draft Environmental Impact Report for Serrano Summit – Area Plan 2009-01 and Tentative Tract Map 17331

Dear Ms. Tai:

The County of Orange has reviewed the Notice of Preparation of a Draft Environmental Impact Report for the Serrano Summit located in the City of Lake Forest and offers the following comments:

Flood Programs:

In response to your request dated May 5, 2011, Flood Programs/Hydrology has reviewed the Notice of Preparation of a Draft Environmental Impact Report for Serrano Summit Area Plan 2009-01 and TT Map No. 17331 located in the City of Lake Forest. We offer the following comments for your consideration:

1. The project proposes 19 Planning Areas that include Medium Density Residential land uses of up to 833 dwelling units, public facilities uses and recreational uses for the total area of 98.9 acres. The intensification of land use that might result from the Serrano Summit Area Plan 2009-01 update would increase the overall impervious area and impact local as well as regional drainage facilities downstream of the project. Therefore, hydrologic and hydraulic analyses need to be performed to evaluate and compare quantitatively the runoff volumes, peak flow rate increases, adequacy of existing storm drains and off-site channels that will ultimately carry these discharges. The analyses are needed to ensure that post-project conditions along OC and/or OCFCD drainage facilities,

including Serrano Creek (Facility No. F19) are not worsened as a result of the project and that they support "less than significant impact" statement of page 117 of Initial Study.

2. Natural reaches within Serrano Creek have been proven to be susceptible to erosion. The Draft EIR needs to contain a section that identifies those reaches, discusses the historic erosion and stream stability issues and proposes mitigation for any impacts to the stream sediment transport resulting from the proposed development/Area Plan/TT. The Draft EIR also needs to discuss and propose measures to adequately protect the proposed development areas from excessive erosion of the creek as applicable. Sediment transport analyses performed by a licensed engineer specialized in the field of sediment transport need to be included as appropriate to support the Draft EIR findings.

3. Should the hydrologic and hydraulic and sediment transport analyses indicate that conditions are worsened, appropriate mitigation measures should be proposed in consultation with OC Public Works/Flood Programs.

4. All hydrologic and hydraulic studies must conform to the current guidelines and criteria as specified in the Orange County Hydrology Manual (OCHM), Addendum No. 1 to the OCHM and the Orange County Flood Control Design Manual.

5. FEMA's FIRM map, Panel No.316J shows that the area of the project is within Zone X. City of Lake Forest, as floodplain administrator for areas within its municipal boundaries should ensure that all FEMA regulations and floodplain requirements applicable to this project are met.

6. All work (if any) within OCFCD right-of-way will require encroachment permits from OCPW/Property Permits Section. For information regarding permit application, please visit our web site http://www.ocplanning.net/ . Technical reviews and approvals for the proposed work will be accomplished within the permit process.

If you have any questions regarding these comments, please contact Anna Brzezicki at 834-5029.

Flood/Santa Ana River/Trails

- The Serrano Creek Regional Riding and Hiking Trail is County master-planned trail.

- The trail is part of an expansive, 350-mile long, network of 53 natural-surface trails designed to connect much of Orange County.
- County Regional trails are categorized as multiple-use trails because they accommodate walkers, joggers, runners, and mountain bicycle and equestrian riders.
- The Serrano Creek Trail begins at the Serrano Creek Equestrian Center in Lake Forest near the intersection of Trabuco Road and Peachwood.
- This 6-mile long trail is complete to Whiting Ranch Wilderness Park and the Santiago Equestrian Center along Santiago Canyon Road.
- The Serrano Creek trail is currently operated by the County of Orange (Orange County Community Resources/OC Parks).
- Trails can serve as an alternative mode of transit besides providing an enjoyable recreation experience.
- Run-off from the project (from the current IRWD site) should be designed to undercross the trail so as not to impact the trail surface.
- The applicant should contact OC Parks directly to discuss the proposed residential development project and its desire to connect with the Serrano Creek Trail.

If you have any questions regarding these comments, please contact Jeff Dickman at 834-2774.

<u>OC Environmental Resources/OC Watershed</u>

In response to your request for input on the subject project, OC Watersheds has reviewed the document. As noted on Page 4 of the Initial Study, the County of Orange would be a Responsible Agency under CEQA for this EIR, since the County would be issuing permits for the project's offsite drainage into Serrano Creek.

1. The decision on Page 129 of the Initial Study (IS) not to address hydrology and water quality issues in the EIR is not appropriate. On Page 128, the IS notes that new Outlet B into Serrano Creek would have a peak discharge of 134 cubic feet per second, far more than is presently discharged in that area. The IS concludes that this outlet's "energy dissipaters, baffles and riprap...would...reduce the erosion potential at this specific location". There is no claim that erosion potential would be completely eliminated. This section of Serrano is currently experiencing significant

hydromodification, and additional discharges have the potential to further destabilize this channel if appropriate mitigation is not provided. Hydromodification management for this project must be addressed by, at the very least, matching the post-project hydrologic condition to the pre-project hydrologic condition at this location.

2. The Preliminary Water Quality Management Plan addresses Hydrologic Concerns on its Pages 13 -14 without making any mention of the significant hydromodification currently taking place within this section of Serrano Creek.

3. If Serrano Creek continues to experience hydromodification of its banks in the direction of Outlet B's energy dissipaters, baffles and riprap, these features could in the long term be undercut. The area between the bottom of the riprap and the low-flow channel may itself erode down in response to discharges of up to 134 cubic feet per second. The EIR needs to address the long-term stability of the outlet and its appurtenances, the potential for hydromodification below the footprint of the outlet and the low-flow channel of Serrano Creek, and within Serrano Creek itself at and below that point, all in the context of a currently unstable creek bed.

4. The Initial Study on Page 121 briefly notes that the San Diego Creek / Newport Bay Watershed (which includes Serrano Creek) is subject to a regulatory sediment TMDL "to reduce the annual average sediment load...50 percent". To the extent peak discharges are closely associated with sediment movement, it is worth noting this project only reduces peak discharges 16.5% (see Page 127 of the Initial Study).

5. The Initial Study does not address whether the new rip rap apron of the outlet, which is of considerable size, is consistent with the aesthetic enjoyment or expectations of recreation users of the Creek area.

If you require any additional information, please contact Grant Sharp at (714) 955-0674.

Sincerely,

R Maldonado

for Michael Balsamo
Manager, OC Communities Planning
OC Public Works/OC Planning
300 North Flower Street
Santa Ana, California 92702-4048
Michael.Balsamo@ocpw.ocgov.com

MB/mmc

cc: Mehdi Sobhani, Flood Programs
Chris Crompton, Environmental Resources
Jeff Dickman, Flood/SAR/Trails

California Regional Water Quality Control Board
Santa Ana Region

Linda S. Adams
Acting Secretary for Environmental Protection

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Edmund G. Brown Jr.
Governor

June 10, 2011

Carrie Tai, Senior Planner
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25550 Commercentre Drive, Suite 100
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INITIAL STUDY AND NOTICE OF PREPARATION FOR DRAFT ENVIRONMENTAL IMPACT REPORT, SERRANO SUMMIT AREA PLAN, TENTATIVE TRACT MAP NO. 17331 – CITY OF LAKE FOREST, SCH# 2011051009

Dear Ms. Tai:

Staff of the California Regional Water Quality Control Board, Santa Ana Region (RWQCB) has reviewed the City of Lake Forest's (City) Initial Study (IS) for the Serrano Summit Area Plan (Project), for which a Draft Environmental Impact Report (DEIR) will be prepared. In accordance with the California Environmental Quality Act (CEQA), the project EIR will tier off the 2008 Opportunities Study (OS) Programmatic EIR adopted by the City. This Project is the first of seven projects within the 838 acre OS EIR project area.

The Project would subdivide a partially graded, 98.9-acre hillside into 37 lots, all located south of Commercentre Drive and the termini of Biscayne Bay and Indian Ocean Drives. A civic center and various residential uses are proposed, with open space dedicated around existing Irvine Ranch Water District facilities and along a portion of Serrano Creek. The eastern border of the tract ("parcel boundary", Exhibit 4.4-1) runs parallel to, and within, the Serrano creekbed.

We request that the following comments be considered when preparing the DEIR, so that the Project protects water quality standards (water quality objectives and beneficial uses) identified in the Water Quality Control Plan for the Santa Ana River Basin, 1995, as amended (Region 8 Basin Plan):

1. Proposed impacts to waters of the state and the United States

It is apparent from IS Exhibits 4.1-6 and -7 (Viewpoints 5 and 6), a comparison of Exhibit 4.4-1 (Jurisdictional Features) and Exhibit 2-8 (Proposed Conceptual Landscape Master Plan), and the text of pages 89-93 (Jurisdictional Waters of the U.S., etc.) that emplaced fill will extend the to the regional trail located upon a dike west of Serrano Creek. The fill would bury Drainage A, a natural perennial seep-fed brook, and its ephemeral Tributary A1, both located between the existing hillside and the dike.

a. At least one Project alternative should evaluate avoidance of Drainage A and Tributary A-1.

b. We understand the combined proposed impact to Drainages A and Tributary A1 will be a total of 1.909 acres of California Department of Fish and Game (CDFG) jurisdictional streambed, including 0.206 acre of "ACOE/RWQCB jurisdictional wetlands." This 0.206 acre area of jurisdictional waters of the U.S. and of the state comprises 0.077 acre of "jurisdictional waters of the U.S./waters of the state" and 0.129 acre of "bordering vegetated wetlands" (p.91; p.89 Table 4.4-4). These are the areas for which in-kind water quality standards compensatory mitigation will be needed to obtain RWQCB approvals

2. Water quality permitting and mitigation

a. IS pg. 91-2, including Mitigation Measure BIO-4, should more directly emphasize that the proposed "disturbance" to Drainages A and Tributary A1 would likely require issuance of a Clean Water Act (CWA) Section 401 Water Quality Standards Certification (Certification) from the Regional Board, rather than waste discharge requirements (WDRs) (p.131-2). Certifications are prerequisite to CWA Section 404 Permits issued by the U.S. Army Corps of Engineers. Certifications and WDRs require in-kind mitigation measures for compensatory mitigation for impacts to water quality standards.

b. If construction of new drainage outlets takes place in areas of ACOE jurisdiction, they may constitute a further "discharge of fill to waters of the U.S." that will be subject to RWQCB CWA Section 401 Certification.

c. The IS states that the acquisition of permits will reduce potential water quality impacts below significant levels and such water quality topics will not be further analyzed in the EIR. We strongly disagree. Merely obtaining permits does not reduce or mitigate water quality impacts. The EIR needs to analyze and indentify specific measures that will be taken to reduce impacts, such as avoidance, and/or provide compensatory mitigation for the Project's permanent impacts to water quality standards.

d. EIR analysis and discussions concerning permanent impacts to water quality standards should address compensatory mitigation for all unavoidable impacts. Compensatory mitigation could include the restoration of impaired beneficial uses, such as improving riparian and streambed habitat and function, and implementing measures that correct past hydromodification of Serrano Creek.

3. TMDLs and Hydraulic Conditions of Concern (HCOC)

The Project will include two detention basins to treat site runoff and moderate post-construction runoff flows, although most runoff flow volume will be directed east from the site toward Serrano Creek (IS p.25). Three existing drains that now connect Drainage A to Serrano Creek through an existing levee will be revised into two new outlets directly discharging to the Creek. The second of these outlets will require energy dissipation (IS p.128) to address HCOC.

Excessive discharges of sediment in the watershed that includes the project site have led to development of sediment total maximum daily loads (TMDLs). This Project must be conducted in such away as to contribute to compliance with these TMDLs. We note that that development of the project will result in an increase of sheetflow runoff into Serrano Creek, and possible HCOC. The project's EIR should include an analysis of the potential

HCOC arising from the proposed increase in discharge from Outlet B and from discharges of sheetflow runoff and if necessary, and thoroughly discuss how any HCOC will addressed.

If you have any questions, please contact Glenn Robertson at (951) 782-3259, grobertson@waterboards.ca.gov, or me at (951) 782-3234, or madelson@waterboards.ca.gov

Sincerely,

Mark G. Adelson, Chief
Regional Planning Programs Section

Enclosure: February 19, 2008 RWQCB letter to the City of Lake Forest

Cc w/ encl: State Clearinghouse
U.S. Army Corps of Engineers, Los Angeles –Veronica Chan
California Department of Fish and Game, Los Alamitos – Leslie McNair
Orange County RDMD, Flood Control, Santa Ana - Andy Ngo
Orange County Resources and Development Management Dept., Watersheds - Mary Ann Skorpanich

X:Groberts on Magnolia/Data/CEQA/CEQA Responses/ DEIR/ City of Buena Park - General Plan-MJA.doc

California Regional Water Quality Control Board
Santa Ana Region

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Secretary for Environmental Protection

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Arnold Schwarzenegger
Governor

February 19, 2008

Cheryl Kuta, Senior Planner
City of Lake Forest
Development Services Department
25550 Commercentre Drive, Suite 100
Lake Forest, CA 92630

Chapter 7 and Recirculated Sections of the Draft Program Environmental Impact Report, City of Lake Forest Opportunities Study General Plan Amendment and Zone Change, Orange County, State Clearinghouse No. 2004071039

Dear Ms. Kuta:

Staff of the California Regional Water Quality Control Board, Santa Ana Region (RWQCB) has considered new Chapter 7 and the recirculated portions of the City of Lake Forest (City) Draft Environmental Impact Report (the Recirculated DEIR) for the Opportunities Study Program (Program). Please consider the following comments before finalizing the Recirculated DEIR:

Hydromodification

We do not agree with the Recirculated DEIR's discussion regarding runoff to Borrego Canyon Wash, Serrano Creek, in the Santa Ana Region, and Aliso Creek, in the San Diego Region. As noted in our prior comments, rapid and improperly mitigated urbanization in areas tributary to Serrano Creek and Borrego Canyon Wash has increased the volume and velocity of stormwater runoff to those drainages, resulting in dramatic channel instability, including bed scour, downcutting and bank collapse. This erosion has is causing and threatens to cause loss of beneficial uses of these drainages and violations of their water quality standards, identified in the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan). This erosions leads to the discharge of substantial sediment and contaminant loads that eventually reach Upper Newport Bay, interfering with Upper Newport Bay's beneficial uses and water quality standards. The correction and reduction of this hydromodification is a priority of the RWQCB. Furthermore, we note that this hydromodifcation also threatens private property and public health and safety.

The Recirculated DEIR still does not adequately analyze the baseline hydrological condition for any of the three watersheds. In our prior comments, we requested that the DEIR adequately discuss the history of development along these three drainages and in their watersheds, and adequately describe the existing condition of the three watersheds. This critical information, necessary to fully understand and evaluate the

Program's potential impacts on hydrology and water quality, and other environmental factors, is absent from the Recirculated DEIR. The Recirculated DEIR does not include any new discussion of the baseline condition of any of the three drainages. Both the Orange County Flood Control District and the RWQCB, among other agencies, have extensive information and literature on the history of these three drainages.

The Recirculated DEIR still does not contain an adequate cumulative impacts analysis. As noted in our prior comments, both Serrano Creek and Borrego Canyon Wash are currently unstable. Any change in the volume, velocity and/or timing of release of stormwater flows from the subject project sites is likely to have a cumulatively significant impact, and the potential to exacerbate the current undesirable conditions in these drainages. The Recirculated DEIR appears to side step engaging in a cumulative impacts analysis by imposing a mitigation measure that each individual project will be required to demonstrate no net increase in peak stormflow rates. However, the Recirculated DEIR does not support this mitigation measure with any analysis discussing how implementing the measure will avoid further significant impacts to these drainages. There is no analysis showing how this mitigation measure will cumulatively effect the hydromodification of the drainages. There is no discussion of the magnitude or duration of peak storm events. There is no discussion of the feasibility of building storm water runoff retention or detention facilities sized to retain peak storm flows on the various parcels that are the subject of the DEIR. There is no discussion of the volume, velocity, timing, duration or other management of the release of the retained /detained storm flows. There is no modeling of the cumulative impacts of the various facilities on the total flows in any of the three drainages.

Total Maximum Daily Loads (TMDLs)

Under section 303(d) of the Clean Water Act, the California Water Code, and related authorities, the RWQCB has adopted TMDLs into the Basin Plan for a number of contaminants for impaired water bodies into which Serrano Creek and Borrego Canyon Wash are tributary, including Lower Newport Bay, Upper Newport Bay, San Diego Creek Reach 1 and San Diego Creek Reach 2. TMDLs adopted by the RWQCB have the force of law. Implementation of the sediment TMDL requires that all dischargers in the watersheds of these impaired waters reduce sediment discharges. Under the TMDL program, the City has significant obligations to reduce excessive sediment discharges from Serrano Creek and Borrego Canyon Wash.

The Recirculated DEIR does not discuss any of the TMDLs, and there is no analysis as to whether the various mitigation measures proposed in the Program are consistent with achieving the TMDLs.

Urban Storm Water Runoff NPDES Permit

Under section 402(p) of the Clean Water Act, the California Water Code, and related authorities, the RWQCB adopted Order No. R8-2002-0010 (NPDES No. CAS618030), Waste Discharge Requirements for the County of Orange, Orange County Flood

Control District and The Incorporated Cities of Orange County Within the Santa Ana Region - Areawide Urban Storm Water Runoff (Orange County), a consolidated a municipal separate storm sewer system (MS4) permit. This MS4 permit expired in 2007 and it has been administratively extended, pending its renewal.

In discussions with City staff on the pending MS4 permit renewal, RWQCB staff has expressed substantial concerns about the effects of urban runoff, municipal storm water flows and other flows covered by the MS4 permit on Serrano Creek and Borrego Canyon Wash.

The Recirculated DEIR fails to discuss the existing MS4 permit, fails to discuss what the likely outcome of the renewed MS4 permit will be with respect to the City's obligations under the MS4 permit, and fails to analyze whether approving the DEIR is consistent with the City's current and likely future MS4 permit obligations.

Conclusion

RWQCB staff believes that a comprehensive plan for the long-term protection and restoration of Serrano Creek and Borrego Canyon Wash (and Aliso Creek) must precede the Program. The Program can provide an opportunity to implement restoration measures identified in such a plan. The City should exercise extreme caution when making major changes in planned land uses within its boundaries, without first developing an understanding of the roles the various parcels might play in contributing to correction of the major water quality problems that are plaguing in the drainages that pass through the City.

The RWQCB looks forward to receiving an extensively revised draft EIR incorporating both these comments and our prior comments, and requests that the revised draft be recirculated for public comment before the City decides whether to certify the EIR for the project. Please contact me at 951-782-3234 or madelson@waterboards.ca.gov , or Glenn S. Robertson of this office, at 951- 782-3259 or grobertson@waterboards.ca.gov with any questions.

Sincerely,

Mark G. Adelson

Mark G. Adelson, Chief
Regional Planning Program Section

cc: State Clearinghouse – Scott Morgan
County of Orange Watersheds Program – Mary Anne Skorpanich

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TECHNICAL MEMORANDUM

Initial Study for DEIR of Serrano Summit – Area Plan 2009-01 & Tentative Tract Map 17331

Response to Initial Study Comments

PREPARED FOR: Carrie Tai, City of Lake Forest

Eddie Torres, RBF Consulting, Inc.

PREPARED BY: Ian Adam, Fuscoe Engineering, Inc.

Trevor Dodson, Fuscoe Engineering, Inc.

CC: Omar Dandashi, Lewis Operating Corporation

DATE: June 29, 2011

PURPOSE

The purpose of this technical memorandum is to provide responses to the comments received on the Notice of Preparation of the DEIR for Serrano Summit – Area Plan 2009-01 and Tentative Tract Map 17331. The response to comments are specific to hydrology, flood control, hydromodification and water quality related issues.

ORANGE COUNTY PUBLIC WORKS COMMENTS DATED JUNE 1, 2011

Flood Programs Comments:

Comment # 1: *"The project proposes 19 Planning Areas that include Medium Density Residential land uses up to 833 dwelling units, public facilities uses and recreational uses for the total area of 98.9 acres……Therefore, hydrologic and hydraulic analyses need to be performed to evaluate and compare quantitatively the runoff volumes, peak flow rate increases, adequacy of existing storm drains and off-site channels that will ultimately carry these discharges. These analyses are needed to ensure that post-project conditions along OC and/or OCFCD drainage facilities, including Serrano Creek (Facility No. F19) are not worsened as a result of the project and they support "less than significant impact" statement of page 117 of the Initial Study."*

Response to Comment #1: Hydrology appendices will be provided as part of the DEIR that include hydrologic and hydraulic comparisons of the existing conditions (pre-project conditions) versus the post-project conditions. The 100-year storm event analysis demonstrates that the peak flow rates will be reduced to under pre-project conditions (200 cfs for pre-project versus 167 cfs for post-project). In addition, the analysis includes quantification of the peak flow rates and volumes associated with the 2-year event as required by the North Orange County MS4 Storm Water Permit. The results indicate peak flow rates will be maintained at existing 2-year pre-project rates and the increase in volume will be retained on-site (approximately 3.1 ac-ft). The retained volume will either be infiltrated or slowly released below critical threshold rates (i.e. 10% of 2-year pre-project flow rate). During the final design, the total volumes retained on-site for the two-year rate and volume control may be adjusted due to more detailed design but rates and volumes above the 2-year pre-project condition will not increase. Similarly, the final post-project 100-year rate may increase or decrease during final design due to more detailed calculations but final post-project peak flow rates for the 100-year storm will be less than pre-project conditions.

Comment # 2: *"Natural reaches with Serrano Creek have proven to be susceptible to erosion……Sediment transport analyses need to be performed by a licensed engineer specialized in the field of sediment transport need to be included as appropriate to support the Draft EIR findings."*

Response to Comment # 2: In 2007, the County of Orange hired Chang Consultants to perform a detailed fluvial study of Serrano Creek stabilization to further understand the existing conditions and identify future improvements to minimize future degradation of the creek bed and creek banks. The study was performed by Dr. Howard Chang of Chang Consultants, a respected expert in the field of fluvial analysis. The study was completed in February 2008 (Fluvial Study of Serrano Creek Stabilization: Trabuco Road to Rancho Parkway (Facility No. F19)) and the study area included the reach of Serrano Creek that the proposed project drains into. The study also included reaches of Serrano Creek both upstream and downstream of the project site.

The 2008 study is considered an extension of two prior studies including Reach 1 (Bake to Trabuco) and Reach 2 (Trabuco to FTC) and analyzes approximately 3 miles of Serrano Creek between Trabuco Road to Rancho Parkway. The Creek was analyzed in consideration of the Serrano Creek Collaborative Use Plan (SCCUP, May 1999). The focus of the study was to address the problem statement identified in the final report – "Because of the reduction in sediment supply from its watershed, the streambed has undergone significant degradation as well as widening to result in the loss of public and private properties. In order to maintain stream channel stability, the degradation and widening problem needs to be checked."

The Fluvial-12 model, a proprietary software model developed by Dr. Chang to analyze streambed and stream bank stability, was utilized for Serrano Creek. Two alternative were analyzed including the "do nothing" alternative and the "moderate improvement" alternative which includes rip rap bank protection and grade control structures. The study divided up the 3-mile reach of Serrano Creek into 6 segments (3B, 3A, 2D, 2C, 2B & 2A with 3B as the upper most segment). Based on the Study's reach designations, the proposed project discharges directly into Segment 2B with segment 2C directly upstream and 2A directly downstream.

Under the "do nothing" alternative, the general trend of channel-bed degradation and bank erosion will continue which in turn increase the total sediment loads passing through Trabuco Road due to the upstream channel erosion. Most of the sediment transport occurs above the 10-year storm event and the results indicate minimal potential for sediment transport and hydromodification for the 2, 5 and 10-year storm events. In addition, results are summarized for each segment.

For Segment 2A (directly downstream of project), channel-bed degradation is limited due to existing grade control structures downstream and channel bank erosion continues to occur at specific areas of the creek. No flooding of the 100-year event occurs and the study recommends rip rap bank protection for those specific areas subject to further bank destabilization.

For Segment 2B (project reach segment), the existing channel is highly incised and further degradation is inhibited by bed rock/hard pan. In addition, bank erosion/lateral migration is also limited based on tall bank height and only significantly large storm events (greater than 10-year) have the potential to cause further bank erosion. No flooding occurs within this segment and the study recommends no further improvements for this segment.

For Segment 2C (directly upstream of project), the channel is deeply incised and continues to degrade. The Autumnwood housing development is vulnerable to bank erosion/lateral migration along the south side. The study recommends six grade control structures to stabilize the streambed and rip rap bank protection along the entire south side of the creek to limit future bank destabilization. No flooding occurs within the existing or proposed condition.

Based on the findings of the 2008 Fluvial Study of Serrano Creek and the runoff controls being proposed by the project, post-project runoff conditions will not worsen as compared to existing conditions and will likely improve. Although the Chang study indicated the potential for further hydromodification is low for smaller more frequent storm events (2 – 10-year storm events), the proposed project will provide for peak flow and volume control for the 2-year storm event as compared to existing conditions which results in approximately 3.1 ac-ft of on-site retention for infiltration or heavily controlled slow release into the channel following peak flow discharges. In addition, the flow rates for the existing 2-year event result in a total discharge of 56 cfs from the project site while the proposed 2-year discharge rate for the project is 98 cfs. The proposed project runoff controls will be designed to limit proposed discharges associated with the 2-year event to 56 cfs from the project site. Implementation of this 56 cfs discharge limit for the 2-year event may result in on-site retention/detention systems in excess of the 3.1 ac-ft volume noted above. In the event the detailed hydrology calculations performed during construction documentation result in different values for the existing and proposed 2-year peak flow and volume conditions, 2-year discharge limits will be based on the revised existing peak discharge and volume values.

Lastly, implementation of the project will result in a maximum 16.5% peak flow reduction of the 100-year discharge rates due to changes in slope, storm drain routing patterns, longer Time of Concentration and on-site detention facilities as compared to existing conditions. Decreases in peak flow discharges for larger storm events will reduce the long-term potential for future streambed degradation and bank erosion/lateral migration.

Comment # 3: *"Should the hydrologic and hydraulic and sediment transport analyses indicate conditions are worsened, appropriate mitigation measures should be proposed in consultation with OC Public Works/Flood Programs."*

Response to Comment #3: Based on the implementation of on-site runoff controls to reduce 2-year volumes and peak flow rates to existing conditions and 100-year peak flow rates to below existing conditions, conditions are not expected to worsen. In addition, see Response to Comment #2.

Comments 4, 5 & 6: *"….conformance with OCHM guidelines and criteria; conformance with FEMA regulations and floodplain requirements through the Floodplain Administrator (City of Lake Forest); OCFCD right-of-way will require encroachment permits though the permit process…."*

Response to Comments 4, 5 & 6: It is the intent of the proposed project to abide by all guidelines, criteria, regulations and permitting requirements as noted in the comments above.

Flood/Santa Ana River/Trails Comments

"Runoff from the project (from the current IRWD site) should be designed to undercross the trail so as not to impact the trail surface."

Response to Comment: All runoff from the site will be collected and discharged to the creek in a manner consistent with the existing trails and to avoid trail surface disruptions to the maximum extent practicable.

OC Environmental Resources/OC Watershed Comments

Comment #1: *"The decision on Page 129 of the Initial Study (IS) not to address hydrology and water quality issues in the EIR is not appropriate. On Page 128, the IS notes that new Outlet B into Serrano Creek would have a peak discharge of 134 cubic feet per second, far more than is presently discharged in that area. The IS concludes that this outlet's "energy dissipaters, baffles and riprap…would…reduce the erosion potential at this specific location". There is no claim that erosion potential would be completely eliminated. This section of Serrano is currently experiencing significant hydromodification, and additional discharges have the potential to further destabilize this channel if* *appropriate mitigation is not provided. Hydromodification management for this project must be addressed by, at the very least, matching the post-project hydrologic condition to the pre-project hydrologic condition at this location."*

Response to Comment #1: The hydrology and water quality technical reports will be included in the DEIR which includes the analyses to support the project's less than significant impact conclusions. Energy dissipation controls for both proposed outlets into Serrano Creek will be designed in accordance with commonly accepted stilling basins (i.e. USBR Type VI Stilling Basin) to minimize localized scour and erosion associated with the discharge point. Any localized erosion potential that may occur will be within the allowable tolerances of the outlet design standard ultimately approved. According to the 2008 Chang study of Serrano Creek, degradation of the channel bed downstream of the project site is limited due to existing grade control structures downstream and is limited within the project vicinity due to the existence of bedrock/hard pan. With respect to the existing banks, further bank destabilization/lateral migration is limited in the vicinity of the project site while banks downstream of the project are likely to experience further degradation in the future. The implementation of the proposed project will result in a lower maximum peak flow rate discharging from the site as compared to existing conditions which will slow degradation process. In accordance with the 4th Term MS4 Storm Water Permit, hydromodification control is being applied to the entire project for the 2-year storm event for both peak flow rate and volume control.

Comment #2: *The Preliminary Water Quality Management Plan addresses Hydrologic Conditions of Concern on pages 13-14 without making mention of the significant hydromodification currently taking place within this section of Serrano Creek.*

Response to Comment # 2: Please refer to Response to Comment # 2 under the Flood Programs section. A statement has been provided indicating the long-term problems associated with Serrano Creek with respect to channel instability, bank destabilization and sediment loading. In addition, the 2008 Chang study notes the channel problems both upstream and downstream of the project site while indicating a relatively stable channel and bank within the location of the project discharge points.

Comment #3: *"If Serrano Creek continues to experience hydromodification of its banks in the direction of Outlet B's energy dissipaters, baffles and riprap, these features in the long term could be undercut…..The EIR needs to address the long-term stability of the outlet and its appurtenances, the potential for hydromodification below the footprint of the outlet and the low-flow channel of Serrano creek, and within Serrano Creek itself at and below that point, all in the context of a currently unstable creek bed."*

Response to Comment # 3: See Response to Comment # 1 under OC Environmental Resources/OC Watershed and Response to Comment # 2 under Flood Programs.

Comment #4: *"The Initial Study on Page 121 briefly notes that the San Diego Creek / Newport Bay Watershed (which includes Serrano Creek) is subject to a regulatory sediment TMDL "to reduce the annual average sediment load…50 percent." To the* *extent peak discharges are closely associated with sediment movement, it is worth nothing this project only reduces peak discharges 16.5%...."*

Response to Comment #4: The development of the proposed project will result in gentler slopes that reduce runoff and erosive velocities, increased hardscape and landscape coverage that limit sediment discharges, runoff control measures to reduce peak flow discharges and water quality BMPs to reduce sediment from discharging from the site. Implementation of the project will not result in an increase of sediment discharges to Serrano Creek. During construction, erosion and sediment controls will be utilized to limit sediment-laden discharges to Serrano Creek. In addition, the 2-year volume and rate control and 100-year peak flow reduction will reduce the potential for downstream streambed and bank destabilization.

Comment #5. "The Initial Study does not address whether the new rip rap apron of the outlet, which is of considerable size, is consistent with the aesthetic enjoyment or expectations of recreation users of the Creek area."

Response to Comment #5: Energy dissipation controls for both proposed outlets into Serrano Creek will be designed in accordance with commonly accepted stilling basins (i.e. USBR Type VI Stilling Basin) to minimize localized scour and erosion associated with the discharge point and to minimize the footprint of the required outlet structures.

SANTA ANA REGIONAL WATER QUALITY CONTROL BOARD COMMENTS DATED JUNE 10, 2011

Comment # 3: TMDLs and Hydraulic Conditions of Concern (HCOCs)

"The Project will include two detention basins to treat site runoff and moderate post-construction runoff flows, although most runoff flow volume will be directed east from the site toward Serrano Creek……The Project's EIR should include an analysis of the potential HCOC arising from the proposed increased in discharge from Outlet B and from discharges of any sheet flow runoff and if necessary, and thoroughly discuss how any HCOC will be addressed.

Response to Comment #3: The potential for localized sediment and scour arising from Outlet B will be addressed by meeting the commonly accepted outlet standards for energy dissipation (i.e. USBR Type VI Stilling Basin as modified by OCPW, Fig 5-41, Local Drainage Manual, OCPW). Regional HCOC concerns have been addressed by the 2008 Fluvial Study of Serrano Creek as noted in earlier responses and the runoff controls being implemented on-site to reduce 2-year and 100-year discharges. Refer to the project WQMP for additional details on runoff control measures.

If you have any questions regarding these technical responses, please contact me at 949-474-1960.

Regards,

Ian Adam
Senior Environmental Resources Manager
Fuscoe Engineering, Inc.

FLUVIAL STUDY OF SERRANO CREEK CHANNEL STABILIZATION

FACILITY NO. F19

FROM

TRABUCO ROAD

TO

RANCHO PARKWAY

FEBRUARY 2008

RESOURCES & DEVELOPMENT MANAGEMENT DEPARTMENT
COUNTY OF ORANGE
SANTA ANA, CALIFORNIA
BRYAN SPEEGLE, DIRECTOR

Bryan Speegle, Director
300 N. Flower Street
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COUNTY OF ORANGE

RESOURCES & DEVELOPMENT MANAGEMENT DEPARTMENT

February 5, 2008

Mr. Robert Woodings
City Engineer
City of Lake Forest
25550 Commercentre Drive, Suite 100
Lake Forest, CA 92630

Mr. Billy Stewart
Senior Engineer
Irvine Ranch Water District
15600 Sand Canyon Avenue
Irvine, CA 92618

SUBJECT: Update on the Serrano Creek Restoration Memorandum of Understanding

Dear Mr. Woodings and Mr. Stewart,

Following is an update on the status of open items in the Memorandum of Understanding (MOU) for the Serrano Creek Restoration dated April 24, 2007. This letter summarizes the activities that have occurred over the past month as well as those that are planned for the next two months. Please refer to the previous updates for a summary of completed action items and terms as described in the MOU.

A meeting between the MOU parties was held on January 22, 2008. Representatives for the City of Lake Forest, IRWD, County-Orange County Flood Control District (OCFCD), and OC Parks participated. The recommendations in the fluvial study were reviewed. Consensus was reached on the following prioritization for the restoration of Serrano Creek:

City Priorities	County-OCFCD Priorities	IRWD Priorities
1. Autumnwood HOA 2. Citrus Lane HOA 3. Dimension Business Park, floodwall and channel downstream of Dimension 4. Nursery access road culvert 5. Channel upstream of the nursery access road 6. Remainder of channel locations identified for improvements on property owned by the City and OC Parks 7. Southern California Edison property at Trabuco Road	1. County-owned properties 2. Autumnwood HOA	1. District-owned property 2. Autumnwood HOA

It was also agreed that one goal of the restoration project is to build improvements in accordance with OCFCD standards. There is no interest on the part of County-OCFCD to purchase or condemn right-of-way for this project. However, OCFCD would be willing to assume ownership and maintenance responsibility for facilities designed and built to District standards where the current owners are willing to relinquish title. These standards will be addressed in preliminary and final engineering.

For the Prop 50 grant application, a preliminary cost estimate of $12.2 million has been developed for the restoration of Serrano Creek from the Citrus HOA through Autumnwood. In order to begin the necessary preliminary engineering work, funding from grants and/or local partners must be secured.

A number of the terms included in the MOU also require further discussion on cost sharing and will be completed based on the outcome of grant awards and subsequent discussions between the MOU parties and other property owners, such as OC Parks and private property owners.

MOU Section 1: Action Plan	
Action Item	**Status**
a-d) All action items completed per 09/27/2007 letter	Complete

MOU Section 2: Terms of Agreement	
Term	**Status**
c) All products (as defined in MOU) must be approved by MOU parties prior to final acceptance: iv. Identification of future tasks necessary for restoration	Initial identification completed; final list to be prepared in February 2008
d) Develop a restoration plan that provides natural attributes of a restored stream channel while minimizing further erosion of the slopes	To be prepared as part of the preliminary engineering studies and cost-sharing discussions
e) Discuss development of a strategy that identifies sources of financial support to implement the restoration plan	Included in discussion at 01/22/2008 meeting. Discussion is ongoing.
f) Discuss long-term public ownership strategies of Serrano Creek	Goal is to restore Serrano Creek such that it meets OCFCD standards. Discussion is ongoing.
g) Report progress to the Sediment TMDL cost-share partners and the Newport Bay Watershed Executive Committee	Update provided at 11/07/2007 NB Watershed Executive Committee Meeting; update planned for 02/20/2008 Executive Committee Meeting
h) Report progress on a regular basis (at least once a quarter) with stakeholders through the Newport Bay Watershed Management Committee or similar process	Update provided at the NB Stakeholders meeting on 01/16/2008; update planned for stakeholder meeting on 03/19/2008
i) Continually seek private, local, state and federal funding sources	See Funding Source summary below

Funding Source Summary

The County continues to seek funding for the Serrano Creek restoration project and is pursuing the following grant opportunities:

Date	Funding Agency	Amount Requested	Estimated Timeframe
06/15/2007	Southern California Wetlands Recovery Project	$1 million for design, CEQA, permits; $500,000 match	Project approved as Tier 1 project in WRP 2008-2009 Work Plan; County to submit additional project info in 02/2008
08/01/2007	DWR/SWRCB: Prop 50 IRWMP Funding	$2.75 million for implementation ($12.2 million estimated total project cost); submitted as priority project in Central Orange County IRCWM Plan	Round 2/Step 2 application submitted 01/28/2008;awards announced in June 2008
	DWR: IRWM Plan Funding – Prop 84	Phase II IRWM Plan is in preparation; program requirements and evaluation criteria have not been released	Implementation grant funding may be available in FY 2008-2009
	DWR: Urban Streams Restoration Program – Prop 84	Program requirements and evaluation criteria have not been released	Spring 2008

It should be noted that funding schedules originally proposed by the State for various funding programs are subject to change due to the State's fiscal condition. We continue to closely monitor funding programs that may be a resource for Serrano Creek.

Status of Fluvial Study
On January 28, 2008 the City provided a draft preface to the fluvial study noting the City's concerns so that they may be addressed appropriately in the implementation phase. The County is working with Chang Consultants to finalize the report based on the last round of comments and the City's preface. Once finalized, the report will be distributed to the MOU parties.

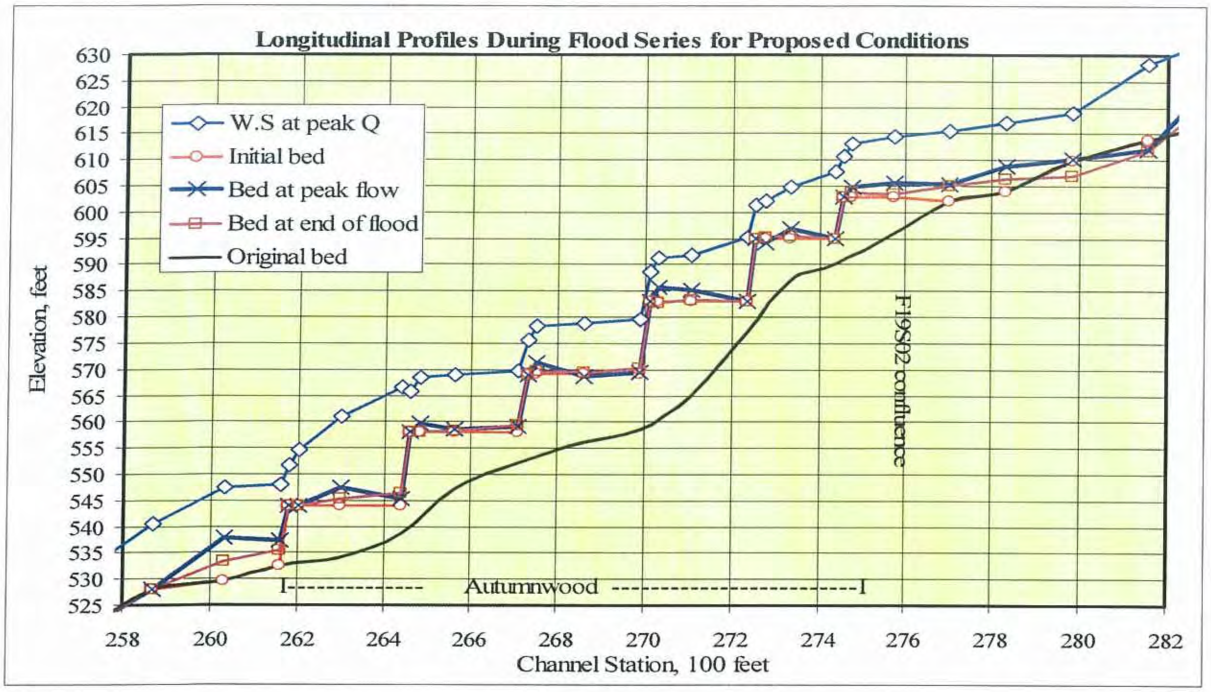
We will continue to provide you with a monthly update on the progress and future funding opportunities that may be suitable for this project. We look forward to continued collaboration with the City of Lake Forest and the Irvine Ranch Water District in achieving milestones that will result in a sustainable restoration for Serrano Creek.

