Workshop on Research with NEES Tsunami Facility

April 6-7, 2001
At Oregon State University, Corvallis, Oregon

written by Harry Yeh, Organizer.

Background

The aims of NEES are to provide a networked collaboratory of shared-use experimental research sites by utilizing Internet infrastructures, and transform the research environment for earthquake engineering. The goals of the NEES Tsunami Facility are to develop a laboratory facility for tsunami research community, and to enhance the effectiveness of tsunami researchers, facilitating reuse of previous experimentation, and supporting experimentation and simulation. Given the network infrastructure, the community will work towards enhancement of international collaboration.

A major goal of this workshop is to generate a sense of ownership within the community; an intermediate step is to familiarize the community with the facility. The community inputs are sought for the required instrumentation, design improvements, as well as risk management issues.

Facility and Equipment

The NEES tsunami basin at Oregon State University will be 48.8m long, 26.5m wide, and 2.0m deep. Tsunami wavemaker will consists of 30 wave generator segments, each has 0.91m wide and 2m high. To achieve a 0.8m high wave in a water depth of 1m, each wave board must be capable of a 2.07m displacement and a maximum velocity of 1.87m/sec. The wavemaker will be driven with both displacement and velocity controls.

The existing wave generator will still be in use: it will be feasible to move it between projects. The panels of the existing wavemaker will be moved up an lengthened downward to suit it to the new water depths.

MTS will provide the entire wavemaker system. The specifications to MTS include velocity, stroke and period range; these specification will be posted on this web site: http://nees.orst.edu/wkshop_apr2001. Discussion was made with regard to checks and balances with MTS to ensure the performance, because this is the primary part of the equipment.

For checks and balances mechanisms, all purchases over $100K need approval by NSF. The intent is to ensure that all vendor requirements meet specification. An external advisory board will be convened – a very clear output of the grant peer review process was that the entire community should have input. This workshop is an important step towards this. There will be periodic reviews with strenuous reporting requirements, allowing NSF to keep close track of happenings at all sites. Finally, at the end of the construction, the system will be reviewed for acceptance by the NEES Collaboratory Acceptance Panel – blue-ribbon panel, with external advisory groups

NEES Schedule:
Equipment Phase 1 – 10/00 to 9/04
Phase 2 – 10/02 to 9/04
System integration 07/01 to 9/04
Consortium development 10/01 to 9/04
Construction complete 9/04
Operation 10/04 to 9/14 (at least)
The system must be operational by 9/30/2004

Relevant Facilities

There are larger wave facilities elsewhere, but those are narrow wave tanks. For example, FZK Hannover wave tank is 330m long, 5m wide, 7m high, and the wavemaker with 4 m stroke. Wide wave basins similar to the OSU tsunami basin also exist, but the wave generation capabilities are much smaller. Those basins are primarily used for studies of coastal wave fields but not suitable for tsunamis. For example, Cedex basin is 34x26x1.6 m in size, with the wavemaker stroke of less than 0.6m. The US Army Corps of Engineer’s basin at CHL has 60x40 m in size, and Texas A&M is currently constructing a basin 23x37x1.5m. It is evident that the OSU tsunami basin will be one of the kind in the world, hence a very careful evaluation for the equipment is required for success.

Potential Research Topics

Tsunami

Potential research topics, which will be investigated with the NEES tsunami tanks are:

- scale effects
- macro-roughness
- tsunami structure interactions
- wave breaking and turbulence
- tsunami generation mechanisms
- landslide generated tsunamis – this topic might be investigated in collaboration with the NEES centrifuge facility.
- overland flows
- volcanic tsunamis
- tsunami propagation and transformation
- Palaeotsunami studies.

- Simulation games – integrated simulations will be made by utilizing the shake table, the centrifuge, the tsunami and the reaction wall, together with numerical simulations – with the aim of public education.

