PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Nick Fish, Commissioner
Michael Stuhr, P.E., Administrator

1120 SW 5th Avenue, Room 600
Portland, Oregon 97204-1926
Information: 503-823-7404
www.portlandoregon.gov/water

EXHIBIT A, INTERGOVERNMENTAL AGREEMENT
for
Testing Linkages and Estimating Ground Motions at Bull Run Watershed Project

CITY OF PORTLAND IGA NO.: _______________

This Intergovernmental IGA (Agreement or IGA) is entered into by and between the City of Portland, Oregon, acting by and through its Water Bureau, hereafter called "City" and the Oregon State University, hereafter called "OSU." This IGA is authorized pursuant to ORS 190.110 and becomes effective upon full execution of this document.

PURPOSE

The Testing Linkages and Estimating Ground Motions at Bull Run Watershed Project (Project) supports the continuation of extensive paleoseismology work conducted by the Oregon State University Active Tectonics and Seafloor Mapping Laboratory on the Cascadia Subduction Zone. The study of the Cascadia Subduction Zone directly impacts engineering techniques that have been successfully applied to Cascadia, as well as around the world, aimed at estimating the level of shaking inland across Portland and Mount Hood, which will be in part derived from work conducted at Bull Run Lake.

NOW, THEREFORE, THE PARTICIPANTS AGREE AS FOLLOWS:

1. STATEMENT OF WORK

The OSU shall perform the work (the "Work") as set forth in the Statement of Work and that is attached hereto as Exhibit A and incorporated herein by this reference. The captions or headings in this IGA are for convenience only and in no way define, limit or describe the scope or intent of any provisions of this IGA.

2. TERM

Work shall commence on the effective date of this IGA. The effective date of this IGA is July 1, 2017. The expiration date of this IGA shall be June 30, 2018. This IGA is subject to renewal only by mutual written amendment of the parties and must be approved through both parties approving authorities.

3. BILLING PROCEDURES AND COMPENSATION

A. The City has authorized a total not to exceed amount of **$10,178** to fund and enter into an IGA. The City currently has funding for this IGA in Fiscal Year (FY) 2017-18. The City's Fiscal Year is defined as July 1 through June 30 of each year.

B. Funding for the work shall only be disbursed upon City Council approval via City Ordinance authorizing an IGA and payment. In the event this IGA is terminated pursuant to all unexpended funds shall be returned to the City within 60 days of said termination

C. The City's policy to pay its invoices via electronic funds transfers through the automated clearing house (ACH) network. To initiate payment of invoices, the OSU shall execute the City's standard ACH Vendor Payment Authorization IGA which is available on the City's website at http://www.portlandoregon.gov/bfs/article/409834?.

Upon verification of the data provided, the Payment Authorization Agreement shall authorize the City to deposit payment for services rendered directly into *the OSU's* accounts with financial institutions. All payments shall be in United States currency. Payment of any invoice, however, does not preclude the City from later determining that an error in payment was made and from withholding the disputed sum from the next monthly payment until the dispute is resolved.

D. By the 15th of the month following the end of the previous month after the effective date, OSU shall submit to the City an invoice for work performed during the previous month.

E. Invoices shall only be submitted to the Portland Water Bureau Finance Office electronically. Email address is as follows: wbaps@portlandoregon.gov

F. OSU shall fully cooperate with a City Audit of the records at any time. OSU shall also fully cooperate with an audit to account for all expenses if necessary.

4. NOTICES

Unless otherwise stated in this IGA, the designees named below shall be the contact for all activities relating to the Work/Services to be performed under this IGA.

Agency (Technical Contact):

Name: Chris Goldfinger
Address: 104 COAS Administration Bldg.
Corvallis OR 97331
Phone: (541) 737-2066
Email: gold@coas.oregonstate.edu

City (Technical Contact/Project Manager):

Name: Tim Collins
Address: 1120 SW 5th Avenue, Room 600
Portland, OR 97204
Phone: (503) 823-5033
Email: Tim.Collins@portlandoregon.gov

Agency (Administrative):

Name: Patricia Hawk
Address: 312 Kerr Admin Bldg.
Corvallis OR 97331-2140
Phone: (541) 737-4933
Email: sponsored.programs@oregonstate.edu

City (Administrative):

Name: Andrew Urdahl
Address: 1120 SW 5th Avenue, Room 600
Portland, OR 97204
Phone: (503) 823-7490
Email: Andrew.Urdahl@portlandoregon.gov

5. TERMINATION

This IGA may be terminated by either party upon thirty (30) days written notice. City shall reimburse OSU for all noncancellable obligations incurred prior to the termination date.

6. NON-DISCRIMINATION

In carrying out activities under this agreement, neither party shall discriminate against any employee or applicant for employment because of race, color, religion, sex, age handicap, familial status or national origin. Either party shall take affirmative actions to insure that applicants for employment are employed and that employees are treated during employment, without regard to their race, color religion, sex, age, handicap, familial status or national origin. Such action shall include but not be limited to, the following: employment, upgrading, demotion, or transfer; recruitment or recruitment advertising; layoff of termination; rates of pay or other forms of compensation; and selection for training, including apprenticeship.

