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Brian Murray
Countywide Policy and Programs Supervisor
River and Floodplain Management Section
King County Water and Land Resources Division
201 S. Jackson Street, Suite 600
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26 April 2012

Subject: Review of Setback and Floodwall Rehabilitation Schemes for the Briscoe/Desimone Levees, Kent, Washington

Dear Mr. Murray:

At your request, I have reviewed two proposed schemes to rehabilitate the Briscoe/Desimone levees along the Green River in Kent, Washington. This letter documents my review, which considered the relative merits of these schemes with respect to site considerations, facility management, consistency with established design guidelines, maintenance concerns, and anticipated design life. Additionally, I make note of relevant findings from performance investigations of other levee systems and provide recommendations regarding a preferred rehabilitation option for the Briscoe/Desimone levees. My recommendation reflects both technical aspects and larger issues with the proposed rehabilitation schemes; however, it does not specifically consider costs. As part of my evaluation, I made a reconnaissance of the levee sites on 16 March 2012 and reviewed relevant design and engineering reports provided via your FTP website. An executive summary of my review is included as an attachment to this letter.

Background

The 2006 King County Flood Hazard Management Plan identifies the Briscoe/Desimone levees as requiring rehabilitation owing to bank instability, among other concerns. In response, both City of Kent and King County have proposed levee rehabilitation schemes. These schemes share the same overarching goal of enhanced flood protection, but differ in their approaches. King County has proposed a levee *setback* scheme, whereby land adjacent to the Green River would be acquired, thus allowing earthen levees to be "setback" from the river to provide a wider flood corridor. The City of Kent has proposed an alternative *floodwall* plan involving installation of steel sheet pile through select portions of the existing distressed levees for stabilization purposes, while leaving more stabile intermediate levee segments as-is (Details of the floodwall scheme are outlined in the "Stability and Certification Report for Briscoe/Desimone Levees," prepared by

GeoEngineers on October 24, 2011). Overall, the King County levee setback proposal is greater in scope and more multi-objective and thus more costly than the City of Kent floodwall proposal, though I note both plans are still preliminary and so there is a high degree of uncertainty in the current cost estimates.

Comparison of Proposed Rehabilitation Schemes

Design Issues and Technical Constraints

There are several technical issues that affect the Briscoe/Desimone levees under routine annual in-service conditions. The levees are subject to bank erosion and scour at their "toe" (i.e., on the river side of the levees, near the riverbank). This has been an ongoing concern at the site, and is the primary reason that the levees are in their current oversteepened and marginal stability condition. This bank erosion is exasperated by the current narrow configuration of the levee-confined river corridor. An additional concern pertains to seepage, a phenomenon whereby water "seeps" (migrates) through the levee soils under a hydraulic gradient (i.e., under the pressure of the water in the river; this pressure substantially increases during flood events). Under extreme flood conditions, seepage can destabilize the levee and increase it propensity for failure by collapse. Lastly, while the specific risk will vary based on a range of site-specific factors, levees everywhere may subject to overtopping in extreme flood events, and thus susceptible to erosion-induced failure.

Seismic issues are also relevant to the Briscoe/Desimone levees. The levees are generally underlain by a mixture of silty and sandy alluvial soils, which is typical in river environments. From a technical perspective, these soils are noteworthy due to their susceptibility to seismically induced soil liquefaction, a phenomenon whereby soil can temporarily undergo significant strength loss in an earthquake. As a result, the overlying levees could permanently deform (i.e., experience horizontal and/or vertical movement), or in an extreme case, collapse, under extreme seismic loading. These are rare but fully plausible long-term scenarios in the seismically active Pacific Northwest.

Setback Scheme Evaluation

The setback option directly addresses all of the major in-service issues outlined above. The wider corridor would allow the levee to be moved back from the river, which would result in significantly reduced toe erosion. Additionally, a wider corridor would have a higher water storage capacity in flood events and therefore reduce seepage intensity and also decrease the likelihood of overtopping. Setback levees would remain susceptible to liquefaction in their foundation soils; however, their flatter side slopes would likely result in less permanent deformation and a much-reduced risk of collapse.

