Burien
Washington, USA

City of Burien
400 SW 152nd St., Suite 300, Burien, WA 98166-1911
Phone: (206) 241-4647 • Fax: (206) 248-5539
www.burienwa.gov

June 20, 2013

Ted Perkins, P. E.
Acting Risk Analysis Branch Chief
FEMA Region X Service Center
20700 44th Ave. W., Suite 110
Lynnwood, WA 98036

RE: Revalidation of LOMR-11-10-033P

The City of Burien is requesting revalidation of the LOMR-11-10-0033P approved by FEMA with an effective date of 11/4/2011 and stands behind the data and methodology used in this study as being more detailed and more specific to the properties along the Puget Sound within the boundaries of the City of Burien.

After years of using outdated FEMA mapping that classified a wide area along the Puget Sound shoreline as a Flood Zone A, with no elevation data, the City of Burien engaged the services of Coast and Harbor Engineering to perform a flood study to more accurately access the flood risk to those properties. City funding at the time was sufficient to cover the cost of determining VE flood zones. This study was submitted to FEMA under LOMR-07-10-0686P, reviewed and approved by FEMA, with an effective date of 1/13/2009.

Unfortunately, this did not address the wide band of Flood Zone A that remained on the maps, causing great inconvenience for property owners whose property or structure by elevation alone should not be in a Flood zone, but were required to purchase flood insurance or pay the costs to go through the LOMR/LOMA process for each property. Understanding that this lack of accurate flood mapping affected so many of the properties, the City secured funding in December 2009 for Coast & Harbor Engineering to expand the flood study by analyzing and accurately mapping the Flood Zone A and re-confirming the elevations and limits of the Flood Zone VE. While it was first expected the study would result in a Flood Zone AE, analysis proved that the type of flooding that would occur in this area could be more accurately mapped using a Flood Zone AO designation.

At this point the City of Burien hadn't been informed by FEMA or King County that they were planning to expand the Vashon Island Flood study to include incorporated areas of King County. Certainly had that been known, the City of Burien would not have spent valuable tax dollars on a study that would be superseded. It wasn't until August of 2010 that King County met with the City of Burien to announce they were studying the same area via a grant approved by FEMA. The City of Burien had already expended funds on the Flood Zone A study and was very near submitting the LOMR. At this meeting, the City requested that King County not remap the Burien shoreline and divert the funding elsewhere, as taxpayers dollars had already been expended to get an accurate assessment of the flood risk.

The City of Burien submitted LOMR-11-10-033P on September 24, 2010. After more than a year of analysis by the STARR team, and having all questions answered, FEMA approved the LOMR and all results were incorporated in the FIRM with the effective date of November 4, 2011.

The City of Burien does not agree with STARR's reasons for superseding Burien's LOMR with the King County analysis performed by Northwest Hydraulic Consultants The data and analysis submitted by Coast & Harbor Engineering for the City of Burien's LOMR is more accurate because that information is based on a more realistic description of the physical processes of coastal flooding and validated with on-the-ground observation and evaluation.

The City of Burien concurs with the enclosed report by Coast & Harbor Engineering that:

- Wind information that Northwest Hydraulic Consultants developed to generate input to the SWAN model for wave propagation does not adequately represent surface winds over Puget Sound.
- Wind speed and direction and tidal elevation Coast & Harbor Engineering used in wave modeling for the LOMR better simulate actual conditions than the synthetic series that Northwest Hydraulic Consultants developed from random combinations of parameters from probability distributions.
- Northwest Hydraulic Consultants did not establish a consistent, and in most cases, a proper bottom elevation near shore for passing wave information output from the SWAN model to the run-up calculation procedure; Coast &

Harbor Engineering did determine the proper bottom elevation in the LOMR study to account for depth effects on wave height and direction.

- Northwest Hydraulic Consultants did not account for beach scour at the toe of the bulkhead and bulkhead failure in the King County study; Coast & Harbor Engineering calculated run-up and overtopping accounting for those factors in the LOMR study.
- Northwest Hydraulic Consultants did not base flood zone boundaries on dissipation of the overtopping wave as it propagates overland; Coast & Harbor Engineering accounted for overtopping wave dissipation in hazard zone mapping.
- LOMR mapping results better represent long-term (about one century) experience of living at this shoreline than does the King County mapped zones.
- Mapping produced in the Burien LOMR therefore should remain as the effective flood maps, and should not be superseded by King County mapping.

Additionally, the NFIP loss statistics for Washington State as of 3/31/13 posted at http://bsa.nfipstat.fema.gov/reports/1040.htm#53 show a total of 18 claims for a total loss of $84,000 since 1978 and few if any of these claims were at Puget Sound shoreline properties. We are confident the study performed by Coast & Harbor Engineering for LOMR-11- -10-033P provides an accurate assessment of the flood risk within the bounds of the City of Burien for properties along Puget Sound. To change the hazard zone boundary and elevation again with King County mapping is unnecessary and would cause needless angst for the affected property owners.

For the reasons stated in this letter and the attached report prepared by Coast & Harbor Engineering, the City of Burien respectfully requests revalidation of the LOMR-11-10-0033P approved by FEMA with an effective date of 11/4/2011

Respectfully,

Charles "Chip" Davis, A.I.C.P.
Director of Community Development

Jan Vogee, C.B.O
Floodplain Administrator
Building Official

COAST & HARBOR ENGINEERING

Technical Memorandum

Revalidation of Coastal Flooding Analysis and Mapping for Burien LOMR 11-10-0033P

1. Purpose and Background

The purpose of this technical memorandum is to demonstrate the superiority of Coast & Harbor Engineering's (CHE's) study results approved in LOMR 11-10-0033P over the King County mapping results for the Burien shoreline. The King County analysis proposed by STARR for superseding the LOMRs is incorrect for reasons listed below, and the data and analysis supporting the Burien LOMRs are deemed to be more accurate because the LOMR analysis is a more realistic description of the physical processes involved in coastal flooding; and therefore, should not be superseded by King County mapping. Components of the engineering study are examined and compared with the King County approach separately in sections below.

