Review Of

TECHNICAL COMPONENTS OF THE MUGU LAGOON SILTATION TMDL FOR CALLEGUAS CREEK

by

Neal E. Armstrong, Ph.D., P.E., BCEE
Austin, TX

OVERVIEW

The authors have done a quite commendable job of synthesizing the available siltation data for Mugu Lagoon and sediment transport data for the Calleguas Creek watershed. They have identified data gaps and developed an adaptive management approach including a research component with guidance from a Science Advisory Panel to determine additional needs and approaches.

There are several areas in which suggestions are made for research that could be part of the adaptive management approach, and there are others that deal with clarifications or alternative interpretations of the data presented in the document.

SOUNDNESS OF SCIENTIFIC KNOWLEDGE, METHODS, AND PRACTICES

Comments in this section will be related to particular parts of the TMDL using the headings of those sections.

<u>Problem Statement</u>. Because this TMDL deals with siltation in Mugu Lagoon, because that siltation is produced by sediments derived from the watershed, and because there is a relative paucity of data available to characterize the siltation, its effects, and its sources, a thorough understanding of the fluvial dynamics of the entire system is needed, and that understanding needs to be captured in a conceptual framework and fleshed out with a data collection program. There is an interrelatedness of the fluvial dynamics (i.e., the hydrologic and physical processes that govern channel shape and sediment transport) of the stream channels in a watershed, the transport of sediment from the land surface to those channels, the transport of sediment downstream, and the water quality and biological components and processes in those streams. The time scales of these processes are quite different; water quality changes occur quickly for substances in the dissolved phase and more slowly for those in the particulate phase (such as hydrophobic pesticides), biological changes take place over a broader time scale, and fluvial dynamics over a span of years. Perhaps the greatest need in this TMDL is to develop that conceptual framework so that the different ways of estimating and representing sediment sources, the processes of sediment transport through the tributaries, and the sedimentation and compaction of sediments in the Lagoon can be interrelated. It is also important to understand the long-term and short-term changes in fluvial dynamics caused by land use changes and sediment

control systems. Actions that may appear to be effective in the short term in controlling siltation may in fact in the long term be quite deleterious.

It should also be realized that estuaries, of which Mugu Lagoon is one, are ephemeral systems, i.e., they, like natural lakes, are born to die. Current estuaries are relatively recent features geologically, created following the last major glaciation period as sea level rose inundating riverine channels. With the stabilization of sea level in the past few millennia, the geomorphic features of estuaries have been modified by sediment loads delivered from the rivers that enter them, the sediments transported along shore to them, and the reworking of those sediments by tidal action through their opening to the ocean and flood events from the rivers. Mugu Lagoon, it can be safely stated, has never been a stable system, and the geology of this system must become known, if it not known already, to understand how it has responded to sediment loads historically.

The other significant need of this TMDL is to relate specifically the impacts of elevated levels of sedimentation/siltation on beneficial uses for Mugu Lagoon. At this point the 303(d) listing states that there is a loss of beneficial uses; however, it is possible to relate to some extent what the specific relationships are between sediment concentrations and beneficial use losses is possible to some extent with available literature data. For example, there is abundant literature on the effects of siltation on Navigation. There is significant literature on the effects of siltation and suspended sediment on finfish and shellfish, benthic organisms, etc. related to the Commercial and Sport Fishing, Estuarine, Marine, and Wildlife Habitat, Preservation of Biological Habitat, Rare, Threatened or Endangered Species habitat, Migration of Aquatic Organisms, Spawning, Reproduction and/or Early Development and Shellfish Harvesting. It may be that getting to this level of detail needs to wait for the research portion of the adaptive management phase of the TMDL implementation.

To be sure, the entire watershed, including Mugu Lagoon, has experienced natural siltation; estimates of erosion from a part of the watershed are given in Table 5, and if those results are extrapolated to the rest of the watershed with the same methodology, some baseline natural load can be estimated. It is also this load that sustained the fluvial dynamics in the system historically, that produced sediment loads to the tributaries and those loads were gradually transported downstream to Mugu Lagoon, which produced siltation in the Lagoon. That siltation was then subject to transport processes that moved sediment out of the Lagoon to the shelf and some sediment to permanent sediments through compaction processes. It is also this siltation and the sediment concentrations produced throughout the Lagoon that affected aquatic life directly or its habitat and to which such aquatic life has adapted. It is this load and the sediment concentrations produced in the streams and Lagoon that provide the baseline impacts on beneficial uses. This baseline needs to be determined through modeling efforts or some other fashion as part of the research conducted during the adaptive management portion of the TMDL implementation.