Sincerely,

Mary Anne Skorpanich, Director
Watershed and Coastal Resources

Cc Robert C. Dunek, City Manager, City of Lake Forest
Paul Jones, II, General Manager, IRWD
Bryan Speegle, RDMD
Nadeem Majaj, RDMD

Fluvial Study of Serrano Creek Channel Stabilization Trabuco Road to Rancho Parkway (Facility No. F19)



Prepared for
Public Works/Flood Control Division
County of Orange

Prepared by
Howard H. Chang
February 2008

CHANG Consultants

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EXECUTIVE SUMMARY

Serrano Creek in the City of Lake Forest has undergone substantial changes in recent years. Such changes are related to major storms as well as human activities. Because of reduction in sediment supply from its watershed, the streambed has undergone significant degradation as well as widening to result in the loss of public and private properties. In order to maintain stream channel stability, the degradation and widening problem needs to be checked. The City of Lake Forest developed the Serrano Creek Collaborative Use Plan (SCCUP) between 1996 and 1998 and the City adopted the SCCUP on May 18, 1999. This report addresses the balance between flood control improvements and the community's desires for recreational usage and to keep the area as natural as possible. The SCCUP identified the two following channel reaches: Reach 2 from Trabuco Road to Dimension Drive and Reach 3 from Dimension to Rancho Parkway. A previous Chang study covered Reach 1while this study covers Reaches 2 and 3 for Serrano Creek. Reach 4 has already been improved; it is only included in this study as it provides sediment inflow for the downstream reaches. For this study, Chang Consultants applied the FLUVIAL-12 model to evaluate stream stabilization alternatives for the subject channel reaches in consideration of recommendations from SCCUP and from the previous study by Chang Consultants.

Along the theme of the SCCUP adopted by the City of Lake Forest, two alternatives for channel improvements were studied: the do-nothing alternative and a moderate improvement alternative consisting of bank protection and grade control structures. Under the Do-Nothing alternative, or the existing conditions, certain insurable properties located near the concave channel banks are found to be vulnerable to potential damages due to bank erosion and lateral migration of the channel. The study identifies these areas and also identifies channel reaches that do not have the capacity for the BASE FLOOD (100-yr flood). One such channel reach is located at a short distance downstream of Dimension Drive; properties located along this reach are subject to flooding-related damages. In addition, the channel reach along the nursery (within Reach 3) does not have the capacity for the BASE FLOOD. Improvements and stabilization measures for these creek reaches are provided in the report under the moderate improvement alternative.

The channel reach along the Autumnwood development has the steepest channel slope and high flow velocities. The creek is now incised in a deep canyon with steep canyon walls, presenting a safety hazard for the adjacent Autumnwood housing development. Potential creek bank erosion poses a threat to the properties.

The alternative for moderate improvements is for the primary purpose of protecting existing insurable properties that are vulnerable to flood related damages. Priorities for improvements are determined in consideration of the degree of vulnerability. The recommended improvements consist of a series of six grade control structures along the Autumnwood reach to raise and stabilize the channel bed and to protect the channel bank along the development. Other areas with insurable properties vulnerable to flood damages are identified. Bank protections are recommended for such areas. Hydraulic parameters for the design of grade control structures and bank protection are provided. It is the intention to avoid unnecessary grade control structures in order to maintain channel improvements at a moderate level as preferred by the public.

It should be noted however that the creek improvements recommended above have little or no maintenance or construction access to construct or maintain such improvements. Investigation of construction and maintenance access was outside the scope of this study, but such an investigation should be discussed/investigated prior to or in conjunction with detailed design of the above recommended improvements.

Grade control structure: A rigid structure constructed across a river channel used to stabilize the bed elevation at the location. A drop structure is also a grade control structure.

Head cutting: Channel-bed erosion occurring upstream of a sand or gravel pit or any other depression.

Model: For this study, a model is a computer software developed to simulate the hydraulics of flow, sediment transport and river channel changes.

Pit capture: A stream is diverted from its normal course into a pit of lower elevation

Power expenditure: The rate of energy dissipation of stream flow

Scour (general and local): Erosion or removal of material caused by stream action. General scour is caused by the imbalance (non-uniformity) in sediment transport along a river channel. Local scour is caused by any local obstruction to flow, such as bridge piers, abutments, tree trunks, etc.

Sediment delivery: The cumulative amount of sediment that is delivered passing a river section in a specified period of time.

Sediment transport/replenishment: Sediment transport is the movement of sediment by flow measured usually in volume or weight per unit time. Replenishment is sediment supply to make up any previous deficit.

Study channel reach: A river channel reach that is covered in a study. Such a reach is defined by a series of cross sections taken along the channel.

Suspended load: Sediment load that travels in suspension, consisting of the finer portion of the transported sediment.

Tractive force: The force exerted by the flow on the channel boundary or on any object in the river channel, usually measured in force per unit surface area.

Fluvial Study of Serrano Creek Channel Stabilization
Trabuco Road to Rancho Parkway (Facility No. F19)

I. INTRODUCTION

This report was prepared for the Resources and Development Management Department (RDMD), County of Orange (County), for channel stabilization of Serrano Creek. Fig. 1 is a location map for Serrano Creek. As a tributary of San Diego Creek, Serrano Creek drains an area of about 2,590 acres at Trabuco Road within the City of Lake Forest. This study of Serrano Creek covers Reaches 2, 3 and 4 from Trabuco Road (Station 213+50) to Portola Parkway (Station 370+85). The limits of these reaches are given below:

Reach 2 – Trabuco Road (Station 213+50) to Dimension Drive (Station 292+00)

Reach 3 – Dimension Drive (Station 292+00) to Rancho Parkway/Lake Forest Drive (Station 336+00)

Reach 4 – Rancho Parkway/Lake Forest Drive (Station 336+00) to Portola Parkway (Station 370+85).

For identification purpose, RDMD has designated Serrano Creek as Facility No. 19. Such channel designations do not denote County of Orange (County) or Orange County Flood Control District (OCFCD) ownership, maintenance responsibility, or regional significance, but are provided for watershed and facility identification. This study is an extension of the following previous studies by Chang Consultants:

(1) "Fluvial Study for Serrano Creek Stabilization (Facility No. F19)" for Reach 1 from Bake Parkway to Trabuco Road, and

(2) "Fluvial Study for Serrano Creek Trabuco Road to Foothill Transportation Corridor Existing Conditions".

Serrano Creek in the City of Lake Forest has undergone substantial changes in recent years. Such changes are related to major storms as well as human activities. Because of reduction in sediment supply from its watershed, the stream bed has undergone significant degradation as well as widening to result in the loss of public and private properties. In order to maintain stream channel stability, the degradation and widening problem needs to be checked. Per this scope of work, Chang Consultants applies the FLUVIAL-12 model to evaluate stream stabilization alternatives for the subject channel reach in consideration of recommendations from previous studies by Chang Consultants and the City of Lake Forest study entitled, "Serrano Creek Collaborative Use Plan," hereinafter referred to as "SCCUP."

In order to implement Serrano Creek restoration and mitigate further channel instability, a comprehensive fluvial study is required to evaluate existing conditions and propose creek stabilization alternatives to be followed by design and implementation phases. This study will utilize the information for the channel reaches under existing conditions as a basis to develop and recommend controlling and mitigation measures for stream channel stabilization of Serrano Creek, Reaches 2 and 3. Reach 4 has already been improved; it is only included in this study as it provides sediment inflow for the downstream reaches.

Channel geometry in the study is defined by a series of cross sections. These cross sections are viewed toward downstream. The right bank is the southeast bank; the left bank is the northwest bank.

The accuracy of this study is limited by the available data furnished by the County as follows:

(1) Topographic survey data obtained in 1998,
(2) Currently non-approved Orange County hydrologic data for Serrano Creek
(3) No geotechnical or slope stability reports, studies, or data,
(4) Minimal right of way and utility data, and
(5) No project reports, design memoranda, or other related studies containing engineering data or information pertinent to Serrano Creek within the study reach.

Because of continued channel bed degradation, many reaches of Serrano Creek have now become incised to the extent that overbank flooding is no longer a concern. However, the channel reach near Dimension Drive and the upstream nursery land does not have sufficient capacity for the BASE FLOOD and the floodplain extends outside the main channel as shown in the effective Flood Insurance Rate Map (FIRM) by the Federal Emergency Management Agency (FEMA). This part of the FIRM map is included in Appendix C of the report. Channel improvements for flood control are also developed for this reach together with channel stabilization.

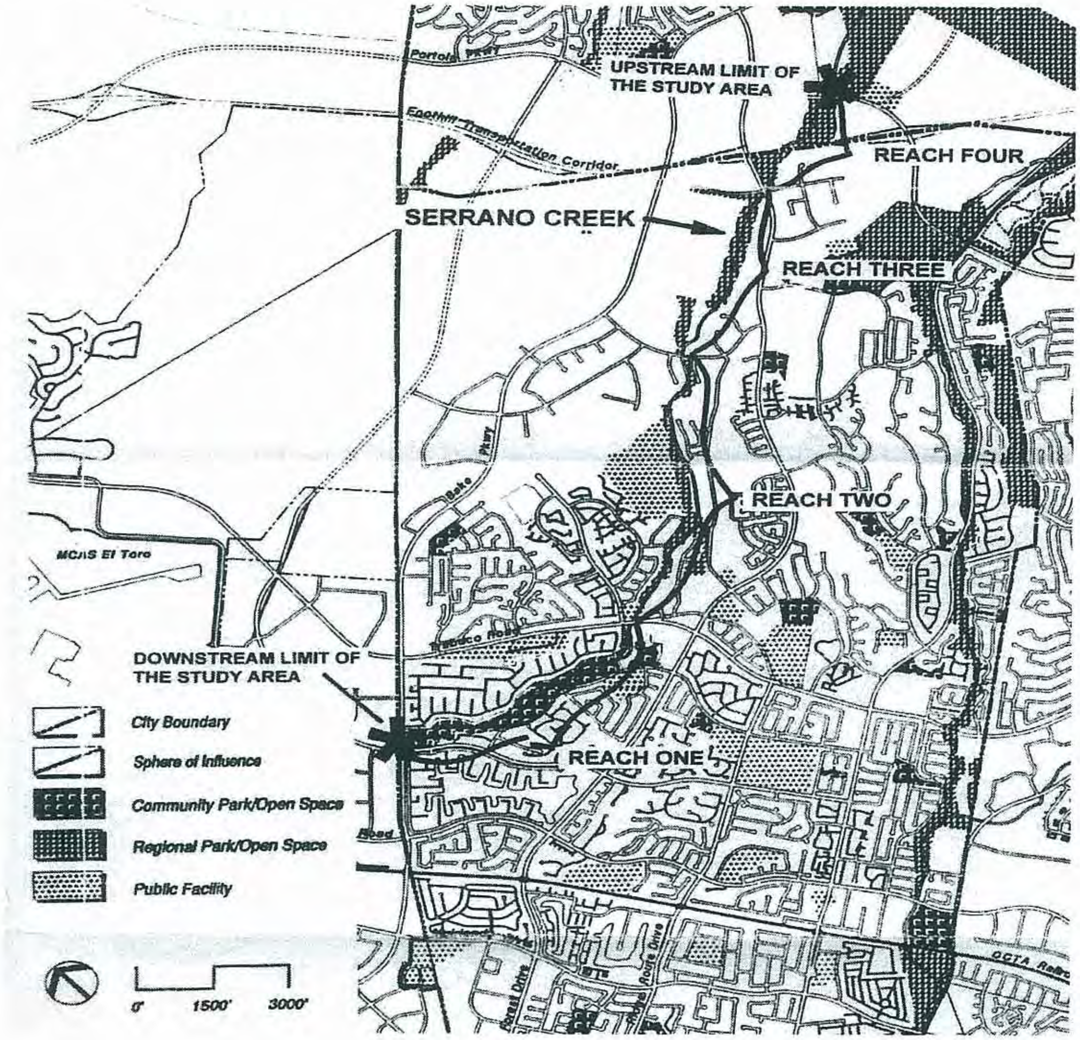


Fig. 1. Location map for Serrano Creek

II. REQUIREMENTS FOR CHANNEL STABILIZATION ALTERNATIVES

Potential stream channel changes need to be assessed not only for short-term changes but also for long-term changes. For this reason, it is necessary to model stream channel changes based on two different flood conditions. For short-term changes, the 100-yr flood event is used as the basis of evaluation. The 100-yr flood is also referred as the BASE FLOOD by FEMA. For long-term changes, a representative flood series for a time span of 100-years is used. In the time span of 100 years, one may expect, statistically, one flood exceeding the 100-year flood, two floods exceeding the 50-year flood, four floods exceeding the 25-year flood, and 10 floods exceeding the 10-yr flood, etc.

A plan for Serrano Creek stabilization and subsequent restoration is subject to local, state, and federal regulations. Chang Consultants considered the following requirements:

- The established BASE FLOOD (100-yr flood) Elevations per Flood Insurance Rate Maps (FIRMs) should not be adversely impacted.
- Peak discharges and hydrologic data provided by RDMD were employed. The discharge ratio of other floods to the 100-year flood was based on relations provided in the Flood Insurance Study by FEMA.
- A comprehensive proposed stabilization plan was provided for the recommended alternatives, and included a phasing plan for the recommended improvements.
- The invert and slope stabilization provided adequate protection for properties along Serrano Creek.
- Alternative methods and locations for grade stabilizers/drop structures and bank protection were developed for Serrano Creek. The recommendations on grade stabilizers/drop structures made by the SCCUP were considered as an initial alternative/condition for project development and evaluated, relocated, and/or modified as required. Grade stabilizer/drop structure recommendations including the crest elevation, length of crest, toe entrenchment, etc., were provided by the consultant in this study.
- Bank protection recommendations included the location, top of bank elevation, toe entrenchment, etc.

- DISTRICT design criteria and flood control standards were applied, as appropriate for a planning (not design) level document, to all improvements, i.e. – freeboard, Manning's roughness coefficients, etc.

III. HYDRAULIC AND SEDIMENT DATA FOR SERRANO CREEK

The County provided the basic data for the stream channel, including a topographic map (see Fig. 2), the 100-year discharges, the available reports and studies related to the project. The digitized cross sectional data were generated using the topographic map. The study reach of Serrano Creek is from Trabuco Road to the Portola Parkway for a total length of about 2.98 miles. Locations of cross sections used in the study are shown in Fig. 2. Points of interest and their respective channel stations are listed in Table 1:

Table 1: Selected cross section numbers

Channel station, feet	Location
213+50	Trabuco Road, Downstream limit of study reach
275+70	Tributary F19S02 confluence
291+15 to 292+20	Dimension Drive
308+00	Access road for nursery
334+60 to 339+75	Culvert for Lake Forest Dr.
344+20 to 352+50	Concrete channel and culvert for Foothill Transportation Corridor
367+30 to 368+55	Portola Parkway
370+85	Upstream limit of study reach

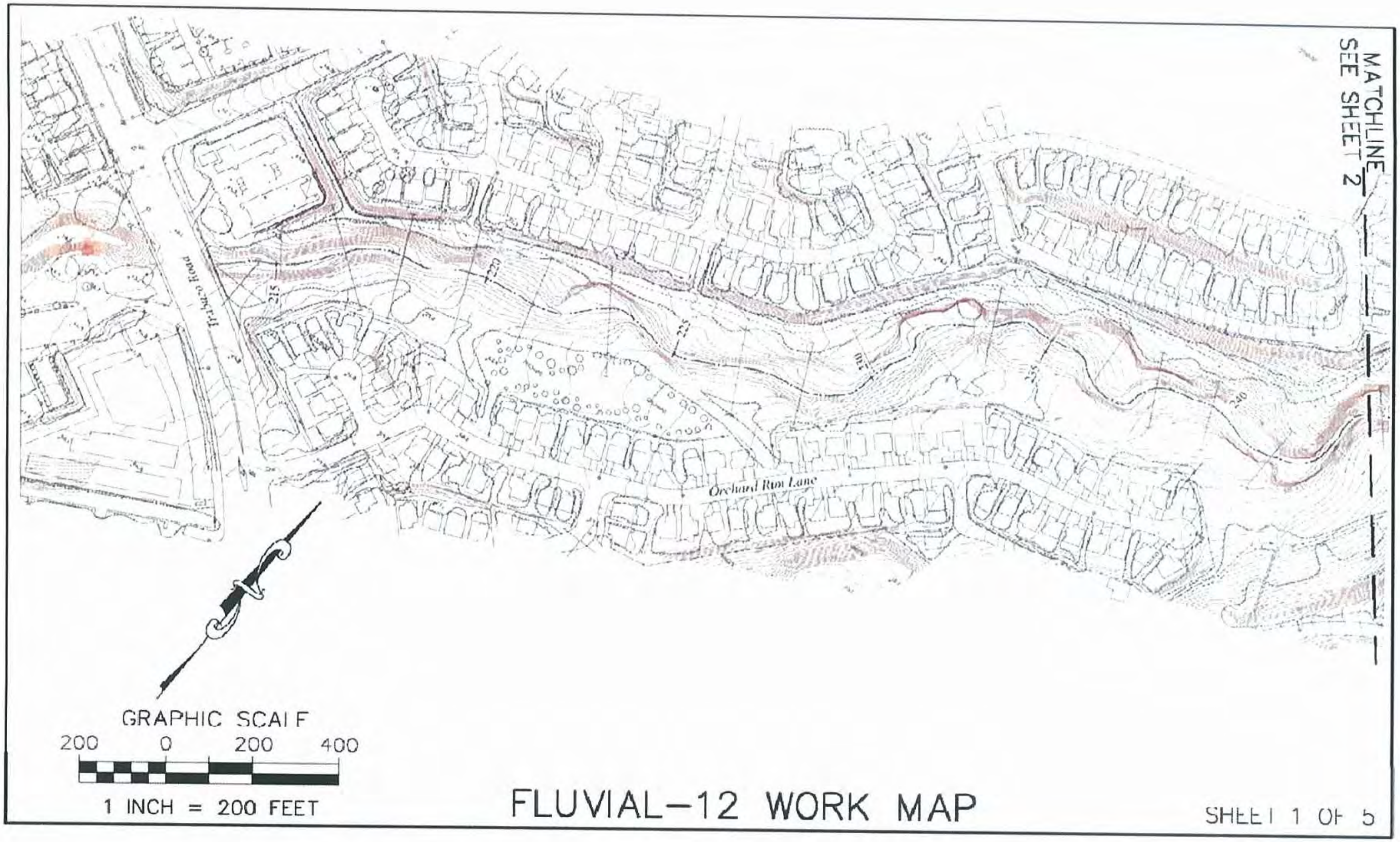


Fig. 2. Topographic map of Serrano Creek with channel stationing

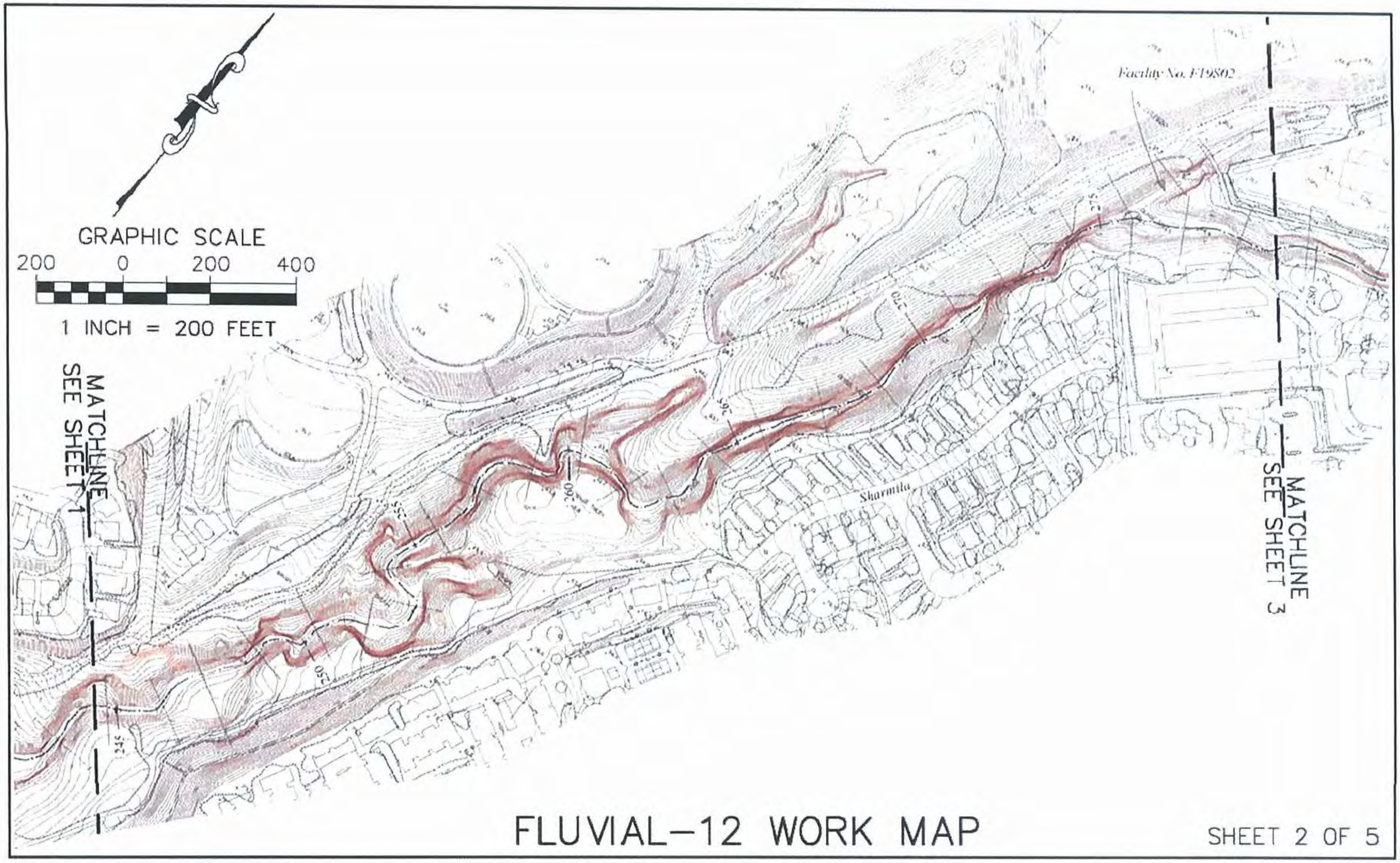


Fig. 2 (continued). Topographic map of Serrano Creek with channel stationing

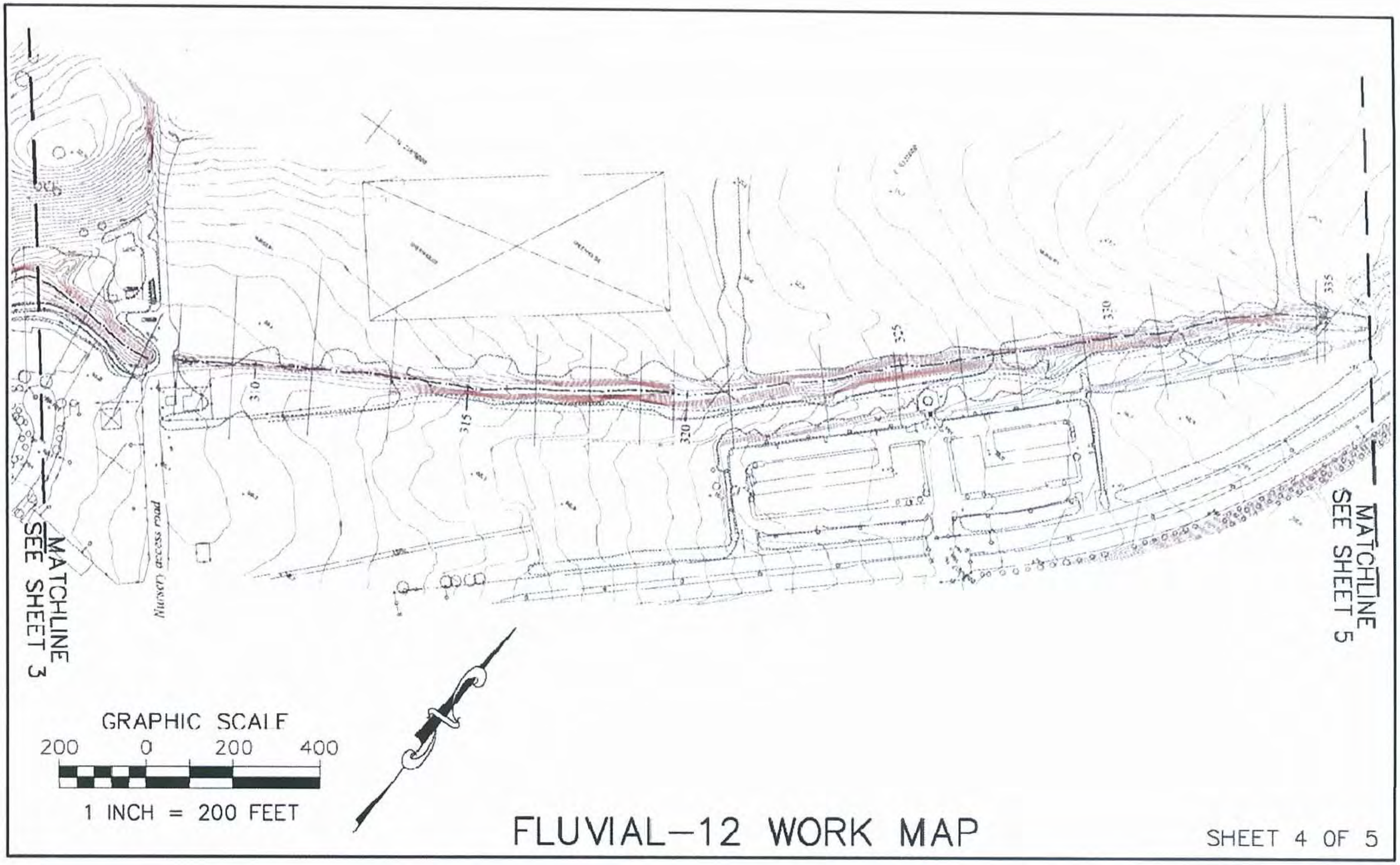


Fig. 2 (continued). Topographic map of Serrano Creek with channel stationing

The 100-yr Flood and the Flood Series - In this study, the 100-yr flood was used together with a flood series representative of the long-term flood flow. Peak discharges for the 100-yr flood provided by the County are as follows:

Upstream of Trabuco Road: 3,450 cfs.

Downstream of tributary F19S02 confluence: 3,150 cfs

Dimension Drive: 2,450 cfs

Foothill Transportation Corridor: 2,250 cfs.

A hydrograph for the 100-yr flood is shown in Fig. 3. For a channel reach, the discharge is based on the value at the downstream point as a conservative measure in the analysis.

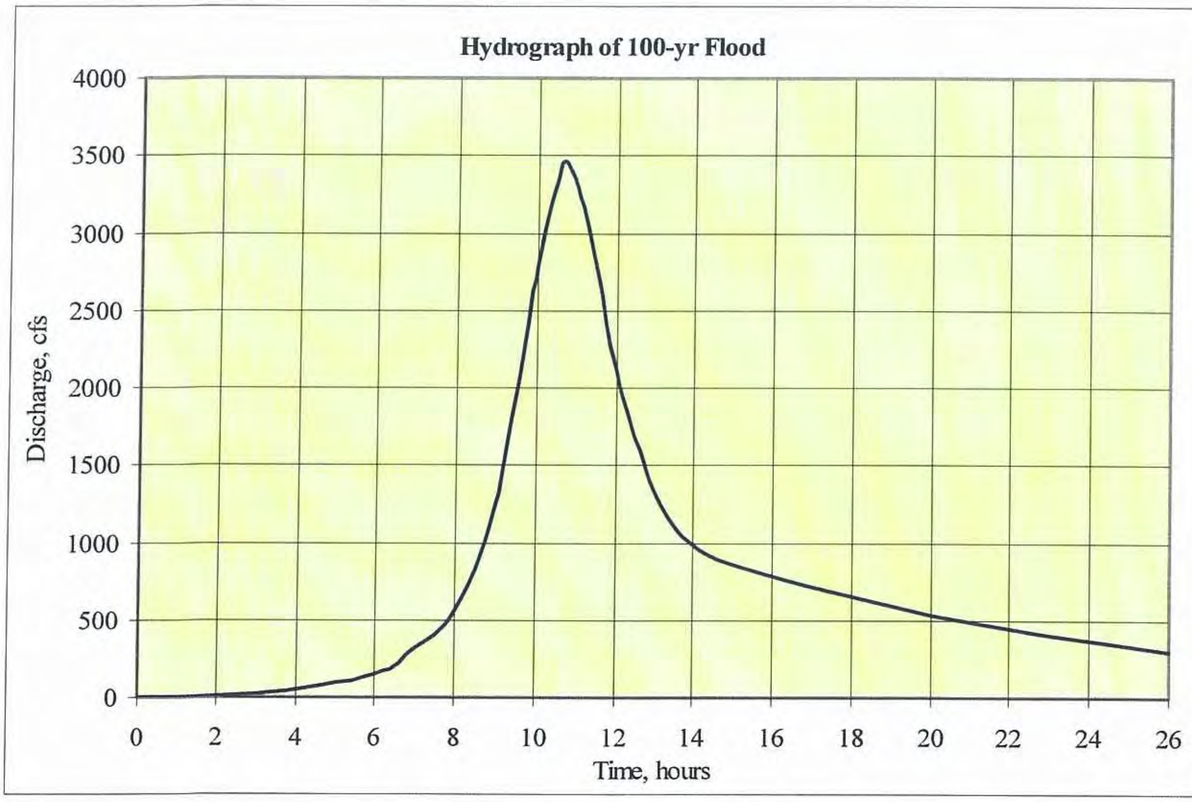


Fig. 3. Hydrograph of 100-yr flood

The 10-yr and 25-yr flood discharges were estimated based on ratios of such discharges in relation to the 100-yr discharge given in the Flood Insurance Study (Federal Insurance Administration, 1979). In the future, one should expect various flood events. In the time span of 100 years, one may expect statistically one flood event exceeding the 100-year flood, two events exceeding the 50-year flood, four events exceeding the 25-year flood, ten events exceeding the

10-yr flood, etc. For this stream reach, most of the sediment transport occurs during major floods. Those events less than the 10-yr flood have limited discharge and hence transport capacity; therefore, only those events equal to or greater than the 10-yr flood were included in the flood series for simulation. The series of flood events occur randomly. The sequence of occurrence of these floods is beyond human prediction, but the particular order of flood events does not affect the results pertaining to the long-term sediment delivery. It was assumed in this study that the occurrence follows the following order: 10-yr flood, 30-yr flood, 20-yr flood, 40-yr flood, 15-yr flood, 100-yr flood, 20-yr flood, 15-yr flood, 70-yr flood, and 10-yr flood. This sequence of flood events as shown in Fig. 4 is employed to represent the long-term flood flow.

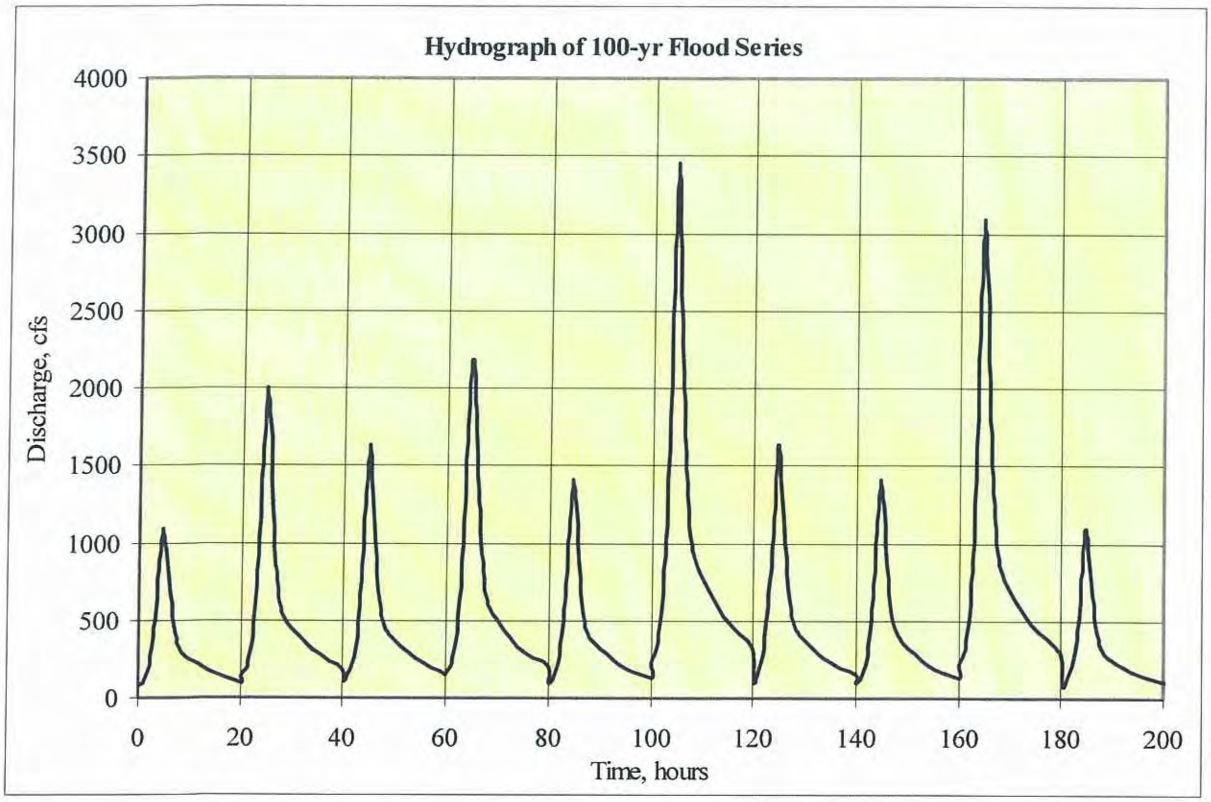


Fig. 4. Hydrograph of the 100-yr flood series

The general trend of channel change for Serrano Creek is characterized by bank erosion and channel-bed degradation. Such changes occur continuously from event to event. For this reason, long-term changes produced by the flood series should be more pronounced than short-term changes produced by a single 100-yr flood. The design for channel stabilization should be based on the results produced by the long-term flood series.

Grade Control Structures and Rock Outcroppings – The existing longitudinal channel bed profile is shown in Fig. 5 together with existing grade control structures and bedrock outcroppings in the channel. The channel bed has a steep slope, especially along the Autumnwood reach. The grade control structures also include box culverts and concrete channels at road crossings. Such features were identified based on the plans, survey information and field inspection. Plans for certain grade control structures are not available. Crest elevations of these structures are based on the topographic map. It was not possible to determine if the structures would withstand the 100-yr flood. However, it was assumed that these structures would not fail during the 100-yr flood or the flood series. Locations of these features are specified in the input/output file for FLUVIAL-12 using the XF records. For a non-erodible feature, field 6 of the XF record has the number of 1.

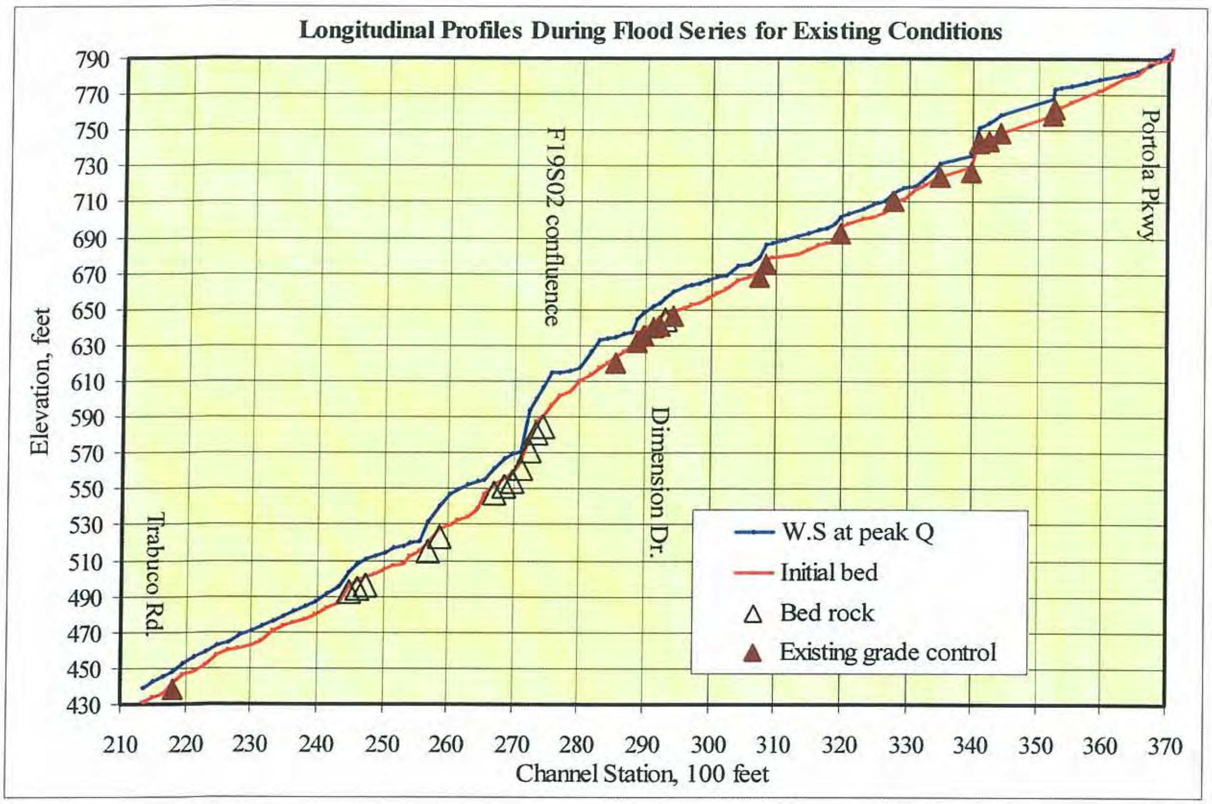


Fig. 5. Longitudinal profiles of Serrano Creek with locations of grade control structures and bed rock outcroppings

Grain Size Distributions of Sediment Samples - Michael Becker of Serrano Creek Conservancy collected sediment samples from Serrano Creek channel bed. He also made sieve analyses for the sediment samples to determine the size distributions. The grain size distributions of the samples are shown in Fig. 6 together with their respective locations.

