

CONTENTS

Of

APPENDIX

Introduction to the Phase 1 *Focused Study Reports*

Acknowledgements of the Focused Study Team Members

Key References from each Focused Study Report

Eleven Focused Study Reports:

Storm Meteorology
Stillwater
Storm Wave Characteristics
Wave Transformation
Wave Setup
Wave Runup and Overtopping
Event-Based Erosion
Coastal Structures
Tsunamis
Sheltered Waters
Flood Hazard Zones

Introduction to the Phase 1 Focused Study Reports

This Appendix to the *Phase 1 Summary Report* (nhc, February 2005) contains eleven (11) Focused Study Reports prepared by the Technical Working Group (TWG) on eleven categories of technical topics pertaining to FEMA Coastal Flood Hazard Assessment and Mapping Guidelines. Goals of the Phase 1 investigations were to evaluate existing FEMA Guidelines for all three coasts and to examine the key technical areas of the current coastal flood hazard mapping process. Initial tasks focused on a review of the existing guidelines and the needs and priorities for their improvement. Under these tasks, coastal experts from the TWG reviewed existing guideline methodologies for the ocean and coastal processes analyzed in flood insurance studies (e.g., storm meteorology, storm surge, wave setup, wave transformation, wave runup, and overtopping) and evaluated their applicability for each coastline. Case studies were prepared to demonstrate application of guideline methodologies in previous coastal flood insurance studies on each coast, and representative studies were prepared to demonstrate application of guideline procedures to particular coastal processes.

An international literature search was conducted to identify sources of information on existing and evolving coastal engineering practices and to identify pertinent scientific research that may be useful in developing new guidelines. The international experience of several TWG members was used during this task to provide the project with information, techniques, and practices from around the world.

The initial tasks described above served as the basis for reporting and discussion at Workshop 1, held in Sacramento, California, on December 2–4, 2003. The workshop was attended by 38 members of the TWG from across the country and Europe. The workshop agenda included:

- ④ review of existing guidelines and practices;
- ④ technical presentations on the state of the science in coastal processes;
- ④ workshop sessions to identify needs, priorities, and potential guideline improvements by coastal geographic areas and coastal processes; and
- ④ Summary sessions to list and prioritize needed guideline improvements.

The primary result of Workshop 1 was a list of 53 technical topics for consideration in updating the current FEMA guidelines. Each item also included an initial assessment of the time and data required to develop improved procedures. This assessment resulted in categorizing each topic as “Critical,” “Important,” “Available,” or “Helpful.” “Critical” and “Important” topics were considered the highest priorities for development of new or improved procedures, and were subdivided into topics that could likely be addressed in the 6-month time frame of the project (“Critical”) and those that would require longer term development by FEMA (“Important”).

“Available” topics were considered areas where existing data or methodologies were readily available for updating or creating guidelines. “Helpful” topics were considered valuable but lower priority. These priority classes were assigned by the TWG for each topic on the Atlantic and Gulf Coasts, Pacific Coast, and in Sheltered Waters (Non-Open Coast).

Results from Workshop 1 were used to formulate *focused studies* that organized the 53 technical topics into 11 categories according to coastal processes and coastal flood hazard mapping procedures. Each of these 11 categories became the subject of a *focused study* and resulted in a stand-alone report, including topics on: (1) Storm Meteorology, (2) Stillwater Elevations, (3) Wave Characteristics, (4) Wave Transformation, (5) Wave Setup, (6) Event-Based Erosion, (7) Wave Runup and Overtopping, (8) Coastal Structures, (9) Sheltered Waters, (10) Tsunamis, and (11) Hazard Zones. These eleven Focused Study Reports are included in this Appendix to the Phase 1 Report.

The *focused studies* were conducted by groups of individuals from the TWG, each coordinated by a focused study leader. This organization allowed the 11 *focused studies* to be completed simultaneously and rapidly. Preliminary drafts of the *focused studies* were presented at Workshop 2 on February 23–26, 2004, and subsequently were refined by the study groups and submitted to FEMA in May 2004. These initial drafts of the Phase 1 Summary Report and Focused Study Reports were revised into Final Drafts that were submitted to FEMA in June 2004. Focused Study leaders responded to FEMA review comments, made revisions to the reporting and prepared the Final Phase 1 Summary Report and this Appendix containing the Focused Study Reports.

The *focused studies* contain recommendations on the approach for updating the guidelines on three coasts (Pacific, Atlantic, and Gulf). These recommendations include further studies and guideline development work that vary in complexity, level of effort, and time requirements. The level of effort required to complete the recommendations for “Critical” and “Available” items identified in Workshop 2 significantly exceeded the available time and budget for Phase 2 (development of Pacific Coast guidelines). Therefore, in March 2004 the project team engaged in a significant effort to develop options for limiting the scope and cost of the next phase of work (Phase 2 – development of Draft Pacific Coast Guidelines) while retaining the most important topics and a balance among the 11 technical categories. The selected option deferred some recommendations for future development in the National Flood Insurance Program (NFIP) but maintained the target of producing reliable guidelines for coastal studies on the Pacific Coast in FY 2004/2005.