The City of Burien contracted in 2007 for completion of an analysis to establish the V Zone elevation and V Zone limit specific to reaches of the Burien shoreline. CHE applied procedures contained in the Pacific Coast Guidelines (FEMA 2005) in conducting the study and teamed with AECOM Water for producing work maps. The City of Burien submitted an application for a Letter of Map Revision (LOMR) with the work maps and engineering report entitled *Coastal Flood Hazard Zone Delineation* dated June 29, 2007. FEMA approved the study and revised the Flood Insurance Rate Map to incorporate the updated mapping as LOMR 07-10-0686P with an effective date of January 13, 2009. Previous to this update, the City's shoreline was mapped as an unnumbered A Zone (effective date May 16, 1995). Where the hazard zone was not revised by the LOMR, the A Zone remained in effect. In December 2009 the City contracted with CHE to establish proper A Zone limits and elevations. The City applied for a LOMR with submission of these mapping results and engineering report entitled *Coastal Flood Hazard Zone AE and AO Delineation* dated September 24, 2010. The results were incorporated as LOMR 11-10-0033P in the FIRM with the effective date of November 4, 2011.

Between the times of the two LOMRs for the City, a property owner within the city limits applied for a separate LOMR to correct an error in delineating the flood hazard zone that had been caused by localized elevation contours generated from LiDAR. The VE Zone and unnumbered A Zone were remapped for a portion of the property to Zones VE and AE using land survey data. FEMA approved this analysis and mapping (LOMR 10-100977P) with the effective date April 25, 2011. These results were also incorporated in LOMR 11-10-0033P.

King County contracted with Northwest Hydraulic Consultants (NHC) to perform a Flood Insurance Study and mapping of incorporated King County shorelines. A meeting was held August 26, 2010 with City of Burien Department of Community Development and King County River and Floodplain Management Section. The City requested that King County not remap the Burien shoreline in the County-wide study because results submitted as a LOMR application were realistic, adequately conservative, and approval of the City's application for the A Zone map change was pending. To change the hazard zone boundary and elevation again with King County mapping would cause unnecessary turmoil for the affected property owners. King County released draft work maps including the restudied Burien shoreline on July 21, 2011.

Analysis approaches of NHC and CHE differ at the detail level. STARR reviewed both studies and recommended revising the map panels of the Burien shoreline according to the King County study results. STARR recommended the following on November 7, 2012:

"It is recommended that the draft Incorporated Areas of King County, Washington study supersede LOMR-11-10-0033P. The methodology adopted in The Incorporated Areas of King County, Washington study is more robust than the earlier study in that it addresses a much longer time period for both the data utilized (60-70 years) and for the simulations performed (1,000 years). This recommendation should be presented to FEMA for final approval."

2. Wind and Tide Statistics

STARR recommended superseding the effective FIRM that contains the Burien shoreline on the basis that the King County study performed by NHC used a longer wind data record for generating input to the SWAN model, and simulated a longer period of storm waves than was used for the CHE study that was the basis of the Burien LOMR. Accuracy in predicting extreme events should be the goal. Presumably, the claim that the King County study is more robust implies that it is more accurate. The measure of accuracy that is relevant to wave modeling for a coastal flood study is accuracy in simulating waves that are input to the runup and overtopping routines that yield hazard zone boundaries and elevations. The preferred method should be the one that most reduces the uncertainty, or narrows the confidence bounds, around the projection of the 0.01 chance value.

NHC generated a 62-year long record of wind speed and direction in the King County study for a statistical base to develop input to the SWAN model by extending the records of anemometers near Puget Sound through correlation with SeaTac Airport wind data. The accuracy of the extended wind record is reduced if the correlation of speeds between the short- and long-term stations is poor. As one example, Figure 1 is a plot of wind speed values greater than 5 meters/sec from the south for Point Robinson matched in time with wind speed measured at SeaTac. Point Robinson is on the eastern tip of Maury Island and is nearer to SeaTac than the other stations NHC analyzed. Figure 2 similarly plots wind speed values from the north. The low R-squared values shown in Figures 1 and 2 (0.31 and 0.23, respectively), reveal that the fraction of the variance explained by the linear regression is very low. (R-squared value of 1.0 implies perfect correlation between two linearly related variables.) The correlation between SeaTac and Point Robinson is poor and is different for north winds and south winds. Relying on regression with SeaTac for wave generation in Puget Sound adds a large uncertainty to the results. Attempting to correlate speeds without consideration of north or south directions also adds uncertainty to the wave runup results, particularly at shorelines exposed to the north.