Nearshore and Coastal Dynamics

The existing Large Scale Sediment Transport Facility (LSTF), Vicksburg, might be more suitable for the studies of sediment transports. This facility includes longshore currents with pumps to provide periodic boundary conditions.

However, studies of coastal hydrodynamics also require large scale experiments, which is currently not available, and the NEES tsunami tank would be an ideal facility. The critical research topics are:

- wave breaking, especially 3-D breaking and fine structure and turbulence
- wave-wave interactions, wave-bottom interactions, wave-current interactions including plumes, bathymetry and currents
- wave-structure interactions: runup, overtopping, slope stability, forces on caissons, walls, porous structures, navigational channels and wave damping, long waves in harbors.
- nearshore circulation needs to be addressed at both small-scale and large-scale (rip currents, shear waves).
- With sand in the OSU tsunami tank, we could also study basics of sediment transport, shear waves and beaches, bar migration, rip current interactions with beaches, inlets and shoals

Geotechnical

Hydrodynamic analysis with the NEES tsunami tank can serve as an input to geotechnical analysis. In particular, hydrodynamic analysis can help to define key parameter ranges for potential hazards near populated coastal areas – so that the geotechnical engineers can focus on the key parameters and physical mechanisms. Conversely, the geotechnical community could bracket a set of likely instability sizes and initial accelerations and time histories, which could be used as source conditions for tsunami modeling.

Application to numerical modeling

Laboratory experiments are used for numerical analyses in order to verify assumptions and numerical algorithms, and to validate numerical results. Many coastal engineering phenomena, e.g. rip currents, are extremely complex, with both spatial and temporal structure. Such complex structures can be only verified with either field experiments or large-scale physical models, which could potentially give enough spatial detail. Wave breaking processes are the key to understand these rip current uncertainties.

National Tsunami Hazard Mitigation Program

There are several field instruments to detect and measure tsunamis in Pacific Ocean. Perhaps the NEES Tsunami Facility will guide further field measurements needed for warning systems.

Discussions

Networking, Tele-preparation, Tele-demonstration

There is some skepticism regarding tele-operation – particularly since many tsunami-related experiments are exploratory in nature. You will miss something by not being on site, but – particularly for large collaborations – it will be less expensive than bringing everybody on site. Additionally, it will always be useful to be able to replay the experiment afterwards. The experiment is then added to the data repository, as a great benefit to the community.

International Collaboration

European and Japanese research communities will be most interested in using the NEES Tsunami Facility if it is clearly better than any existing 3-D facility. It would need to be accessible and affordable: a good network minimizing the need for actual presence would also be beneficial. Access to European and Japanese large facilities, particularly wave flumes, would be desirable: these would be complementary to the NEES facility because of their much large scales, particularly with regard to sediment and structure dynamics.

Instrumentation and Data Acquisition

Sensors

Velocity sensors might include: Laser Doppler Velocimetry (LDV), Acoustic Doppler Velocimetry (ADV), Acoustic Doppler Profilers (ADP), Particle Image Velocimetry (PIV), Particle Tracking Velocimetry (PTV)

Other suggestions:

> MEMS: micro-electromechanical sensors to detect accelerations, pressures, temperatures.
>
> Synoptic coverage, over a large area, of the flow field. An example might be 10x10 arrays of off-the-shelf ADVs, synchronized together.
>
> High-speed video is really important for the study of wave breaking.
>
> Automatic calibration of the wave gauges would be needed.
>
> Cameras may provide synoptic coverage of the water surface, if roof-mounted – perhaps the water could be seeded with slightly buoyant particles and then sampled with CCD cameras.

Data Acquisition

SCXI System, National Instruments Data Acquisition – including stepper motors and motor control – may be a good place to start.

Image acquisition: Almost all digital cameras can be streamed in real-time to computer hard drives allowing tens of minutes of digital image data to be collected.