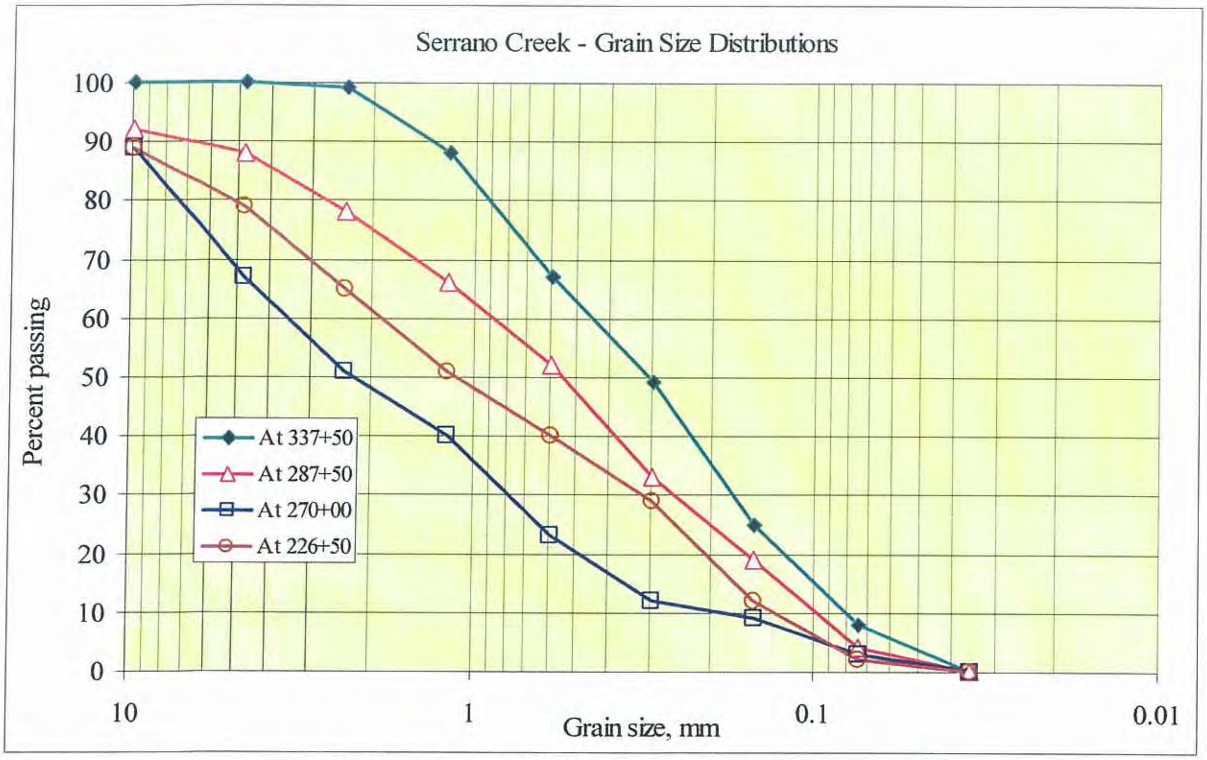


Fig. 6. Grain size distributions of sediment samples

IV. SEDIMENT TRANSPORT MODELING USING FLUVIAL-12

Stream channel scour consists of general scour and local scour. General scour is related to the sediment supplied to and transported out of a channel reach. Local scour, if any, is due to local obstruction to flow by a bridge pier/bent or abutment. To determine general scour, it is necessary to consider the sediment supply by flow to the channel reach and sediment removal out of the reach. Sediment delivery in a stream channel is related to the flood hydrograph, channel geometry, sediment characteristics, etc. Channel projects alter the channel-bed configuration and therefore affect sediment delivery and erosion pattern. To account for these factors, it requires mathematical simulation of the hydraulics of stream flow, sediment transport and stream channel changes.

Mathematical Model for General Scour - The FLUVIAL-12 model (Chang, 1988) was employed for this project. For a given flood hydrograph, the model simulates spatial and temporal variations in water-surface elevation, sediment transport and stream channel changes. Scour and fill of the stream bed are coupled with width variation in the prediction of stream channel changes. Computations are based on finite difference approximations to energy and mass conservation that are representative of open channel flow. Sediment transport for Serrano Creek was computed in the model using the Engelund-Hansen formula (see Chang, 1988) for sediment.

The model simulates the inter-related changes in channel-bed profile and channel width, based upon a stream's tendency to seek uniformities in sediment discharge and power expenditure. At each time step, scour and fill of the channel bed are computed based on the spatial variation in sediment discharge along the channel. Channel-bed corrections for scour and fill will reduce the non-uniformity in sediment discharge. Width changes are also made at each time step, resulting in a movement toward uniformity in power expenditure along the channel. Because the energy gradient is a measure of the power expenditure, uniformity in power expenditure also means a uniform energy gradient or linear water surface profile. A stream channel may not have a uniform power expenditure or linear water-surface profile, but it is constantly adjusting itself toward that direction. The model has been calibrated using field data of the San Diego River (Chang, 1982), the San Dieguito River (Chang, 1984), the San Lorenzo River (Chang, 1985), the San Luis Rey River (Chang, 1990), and the San Dieguito River (Chang, 1994).

Upstream Boundary Conditions for Sediment Inflow - The rate of sediment inflow into the study reach is provided by the upstream boundary condition for sediment. If this rate is known, it may be included as a part of the input and used in the simulation. Unfortunately, sediment rating data are rarely very reliable or simply not available. For this study, it was assumed that the stream channel remains unchanged above the study reach, and sediment inflow rate was computed at the upstream section at each time step, the same way they were computed at other cross sections.

V. MODELING RESULTS ON SEDIMENT DELIVERY

Sediment delivery is defined as the cumulative amount of sediment that has been delivered passing a certain channel section for a specified period of time, that is,

$$Y = \int_{T} Q_s \, dot \tag{1}$$

Where Y is sediment delivery (yield); Q_s is sediment discharge; t is time; and T is the duration. The sediment discharge Q_s pertains only to bed-material load of sand, gravel and cobble. Fine sediment of clay and silt constituting the wash load may not be computed by a sediment transport formula. Sediment delivery is widely employed by hydrologists for watershed management; it is used herein to keep track of sediment supply and removal along the channel reach.

Spatial variations in sediment delivery are manifested as channel storage or depletion of sediment associated stream channel changes since the sediment supply from upstream may be different from the removal. The spatial variation of sediment delivery depicts the erosion and deposition along a stream reach. A decreasing delivery in the downstream direction, i.e. negative gradient for the delivery-distance curve, signifies that sediment load is partially stored in the channel to result in a net deposition. On the other hand, an increasing delivery in the downstream direction (positive gradient for the delivery-distance curve) indicates sediment removal from the channel boundary or net scour. A uniform sediment delivery along the channel (horizontal curve) indicates sediment balance, i.e., zero storage or depletion. Channel reaches with net sediment storage or depletion may be designated on the basis of the gradient. From the engineering viewpoint, it is best to achieve a uniform delivery, the non-silt and non-scour condition, for dynamic equilibrium.

Figure 7 shows the simulated spatial variations in sediment delivery during the flood series for exiting conditions. The sediment delivery has a clear increasing trend toward downstream. The total delivery passing Trabuco Road far exceeds the total inflow to the channel reach at Portola Parkway. Such a large increase in sediment delivery indicates erosion of the channel boundary.

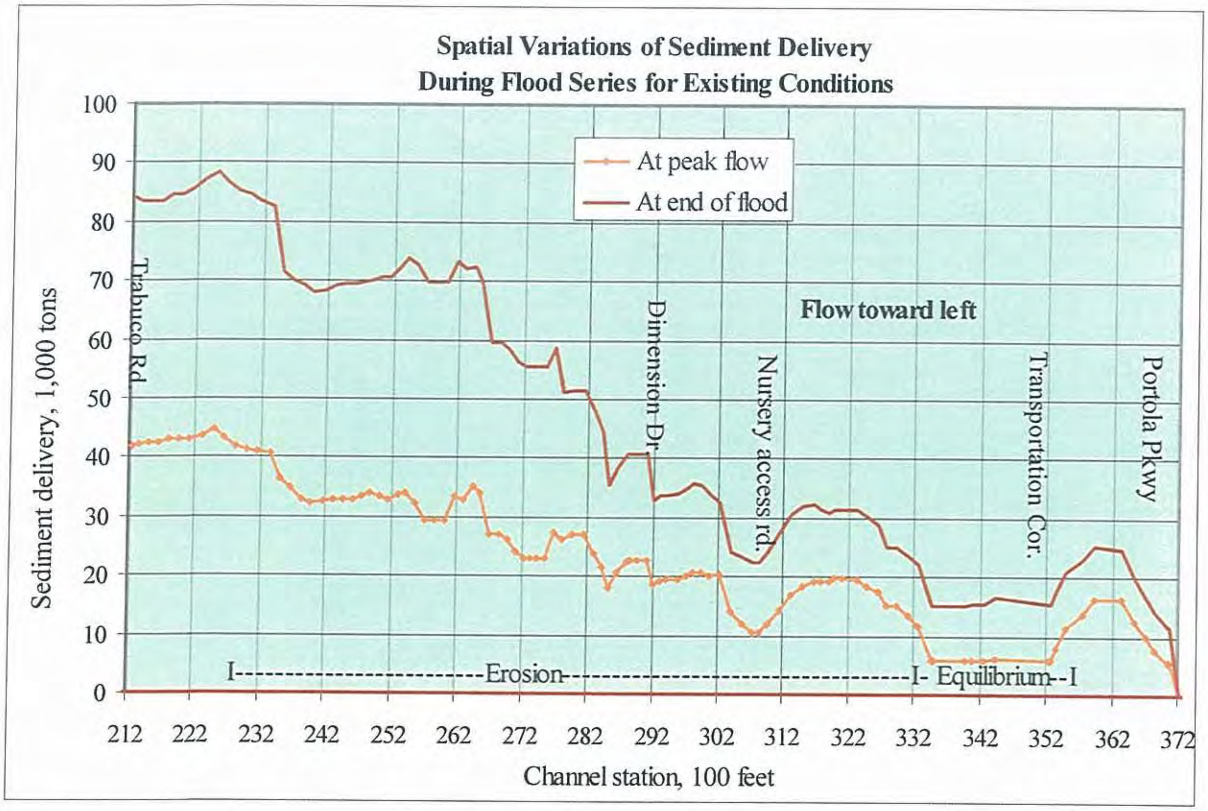


Fig. 7. Spatial variations of sediment delivery during flood series for existing conditions

VI. EXISTING CONDITIONS OF CHANNEL AND SIMULATED CHANGES

Existing conditions of the stream channel are described from reach to reach. Stream channel changes during the 100-yr flood and the flood series were simulated. Since the changes during the flood series are greater in magnitude, they are used to assess the potential channel changes to be used as the basis for developing alternatives for channel stabilization. Simulated results are described below from reach to reach.

Channel Reach from Trabuco Road to Station 244+00 - The first channel reach is from Trabuco Road at station 213+50 to station 244+00. The channel along this reach has a sand bed as shown in Fig. 8 and it is now incised resulting from previous channel-bed degradation. The present channel is now in a deep canyon with the canyon depth increasing toward upstream. Most of the channel bed is not visible because of dense vegetation growth in the valley.

Fig. 8. Channel with sand bed near Trabuco Road crossing

The channel bed under the Trabuco Road Bridge is protected with grouted riprap. There is also a riprap grade control structure at station 218+00. Such grade controls structures were constructed as counter measures to check degradation development. The south channel bank near the grade control structure has scattered riprap bank protection.

Simulated results for the existing conditions are shown in Figs. 9, 10 and 11. Fig. 9 shows the longitudinal water-surface and channel bed profiles during the flood series. Because of the existing grade control structures, future channel-bed degradation will be limited in magnitude. However, the degradation is also accompanied by erosion of the channel banks. The topographic map shows erosion of the north channel bank near station 233+00 that occurred in recent floods. This bank has since been restored. Potential cross-sectional changes are illustrated in Fig. 10 by the simulated changes at station 230+10. This figure includes the cross-sectional profiles before the flood (initial), at the peak flow, and at the end of the event. The changes include both channel bed degradation and bank erosion. This channel reach is subject to a net loss of the channel boundary material due to erosion. Fig. 11 shows the simulated flow velocity variation along the channel reach at the peak flow. The average velocity is about 10 feet per second, with higher velocities at steeper areas and/or narrower channel widths.

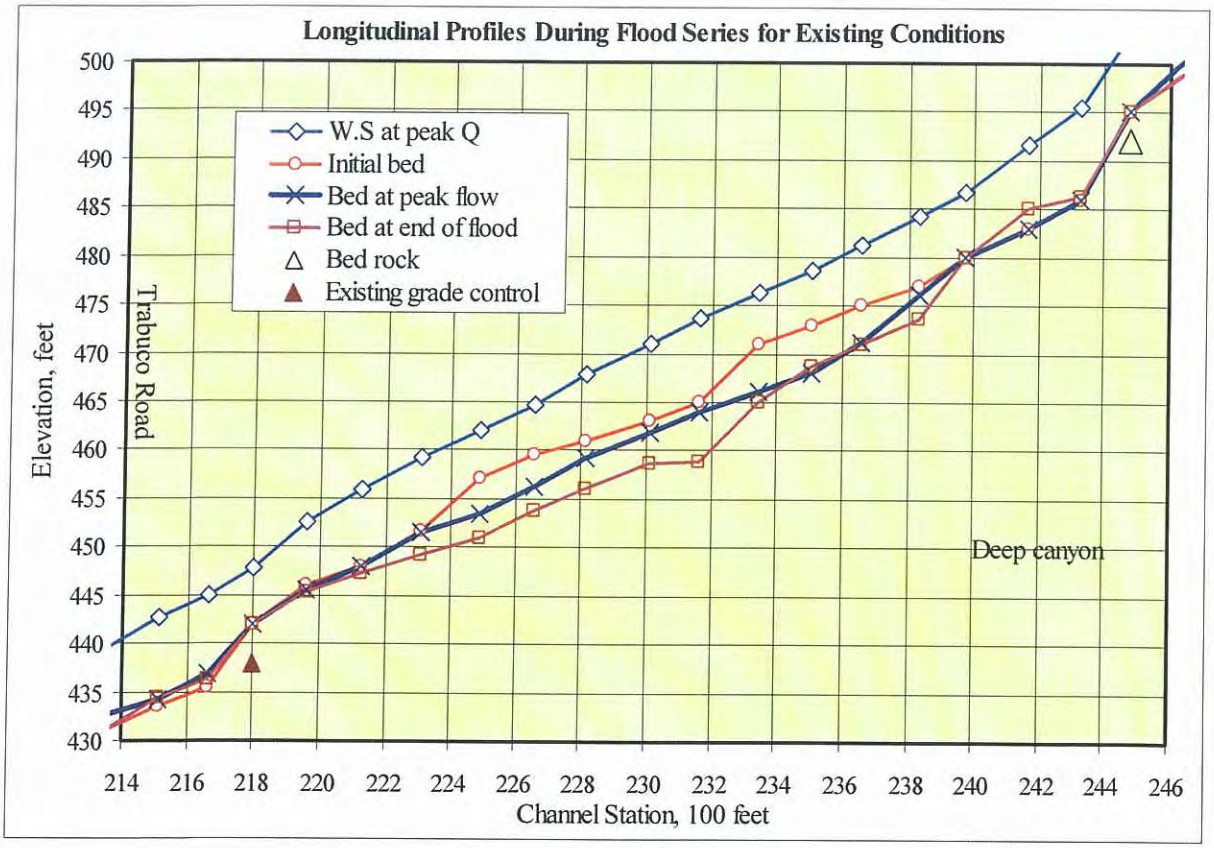


Fig. 9. Longitudinal water-surface and channel bed profiles during the flood series

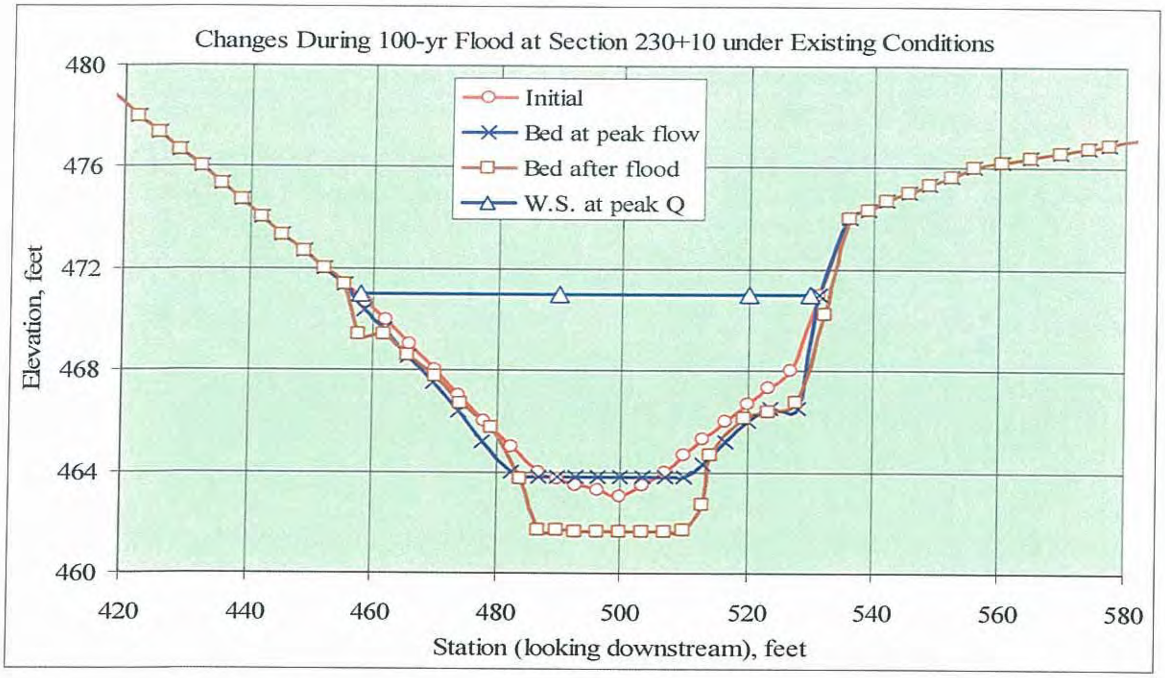


Fig. 10. Simulated cross sectional changes during flood series

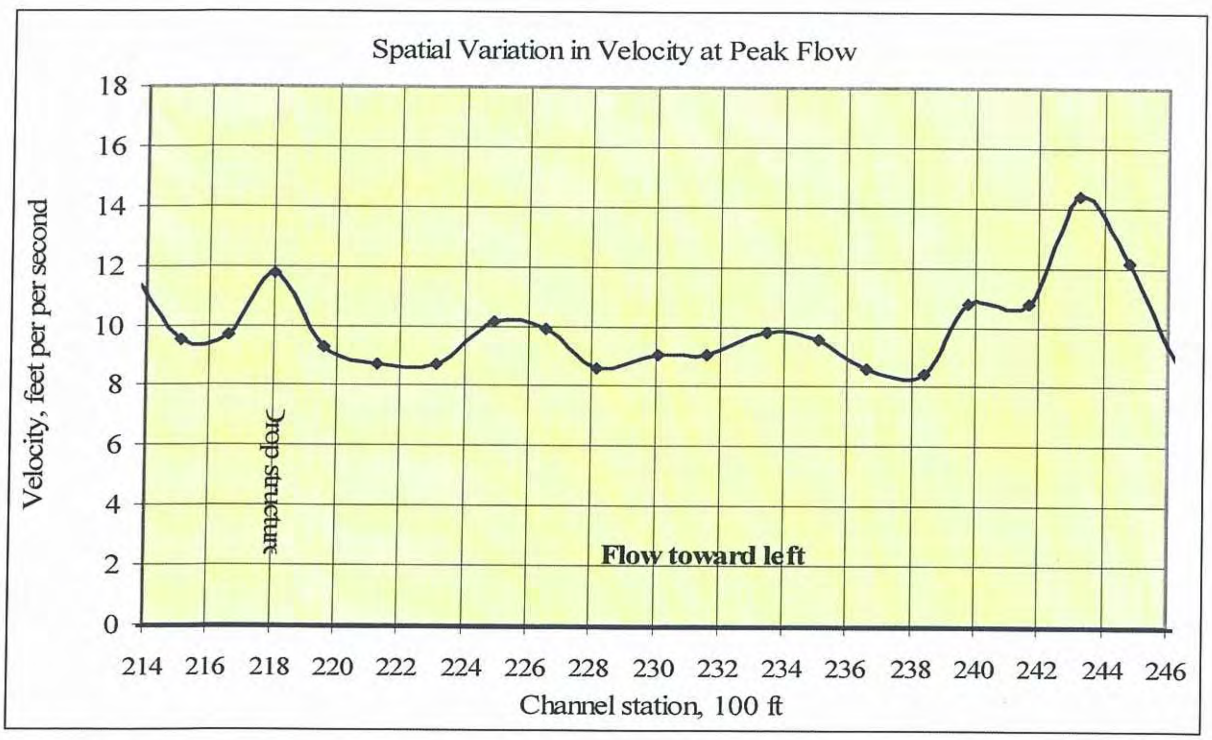


Fig. 11. Simulated flow velocity variation along the channel reach at peak flow

Channel Reach from Station 244+00 to Station 261+00 - The second channel reach is from station 244+00 to station 261+00. The channel along this reach is now incised to the extent that the entire reach is in a deep canyon. Most of the channel bed is not visible because of dense vegetation growth in the valley. Channel bed degradation has largely stripped original alluvium from the channel bed to expose the bed rock at many locations as shown in Figs. 12 and 13. The exposed bed rock inhibits further degradation. In addition to channel bed degradation, the planform of the channel has become highly sinuous as the stream seeks to develop a flat slope in response to a deficit in sediment supply. The sinuous meandering channel has eroded channel banks to result in lateral migration, which may pose a threat to adjacent homes. As a countermeasure, the County has installed bank protection along the concave channel bank between stations 251+50 and 253+00 pursuant to the engineering plans by Tetra Tech.

Fig. 12. Channel bed with exposed bed rock

Fig. 13. Channel bed with exposed bed rock

Simulated results for the existing conditions are shown in Figs.14 and 15. Fig. 14 shows the longitudinal water-surface and channel bed profiles during the flood series. Because of bed rock outcroppings, future channel-bed degradation will be limited in magnitude. However, the degradation is also accompanied by erosion of the channel banks. This channel reach is subject to a net loss of the channel boundary material due to erosion.

Figure 15 shows the simulated flow velocity variation along the channel reach at the peak flow. The velocities are generally over 10 feet per second. Such high velocities are associated with steep channel slope and narrow canyon.

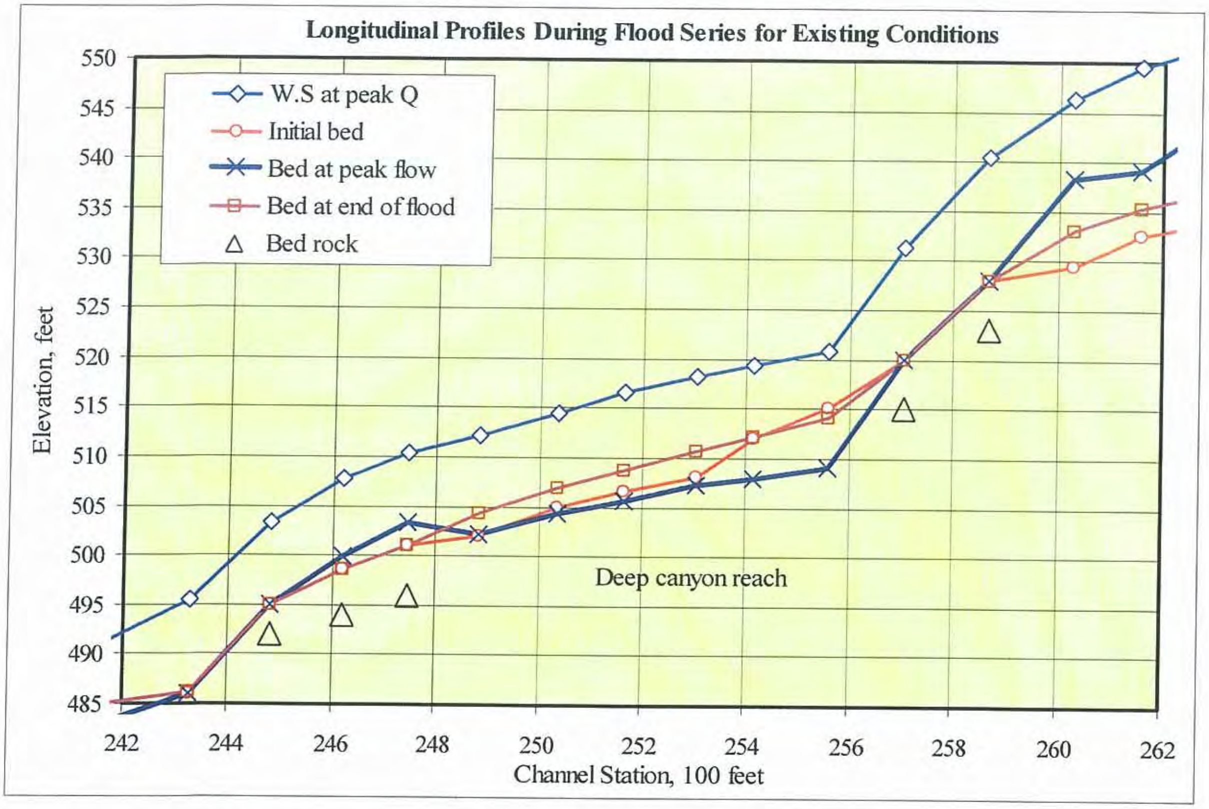


Fig. 14. Longitudinal water-surface and channel bed profiles during the flood series

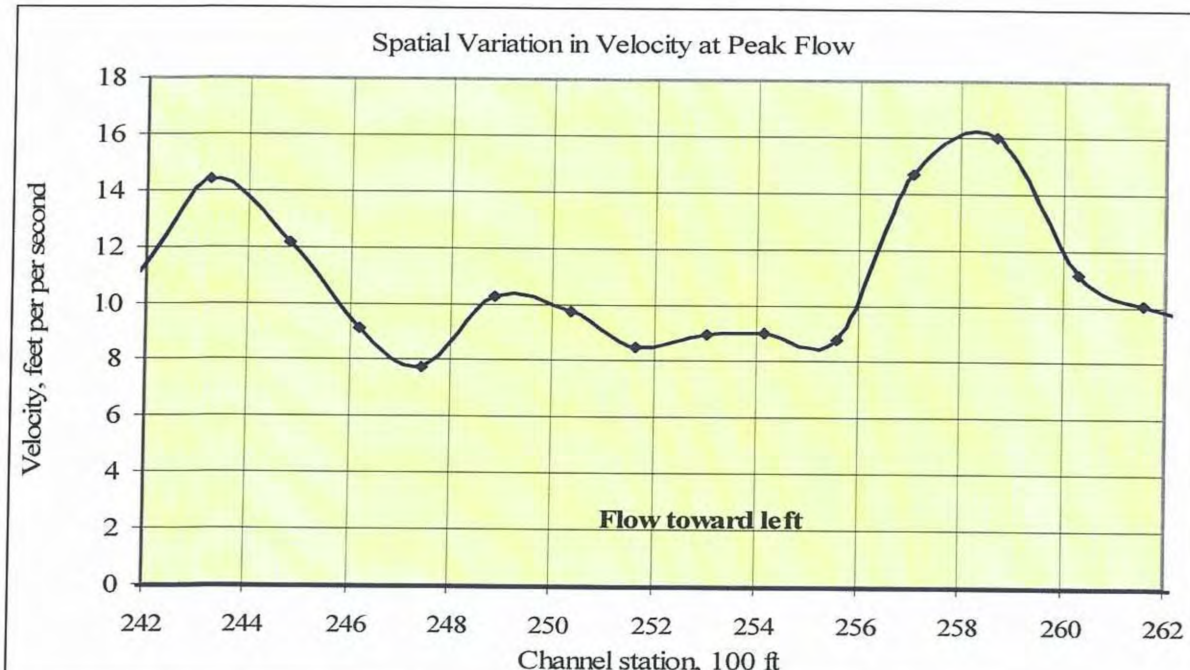


Fig. 15. Simulated flow velocity variation along the channel reach at peak flow

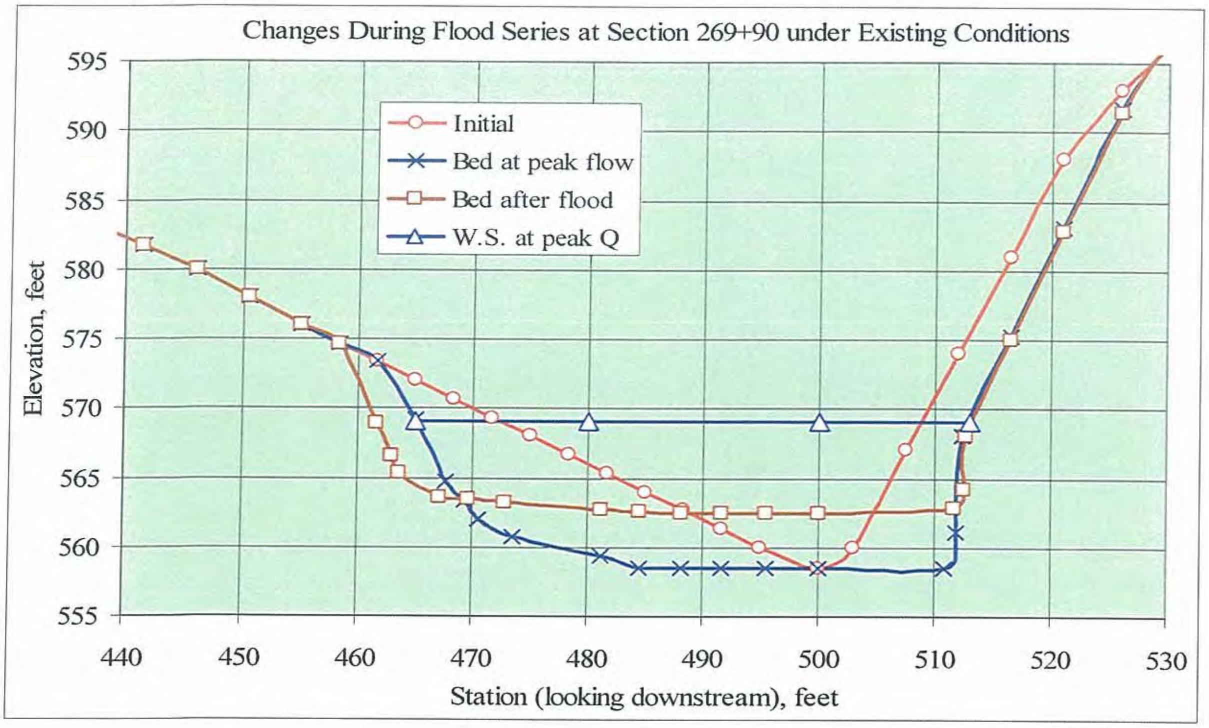


Fig. 18. Sample cross-sectional changes during flood series

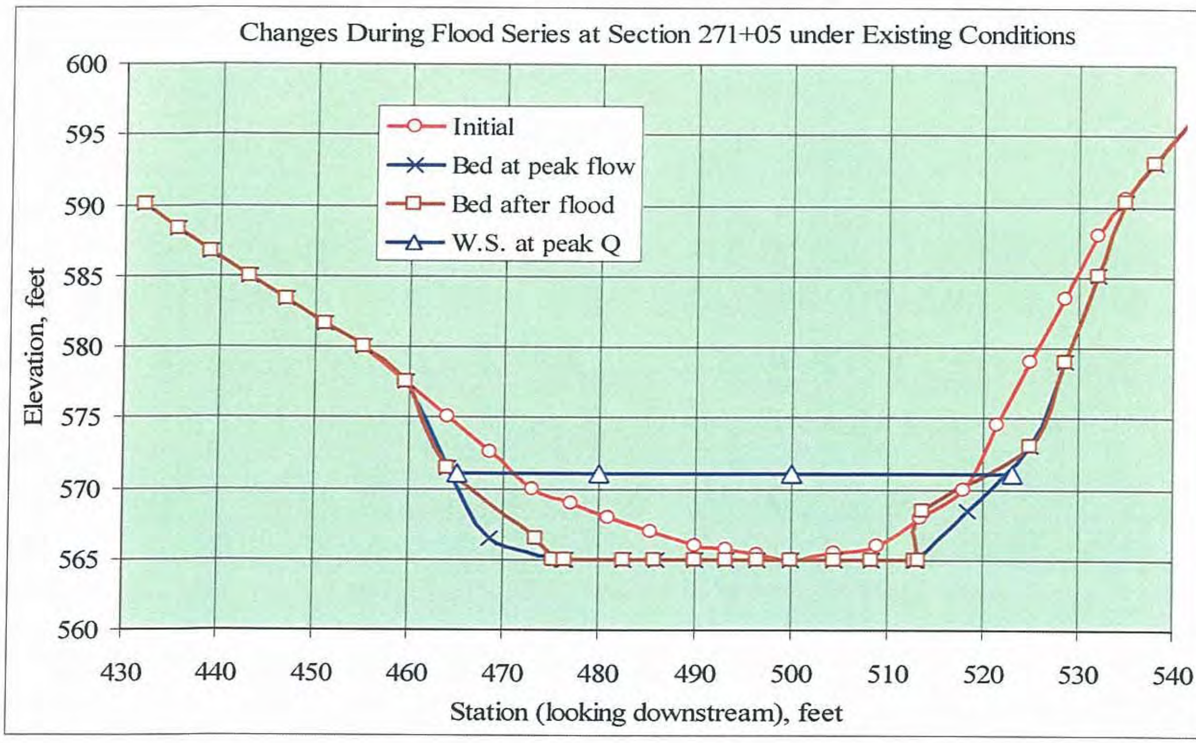


Fig. 18 (continued). Sample cross-sectional changes during flood series

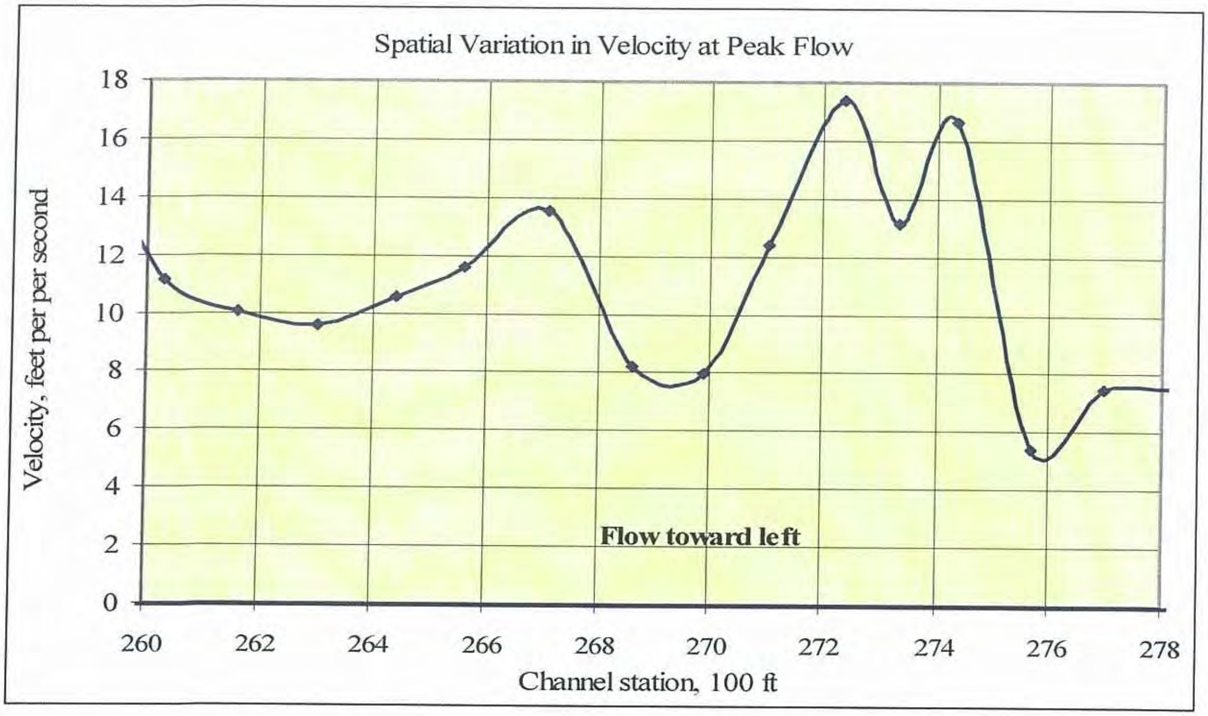


Fig. 19. Simulated flow velocity variation along the channel reach at peak flow

Channel Reach from Station 276+00 to Dimension Drive – This channel reach is from station 276+00 to Dimension Drive at station 293+00. Unlike other lower reaches, the channel along this reach is not nearly as incised. It still has a sand bed except at grade control structures.

The F19S02 tributary enters (see Fig. 20) Serrano Creek at station 275+70. The inflow from this storm drain carries little or no sediment; the clear water has removed much sediment to cause deep channel bed scour. As a countermeasure to stop the scour, the channel is now protected with a concrete lining.

This channel reach has a mild sinuosity and it is not as incised as other downstream channel reaches. Riprap bank protection has been installed along a stretch of the south bank and there are two riprap drop structures at stations 285+00 and 289+00, respectively. Several buildings located along the channel banks are not far from the stream channel. The channel bed is protected with grouted riprap at the Dimension Drive Bridge crossing as shown in Fig. 21. Engineering plans for the grade controls structures and bank protection are not available.

Fig. 20. Inflow channel for F19S02

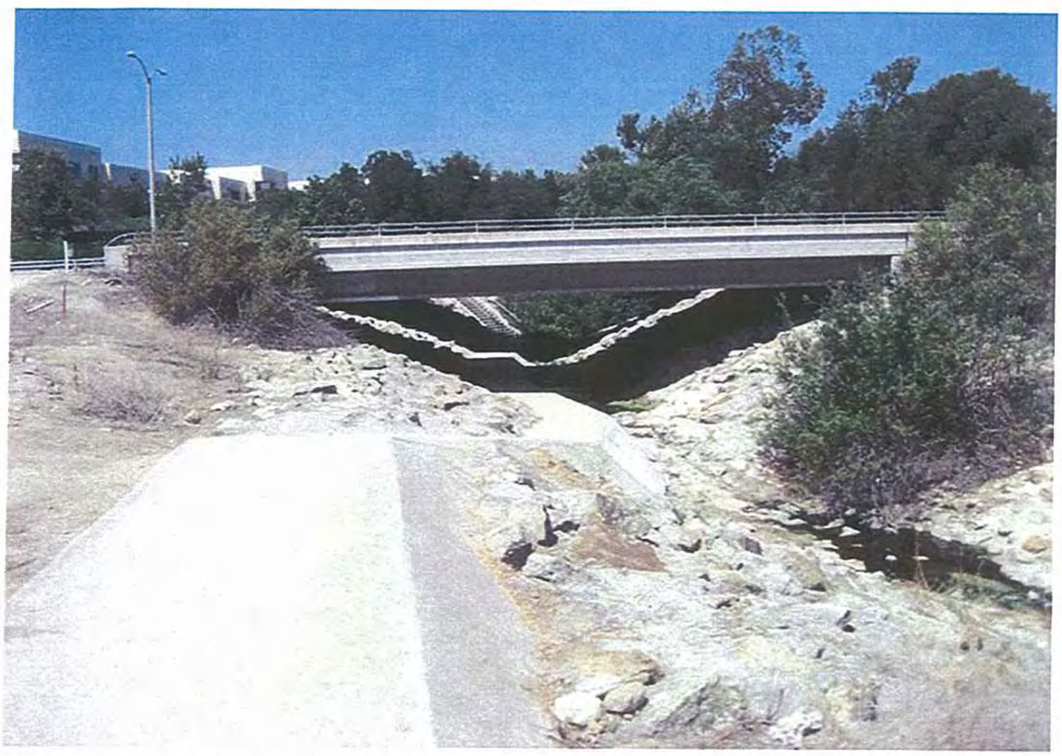


Fig. 21. Serrano Creek at Dimension Drive crossing

Simulated results for the existing conditions are shown in Figs.22, 23 and 24. Fig. 22 shows the longitudinal water-surface and channel bed profile changes during the flood series. The short channel reach near station 283+00 does not have sufficient capacity for the 100-yr flood (see Fig. 23). The computed water-surface elevation is higher than the top of the south bank. The adjacent properties are subject to flooding. Because of the grade control structures, future channel-bed degradation will be limited in magnitude. However, the degradation is also accompanied by erosion of the channel banks as illustrated in Fig. 23. This section has bank protection on the left bank but the unprotected right bank is predicted to undergo erosion. This channel reach is subject to a net loss of the channel boundary material due to erosion.