The setback scheme also offers a number of practical benefits for long-term management and operation of the levee system. The wide corridor would more readily accommodate access for inspection, maintenance, and emergency repairs (if needed). Barring any concerns with significant ground settlement (due to the weight of the levee), the functional lifespan of similar well-maintained setback levees at other locations has been

observed to be very long (greater than 50 years). Soils underlying the Briscoe/Desimone levees are not highly compressible so high rates of long-term settlement are not expected to be a major concern.

Floodwall Scheme Evaluation

The floodwall system as detailed (at the early 35% design level) in the cited 24 October 2011 design report is technically viable. The high quality design analysis is commensurate with the current state of engineering practice and contemporary levee design standards (e.g., guidance documents of the Army Corps of Engineers, established safety margins or "factors of safety"). In addition to providing a measure of structural enhancement to the existing levees, the floodwall would serve as a subsurface "cutoff" wall to modify (lengthen) seepage flow paths and thus reduce seepage forces at the locations where sheet piles are installed (however, near transition locations, floodwalls could locally increase seepage in adjacent unmodified sections due to three-dimensional effects; this scenario should also be evaluated). Moreover, because they serve to structurally enhance the levee segments, the floodwalls would likely lessen the consequences (e.g., deformation) of soil liquefaction at locations where they are employed.

Because the existing levee system will remain in its current configuration, the floodwall scheme will not reduce toe erosion or scour, and this will remain an ongoing maintenance concern[1]. Additionally, past case studies have shown that the segmented (i.e., discontinuous) floodwall systems can inadvertently increase the risk of overtopping-induce erosion failure due to the differing heights and contrasting steel-earthen materials at segment transitions. This is because under extreme flood events (i.e., those approaching the top elevation of the levee system), segmented floodwall levee systems tend to result in concentrated, high velocity surface water flow and consequent scour of adjacent softer earthen levee segments. This was the most common mode of failure of the levee system in New Orleans.

Although subject to corrosion, sheet pile floodwall systems have nevertheless been generally shown to remain functional over long periods of time under typical conditions. Therefore, provided they are properly maintained, the floodwalls may be expected to have a long design life. As the levee system will remain in its current location, access for routine inspection and maintenance will remain limited for the floodwall option. This will increase management and operation costs over the longer term.

Discussion and Recommendations

Overall, the setback scheme proposed by King Country is both technically viable and directly aligned with the overarching multi-objective goals of the King Country-adopted

[1] The design report indicates that the floodwalls were designed to remain stabile after "sloughing," however, from my review it was not clear how this design assumption was incorporated into the engineering analysis and therefore I believe that it would be prudent to continue maintenance of the toe of the modified levee system.

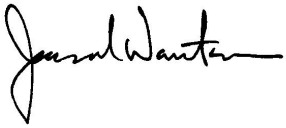
2006 Flood Plan (i.e., main goals of reducing flood risk, minimizing environmental effects of flood mitigation, and reducing long-term costs of flood hazard management). However, as this option involves encroachment unto private property, it is the more costly of the two schemes and also potentially disruptive to existing businesses. Moreover, the planned timeframe for this work is longer than that of the floodwall scheme and therefore leaves the community with a higher vulnerability over the short-term. These two issues are the setback scheme's most significant limitations.