Required Bandwidth

O(100) ADVs at 25 Hz: ~2 Mbps

O(100) wave height gauges at 100 Hz ~ 0.2 Mbps

Ten (10) 1k x 1k x 8 bit digital cameras at 30 Hz ~ 300 Mbps

One (1) 1k x 1k x 12 bit digital camera at 60 Hz ~160 Mbps

Building, Basin and Wave Maker

There will be a bridge crane spanning the basin, 30 feet from the floor. The rails for the bridge and carriage will be installed.

Paint on the bottom of the tank might be useful.

Inserts for supporting synoptic arrays would be useful. Stainless steel unistrut inserts are currently available every 7 feet. Also on the basin floor, several access ports for data collection and instrument control, as well as electric power source, would be installed and connected to the control room via conduits through underneath the floor concrete slab. Such provision would be useful for the large-scale experiments, since it is annoying to hang so many wires for instruments above the basin, and more important, such wires will cause inconvenience for flow-visualization.

It is important to plan now for glass windows, access tunnels, etc. under the basin floor, which can easily be included in the initial basin construction but which would be costly later. Such provision can be used for non-intrusive optical access, particularly from underneath for the LDV and other optical instruments. Although it may not be practical, human access underneath the basin would be desirable, to re-seat instruments from time to time and to tweak new equipment. It is proposed that access chambers will be placed in the tank bottom for now. Conduits should be provided between the access chambers or sumps – possibly double conduits, allowing for both optical pipe and electrical cable.

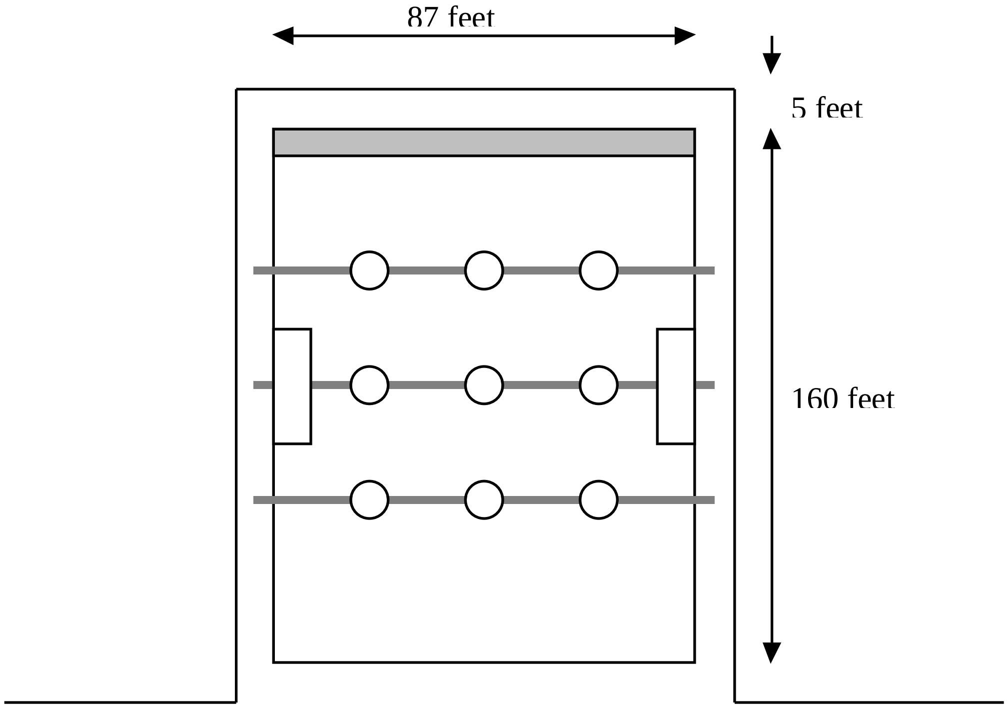
A mechanism for generating model landslides would eventually be desirable. A large chamber, either at the center or a side of the basin, could later contain a bottom wave generator.