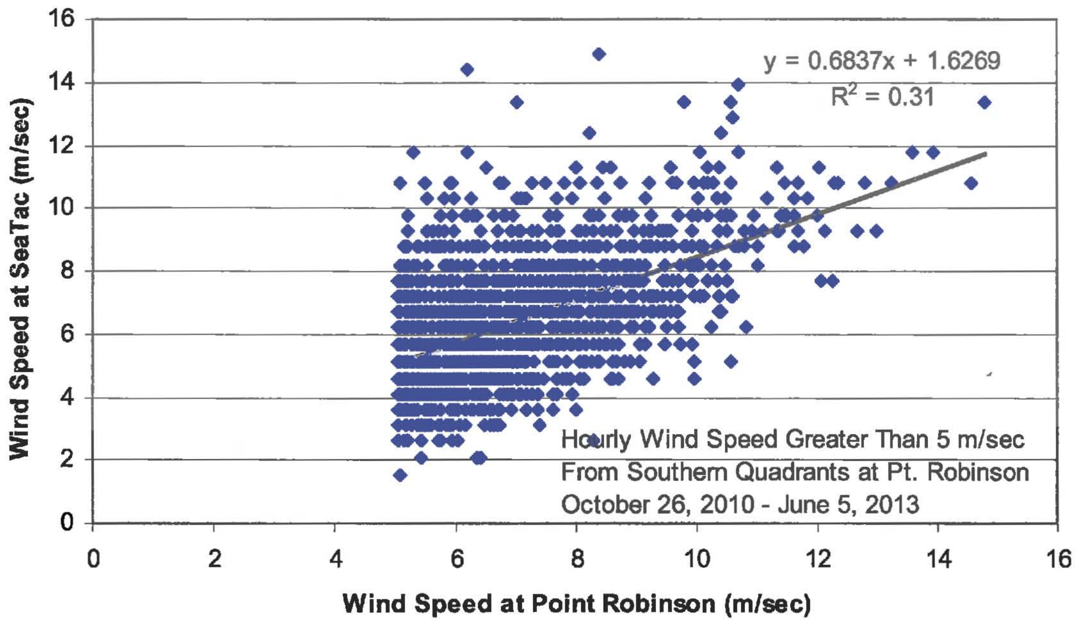

Figure 1. Correlation of southerly winds, Point Robinson and SeaTac, 2010 – 2012

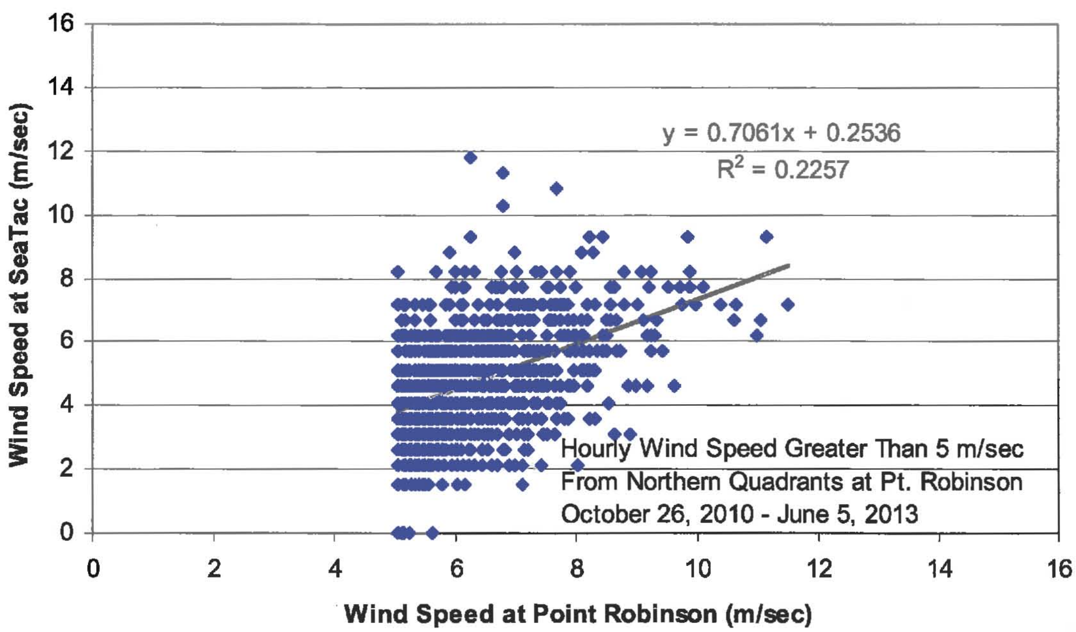

Figure 2. Correlation of northerly winds, Point Robinson and SeaTac, 2010 – 2012

Documentation for wave modeling produced by NHC (2011) described the wind directions at Puget Sound wind measuring stations as statistically related to direction at SeaTac. Analyses were limited to speeds greater than or equal to 5 m/s at SeaTac. As one example of variability of direction, Table 1 of the document stated that wind from the southwest at SeaTac correlated with wind from the south at Alki Point. Those directions were stated to agree 70 percent of the time. That is the only percentage stated and is assumed to be one of the better agreements between a Puget Sound station and SeaTac. Basing a wave-generating wind field on SeaTac therefore injects substantial uncertainty in modeled wave direction. More uncertainty in wind direction was introduced by selecting a direction for input to the wave model from a probability distribution of direction that was derived for different speed categories at SeaTac (NHC 2011, p. 13). Correct wind direction with wind speed is important in wave modeling because wave approach relative to shoreline angle affects calculated wave runup height.

By selecting 10 largest wind speeds each year for input to SWAN as NHC did, it is possible the modeled waves for a year could be all from the south. Wave runup at shorelines that are exposed to the north and sheltered from the south will not then be adequately represented.

Water levels that NHC input to SWAN in the King County study were developed by statistically analyzing the time series of tidal residual at the Seattle tide gauge and recombining it with predicted tide for Burien to create a simulated water level database. This procedure disconnects the actual tide from the wind data for modeling a known meteorological event. Additional statistical uncertainty is thereby injected into the wave modeling. By randomly combining astronomical tide level, tidal residual, wind speed, and wind direction according to probability distribution functions and simulating a 1,000-year-long sequence it is possible to generate wave events of given occurrence probabilities. The confidence bounds were not shown with the study results, but it is expected to be quite broad at the 100-year return period because the uncertainties are compounded with each combination of tide level, tidal residual, wind speed, and wind direction.

The CHE study for the Burien LOMRs, on the other hand, adhered more strictly to guidance of the Pacific Coast Guidelines. Wind direction during severe storms at Burien is either from the northerly or southerly directions. The station having the longest period of record best situated to record wave generating wind data in central Puget Sound is West Point. It is located at a distance from the wave generating area affecting the Burien shoreline, but the lack of obstructions between the two sites, the quality of data, and its elevation and location at Puget Sound justify using this data for wave modeling at Burien. West Point wind data were matched with measured tide elevation, adjusted for Burien, to create 23 years of actual wind speed with actual wind direction and the tide level occurring in the same hour. For each year, the 10 highest wind speeds from the north with actual tide, 10 highest wind speeds from the south with actual tide, and 10 highest tides with actual wind speed and direction were tabulated for developing input to SWAN. As an example of statistical confidence in this procedure, Figure 3 shows a distribution of the 50 highest actual cases of waves from the south modeled at a location near the southern boundary of Seahurst Park where the bottom elevation is -3 m. The 90 percent confidence bounds are shown on the figure. Figure 4 shows similar results for waves from the north modeled with actual meteorological conditions.

