THE RANCH PLAN PLANNED COMMUNITY

PLANNING AREAS 3 AND 4 RUNOFF MANAGEMENT PLAN

Michael Baker INTERNATIONAL

TECHNICAL APPENDIX O.3

Updated Lateral Erosion Analysis

Technical Memorandum

Date: February 9, 2018 (revised)

From: Bruce M. Phillips, PE

Re: **RMV Ranch Plan Updated Assessment for Lateral Streambank Erosion Analyses for PA1 / PA2** B097

Introduction / Background

This memorandum provides updated lateral streambank erosion analyses along a portion of the mainstem San Juan Creek within the Rancho Mission Viejo (RMV) property addressing hydrologic impacts from urbanization and technical peer review comments from previous fluvial studies. These updated analyses specifically address adjustments to the lateral erosion limits adjacent to PA1/PA2 through the application of technical scientific approaches recently used for studies along PA3/PA4/PA5 as well as update the analyses for these planning areas also. The updated analyses include the application of revised hydrology (development mitigated condition) for all the different development Planning Areas (PA). The proposed RMV development, The Ranch Plan, within the San Juan Creek (SJC) watershed was developed through a comprehensive watershed planning program that incorporated various strategies to provide appropriate levels of mitigation that will ensure the long-term protection of the watershed resources by addressing development impacts. Part of this program provides the control measures to adequately setback from natural river systems to account for future lateral streambank migration as an important land management tool. Defining the anticipated long term lateral erosion limits adjacent to active creek corridors also limits the need for the construction of engineered "structural" streambank protection measures since this role is fulfilled instead with development building setbacks.

Two separate engineering studies, *San Juan Creek – PA1 RMV Development Area – Lateral Stream Bank Erosion Analysis* (PACE, September 2006) and *San Juan Creek Lateral Erosion Analysis – Gobernadora Creek to Upstream RMV Boundary – PA3/PA4 RMV Development Areas* (PACE, July 2017), involving detailed fluvial analyses and geomorphic assessments were performed to predict the potential future lateral streambank migration / erosion limits (see *Figure No.1- Typical Channel Section Lateral Erosion Limits*) along the different portions of the mainstem San Juan Creek within the RMV property. The comprehensive assessment used rigorous scientific procedures from a variety of different analyses/assessments that were combined together to predict the future lateral erosion boundaries and define a maximum envelope of the erosion hazard limits. The combination of the different maximum erosion limits generated from the multiple scientific engineering techniques applied and review of various data sources (including historical aerial photos, historical topography, and multiple field investigations) were used at each creek cross-section location to establish the maximum envelope in order to define the erosion hazard boundary. Where minor localized adjustments were made based on engineering interpretation.