However, it might be a good idea to start operating the system without sand – there should be plenty of basic hydrodynamic research to be carried out, and cleaning the tank is an issue.

Straw man basin layout:

The figure shows the following features.

- Wave maker at far end, allowing cameras to be set up with more room at the beach end.
- Sufficiently large nine holes, 2m (ideally 2.5m) deep, connected by conduit – quite possibly double conduit holes, to allow optical pipes to be separated from the electrical connections. Access to the conduit at either end of the basin is not shown.
- Larger chambers, perhaps 1.2m by 1.5m by 1.2m deep at either side, to allow a moveable bottom for landslide models.



Existing 2-D flume

There was a general discussion as to whether the OSU's existing long flume was to be considered part of the NEES facility – particularly since it would be quite common to carry out tests at 2-D in the flume before going to the 3-D basin. Currently, the long flume is not part of the NEES facility. It is important to supply sufficient funding to carry out experiments at the 2-D flume – particularly since these will often be precursors to the 3-D (NEES) experiments.

Working Group on Coastal Engineering within NSF

Tsunamis behave differently from wind-generated sea waves, and consequently, research approach for tsunamis is also different. However, it must be recognized that the facility will be capable of modeling nearshore waves in general, because the OSU tsunami facility will be constructed as a "long-wave" basin. Therefore, the OSU facility will provide great opportunities to explore critical problems not only for tsunamis but also for coastal-engineering and nearshore-oceanography.

Presently the size of the tsunami community is small. There creates a potential risk that the OSU facility will be under-used if its usage be limited to tsunami research only. To circumvent such a risk, it is essential to promote coastal-engineering research with this facility. It should be emphasized that the same basin configuration and similar instrumentation that are used for tsunami experiments can be used for coastal engineering research by simply generating a different type of waves. This facility will provide a new dimension of opportunities for coastal engineering research.

While such an opportunity is in reality, we recognize that there is no coastal engineering program within the NSF. This has limited the availability of funds to coastal engineering research.

These discussions led to the formation of a Working Group on Coastal Engineering within NSF to address this issue.

Recommendations

After the workshop and based on discussions among the workshop participants via a mail-list (NEES@u.washington.edu), the following recommendations are made:

1. The existing two-dimensional wave channel at Oregon State University (104m long, 3.66m wide and 4.57m deep) should be included as a part of the NEES Tsunami facility. This channel has a hinged flap wave board, which is hydraulically driven with digital controls and generates periodic and random waves up to 1.52m high. This large wave channel is ideal for investigating two-dimensional nearshore dynamics of tsunamis.
2. A detailed research plan for the first tsunami experiment using the NEES facility must be made as soon as possible. The research topic should be selected by taking advantage of the NEES infrastructure. Collaboration with other NEES sites, scientific merit, and current interest of the research and mitigation communities must be considered for the selection process.
3. The following instrumentation is considered desirable for performing tsunami research. It is recommended to make them available by the time of the facility completion.
   a. Wave gages - the gages should be able to measure a wide range of the water-surface variations, from a few millimeter to 100 cm in wave height. Some resistance-type wave gages are already available at OSU, but it is worth exploring

other options: for example, the gages used at CHL, USACOE, for large-size gages, and UW gages for small-size gages. We should also seek development of wireless wave-gage systems. All the wave gages must be calibrated in situ without changing water level. This means that the gages must be mounted on vertical traversing system.