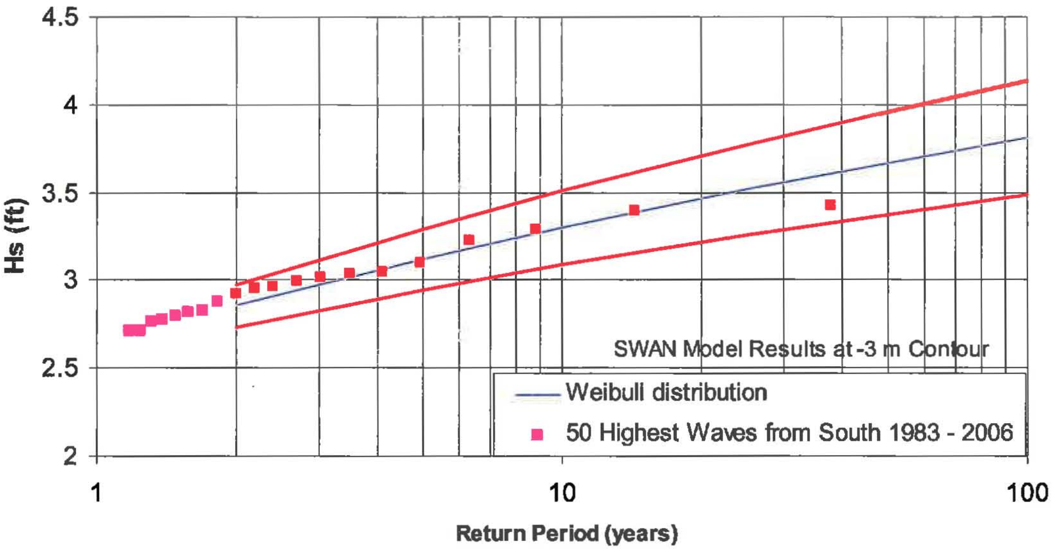

Figure 3. Extreme value distribution of storm waves transformed to nearshore, with 90 percent confidence bounds on projected wave height, waves from south

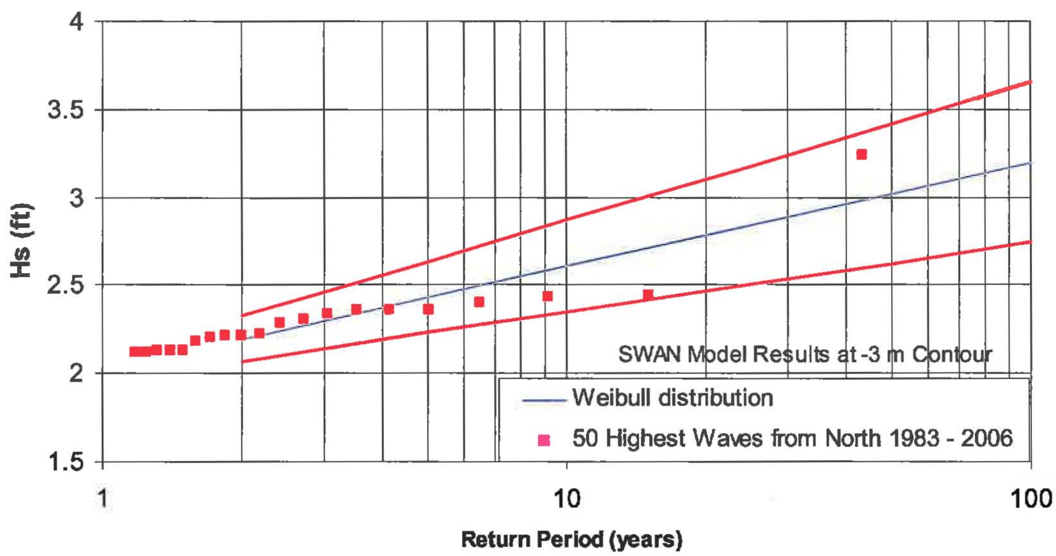

Figure 4. Extreme value distribution of storm waves transformed to nearshore, with 90 percent confidence bounds on projected wave height, waves from north

3. Nearshore Wave Modeling

Bathymetry data and gridding of the model domain were not examined in the NHC modeling for King County. Elevation data and grid construction are critical to obtaining accurate wave results near the shore. A standard Digital Elevation Model of Puget Sound is available and is assumed to be the model bathymetry data source. Descriptions in the wave modeling documentation (NHC 2011) do not indicate an improper setup of SWAN for modeling deepwater waves.

NHC generated files that contain information on elevation of the pass point for the analysis transect. This is the location where modeled wave height, period, and direction output were transferred from the SWAN model to other routines that compute wave runup and overtopping at the shore. Values listed under the column heading "zPass" in the NHC file named RunupOutputKey.XLSX show that the bottom elevation at which wave height and direction were passed to the runup routine varied from -0.2 ft to -107 ft (Figure 5). Half of the zPass values for Burien transects were less than -3.8 ft. Extracting SWAN model results so close to shore could cause the wave height input to the routine for runup without structures to be too low (wave already broken), depending on tide level. Where the pass point is selected at a point too far from shore, refraction effects on wave height and direction are not fully accounted for and an inaccurate factor is calculated for wave direction effect on runup on a structure. The pass point should be located seaward of the breaking zone in all cases, but in water shallow enough to reasonably represent refraction effects.

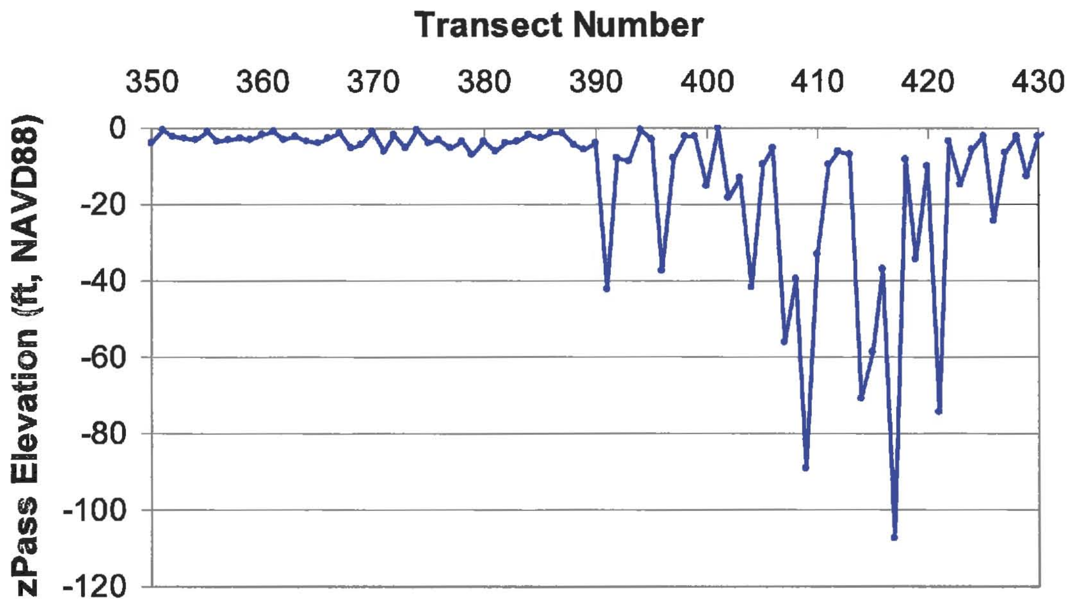

Figure 5. Pass point elevations for wave input to runup calculation in King County study

