Research Project Highlight

Performance Based Tsunami Engineering II

Project # 1123-NCTRYH

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Start-End Dates:
2/1/2016-6/30/2016

Abstract
In spite of the advances in numerical modeling and computer power, coastal buildings and infrastructures are still designed for tsunami hazards based on parametric criteria with engineering conservatism, largely because the complex numerical simulations take time and efforts to obtain adequate results for a specific structure at the specific location of interest. It is especially challenging when we need to conduct multiple scenarios with a variety of probabilistic tsunami occurrence. Numerical computations with high resolution in time and space yield extremely large datasets. This project introduces a new web-based tool (we call it the Data Explorer) to facilitate extraction of numerical tsunami simulation data. The concept for retrieving pre-computed simulation data is not new. Nonetheless, the Data Explorer is unique in its ability to retrieve a time-series data extremely fast from massive output datasets, to run in a standard web browser, and in its engineering user-centric design. The tool's usability, together with nearly instantaneous retrieval of the data, makes the simulation-based analysis more accessible; consequently the model-based quantification of the uncertainties is achievable, instead of determination based simply on expert judgment. The Data Explorer is designed for the use in conjunction with the methodology called Performance Based Tsunami Engineering (PBTE) for examining critical coastal structures and lifelines such as ports and harbors, coastal bridges, oil and LNG refinery and storage facilities, and nuclear and other gas and coal-fired power plants. Presently, the coastal area of Port Hueneme, California is implemented as a test case, and the portal contains total fifteen tsunami inundation scenarios.

Deliverables
The deliverable will be a user-friendly portal that can be effectively and efficiently used for damage/loss analysis. The improved Data Explorer will be fully integrated with PBTE methodology for the analysis of several critical facilities and lifelines, including quantification of uncertainty based on the polynomial chaos method. The up-to-date outcomes are reported in the Journal of Disaster Research (2016).

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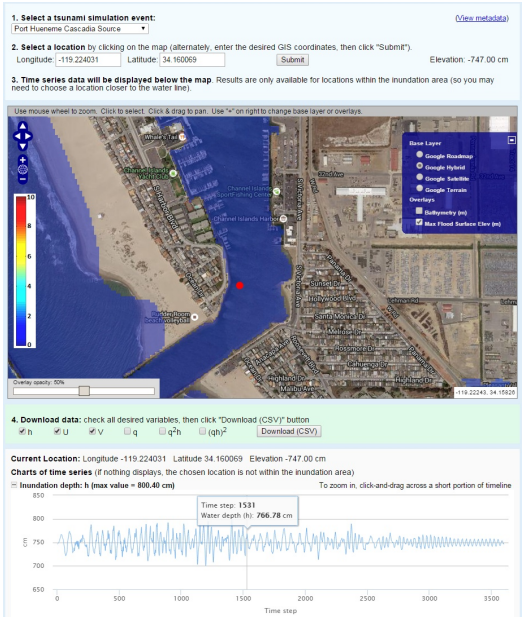
Research Impact

The development of Performance Based Tsunami Engineering (PBTE) together with the effective IT tool – the Data Explorer – drastically improves the engineering design (or retrofit) practice for critical coastal facilities and structures. The Data Explorer represents an effective tool for the analysis of critical structures that require probabilistic considerations with regard to uncertainty quantification. Significant advances in information technology – in particular, computational speed, data handling, and the ability to store massive datasets and quickly index through them – have facilitated the development of this tool. The Data Explorer can be used to evaluate quantifiable uncertainty supported by the data for a given critical structure. In spite of the presence of substantial uncertainty in tsunami hazard estimates, this tool enables users to comprehensively analyze a structure using the best available engineering models and knowledge, minimizing potentially unreliable expert judgment and guesswork. The present methodology is necessary for critical facilities that require analysis beyond the justification made via the forthcoming ASCE 7 guidelines. Further development of the Data Explorer is being pursued, including the ability to automate the calculation of additional parameters and the production of additional charts and graphs, as well as the ability to define multiple points of interest in the interface itself and download a spreadsheet containing all simulated and calculated data for all points. The technique called the polynomial chaos method is used for part of the analysis of uncertainty quantification. The development of the Data Explorer was reported in *Computer* (Keon et al. 2015), the *Journal of Disaster Research* (Keon et al. 2016), and at the ASCE *Coastal Structures & Solutions to Coastal Disasters Joint Conference* (Yeh et al. 2015).

Project Images



The Data Explorer interface.

