BROWN AND CALDWELL
9665 Chesapeake Drive, Suite 201
San Diego, CA. 92123
Tel: 858-514-8822
Fax: 858-514-8833

Project No: 133904

San Diego County Hydromodification Management Plan (HMP)

Subject: Flow Threshold Analysis for San Diego HMP

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To: Sara Agahi – County of San Diego
San Diego NPDES Copermittees
Hydromodification Technical Advisory Committee (TAC)

From: Eric Mosolgo – Brown and Caldwell
Andy Collison – Phillip Williams and Associates
Christie Beeman – Phillip Williams and Associates

Copy to: Nancy Gardiner – Brown and Caldwell

This Technical Memorandum details flow threshold analysis efforts conducted in association with preparation of the San Diego Region's Hydromodification Management Plan (HMP), as required per Regional Water Quality Control Board Order R9-2007-0001, Provision D.1.g. The purpose of the HMP is to prevent development-related impacts to storm water runoff from causing, or further accelerating, stream channel erosion or other adverse impacts to beneficial stream uses.

The development of flow threshold limits for the San Diego HMP has been a collaborative process involving the County of San Diego, San Diego Copermittees, the consultant team, the Copermittee work group, and a Technical Advisory Committee comprised of water resources engineering and academic experts from throughout the San Diego and Southern California region.

Assumptions and the overall direction of the flow threshold analysis have been discussed with the aforementioned stakeholders and decisions were influenced based upon the compressed timeline associated with the RWQCB Order deadline. The consultant team reviewed flow threshold analysis methodology at multiple meetings of the Technical Advisory Committee prior to embarking upon the full hydrologic and sediment transport analysis. Subsequent to the submittal of the preliminary flow threshold limit analysis, the Copermittees contracted with West Consultants to provide an independent third-party review.

Brown and Caldwell, on behalf of the San Diego County Copermittees, is currently in the process of preparing the HMP. The Draft HMP submittal on January 24, 2009 includes the following requirement with

regard to flow threshold limits.

- Identification of flow threshold limits to define the geomorphically significant flow range. Priority Projects will be required to mitigate increases to peak flows and flow durations within this defined flow range to or below pre-project levels. Determination of these thresholds includes long-term continuous simulation modeling considering various development types, various flow control scenarios, and sediment transport modeling to quantify long-term channel erosion impacts.

To determine the flow threshold limits, the Brown and Caldwell team including subconsultant Phillip Williams Associates (PWA), has prepared detailed hydrologic and sediment transport modeling studies simulating a wide range of potential hydraulic conditions.

This memo summarizes the modeling efforts and details areas for future additional modeling.

Summary of Flow Threshold Limit Analysis

As part of the San Diego County Hydromodification Management Program (HMP), PWA has evaluated the effectiveness of different flow control standards for mitigating potential erosion impacts of new development using computer simulations of a wide range of watershed and channel conditions. The goal of this task was to identify a suitable standard (or standards) to protect creeks from additional erosion above baseline levels.

Background

The project team initially planned to perform rainfall-runoff and sediment transport modeling for numerous field sites throughout the County, using a combination of field data collection and available cross-section survey data. Project-induced erosion would have been estimated by comparing pre- and post-project cross-sections, providing an empirical basis for calculating erosion thresholds. Stream channel cross-section data representing baseline conditions and post-project channel response were requested from numerous sources, including the SCCWRP, San Diego Copermittees and HMP Technical Advisory Committee members, but available data proved to be very limited. An effort was also made to identify field sites where existing channel conditions could be surveyed, but project deadlines precluded the collection of significant field data in time to be incorporated into the analysis, and the field effort was halted.

Given the lack of available data, the time constraints of the RWQCB deadline, and because so many independent variables affect channel response, the project team revised the approach. In place of surveyed cross-sections, PWA developed a matrix of channel characteristics representing a wide range of channel conditions likely to occur in western San Diego County. While this approach is more theoretical and lacks field validation, it allowed for sensitivity testing of a much wider range of channel conditions and runoff controls.

In all, PWA evaluated the response of over 200 possible channel configurations to 40 years of runoff from 24 different watershed scenarios, a significant modeling effort for four technical staff over three months. By comparison the Santa Clara HMP flow control thresholds were based on assessment of four channels using actual existing conditions and assumed pre-development conditions.