Figure 24 shows the simulated flow velocity variation along the channel reach at the peak flow. This reach has moderately high velocities around 10 feet per second associated with a steep slope.

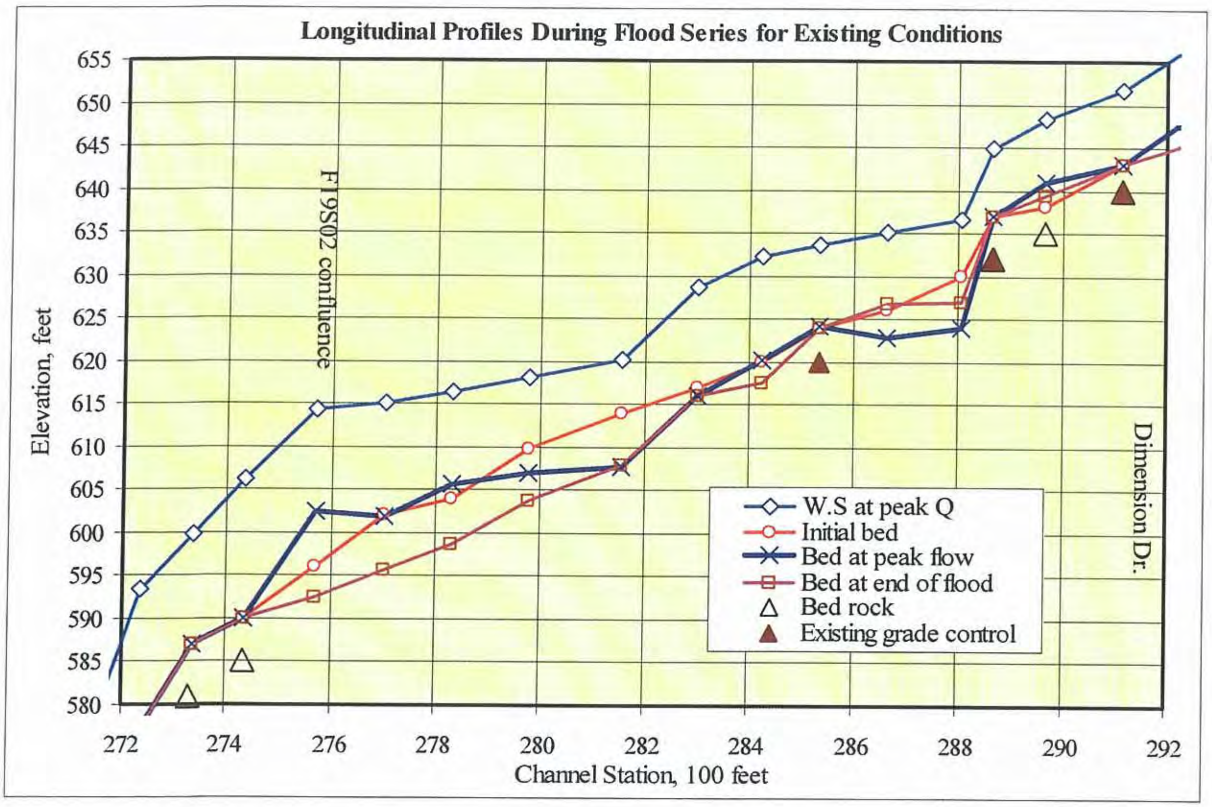


Fig. 22. Water-surface and channel bed profile changes during flood series

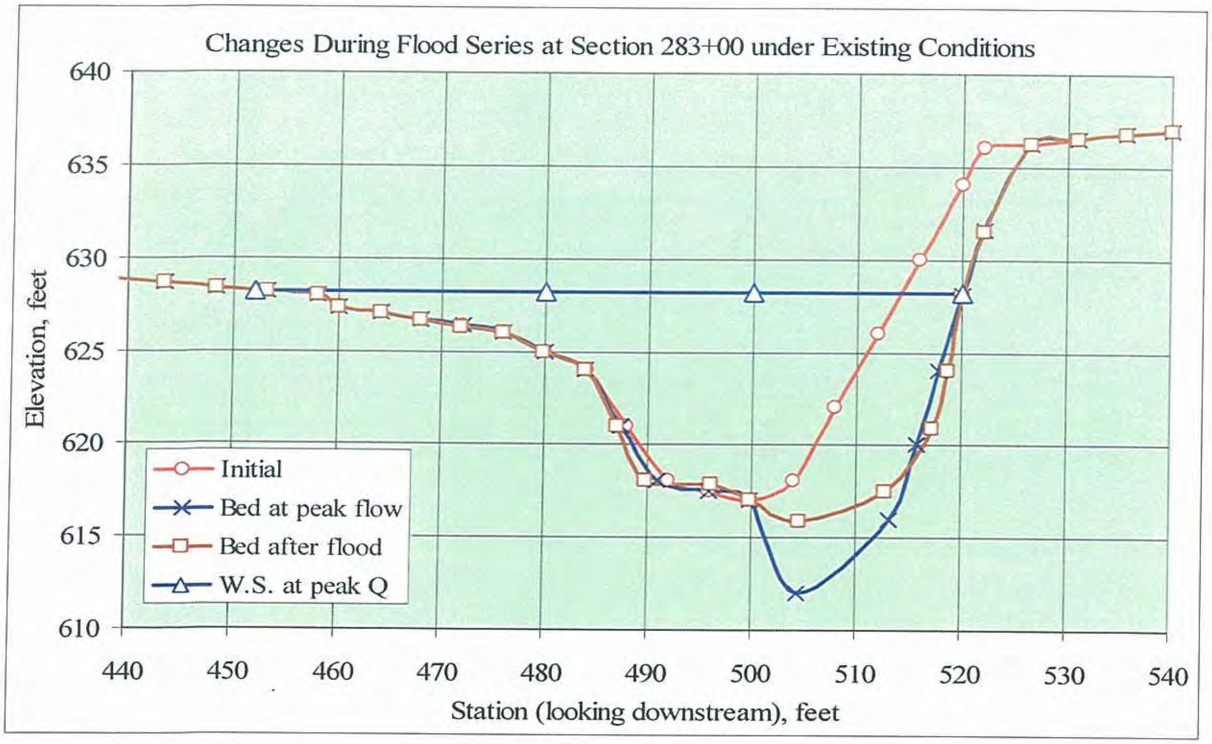


Fig. 23. Simulated changes at station 283+00. The left bank is protected with riprap but erosion occurs on unprotected right bank

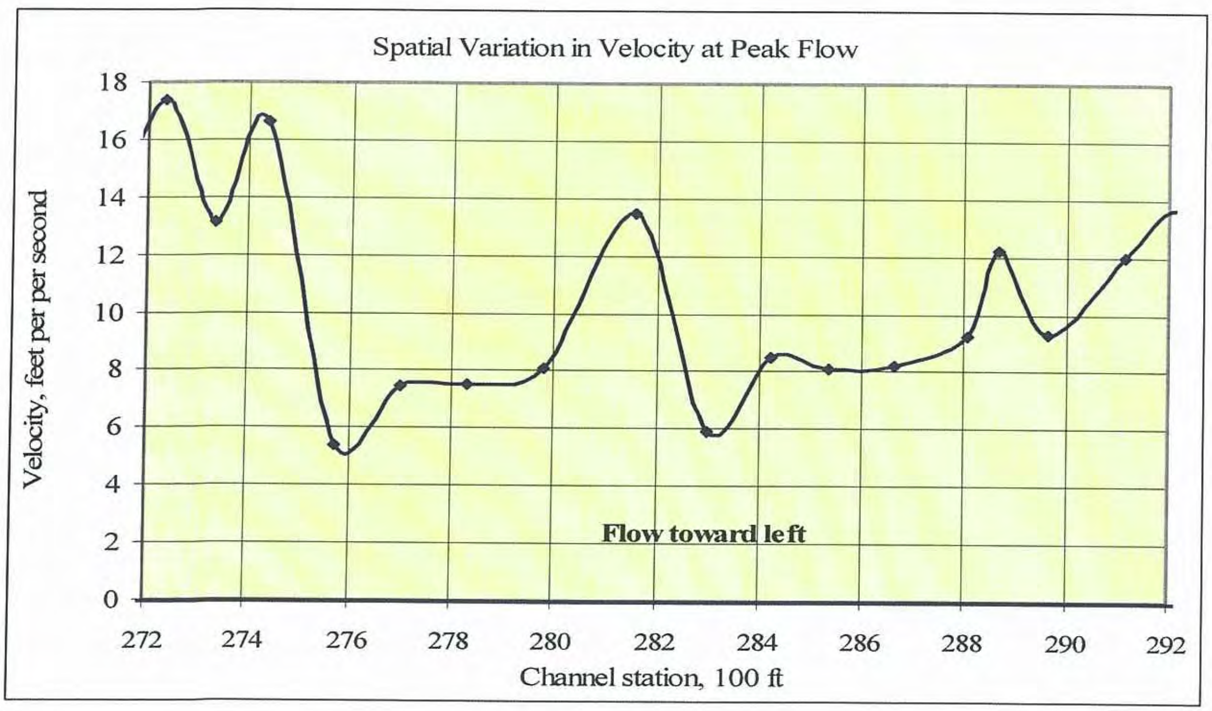


Fig. 24. Simulated flow velocity variation along the channel reach at peak flow

Channel Reach from Dimension Drive to Nursery Access Road - This reach is from Dimension Drive at station 292+00 to the nursery access road at station 308+50. The channel is protected with grouted riprap at both downstream and upstream ends. There is also a drop structure located just upstream of Dimension Drive. The south bank of the channel has scattered bank protection, apparently placed as a protection for the buildings along the channel bank. Engineering plans for the bank protection are not available. The north bank remains in its natural state since there are no buildings located near the north channel bank.

The channel for this reach has the capacity for the 100-yr flood. Flooding of the south overbank as shown in the FIRM is due to the deficient culvert at the Nursery Road crossing.

Simulated results for the existing conditions are shown in Figs. 25, 26 and 27. Fig. 25 shows the longitudinal water-surface and channel bed profile changes during the flood series. Fig. 26 shows sample cross-sectional changes along the channel reach. The channel is not subject to major changes in bed elevation. However, channel changes will also occur along channel banks to result in a net loss of materials from the channel boundary as illustrated in Fig. 26. This channel reach is not as incised as the lower reaches. The existing channel has the capacity for the 100-yr flood. However, floodwater overflowing the nursery access road floods the south overbank area just downstream of the nursery access road.

Figure 27 shows the simulated flow velocity variation along the channel reach at the peak flow. This reach has moderately high velocities around 10 feet per second associated with a steep slope.

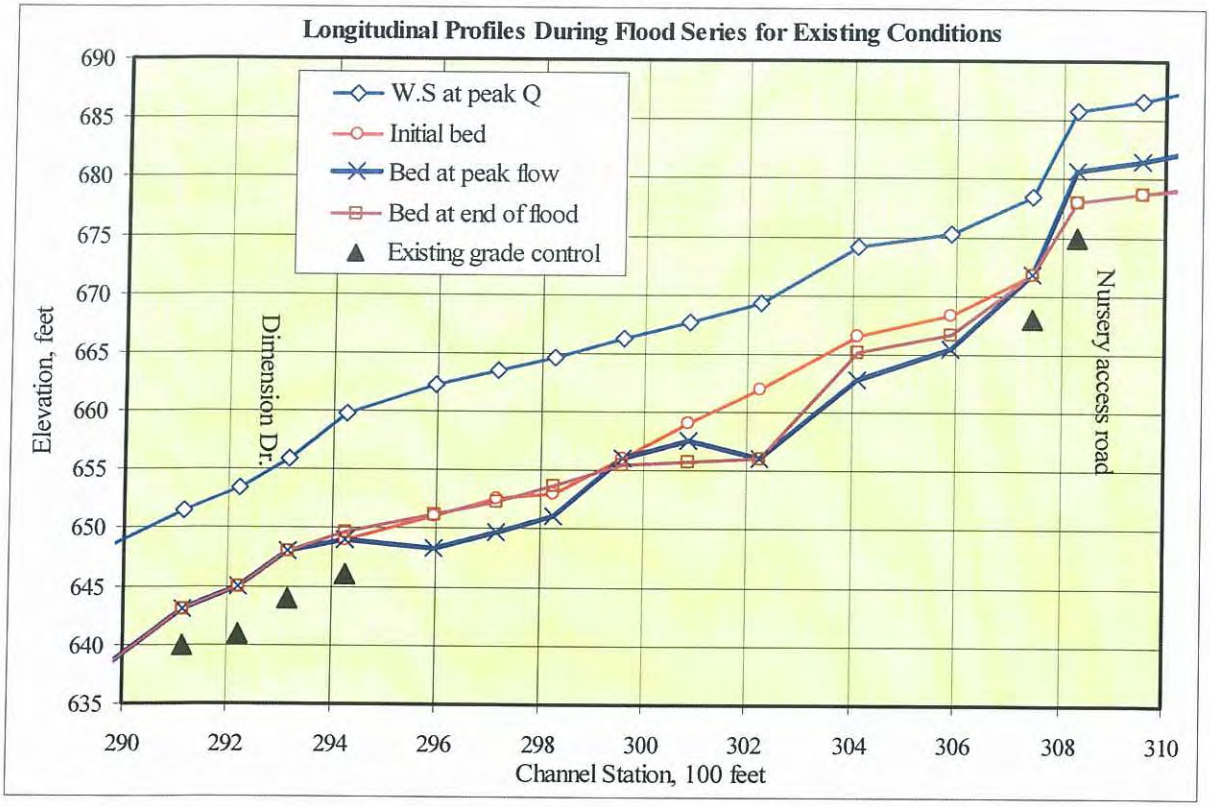


Fig. 25. Water-surface and channel bed profile changes during flood series

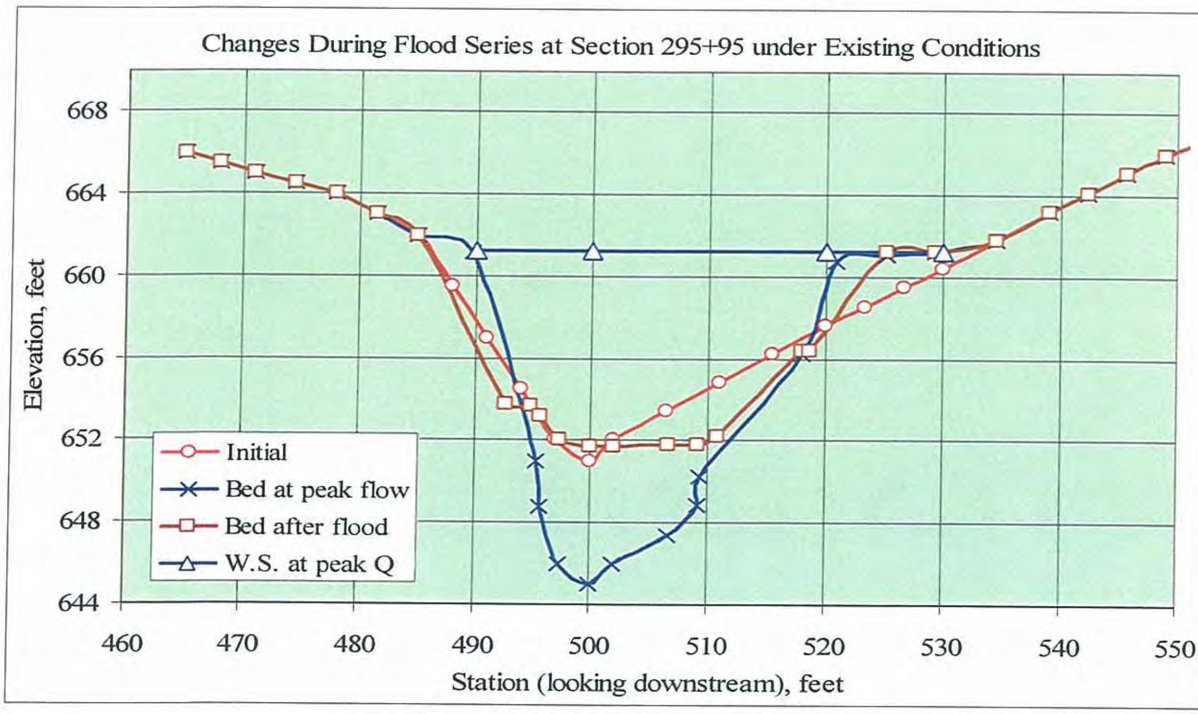
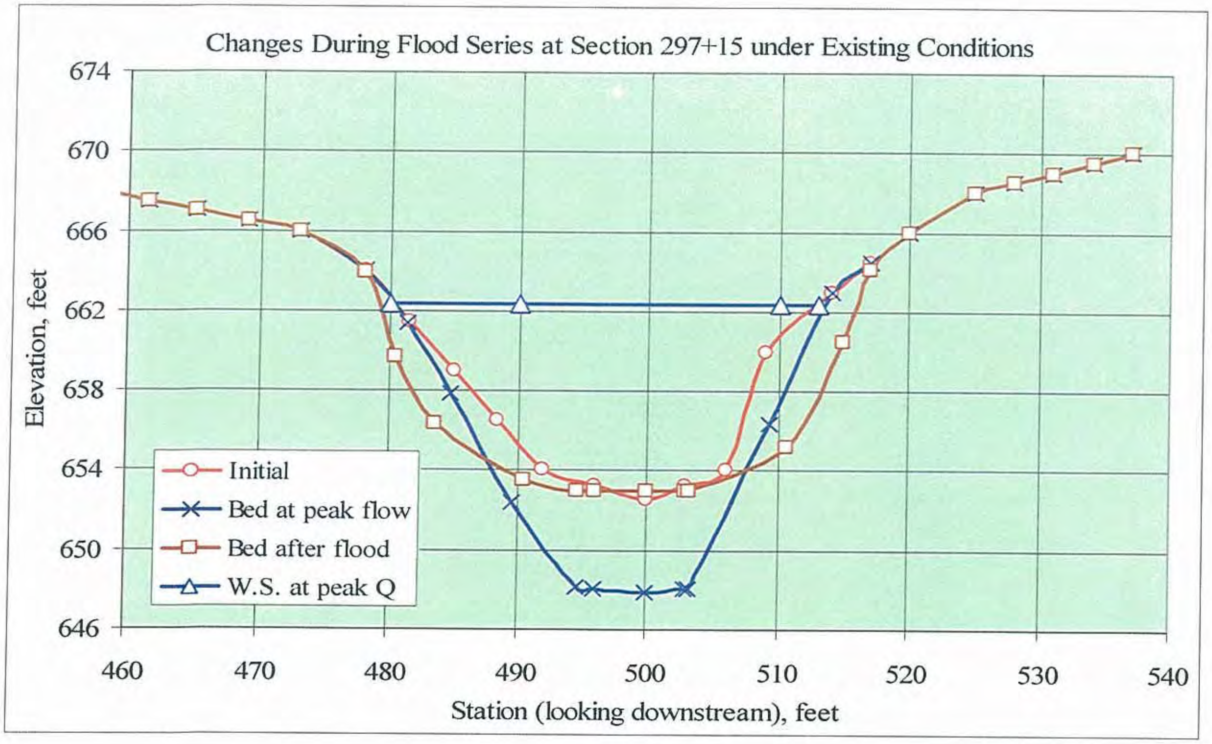


Fig. 26. Simulated changes at Station 295+95



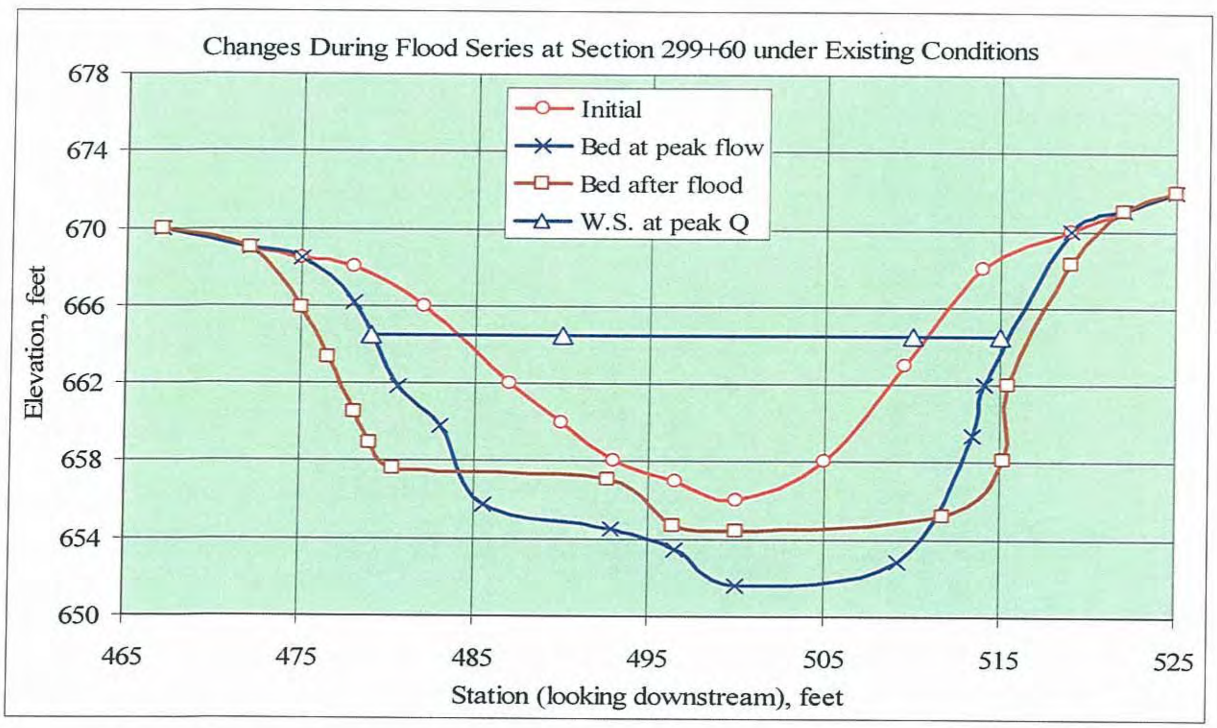
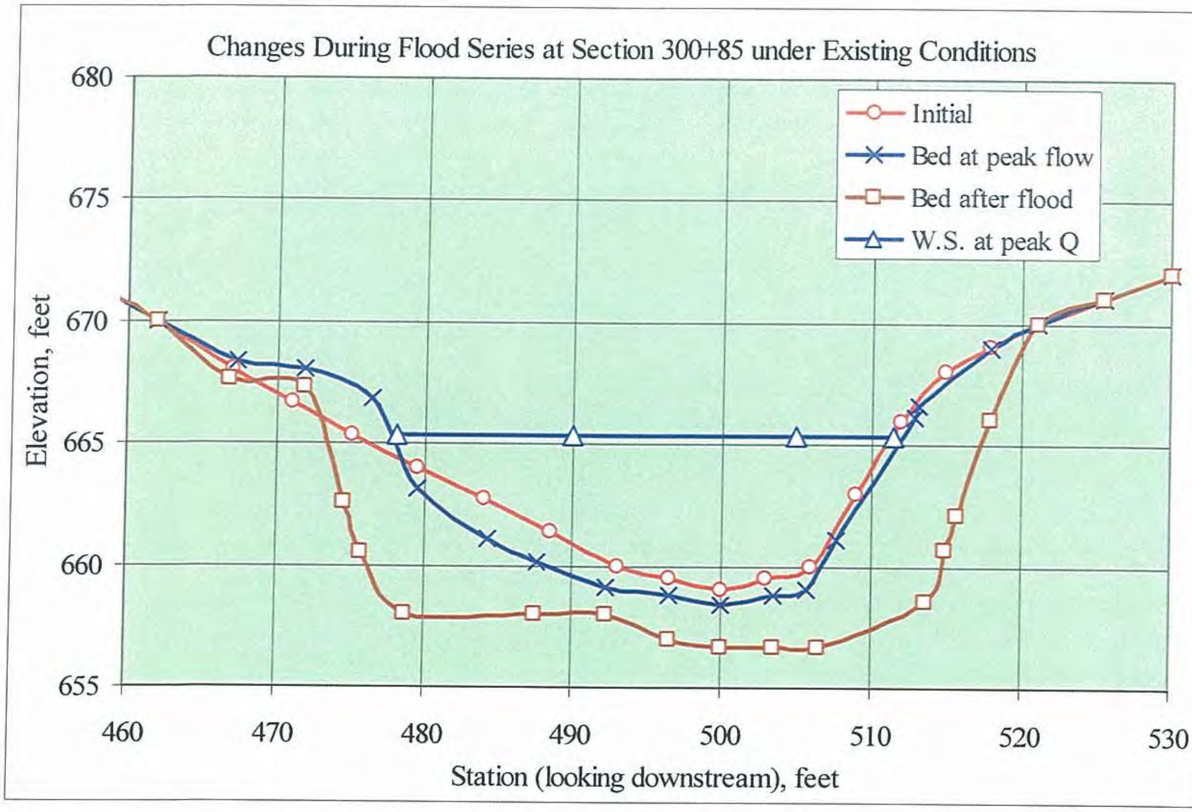


Fig. 26(continued). Simulated changes at sample sections (Stations 297+15 and 299+60)



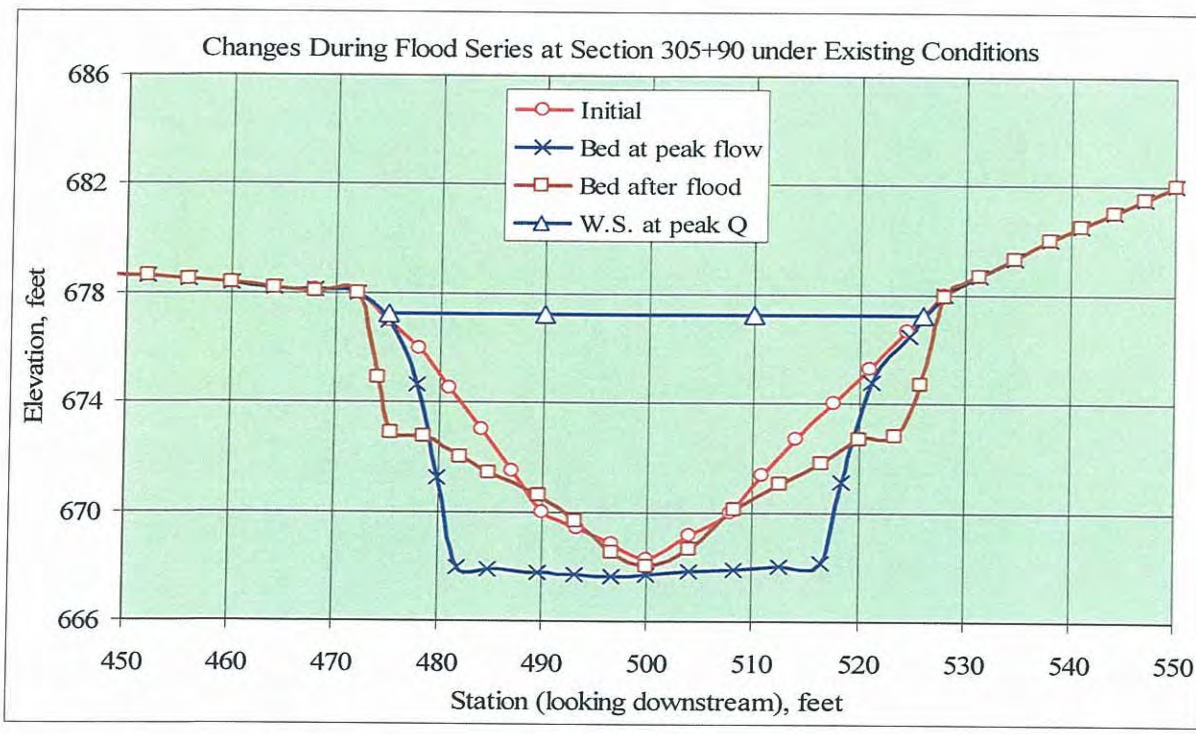


Fig. 26(continued). Simulated changes at sample sections (Stations 300+85 and 305+90)

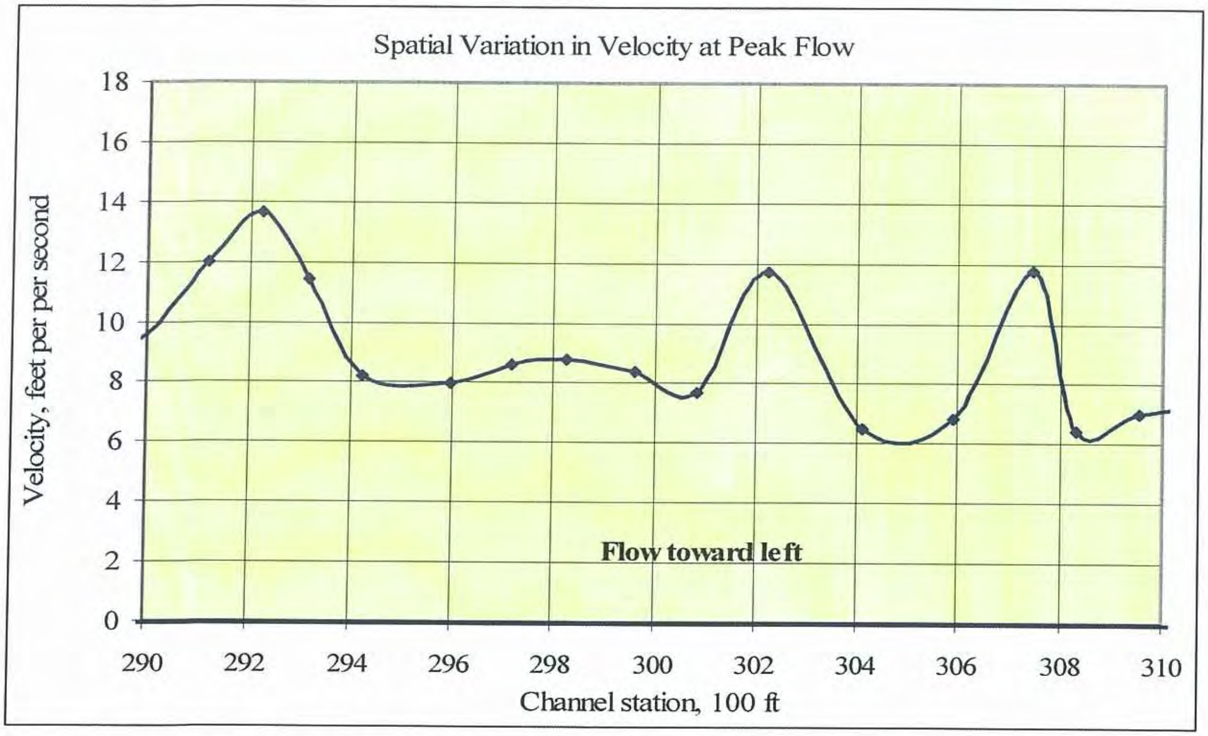


Fig. 27. Simulated flow velocity variation along the channel reach at peak flow

Channel Reach from Nursery Access Road to Lake Forest Drive - This channel reach is from the nursery access road at station 306+00 to Lake Forest Drive at station 336+00; it is along a nursery with a straight alignment. The nursery access road as shown in Fig. 28 is a rigid structure with an 84-inch RCP; it acts like a grade control structure to stabilize the upstream channel bed. The channel under Lake Forest Drive at the upstream end is a concrete box culvert. The channel also has two concrete grade control structures at stations 319+75 and 327+80 (see Fig. 29); it has a sand bed (see Fig. 30) except at grade control structures.

Fig. 28. Nursery access road on Serrano Creek

Fig. 29. Concrete grade control structure

Fig. 30. Serrano Creek along a nursery

Simulated results for the existing conditions are shown in Figs.31, 32 and 33. Fig. 31 shows the longitudinal water-surface and channel bed profile changes during the flood series. Because of the grade control structures, future channel-bed degradation will be limited in magnitude. However, the degradation is also accompanied by erosion of the channel banks (see Fig. 32). This channel reach is subject to a net loss of the channel boundary material due to erosion.

Figure 33 shows the simulated flow velocity variation along the channel reach at the peak flow. This reach has high velocities mostly above 10 feet per second associated with a steep slope.

The channel reach near the nursery access road does not have sufficient capacity for the 100-yr flood. The computed water-surface elevation is higher than the top of the right channel bank at a few locations. The grade control structures do not have sufficient bank height to contain the 100-yr flood; they are subject to out-flanking. Channel stabilization of this reach for flood control will require considerable improvements.

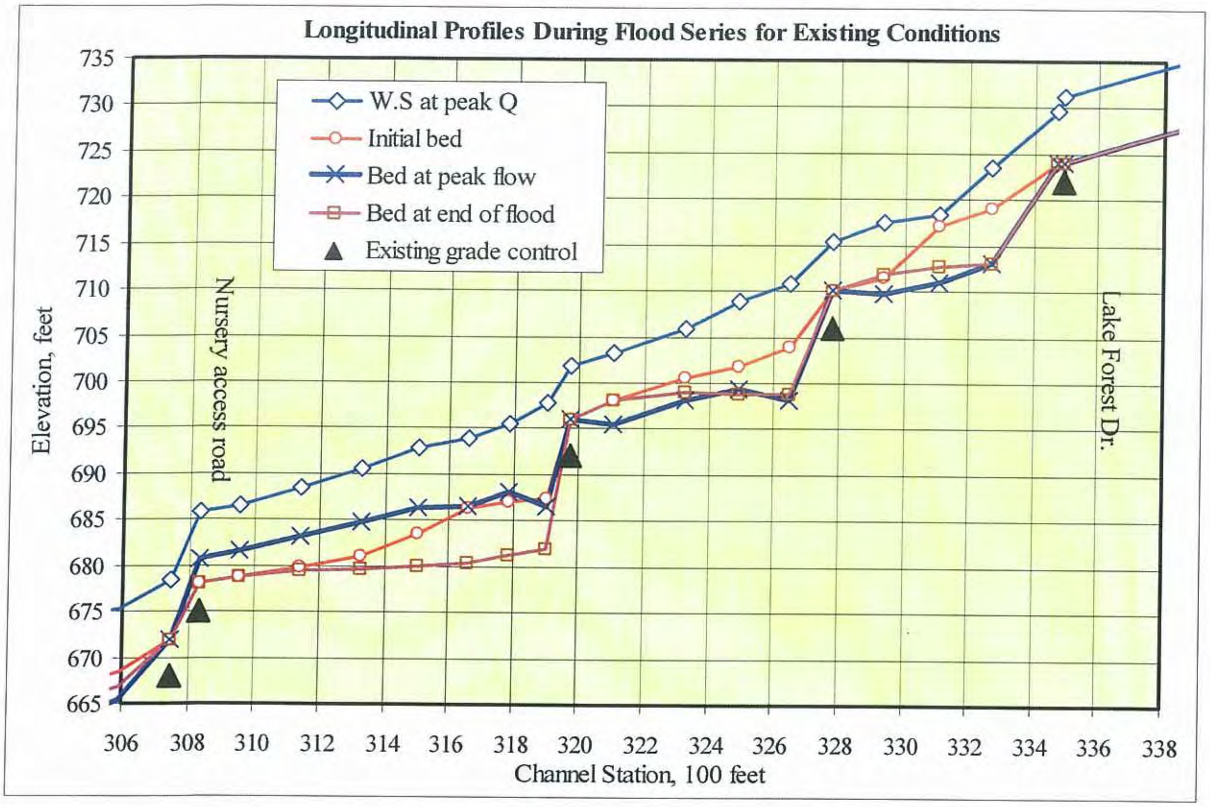


Fig. 31. Water-surface and channel bed profile changes during flood series

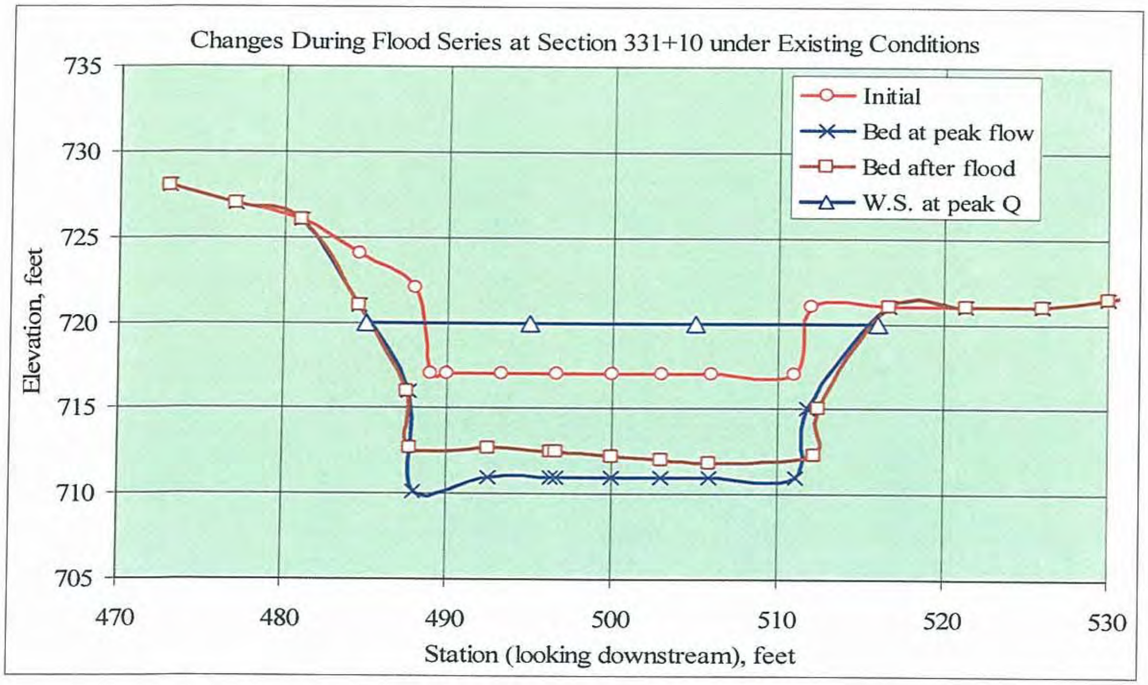


Fig. 32. Simulated cross-sectional changes at station 331+10

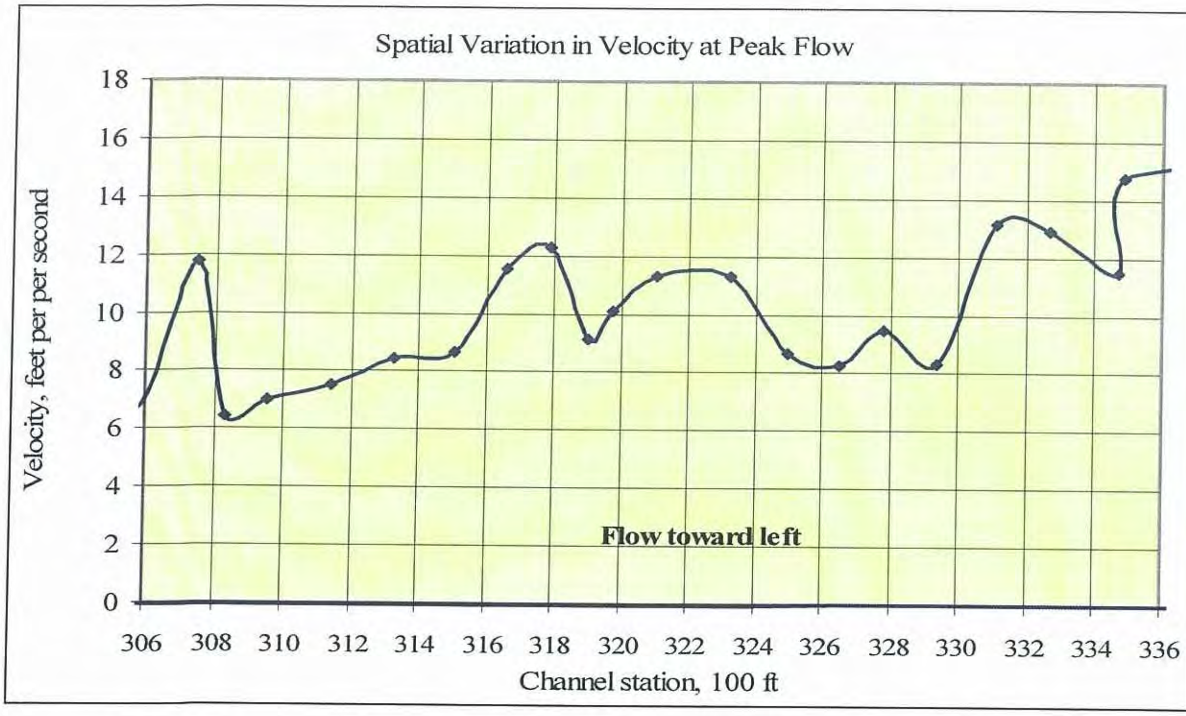


Fig. 33. Simulated flow velocity variation along the channel reach at peak flow

Channel Reach from Lake Forest Drive to Portola Parkway – This channel reach is from Lake Forest Drive at station 334+00 to the grade control structure located just upstream of Portola Parkway at station 370+85. Serrano Creek is channelized with erosion protection (see Fig. 34) between Lake Forest Drive and the Transportation Corridor; the channel has sufficient capacity for the 100-yr flood. Upstream of the Transportation corridor, the natural channel also has sufficient capacity.