SUMMARY OF KEY FINDINGS FROM THE PHASE 1 FOCUSED STUDIES

A complete list of topics and recommendations developed by the TWG during Workshops 1 and 2 is provided in Table 2 of the Phase 1 Summary Report. Following are a few of the key findings from the Phase 1 activities and the completion of the eleven *Focused Studies*:

- ④ Procedures are needed to compute the 1% annual chance flood elevation where 1% stillwater levels do not necessarily coincide with 1% wave conditions (e.g., Pacific Coast and sheltered waters along all three coasts).
- ④ Procedures to better represent wave setup are needed on all coasts.
- ④ Procedures should be developed to use regional databases and wave transformation models to develop wave spectra at the surf zone.
- ④ Methods are needed to evaluate the amount of wave dissipation due to propagation over muddy or flat nearshore areas.
- ④ Procedures to quantify the effects of wave setup and event-based erosion in a variety of geomorphic settings are needed.
- ④ On the Atlantic Coast, a review of the 540 square feet erosion criterion is needed in light of new data; on the Pacific Coast, a similar geometric method is needed based on Pacific Coast data.
- ④ A probabilistic method for tsunami hazard assessment and methods for combining tsunami hazards with other coastal hazards are needed.
- ④ Updates and amplification of existing guidelines for wave runup and overtopping and associated hazard zones are needed. Improved methodology for wave overwash is needed.
- ④ Some coastal processes, such as surge, wave transformation, and tsunamis, are best analyzed at a regional scale rather than in flood studies of individual communities.
- ④ Sheltered waters (non-open coast areas) require specialized guidance because of their unique hydrodynamic and geomorphic characteristics compared to the open coast. For example, new methods for calculating fetch-limited wind waves should be evaluated and incorporated in guidelines, to the extent appropriate.

Recommended approaches to address these and other needs are included in Sections 4 and 5 of the February 2005 Phase 1 Summary Report.

Following are Acknowledgements for those who participated on the Technical Working Group and a listing of selected Key References from each Focused Study Report. Following the Acknowledgements and Key References are the eleven Focused Study Reports discussed in the February 2005 Phase 1 Summary Report.

INTRODUCTION

ACKNOWLEDGEMENTS OF FOCUSED STUDY TEAM MEMBERS

The following individuals are gratefully acknowledged for their contributions and participation as members of the Technical Working Groups and for the key roles they played as participants and writers on one or more of the eleven Focused Study Teams. These individuals performed the focused studies, participated in technical workshops, and prepared this report.

Storm Meteorology Focused Study Leader

David Divoky

Team Members

Robert Battalio, P.E.
Bob Dean, Sc.D.
Ian Collins, Ph.D.
Darryl Hatheway, CFM
Norm Scheffner, Ph.D.

Stillwater Focused Study Leader

David Divoky

Team Members

Robert Battalio, P.E.
Bob Dean, Sc.D.
Ian Collins, Ph.D.
Darryl Hatheway, CFM
Norm Scheffner, Ph.D.

Storm Wave Characteristics Focused Study Leader

Shyamal Chowdhury, Ph.D., CFM

Team Members

Robert Battalio, P.E.
Carmela Chandrasekera, Ph.D.
Ian Collins, Ph.D.
Jeff Gangai, CFM
Darryl Hatheway, CFM
Ron Noble, P.E.
Dick Seymour, Ph.D., P.E.

Wave Transformation Focused Study Leader

Robert Battalio, P.E.

Team Members

Carmela Chandrasekera, Ph.D.

David Divoky

Darryl Hatheway, CFM

Terry Hull, P.E.

Bill O'Reilly, Ph.D.

Dick Seymour, Ph.D., P.E.

Rajesh Srinivas, Ph.D., P.E.

Wave Setup Focused Study Leader

Bob Dean, Sc.D.

Team Members

Ian Collins, Ph.D.

David Divoky

Darryl Hatheway, CFM

Norm Scheffner, Ph.D.

Wave Runup and Overtopping Focused Study Leader

Chris Jones, P.E.

Team Members

Ida Brøker, Ph.D.

Kevin Coulton, P.E., CFM

Jeff Gangai, CFM

Darryl Hatheway, CFM

Jeremy Lowe

Ron Noble, P.E.

Rajesh Srinivas, Ph.D., P.E.

Event-Based Erosion Focused Study Leader

Bob MacArthur, Ph.D., P.E.

Team Members

Kevin Coulton, P.E., CFM

Bob Dean, Sc.D.

Darryl Hatheway, CFM

Maria Honeycutt, Ph.D.

Jeff Johnson, P.E.

Chris Jones, P.E.

Paul Komar, Ph.D.
Chia-Chi Lu, Ph.D., P.E.
Ron Noble, P.E.
Trey Ruthven, P.E.
Dick Seymour, Ph.D., P.E.

Coastal Structures Focused Study Leader

Chris Jones, P.E.

Team Members

Bob Battalio, P.E.
Ida Brøker, Ph.D.
Kevin Coulton, P.E., CFM
Jeff Gangai, CFM
Darryl Hatheway, CFM
Jeremy Lowe
Ron Noble, P.E.

Tsunamis Focused Study Leader

Shyamal Chowdhury, Ph.D., CFM

Team Members

Eric Geist
Frank Gonzalez, Ph.D.
Robert MacArthur, Ph.D., P.E.
Costas Synolakis, Ph.D.

Sheltered Waters Focused Study Leader

Kevin Coulton, P.E., CFM

Team Members

David Divoky
Darryl Hatheway, CFM
Jeff Johnson, P.E.
Ron Noble, P.E.

Flood Hazard Zones Focused Study Leader

Darryl Hatheway, CFM

Team Members

Kevin Coulton, P.E., CFM
Michael DelCharco, P.E.
Chris Jones, P.E.