The floodwall scheme is also technically viable, but it does not satisfy all of the goals of the 2006 Flood Plan (especially that of avoiding or minimizing the environmental effects of flood hazard mitigation efforts). In adopting the 2006 Flood Plan, King County has committed to several well-conceived goals that should, to the practical degree possible, be honored. Additionally, while the floodwall scheme is technically sound, I am concerned from a larger perspective about its piecemeal, or "patchwork" nature (i.e., the segmented scheme of localized floodwalls interspersed with sections of existing earthen levee). This markedly contrasts with the notion of an integrated flood protection "system" — the need for which have been a critical lesson from the investigations of levees failures in New Orleans and other locations. There are several specific issues with this larger concern, the most significant being that segmented earthen/floodwall systems have a heightened risk of erosion-induced failure due to the differing heights and contrasting materials at segment transitions.

I should note that while floodwall systems tend to exhibit a less resilient response than traditional earthen levees during flood events, they are not inherently unstable systems. Indeed, with proper engineering and use of an adequate margin of safety against failure, these can and do perform quite well at locations across the United States. Thus, the issue here is not the floodwall itself, but rather its proposed segmentation across the project area. This can be addressed by installing continuous sheet piling over the entire length of the project area, though this would add significant cost to the project.

Overall, it is my opinion that from both a technical and broader flood management perspective the setback scheme is preferable to the floodwall option. Should King County adopt the setback plan, it is likely that further optimization and refinement of this scheme will result in reduced capital investment costs. Further design optimization should include a detailed life-cycle cost assessment and specifically consider the tradeoff between the width of the flood corridor (an its associated reduction in flood risk and long-term operation costs, and improved environmental benefits,) and cost. It is possible that even an intermediate widening and redesign of the corridor will largely achieve the goals of the 2006 Flood Plan at a relatively modest cost.

Sincerely,



Joseph Wartman, Ph.D., P.E.

Enclosure: Executive Summary

Attachment 1

Executive Summary

Review of Setback and Floodwall Rehabilitation Schemes For the Briscoe/Desimone Levees Along the Green River in Kent, Washington

The 2006 King County Flood Hazard Management Plan identifies the Briscoe/Desimone levees as requiring rehabilitation owing to bank instability, among other concerns. In response, King County has proposed a *levee setback* rehabilitation scheme while the City of Kent has proposed a less costly alternative *floodwall* levee rehabilitation scheme.

Both rehabilitation plans are technically viable. The setback option directly addresses all key in-service issues affecting the levees and additionally offers a number of practical benefits for long-term management and operation of the levee system. The floodwall system will stabilize critical portions of the existing levee system, but will not reduce toe erosion or long-term maintenance costs. Additionally the floodwall scheme's "patchwork" (discontinuous) nature markedly contrasts with the contemporary notion of an integrated flood protection system.

Overall, it is my opinion that from both a technical and broader flood management perspective the setback scheme is preferable to the floodwall option. Should King County adopt the setback plan, it is likely that further optimization and refinement of this scheme will result in reduced capital investment costs.

Memorandum

To: Brian Murray
River and Floodplain Management Section
King County Water and Land Resources Division

From: Joseph Wartman, Ph.D., P.E.

Date: 2 May 2012

Subject: Response to Additional Questions Regarding Briscoe/Desimone Levees

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This memo documents my response to several additional questions pertaining to the proposed rehabilitation schemes for the Briscoe/Desimone Levees. These questioned were forwarded via e-mail and are reproduced below, along with my responses.

1. (Your) report concludes that floodwalls are technically viable and can perform quite well, "with proper engineering and use of an adequate margin of safety against failure." While accepting this general maxim, we are concerned for the specific Briscoe/Desimone design proposal. In our review of the available documents in support of the city proposal, we see several factors of safety that are below Corps guidance, some of them below 1.0. We see 1.0 as the specified factor of safety in the wall design calculations. Are you satisfied that the design basis for this particular floodwall proposal provides an adequate margin of safety against failure?

Response: The factor-of-safety values adopted in the floodwall design report are commensurate with the current safety standards established by the Corps of Engineers, so I think the concern falls to the issue of: what is the likelihood of a given loading scenario? Factor-of-safety values less than 1 indicate that under a given scenario the localized levee segment will fail. This is the case for several sections of the levee under an assumed extreme event drawdown rate of 1 foot/hour. However, the design report suggests that this rapid rate of drawdown is unrealistic and that a reduced drawdown rate of 2 feet/day is more appropriate (for which an acceptable safety factor is computed).