In the Burien LOMR study, SWAN wave information computed at a nearshore location with bottom elevation of -3 meters (-9.8 ft) was passed to runup routines for all transects. CHE analyzed wave transformation for determining optimal depth for specifying the pass point location. Wave height for an example high tide case for a west-facing part of the shore was selected for comparing calculated wave height at different water depths approaching shore. The significant wave height was 1.01 meters at the minus 3-meter bathymetric contour, and 1.08 meters at the minus 25-meter (-82 ft) contour along the same transect, only 7 cm different for a large storm wave (for central Puget Sound). Water depth at the minus 25-meter contour is considered deep water for wave periods at this location. The wave direction, however, was 10 degrees different between those two water depths. Direction at the -3-meter contour better represents the approach direction of the wave to the shoreline. The pass point should have a constant elevation for consistency of results. Considering height and direction together, SWAN model results of waves transformed to the -3-meter contour are optimal for use in wave runup statistics for beach profiles and at structures.

4. Wave Runup Calculation

The NHC description of runup routines applied in the King County study is generally thorough and generally follows procedures of the Pacific Coast Guidelines or the original work from which the procedures were adapted. A source of uncertainty in runup height is the practice of moving the toe of the structure to different locations on the profile within the surf zone in order to "find" deeper water and generate the maximum runup height for the given water level and incident wave. It is doubtful that this procedure reliably simulates the actual runup height at the structure because it effectively changes the structure profile from that which was developed with field data.

NHC documentation does not mention allowance for scour or beach lowering of the profile at the toe of steep structures. It is assumed that beach scour during a storm was not accounted for. The King County study did not account for bulkhead failure in the 100-year storm. At the start of the Burien LOMR study, FEMA Region 10 gave direction to CHE to assume the bulkheads failed unless they were certified to withstand the 100-year storm, which is a more reasonable assumption.

The slope of the structure face for input to the runup equation was described as averaging the slope between two points on the profile. The lower elevation is of concern because it is at the location on the profile determined by 1.5 * incident wave height. Many wave and water level combinations would produce the situation where the lower elevation would be on the fronting beach. In those cases, the resulting average slope applied to the structure would be much flatter than the correct slope.

CHE's analysis of runup accounted for beach scour by lowering the toe elevation of the structure by the amount equal to the root-mean-square wave height, which represents the frequency of occurrence and energy content of waves in a storm that would accomplish this kind of profile change. This approach was verified by scour measurements at locations in the Burien study area and approved by STARR reviewers. CHE analyzed runup at bulkheads assuming structural failure, as directed by FEMA Region 10. The profile slope where failure was assumed was 1.5 horizontal to 1 vertical. The crest of the slope was thus translated landward relative to the existing bulkhead, which moved the calculated hazard zone limits a corresponding distance landward. The added distance was accounted for in tabulating stationing of V and A Zone limits in Table 3 of the LOMR engineering report (CHE 2010) and in mapping the results relative to the existing bulkhead crest identifiable in aerial photography. The bulkhead is assumed to be in a permanent location and if damaged, would be repaired within the same footprint.

Wave runup heights above static water level for the case of the one-percent-chance flood at the Burien transects ranged from 1.38 ft to 12.51 ft in the NHC analysis. The CHE runup calculation ranged from 2.8 ft to 11.3 ft. Values calculated by CHE are in a narrower range than those of NHC. Figure 6 compares the runup heights calculated in the two analyses for transects arranged from north to south in the Burien city limits. The figure illustrates the erratic runup values calculated by NHC, and indicates the uncertainty factors described above are likely responsible for the large changes in runup at successive transects. NHC

(2011, p. 27) states that engineering judgment was used to deal with the irregularities by averaging values and ignoring isolated anomalies to determine average characteristics along a shoreline. STARR's recommendation to supersede the Burien LOMR with the King County study on the basis that procedures NHC employed are more robust is negated by the practice of averaging through irregularities and using engineering judgment to derive mapping parameters. CHE made no arbitrary adjustment of runup elevation in the analysis for the Burien LOMR.