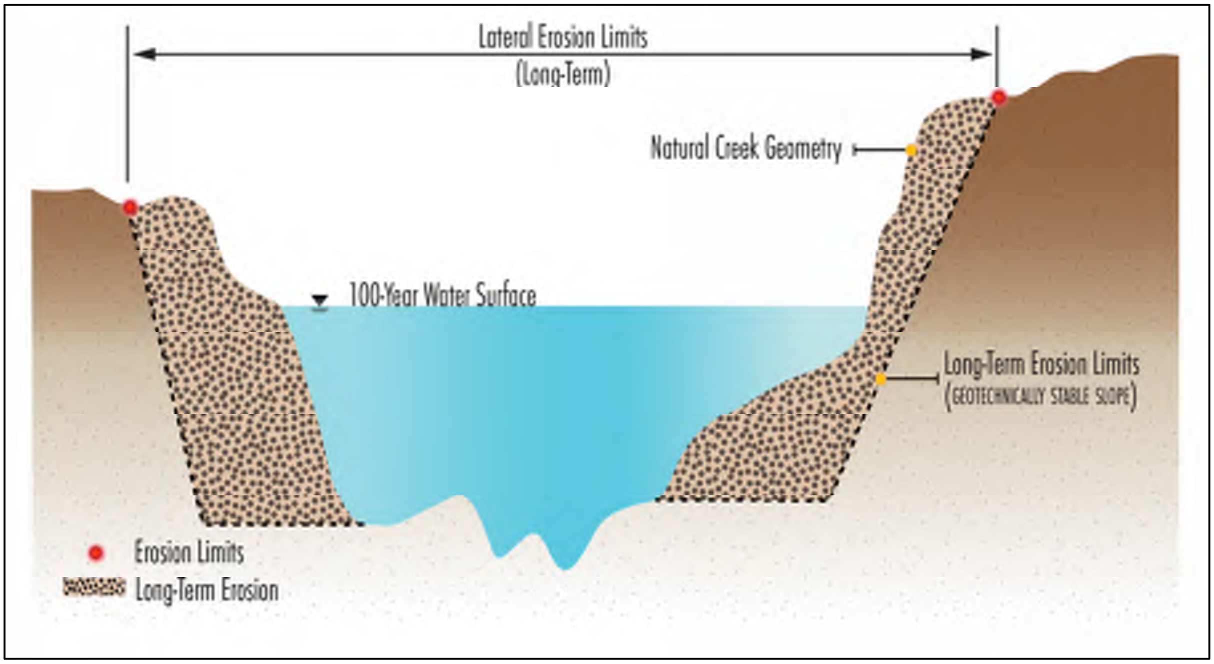

Figure 1 - Typical Channel Section Lateral Erosion Limits

The County review process for the different previous lateral erosion studies had used independent peer review as well as their own internal staff review. The peer review had included the application of a separate sediment transport computer program, FLUVIAL-12, to model the long term lateral erosion along the study limits and compare the results with the two different PACE studies. The long-term time simulation in PACE modeling was different than the peer review modeling. PACE has computed from the HEC-6T modeling an annualized sediment erosion deficit at each cross section and multiplied this value by 60 in order to compute 60-years of erosion, plus adding a single 100-year storm erosion amount to compute the total lateral erosion. This is the procedure adopted from Maricopa County Flood Control District studies. The peer review modeling had used a sequence of storms over a 20-year period The primary findings from the comparison with peer review computed erosion limits indicated that (1) the July 2017 PACE lateral erosion limits/hazard zones along the PA3/PA4 development areas were the same or provided larger erosion boundary limit than peer review FLUIAL-12 model results (see *Figure No.3 – Comparison 2017 PACE Lateral Erosion Limits and Peer Review FLUVIAL-12 Model*), and (2) along the northern San Juan Creek bank adjacent to the PA1 development area there was a significant deviation between the PACE (September 2006) and the peer review model had computed much greater lateral erosion in this area (see *Figure No. 2 Comparison of Long Term Lateral Erosion Estimates PA1 Development Area)*.

An updated series of analyses was prepared for the PA1 zone using the improved scientific procedures adopted for the July 2017 erosion study in order to evaluate the effects of the developed condition hydrology on the estimated lateral erosion limits as well as address the differences identified in the peer review for the PA1 area. The specific items addressed in this updated fluvial analysis include the following:

1. <u>**Lateral Erosion Applying Revised Hydrology**</u> - An important technical foundation for the analyses associated with the previous lateral erosion fluvial studies (PACE, September 2006 and July 2017) was the hydrology which has assumed that the development runoff would be mitigated to the "existing" conditions. The revised "mitigated developed condition" hydrology was incorporated into the sediment transport HEC-6T models, which was used as one of the procedures to quantify the lateral erosion. The updated HEC-6T models with the revised

hydrology input was used to compute the "total eroded sediment volume" at each channel cross section and compared to the original analysis to determine if there were any significant differences that would influence the previous computed lateral erosion estimates.

2. **PA1 Development Area Revised Lateral Erosion Analysis** – The previous 2006 PACE study which focused on the lateral erosion in the PA1 development area had used slightly different procedures than the July 2017 study. The July 2017 study used a more rigorous and detailed procedure related to the modeling effort to quantify the amount of lateral erosion. The previous 2006 PACE study had used a slightly modified procedure by evaluating longer "reaches" rather than "individual" cross sections in the sediment transport modeling along the PA1. A revised lateral erosion analysis using HEC-6T modeling was prepared by PACE for the north bank of San Juan Creek adjacent to PA1 specifically addressing those areas where the peer review FLUIVAL-12 models had indicated greater amounts of lateral erosion than the original PACE estimates.