Note that wave gages are an intrusive device for point measurements. There are new (≈ 15 year old) technologies available to map the water-surface slope non-intrusively and optically, based on the light refraction. Such a device is called the wave-slope imagery (both gray-scale and color-scale have been used) and should be considered for the use in the tsunami facility.

b. Point gages for several different applications -- depth, simple wave gage use.

c. Data and image acquisition systems. We must select them with the careful consideration for future expansion and demand. For example, we should consider a modular commercial off-the-shelf technology, which allows easy upgrade and expansion of the system.

d. Video cameras - Some video cameras are already available and/or will be purchased. Some of them are under-water cameras. But, one of the critical experiments on tsunamis is to measure the runup. The runup processes can only be quantified by the optical measurements with high-resolution, high-speed, digital video cameras. Such cameras with multi-mega pixels (perhaps 1M x 1M) are essential. Two (2) such cameras, in addition to several regular digital video cameras for observation purpose are recommended. The frame grabbers and the streaming data acquisition systems are also needed.

e. 20W Argon-ion laser - the laser will be used for flow visualization, PIV/PTV system, as well as a component of LDV system.

f. ADVs - we recommend 25 sets of ADVs with flexible cable mounted probe head systems.

g. Flood lights - High quality and intense flood lighting systems are needed for flow visualization.

h. Two sets of good and sturdy carriages spanning the basin are essential. These carriages will be used for precision placements of instrumentation listed above; they should be moveable and not the same as the people carriage. The cross members spanning the tank should be mounted on appropriate motor driven wheeled units which can travel easily on accurately leveled rails attached to the tank

i. LDV - Two-component back-scatter LDV is needed with a submersible head with a 10m-long fiber optic lead.

4. The design of the tsunami basin and facility must be made with careful consideration of future needs, especially for the use of the state-of-the-art optical instrumentation. The following is a list of recommendations based on the consensus made at the

workshop that no sediment will be introduced in the basin in the initial stages of the NEES program.

a. The wave maker will be installed at the end of the newly constructed portion of the basin farthest from the control room. Although this is inconvenient for the construction plan, this change is critical for the efficient use of the facility.

b. Install internet accesses at 15m intervals around the basin. In some case, special data acquisition can be made with a portable computer that must be linked to the control room, and/or elsewhere.

c. The basin floor must be constructed with care. OSU should set the specification of the floor construction in terms of its smoothness and a tolerance in a horizontal plane.

d. Painting the basin floor and side walls in white is important for visualization.

e. Inserts for supporting synoptic arrays would be useful. Stainless steel unistrut inserts are currently available every 2.1 m. Also on the basin floor, several access ports for data collection and instrument control, as well as electric power source, should be installed and connected to the control room via conduits underneath the floor concrete slab. Such provision is useful for large-scale experiments, which avoids having many wires for instruments above the basin. More importantly, those wires will cause inconvenience for flow-visualization.

f. Two separate water supply lines should be installed: one for large, the other for small discharge rate. The small line will be used as a make-up line.

g. Two separate drains should be installed. One to drain the entire basin water for service, the other will be used for recirculation for water filtration/purification to maintain good water quality. The entrance of the small drain will be threaded so that a riser with adjustable height can be attached. The water intake from the riser at the water surface level will provide the means to skim the surface layer of water so that surface contamination due to air-borne dust, etc. can be minimized. Note that the water quality may not be important for some of the experiments, but this provision can be made now with a small expense.

a. Glass windows, access tunnels, etc. under the basin floor, used for non-intrusive optical access, particularly from underneath for the wave-slope imagery (see 3.a), LDV, and other optical instruments. This provision is important and we discussed extensively at the workshop and one possible plan is found in the workshop minutes.