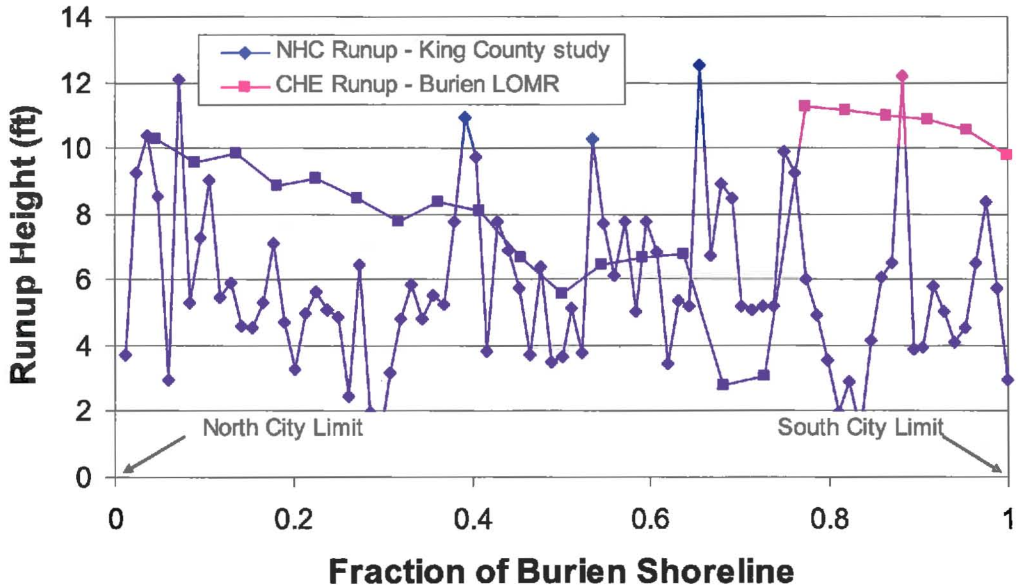

Figure 6. Runup height at Burien shoreline calculated by NHC and CHE

5. Wave Overtopping Calculation

NHC determined wave overtopping onto the upland in the King County study using Zone VE elevations and bluff or barrier crest elevations. Mapping specification rather than physical processes of dissipation of wave splash was the basis for establishing the flood zone limit. The Total Water Level (TWL) (100-year runup elevation) was mapped as Zone VE up to 0.1 inch at map scale (50 ft) landward from the bulkhead. The VE Zone was narrower only where topography was higher than the TWL within the 50-ft distance. Zone AE was designated landward of Zone VE to the extent that topography was lower than 38 percent of the height of the excess potential runup added to the crest elevation. Where the excess potential runup was less than 3 ft, the Zone AE elevation was selected to equal the TWL.

Such treatment of the overtopping water from wave runup is to assume the elevation reached by the runup could flood the upland at that elevation all the way back to higher topography, which might be a hillside at the back of a property. This allows for no dissipation of the overtopping wave or splash as it moves across the upland. Video recordings and photographs, and particularly on-site acquaintance with storm wave runup, make it apparent that most of the water propelled up a bulkhead face falls back to the ground within a very short distance from the bulkhead. Spray is usually blown landward at the runup elevation, but does not constitute flooding. A sheet of water only inches thick runs landward, as shown in video recordings, but eventually dissipates even on a flat, impermeable surface. NHC does not simulate this mechanism of transporting floodwater across the upland for determining the flood zone limits in the King County study. Instead, NHC bases flood zone limits on geometrical factors.

The overtopping mechanism that CHE applied in the Burien LOMR is described mathematically by the Cox-Machemehl equation. The equation contains a coefficient that was calibrated using measured overtopping distance from a known wave overtopping event, and is documented in CHE's (2010) engineering report. This approach was used at transects containing bulkheads that would be overtopped in the one-percent-chance coastal flood to calculate the limits of the V and A Zones. A snapshot of actual storm wave overtopping of a bulkhead at the Burien shoreline is shown in Figure 7. Mapping results based on calculations of overtopping distance were approved by FEMA in 2011, reviewed by the public, and adopted by the City.

Figure 7. Wave runup and overtopping of bulkhead at Burien, December 17, 2012

Accurate overtopping prediction depends on accuracy of the topography and clear definition of coastal structures. King County mapping topography was based on photogrammetry with elevation contours at 2-ft intervals. Burien LOMR mapping was based on raw LiDAR data collected in 2002 that was accurate to within 6 inches, and a 2009 rectified high resolution aerial photograph showing precise locations of bulkheads. Land surveying was employed in 2007 to perform several spot checks of elevations of features covered with the LiDAR data. This verification is described in CHE's (2010) report. Because of the density and accuracy of the LiDAR data and use of land survey data, transect profiles and elevation contours generated in the LOMR study are accurate and are a proper basis for mapping.

6. Field Verification and Mapping of Results

NHC does not indicate that field verification of calculated runup and overtopping distances was performed in the King County study. Experienced engineers from CHE and AECOM observed and photographed all of Burien's study shoreline for the LOMR, and noted indicators of historical storm debris lines, bulkhead conditions, beach scour evidence, and evidence of previous overtopping events and wave damage.

NHC mapped AE Zones and no AO Zones at Burien in the King County study. The AE Zone limit corresponded to the location of topography with elevation equal to the AE elevation because energy dissipation with overland travel was not accounted for. CHE's analysis did account for dissipation of the overtopping wave, and was therefore able to delineate the AO Zone at a location having a ground elevation lower than that of the initial overland bore. AE Zone is described in FEMA (2005) as area with wave height less than 3 ft. AO Zone is described in Section D.4.9.2.4. as "sheet flow ... dissipating because of ground friction and energy losses." For cases where waves overtop a bulkhead and dissipate on a level lawn, as at most of the Burien waterfront properties, the more appropriate description is Zone AO. One example of NHC mapping according to topography, with the result indicating the A Zone extended over 60 feet landward from the bulkhead, is at King County transect 357 (Shorewood Lane), shown in Figure 8.

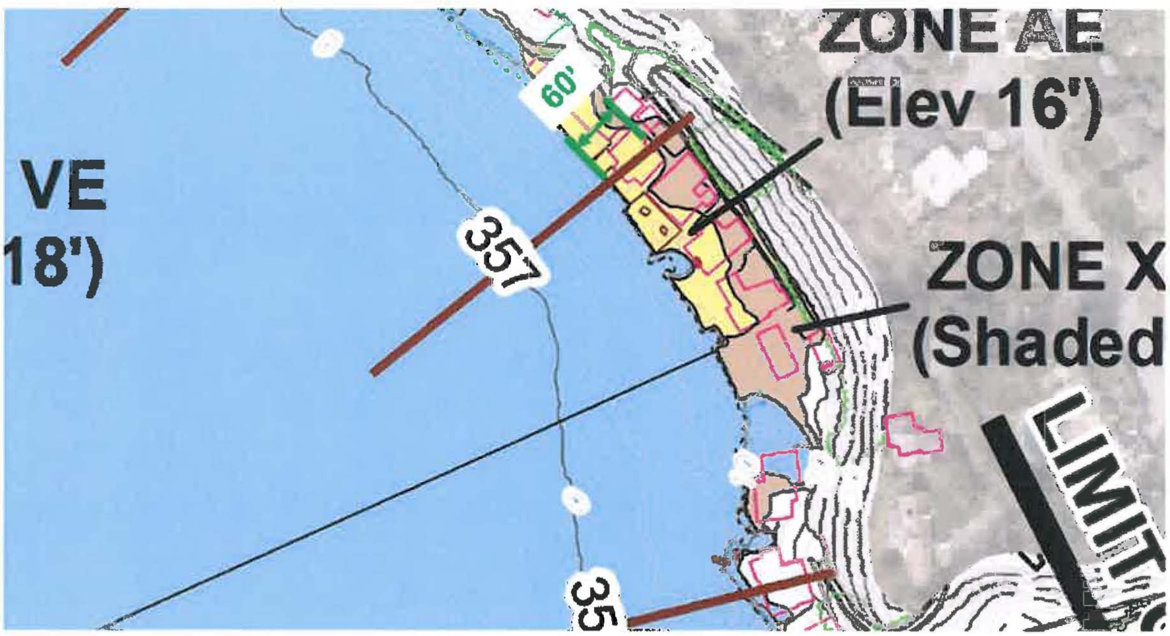

Figure 8. Portion of draft work map by NHC showing large landward extent of AE Zone