Updated PA1 Streambank Lateral Erosion Analysis

The previous initial lateral erosion analysis (PACE, September 2006) along San Juan Creek adjacent to the PA1 development area had used slightly different procedures than the July 2017 study. The July 2017 study utilized a more rigorous and detailed procedure than the 2006 study related to the modeling effort to quantify the amount of lateral erosion. HEC-6T was the sediment transport model used by PACE in both studies, however, HEC-6T does not directly compute lateral erosion was developed by PACE. A specialized procedure that used HEC-6T computed results to determine the amount of lateral erosion. This procedure involved using the HEC-6T computed total sediment deficit (scour) or surplus (deposition) for the computation of total eroded sediment volume for each channel cross section during the entire storm hydrograph. This total eroded sediment volume was used to adjust the horizontal erosion boundary of the streambank cross section either on the right or left bank. The total volume was divided by the average distance between next adjacent cross section, assuming all the bank erosion occurred on only one side of the channel, which determined the bank erosion area. Although this procedure does not directly analyze the additional erosion forces on the streambank for bends or curves, it does however provide a very conservative estimate of the lateral streambank erosion distance since the total eroded volume of the entire streambed is applied to only one bank at a time. In addition, this procedure for defining lateral erosion hazard boundaries has been adopted and used on multiple large watershed masterplans by other agencies in the Southwest, including Maricopa County Flood Control District (Arizona).

The previous 2006 PACE study had used a slightly modified procedure by evaluating longer "reaches" rather than "individual" cross sections in the sediment transport modeling along the PA1. This procedure resulted in "averaging" the total eroded sediment volume over several cross sections and reducing the total estimated eroded volume at this particular location. The reduced estimated eroded sediment volume then also reduced the estimated lateral erosion distance for that area. The "averaging" procedure is the reason why the narrower lateral erosion limits are reflected in the comparison of PACE's results with the peer review FLUIVAL-12 results.

A revised lateral erosion analysis using HEC-6T modeling was prepared by PACE for San Juan Creek adjacent to PA1 specifically addressing those areas where the peer review FLUIVAL-12 models had indicated greater amounts of lateral erosion than the original PACE estimates. The revised lateral erosion analysis involved preparing an updated HEC6-T model and using the more rigorous procedure, applying the estimated total eroded volume at each cross section to compute the eroded streambank migration distance. The basic steps of this procedure included the following:

1. HEC6-T model was developed to analyze separately the 100-year and 10-year storm hydrographs.
2. The computed total eroded sediment volume at each cross section for the entire storm hydrograph was extracted from HEC-6T. The two values were used to compute the "annualized" sediment transport volume and then this value was multiplied by 60 to determine the 60-year long

term eroded volume. However, the maximum long-term sediment volume used was the 60-year plus the single 100-year storm event.

3. The maximum computed sediment deficit for each cross section was applied to the cross-section geometry graphically to estimate an eroded area that was equivalent to the volume computed divided by the average distance between adjacent cross sections. The eroded limits were adjusted in a trial-and-error process until the correct eroded geometry matched the computed eroded volume. The eroded bank slope used in generating this geometry matched the existing bank slope. (This procedure follows the standard process used in Maricopa County studies for lateral stability assessment)
4. The deficit for that cross section was applied to either the left or right bank individually, as if none of the deficit was satisfied from the opposite bank or the streambed.

PA1/PA2 Revised Lateral Erosion Results / Recommendations

The results of this revised lateral erosion for the PA1 area are summarized on *Figure No. 2 – Comparison of Long Term Lateral Erosion Estimates PA1 Development Area* which compares the different analyses by PACE and Dr. Chang. The figure only illustrates the portion of the PA1 area where there was difference identified or additional erosion from the peer review modeling. The remainder of the erosion boundaries in the PA1/ PA2 area are adequate. The figure illustrates that **the revised PACE analysis generates lateral erosion distances that exceed the Dr. Chang model estimates, but does not extend into the development area** since the development was actually setback further using the floodplain limits. The detailed calculations that were performed for each individual cross section are provided in the *Technical Appendix*. Although improvements continue to be outside of the conservative limits of the erosion setback line, the County should continue to require evaluation and survey of the special monitoring monuments for this area. Site-specific erosion monitoring program and mitigation program was developed to specifically address lateral migration along a large river meander bend in this area. The monitoring composed of several different monitoring features/processes which also serve to identify level of risk. The results of the active monitoring program would potentially trigger different levels of corrective/preventative erosion mitigation measures depending on the severity of the measured erosion. This involves using three monuments which are four-inch buried steel pipes filled with concrete differentiated by either a (1) green – closest monument to the bank, (2) yellow – intermediate monument to bank and development, or (3) red – monument closest to the development edge. Each of the monuments have the colored metal tag identifier. The horizontal distance from the closest remaining monument to the active streambank edge is measured after each rainfall event of significance. The severity of lateral erosion associated with a storm event would be defined by the location of the erosion relative to the type of monument (green, yellow, or red). This specialized monitoring effort for this area provides an additional layer of safety to ensure the long protection of the development.