<u>Current Conditions:</u> From the information presented, it appears that there are limited data in critical areas of sediment sources, transport, and deposition. For the streams, there are estimates of sediment delivered from the land to the stream channels, there are some measures of temporary storage of sediment in the stream channels (and hence their gradual transport through

the stream network to the Lagoon), there are estimates of sediment loads with storm runoff events to Mugu Lagoon, and there are estimates of sediment loads to the Lagoon based on sedimentation in the Lagoon (however, see the comment below about the assumption of sediment density used in these estimates). For the Lagoon, there are estimates of the sediment loads into the system but no estimates of sediment loss to the shelf over a significant period of time and no estimates of sediment loss to permanent sediments via compaction. In the research phase of the adaptive management portion of this TMDL, these estimates need to be checked so that there are reliable estimates of the sediment loads throughout the Calleguas watershed and in Mugu Lagoon.

Where estimates are available, it is not totally clear whether they include sand, silt, and clay or just silt and clay or just silt. In some cases, "silt" appears to be used to represent all of the sediment rather than the portion represented by a certain size class. This interchanging of terms is confusing and in relation to fluvial dynamics will mean quite different things. For example, in the last paragraph on page 3, it is reported that Inman and Jenkins (1999) measured sedimentation volumes in Calleguas Creek between 1944-1968; measuring volumes might imply measuring the volume of gravel, sand, silt, and clay. But in the next sentence, they are said to have reported the volume of transported silt; is this just the silt fraction of sediment or is this really sediment made up of gravel, sand, silt, and clay or just sand, silt, and clay? This needs to be clarified. On page 4 at the end of the discussion of the RMA (2003) work, there is mention of silt and clay as if these are the fractions of the sediment load RMA estimated, yet a correction was made to these loads using silt data from Inman and Jenkins. The terminology needs to be clarified, and the studies referenced need to be reviewed once again to discern precisely what portions of the total sediment there were measuring. Also, where different portions of the sediment are represented in these studies, combining sediment load estimates based on them is problematic. In Table 3, for example, the title indicates that the loads given are for the silt and clay portions of the sediment, yet the Inman and Jenkins study appeared to measure gravel, sand, silt, and clay while the RMA study examined silt and clay only. If this is the case, then these two estimates really cannot be compared, and the RMA estimate for silt and clay will grossly underestimate total sediment loading if gravel and sand are not included.

Finally, the estimates for sediment loading using "loss of capacity" appear to be underestimated. Assuming that "loss of capacity" in this case refers to sediment build-up in the bottom of Mugu Lagoon and that the material of concern is the sediment that displaces the water in the Lagoon and not the water being displaced, the bulk density (mass of sediment plus water/volume) of 1,000 kg/m^3 significantly underestimates the amount of sediment load needed to produce that loss of capacity. The bulk density of the sediments subject to estimates by the USDA (1995) is assumed by RMA (2003) to be 1,000 kg/m^3 which is the density of water. Chang (2004) uses the RMA (2004) assumption as well. However, this value of 1,000 kg/m^3 is a significant underestimate of the bulk density of the sediment. As Di Toro (2001, pp. 3-5) notes, the bulk density, ρ_b, is calculated as:

$$\rho_b = (1 - \phi)\rho_s + \phi\rho_w$$

where ρ_w = density of water, ρ_s = density of solids, and ϕ = porosity. Di Toro (2001) reports that a typical value for ρ_s is 2.6 gm/cm^3 (equivalent to 2.6 kg/L or 2,600 kg/m^3). For the bulk density of the sediment to be equal to 1,000 kg/m^3 or 1 kg/L, the porosity must be equal to 1.0, or

$$\rho_b = (1 - \phi)\rho_s + \phi\rho_w = (1 - 1)\ 2.6 \text{ kg/L} + 1.0 \times 1{,}000 \text{ kg/m}^3 = 1{,}000 \text{ kg/m}^3.$$