As the rate of extreme event drawdown is largely (and artificially) governed by controlled discharge from the upstream Howard Hanson Dam, an appropriate drawdown rate representing a plausible worst-case design scenario should be relatively easy to determine. If current and anticipated future water management polies allow a discharge of up to 1 foot/hour, then this should be the controlling worst-case design scenario. In this extreme situation, failure of the levee is predicted, which is obviously unacceptable. Alternatively, if existing and anticipated future water management policies dictate a maximum rate of drawdown of 2 feet/day, then this should be considered the controlling drawdown design scenario.

Factor-of-safety values of less than 1 are also induced under seismic conditions owing to inertial slope instability and/or liquefaction (also with implications for slope instability). This situation is common in seismically active regions and less of a concern due to the transient nature of earthquake loading, which will typically include only a limited number of brief (~1 sec.) pulses of strong shaking that could result in incremental displacement of the levee. This situation necessitates that a subsequent seismic displacement analysis to be performed (as detailed in the floodwall design report). The results of the seismic displacement analysis indicate that although the factor of safety may temporarily fall below 1, the resulting displacements would be relatively small and not affect the serviceably of the levee; therefore these are judged to be tolerable.

In summary, if current water management policies allow an extreme event drawdown rate of up to 1 foot/hour, then an adequate margin against failure does not exist for the proposed floodwall design. If these policies limit discharge to 2 feet/day, then an adequate safety margin does exist. Under seismic conditions, factors or safety of less then 1 are acceptable provided that resulting deformations are minor, as appears to be the case for the Briscoe/Desimone Levees.

2. (Your) report references design assumptions of floodwall stability after sloughing and recommends continuing maintenance of the levee toe in order to protect the wall. We agree that this would be important. Sloughing can occur at elevations as low as 17 feet below the bottom tip of the proposed wall, where the existing levee and its maintenance are the wall's only defenses. We are concerned that the proposed wall may tend to make our levee maintenance responsibilities both more urgent and more difficult. Can you help us understand these issues?

Response: Although sloughing may occur to depths below the sheet pile wall, the area of active erosion is laterally offset from the wall and therefore not likely to result in immediate failure of the floodwall. However, in the absence of repair, continued erosion will likely cause sloughing progressively closer to the sheetpile; this will more directly threaten the stability of the floodwall system. This is due to the fact that the existing levee serves to "buttress" the sheetpile, and as this buttress is progressively removed (by sloughing) the floodwall system will become increasingly destabilized. The relationship between erosion and destabilization is highly site specific and can only be determined through detailed computer slope stability analyses that have not been presented (or possibly performed). Therefore, in the absence of any such analysis, I feel it is prudent to immediately repair any sloughing so that the stability of the wall system is not compromised.

Your expressed concerns are legitimate, as the discussion above highlights the importance (and urgency) of maintaining the levee. Additionally, the proposed floodwall scheme will impair access to the levee, making its maintenance more difficult.

3. We understand that the walls are proposed in areas of relatively low stability. We do not find supporting calculations or graphics to demonstrate the relatively low stability in the wall areas. We do not challenge the findings in this regard, but we wonder at the

potential failure surfaces associated with relatively low stabilities, and the relationships of these relatively weak surfaces to the proposed walls. Would it not be important to understand how these potential failure surfaces might relate to the proposed wall locations and depths?

Response: Analyses results for current conditions are not provided and the design report presents only the analyses results for the floodwall rehabilitation proposal. Therefore, it is only possible to speculate about the nature of the critical failure surfaces/zones and what these tell us about the overall system. Still, comparison of the results from the modified with those of the adjacent unmodified sections suggest that the key effect of the sheetpile is to push the critical failure surfaces lower into deeper stronger soil layers, thus "bypassing" shallower, weaker layers. This could be confirmed by obtaining and reviewing the full suite of analyses (i.e., for both current and proposed configurations).