Simulated results for the existing conditions are shown in Figs.35 and 36. Fig. 35 shows the longitudinal water-surface and channel bed profiles during the flood series. This channel reach is not expected to undergo major changes. Fig. 36 shows the simulated flow velocity variation along the channel reach at the peak flow. This channel has very high velocities through the channelized reach.

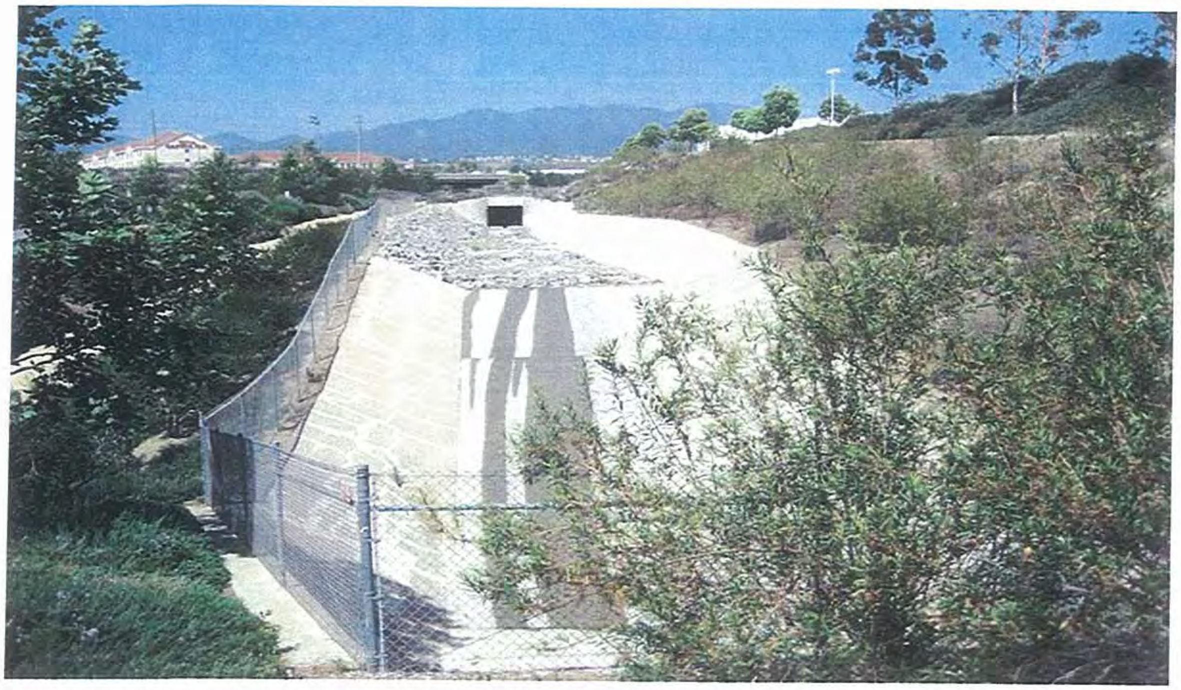


Fig. 34. Serrano Creek viewed from Lake Forest Drive to Transportation Corridor

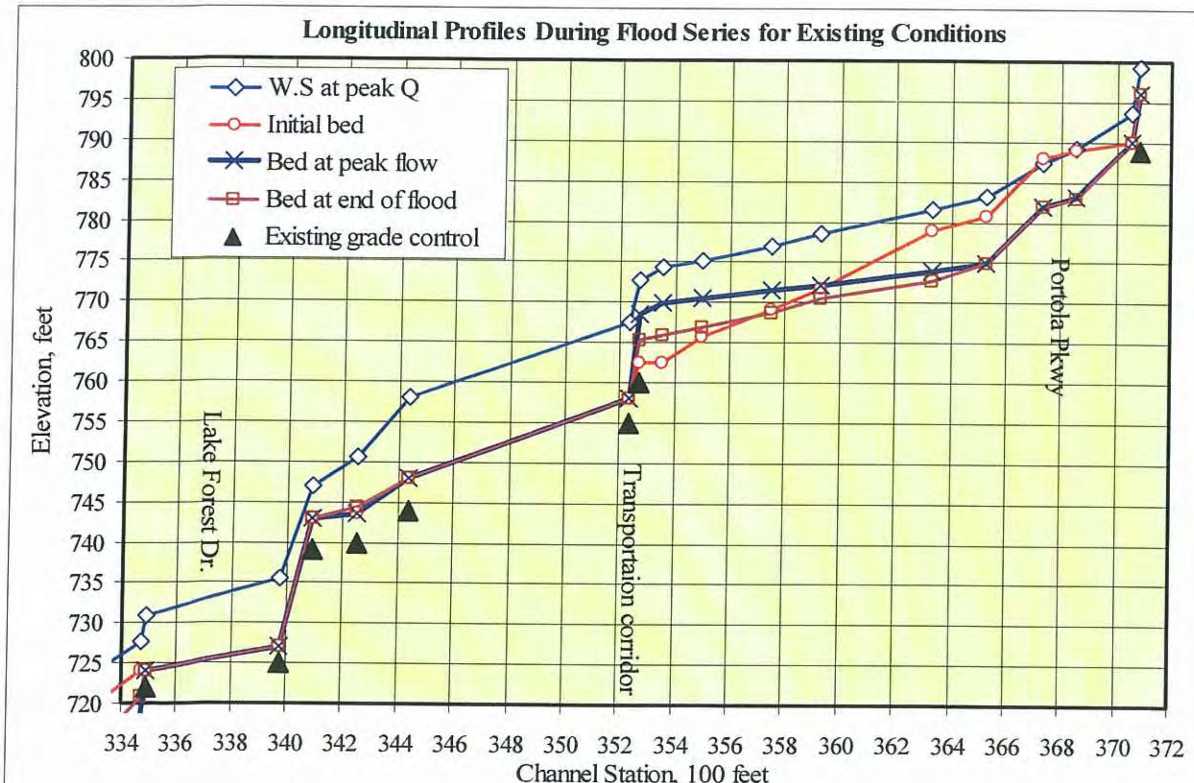


Fig. 35. Water-surface and channel bed profile changes during flood series

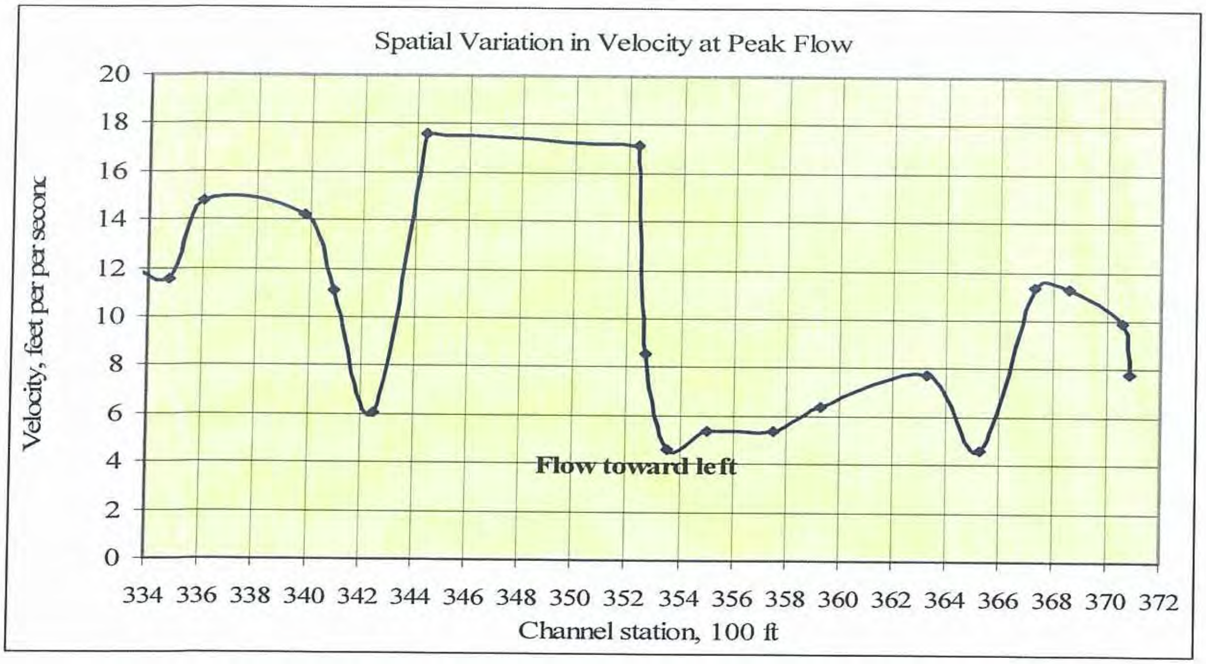


Fig. 36. Simulated flow velocity variation along the channel reach at peak flow

VII. CHANNEL STABILIZATION WITH EVALUATION BY FLUVIAL MODELING

The purpose of the project is to stabilize Serrano Creek in order to provide flood control and erosion protection for properties. In this section, applicable methods for erosion control are described. Stabilization methods are analyzed and selected based on fluvial modeling. The impacts of the stabilization methods will also be assessed based on the modeling results. Re-vegetation in connection with the channel project would be considered if such a measure is found beneficial from the viewpoint of channel stabilization.

General Guidelines and Methods for Channel Stabilization - The Serrano Creek Collaborative Use Plan listed the four following flood control alternatives for channel improvements that were discussed in public meetings:

Alternative 1. No improvement.

Alternative 2. Minor improvements consisting of the construction of drop structures and the laying back of stream banks.

Alternative 3. Moderate improvements consisting of placing of ungrouted riprap on concave banks.

Alternative 4. Extensive improvements consisting of placing of ungrouted riprap on concave banks.

The interested participants for the project considered alternatives for channel stabilization. In the final poll, Alternative 1 gets no vote; Alternative 2 gets 31 votes: Alternative 3 has 32 votes and Alternative 4 has no vote. The poll and votes on the alternatives may be characterized as general consensus.

The principle of channel stabilization is twofold: (1) The training works must be designed to withstand the design flow, and (2) the impacts (consequences) on the stream channel should be understood and evaluated whenever feasible. Therefore, the training works must be strong enough for the design velocity; they must also extend beyond the potential scour in order to safeguard against undermining. A stream, as a system, is subject to changes in response to any type of training or regulation in the system. The commonly used types of training works can be broadly classified as bank protection, dikes, and grade-control structures; they are described in the following.

Different types of bank protection are in use, including riprap, rock trench, mattress, gabion, geofabric (geoweb), soil cement, concrete blocks, cribs, and so on. Products of geofabric are available in the market. One such example of geofabric material is Vmax. Pictures for Vmax are shown in Figs. 37 and 38.

Fig. 37. Channel stabilization with the geoweb material Vmax

Fig. 38. Field application of Vmax

General Requirements for Channel Stabilization - In general, the top elevation of bank protection should stay above the design high water. Within curved reaches, the superelevation of water surface should also be considered. A freeboard of various heights is usually used for water waves; it also serves as a safety margin for the unaccounted factors, such as erratic hydrologic phenomena, changes in flood plain vegetation, unforeseen riprap settlement, channel-bed aggradation, accumulation of trash and debris, and so on. The computed water-surface elevations at the peak flow for the channel with recommended stabilization works are listed in Table 2. The OCFCD freeboard criteria require the following:

(1) Leveed channels and channels within the supercritical flow regime – A freeboard of 3 to 4 feet.

(2) Stable subcritical flow channels – A freeboard of 1.5 feet.

(3) Unstable channel (Froude number between 0.9 and 1.2 - A freeboard of conjugate depth plus 3 feet.

For this study, the freeboard will be met by additional bank height above the computed 100-yr water surface at most locations. At a few locations with levees and flood wall, the freeboard will be met by a higher top-of-levee or top-of-floodwall elevation.

Toe-down depths for the bank protection shall entrench below the elevation of maximum channel bed scour. For this case, maximum channel bed scour occurs either at the peak flow or at the end of the flood series, whichever is lower. Table 2 lists the peak water-surface elevation at the peak flow during the flood series, the existing channel-bed elevation, the minimum bed elevation reached by scour during the flood series, and the recommended top elevation for bank protection (if any). The results in Table 2 were obtained from the erodible boundary model FLUVIAL-12; they are somewhat different from those produced by a fixed- boundary model such as HEC-RAS. The top-of-bank elevation provides an adequate freeboard based on the peak water-surface elevation from the FLUVIAL-12 model; it is also above the BASE FLOOD elevation from the HEC-RAS model.

Table 2. Summary of hydraulic parameters required for channel design (proposed conditions)

Channel Station 100 feet	Water surface elevation feet	Existing bed elevation feet	Bed elevation reached by scour feet	Top elevation for bank protection (if any) feet
213+50	438.66	431.00	430.99	440.7
215+10	442.10	433.60	432.34	444.1
216+60	444.40	435.50	435.51	447.2
218+00	447.79	442.00	441.98	450.8
219+60	452.51	446.00	445.22	456.0
221+25	455.40	448.00	446.40	457.8
223+10	458.67	451.60	449.58	460.7
224+90	461.07	457.00	451.00	468.4
226+55	463.44	459.50	453.50	471.0
228+15	465.95	461.00	455.28	472.2
230+10	468.54	463.00	459.06	473.0
231+60	470.58	465.00	461.15	475.0
233+45	474.46	471.00	464.71	481.7
235+05	479.84	473.00	468.04	484.3
236+55	481.90	475.00	470.78	486.0
238+35	484.33	477.00	471.30	487.0
239+75	486.62	480.00	479.99	489.6
241+65	491.60	483.00	483.00	493.6
243+25	495.40	486.00	485.99	498.4
244+80	503.15	495.00	494.85	506.2
246+20	507.60	498.50	498.50	509.6
247+45	510.03	501.00	501.00	512.0
248+85	511.62	502.00	498.77	516.5
250+35	513.73	505.00	502.93	519.6
251+65	515.64	506.50	505.01	520.5
253+05	517.44	508.00	507.20	519.4
254+15	518.51	512.00	507.49	521.5

Channel Station 100 feet	Water surface elevation feet	Existing bed elevation feet	Bed elevation reached by scour feet	Top elevation for bank protection (if any) feet
255+60	520.99	515.00	508.76	529.3
257+05	531.19	520.00	520.00	533.2
258+70	540.41	528.00	528.00	543.4
260+30	547.75	529.50	533.49	549.8
261+60	548.56	532.50	535.44	550.6
261+80	551.36	544.00	543.99	554.6
262+00	553.66	544.00	543.95	555.7
263+00	555.08	544.00	544.12	557.1
264+40	556.54	544.00	542.89	558.5
264+60	563.74	558.00	558.00	566.6
264+80	564.91	558.00	557.51	567.1
265+60	566.96	558.00	558.74	569.0
267+10	568.69	558.00	560.53	570.7
267+30	573.99	569.00	568.94	577.0
267+50	575.66	569.00	569.19	577.7
268+60	577.02	569.00	569.38	579.0
269+90	578.53	569.00	570.87	580.5
270+10	586.83	583.00	582.99	589.8
270+30	588.32	583.00	583.20	590.3
271+05	589.37	583.00	582.74	591.4
272+35	595.07	583.00	583.00	598.1
272+55	602.67	595.00	594.98	605.6
272+75	603.53	595.00	594.32	605.5
273+35	606.55	595.00	595.03	608.5
274+35	607.46	595.00	594.99	610.2
274+55	610.53	603.00	602.89	613.5
274+75	610.73	603.00	600.84	614.8
275+70	616.11	603.00	607.90	619.1
277+00	616.57	602.00	603.95	619.6
278+30	617.67	604.00	605.55	620.7
279+80	618.77	609.80	607.02	623.8
281+55	620.32	613.90	607.90	628.0
283+00	625.38	617.00	615.65	631.0
284+25	631.78	620.00	614.00	635.0
285+35	636.78	624.00	625.63	640.0
286+65	638.13	626.00	626.33	641.1
288+05	639.45	630.00	625.69	643.0
288+65	644.76	637.00	637.00	648.0
289+65	648.17	638.00	640.36	652.0
291+15	651.57	643.00	642.90	655.7
292+20	656.26	645.00	645.00	658.3
293+15	659.00	648.00	648.00	661.0
294+25	660.18	649.00	646.69	662.2
295+95	662.00	651.00	645.00	665.1
297+15	663.15	652.50	649.58	665.2
298+25	664.21	653.00	650.78	667.2
299+60	665.53	656.00	650.59	670.1

Channel Station 100 feet	Water surface elevation feet	Existing bed elevation feet	Bed elevation reached by scour feet	Top elevation for bank protection (if any) feet
300+85	666.27	659.00	653.00	672.2
302+25	669.96	662.00	656.00	674.0
304+10	676.05	666.50	666.44	678.1
305+90	677.09	668.30	667.55	679.1
307+45	678.46	671.80	671.80	682.0
308+30	682.56	676.50	676.50	685.0
309+55	685.17	678.80	677.19	687.2
311+40	686.20	679.90	678.26	688.3
313+25	687.23	681.00	679.33	689.4
315+05	688.22	682.00	680.35	690.5
316+60	689.07	683.00	681.14	691.4
317+85	689.77	683.70	681.65	692.2
319+00	690.40	684.40	681.66	692.8
319+50	690.67	684.70	681.80	693.1
319+75	701.18	696.20	696.19	703.2
321+05	703.58	697.00	696.99	706.4
323+25	704.83	698.30	697.82	707.7
324+95	705.82	699.30	698.77	707.8
326+50	706.90	700.20	699.57	708.9
327+50	707.66	700.80	700.04	709.7
327+80	716.96	712.00	712.00	720.0
329+35	720.61	711.50	714.47	722.8
331+10	722.15	717.00	712.95	726.2
332+70	723.14	719.00	713.00	730.1
334+70	729.54	724.00	724.00	731.8
334+90	731.04	724.00	723.99	733.0
339+75	736.04	729.00	729.00	738.0
340+90	750.74	745.00	745.00	752.7
342+50	753.73	745.00	746.52	755.7
344+35	757.43	748.00	748.00	759.4
352+35	767.39	758.00	758.00	769.4
352+70	772.59	762.40	765.94	774.6
353+55	774.06	762.50	766.70	776.1
355+00	774.92	765.70	767.70	776.9
357+50	776.84	769.00	769.21	778.8
359+30	778.35	771.60	770.96	780.3
363+30	781.57	778.80	773.65	783.6
365+30	783.49	780.80	774.79	785.5
367+30	786.29	786.90	780.90	788.3
368+55	787.53	787.90	781.90	789.5
370+55	793.63	789.90	789.90	795.6
370+85	799.33	796.00	796.00	801.3

The approximate locations of existing riprap bank protection were determined from field observation. Since engineering plans for such bank structures are not available, their adequacies need to be checked. Basically, an erosion control structure, such as bank protection or grade control structure, should meet the following conditions:

(1) It should be strong enough to withstand the force of flow.

(2) It should have adequate bank height and freeboard consistent with the OCFCD criteria.

(3) It should have adequate toe-down depth.

(4) The drop structures should have sufficient bank height to avoid out flanking.

Specific recommendations for channel stabilization measures are described below reach by reach.

Channel Reach from Trabuco Road to Station 244+00 - This channel reach has Trabuco Road at the downstream end. The sand bed channel is now incised resulting from previous channel-bed degradation. The present channel is in a deep canyon with the canyon depth increasing toward upstream. There are existing housing developments along both channel banks. Most of the channel bed is not visible because of dense vegetation growth in the valley.

The following conditions were considered in recommending stabilization measures for this channel reach.

(1) Safety hazard.

(2) The potential for channel bed degradation.

(3) The potential for channel migration or bank erosion that may affect adjacent homes.

The Collaborative Use Plan suggests the installation of grade control structures in this channel reach for channel stabilization. The existing grade control structures are at the Trabuco Road crossing and its upstream vicinity as shown in Fig. 39. In analyzing the results for the existing conditions, it was decided not to use additional grade control structures for the following reasons:

(1) Grade control structures, if used in this reach, would be limited in height say around 5 to 10 feet. Such structures do not substantially raise the channel bed level and the channel will remain incised as viewed from the neighborhood.

(2) By raising the channel bed profile, grade control structures would lower the flow velocity, but at the same, they would raise the water level to the higher bank, where the bank material is more susceptible to erosion. Such a measure may reduce bank stability.

(3) The channel reach, under existing conditions, is not expected to undergo major degradation in the future. It is not necessary to check future channel bed degradation.

(4) A grade control structure, while induces deposition on the upstream channel, also causes erosion in the downstream channel. Advantages gained are compensated by disadvantages.

(5) From the economical viewpoint, it is advantageous not to use grade control structures.

Because of the above considerations, the use of grade control structures in this reach has no clear advantages.

Recommended measures to achieve channel stabilization and flood control for the reach are shown in Fig. 39, together with the existing grade control structure and bank protection. They are described below.

(1) Survey of the existing grade control structures and bank protection to insure that they meet the requirements for flood control and channel stabilization. The existing bank protection should extend to station 220+50 on the north bank.

(2) Placement of riprap bank protection (or equivalent) along both channel banks from the Trabuco Bridge abutments to the grade control structure near station 218+00.

(3) Placement of riprap bank protection along the north bank from station 222+00 to station 224+00. It has a total length of about 200 feet.

(4) Placement of riprap bank protection along the south channel bank from station 227+50 to station 230+40.

(5) Placement of riprap bank protection along the north channel bank from station 230+80 to station 235+50.

(6) Placement of riprap bank protection along the south channel bank from station 236+20 to station 238+00.

(7) Selection of the riprap size considering the flow velocity and its spatial variation shown in Fig. 41.

Toe-down depths for the bank protection shall entrench below the profile of maximum channel bed scour shown in Fig. 40 and listed in Table 2. For this case, maximum channel bed scour occurs either at the peak flow or at the end of the flood series, whichever is lower. The top of bank shall reach above the water-surface profile at the peak flow, also shown in Fig. 40 and listed in Table 2.

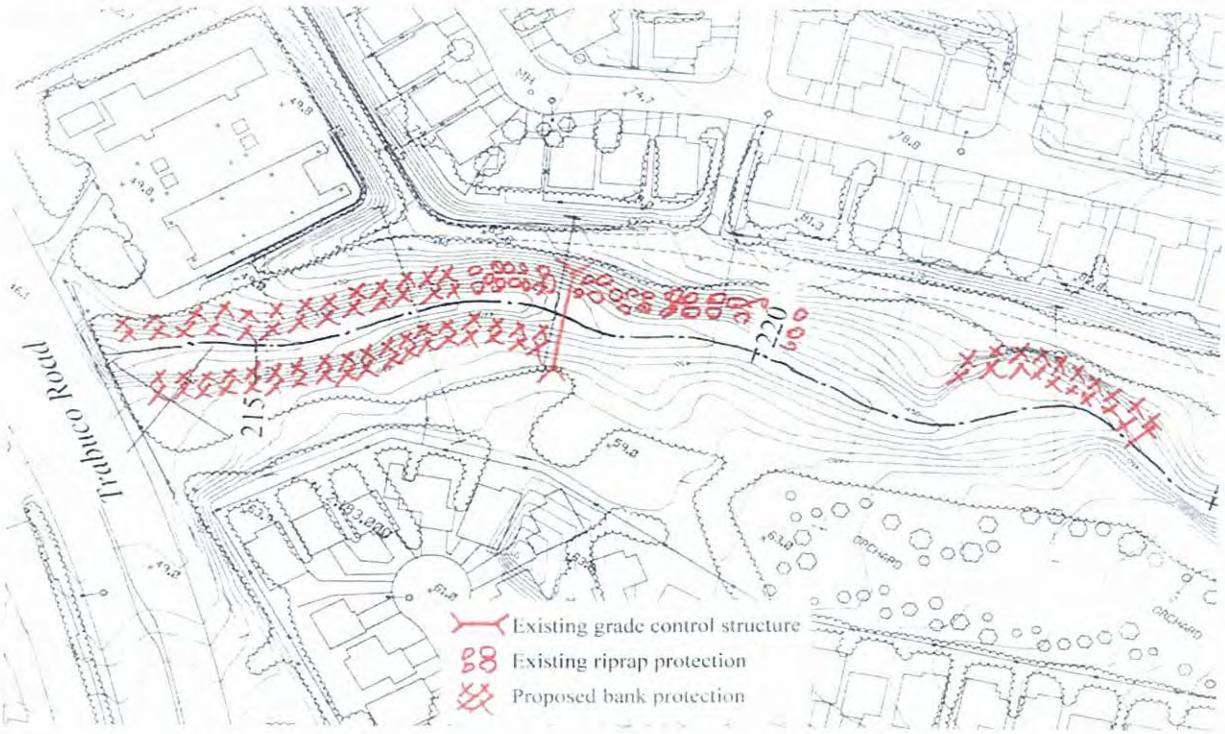


Fig. 39. Existing and proposed measures for channel stabilization

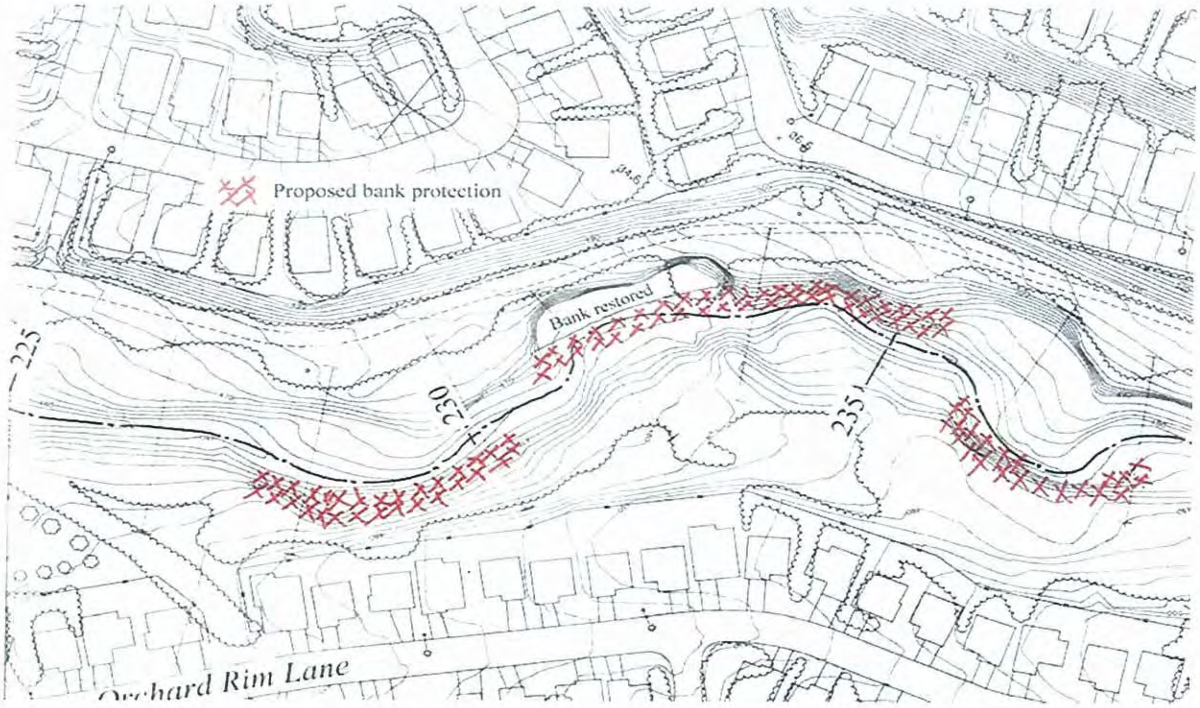


Fig. 39 (continued). Existing and proposed measures for channel stabilization

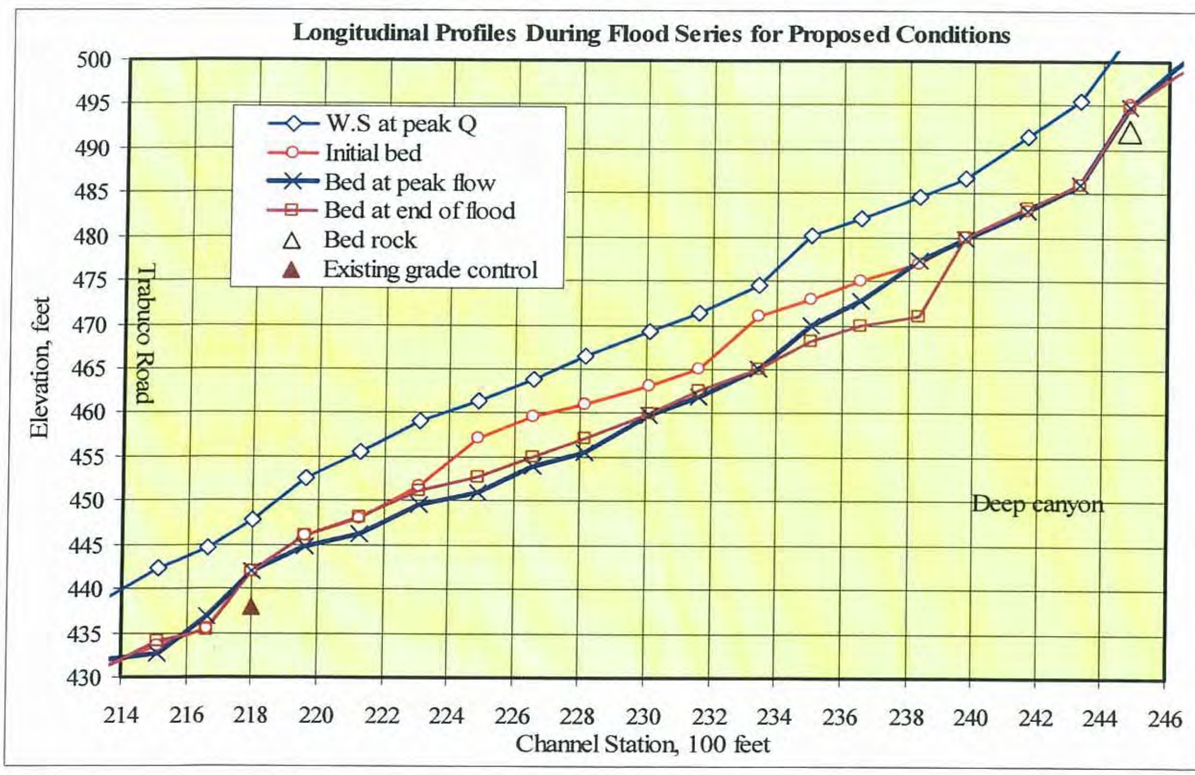


Fig. 40. Water-surface and channel bed profile changes
during flood series for proposed conditions

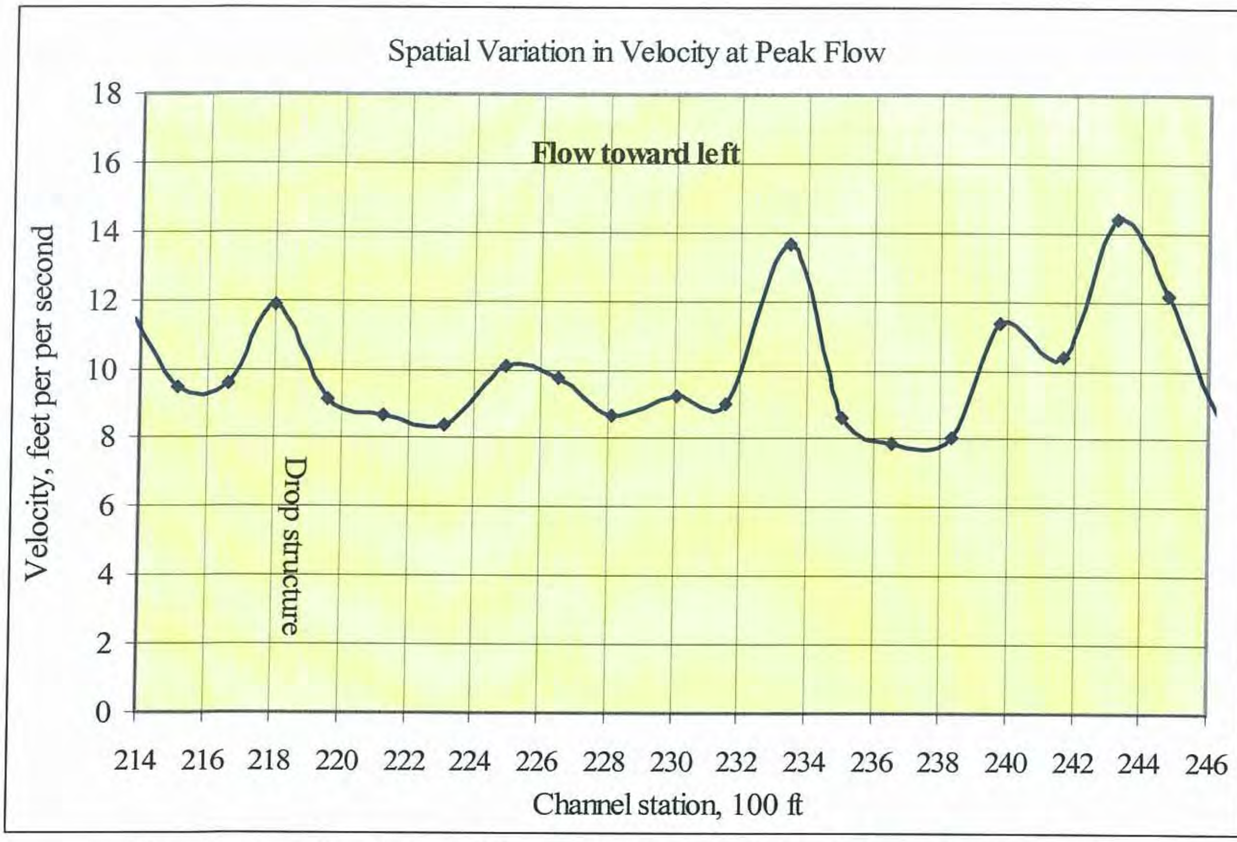


Fig. 41. Spatial variation of flow velocity at peak flood along channel reach.

Channel Reach between Stations 244+00 and 261+00 – This channel reach is highly incised resulting from channel-bed degradation. The present channel is now in a deep canyon as shown in Fig. 42. The existing housing development is primarily on the south channel bank, located high above the stream valley. Most of the channel bed is not visible because of dense vegetation growth in the valley.

This highly incised channel reach has relative stability because channel bed degradation along this reach is inhibited by bed rock or hard pan. Bank erosion and lateral migration is also limited by the tall bank height. A bank protection has already been installed on the concave south channel bank between stations 251+50 to 253+00. No further channel stabilization measures are recommended other than the existing bank armament that currently exists, but further improvements may be necessary to conform to OCFCD design standards and criteria if this channel reach is to be offered to OCFCD for ownership, operation, and maintenance.

Fig. 42. Topography of channel with existing channel bank protection

Channel Reach between Stations 261+00 and 275+00 – This channel reach along the Autumnwood development is highly incised resulting from channel-bed degradation. The present channel is now in a deep canyon. The existing Autumnwood housing development is on the south channel bank, located high above the valley floor. Unlike other downstream housing developments, the Autumnwood Development is located very close to the top of the channel bank; thus, it is vulnerable to bank erosion or lateral migration of the channel.

In consideration of the vulnerability of the housing development to channel instability, this channel reach will require major stabilization measures, which at the same time should also improve the site and reduce the safety hazard of a deep canyon. Based on these considerations, the following measures are recommended:

(1) Installation of a series of grade control structures,

(2) channel backfill by raising the bed profile to the crest elevation of the downstream drop structure,

(3) bank protection using geoweb in areas with velocities lower than 10 fps, and riprap bank protection in areas with velocities higher than 10 fps.

(4) required bank protection for the south bank but optional for the north bank,

(5) bank protection not needed if non-erodibility of bank material certified by a geotechnical engineer.

The details are given below.

A series of six grade control structures are recommended for use to stabilize the channel and to bring up the channel bed. The locations and crest elevations of the structures are shown in Fig. 43; they are also listed in Table 3 together with other hydraulic geometries. These rigid structures are about 12 feet in height, each having a crest length matching the local channel width at the crest elevation and a side slope of 2 to 1. The top of bank for each drop structure should maintain an adequate freeboard above the computed water surface elevation. These structures can be constructed with riprap or concrete.