The shoreline reach containing King County transect 357 is represented by CHE transect 20. A ground photograph characterizing the shoreline in this reach is shown in Figure 9. Most structures are set back from a nearly vertical bulkhead. Analysis and mapping results of runup and overtopping for the Burien LOMR are shown in Figure 10. CHE calculated the AO Zone limit to be 22.8 ft landward from the bulkhead in Reach 20, and the LOMR mapping of hazard zone limits are compared with those of NHC in the figure. Text by the circled residential lot (King County transect 357) indicates that the King County mapping reduces the width of the V Zone and greatly expands the width of the A Zone relative to the effective map. Although experience at the site is anecdotal, appearance of storm effects and history of the site indicate CHE's results are more realistic for this shoreline reach. Investment in improving these properties has been gradual over many decades, and in most cases structures have been placed landward of the extent of storm damage based on experience.

Figure 9. Bulkhead configuration representative of Shorewood Lane

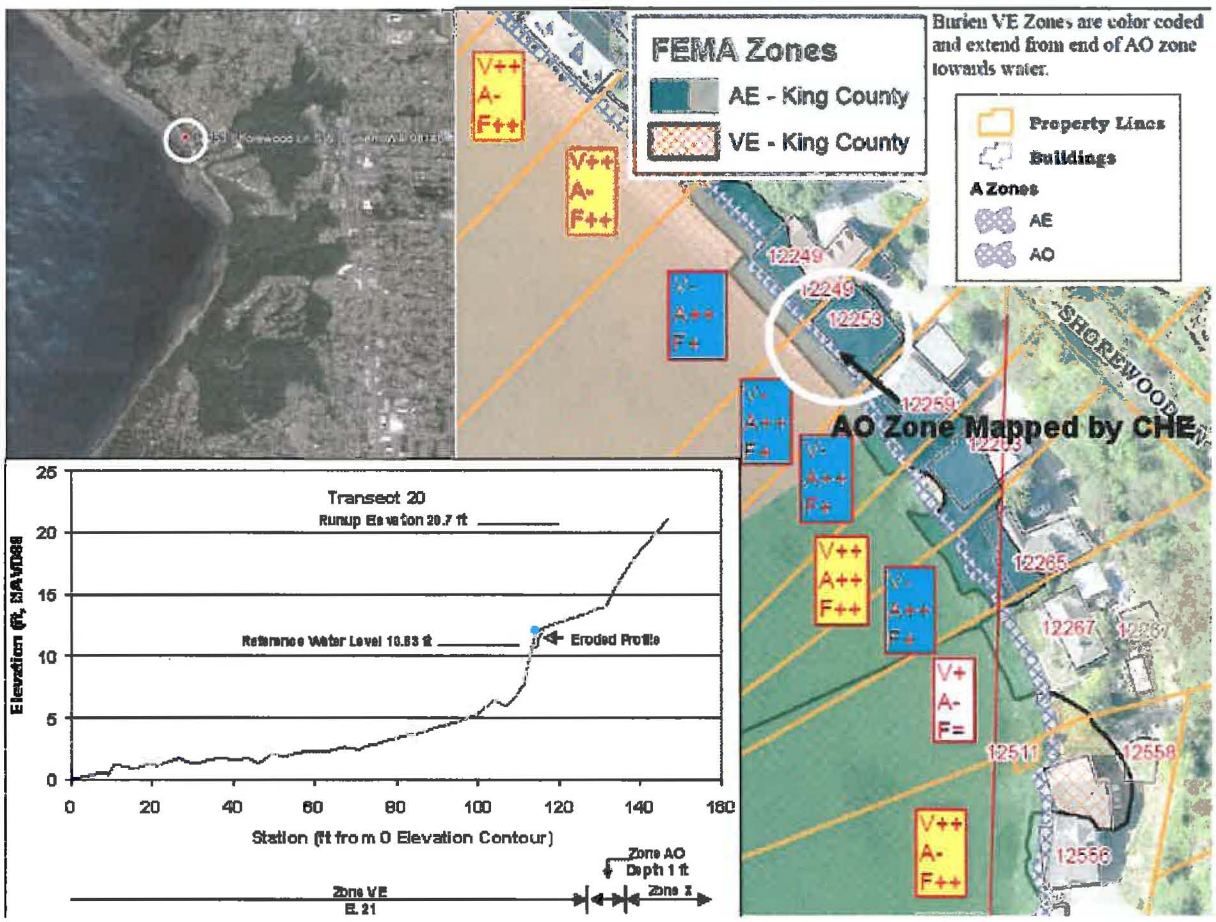

Figure 10. Comparison of hazard zone limits of Burien LOMR and King County Mapping at Shorewood Lane

Although King County mapping by NHC increases the flood hazard designation for 160 Burien properties as compared to the effective map established by the LOMR, some other properties are shown to have a decreased flooding risk. The area of S.W. 172 Street on the south-facing side of Three Tree Point is shown in Figures 11 and 12 on December 17, 2012. The high water event at Burien on that date is historic. High tide at the Seattle NOAA tide gauge on that date was the highest ever recorded there[1]. In the hours preceding the peak of the tide, wind speed measured at Point Robinson was 20 to 30 miles per hour from the southerly direction, which would produce high waves. Figure 11 shows the water level at the bulkhead and the large-size debris tossed onto the upland within the short distance from the bulkhead, which tends to validate CHE's calculation of VE Zone width there. Figure 12 compares the hazard zone limits calculated by CHE and by NHC for the area of S.W. 172nd Street. In the figure the V Zone limit mapped by NHC is located at the bulkhead and the AE Zone extends only a few feet landward. CHE calculated the V Zone to extend landward of the bulkhead face and the AO Zone to extend into S.W. 172nd Street. Small-size storm debris on the street marks the extent of wave overwash and is an indicator of the A Zone limit. The comparison in Figure 12 illustrates the accuracy of CHE's mapping of the AO Zone limit and the under estimation by NHC of overtopping distance at properties in this reach.