Upstream San Juan Creek Sediment Transport Model – Updated Revised Hydrology

A revised HEC-6T sediment transport modeling effort was prepared for the entire study each of San Juan Creek within the RMV boundary. This revised modeling involved using different storm hydrographs to reflect the "mitigated development" conditions. The revised "mitigated developed condition" hydrology was incorporated into the sediment transport HEC-6T models. The computed "total eroded sediment volume" at each cross section for the entire storm hydrograph was extracted from HEC-6T for both the 10- and 100-year storm events. The two values were used to compute the "annualized" sediment transport volume and then this value was multiplied by 60 to determine the 60-year long term eroded volume. However, the maximum long-term sediment volume used was the 60-year plus the single 100-year storm event. Tables in the *Technical Appendix* provides a summary of the revised computed cross section eroded volume as well as the "long-term" value. The revised or updated eroded sediment volumes are compared to the previous 2017 modeling results.

The results of the revised HEC6-T modeling shown in the tables (*Technical Appendix*) indicated that the change in hydrology did not significantly influence the previous results and almost half of the cross sections were in deposition (positive volume) rather than erosion (negative volumes). In addition, as will be shown below from the analysis, in most of the areas where there was increased eroded volume (1) the amount was generally small; and (2) at locations where it appears to be larger, the HEC-6T procedure did not govern the lateral erosion limits, but either the “erosion template” procedure (see *Figure No.4 – Erosion Template*) used in the PACE 2017 study or the historical geomorphology streambank limits controlled. This ultimately resulted in no change to the previously published erosion limits except in the PA1 as shown in the *Figure No.2*. The results of the HEC-6T analysis are provided in a spreadsheet (see the *Technical Appendix*) that was used to perform all the calculations at each cross section and estimate the long term eroded volumes.

Upstream San Juan Creek Long Term Lateral Erosion

An updated lateral erosion analysis was performed for the PACE 2017 study in order to incorporate the developed condition hydrology used in the HEC-6T analyses. A specialized procedure was developed that used HEC-6T computed results to determine the amount of lateral erosion in the PACE studies. This procedure involved using the HEC-6T computed total sediment deficit (scour) or surplus (deposition) for the computation of total eroded sediment volume for each channel cross section during entire storm hydrograph as discussed in the previous section (Updated PA1 Streambank Erosion Analysis). This total eroded sediment volume was used to adjust the horizontal erosion boundary of either the right or left bank of the channel cross section. The total volume was divided by the average distance between next adjacent cross section, assuming all the bank erosion occurred on only one side of the channel, which determined the bank erosion area. Although this procedure does not directly analyze the additional erosion forces on the streambank for bends or curves, it does however provide a conservative and reasonable estimate of the lateral streambank erosion distance since the total eroded volume of the entire streambed is applied to only one bank at a time. This is a conservative estimate because other models such as FLUIVAL-12 calculate the amount of total erosion through a similar “sediment transport continuity analysis” and the results are applied to both the streambed and streambank. FLUVIAL-12 has an additional feature to compute additional lateral erosion using stream power, but that amount does not exceed the total eroded volume from the sediment continuity procedure. The PACE procedure, adopted from Maricopa County Flood Control District studies, applies the total eroded volume for the cross section to just one side of the streambank and converts streambed erosion to lateral streambank erosion. However, since multiple procedures were used in the PACE 2017 study, the HEC-6T analysis was not necessarily the method which provided the maximum or controlling erosion boundary limits.