ACKNOWLEDGEMENTS

Storm Meteorology

- Benjamin, J.R., and C.A. Cornell, 1970. *Probability, Statistics, and Decision for Civil Engineers*. McGraw-Hill Book Company, NY, 684pgs.
- Borgman, L.E., and N.W. Scheffner. 1991. *The simulation of time sequences of wave height, period, and direction*. (TR-DRP-91-2.) USACE CERC Waterways Experiment Station.
- Dean, R.G., T.Y. Chiu, and S.Y. Wang. 1992. *Combined Total Storm Tide Frequency Analysis for Palm Beach County, Florida*. Florida Department of Natural Resources.
- Federal Emergency Management Agency (FEMA). 1988 (August). *Coastal Flooding Hurricane Storm Surge Model*, Volumes 1, 2, and 3. Washington, D.C.
- Hawkes, P.J., and R.C. Hague. 1994 (November). *Validation of Joint Probability Methods for Large Waves and High Water Levels*. HR Wallingford Report SR 347.
- Hawkes, P.J., B.P. Gouldby, J.A. Twain, and M.W. Owen. 2002 (April). The joint probability of waves and water levels in coastal engineering design. *Journal of Hydraulic Research* 40(3):241–251.
- HR Wallingford. 1998 (November). *The Joint Probability of Waves and Water Levels: JOIN-SEA*. (Report SR 537.) With minor amendments, May 2000.
- Myers, V. 1970. *Joint Probability of Tide Frequency Analysis Applied to Atlantic City and Long Beach Island, NJ*. (ESSA Tech Memo WBTM Hydro-11.)
- National Weather Service. 1987. *Hurricane Climatology for the Atlantic and Gulf Coasts of the United States*. (NWS 38.) U.S. Department of Commerce. Prepared for FEMA.
- Philip Williams and Associates (PWA). 2002. *Coastal Hydraulics Phase Report for a Coastal Flood Insurance Study, Sandy Point, Whatcom County, Washington*. Prepared for Whatcom County Public Works.
- Scheffner, N.W., J.E. Clausner, A. Militello, L.E. Borgman, and B.L. Edge. 1999. *Use and Application of the Empirical Simulation Technique: User's Guide*. (USACE Technical Report ERDC/CHL-99-10).
- Scheffner, N.W., and L.E. Borgman. 1992. A stochastic time series representation of wave data. *ASCE Journal of Waterways, Ports, Coastal and Ocean Engineering* 118(4).
- Scheffner, N.W., and F.C. Carson. 2001. *Coast of South Carolina Storm Surge Study*. (USACE Technical Report ERDC/CHL TR-01-11.)
- Tetra Tech. 1982. *Methodology for Computing Coastal Flood Statistics in Southern California*. (Tetra Tech Report TC-3205.) Prepared for Federal Emergency Management Agency, Washington, DC.
- . 1982. *Methodology for Computing Coastal Flood Statistics in Southern California*. (Tetra Tech Report TC-3205.) Prepared for Federal Emergency Management Agency, Washington, DC.

Stillwater

- Cox and Swail. 2001. A global wave hindcast over the period 1958-1977: Validation and assessment. *Journal of Geophysical Research* Vol 106
- Dean et al. 1992. *Combined Total Storm Tide Frequency Analysis for Palm Beach County, Florida*. Florida Department of Natural Resources.
- Federal Emergency Management Agency (FEMA). 1991. *Projected Impact of Sea Level Rise on the National Flood Insurance Program*.
- Harris, D. Lee. 1963. *Characteristics of the Hurricane Storm Surge*. (Technical Paper 48.) U.S. Weather Bureau.
- Komar, P.D. 1988. *Beach Processes and Sedimentation*, 2nd edition. Prentice-Hall.
- Komar, P.D. 1997. *The Pacific Northwest Coast: Living with the Shores of Oregon and Washington*. Duke University Press, Durham, NC.
- Komar, P.D. 1998. The 1997-98 El Niño and erosion on the Oregon coast. *Shore & Beach*, 66(3): 33-4.
- Philip Williams and Associates Ltd. [PWA]. 2002 (November 6). *Sausalito Flood Study*. Prepared for the City of Sausalito, California.
- San Francisco Bay Conservation and Development Commission (BCDC). 1987. *Future Sea Level Rise: Predictions and Implications for San Francisco Bay*. Prepared by Moffatt & Nichol Engineers, Wetlands Research Associates, and BCDC, San Francisco, CA.
- Scheffner et al. 2001. *Coast of South Carolina Storm Surge Study*. (Technical Report CHL TR-01-11.) U.S. Army Corps of Engineers, Waterways Experiment Station.
- Scheffner et al. In preparation. *Coastal Erosion Study for the Open Coast from Sabine to San Luis Pass, Texas Tropical Storm Surge Frequency Analysis*. (Technical Report ERDC/CHL.) U.S. Army Corps of Engineers, Waterways Experiment Station.
- U.S. Army Corps of Engineers. 1984 (October). *San Francisco Bay Tidal Stage vs. Frequency Study*. San Francisco District.