This is not reasonable for consolidated sediments in the bottom of Mugu Lagoon. Indeed, Di Toro (2001, p. 4) notes that porosity is typically 0.7-0.9 in the top few centimeters of sediments then increases with depth to 0.4-0.7 because of compaction (i.e., water squeezed out). If a value of 0.5 is chosen, then the bulk density of the sediments would be:

$$\rho_b = (1 - \phi)\rho_s + \phi\rho_w = (1 - 0.5)\ 2.6 \text{ kg/L} + 0.5\ (1 \text{ kg/L}) = 1.8 \text{ kg/L or } 1{,}800 \text{ kg/m}^3$$

a value significantly higher than the value of 1,000 kg/m^3 assumed. Using this value or some other value calculated using a different porosity would impact the depth of sediments in the Lagoon resulting from sedimentation and compaction. This would also affect estimates of sedimentation in the Lagoon as well as estimates of sediment load to the Lagoon based on bathymetric changes. The RMA (2003) and Chang (2004) estimates may need to be recalculated.

<u>Numeric Targets:</u> In Table 3, long-term values for Mugu Lagoon sedimentation are given as 4,291 tons/yr and 6,139 tons/yr with an average of 5,200 tons/yr. These may need to be modified upwards by almost a factor of two based on the assumption of the bulk density used in the original estimates.

<u>Source Analysis:</u> It is interesting to note that 57% of the total sediment yield of 347,000 tons/yr to the streams in the Callequas watershed are from Streambanks and Natural Areas with Streambanks alone accounting for 44% of that total yield. In contrast the most controllable sources from Orchards, Construction, and Other roads make up 43% of the total yield. This distribution of sediment yield needs to be considered in the allocation of sediment load.

<u>Linkage Analysis:</u> The consequences of sediment accumulation throughout Mugu Lagoon by RMA (2003) may need to be re-evaluated if the bulk density value needs to be changed as noted above.

On page 6, it is noted that Total Suspended Solids (TSS) may be the measurement by which silt reduction in the upper portions of the watershed may be monitored. The text also mentions that the USGS gauge near the University rating curve predicted certain TSS values. Confirmation is needed that these are indeed TSS measurements, because the USGS uses a Suspended Sediment (SS) measurement rather than TSS. They may appear to be the same, but SS includes larger sediment particles like sands whereas TSS typically does not because the sampling and analytical procedures are different for the two measurements. USGS has published in recent years documents that compare the two measurements and provide convincing evidence that at higher flows the SS measurement does indeed give a higher value than the TSS measurement because sands and larger silt particles are suspended under those conditions and detected in the SS measurement. I would recommend that any sampling regime that is going to estimate suspended sediment load use the USGS procedures. If TSS is an important measurement for water quality purposes, it can be sampled and analyzed for as well. Again, the RMA report needs to be reviewed to determine whether TSS or SS was measured, and the consequences of the result of that review on the sediment load estimates given in the section.

Critical Condition: As stated on page 7, the critical condition for this siltation TMDL considers both critical conditions of wet and dry periods. The authors may wish to review a just-published article by Zhang and Yu (2005) on the TMDL Critical Condition. Zhang, a principal engineer with Parsons Corporation in Fairfax, VA, and Yu, professor emeritus at the University of Virginia, suggest that a low-flow analysis method using steady-state models be used for dry weather conditions because such models are simple and well established. For wet weather conditions, however, they recommend an event-based critical flow-storm approach because the approach: (1) explicitly addresses the critical condition as a combination of stream flow, magnitude of storm event, and initial watershed condition; (2) offers the ability to estimate the risk and return period – thus, the nonpoint source management plan could be linked with its corresponding return period to determine the reasonable assurance of the TMDL implementation; and (3) is an event-based approach which is less data intensive. They also note that current research shows that the critical flow-storm concept will be more pronounced for urban and smaller watersheds.

I suggest that the event-based approach be considered to help define the wet weather Critical Condition. Some information in this direction is already available and has been incorporated into this TMDL, and perhaps other data could be compiled to define better how this Critical Condition would be characterized in terms of flow and sediment concentrations.