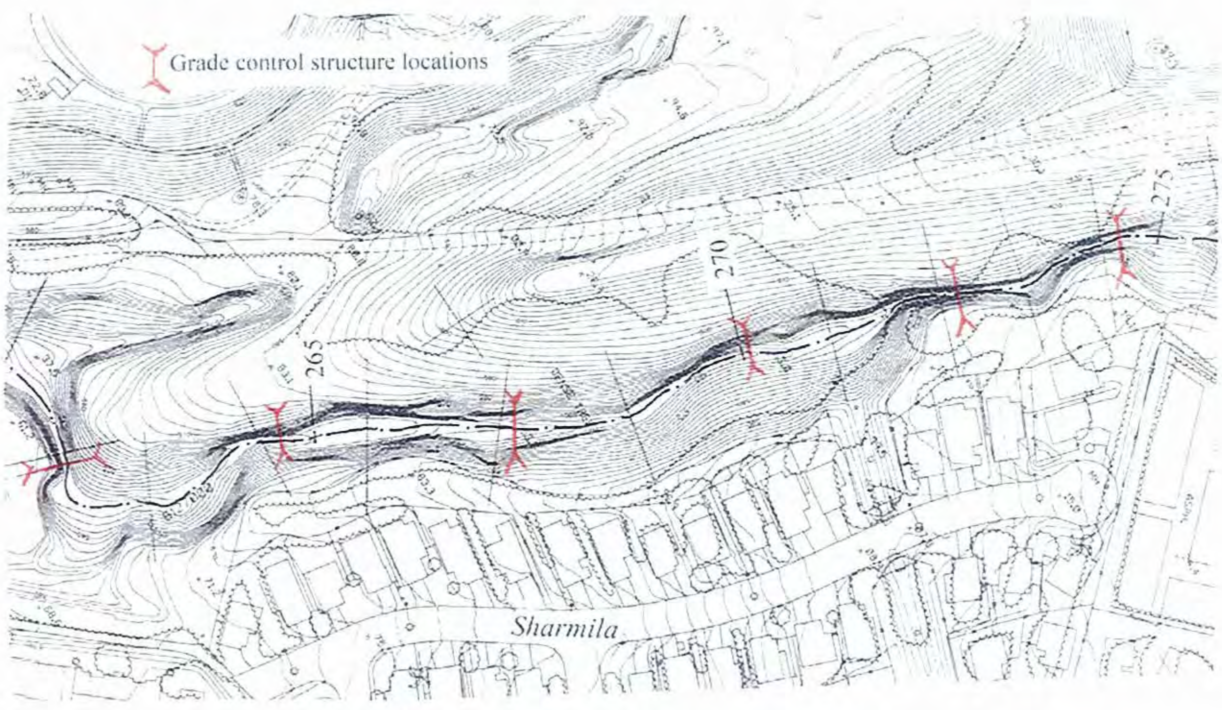


Fig. 43. Locations of grade control structures

Table 3. Hydraulic geometries for drop structures

Location 100 feet	Crest elevation feet	Length of crest feet	Top of bank elevation feet
261+80	544.0	24.0	553.9
264+60	558.0	40.0	566.3
267+30	569.0	52.0	576.5
270+10	583.0	80.0	589.2
272+55	595.0	22.0	605.1
274+55	256.3	20.0	613.1

Simulated water-surface and channel-bed profile changes along the channel reach with the proposed grade control structures are shown in Fig. 44. The grade control structures will reduce the channel slope and a flat slope will develop between two adjacent structures. The flat slope reflects the reduced sediment supply to Serrano Creek.

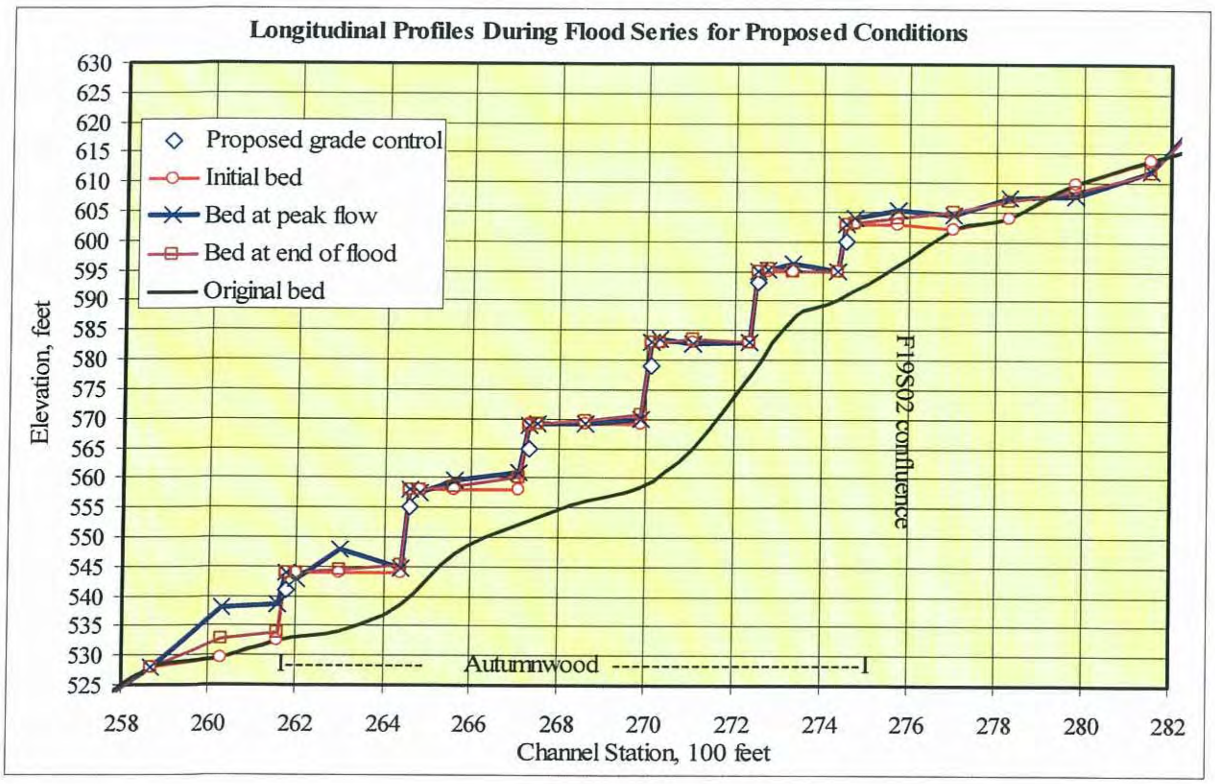


Fig. 44. Water-surface and channel bed profile changes along the Autumnwood channel reach

The computed spatial variation of flow velocity along the reach at the peak flow is shown in Fig. 45. Velocities at the crests of the structures are very high. However, the grade control structures will reduce the channel slope to slow down the flow velocity between two adjacent structures. Because of the lower velocities, the channel bank between two adjacent structures can be protected with geoweb or buried riprap. Buried riprap can be planted with willow and other native species. Geoweb or buried riprap is desirable from the environmental viewpoint since it will allow vegetation to develop.

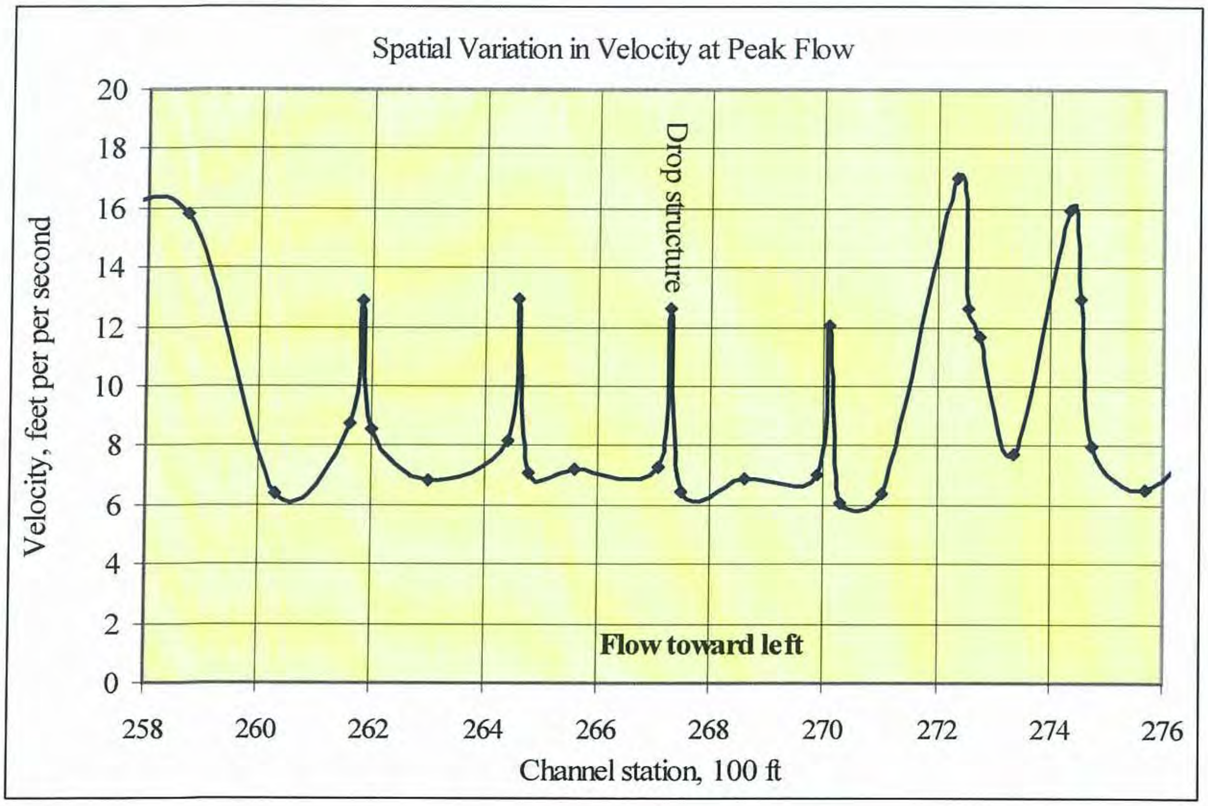


Fig. 45. Spatial variation of flow velocity at peak flood along the Autumnwood channel reach

Bank stabilization is recommended for the Autumnwood channel reach. It is necessary to provide bank protection of the south channel bank along the housing development but it is optional for the north bank since there exist no insurable structures in the vicinity of the north bank. However, protection of the north bank should eliminate a source of sediment for Lower San Diego Creek and Newport Back Bay. Without bank protection, the north channel bank is subject to potential erosion and retreat. Figs. 46 and 47 show simulated channel changes at two channel stations, where the channel bed is stabilized by the respective grade control structures but erosion occurs at the right (north) channel bank.

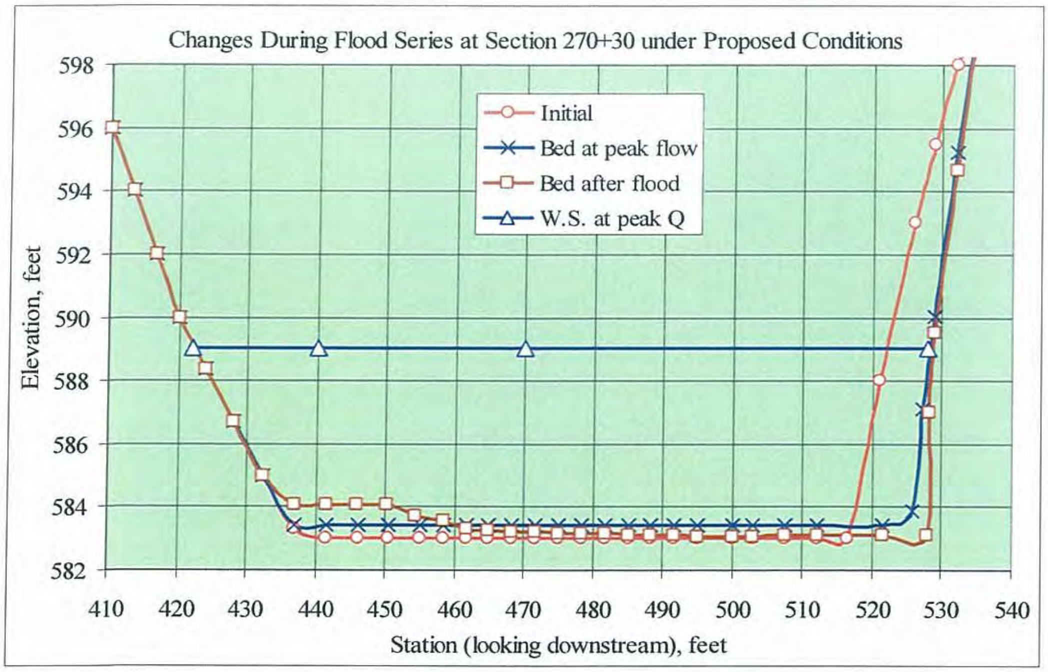


Fig. 46. Simulated channel changes at station 270+30 showing erosion of right bank

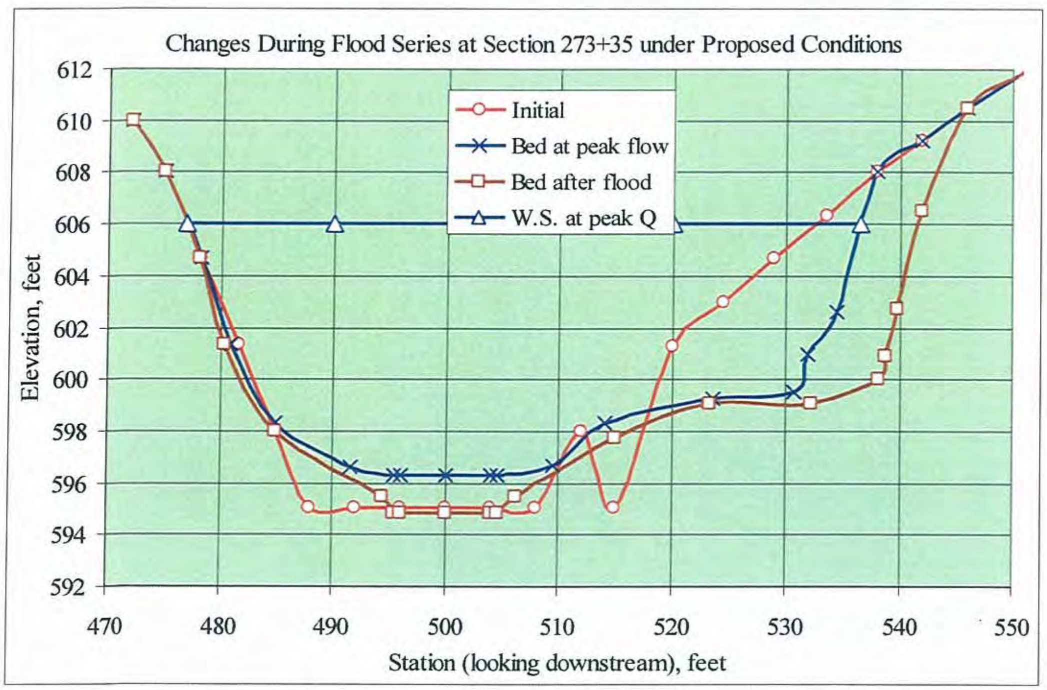


Fig. 47. Simulated channel changes at station 273+35 showing erosion of right bank

Channel Reach between Stations 276+00 and 291+00 – This channel reach is between the confluence of F19S02 and Dimension Drive. Serrano Creek along this reach has existing riprap drop structures and scattered bank protection. The channel bed is protected with grouted riprap at the Dimension Drive Bridge crossing.

This channel reach has a mild sinuosity and it is not as incised as other downstream channel reaches. There exists scattered riprap placed on the channel bank and two riprap drop structures located at stations 285+00 and 289+00, respectively. Several buildings located along the channel banks are not far from the stream channel. This channel reach has a steep slope and high velocities over 10 feet per second. The channel banks are subject to erosion. Analyses have been made to determine the feasibility for channel stabilization. The option of using drop structures has been analyzed and the findings are described below. Because of relatively shallow depth, tall drop structures will cause flood water to overflow the channel banks and therefore may not be used. A series of low drop structures will not substantially reduce the flow velocity.

The approximate locations of existing riprap bank protection, determined from field observation, are marked on the map in Fig. 48. Since engineering plans for such bank structures are not available, their adequacies need to be checked. Basically, a bank protection should be strong enough to withstand the force of flow and it should have adequate bank height and toe-down depth. Each drop structure should have sufficient bank height to avoid out flanking.

Under the existing conditions, the short channel reach near station 283+00 does not have sufficient capacity for the 100-yr flood. The computed water-surface elevation based on the existing channel geometry is higher than the top of the south bank as shown in Fig. 49. Existing buildings along the south bank are subject to flooding. A levee or a floodwall is needed to contain the design flood.

Simulated water-surface and channel-bed profile changes during the long-term flood series are shown in Fig. 50. For the long term, the flood level is expected to drop with future channel bed degradation. At station 283+00, the simulated peak water-surface elevation of 625 feet is more than 3 feet lower than the peak water surface under the existing channel geometry.

The recommended stabilization measures are as follows:

(1) Survey of existing bank protection and grade control structures and to determine if they meet the basic requirements.

(2) Construction of a floodwall along the south bank as protection for the existing buildings that are subject to flooding under existing conditions.

(3) Top priority for bank protection shall cover those areas most vulnerable to bank erosion and potential damages to adjacent properties. Such areas are marked on the map in Fig. 48.

(4) Bank protection plan for long-term channel stabilization shall cover the entire channel reach.

(5) Selection of the riprap size considering the flow velocity and its spatial variation shown in Fig. 51.

The recommended bank stabilization for this reach is the use of heavy materials that are resistant to erosion by high flow velocities. This can be heavy duty riprap, soil cement, concrete, sheet piles, mechanically stabilized earth, etc. The toe of bank protection must entrench beyond the potential channel bed scour. The top of bank protection should extend above the 100-yr water surface with an adequate freeboard.

Computed water-surface and channel bed profile changes along the channel reach are shown in Fig. 50. The water-surface and channel bed elevations are also listed in Table 2.

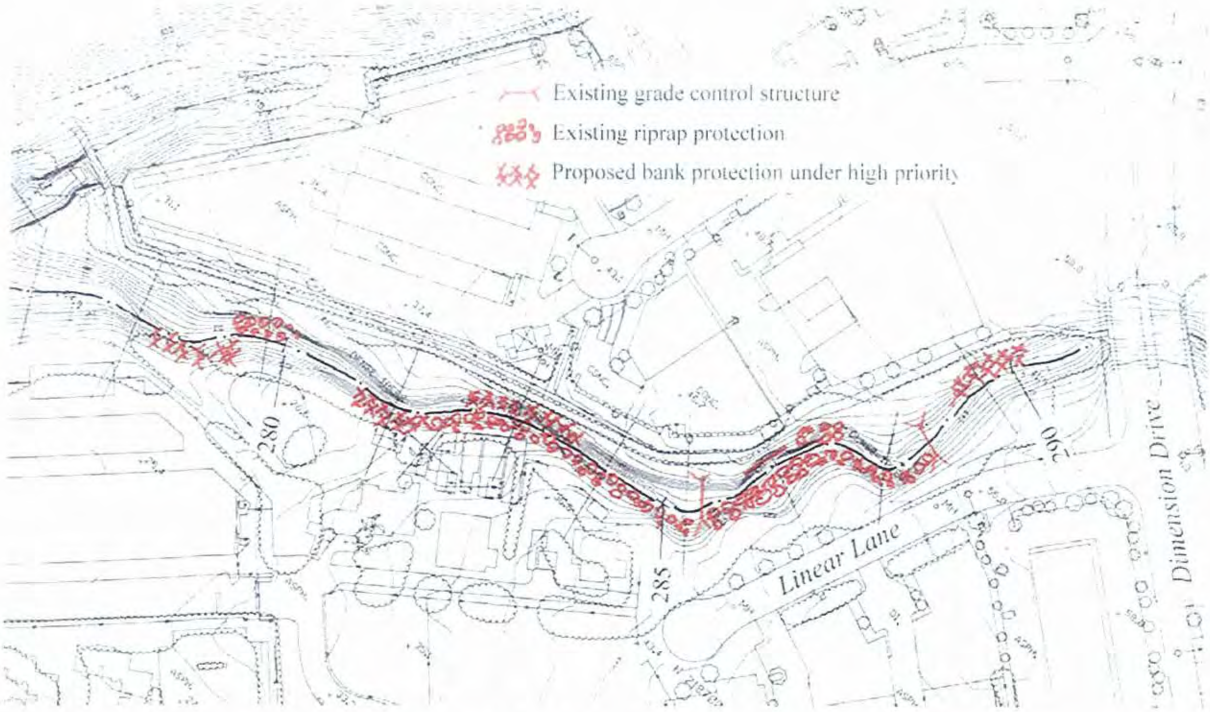


Fig. 48. Topography of channel reach with existing and proposed stabilization measures

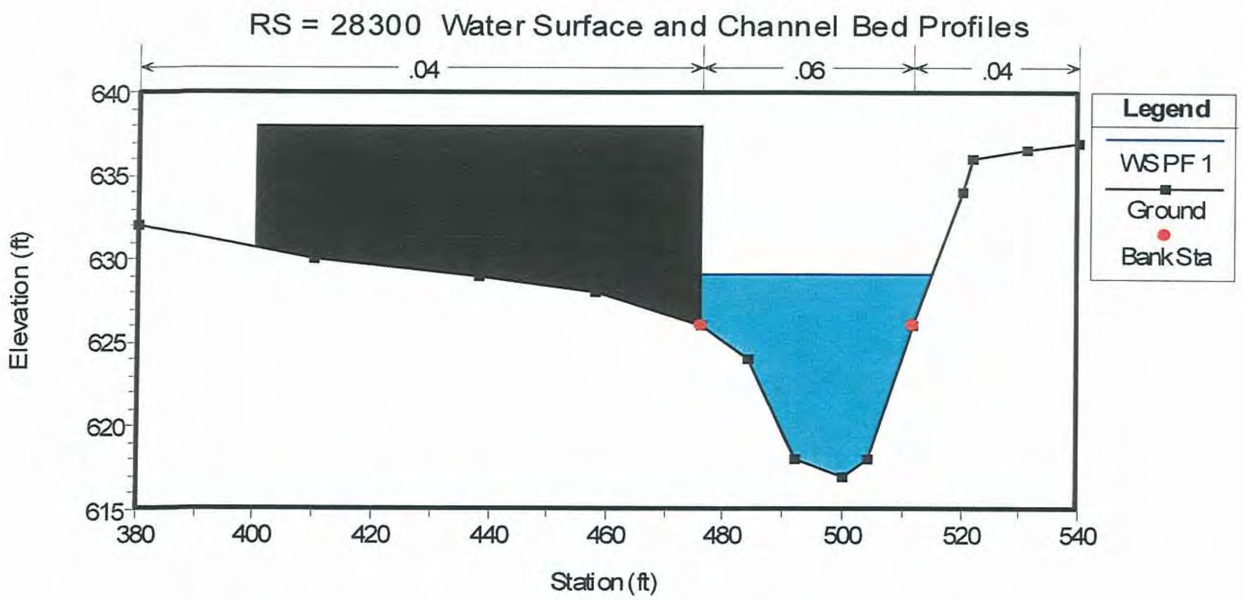


Fig. 49. Cross-sectional profile at channel station 283+00 showing existing building on left bank subject to flooding

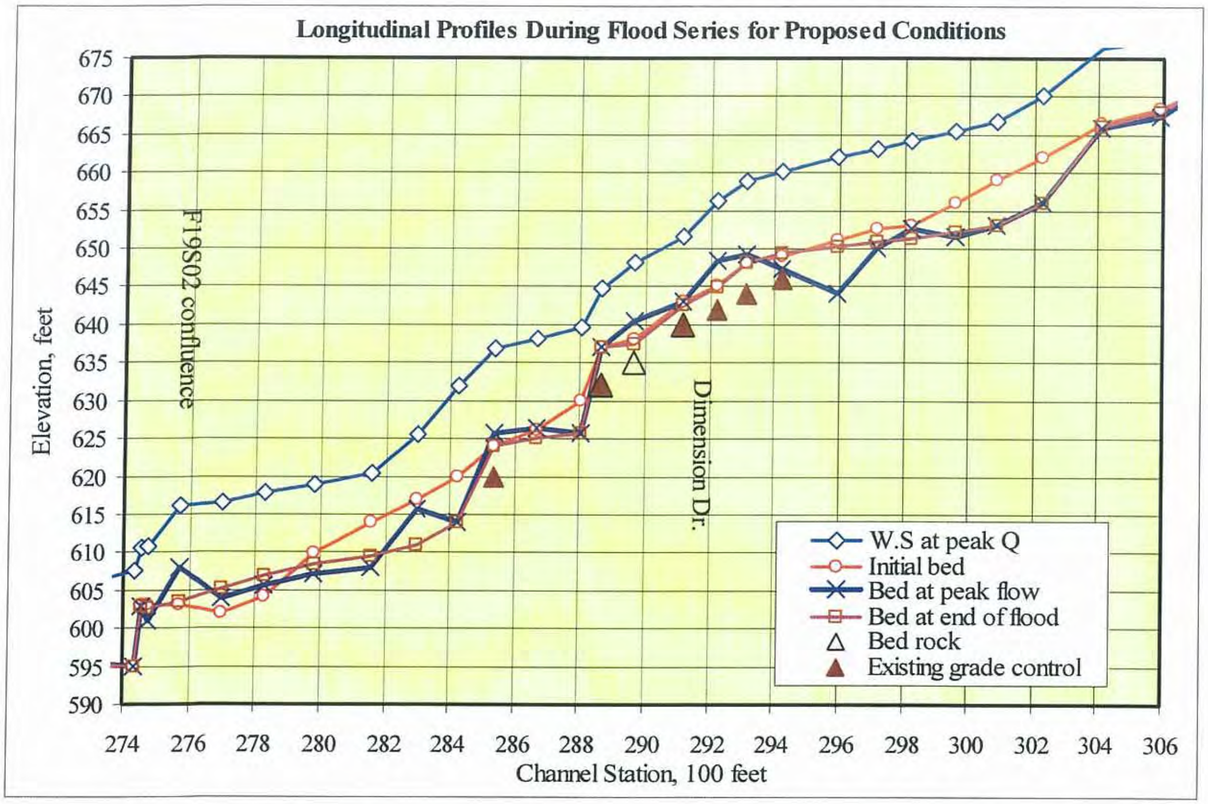


Fig. 50. Water-surface and channel-bed profile changes along channel reach

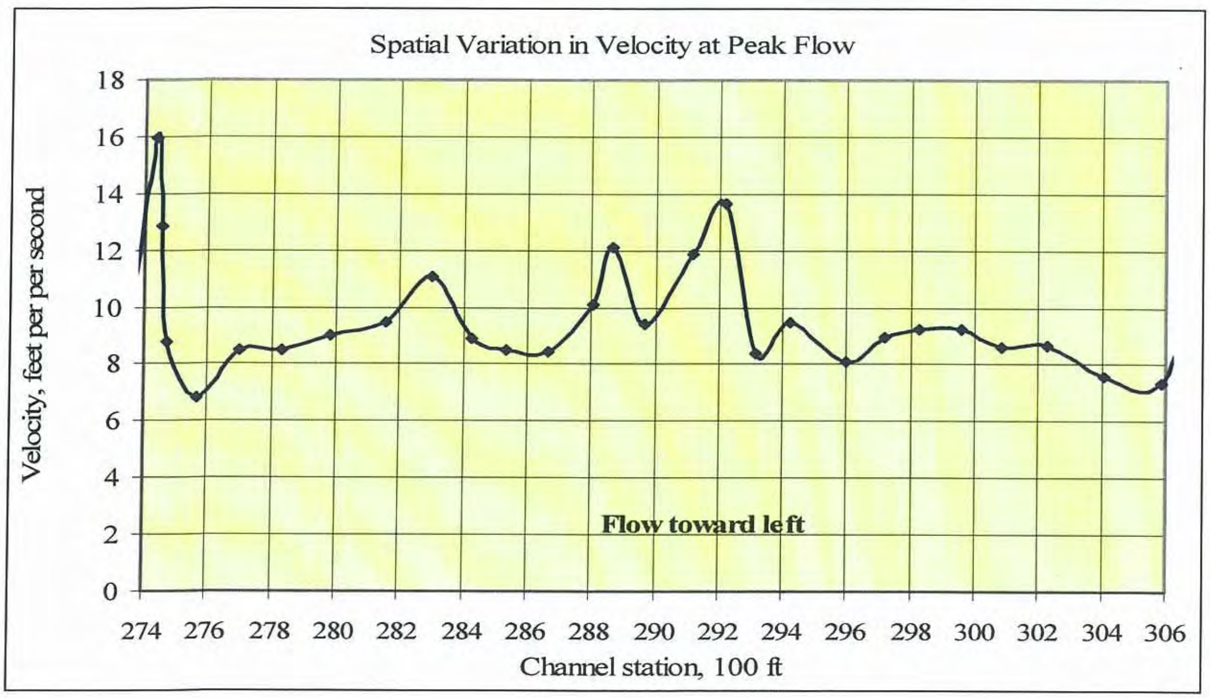


Fig. 51. Spatial variation of flow velocity at peak flood along channel reach

Channel Reach between Stations 291+00 and 308+00 – This channel reach is between Dimension Drive and the nursery access road; it has a mild sinuosity and it is not as incised as other downstream channel reaches. This channel reach has the capacity for the design flood. However, the FIRM map shows flooding of the overbank area as discussed on page 35. This is because the existing culvert under the nursery access road does not have the capacity for the 100-yr flood and floodwater overflowing the nursery access road can not enter the channel but it will flood the south overbank area of this reach. Such overbank flooding will be eliminated by improvements of the nursery access road together with a new bridge or larger culverts to pass the 100-yr flood through the road crossing. The existing channel has grouted riprap protection of the channel boundary at both ends of the channel reach. Water-surface and channel-bed profile changes for this reach are shown in Fig. 50; spatial variation of flow velocity at the peak flow is shown in Fig. 51.

This channel reach has a steep slope and high velocities over 10 feet per second. Because of relatively shallow depth, tall drop structures will cause floodwater to overflow the channel banks and therefore may not be used. A series of low drop structures will not substantially reduce the flow velocity.

The channel banks are subject to erosion. This reach has buildings located along the south bank but hill slope along the north bank. Since the buildings on the south bank are also close to the channel, they can be affected by long- term bank erosion or lateral migration. Several buildings located along the south channel bank are not far from the stream channel. Riprap bank protection has already been installed along certain concave banks that are vulnerable to erosion.

The approximate locations of existing riprap bank protection, determined from field observation, are marked on the map in Fig. 48. Since engineering plans for such bank structures are not available, their adequacies need to be checked. Basically, a bank protection should be strong enough to withstand the force of flow and it should have adequate bank height and toe-down depth. The drop structures should have sufficient bank height to avoid out flanking.

Since the buildings on the south bank are also close to the channel. They can be affected by long-term bank erosion or lateral migration. The recommendation is to install riprap bank protection along the south channel bank. The recommended stabilization measures are as follows:

(1) Survey of existing bank protection and grade control structures and to determine if they meet the basic requirements.

(2) Top priority for bank protection shall cover those areas most vulnerable to bank erosion and potential damages to adjacent properties. Such areas are marked on the map in Fig. 52.

(3) Bank protection plan for long term channel stabilization shall cover the south channel bank for the channel reach.

The recommended bank stabilization for this reach is the use of heavy materials that are resistant to erosion by high flow velocities shown in Fig. 50. This can be heavy-duty riprap, soil cement, concrete matt such as for armorflex, Vmax, etc. The toe of bank protection must entrench beyond the potential channel bed scour. The top of bank protection should extend above the 100-yr water surface.

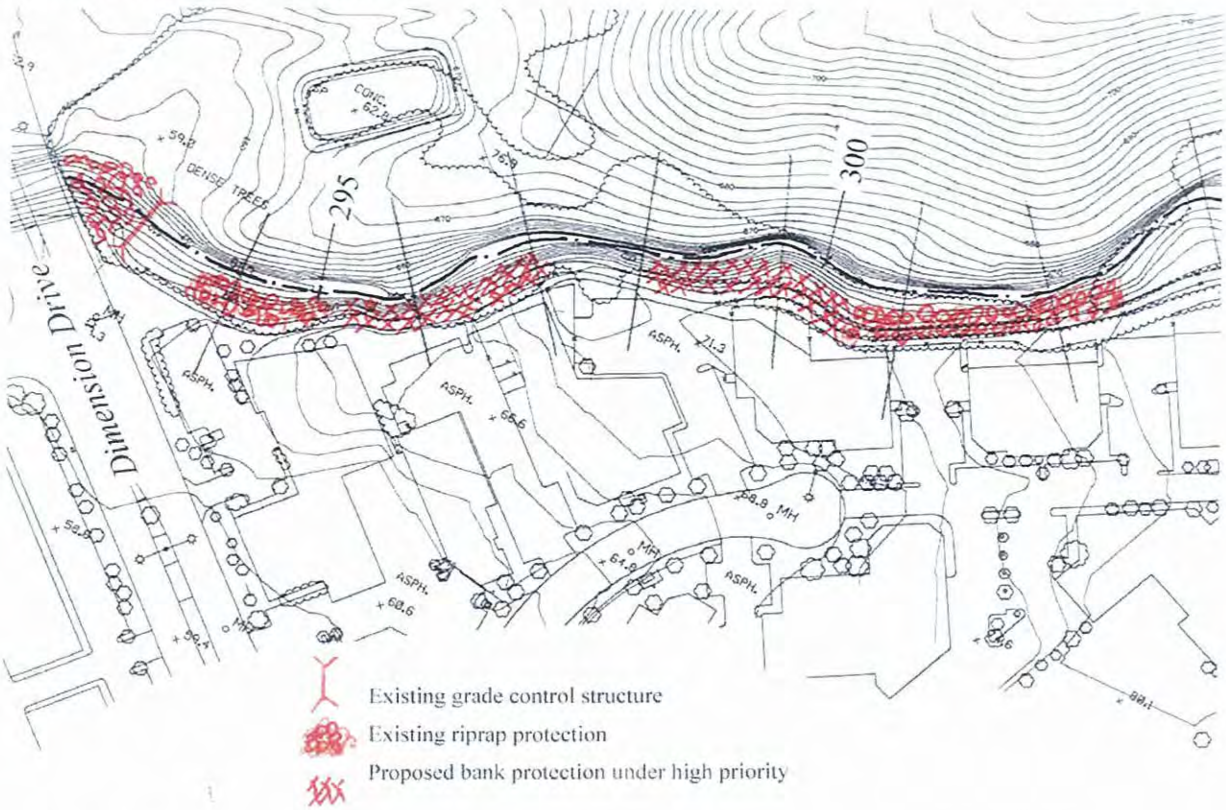


Fig. 52. Topography of channel reach with existing and proposed stabilization measures

Channel Reach between Stations 308+00 and 334+60 – This channel reach is between the nursery access road and Lake Forest Drive culverts; it has grouted riprap protection of the channel boundary at both ends of the channel reach. The channel also has two concrete grade control structures at stations 319+75 and 327+80, respectively. A topographic map for this channel reach is shown in Fig. 2 on page 12.

This channel reach does not have the capacity for the design flood near the nursery access road. The earth channel is subject to erosion changes. The existing grade control structures do not have sufficient bank height to contain the 100-yr flood and therefore they are subject to overtopping or out-flanking. In summary, channel stabilization of this reach for flood control will require considerable improvements.

Existing buildings along the channel reach are located on the south side of the channel; they are separated from the channel bank by a comfortable distance. At this time, no insurable structures are subject to flooding or erosion damages by the stream channel. In order to provide flood control and maintain channel stability, improvements of this channel reach will include the following items:

(1) Channel improvements: Most of the channel reach under existing conditions does not have sufficient capacity to contain the 100-yr flood. The channel needs to be enlarged to the 100-yr standard. The proposed channel has a bed width of 34 feet and 2 (horizontal) to 1 (vertical) side slope. The longitudinal slope is 0.006. It will maintain a soft bed with bank protection and grade control structures for scour protection. Simulated water-surface profile and channel-bed profile changes along the channel reach are shown in Fig. 53. The spatial variation of velocity at the peak flow is shown in Fig. 54. The north overbank area is the nursery, which has a lower terrain than the south overbank area. The north overbank area adjacent to the channel can be raised to stay above the computed 100-yr flood level in the channel. Otherwise, the bank protection along the north side needs to be designed as a levee.

(2) Channel stabilization: Bank protection and three grade control structures are recommended for scour protection. Recommended top-of bank elevations listed in Table 2 include a freeboard above the computed 100-yr water surface. Hydraulic geometries for the grade control structures are summarized as listed in Table 4. Materials for bank

protection may be selected based on the velocity distribution shown in Fig. 53. The grade control structures are rigid structures designed to resist the high flow velocities. The channel within 20 feet of a grade control structure requires riprap bank protection. Loose riprap should also be placed on the channel bed just downstream of a grade control. For the remaining channel reaches, the computed velocities are about 8 feet per second for which geoweb can be used effectively for scour protection of the channel banks.

(3) New bridge or box culverts at the nursery access Road: The existing dip crossing/culvert at the nursery access road does not have the capacity for the 100-yr flood. In order to pass the 100-yr flood within the channel, the existing crossing needs to be replaced by a bridge or box culverts with the 100-yr flow capacity. The bridge is expected to have a single span. In the case of box culverts, three 12' by 7' (12 feet wide and 7 feet high, not 7 by 12) boxes will be required. For the proposed hydraulic improvements, the nursery access road at the bridge or culvert crossing needs to be rebuilt but the adjacent road does not need to be raised.