Wave Characteristics

- Cardone, V.J., A.T. Cox, and V.R. Swail. 2000. Specification of the Global Wave Climate: Is this the Final Answer? *6th International Workshop on Wave Hindcasting and Forecasting*. November 6-10, 2000, Monterey, California.
- Cox, A.T., and V.R. Swail. 2001 (February). A Global Wave Hindcast over the Period 1958-1997: Validation and Climate Assessment. *JGR (Oceans)* 106(C2):2313–2329.
- Dewberry & Davis, LLC. 2004. Coastal Engineering Manual vs. Shore Protection Manual: An Overview and List of Recommendations for Improving Existing FEMA Coastal Hazard

- Analysis Methodologies. (For Use and Consideration in the Guidelines Project Focus Studies). January 23, 2004
- Federal Emergency Management Agency (FEMA). 1995. Guidelines and Specification for Wave Elevation Determination and V Zone Mapping. National Flood Insurance Program, Mitigation Directorate, FEMA, Federal Insurance Administration. Final Draft, March. http://www.fema.gov/mit/tsd/DL_VZn.htm
- Goda Y. 1985. *Random Seas and Design of Maritime Structures*. University of Tokyo Press, Tokyo, Japan.
- National Academy of Sciences. 1977. *Methodology for Calculating Wave Action Effects Associated with Storm Surges*. Washington, DC.
- Tolman, H.L. 1989. The numerical model WAVEWATCH: a third generation model for the hindcasting of wind waves on tides in shelf seas. *Communications on Hydraulic and Geotechnical Engineering*, Delft Univ. of Techn., ISSN 0169-6548, Rep. no. 89-2, 72 pp.
- U.S. Army Corps of Engineers. 1984. Shore Protection Manual. Waterways Experiment Station, Vicksburg, MS.
- WAMDIG. 1988. The WAM model - A third generation ocean wave prediction model. *Journal of Physical Oceanography* 18:1775–1810.
- CEDAS (2001), Coastal Engineering Design and Analysis System, Version 1.0. Veri-Tech Inc., Vicksburg, Mississippi.
- Coastal Engineering Manual. 2003. Part 2, Chapter 2, Meteorology and Wave Climate. U.S. Army Corps of Engineers, July 2003.
- US Army Corps of Engineers. (2001). Coastal Engineering Manual. Part 11. Chapter 4. p.11-4-11.
- US Army Corps of Engineers, (1992). ACES 1.07. Waterways Experiment Station, Vicksburg, Mississippi.

Wave Transformation

- Baker, Michael, Jr., Inc. 1989. Proposed Approach for the Determination of High-Hazard Flood Areas Along San Francisco Bay and Puget Sound. Prepared for Federal Emergency Management Agency.
- CH2M Hill, Inc. 1995. Draft Engineering Report, Coastal Flood Insurance Study for Bandon (Incorporated Area) Coos County, Oregon (Community No. 410043). September 1995.

KEY REFERENCES

- Coastal Engineering Manual. 2003. Part 2, Chapter 3, Estimation of Nearshore Waves. US Army Corps of Engineers, July 2003.
- Coulton, K.G., 1988. Coastal Flood Insurance Study Procedures for Puget Sound, Hydraulic Engineering; *Proceedings of the 1988 National Conference*, Hydraulics Division of the American Society of Civil Engineers, Colorado Springs, Colorado, August 8-12, pp 294-299.
- Dorratoague, D., Humphrey, J.H., and Black, R.D. 1977. *Determination of Flood on the Pacific Northwest Coast for Federal Insurance Studies*. Hydraulics in the Coastal Zone, Proceedings, 25th Annual Hydraulics Division Specialty Conference, August 1977.
- Ebersole B.A., Cialone, M.A., and Prater, M.D. 1986. RCPWAVE – A Linear Wave Propagation Model for Engineering Use. Technical Report CERC – 86-4. US Army Engineer Waterways Experimental Station, Vicksburg, MS.
- Federal Emergency Management Agency. (1984). Procedures for Applying Marsh Grass Methodology. Washington, D.C.
- Federal Emergency Management Agency. (February 1981). Users Manual for Wave Height Analysis, revised. Washington, D.C.
- Federal Emergency Management Agency. (January 1981). Computer Program for Determining Wave Height Elevations for Flood Insurance Studies, revised. Washington, D.C.
- Goda Y. 1985. *Random Seas and Design of Maritime Structures*. University of Tokyo Press.
- O'Reilly W. C., R. T. Guza, and R. J. Seymour, 1999, Wave Prediction in the Santa Barbara Channel, Proc. 5th California Islands Symposium, Minerals Management Service, Santa Barbara, CA, March 29-31, 1999. Forristal, G.Z. and Reece, A.M. 1985. Measurements of Wave Attenuation due to Soft Bottom: The SWAMP Experiment. *Journal of Geophysical Research* 90(C2), 3367-3380.
- O'Reilly W. C., and R. T. Guza, 1991, Comparison of spectral refraction and refraction-diffraction wave models. *J. of Waterway, Port, Coastal, and Ocean Engineering*, 117(3), 199-215
- O'Reilly, W. C., and R. T. Guza, 1993, A comparison of spectral wave models in the Southern California Bight, *Coastal Engineering*, 19(3), 263-282.
- O'Reilly, W. C., 1993, The southern California wave climate: effects of islands and bathymetry, *Shore and Beach*, 61(3), 14-19.
- Ott Water Engineers, Inc. 1984. Northern California Coastal Flood Studies. Prepared for Federal Emergency Management Agency, August, 1984.