Margin of Safety: Several clarifications are needed for the Margin of Safety assumptions given in Table 6. First, the silt numeric target is given as 5,200 tons/yr reduction; is this in fact the case? Is not the estimated load being reduced to 5,200 tons/yr, and the Margin of Safety comes from the conservative nature of the value, i.e., it is lower than it probably needs to be? From Table 7, the estimated sediment supply is given as 181,000 tons/yr, and it is being reduced to 5,200 tons/yr or a 97% reduction. In contrast, a 5,200 ton/yr reduction in this sediment supply would be equivalent to a 2.9% reduction in load, and that does not appear to be what is intended.

Second, the TSS measure of reduction may need to be changed to the SS measure. While SS may not be the more common measure of sedimentation change, it is the more accurate primarily because it reliably measures more of the total sediment concentration than TSS. Further, the statement that TSS is less accurate in low flow conditions and more accurate in flood conditions is just not true unless extraordinary efforts are taken to assure that the TSS sample is representative of the entire water column. Having taken hundreds of TSS samples myself in the field, the inability of the sampling procedure for TSS to accurately represent the heavier particle component of the total sediment in the water column under flood conditions reduces its accuracy and usefulness. Any water quality analysis method becomes less accurate as its minimum detection level is approached, but in stream waters and certainly shallow estuarine systems, the TSS measurement is quite good under normal low flow conditions.

Allocations: At the beginning of this section, the same confusion as noted above under Margin of Safety is found, i.e., the 5,200 tons/yr is a target that loads will be reduced to rather than being a load reduction of that amount – this needs to be clarified. Next, the 5,200 tons/yr load allocation is to be allocated to the agricultural dischargers, and that allocation is shown in Table 7. The silt supply numbers in Table 7 do not match those in Table 4 even though they come from the same source; thus, some explanation for that difference is needed. Further, the agricultural source in Table 4 is the Orchards which produce a yield of 74,000 tons/yr for the whole watershed, so it is not clear where the value of 181,000 tons/yr for agricultural sources in Table 7 comes from – this needs to be clarified.

Implementation Plan: The implementation plan appears to be a good plan and on target. I suggest that the Year 1 activities include the various studies I have suggested throughout this review.

CLARIFICATIONS NEEDED

Page 2, Table 1: the Onuf (1987) reference needs to be added to the list of references given in Attachment 2.

Page 3, paragraph 2: the RMA (2002) reference needs to be changed to RMA (2003)

Page 3, Table 2: the assumption is that "tons" are short tons of 2,000 lbs rather than metric tons.

Page 3, Table 2: the bulk density of the sediments is assumed to be 1000 kg/m^3 which is the density of water. As Di Toro (2001, pp. 3-5) notes, the bulk density, ρ_b, is calculated as:

$$\rho_b = (1 - \phi)\rho_s + \phi\rho_w$$

where ρ_w = density of water, ρ_s = density of solids, and ϕ = porosity. For the bulk density of the sediment to be equal to 1000 kg/m^3 or 1 kg/L, the porosity must be equal to 1.0. This does not seem reasonable for consolidated sediments in the bottom of Mugu Lagoon. Indeed, Di Toro (2001, p. 4) notes that porosity is 0.7-0.9 in the top few centimeters of sediments then increases with depth to 0.4-0.7 because of compaction (i.e., water squeezed out). If a value of 0.5 is chosen, then the bulk density of the sediments would be:

$$\rho_b = (1 - \phi)\rho_s + \phi\rho_w = (1 – 0.5)\ 2.6\ \text{kg/L} + 0.5\ (1\ \text{kg/L}) = 1.8\ \text{kg/L or } 1000\ \text{kg/m}^3$$

a value significantly higher than the value assumed. Using this value or some other value calculated using a different porosity would impact the depth of sediments in the Lagoon resulting from sedimentation and compaction. This would also affect estimates of sedimentation in the Lagoon.

Page 4, paragraph 2: Is the Fig 4-20 reference from RMA (2003)? If so, some clarification should be added to that effect.

Page 4, Table 3: RMA 2002 needs to be changed to RMA (2003)

REFERENCES

Di Toro, Dominic M. 2001. Sediment Flux Modeling. Wiley-Interscience, New York.

Zhang, Harry X. and Shaw L. Yu. 2005. "Condition Critical." Water Environment & Technology 17(6): 38-42.