OSU's response to the recoimmendations

Item 3.(a): A vertical traversing system requires that the wave gauges be cantilevered from the surface with a stiff frame to avoid gauge deflection. The design tsunami will generate velocities on the order of 2 m/sec which will yield drag forces on the order of 0.3 pounds per square inch of gauge cross section. For a single probe, 1/8th inch diameter and 2 m long, this will generate a load of approximately 3 pounds, which will cause a stainless steel rod to deflect many inches. This dynamic deflection precludes high-resolution water surface measurements. To overcome the deflection problem one must construct a stiff frame to resist the moments. In order to make the frame stiff, it must be so large as to cause diffracted and radiated waves that disturb the local water surface profile. The alternative is to make the gauge larger in diameter but this introduces runup distortion to the water surface elevation. You must remember that we are making measurements of large waves, not tabletop scale experiments with negligible loads. Our experience is that you can overcome this problem by tensioning 0.4 mm stainless steel cable between a fixed attachment at the bottom of the basin and a frame above the surface to minimize the size of the gauge and deflection simultaneously. With a fixed gauge you must change the water surface elevation to calibrate and this is accomplished easily at the beginning and end of each test day. All gauges are calibrated in parallel, simultaneously, so the time required is a tradeoff with serial calibration of traversing gauges. The gauges are inherently linear so you do not have to calibrate over the full depth of the gauge except to convince yourself, every so often, that the gauges are linear. Unless you have a design for an infinitesimally thin, infinitely stiff gauge, traversing gauges in large-scale facilities may not be feasible. Regarding costs, each gauge requires signal conditioning (power supply, bridge circuitry) at a cost of approximately $500 per gauge. In addition, anti-aliasing filters must be provided as a front end to the AD system at a cost of $300 per channel, or more. So, we are looking at approximately $1,000 per gauge without the traversing system. Again, if you are promoting a traversing gauge system, please construct a prototype of your design and test it in a 2 m depth with a 2m/sec velocity to demonstrate that it is structurally stable and hydrodynamically clean.

I welcome the advent of remote sensing for broad aerial coverage in the laboratory. When the resolution of laser, radar, microwave or visual sensing and analysis approach that of local sensor based instruments, I will promote the procurement of the appropriate system.

Item 3.(d): Twenty-two digital video streams will swamp our gigabit Ethernet line. We are planning on 10 cameras, 6 surface and 4 underwater, with pan-tilt-zoom control so that we can cover the critical portions of the basin with high resolution and achieve overviews with low resolution. We will need to accomplish substantial compression to make these ten cameras accessible to real time remote observers.

Item 3.(i): Items 3e and 3i are required to accommodate LDV measurements. It is not apparent to me that the high frequency turbulent structure of tsunami waves is crucial to the understanding of 3D tsunami evolution near shore. Some well-written NSF proposals for relevant tsunami experiments will be required to justify these items.

Item 4: Regarding sediment in the basin, it will be cost effective to use a sand or pea gravel fill with a concrete surface each time we change the bathymetry. This is standard procedure in virtually all coastal modeling laboratories and does not inhibit measurements of the type that we are considering. Also, tsunami induced erosion is likely to be a topic of some interest. We are familiar with the effort required to remove sediment and restore clean boundary conditions in both our 2D wave channel and directional wave basin. This should not deter proposals for good science.

Item 4.(c): Plus or minus 1/8th inch, with a maximum differential of 1/4 inch in 8 feet, is the specification that we achieved in our existing basin. A tighter specification will require much grinding and patching, at great cost, with little benefit to wave behavior. One-quarter inch variation in a depth of one meter is within 0.6% of perfection, a tolerance that is seldom achieved in most sensor based hydrodynamic measurements.

Item 4.(d): White surfaces are too reflective for video and still photos; you will not be able to discern bubbles at the leading edge of runup or incipiently breaking waves. Black is too opaque. An intermediate shade of gray, like finished concrete, is a good compromise.

Item 4.(f): We presently have one large and one small capacity fill line in the existing basin. We will add a second large line to augment the fill rate for the expanded basin.

Item 4.(g): Fresh water addition to compensate for water drainage is cheaper than water treatment. It is difficult to overcome the economies of scale achieved at municipal water treatment plants.

Item 4.(h): The architect will design and determine the cost of 18 inch diameter pits, 8 ft deep, in rows of three across the basin. The pits will be connected with 6 inch diameter, schedule 80, PVC pipe to provide an optical path for a remote laser. Remember, however, there is no more money.

List of Participants

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