- Philip Williams and Assoc. Ltd. 1995. An Assessment of the Impact of The Operation of an Additional Ferry on Shoreline Erosion in Marin County. April 1995.
- Philip Williams and Associates, Ltd. 2002a. Coastal Hydraulics Phase Report for a Coastal Flood Insurance Study, Sandy Point, Whatcom County, Washington. Prepared for Whatcom County Public Works, June 2002.
- Philip Williams and Associates, Ltd. 2002b. Coastal Hydraulics Phase Report for a Coastal Flood Insurance Study, Birch Bay, Whatcom County, Washington. Prepared for Whatcom County Public Works, October, 2002.
- Philip Williams and Associates, Ltd. and William O'Reilly, Ph.D. 1999. Bolinas Lagoon Supplemental Wave Analysis Report, Prepared for the U.S. Army Corps of Engineers, April 1999.
- Shermet, A. and Stone, G.W. 2003a. Wave Dissipation Due to Heterogeneous Sediments on the Inner Louisiana Shelf. Proceedings, Coastal Sediments '03.
- Shermet, A. and Stone, G.W. 2003b. Observations of Nearshore Wave Dissipation Over Muddy Sea Bottoms. Journal of Geophysical Research 108 (C11)
- Suhayda, J.N. 1984. Attenuation of Storm Waves over Muddy Bottom Sediments. Prepared for the Federal Emergency Management Agency.
- Suhayda, J.N. 1984. Attenuation of Storm Waves over Muddy Bottom Sediments. Prepared for the Federal Emergency Management Agency.
- Tetra Tech, 1982. "Methodology for Computing Coastal Flood Statistics in Southern California," Prepared for FEMA.
- Tubman, M. W. and Suhayda, J.N. 1976. Wave Action and Bottom Movements in Fine Sediments. Proceedings, 15th Conference on Coastal Engineering, ASCE. 1168-1183.
- U.S. Army Corps of Engineers, Waterways Experiment Station. 1984. Shore Protection Manual

Wave Setup

- Battjes, J. A. (1972) "Set-up Due to Irregular Waves", Report No. 72-2, Communications on Hydraulics, Delft University of Technology, Department of Civil Engineering, 13 Pages. (Note: This Paper Also Presented at the 13th International Conference on Coastal Engineering, Vancouver, B. C.)
- Battjes, J. A. and J. P. F. M. Janssen (1978) "Energy Loss and Setu-up Due to Breaking of Random Waves", ", Proceedings, ASCE 16th International Conference on Coastal Engineering, pp. 569-587 .

KEY REFERENCES

- Bretschneider, C. L. (1972) "A Non-Dimensional Stationary Hurricane Wave Model", Offshore Technology Conference, Preprint No. OTC 1517, Houston, TX.
- Davis, G. A. and Nielsen, P. (1988) "Field Measurement of Wave Set-up", Chapter 38, ASCE International Conference on Coastal Engineering, Malaga, Spain, pp. 539 – 552.
- Dean, R. G. "Stream Function Representation of Nonlinear Ocean Waves", Journal of Geophysical Research, Vol. 70, No. 18, pp. 4561 – 4572.
- Dean, R. G. (1978) "Recommended Interim Methodology for Calculation of Wave Action and Wave Set-up Effects", Research Report CE_82_31, University of Delaware, Civil Engineering Department, Newark, DE.
- Dean, R. G. (1978) "Recommended Procedure for Calculating Wave Damping Due to Vegetation Effects and Wave Instability", Research Report CE_78_30, University of Delaware, Civil Engineering Department, Newark, DE.
- Dunn, S. L. and Nielsen, P. (2000) "Wave Setup in Rivers", ASCE International Conference on Coastal Engineering, Sydney, Australia, 3432 – 3445.
- Goda, Y. (1975) "Irregular Wave Deformation in the Surf Zone", Coastal Engineering in Japan, Vo.l. 18, pp. 13-26.
- Goda, Y. (1985) "Random Seas and Design of Maritime Structures", University of Tokyo Press, 323 Pages.
- Guza, R. T. and Thornton, E. B. (1981) "Wave Set-up on a Natural Beach", Journal of Geophysical Research, Vol. 96, No. C2, pp. 4133 – 4137.
- Guza, R. T. and Thornton, E. B. (1984) "Swash on Steep and Shallow Beaches", Proceedings, ASCE International Conference on Coastal Engineering, pp. 708 – 723.
- Hansen, U. A. (1978) "Wave Setup and Design Water Level", Journal of Waterway, Port, Coastal and Ocean Division, American Society of Civil Engineers, Vol. 104, No. WW2, pp. 227 – 240.
- Holman, R. A. and A. H. Sallenger (1985) "Setup and Swash on a Natural Beach", Journal of Geophysical Research, Vol. 90, No. C1, pp. 945 – 953.
- Holman, R. A. (1990) "Wave Set-up", Chapter 11, Volume 1, Handbook of Coastal and Ocean Engineering, J. Herbich, Editor, pp. 635 – 646.
- Kennedy, A. B., Q. Chen, J. T. Kirby, and R. A. Dalrymple (2000) "Boussinesq Modeling of Wave Transformation, Braeking and Wave Runup. I: 1D", ASCE Journal of Waterway, Port Coastal and Ocean Engineering, Vol. 126, No. 1, pp. 39 – 47.