PA3/PA4 Updated Lateral Erosion Results / Discussion

The results indicated that there was not a significant deviation in the lateral distances as shown on the original comparison of the lateral erosion limits on *Figure No. 3.* From the results of the updated study that is provided in the *Technical Appendix*, lateral erosion migration is predicted to vary from -10 feet to +20 feet from the 2017 PACE HEC-6T analysis. The revised analysis illustrating the long-term erosion distance in comparison to the 2017 results is summarized in the *Technical Appendix* for the study portion of San Juan Creek extending from the downstream Gobernadora Canyon confluence to the upstream RMV boundary. The lower reach of San Juan Creek was modeled in the updated analyses for the PA1 development area and the only changes were in the small area of discrepancy identified by peer review performed by Dr. Chang. Although there were only minor changes in the HEC-6T results, the HEC-6T model generally did not control the ultimate erosion boundary limits. A detailed description of the assumptions and selection of the final boundary line at different locations along the San Juan Creek study reach is discussed below beginning at the downstream confluence with Gobernadora Canyon and extending to the upstream RMV boundary. This discussion is provided as a guidance to indicate the controlling input in each location along the creek for the erosion boundary, since the HEC-6T modeling results did not necessarily govern and one of the other procedures provided a larger erosion limit value which was generally the “erosion template” adopted by other agencies for these analyses including the City of Austin, TX (see *Figure No.4 – Erosion Template*).

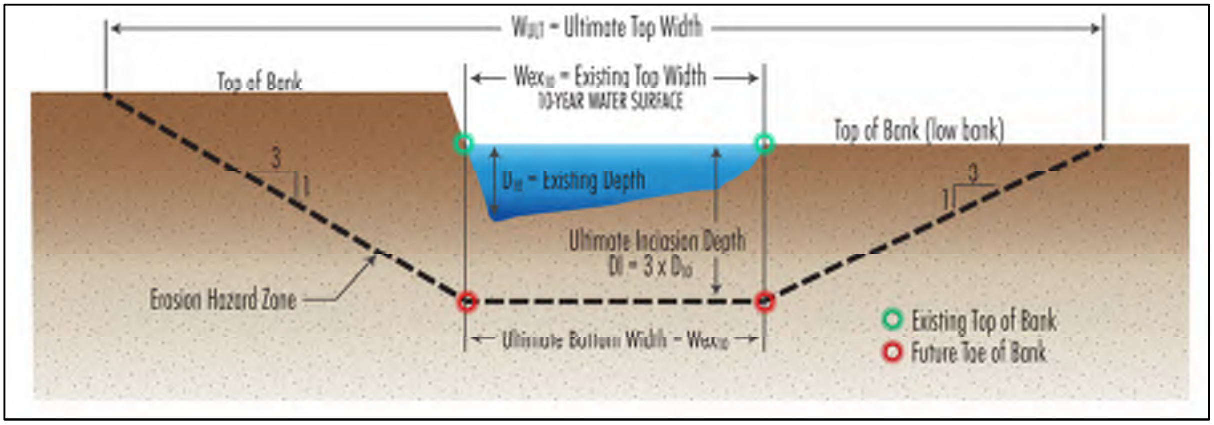

Figure 4: Defining limits of maximum eroded channel based on conceptual erosion limits geometry template

Sta. 395+24 to 402+73 - Maximum lateral erosion limits defined on both the left and right banks by large historical flood bank lines from **1967 and the current100-year floodplain delineation** on the south bank.

Sta. 402+73 to 408+73 - The erosion limits, both on the left and right bank, are located along the limits **"lateral erosion template"** which was the controlling boundary line.

Sta. 408+73 to 426+73 - The northerly bank line limits were controlled by the **"lateral erosion template" and the 100-year floodplain limits**, but adjusted to conform to topographic influences.

Sta. 426+73 to 435+73 - The northerly bank erosion limits were defined by the **1980 floodplain bank line limits** and the top of slope for the adjacent bluff/terrace.

Sta. 435+73 to 443+98 - The northerly bank erosion limits use **1980 historical bank limits**, since the 1938 and 1967 were ignored because of the channel breakout elimination.

Sta. 443+98 to 451+47 - This reach is within the central portion of the exposed bedrock area of the channel which defines the narrow channel section. The erosion limits for both the north and south banks were defined by the limits **"lateral erosion template"** geometry which is very conservative since it discounts the bed rock influence, although the bedrock is erodible.

Sta. 451+47 to 461+98 - This reach limits correspond to the transition from the exposed bedrock limits with the narrow channel to the upstream expanded channel width. The northerly bank erosion limits were defined by **1980 floodplain bank line** which corresponds well to the top of bank.

Sta. 461+98 to 468+87 - The northerly limits corresponded to the **1938 and 1967 historical bank line** limits which encompassed all the other lines.