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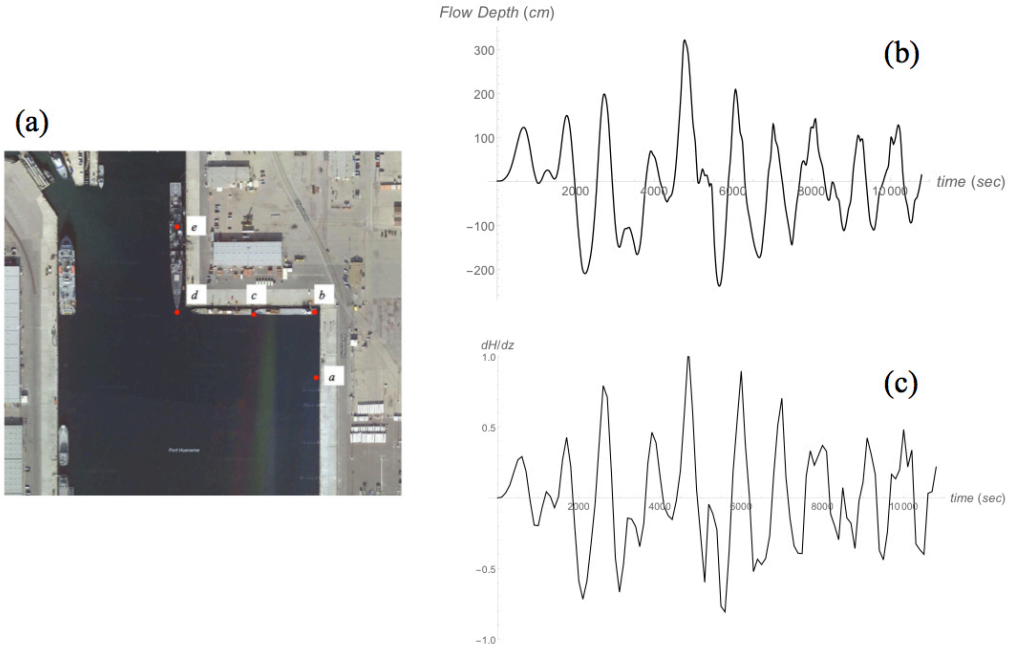

Tsunami Scenarios	Locations	Max. WS EL (cm)	Min. WS EL (cm)	Min. $\partial H/\partial z$	depth (cm) of $\partial H/\partial z < -0.5$
AK	a	312.7	-237.9	-0.807	-209.6
AK	b	323.9	-231.7	-0.794	-189.8
AK	c	328.5	-236.2	-0.741	-77.4
AK	d	323.7	-252.8	-0.797	-93.7
AK	e	340.8	-260.5	-0.783	-86.8
CAS	a	33.8	-41.7	-0.206	0.0
CAS	b	35.1	-33.7	-0.134	0.0
CAS	c	34.5	-33.8	-0.146	0.0
CAS	d	38.3	-37.4	-0.216	0.0
CAS	e	37.9	-36.8	-0.130	0.0
CH	a	206.2	-225.7	-0.628	-95.3
CH	b	210.1	-235.8	-0.584	-68.5
CH	c	210.7	-229.7	-0.641	-96.9
Ch	d	211.0	-230.6	-0.619	-85.2
Ch	e	204.6	-230.3	-0.636	-88.7
JP	a	58.2	-80.3	-0.282	0.0
JP	b	59.1	-81.0	-0.281	0.0
JP	c	58.6	-80.8	-0.281	0.0
JP	d	59.1	-80.8	-0.287	0.0
JP	e	59.6	-81.5	-0.288	0.0

Quantification of uncertainties using the Data Explorer for the quay wall of the port of Port Hueneme. This figure displays: (a) The locations of interest (five locations *a*-*e* are selected here); (b) the retrieved time-series data of the water-surface elevation at the location a; (c) the computed pore-water-pressure gradient at $z = 0$. Table: summary of soil instability analysis at the five locations along the quay wall for four scenario tsunami cases. We use the instability criterion assuming that momentary soil liquefaction will be induced when the pore-water-pressure gradient becomes $\partial H/\partial z < -0.5$.

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Keon, D., Pancake, C.M., and Yeh, H. 2015. Protecting our shorelines: modeling the effects of tsunamis and storm waves. *Computer*, November 2015, 23 – 32.

Keon, D., Yeh, H., Pancake, C.P., and Steinberg, B. 2016. Performance-based tsunami engineering via a web-based GIS Data Explorer. *J. Disaster Res*. (in press).

Yeh, H., Keon, D., Lynett, P., and Thio, H.K. 2015. Performance-Based Tsunami Engineering: Data Explorer. COPRI Coastal Structures and Solutions to Coastal Disasters Joint Conference 2015, September, Boston, MA

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