- Kennedy, A. B., and J. T. Kirby (2003) “An Unsteady Wave Driver for Narrow Banded Waves: Modeling Nearshore Circulation Driven by Wave Groups” *Coastal Engineering*, Vol. 48, pp. 257 – 275.
- Kotense, J. K. (1984) “Measurements of Surf Beat and Set-Down Beneath Wave Groups”, *Proceedings, ASCE International Conference on Coastal Engineering*, pp. 724 – 740.
- Lentz, S. and B. Raubenheimer (1999) “Field Observations of Wave Setup”, *Journal of Geophysical Research*, Vol. 104, No. C11, pp. 25,867 – 25,875.
- Lo, J. M. (1981) “Surf Beat: Numerical and Theoretical Analyses”, Ph. D. Dissertation, Department of Civil Engineering, University of Delaware, 199 pages.
- Lo, J. M. and R. G. Dean (1995) “Long Waves Due to Interaction beneath Wave Groups”, *ASCE Journal of Waterway, Port Coastal and Ocean Engineering*, Vol. 121, No. 6, pp. 317 – 325.
- Longuet-Higgins, M. S. (1962) “Radiation Stress and Mass Transport in Gravity Waves with Application to ‘Surf Beats’”, *Journal of Fluid Mechanics*, Vol. 13, No. 4, pp. 481 – 504.
- Longuet-Higgins, M. S. (1983) “Wave Set-up, Percolation and Undertow in the Surf Zone”, *Proceedings, Royal Society of London, A*, Volume 390, pp. 283 – 291.
- Longuet-Higgins, M. S. (1967) “On the wave-Induced Difference in Mean Sea Level Between the Two Sides of a Submerged Breakwater”, *Journal of Marine Research*, Volume 25, No. 2, pp. 148 – 153.
- Madsen, P. A., O. R. Sorensen and H. A. Schaffer (1997) “Surf Zone Dynamics Simulated by a Boussinesq Type Model. Part I. Model Description and Cross-Shore Motion of Regular Waves”, *Coastal Engineering*, Vol. 32, pp. 225 – 287.
- Madsen, P. A., O. R. Sorensen and H. A. Schaffer (1997) “Surf Zone Dynamics Simulated by a Boussinesq Type Model. Part II. Surf Beat and Swash Oscillations for Wave Groups and Irregular Waves” *Coastal Engineering*, Vol. 32, pp. 289 – 319.
- McReynolds, D. J. (1977) “Wave Set Up and Set Down Due to a Narrow Frequency Wave Spectrum”, *Masters Thesis, Naval Post Graduate School*, 42 Pages.
- Nielsen, P. (1989) “Wave Setup and Runup: An Integrated Approach”, *Coastal Engineering*, Vol. 13, pp. 1 – 9.
- Raubenheimer, B., R.T. Guza, and Steve Elgar (2001) “Field Observations of Setdown and Setup”, *J. Geophysical Research*, Vol. 106, 4629-4638.
- Schaffer, H. A. and I. A. Svendsen (1988) “Surf Beat Generation on a Mild-Slope Beach”, *Proceedings, ASCE International Conference on Coastal Engineering*, pp. 1,058 – 1072.

- Schaffer, H. A. and I. G. Jonsson (1990) "Theory Versus Experiments in Two-Dimensional Surf Beats", Chapter 85, Proceedings, ASCE International Conference on Coastal Engineering, pp. 1,131 - 1143.
- Sharma, J. N. and R. G. Dean (1982) "Second-Order Directional Seas and Associated Wave Forces", Journal, Society of Petroleum Engineers, pp. 129_140.
- Sorensen, O. R., H. A. Schaffer and P. A. Madsen (1998) "Surf Zone Dynamics Simulated by a Boussinesq Type Model. Part III. "Wave-Induced Horizontal Nearshore Circulations" Coastal Engineering, Vol. 33, pp. 155 - 176.
- Stive, M. J. F. and H. G. Wind "A Study of Radiation Stress and Set-up in the Nearshore Zone", Publication No. 267, Waterlopkundig Laboratorium, Delft Hydraulics Laboratory, 25 Pages.
- Svendsen, I. A. (1984) "Wave Heights and Set-up in a Surf Zone", Coastal Engineering, Vol. 8, pp.302-329.
- Symonds, G. and A. J. Bowen (1984) "Interaction of Nearshore Bars With Wave Groups", Journal of Geophysical Research, Vol. 89, No. C2, pp. 1953 – 1959.
- Symonds, G., D. A. Huntley and A. J. Bowen (1982) "Two-Dimensional Surf Beat: Long Wave Generation by a Time-Varying Breakpoint", Journal of Geophysical Research, Vol. 87, No. C1, pp. 492 – 498.
- Thornton, E. B. and R. T. Guza (1983) "Transformation of Wave Height Distribution", Journal of Geophysical Research, Vol. 88, No. C10, pp. 5925 – 5938.
- U. S. Army Corps of Engineers (1977) "Shore Protection Manual", U. S. Government Printing Office, Washington, D. C.
- U. S. Army Corps of Engineers (2003) "Coastal Engineering Manual", EM 1110-2-1100, pp. II-4-18. II-4-12.

Wave Runup and Overtopping

- Dewberry & Davis. 1991 (April). *Investigation and Improvement of Capabilities for the FEMA Wave Runup Model (Technical Documentation for Runup Program 2.0)*.
- Goda, Y. 1985. *Random Seas and Design of Maritime Structures*. University of Tokyo Press. Tokyo, Japan.
- Kriebel, D., L. Buss, and S. M. Rogers, Jr. 2000. *Impact Loads from Floodborne Debris*. Phase I Project Report prepared for the American Society of Civil Engineers by Academy Engineering LLC. Millersville, MD.