Sta. 468+87 to 471+74 - This reach corresponds to the widened channel section immediately upstream of the existing Gibby Road low-water culvert crossing. The maximum **lateral erosion template** was used for both the north and south bank erosion limits which was close to the 100-year floodplain limits.

Sta. 471+74 to 477+74 - This reach is the widened channel area further upstream of the Gibby Road low-water culvert crossing, but still under the hydraulic influence of the culvert. The northerly bank erosion limits reflect the maximum "lateral erosion template" geometry which is above the 100-year floodplain.

Sta. 477+74 to 488+24 - This reach is a widened floodplain with the northern bank more pronounced steepened banks, but with large overbank area contained outside the active channel. The northern erosion limits were defined **combining both the maximum of either the HEC-6T calculated limits or the "erosion template"** whichever was larger.

Sta. 488+24 to 495+74 - The erosion limits were defined along this reach based on the **"erosion template"** on both the north and south bank.

Sta. 495+74 to 524+24 - This reach corresponds to the widened floodplain area up to the bedrock constricted channel at the upstream limits of this reach. The erosion limits were defined along this reach based on the **"erosion template"** on both the north and south bank.

Sta. 524+24 to 535+49 – This reach corresponds to the contracted channel section within the exposed bedrock and the majority of the historical active streambank lines are contained within the smaller active channel width. The erosion limits were defined along this reach based on the **"erosion template"** on both the north and south bank.

Sta. 535+49 to 545+24 – This reach corresponds to the narrow-incised channel within bedrock and the transition to the widened floodplain upstream. The **"erosion template"** contained the majority of the historical bank limits and the HEC-6T calculated long term erosion.

Sta. 545+24 to 582+74 – This reach corresponds to the widened floodplain upstream of the contracted section that extends to the upstream Ranch boundary. The erosion limits were defined along this reach based on the **"erosion template"** on both the north and south bank. The northern bank erosion limits were adjusted to corresponded more closely with actual topography of the top of bank limits.

Conclusion / Discussion of Lateral Erosion Analyses Results

Additional updated analyses were performed to updated both the 2006 and 2017 Lateral Erosion Studies prepared by PACE for the portion of San Juan Creek within the RMV boundary. The updated analysis was prepared to address several comments generated during the County review process for the most recent lateral erosion study. Technical peer review of these studies had indicated that along the northern San Juan Creek bank adjacent to the PA1 development area that there was a significant deviation between the PACE (September 2006) and identified more lateral erosion in a portion of PA1. The updated fluvial analysis was prepared to evaluate the effects of the changed hydrology from urbanization influencing the estimated lateral erosion limits as well as addressing the computed differences in the amount of lateral erosion identified in the peer review for the PA1 area. The results of these revised analyses indicated the following:

1. The lateral erosion hazard zones provided in the June 2017 PACE study do not need to be modified since the revised HEC-6T modeling using the updated hydrology indicated that the changes in lateral erosion distance was small or nonexistent, and generally the "erosion template" governed the limits of defined lateral erosion. The most conservative erosion boundary was used in developing the erosion hazard boundary.

2. The lateral erosion limit near the PA1 development did change with the more detailed modeling procedure and the revised limits are shown for comparison on *Figure No.2*. This figure illustrates that **the revised PACE analysis generates lateral erosion distances that exceed the Dr. Chang model estimates, but does not extend into the development area** since the development was actually setback further using the floodplain limits. However, in this area a site-specific erosion monitoring program and mitigation program was developed to specifically address lateral migration along a large river meander bend. The monitoring composed of several different monitoring features/processes which also serve to identify level of risk. This specialized monitoring effort for this area provides an additional layer of safety to ensure the long protection of the development.

SAN JUAN CREEK LATERAL EROSION HAZARD BOUNDARIES STUDY

ORANGE CO. CA

Legend

- Erosion Hazard Boundary (PACE New)
- Erosion Hazard Boundary (PACE Old)
- Erosion Hazard Boundary (Chang)
- XS Cut Lines