Figure 11. Large-size wave tossed debris within narrow zone landward from bulkhead

[1] Tide height recorded at Seattle on December 17, 2012 was 14.51 ft above MLLW. Hourly water height has been recorded at the Seattle tide gauge since January 1901. High tide at Burien is about 1.03 x Seattle high tide.

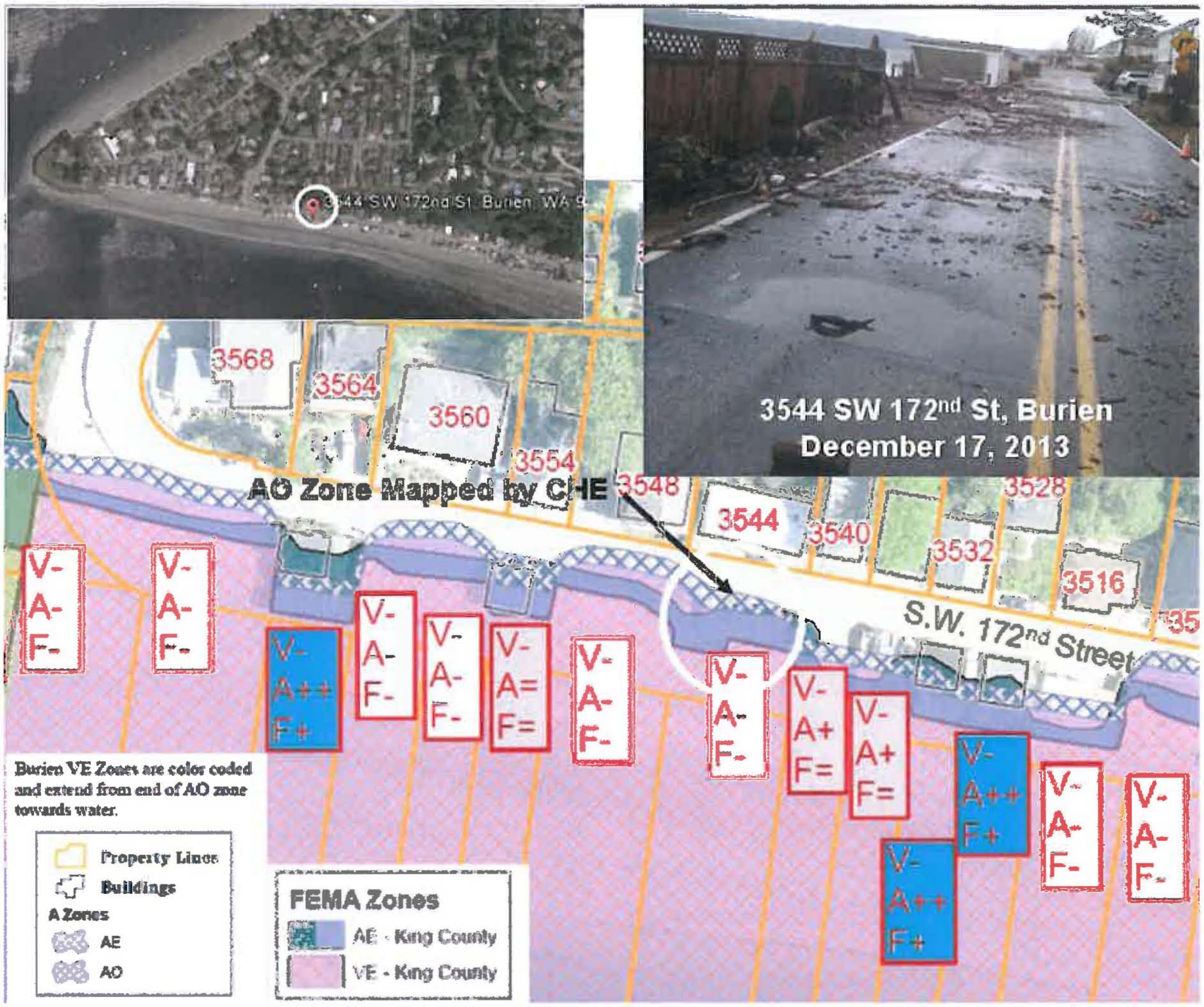

Figure 12. Comparison of hazard zone limits of Burien LOMR and King County Mapping at S.W. 172nd Street and validation of CHE calculation results

7. Summary Discussion

The King County analysis performed by NHC and proposed by STARR for superseding the Burien LOMRs is incorrect or inaccurate in several aspects, and the data and analysis submitted by CHE for the LOMRs are deemed to be more accurate because that information is based on a more realistic description of the physical processes of coastal flooding and validated with on-the-ground interpretation. The basis of this statement is:

- Wind information that NHC developed to generate input to the SWAN model for wave propagation does not adequately represent surface winds over Puget Sound.
- Wind speed and direction and tidal elevation that CHE used in wave modeling for the LOMR better simulate actual conditions than the synthetic series that NHC developed from random combinations of parameters from probability distributions.
- NHC did not establish a consistent, and in most cases, a proper bottom elevation near shore for passing wave information output from the SWAN model to the runup

calculation procedure; CHE did determine the proper bottom elevation in the LOMR study to account for depth effects on wave height and direction.

- NHC did not account for beach scour at the toe of the bulkhead and bulkhead failure in the King County study; CHE calculated runup and overtopping accounting for those factors in the LOMR study.
- NHC did not base flood zone boundaries on dissipation of the overtopping wave as it propagates overland; CHE accounted for overtopping wave dissipation in hazard zone mapping.
- LOMR mapping results better represent long-term (about one century) experience of living at this shoreline than does the King County mapped zones.

Mapping produced in the Burien LOMR therefore should remain as the effective flood maps, and should not be superseded by King County mapping.

8. References

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DAVID P. SIMPSON
STATE OF WASHINGTON
23527
REGISTERED
PROFESSIONAL ENGINEER

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