Hydrology

Three representative watersheds were selected from western San Diego County. After studying County general plans and meetings with members of the Technical Advisory Committee (TAC) and Copermitee group, the consultant team determined where development was most likely to occur in the next 5-10 years. PWA then identified three target watersheds where development is occurring or is likely to occur, which were geographically distributed and which represented a range of hydrologic conditions. To meet the compressed deadline constraints, PWA used the San Diego Hydrology Model (SDHM) instead of the

more data intensive HSPF or HEC-HMS computer models as the rainfall runoff analysis component to simulate development scenarios, size infiltration and detention facilities, and test different flow control standards. Since detailed site-specific rainfall gage information was not available at the time of the flow threshold study initiation, the scaled rainfall feature built into SDHM was used to simulate rainfall for the hydrologic models. Runoff was simulated from the three watersheds under eight different scenarios.

- Pre-developed conditions
- Unmitigated post-developed conditions
- Post-developed conditions with 3 detention basin controls
- Post-developed conditions with 3 infiltration basin controls

In totality, a total of 24, 40-year rainfall-runoff simulations were prepared. The controls were simulated using the Pond Sizer function within SDHM to match the pre-project flow-duration curves for 0.1Q2, 0.1Q5 and 0.2Q5.

Sediment Transport Modeling

For synthetic channel modeling based on existing terrain (i.e. drainage area) and climate (i.e. precipitation), comparisons were made between several regression methods for estimating channel geometry. Plots of drainage area versus width to depth ratio for several relations were made to determine the applicability of these relations in future synthetic modeling endeavors. Representative channel configurations and sediment sizes were selected for use in the sediment transport portion of the analysis, resulting in a total of over 200 different channel/sediment combinations.

Output from the hydrologic simulations was used to run sediment transport models of the different channel/sediment combinations, resulting in hundreds of sediment transport scenarios being tested in HEC-RAS 4.0. The results of the sediment transport analyses were evaluated in terms of percent increase in erosion as compared to pre-project conditions, which allowed comparison of the effectiveness of the various controls simulated in SDHM.

Results of the flow threshold analysis are summarized below.

- The results show that without flow control, typical levels of unmitigated impervious area development would result in dramatic increases in channel erosion over baseline conditions (in the order of 200-300% for most conditions).
- Further, the results show great variability in the degree of channel sensitivity to urbanization and to the different flow controls, depending on channel type (width, depth, slope and sediment size). Many of the predicted erosion results vary by 100-200% when only one variable is altered (e.g. flow control, or sediment size), and where multiple variables are altered larger differences are found. This is typical for long-term sediment transport modeling simulations, where many independent variables affect channel response and small differences are amplified over time.
- Results indicate that infiltration basin controls (in this case defined as unlined extended detention basins) are generally more effective than the detention basin controls because they completely eliminate many of the small runoff events that cumulatively contribute to erosion.
- Sediment reduction has a great effect on the erosion rate of the receiving water, with 50% reductions in sediment input causing a 50-100% increase in the erosion of the upstream segment of the receiving channel according to model results. This effect would be expected to diminish downstream somewhat, through erosion of the receiving water channel.

- The different lower limits for flow control tested in the models resulted in significantly different channel erosion levels. Higher values for the lower flow control limit resulted in higher channel erosion rates.
- As with other studies, modeling results indicate that very small, frequent runoff events have a significant impact on channel erosion, resulting in very low values for the lower flow control limit.

This study evaluated lower flow control limits expressed as a percentage of Q5 and Q2 for the test watersheds. For very small watershed areas, a fraction of the 2-year flow could translate to a flow rate below the critical rate for sediment movement. In addition, a quick analysis suggested that for some small watersheds (tens of acres or smaller), channel bed infiltration losses may significantly reduce the effective flow. Further evaluation of this issue is warranted, with the goal of establishing a minimum flow rate that may be applied in small watersheds.

For more detailed information regarding the flow threshold analysis, refer to the memo titled *"Determining Flow Control Thresholds to Avoid and Minimize Channel Erosion due to Hydrograph Modification,"* prepared by PWA and dated November 12, 2008.

Third Party Review

West Consultants conducted an in-depth, independent third-party review of the flow threshold analysis prepared by PWA. The following list offers a summary of the third-party review.

- Concern was noted regarding the lower flow control limit suggested by the modeling results, especially with regard to implementation practicality and its derivation based solely on sediment movement.
- The review noted that literature suggests standard hydrologic design practices may be inadequate for characterizing cumulative effects of urbanization for flow events more frequent than the 2-year event – specifically with regard to sediment transport and channel disturbance potential.
- The review questioned the use of a specific frequency discharge as an indicator of shear stress to move particles given the variability of other site-specific parameters such as grain size, slope, roughness, and channel shape.
- The review suggested that hydraulic and sediment transport results should be supplemented with actual field data (slope, sediment properties, roughness, and channel shape) to set thresholds (flows, shear stresses, or velocities).