N

0 100 200 400 Feet

PACE Advanced Water Engineering

Date: 1/25/2018

Job Number B097

Drawn By sfifield

Figure No. 2

COMPARISON OF LONG TERM LATERAL EROSION ESTIMATES PA1 DEVELOPMENT AREA

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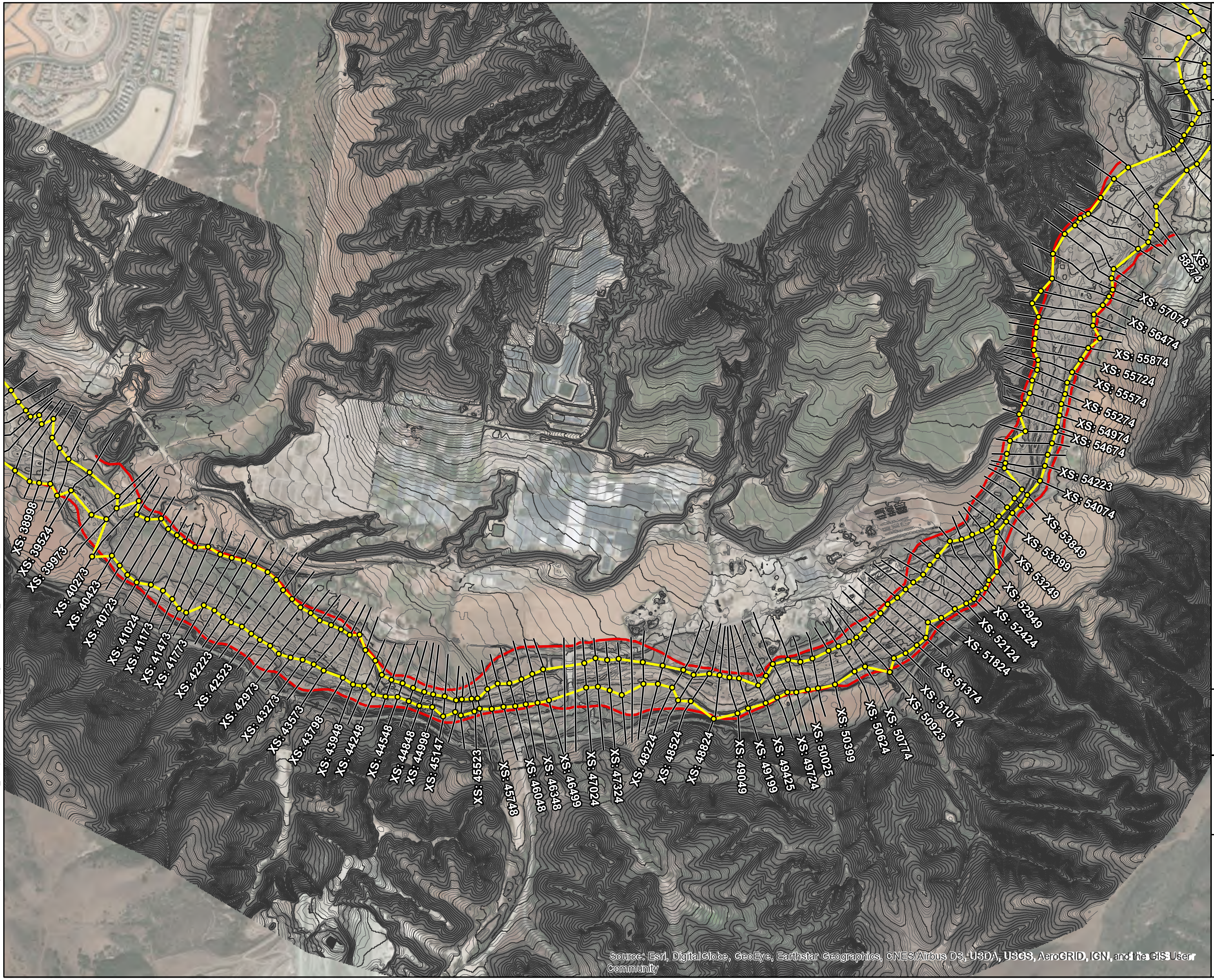

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SAN JUAN CREEK LATERAL EROSION HAZARD BOUNDARIES STUDY

ORANGE CO. CA

Legend

- Erosion Hazard Points (Chang)
- XS Cut Lines
- Erosion Hazard Boundaries (Chang)
- Long Term Erosion Hazard Zone

0 600 1,200 2,400 Feet

PACE Advanced Water Engineering

Date: 1/25/2018

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Figure No. 3

COMPARISON 2017 PACE LATERAL EROSION LIMITS AND DR. CHANG FLUVIAL-12 MODEL