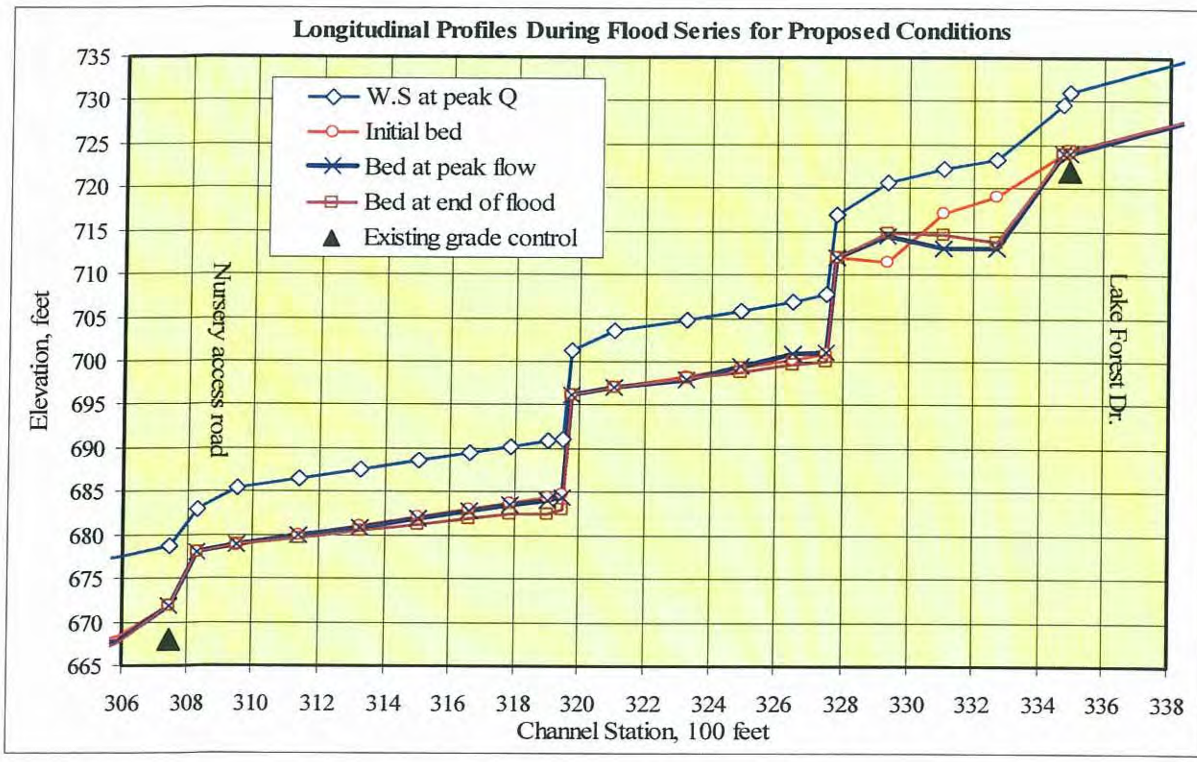


Fig. 53. Simulated water-surface profile and channel-bed profile changes along the channel reach

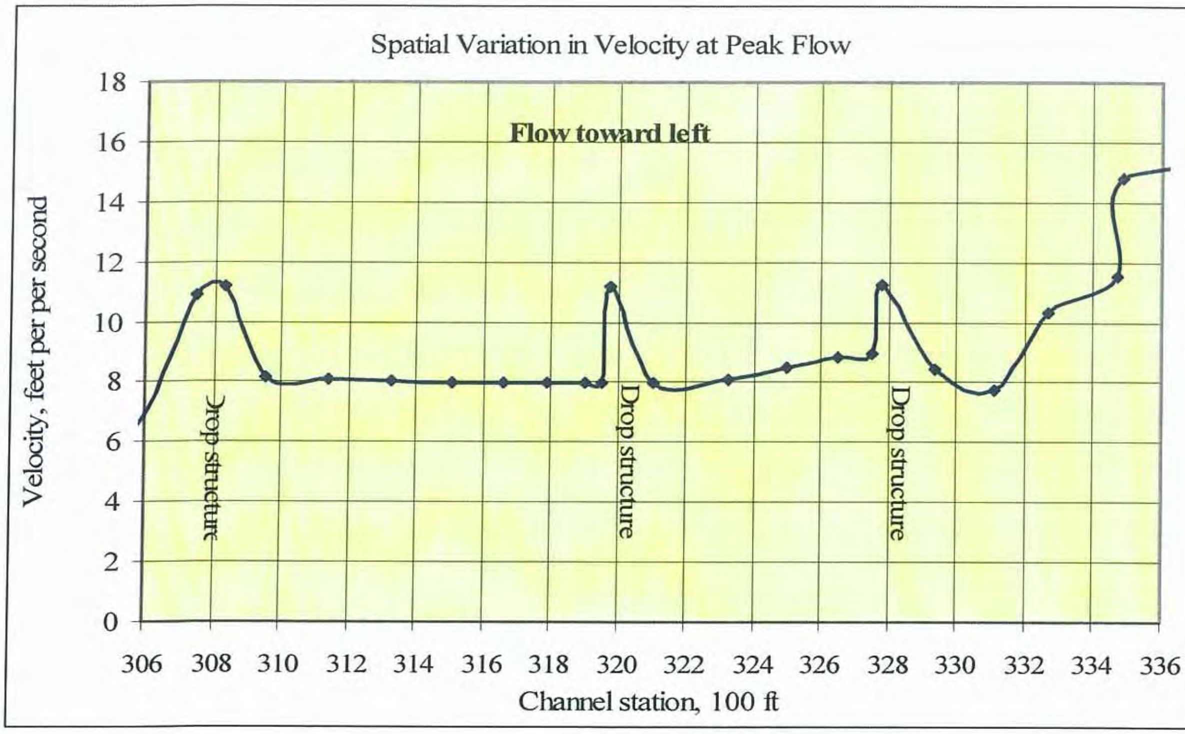


Fig. 54. Spatial variation of velocity at the peak flow

Table 4. Hydraulic geometries for grade control structures

Location feet	Crest elevation Feet	Length of crest feet	Top of bank elevation Feet
308+30	676.5	34.0	685.0
319+75	696.2	34.0	703.2
327+80	712.0	34.0	719.0

Impacts of Proposed channel Stabilization Works on Sediment Delivery – Sediment delivery is the cumulative amount of sediment that is delivered passing a river section in a specified period of time. In order to assess the long-term impacts of the proposed channel works on sediment delivery, the computed spatial variations for sediment delivery during the flood series for the existing and proposed conditions are compared as shown graphically in Fig. 55. The proposed channel works modifies the flow pattern, which in turn changes sediment transport and delivery.

The major difference in delivery is along the Autumnwood reach from station 261+00 to 275+00, and along the reach from station 308+00 at the nursery access road to station 330+00 at Lake Forest Drive. For the existing conditions, the major variations in sediment delivery indicate erosion just below Lake Forest Drive and deposition above the nursery access road. But for the proposed conditions, the changes in delivery along this reach become very small, indicating approximate sediment balance since sediment inflow to the reach is equal approximately to the outflow. For the proposed conditions, sediment delivery will also have approximate balance through the Autumnwood channel reach. Two options for bank protection are proposed for the Autumnwood channel reach: bank protection of the south channel and protection of both channel banks. The sediment deliveries of these two options are only slightly different as depicted in the figure.

The comparison also shows that the proposed channel stabilization will result in a reduction of sediment delivery toward the channel reach downstream of Trabuco Road (Reach 1). In the previous fluvial study for Reach 1, a sediment inflow of 32,500 tons was assumed at the time since the sediment transport through the upper reaches was not determined. Now, the computed sediment delivery to Reach 1 of 67,000 tons is greater than the value assumed in the previous study. This means, the previous study was based on a conservative assumption for the sediment inflow for Reach 1. However, it would be desirable to update the study for Reach 1 using the more accurate sediment inflow and make necessary changes to the original recommendations if necessary.

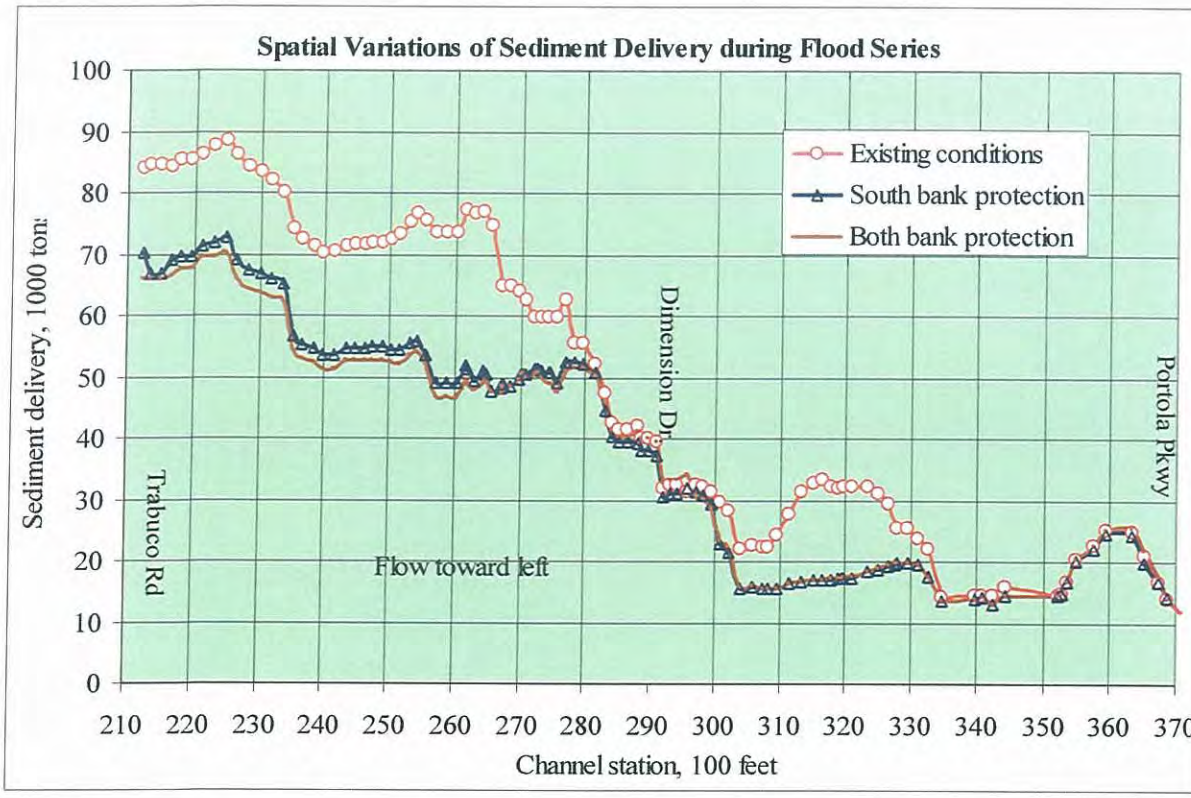


Fig. 55. Comparison of sediment deliveries for the existing and proposed conditions

VIII. HEC-RAS MODELING FOR CHANNEL WITH IMPROVEMENTS

The hydraulics of flow in the channel with improvements has also been modeled using the HEC-RAS program developed by the U. S. Army Corps of Engineers. A folder for the HEC-RAS computer files is submitted as an attachment to the report. A summary of computed hydraulic parameters is given in Table 5. The computed 100-yr water-surface elevations are shown in Fig. 56 together with the channel bed profile.

The HEC-RAS model is a fixed boundary model while the FLUVIAL-12 model is an erodible boundary model. In other words, the computation for the HEC-RAS model is based on the initial channel boundary and it does not consider potential channel changes during future floods. Since Serrano Creek has undergone changes in the past and it will also change in the future, the computed flow velocities and water-surface profiles using these two models, HEC-RAS and FLUVIAL-12, are not the same but only similar.

The channel reach of Serrano Creek from Trabuco Road to station 261+50 is incised or highly incised. The 100-yr water-surface elevations computed using HEC-RAS in Table 5 and Fig. 56 are well below the adjacent roads and buildings. The channel reach along the Autumnwood development from station 261+50 to station 275+00 is highly incised at this time. The series of grade control structures as proposed will raise the channel bed and the water-surface profile. However, the computed 100-yr water-surface profile will be totally contained in the channel and no insurable structure will be subject to flooding. As a follow up of this project, the HEC-RAS model from this study may be used to apply for a FEMA Letter of Map Revision (LOMR).

For the channel reach above the Autumnwood development, the stabilization project with the proposed improvements will not impact the flood level since only bank protection is proposed. The computed 100-yr water surface is contained in the channel except at the following locations:

(1) A short reach near station 283+00, and

(2) A reach from the nursery access road and further upstream.

For these locations, measures for flood control and stabilization are provided in the report.

Table 5 lists the computed results from the HEC-RAS model. Symbols used in the table are defined below:

Q Total: The BASE FLOOD (100-yr flood) discharge;

Min Ch El: Minimum channel bed elevation or the invert elevation at a channel station;

W.S. Elev: Computed water-surface elevation;

Vel Chnl: Velocity of flow in the channel;

Top Width: Width of channel at water surface; and

Froude #: Froude number.

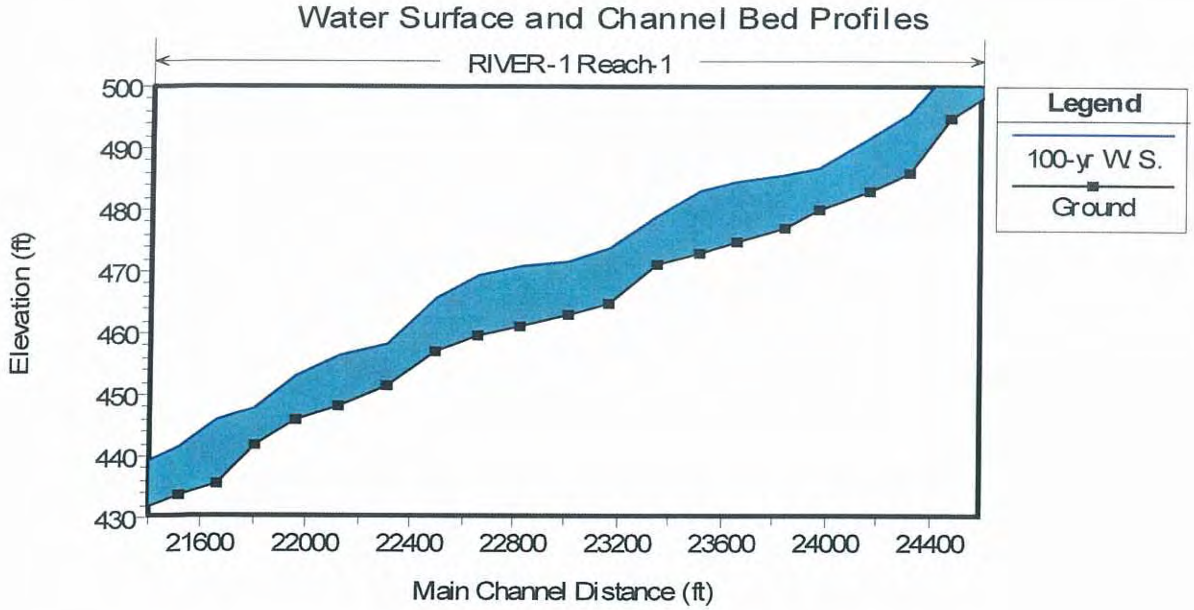
Table 5. Summary of hydraulic parameters

River Sta	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Top Width (ft)	Froude #
37085	2250	796.00	799.24	7.85	149.82	1.00
37055	2250	789.90	794.27	8.25	74.44	0.76
36860	2250	787.90	792.30	9.80	65.82	0.92
36795	Bridge					
36730	2250	786.90	791.09	10.42	64.55	1.00
36530	2250	780.80	786.37	3.85	194.04	0.39
36330	2250	778.80	784.98	4.24	271.27	0.53
35930	2250	771.60	777.22	8.57	116.12	1.00
35750	2250	769.00	774.99	5.33	128.14	0.52
35500	2250	765.70	772.31	6.54	102.45	0.63
35355	2250	762.50	772.30	2.81	140	0.21
35270	2250	762.40	772.29	2.57	107.00	0.16
35235	2250	758.00	767.85	16.32	14.00	0.92
34835	Bridge					
34435	2450	748.00	757.83	17.81	14.00	1.00
34250	2450	745.00	753.28	7.12	57.00	0.51
34090	2450	745.00	750.70	11.82	47.78	1.00
34000	2450	727.00	735.44	11.63	24.99	0.71
33976	2450	724.70	736.03	8.67	24.96	0.45
33789	Culvert					
END OF EXISTING CONDITIONS						
START OF IMPROVED CONDITIONS						
33490	2450	722.00	728.83	14.39	24.96	0.97
33470	2450	722.00	729.76	10.59	49.97	0.78
33270	2450	719.00	727.07	10.81	78.68	0.82
33110	2450	717.00	724.04	11.46	75.57	0.77
32935	2450	711.50	720.78	12.34	55.33	0.86
32780	2450	712.00	716.90	11.42	53.60	1.01
32750	2450	700.80	707.24	8.12	59.74	0.64
32650	2450	700.20	706.65	8.09	59.81	0.63
32495	2450	699.30	705.74	8.12	59.74	0.64
32325	2450	698.30	704.72	8.14	59.69	0.64
32105	2450	697.00	703.38	8.22	59.50	0.65
31975	2450	696.20	701.10	11.42	53.60	1.01
31950	2450	684.70	691.12	8.15	59.69	0.64
31900	2450	684.40	690.82	8.14	59.70	0.64

River Sta	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Top Width (ft)	Froude #
31785	2450	683.70	690.16	8.09	59.83	0.63
31660	2450	683.00	689.38	8.22	59.51	0.65
31505	2450	682.00	688.50	8.02	60.00	0.63
31325	2450	681.00	687.42	8.15	59.67	0.64
31140	2450	679.90	686.31	8.17	59.62	0.64
30955	2450	678.80	685.16	8.24	59.45	0.65
30872	2450	676.70	684.77	7.99	38.00	0.50
30851	Culvert					
30830	2450	676.50	681.54	12.80	38.00	1.00
END OF IMPROVED CONDITIONS						
30745	2450	671.80	679.85	8.69	55.26	0.68
30590	2450	668.30	677.12	9.73	51.07	0.71
30410	2450	666.50	676.06	6.16	86.70	0.44
30225	2450	662.00	671.92	12.29	44.07	0.97
30085	2450	659.00	670.19	6.79	60.39	0.44
29960	2450	656.00	668.52	9.27	40.38	0.57
29825	2450	653.00	665.51	11.61	30.95	0.78
29715	2450	652.50	663.57	10.26	36.54	0.70
29595	2450	651.00	661.93	9.07	49.82	0.65
29425	2450	649.00	658.79	10.14	53.64	0.75
29315	2450	648.00	656.14	10.58	54.44	0.89
29267	Bridge					
29220	2450	645.00	654.24	8.51	55.77	0.63
29115	3150	643.00	651.44	12.61	57.80	0.94
28965	3150	638.00	647.65	10.64	58.77	0.74
28865	3150	637.00	644.67	12.26	55.13	1.00
28805	3150	630.00	639.54	13.12	48.52	0.91
28665	3150	626.00	635.44	13.03	49.22	0.97
28535	3150	624.00	635.49	6.32	67.92	0.39
28425	3150	620.00	632.12	13.90	41.38	0.84
28300	3150	617.00	629.78	8.56	100.43	0.51
28155	3150	613.90	624.93	14.89	30.87	1.00
27980	3150	609.80	618.71	13.43	42.64	1.01
27830	3150	604.00	616.35	8.21	56.12	0.53
27700	3150	602.00	614.38	10.12	51.19	0.66
27570	3450	603.00	615.10	3.04	128.25	0.17
27475	3450	603.00	611.75	13.85	42.85	1.00
27455	3450	603.00	610.54	13.04	50.17	1.00

River Sta	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Top Width (ft)	Froude #
27435	3450	595.00	607.22	16.38	26.15	0.99
27335	3450	595.00	607.22	7.02	60.09	0.41
27275	3450	595.00	603.44	15.20	31.92	1.00
27255	3450	595.00	602.59	13.47	45.52	1.00
27235	3450	583.00	595.05	17.20	22.08	1.01
27105	3450	583.00	589.07	6.39	99.32	0.48
27030	3450	583.00	587.93	8.00	95.93	0.66
27010	3450	583.00	586.76	10.72	91.28	1.01
26990	3450	569.00	577.77	7.82	63.51	0.51
26860	3450	569.00	576.73	7.68	70.75	0.53
26750	3450	569.00	575.29	8.70	70.62	0.65
26730	3450	569.00	573.90	11.85	66.71	1.00
26710	3450	558.00	567.94	8.11	53.75	0.51
26560	3450	558.00	566.89	7.64	57.92	0.48
26480	3450	558.00	564.03	12.82	51.26	0.99
26460	3450	558.00	563.69	12.49	57.07	1.00
26440	3450	544.00	554.64	15.00	33.28	1.01
26300	3450	544.00	555.44	4.81	81.55	0.28
26200	3450	544.00	553.08	11.51	45.19	0.79
26180	3450	544.00	551.57	15.02	46.72	0.96
26160	3450	532.50	546.37	16.04	27.35	1.00
26030	3450	529.50	545.12	4.35	72.95	0.23
25870	3450	528.00	540.36	16.08	27.11	1.01
25705	3450	520.00	531.13	14.81	34.34	1.00
25560	3450	515.00	526.27	12.72	45.14	0.91
25415	3450	512.00	521.20	13.97	40.76	1.00
25305	3450	508.00	519.14	6.45	80.34	0.42
25165	3450	506.50	518.92	4.80	84.02	0.27
25035	3450	505.00	518.03	7.19	59.12	0.42
24885	3450	502.00	513.46	14.85	34.11	1.00
24745	3450	501.00	509.56	7.20	132.25	0.58
24620	3450	498.50	507.39	9.13	70.71	0.69
24480	3450	495.00	503.15	12.36	59.81	1.01
24325	3450	486.00	495.37	14.51	36.62	1.00
24165	3450	483.00	491.40	10.47	53.70	0.73
23975	3450	480.00	486.55	11.83	68.50	0.99
23835	3450	477.00	485.38	6.91	99.36	0.52
23655	3450	475.00	484.44	5.74	121.83	0.40

River Sta	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Top Width (ft)	Froude #
23505	3450	473.00	482.87	8.26	83.12	0.57
23345	3450	471.00	478.72	12.52	56.70	1.00
23160	3450	465.00	473.54	8.29	78.68	0.61
23010	3450	463.00	471.44	8.77	77.33	0.69
22815	3450	461.00	470.69	5.05	114.59	0.36
22655	3450	459.50	469.35	7.38	109.36	0.52
22490	3450	457.00	465.44	11.88	66.86	1.00
22310	3450	451.60	458.21	8.23	96.04	0.69
22125	3450	448.00	456.32	6.76	101.04	0.53
21960	3450	446.00	452.93	10.50	72.81	0.87
21800	3450	442.00	447.75	11.92	66.65	1.01
21660	3450	435.50	445.78	8.54	62.59	0.59
21510	3450	433.60	441.63	12.74	54.31	1.01
21350	3450	431.00	438.06	12.06	63.50	1.00



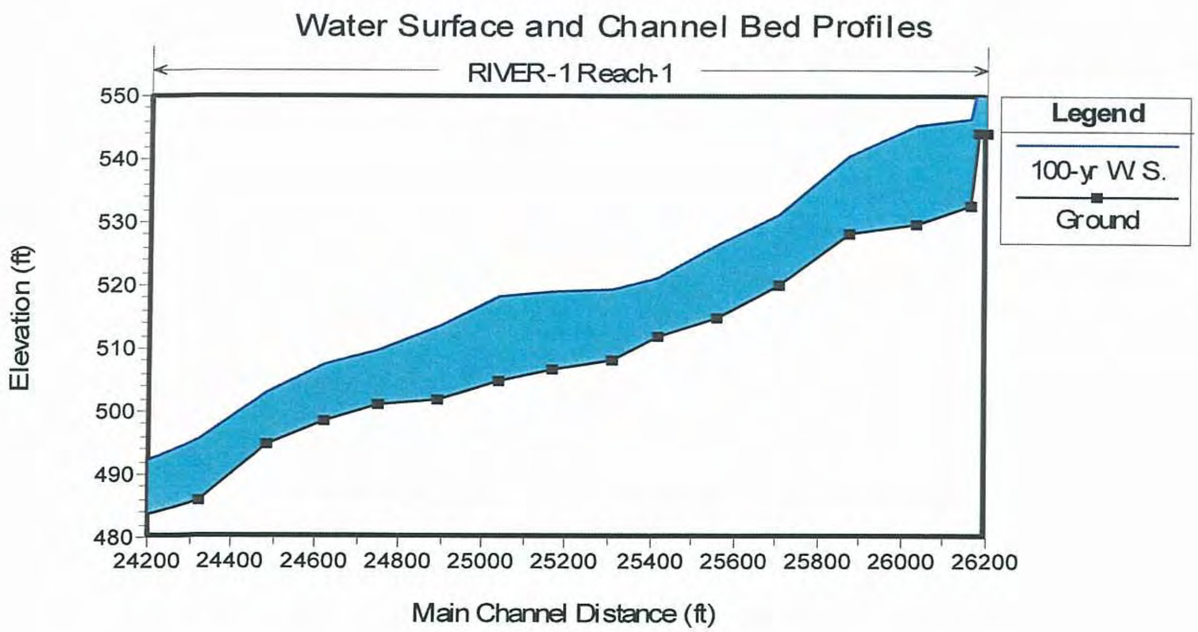
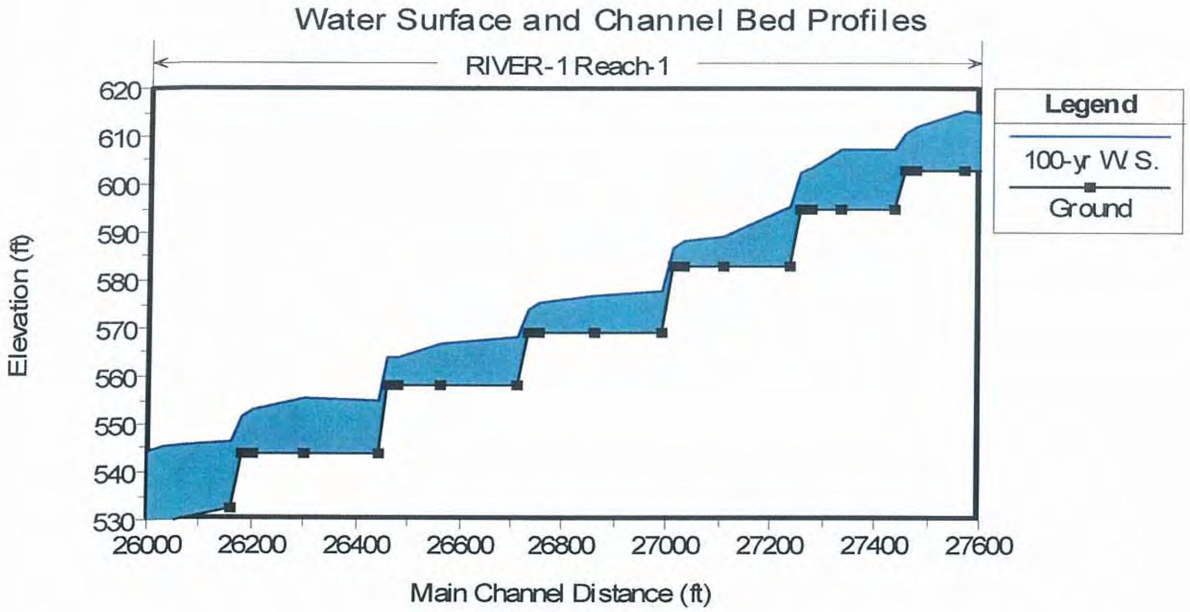


Fig. 56. Water-surface and channel bed profiles from the HEC-RAS model



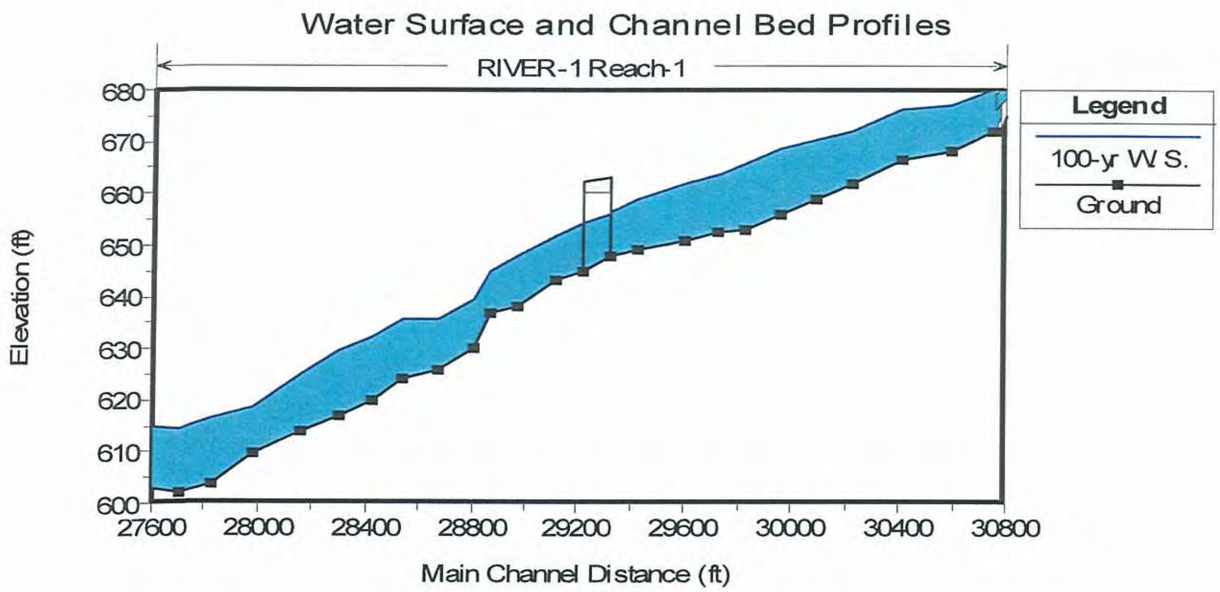
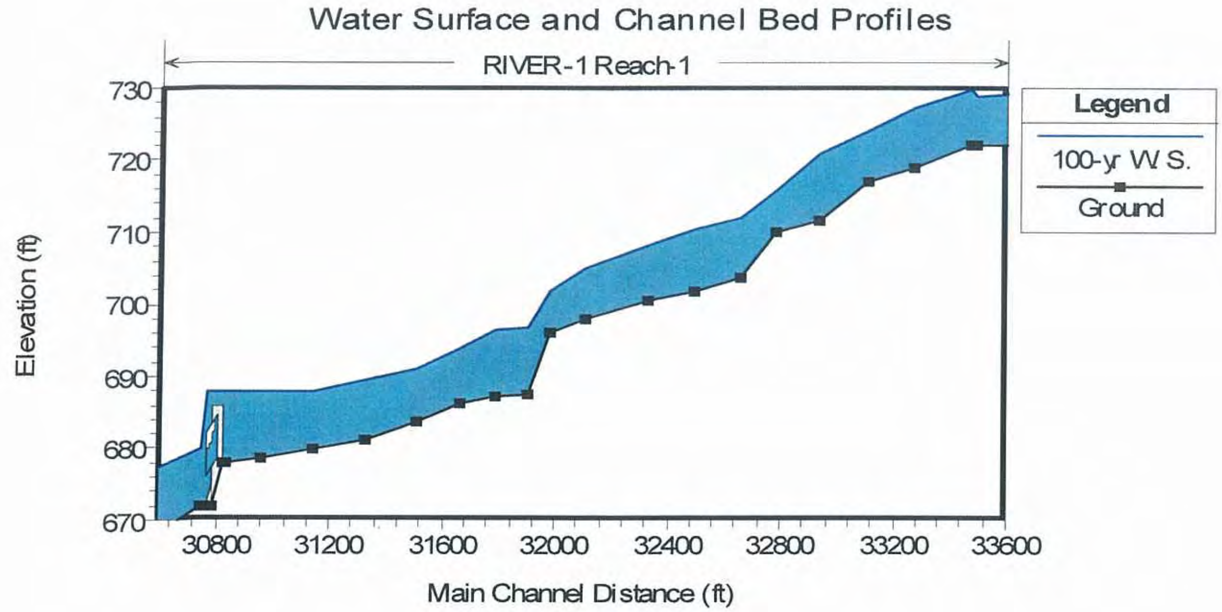


Fig. 56(continued). Water-surface and channel bed profiles from the HEC-RAS model



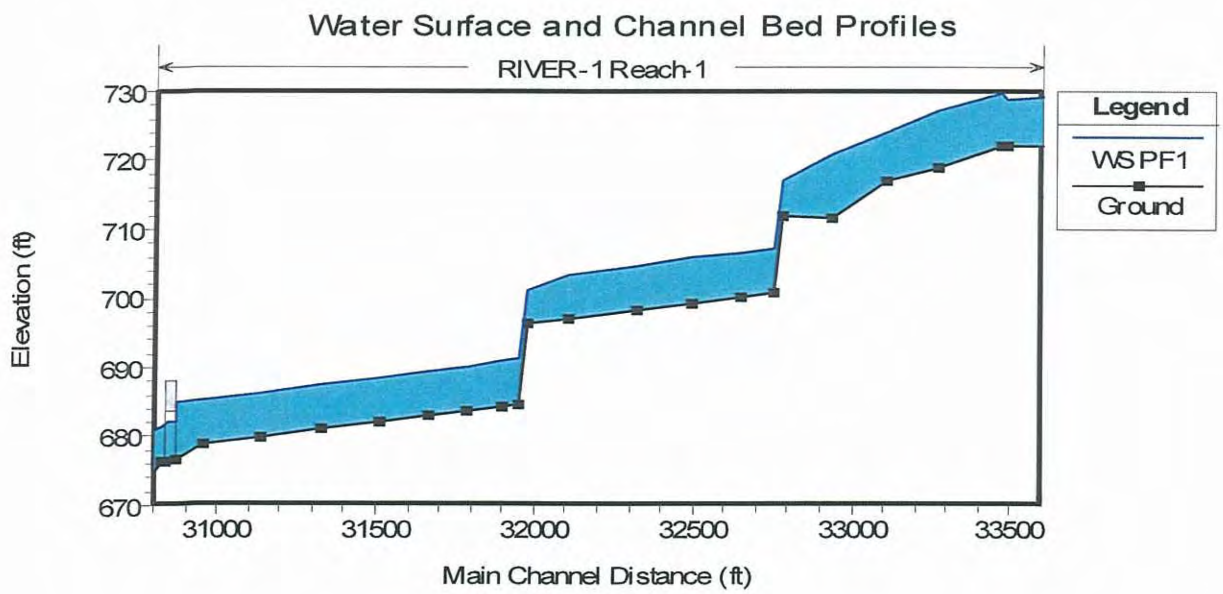


Fig. 56 (continued). Water-surface and channel bed profiles from the HEC-RAS model.
The top figure is for the existing conditions.
The bottom future is for the proposed conditions

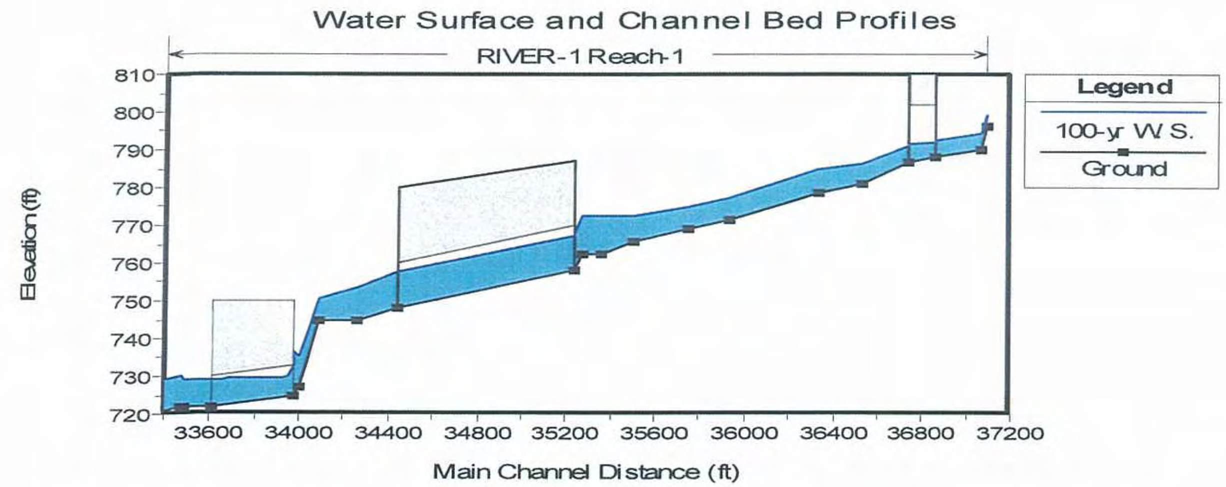


Fig. 56 (continued). Water-surface and channel bed profiles from the HEC-RAS model

REFERENCES

Chang, H. H., 1982, "Mathematical Model for Erodible Channels", Journal *of the Hydraulics Division*, ASCE, 108(HY5), 678-689.

Chang, H. H., 1984, "Modeling River Channel Changes", *Journal of Hydraulic Engineering*, ASCE, 110(2), 157-172.

Chang, H. H., 1985, "Water and Sediment Routing Through Curved Channels", *Journal of Hydraulic Engineering*, ASCE, 111(4), 644-658.
Chang, H. H., *Fluvial Processes in River Engineering*, John Wiley & Sons, New York, NY, 1988, 432 pp.

Chang, H. H., 1987, "Modeling Fluvial Processes in Streams with Gravel Mining," in *Sediment Transport in Gravel-Bed Rivers*, Thorne, et al. editors, John Wiley & Sons, pp. 977-988. Also presented at the Intern. Workshop on Problems of Sediment Transport in Gravel-Bed River, Colorado State University, August 12-17, 1985.

Chang, H. H., 1990, "Test and Calibration Study of FLUVIAL-12 Using Data from the San Luis Rey River", prepared for Nolte and Associates and the San Diego County Water Authority.

Chang, H.H., 1994, "Test and Calibration of FLUVIAL-12 Mode Using Data from the San Dieguito River.

Federal Insurance Administration, U.S. Dept. of Housing & Urban Development, "Flood Insurance Study, Orange County, California", March 1979.

County of Orange Public Facilities and Resources Department, Orange County Flood Control District Design Manual, November 2000.

Willdan Associates, "Serrano Creek Collaborative Use Plan", 1999

APPENDIX A. INPUT/OUTPUT DESCRIPTIONS FOR FLUVIAL-12

I. INPUT DESCRIPTION

The basic data requirements for a modeling study include (1) topographic maps of the river reach from the downstream end to the upstream end of study, (2) digitized data for cross sections in the HEC-2 format with cross-sectional locations shown on the accompanying topographic maps, (3) flow records or flood hydrographs and their variations along the study stream reach, it any, and (4) size distributions of sediment samples along the study reach. Additional data are required for special features of a study river reach.

The HEC-2 format for input data is used in all versions of the FLUVIAL model. Data records for HEC-2 pertaining to cross-sectional geometry (X1 and GR), job title (T1, T2, and T3), and end of job (EJ), are used in the FLUVIAL model. If a HEC-2 data file is available, it is not necessary to delete the unused records except that the information they contain are not used in the computation. For the purpose of water- and sediment-routing, additional data pertaining to sediment characteristics, flood hydrograph, etc., are required and supplied by other data records. Sequential arrangement of data records are given in the following.

Records	**Description of Record Type**
T1,T2,T3	Title Records
G1	General Use Record
G2	General Use Records for Hydrographs
G3	General Use Record
G4	General Use Record for Selected Cross-Sectional Output
G5	General Use Record
G6	General Use Record for Selecting Times for Summary Output
G7	General Use Record for Specifying Erosion Resistant Bed Layer
GS	General Use Records for Initial Sediment Compositions
GB	General Use Records for Time Variation of Base-Level
GQ	General Use Records for Stage-Discharge Relation of Downstream Section
GI	General Use Records for Time Variation of Sediment Inflow
X1	Cross-Sectional Record
XF	Record for Specifying Special Features of a Cross Section
GR	Record for Ground Profile of a Cross Section
SB	Record for Special Bridge Routine
BT	Record for Bridge Deck Definition
EJ	End of Job Record

Variable locations for each input record are shown by the field number. Each record has an input format of (A2, F6.0, 9F8.0). Field 0 occupying columns 1 and 2 is reserved for the required record identification characters. Field 1 occupies columns 3 to 8; Fields 2 to 10 occupy 8 columns each. The data records are tabulated and described in the following.

T1, T2, T3 Records - These three records are title records that are required for each job.

Field	Variable	Value	Description
0	IA	T1	Record identification characters
1-10	None		Numbers and alphameric characters for title

G1 Record - This record is required for each job, used to enter the general parameters listed below. This record is placed right after the T1, T2, and T3 records.

Field	Variable	Value	Description
0	IA	G1	Record identification characters
1	TYME	+	Starting time of computation on the hydrograph, in hours
2	ETIME	+	Ending time of computation on the hydrograph, in hours
3	DTMAX	+	Maximum time increment Δt allowed, in seconds
4	ISED	1	Select Graf's sediment transport equation.
		2	Select Yang's unit stream power equation. The sediment size is between 0.063 and 10 mm.
		3	Select Engelund-Hansen sediment equation.
		4	Select Parker gravel equation.
		5	Select Ackers-White sediment equation.
		6	Select Meyer-Peter Muller equation for bed load.
5	BEF	+	Bank erodibility factor for the study reach. This value is used value between 0 and 1 may be used.
6	IUC	0	English units are used in input and output.
		1	Metric units are used in input and output.
7	CNN	+	Manning's *n* value for the study reach. This value is used for a section unless otherwise specified in Field 4 of the XF record. If bed roughness is computed based upon alluvial bedforms as specified in Field 5 of the G3 record, only an approximate *n* value needs to be entered here.
8	PTM1	+	First time point in hours on the hydrograph at which summary output and complete cross-sectional output are requested. It is usually the peak time, but it may be left blank if no output is requested.
9	PTM2	+	Second time point on the hydrograph in hours at which summary usually the time just before the end of the simulation. This field may be left blank if no output is needed.