If the reasoning above is correct, then these soft layers would be contained within a potential failure mass, but not actively play a role in the a failure of the floodwall system (e.g., weak layers would, in effect, be isolated and shearing within these layers would not be expected). These weak layers would remain in place and although not explicitly stated, the results of the global slope stability analysis imply that these layers become less critical when "reinforced" by the sheet pile [that is, smaller slope failures in soil mass in front (river side) of floodwall will not occur].

Finally, your question raises a related and important point (and major lesson from Hurricane Katrina): detailed geotechnical peer-review should be part of any final design. It would not be appropriate to expend significant effort on this now due to the limited 35% design, but it will become critical as design is finalized. A detailed review would allow specific questions such as these to be directly assessed, and slope stability analyses to be independently replicated.

4. The report mentions the potential for deformation of the levee structure due to liquefaction of underlying strata. It further mentions that the flatter slopes of the proposed setback levees would reduce this concern. Given that the floodwall alternative involves additional fill on the levee back slope, increasing the weight on the existing levee footprint, would this not tend to exacerbate the liquefaction concern?

Liquefaction-induced permanent ground deformation is directly correlated with shear stress in a slope. Shear stress will increase as a function of both slope inclination and height, but at different rates. Thus, while increased height will indeed increase liquefaction deformation potential, this will in all likelihood be far outweighed by reductions in shear stress that result from a flatter slope inclination. The anticipated net effect would be an overall reduction in liquefaction-induced ground deformation.

Memorandum

To: Brian Murray
River and Floodplain Management Section
King County Water and Land Resources Division

From: Joseph Wartman, Ph.D.

Date: 26 April 2012

Subject: Phased Construction of Briscoe/Desimone Levees Rehabilitation

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This memo serves to document my response to your question posed during our telephone conversation of 26 April 2012 regarding my review of the two proposed schemes to rehabilitate the Briscoe/Desimone levees. During our conversation, you noted that due to the magnitude of the initial capital costs, it was not likely that either of two proposed schemes would be constructed in a single phase of construction. Instead, construction was more likely to be spread over multiple phases (and time periods) of work. This is the case for the setback scheme as currently proposed, and also for the floodwall scheme if adopted in a continuous manner across the current levee system.

Based on this likely phased construction, you asked: which of the two schemes can be best implemented in phases? (Here "best" is taken in the context of lowest risk to public safety). In my opinion, the setback scheme would be preferable, as it would eliminate the potentially problematic earthen-steel sheet pile transitions that would be required with a phased floodwall scheme. Here it should be noted that should the setback scheme be selected and constructed in a phased manner, work should be scheduled so as to first address the most unstable (i.e., critical) portions of the existing levee. This would require that property acquisition required for this scheme not be prioritized based solely on convenience or immediate availability, but with appropriate consideration of the location of the most unstable levee sections.

-----Original Message-----
From: Joseph Wartman [mailto:wartman@uw.edu]
Sent: Monday, May 07, 2012 8:56 PM
To: Murray, Brian
Subject: Follow-up

Brian,

I wanted to follow up again with a few short misc. items you have written about:

• The low factor of safety (FOS = 1) for drawdown events reflects that the fact that the loading is rare, but nevertheless possible (the same idea pertains with seismic FOS values). Based on the information provided from your review of the relevant water policy, I strongly agree that the 1 ft/hr should be adopted as the worst-case design event. In this case the proposed floodwall design is unsatisfactory, although it is possible that the FOS could be raised by driving the sheet piles to deeper depths (at greater expense).

I am glad you raised this concern as it allowed us to get into this important issue in greater depth. In retrospect, I should have confirmed this important design assumption earlier with you.

Regards,

-Joe

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