For more detailed information regarding West Consultants' independent third-party review, refer to the memo titled *"Review of Hydromodification Work by Phillip Williams and Associates (PWA),"* prepared by West Consultants and dated December 19, 2008.

Summary of PWA Sensitivity Analysis

Subsequent to its original analysis, the Copermittees requested that PWA conduct a sensitivity analysis based on historical rainfall records in the vicinity of the test watershed sites. The purpose of the sensitivity analysis based on the revised rainfall input data is described below.

- There are two potential concerns associated with the use of the SDHM in this analysis. First, the SDHM uses a single rainfall time series (Lindbergh Field) for all simulations. Rainfall records for other areas are synthesized by taking the difference in mean annual rainfall between a nearby

rain gage and developing a linear adjustment for the Lindbergh series (e.g. if the test site mean annual rainfall is 15% greater than the mean annual rainfall at Lindberg, then 15% is added to all hourly rainfalls). PWA performed the initial analysis using the SDHM default method, as other data were not in a suitable format at the time of the initial analysis. Rainfall data from a gage at Lower Otay Reservoir, which was prepared in collaboration between Brown and Caldwell and the County of San Diego, has since become available and is thus more relevant to the Otay simulations performed for this study. A test hydrologic analysis, conducted by Brown and Caldwell, showed significant hydrologic response differences between the historical rainfall record for Lower Otay Reservoir and the scaled data from Lindbergh Field.

- Second, the SDHM uses an "annual peak" method to calculate the rainfall recurrence interval, rather than a partial duration method. The two methods result in significantly different predictions of the two year flow (Q2). From discussions with rainfall statistical experts at the Hydrologic Research Center, Brown and Caldwell has determined that the partial duration series is a more applicable rainfall series for the semi-arid climate in San Diego County. Brown and Caldwell has generated partial duration flow statistics for the Otay simulation. The test hydrologic analysis conducted by Brown and Caldwell showed significant hydrologic response differences between the partial duration series and annual peak series methods.

There is significant variability in the HEC-RAS modeling results for the different channel and sediment scenarios, as reflected in the results of the original analyses. Therefore, it is important to focus on the general trends reflected in the sensitivity runs rather than the specific numerical results. As such, the sensitivity runs confirm that the selection of rainfall data, flow frequency methodology and sediment size distribution do affect the results of the flow control analysis.

For more detailed information regarding the PWA sensitivity analysis based on revised rainfall data, refer to the memo titled *"Sensitivity of Changing Rainfall Series and Analysis on Erosion Threshold,"* prepared by PWA and dated January 5, 2009.

Summary of Need for Future Modeling

Based on the results detailed in this technical memo, the following items were identified for future modeling efforts related to flow threshold determinations.

- Initial assumptions and direction for the flow threshold analysis were dictated by time constraints as required by RWQCB permit. Given the lack of existing field data and to meet the permit deadline, PWA, upon direction from the Technical Advisory Committee, initiated the analysis using a synthetic modeling approach. Assumptions used in the synthetic modeling approach are conservative and thus, validation of input parameters is warranted.
- Additional analysis to fully address concerns raised by the independent third-party review and the Technical Advisory Committee, especially with regard to identification of the lower flow threshold limit(s).
- Additional analysis to fully incorporate historical rainfall station data, which was not available at the time of the flow threshold study initiation, and the use of partial-duration rainfall series in lieu of the peak average annual series.
- Additional analysis to quantify lower flow threshold limit alternatives for small watersheds generating very low flows (alternatives could include minimum orifice size, minimum outflow limits, etc.).
- Additional analysis to run sensitivity checks to determine validity of sediment movement and shear stress calculations for very low flows.

Results of the subsequent flow threshold analysis is detailed in a Technical Memo titled *"Lower Flow Threshold Alternatives,"* dated April 30, 2009.

References

Memo - "*Determining Flow Control Thresholds to Avoid and Minimize Channel Erosion due to Hydrograph Modification,"* prepared by PWA and dated November 12, 2008.

Memo - "*Review of Hydromodification Work by Phillip Williams and Associated (PWA),"* prepared by West Consultants and dated December 19, 2008.

Memo - "*Sensitivity of Changing Rainfall Series and Analysis on Erosion Threshold,"* prepared by PWA and dated January 5, 2009.