- Owen, M. W. 1980. *Design of Seawalls Allowing for Wave Overtopping*. Report Ex. 924. Hydraulics Research Station, Wallingford, United Kingdom.
- Phillip Williams & Associates. 2002. *Coastal Hydraulics Phase Report, Sandy Point, Whatcom County, Washington, Coastal Flood Insurance Study*.
- Ruggiero, P., P. D. Komar, W. G. McDougal, J. J. Marra, and R. A. Beach. 2001. Wave Runup, Extreme Water Levels and the Erosion of Properties Backing Beaches. *Journal of Coastal Research* 17(2):407-419.
- Stone & Webster Engineering Corporation. 1981. *Manual for Wave Runup Analysis, Coastal Flood Insurance Studies*. Boston, MA.

Event-Based Erosion

- Bruun, P. 1962. Sea-level Rise as a Cause of Shore Erosion. *Journal Waterways and Harbors Division* 88(WW1):117-130. American Society of Civil Engineers.
- Dean, R.G. 1977. Equilibrium Beach Profiles: US Atlantic and Gulf Coasts, Ocean Engineering Technical Report No. 12, Department of Civil Engineering and College of Marine Studies, University of Delaware, Newark.
- Edelman, T. 1968. Dune Erosion during Storm Conditions. Pages 719-722 in *Proceedings: 11th Conference on Coastal Engineering held in London, England*. American Society of Civil Engineers.
- Komar, P.D., J.J. Marra, and J.C. Allan. 2002. Coastal Erosion Processes and Assessments of Setback Distances. Pages 808-822 in Lesley Ewing and Louise Wallendorf (eds.) *Solutions to Coastal Disasters '02 in San Diego, California*. American Society of Civil Engineers.
- Kriebel, D.L., and R.G. Dean. 1985. Numerical Simulation Of Time-Dependent Beach And Dune Erosion. *Coastal Engineering* 9:221-245.
- Larson, M., and N.C. Kraus. 1989. SBEACH: Numerical Model for Simulating Storm-Induced Beach Change; Report 1, Empirical Foundation and Model Development, Technical Report CERC-89-9. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Kriebel, D. L. and R. G. Dean. 1993. Convolution Method For Time-Dependent Beach Profile Response", *Journal of Waterway, Port, Coastal and Ocean Engineering*, Vol. 119, No. 2, pp. 204_226.
- Byrnes, M.R., M. Crowell, and C. Fowler. 2003. Shoreline Mapping and Change Analysis: Technical Considerations and Management Implications, *Journal of Coastal Research*, Special Issue #38.

Coastal Structures

- Basco, D.R. 2003 (July). *Shore Protection Projects*. In: J. Pope (ed.), *Coastal Engineering Manual*, Part V, Coastal Project Planning and Design, Chapter V-3, Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, DC.
- Burcharth, H.F., and S.A. Hughes. 2003 (April). *Fundamentals of Design*. In: S.A. Hughes (ed.), *Coastal Engineering Manual*, Part VI, Design of Coastal Project Elements, Chapter VI-5, Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, DC.
- Camfield, F.E. 1980. *Tsunami Engineering*. Special Report No. 6. USACE Coastal Engineering Research Center.
- Chiu, T.Y. 1977. *Beach and Dune Response to Hurricane Eloise of September 1975*. Pages 116–134 in Proceedings of Coastal Sediments '77. American Society of Civil Engineers.
- Federal Emergency Management Agency. 1990. *Criteria for Evaluating Coastal Flood Protection Structures for National Flood Insurance Program (NFIP) Purposes*, Memorandum from Harold Duryee, FIA Administrator to FEMA Regional Directors. April 23, 1990. 7 pp.
- . 2002. *Revisions to National Flood Insurance Program Maps, Application Forms and Instructions for Conditional Letters of Map Revision and Letters of Map Revision*. MT-2 form package
- . April 2003. *Guidelines and Specifications for Flood Hazard Mapping Partners*, Appendix D: Guidance for Coastal Flooding Analyses and Mapping.
- Fulton-Bennett, Kim, and Gary B. Griggs. 1986. *Coastal Protection Structures and their Effectiveness*. State of California Department of Boating and Waterways and the Marine Sciences Institute of the University of California at Santa Cruz.
- Griggs, G. B., J. F. Tait, and W. Corona. 1994. The interaction of seawalls and beaches: seven years of field monitoring, Monterey Bay, California. *Shore and Beach* 62(2)21–28.
- Kraus, N.C., and O.H. Pilkey (editors). 1988. The Effects of Seawalls on the Beach: An Extended Literature Review. Special Issue No. 4. Pages 1-28 in *Journal of Coastal Research*
- Kraus, N.C., and W.G. McDougal. 1996. The Effects of Seawalls on the Beach: Part I, An Updated Literature Review. *Journal of Coastal Research* 12(3):691–701.
- McDougal, W.G., M.A. Sturtevant, and P.D. Komar. 1987. Laboratory and field investigations of the impact of shoreline stabilization structures on adjacent properties. Pages 961-973 in *Proceedings of Coastal Sediments '87*. ASCE press.
- Phillip Williams & Associates, Ltd. 2002. *Coastal Hydraulics Phase Report*, Sandy Point, Whatcom County, Washington, Coastal Flood Insurance Study.
- U.S. Army Corps of Engineers. 1984. *Shore Protection Manual*. Washington, D.C. (2 volumes)

- . 2002, 2003. *Coastal Engineering Manual*. Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes).
- Walton, T.L., J.P. Ahrens, C.L. Truitt, and R.G. Dean. 1989. *Criteria for Evaluating Coastal Flood-Protection Structures*. Technical Report CERC 89-15. USACE Waterways Experiment Station. Vicksburg, MS.