10	KPF	+	Frequency of printing summary output, in number of time steps.

G2 Records - These records are required for each job, used to define the flow hydrograph(s) in the channel reach. The first one (or two) G2 records are used to define the spatial variation in water discharge along the reach; the succeeding ones are employed to define the time variation(s) of the discharge. Up to 10 hydrographs, with a maximum of 120 points for each, are currently dimensioned. See section II for tributaries. These records are placed after the G1 record.

Field	**Variable**	**Value**	**Description**
First G2			
0	IA	G2	Record identification characters
1	IHP1	+	Number of last cross section using the first (downstream most) hydrograph. The number of section is counted from downstream to upstream with the downstream section number being one. See also section II.
2	NP1	+	Number of points connected by straight segments used to define
3	IHP2	+	Number of last section using the second hydrograph if any. Otherwise leave it blank.
4	NP2	+	Number of points used to define the second hydrograph if any. Otherwise leave it blank.
5	IHP3	+	Number of last section using the third hydrograph if any. Otherwise leave it blank.
6	NP3	+	Number of points used to define the third hydrograph if any. Otherwise leave it blank.
7	IHP4	+	Number of last section using the fourth hydrograph if any. Otherwise leave it blank.
8	NP4	+	Number of points used to define the fourth hydrograph if any. Otherwise leave it blank.
9	IHP5	+	Number of last section using the fifth hydrograph if any. Otherwise leave it blank.
10	NP5	+	Number of points used to define the fifth hydrograph if any. Otherwise leave it blank.

Second G2: Note that this record is used only if more than 5 hydrographs are used for the job. It is necessary to place a negative sign in front of NP5 located in the 10th field of the first G2 record as a means to specify that more than 5 hydrographs are used.

0	IA	G2	Record identification characters
1	IHP6	+	Number of last cross section using the sixth hydrograph if any. Otherwise leave it blank.
2	NP6	+	Number of points connected by straight segments used to define
3	IHP7	+	Number of last section using the seventh hydrograph if any. Otherwise leave it blank.
4	NP7	+	Number of points used to define the seventh hydrograph
5	IHP8	+	Number of last section using the eighth hydrograph if any. Otherwise leave it blank.
6	NP8	+	Number of points used to define the eighth hydrograph
7	IHP9	+	Number of last section using the ninth hydrograph if any. Otherwise leave it blank.
8	NP9	+	Number of points used to define the ninth hydrograph
9	IHP10	+	Number of last section using the tenth hydrograph if any. Otherwise leave it blank.
10	NP10	+	Number of points used to define the tenth hydrograph

Succeeding G2 Record(s)

1	Q11, Q21 Q31	+	Discharge coordinate of point 1 for each hydrograph, in ft^3/sec or m^3/sec
2	TM11,TM21 TM31	+	Time coordinate of point 1 for each hydrograph, in hours
3	Q12, Q22 Q32	+	Discharge coordinate of point 2 for each hydrograph, in cfs or cms
4	TM12,TM22 TM32	+	Time coordinate of point 2 for each hydrograph, in hours

Continue with additional discharge and time coordinates. Note that time coordinates must be in increasing order.

G3 Record - This record is used to define required and optional river channel features for a job as listed below. This record is placed after the G2 records.

Field	Variable	Value	Description
0	IA	G3	Record identification characters
1	S11	+	Slope of the downstream section, required for a job
2	BSP	0	One-on-one slope for rigid bank or bank protection
		+	Slope of bank protection in BSP horizontal units on 1 vertical unit. for all cross sections unless otherwise specified in Field 8 of the XF record for a section.
3	DSOP	0	Downstream slope is allowed to vary during simulation.
		1	Downstream slope is fixed at S11 given in Field 1.
4	TEMP	0	Water temperature is 15°C.
		+	Water temperature in degrees Celsius
5	ICNN	0	Manning's n defined in Field 7 of the G1 record or those in Field 4 of the XF records are used.
		1	Brownlie's formula for alluvial bed roughness is used to calculate Manning's n in the simulation.
6	TDZAMA	0	Thickness of erodible bed layer is 100 ft (30.5 m).
		+	Thickness of erodible bed layer in ft or m. This value is applied to
7	SPGV	0	Specific gravity of sediment is 2.65.
		+	Specific gravity of sediment
8	KGS	0	The number of size fractions for bed material is 5.
		+	The number of size fractions for bed material. It maximum value is 8.
9	PHI	0	The angle of repose for bed material is 36°.
		+	Angle of repose for bed material

G4 Record - This is an optional record used to select cross sections (up to 4) to be included at each summary output. Each cross section is identified by its number which is counted from the downstream section. This record also contains other options; it is placed after the G3 record.

Field	Variable	Value	Description
0	IA	G4	Record identification characters
1	IPLT1	+	Number of cross section

2	IPLT2	+	Number of cross section
3	IPLT3	+	Number of cross section
4	IPLT4	+	Number of cross section
5	IEXCAV	+	A positive integer indicates number of cross section where sand/gravel excavation occurs.
6	GIFAC	+	A non-zero constant is used to modify sediment inflow at the upstream section.
7	PZMIN	0	Minimum bed profile during simulation run is not requested.
		1	Output file entitled TZMIN for minimum bed profile is requested.
10	REXCAV	+	A non-zero value specifies rate of sand/gravel excavation at Section IEXCAV.

G5 Record - This is an optional record used to specify miscellaneous options, including unsteady-flow routing for the job based upon the dynamic wave, bend flow characteristics. If the unsteady flow option is not used, the water-surface profile for each time step is computed using the standard-step method. When the unsteady flow option is used, the downstream water-surface elevation must be specified using the GB records.

Field	Variable	Value	Description
0	IA	G5	Record identification characters
1	DT	0	The first time step is 100 seconds.
		+	Size of the first time step in seconds.
2	IROUT	0	Unsteady water routing is not used; water-surface profiles are computed using standard-step method.
		1	Unsteady water-routing based upon the dynamic wave is used to compute stages and water discharges at all cross sections for each
3	PQSS	0	No output of gradation of sediment load
		3	Gradation of sediment load is included in output in 1,000 ppm by weight.
5	TSED	0	Rate of tributary sediment inflow is 1 times the discharge ratio.
		+	Rate of tributary sediment inflow is TSED times the discharge ratio.
6	PTV	0	No output of transverse distribution of depth-averaged velocity
		1	Transverse distribution of depth-averaged velocity is printed. The

			velocity distribution is for bends with fully developed transverse flow.
10	DYMAX	0	No GR points are inserted for cross sections.
		+	Maximum value of spacing between adjacent points at a cross

G6 Record - This is an optional record used to select time points for summary output. Up to 30 time points may be specified. The printing frequency (KPF) in Field 10 of the G1 Record may be suppressed by using a large number such as 9999.

Field	Variable	Value	Description
First G6 Record			
0	IA	G6	Record identification characters
1	NKPS	+	Number of time points
Succeeding G6 Record(s)			
0	IA	G6	Record identification characters
1	SPTM(1)	+	First time point, in hours
2	SPTM(2)	+	Second time point, in hours

Continue with additional time points.

G7 Record - This is an optional record used to specify erosion resistant bed layer, such as a caliche layer, that has a lower rate of erosion.

Field	Variable	Value	Description
First G7 Record			
0	IA	G7	Record identification characters
1	KG7	+	Number of time points used to define the known erosion rate in relation to flow velocity
2	THICK	+	Thickness of erosion resistant layer, in feet
Succeeding G7 Record(s)			
0	IA	G7	Record identification characters
1	ERATE(1)	+	Erosion rate, in feet per hour
2	G7V(2)	+	Velocity, in feet per second

Continue with additional time points.

GS Record - At least two GS records are required for each job, used to specify initial bed-material compositions in the channel at the downstream and upstream cross sections. The first GS record is for the downstream section; it should be placed before the first X1 record and after the G4 record, if any. The second GS record is for the upstream section; it should be placed after all cross-sectional data and just before the EJ record. Additional GS records may be inserted between two cross sections within the stream reach, with the total number of GS records not to exceed 15. Each GS record specifies the sediment composition at the cross section located before the record. From upstream to downstream, exponential decay in sediment size is assumed for the initial distribution. Sediment composition at each section is represented by five size fractions.

Field	Variable	Value	Description
0	IA	GS	Record identification characters
1	DFF	+	Geometric mean diameter of the smallest size fraction in mm
2	PC	+	Fraction of bed material in this size range

Continue with other DFF's and PC's.

GB Records - These optional records are used to define time variation of stage (water-surface elevation) at a cross section. The first set of GB records is placed before all cross section records (X1); it specifies the downstream stage. When the GB option is used, it supersedes other methods for determining the downstream stage. Other sets of GB records may be placed in other parts of the data set; each specifies the time variation of stage for the cross section immediately following the GB records.

Field	Variable	Value	Description
First GB Record			
0	IA	GB	Record identification characters
1	KBL	+	Number of points used to define base-level changes
Succeeding GB Record(s)			
0	IA	GB	Record identification characters
1	BSLL(1)	+	Base level of point 1, in ft or m
2	TMBL(1)	+	Time coordinate of point 1, in hours
3	BSLL(2)	+	Base level of point 2, in ft or m
4	TMBL(2)	+	Time coordinate of point 2, in hours

Continue with additional elevations and time coordinates, in the increasing order of time.

GQ Records - These optional records are used to define stage-discharge relation at the downstream section. The GQ input data may not used together with the GB records.

Field	Variable	Value	Description
First GQ Record			
0	IA	GQ	Record identification characters
1	KQL	+	Number of points used to define base-level changes
Succeeding GQ Record(s)			
0	IA	GQ	Record identification characters
1	BSLL(1)	+	Base level of point 1, in ft or m
2	TMQ(1)	+	Discharge of point 1, in cfs or cms
3	BSLL(2)	+	Base level of point 2, in ft or m
4	TMQ(2)	+	Discharge of point 2, in cfs or cms

Continue with additional elevations and discharges, in the increasing order of discharge.

GI Records - These optional records are used to define time variation of sediment discharge entering the study reach through the upstream cross section. The GI input data, if included, will supersede other methods for determining sediment inflow. The sediment inflow is classified into the two following cases: (1) specified inflow at the upstream section, such as by a rating curve; and (2) sediment feeding, such as from a dambreach or a sediment feeder. These two cases are distinguished by DXU in Field 2 of this record. For the first case, sediment discharge at the upstream section is computed using size fractions of bed-material at the section, but for the second case, the size fractions of feeding material need to be specified using the PCU values in this record. The upstream section does not change in geometry for the first case but it may undergo scour or fill for the second case.

Field	Variable	Value	Description
First GI Record			
0	IA	GI	Record identification characters
1	KGI	+	Number of points used to define time variation of sediment inflow.
2	DXU	+ or 0	Channel distance measured from the upstream section to the and KGI signify case 2, for which PCU values are required.
3-10	PCU	+	Size fractions of inflow material. The number of size fractions is given in Field 8 of the G3 record and the sizes for the fractions are given in the second GS record.

Succeeding GI Record(s)

0	IA	GI	Record identification characters
1	QSU(1)	+	Sediment discharge of point 1, in cubic ft or m (net volume) per second
2	TMGI(1)	+	Time coordinate of point 1, in hours
3	QSO(2)	+	Sediment discharge of point 2
4	TMGI(2)	+	Time coordinate of point 2.

Continue with additional sediment discharges and time coordinates, in the increasing order of time coordinates.

X1 Record - This record is required for each cross section (175 cross sections can be used for the study reach); it is used to specify the cross-sectional geometry and program options applicable to that cross-section. Cross sections are arranged in sequential order starting from downstream.

Field	Variable	Value	Description
0	IA	X1	Record identification characters
1	SECNO	+	Original section number from the map
2	NP	+	Total number of stations or points on the next GR records for
7	DX	+	Length of reach between current cross section and the next down-stream section along the thalweg, in feet or meters
8	YFAC	0	Cross-section stations are not modified by the factor YFAC.
		+	Factor by which all cross-section stations are multiplied to increase or decrease area. It also multiplies YC1, YC2 and CPC in the XF record, and applies to the CI record.
9	PXSECE	0	Vertical or Z coordinate of GR points are not modified.
		±	Constant by which all cross-section elevations are raised or lowered
10	NODA	0	Cross section is subject to change.
		1	Cross section is not subject to change.

XF Record - This is an optional record used to specify special features of a cross section.

Field	Variable	Value	Description

0	IA	XF	Record identification characters
1	YC1	0	Regular erodible left bank
		+	Station of rigid left bank in ft or m, to the left of which channel dinates in GR records but not the first Y coordinate.
2	YC2	0	Regular erodible right bank
	+		Station of rigid right bank, to the right of which channel is non-erodible. Note: This station is located at toe of rigid bank; its value must be equal to one of the Y coordinates in GR records but not the last Y coordinate.
3	RAD	0	Straight channel with zero curvature
		+	Radius of curvature at channel centerline in ft or m. Center of radius is on same side of channel where the station (Y-coordinate) starts.
		-	Radius of curvature at channel centerline in ft or m. Center of radius is on opposite side of zero station. Note: RAD is used only if concave bank is rigid and so specified using the XF record. RAD produces a transverse bed scour due to curvature.
4	CN	0	Roughness of this section is the same as that given in Field 7 of the G1 record.
		+	Manning's *n* value for this section
5	CPC	0	Center of thalweg coincides with channel invert at this section.
		+	Station (Y-coordinate) of the thalweg in ft or m
6	IRC	0	Regular erodible cross section
		1	Rigid or nonerodible cross section such as drop structure or road crossing. There is no limit on the total number of such cross sections.
8	BSP	0	Slope of bank protection is the same as that given in Field 2 of the G3 record.
		+	Slope of bank protection at this section in BSP horizontal units
		5	Slope of rigid bank is defined by the GR coordinates.
9	BEFX	0	Bank erodibility factor is defined in Field 5 of the G1 record.
		+	A value between 0.1 and 1.0 for BEFX specifies the bank erodibility factor at this section.
	RWD	+	RWD is the width of bank protection of a small channel in the specified by a value greater than 1 (ft or m) in this field. When RWD is used, BEFX is not specified.
10	TDZAM	0	Erodible bed layer at this section is defined by TDZAMA in Field
		+	Thickness of erodible bed layer in ft or m. Only one decimal place

			is allowed for this number.
	ENEB	±	Elevation of non-erodible bed, used to define the crest elevation of a grade-control structure which may be above or below the existing channel bed. In order to distinguish it from TDZAM, ENEB must have the value of 1 at the second decimal place. For example, the ENEB value of 365 should be inputted as 365.01 and the ENEB value of -5.2 should be inputted as -5.21. When ENEB is specified, it supersedes TDZAM and TDZAMA

CI Record - This is an optional record used to specify channel improvement options due to excavation or fill. The excavation option modifies the cross-sectional geometry by trapezoidal excavation. Those points lower than the excavation level are not filled. The fill option modifies the cross-sectional geometry by raising the bed elevations to a prescribed level. Those points higher than the fill level are not lowered. Excavation and fill can not be used at the same time. This record should be placed after the X1 and XF records but before the GR records. The variable ADDVOL in Field 10 of this record is used to keep track of the total volume of excavation or fill along a channel reach. ADDVOL specifies the initial volume of fill or excavation. A value greater or less than 0.1 needs to be entered in this field to keep track of the total volume of fill or excavation until another ADDVOL is defined.

Field	Variable	Value	Description
0	IA	G5	Record identification characters
1	CLSTA	+	Station of the centerline of the trapezoidal excavation, expressed according to the stations in the GR records, in feet or meter.
2	CELCH	+	Elevation of channel invert for trapezoidal channel, in feet or meters.
4	XLSS	+	Side slope of trapezoidal excavation, in XLSS horizontal units for 1 vertical unit.
5	ELFIL	+	Fill elevation on channel bed, in feet or meters.
6	BW	+	Bed width of trapezoidal channel, in feet or meters. This width is measured along the cross section line; therefore, a larger value should be used if a section is skewed.
10	ADDVOL	0	Volume of excavation or fill, if any, is added to the total volume already defined.
		+	Initial volume of fill on channel bed, in cubic feet or cubic meters.
		-	Initial volume of excavation from channel bed, in cubic feet or meters.

GR Record - This record specifies the elevation and station of each point for a digitized cross section; it is required for each X1 record.

Field	Variable	Value	Description
0	IA	GR	Record identification characters
1	Z1	"	Elevation of point 1, in ft or m. It may be positive or negative.
2	Y1	"	Station of point 1, in ft or m
3	Z2	"	Elevation of point 2, in ft or m
4	Y2	"	Station of point 2, in ft or m

Continue with additional GR records using up to 79 points to describe the cross section. Stations should be in increasing order.

SB Record - This special bridge record is used to specify data in the special bridge routine. This record is used together with the BT and GR records for bridge hydraulics. This record is placed between cross sections that are upstream and downstream of the bridge.

Field	Variable	Value	Description
0	IA	SB	Record identification characters
1	XK	+	Pier shape coefficient for pier loss
2	XKOR	+	Total loss coefficient for orifice flow through bridge opening
3	COFQ	+	Discharge coefficient for weir flow overtopping bridge roadway
4	IB	+	Bridge index, starting with 1 from downstream toward upstream
5	BWC	+	Bottom width of bridge opening including any obstruction
6	BWP	0	No obstruction (pier) in the bridge
		i	Total width of obstruction (piers)
7	BAREA	+	Net area of bridge opening below the low chord in square feet
9	ELLC	+	Elevation of horizontal low chord for the bridge
10	ELTRD	+	Elevation of horizontal top-of-roadway for the bridge

BT Record - This record is used to compute conveyance in the bridge section. The BT data defines the top-of -roadway and the low chord profiles of bridge. The program uses the BT, SB and GR data to distinguish and to compute low flow, orifice flow and weir flow.

Field	Variable	Value	Description
0	IA	BT	Record identification characters
1	NRD	+	Number of points defining the bridge roadway and bridge low chord to be read on the BT records
2	RDST(1)	+	Roadway station corresponding to RDEL(1) and XLCEL(1)
3	RDEL(1)	+	Top of roadway elevation at station RDST(1)
4	XLCEL(1)	+	Low chord elevation at station RDST(1)
5	RDST(2)	+	Roadway station corresponding to RDEL(2) and XLCEL(2)
6	RDEL(2)	+	Top of roadway elevation at station RDST(2)
7	XLCEL(2)	+	Low chord elevation at station RDST(2)

Continue with additional sets of RDST, RDEL, and XLCEL.

EJ Record - This record is required following the last cross section for each job. Each group of records beginning with the T1 record is considered as a job.

Field	Variable	Value	Description
0	IA	EJ	Record identification characters
1-10			Not used

II. OUTPUT DESCRIPTION

Output of the model include initial bed-material compositions, time and spatial variations of the water-surface profile, channel width, flow depth, water discharge, velocity, energy gradient, median sediment size, and bed-material discharge. In addition, cross-sectional profiles are printed at different time intervals.

Symbols used in the output are generally descriptive, some of them are defined below:

SECTION	Cross section
TIME	Time on the hydrograph
DT	Size of the time step or Δt in sec
W.S.ELEV	Water-surface elevation in ft or m
WIDTH	Surface width of channel flow in ft or m
DEPTH	Depth of flow measured from channel invert to water surface in ft or m

Q	Discharge of flow in cfs or cms
V	Mean velocity of a cross-section in fps or mps
SLOPE	Energy gradient
D50	Median size or d_{50} of sediment load in mm
QS	Bed-material discharge for all size fractions in cfs or cms
FR	Froude number at a cross section
N	Manning's roughness coefficient
SED.YIELD	Bulk volume or weight of sediment having passed a cross section since beginning of simulation, in cubic yards or tons.
WSEL	Water-surface elevation, in ft or m
Z	Vertical coordinate (elevation) of a point on channel boundary at a cross-section, in ft or m
Y	Horizontal coordinate (station) of a point on channel boundary at a cross-section, in ft or m
DZ	Change in elevation during the current time step, in ft or m
TDZ	Total or accumulated change in elevation, in ft or m

APPENDIX B. CONSTRUCTION PHASING AND COST ESTIMATES

Because of the large expense required for channel improvements, the construction for such improvements will be made in several phases. For the purpose of construction phasing, the improvements are ranked based on priorities. The ranking of priorities can be made in consideration of several factors, including the vulnerability of adjacent properties, public and private safety hazards, costs, visual effects, etc. The ranking order presented in this section represents the opinion of the County and the City of Lake Forest and it is intended as a recommendation for the stakeholders to make the final decision.

Cost estimates (of materials costs only) have also been made for the recommended channel improvements. The purpose is to prepare an estimate of probable cost for each improvement to be used in budgeting and setting the construction phases. A compiled list of cost estimates is provided in this section. The eleven items are listed according to their locations starting from downstream toward upstream. The unit costs for various items as listed blow are for the purpose of cost estimates; they should be verified by qualified engineers and contractors.

Structural backfill: $50 per cubic yard

Unclassified fill: $33 per cubic yard

Riprap: $100 per cubic yard

Grouted riprap: $300 per cubic yard

Reinforced concrete drop structure: $500 per cubic yard.

Reinforced concrete bridge: $1000 per cubic yard or $350 per square foot

Geoweb: $7 per square foot

The improvements described below are given in no particular order. The cost estimate for each item is also provided.

Note the cost estimate does not include the EIR, land costs, acquisition costs (legal fees, deeds, appraisals, field survey, condemnation, etc.), development of engineering plans, planning services, contingencies, project management/supervision, inspection, connecting road for the bridge at the nursery access road, etc.

Item 1 – Floodwall construction for protection of existing buildings along the short channel reach near station 283+00. This short channel reach does not have sufficient capacity for the 100-yr flood; therefore, the adjacent properties are subject to flooding. Because of limited space between the existing buildings and the channel, a floodwall is recommended as a flood protection for the buildings. Estimated features and their respective costs are given below:

- Estimated length of floodwall: 120 feet
- Average height above ground: 7 feet
- Toe-down depth: 4 feet
- Total volume of reinforced concrete: 50 cubic yards
- Total estimated cost: $500 x 50 = $25,000

Item 2 – Bank protection along the concave bank of the short channel reach from channel station 222+00 to station 224+00. The concave bank of the short channel reach as shown in the figure is vulnerable to scour related to the channel curvature. Bank protection constructed along the concave channel bank will provide scour protection for the home buildings near the top channel bank.

- Total length of riprap layer: 200 feet
- Average width of riprap layer: 28 feet
- Average thickness of riprap layer: 2.5 feet
- Total volume of riprap: 520 cubic yards
- Total estimated cost: $100 x 520 = $52,000

Item 3 - Bank protection along the short channel reach from station 227+50 to station 230+40. The concave bank of the short channel reach is vulnerable to scour related to the channel curvature. Bank protection constructed along the concave channel bank will provide scour protection for the home buildings near the top channel bank.

- Total length of riprap layer: 290 feet
- Average width of riprap layer: 30 feet
- Average thickness of riprap layer: 2.5 feet
- Total volume of riprap: 805 cubic yards
- Total estimated cost: $100 x 805 = $80,500

Item 4 – Bank protection along the short channel reach from channel station 230+80 to station 235+50. The concave bank of the channel reach is vulnerable to scour related to the channel curvature. Bank protection constructed along the concave channel bank will check future lateral migration of the channel toward the home buildings near the top channel bank.

- Total length of riprap layer: 470 feet
- Average width of riprap layer: 30 feet
- Average thickness of riprap layer: 2.7 feet
- Total volume of riprap: 1,410 cubic yards
- Total estimated cost: \$100 x 1,410 = \$141,000

Item 5 - Improvements along the Autumnwood development channel reach. Recommended improvements along this reach include a series of six grade control structures, raising the channel bed by backfill, and bank protection along the south channel bank. Such improvements will provide protection for the housing development as well as improving the sight and mitigate the safety hazard of a deep canyon.

- Backfill: The total backfill is about 16,000 cubic yards. For the unit cost of \$50 per yard, the total cost is \$800,000.
- Protection for both banks using riprap or geoweb: The total surface area to be covered by geoweb is estimated to be 74,000 square feet or 10,960 cubic yard. For the riprap unit cost of \$100 per cubic yard, the total cost is \$1,096,000.
- Reinforced concrete grade control structures: The grade control structures may either be reinforced concrete structures or grouted riprap structures. The detailed geometric features for reinforced concrete structures shall be designed by a structural engineer. The total volume of reinforced concrete is estimated to be 400 cubic yards. For the unit cost of \$500 per cubic yard, the total cost for such structures is \$200,000.
- Grouted riprap grade control structures: A grouted riprap grade control structure has a riprap layer and a required filter layer, the total volume of riprap and filter is estimated to be 1,000 cubic yards. For the unit cost of \$300 per cubic yard, the total cost for such structures is \$300,000.
- The total cost for implementing the recommended channel improvements for this channel reach is estimated to be \$2,200,000 if grouted riprap grade control structures are used; it is \$2,100,000 if reinforced concrete structures are used.

Item 6 - Bank protection along the concave banks of the four following short channel reaches: (1) the reach from channel station 278+40 to station 279+40, (2) the reach from channel station 281+00 to station 282+00, and (3) the reach from channel station 282+30 to station 283+80, and (4) the reach from channel station 289+40 to station 290+20.

Total length of riprap layer: 100+100+150+80 = 430 feet

- Average width of riprap layer: 28 feet
- Average thickness of riprap layer: 3.5 feet
- Total volume of riprap: 1,560 cubic yards
- Total estimated cost: \$100 x 1,560 = \$156,000

Item 7 - Bank protection for both channel banks along channel reach from Trabuco Road Bridge crossing (channel station 214+00) to channel station 218+00.

- Total length of riprap layer: 2 x 400 feet = 800 feet
- Average width of riprap layer: 25 feet
- Average thickness of riprap layer: 3.5 feet
- Total amount of riprap: 2,592 cubic yards
- Total estimated cost: \$100 x 2,592 = \$259,200

Item 8 - Channel improvements and stabilization for the reach from the nursery access road to Lake Forest Drive – Recommended improvements along this reach include a new channel, a series of three grade control structures, backfill of the nursery area near the channel, bank protection along both channel banks, and a new bridge for the nursery access road crossing. Such improvements will confine the floodplain to the new channel.

- New channel: The new channel will be created by excavation along the existing channel. The amount of earth moving is estimated to be about 30,000 cubic yards, with an estimated of earth surplus of 15,000 cubic yards. The surplus material can be placed as backfill on the nursery adjacent to the channel. Since the new channel will encroach upon adjacent land, a strip of land along the channel edge will have to be acquired from the property owners. The total cost for grading is estimated to be \$1,500,000 at \$50 per cubic yard.
- Backfill: The total backfill is about 25,000 cubic yards. For the unit cost of \$50 per yard, the total cost is \$1,250,000.

- Bank protection using riprap or geoweb: The total surface area to be covered by geoweb is estimated to be 114,000 square feet. For the geoweb unit cost of $7 per square feet, the total cost is $798,000. In the case of riprap, the total volume of riprap is about 12,700 cubic yards. The total cost is $1,270,000 at the unit cost of $100 per cubic yard.
- Bank protection using riprap: The total bank surface area to be covered by rock rip bank protection is estimated to be 270 cubic yards. The total cost is estimated to be $27,000 at the unit cost of $100 per cubic yard.
- Reinforced concrete grade control structures: The grade control structures may either be reinforced concrete structures or grouted riprap structures. The detailed geometric features for reinforced concrete structures shall be designed by a structural engineer. The total volume of reinforced concrete is estimated to be 175 cubic yards. For the unit cost of $500 per cubic yard, the total cost for such structures is $87,500.
- New bridge for nursery access road. The bridge replacing the existing dip crossing for the nursery access road is assumed to have a two-lane road with a road width of 48 feet, single bridge span of 60 feet. The total cost is estimated to be $1,008,000 at the unit cost of $350 per square foot. This estimate is based on the assumption of ultimate improvement the road crossing.
- New reinforced concrete box culverts. Three 12' by 7' box culverts that are 48 feet in length are required to pass the 100-yr flood. Wing walls at the upstream culvert entrance shall be installed to provide transition from the culvert section to the upstream trapezoidal channel. The total volume of concrete is about 300 cubic yards. The total cost for culverts is estimated to be $152,000 at the unit cost of $500 per cubic yard. The cost for construction grading and road construction is estimated to be $250,000. The total cost for culverts and road is $402,000. The width of a bridge or culvert could be similar if the area served remains a nursery or may need to be considerably wider depending upon development.
- The total cost for implementing the recommended channel improvements for this channel reach is estimated to be $4,537,000 if box culverts are used at nursery access road.

Item 9 - Survey and retrofitting of existing bank protection and grade control structures. Serrano Creek has existing bank protection and grade control structures. They have been built apparently as countermeasures in response to channel changes. As-built plans for most structures are not available. The adequacy of these structures could not be verified in field inspection. For this reason, field survey needs to be carried out in order to assess the adequacies of the structures and to retrofit those that are found inadequate. need to be checked. Basically, an erosion control structure, such as bank protection or grade control structure, should meet the following conditions:

(1) It should be strong enough to withstand the force of flow.

(2) It should have adequate bank height.

(3) It should have adequate toe-down depth.

(4) The drop structures should have sufficient bank height to avoid out flanking.

The cost estimate for survey and retrofitting are not provided in this study. However, the total cost is estimated to be between $1,000,000 and $2,000,000 based on field observations.

Item 10 – Bank protection along the south channel bank from channel station 236+20 to station 238+00. The concave bank of the channel reach is vulnerable to scour related to the channel curvature. Bank protection constructed along the concave channel bank will check future lateral migration of the channel toward the home buildings near the top channel bank.

- Total length of riprap layer: 180 feet
- Average width of riprap layer: 30 feet
- Average thickness of riprap layer: 2.7 feet
- Total volume of riprap: 540 cubic yards
- Total estimated cost: $100 x 540 = $54,000

Item 11 - Bank protection along the south bank of the two following short channel reaches: (1) the reach from channel station 295+30 to station 297+10, (2) the reach from channel station 298+30 to station 300+40. The south channel bank is vulnerable to scour related to the channel curvature. Bank protection constructed along the concave channel bank will provide scour protection for the buildings near the top channel bank.

- Total length of riprap layer: 390 feet
- Average width of riprap layer: 28 feet
- Average thickness of riprap layer: 2.5 feet
- Total volume of riprap: 1,010 cubic yards
- Total estimated cost: $100 x 1,010 = $101,000

Table B-1: Summary of improvements cost estimates

Channel reach	Improvements	Estimated cost
2	Item 1. Protection of properties along channel reach near channel station 283+00	$25,000
2	Item 2. Bank protection for channel reach from station 222+00 to station 224+00.	$52,000
2	Item 3. Bank protection for the short channel reach from station 227+50 to station 230+40	$80,500
2	Item 4. Bank protection for the short channel reach from station 230+80 to station 235+50	$141,000
3	Item 5. Improvements along the Autumnwood development channel reach	$2,200,000
3	Item 6. Bank protection for four short channel reaches between stations 278+40 and 290+20	$156,000
2	Item 7 - Bank protection for channel reach from Trabuco Road Bridge crossing to station 218+00	$259,200
3	Item 8. Improvement of channel reach above nursery access road	$4,537,000
2,3,4	Item 9. Survey and retrofitting of existing channel improvements	$1,000,000 – $2,000,000
2	Item 10. Bank protection for the south channel bank from station 236+20 to station 238+00	$54,000
3	Item 11. Bank protection for two short channel reaches between stations 295+30 and 300+40	$101,000
*Total		$8,605,700 - $9,605,700

*The cost estimate does not include environmental/CEQA, regulatory permitting, and mitigation costs, land, acquisition costs (legal fees, deeds, appraisals, field survey, condemnation, etc.), maintenance access costs, utility relocation costs, preliminary design engineering and development of engineering plans (PS&E), planning services, project management/supervision, construction administration and inspection, connecting road for the bridge at the nursery access road, contingencies, etc.

APPENDIX C.
FIRM by FEMA

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at (800) 638-6620.

MAP SCALE 1" = 500'

250 0 500 1000 FEET

150 0 150 300 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0316H

FIRM

FLOOD INSURANCE RATE MAP

ORANGE COUNTY, CALIFORNIA AND INCORPORATED AREAS

PANEL 316 OF 550

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
ORANGE COUNTY, UNINCORPORATED AREAS	060212	0316	H
LAKE FOREST, CITY OF	060759	0316	H

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER 06059C0316H

MAP REVISED: FEBRUARY 18, 2004

Federal Emergency Management Agency

LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD EVENT

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water surface elevation of the 1% annual chance flood.

ZONE A No base flood elevations determined.

ZONE AE Base flood elevations determined.

ZONE AH Flood depths of 1 to 3 feet (usually areas of ponding); base flood elevations determined.

ZONE AO Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.

ZONE AR Area of special flood hazard formerly protected from the 1% annual chance flood event by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood event.

ZONE A99 Area to be protected from 1% annual chance flood event by a Federal flood protection system under construction; no base flood elevations determined.

ZONE V Coastal flood zone with velocity hazard (wave action); no base flood elevations determined.

ZONE VE Coastal flood zone with velocity hazard (wave action); base flood elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X Areas determined to be outside the 0.2% annual chance floodplain.

ZONE D Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

Floodplain boundary

Floodway boundary

Zone D boundary

CBRS and OPA boundary

Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or velocities.

~~~~~513~~~~~ Base Flood Elevation line and value; elevation in feet*

(EL 987) Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988
~~~~~

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

	Floodplain boundary
	Floodway boundary
	Zone D boundary
	CBRS and OPA boundary
	Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or velocities.
~~513~~~	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

A —— A	Cross Section Line
23 - - - - - 23	Transect Line
97°07'30", 32°22'30"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83)
4276000M	1000-meter Universal Transverse Mercator grid values, zone 11
600000 FT	5000-foot grid ticks
DX5510	Bench mark (see explanation in Notes to Users section of this FIRM panel).
• M1.5	River Mile

MAP REPOSITORY
Refer to Repository Listing on Index Map

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
SEPTEMBER 15, 1989

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

February 5, 1992 November 3, 1993 January 3, 1997
February 18, 2004: to update corporate limits, to add special flood hazard areas, to change zone designations, to update map format, to incorporate previously issued letters of map revision, to update roads and road names.

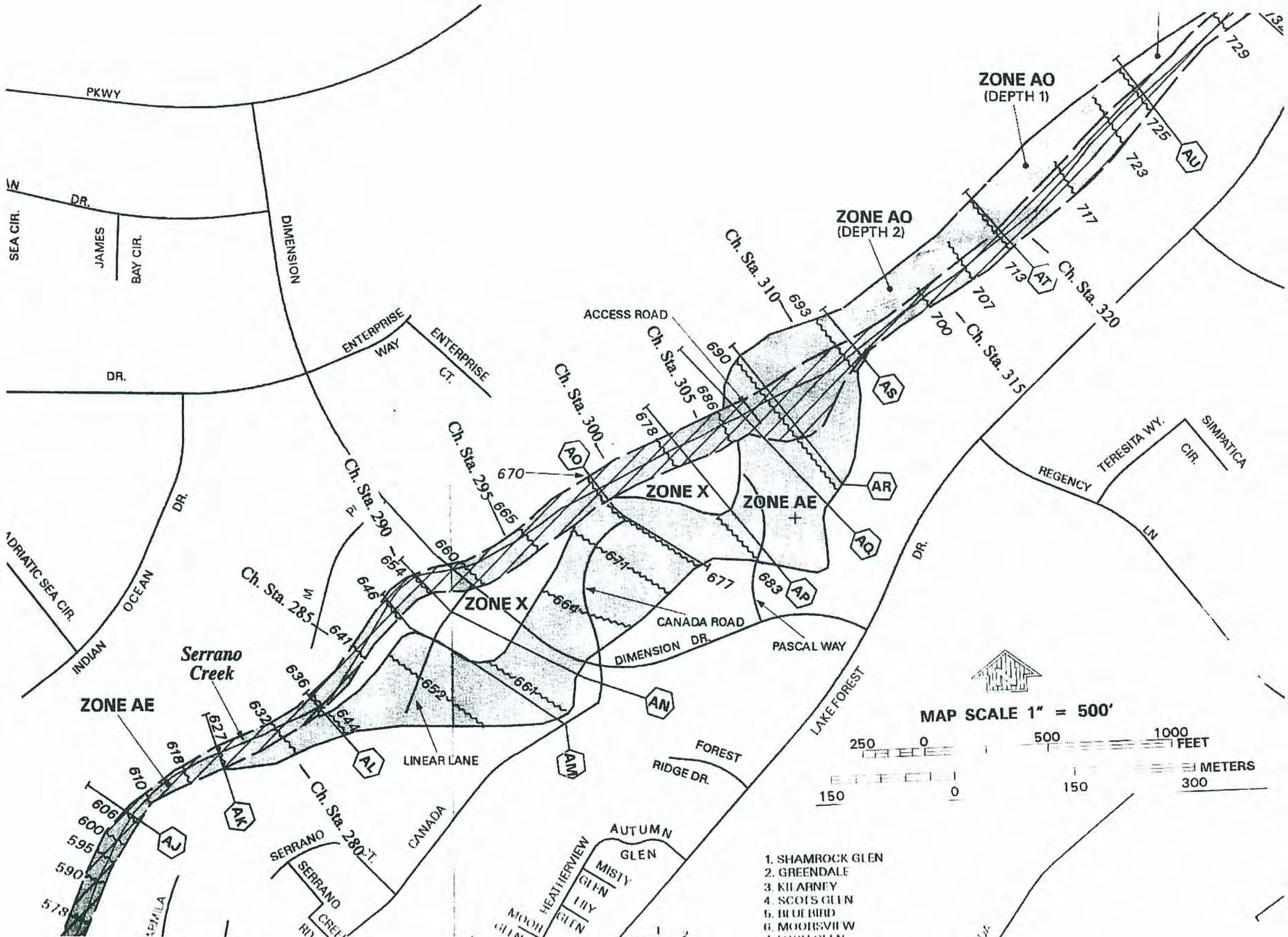
For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at (800) 638-6620.

MAP SCALE 1" = 500'

250 0 500 1000 FEET

150 0 150 300 METERS


ZONE AO
(DEPTH 1)
ZONE AO
(DEPTH 2)
ZONE AE
ZONE X
ZONE X
ZONE AE
Serrano Creek
Ch. Sta. 280
Ch. Sta. 285
Ch. Sta. 290
Ch. Sta. 295
Ch. Sta. 300
Ch. Sta. 305
Ch. Sta. 310
Ch. Sta. 315
Ch. Sta. 320
AJ
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671
677
678
683
686
690
693
700
707
713
717
723
725
729
ACCESS ROAD
CANADA ROAD
PASCAL WAY
LINEAR LANE
PKWY
DIMENSION
DR.
SEA CIR.
JAMES
BAY CIR.
ENTERPRISE WAY
ENTERPRISE CT.
ADRIATIC SEA CIR.
INDIAN OCEAN DR.
DIMENSION DR.
LAKE FOREST DR.
FOREST RIDGE DR.
REGENCY LN
TERESITA WY.
SIMPATICA CIR.
CANADA
SERRANO
SERRANO
AUTUMN GLEN
MISTY GLEN
LILY GLEN
HEATHERVIEW
MAP SCALE 1" = 500'
250 0 500 1000 FEET
150 0 150 300 METERS
1. SHAMROCK GLEN
2. GREENDALE
3. KILARNEY
4. SCOTS GLEN
5. BLUEBIRD
6. MOORSVIEW