Tsunamis

- Bernard, E.N., and the Tsunami Hazard Mitigation Federal/State Working Group. 1996. Tsunami Hazard Mitigation Plan, A report to the Senate Appropriations Committee, NOAA report, available at <http://www.pmel.noaa.gov/tsunami-hazard/>.
- Downes, G.L., and M.W. Stirling. 2001. Groundwork for development of a probabilistic hazard model for New Zealand, Proceedings International Tsunami Symposium, ITS-2001, 293–301, published by NOAA-PMEL, Seattle, Washington. (Also available from www.pmel.noaa.gov/its2001.)
- Eisner, R.K., J.C. Borrero, and C.E. Synolakis. 2001. Inundation maps for the State of California, Proceedings International Tsunami Symposium, ITS-2001, 55–68, published by NOAA-PMEL, Seattle, Washington. (Also available from www.pmel.noaa.gov/its2001.)
- Geist, E.L. 2003. Complex earthquake rupture and local tsunamis, *Journal of Geophysical Research*, 108:2-1 to 2-15.
- González, F.I., Vasily Titov, Harold Mofjeld, Angie Venturato, Scott Simmons, Roger Hansen, Rod Combellick, Richard Eisner, Don Hoirup, Brian Yanagi, Sterling Yong, Mark Darienzo, George Priest, George Crawford, Timothy Walsh. 2004. Progress in NTHMP Hazard Assessment, *Journal of Natural Hazards*, in review.
- Houston, J.R., and A.W. Garcia. 1980. Type 19 Flood Insurance Study USACE WES Report HL-80-18.
- Satake, K., K. Wang, and B.F. Atwater. 2003. Fault slip and seismic moment of the 1700 Cascadia earthquake inferred from Japanese tsunami records. *Journal of Geophysical Research* 108:1–17.
- Synolakis, C.E., J.P. Bardet, J. Borrero, H. Davies, E. Okal, E. Silver, J. Sweet, and D. Tappin. 2002a. Slump origin of the 1998 Papua New Guinea tsunami. *Proceedings of the Royal Society of London A* 458:763–769.

Synolakis, C.E., A.C. Yalciner, J.C. Borrero, and G. Plafker. 2002b. Modeling of the November 3, 1994, Skagway, Alaska tsunami, Solutions to Coastal Disasters, Eds: L. Wallendorf and L. Ewing, ISBN 0-7844-0605-7, Proc. ASCE, 915-927.

Titov, V.V., and C.E. Synolakis. 1997. Extreme inundation flows during the Hokkaido-Nansei-Oki tsunami. *Geophysical Research Letters* 24(11):1315-1318.

Sheltered Waters

Kevin Downing, J., 1983. *The Coast of Puget Sound: Its Processes and Development*, Puget Sound Books, A Washington Sea Grant Publication

University of Washington Press, Seattle WA, 126 p. Coulton, K.G. 1988. Coastal flood insurance study procedures for Puget Sound, Proceedings of the 1988 National Conference on Hydraulic Engineering, Colorado Springs, CO, August 8-12.

Coulton, K.G. et al, 2002. Coastal Flood Studies in Puget Sound, Washington State, U.S.A., Solutions to Coastal Distasters Conference, The American Society for Civil Engineers, San Diego CA February 24-27.

U.S. Army Corps of Engineers, 1970. *Low Cost Shore Protection...a Guide for Local Government Officials*, Coastal Hydraulics Laboratory, Engineer Research and Development Center, Section 54 Program, <http://chl.ercd.usace.army.mil/section227/chl.aspx?p=Publications>

Perillo, G.M.E., 1995. *Geomorphology and Sedimentology of Estuaries*, Elsevier, New York, NY.

O'Brien, M.P., 1976. Notes on sandy inlets on tidal shores, Department of the Army Coastal Engineering Research Center, DACW72-71-C-0005, February.

Flood Hazard Zones

Cox, J. C., and J. Machemehl. 1986. Overland Bore Propagation Due to an Overtopping Wave. *Journal of Waterway, Port, Coastal and Ocean Engineering* 112:161-163.

de Waal, J. P., and J.W. van der Meer. 1992. Wave Runup and Overtopping on Coastal Structures. Proceedings 23rd Coastal Engineering Conference, pp. 1758-1771.

Delft Hydraulics Laboratory. 1983. Wave Runup and Overtopping at Dunes During Extreme Storm Surge Report M1819, Part II. (in Dutch). Delft, The Netherlands.

Federal Emergency Management Agency. 1986 (September). *Assessment of Current Procedures Used for the Identification of Coastal High Hazard Areas (V Zones)*. Washington, D.C.

-
- . 1988 (November). *Basis of Erosion Assessment Procedures for Coastal Flood Insurance Studies*. Washington, D.C.
- . 1995 (March). *Guidelines and Specifications for Wave Elevation Determination and V Zone Mapping*, final report. Washington, D.C.
- . 2003 (April). *Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix D: Guidance for Coastal Flooding Analyses and Mapping*. Washington, D.C.
- U.S. Army Corps of Engineers, Galveston District. 1973 (June). *General Guidelines for Identifying Coastal High Hazard Zone, Flood Insurance Study - Texas Gulf Coast Case Study*. Galveston, Texas.
- U.S. Army Corps of Engineers, Coastal Engineering Research Center. (1984). *Shore Protection Manual, Volumes I and II, 4th Edition*, Washington, D.C.
- Vellinga, P. 1986 (December). *Beach and Dune Erosion During Storm Surges*. Communication No. 372. Delft Hydraulics Laboratory. Delft University of Technology. Delft, The Netherlands.