7. ACCESS TO RECORDS

Both parties and their duly authorized representatives shall have access to the books, documents, and records which are directly pertinent to the specific IGA for the purpose of making audit, examination, excerpts and transcript.

8. INDEMNIFICATION

Subject to the conditions and limitations of the Oregon Constitution, Article XI, Section 7, and Oregon Tort Claims Act, ORS 30.260 through 30.300, the OSU shall indemnify, defend and hold harmless the City from and against all liability, loss and costs arising out of or resulting from the negligent or intentionally wrongful acts of the OSU, its officers, employees and agents in the performance of this IGA.

Subject to the conditions and limitations of the Oregon Constitution, Article XI, Section 9, and the Oregon Tort Claims Act (ORS 30.260 to 30.300) City shall indemnify, defend and hold harmless the OSU from and against all liability, loss and costs arising out of or resulting from the negligent or intentionally wrongful acts of City, its officers, employees and agents in the performance of this IGA.

9. INSURANCE

The OSU shall each be responsible for providing workers compensation insurance as required by law.

10. SUBCONTRACTING AND ASSIGNMENT

The OSU shall not subcontract its work under this IGA, with the exception of work identified in this IGA or attached Statement of Work, without the written consent of the other party. The OSU shall assure that all subcontractors used to perform the services under this IGA, meet the City Codes pertaining to permits, workmen's compensation, licensing, and all other requirements.

11. DISPUTES

The signatories to this IGA shall expend their best efforts to amicably resolve any dispute that may arise under this IGA. Any dispute that the signatories are unable to resolve shall be submitted to the Director of the OSU or his/her designee and the City of Portland Water Bureau Administrator or his/her designee for resolution.

12. OREGON LAWS AND FORUM

This IGA shall be construed according to the laws of the State of Oregon. Any litigation between the City and OSU arising under this contract or out of work performed under this contract shall occur, in the state courts, in the Multnomah Court having jurisdiction thereof and if in the federal Courts, in the United States District Court for the State of Oregon.

13. FUNDS AVAILABLE AND AUTHORIZED

The City certifies that at the time the IGA is written that sufficient funds are available and authorized for expenditure to finance costs of this IGA within current appropriation and limitation. In the event of any extension or non-appropriation, the City shall notify the OSU its intent to terminate this IGA. The City's contribution for the term of the IGA is contingent upon receipt of approval by City Council and upon continuation of funding.

14. Severability

If any term or provision of this IGA is declared by a court of competent jurisdiction to be illegal or in conflict with any law, the validity of the remaining terms and provisions shall not be affected, and the rights and obligations of the parties shall be construed and enforced as if the IGA did not contain the particular term or provision held to be invalid.

15. Compliance with Applicable Law

Both parties shall comply with all federal, state and local laws, regulations, executive orders and ordinances applicable to the Work under this IGA. Without limiting the generality of the foregoing, parties expressly agrees to comply with (i) Title VI of Civil Rights Act of 1964; (ii) Section V of the Rehabilitation Act of 1973; (iii) the Americans with Disabilities Act of 1990 and ORS 659.425; (iv) all regulations and administrative rules established pursuant to the foregoing laws; (v) Any applicable sections of ORS Chapter 279, and (vi) all other applicable requirements of Federal and State civil rights and rehabilitation statues, rules and regulations.

16. Force Majeure

Neither Party shall be held responsible for delay or default caused by fire, riot, acts of God and war which are beyond its reasonable control. The affected party shall, however, make all reasonable efforts to remove or eliminate such a cause of delay or default and shall, upon cessation of the cause, diligently pursue performance of its obligation under the IGA.

17. No Third Party Beneficiary

The City and OSU are the only parties to this IGA and such are the only parties entitled to enforce its terms. Nothing contained in this IGA gives or shall be construed to give or provide any benefit, direct, indirect, or otherwise to third parties unless third persons are expressly described as intended to be beneficiaries of its terms.

18. Merger Clause

This IGA constitutes the entire IGA between the parties. No waiver, consent, modification or change of terms of this IGA shall bind either party unless in writing and signed by both parties. Such waiver, consent modification or change, if made, shall be effective only in the specific instance and for the specific purpose given. There are no understandings, IGAs, or representations, oral or written not specified herein regarding this IGA.

19. Amendments

The City and OSU may amend this IGA at any time only by written amendment executed by the City and OSU. The City's Water Bureau Administrator, upon approval by City Council, is authorized to approve amendments for the City to this IGA that do not increase the total IGA amount above 25% of the original IGA amount. The OSU shall submit a written request to the City's Technical Contact/Project Manager prior to any amendments to the IGA. Any amendment to the IGA shall require the signature of both parties approving authorities.

20. Ownership of documents

A. The City and OSU shall jointly own any and all data, documents, plans copyrights, specifications, working papers, and any other materials produced jointly in connection with this IGA.

B. The OSU, upon request by the City shall provide the City copies of the materials referred to above, including any electronic files containing the materials.

21. SEVERABILITY/SURVIVAL

If any of the provisions contained in this IGA are held unconstitutional or unenforceable, the enforceability of the remaining provisions shall not be impaired. All provisions concerning the limitation of liability, indemnity and conflicts of interest shall survive the termination of this IGA for any cause.

22. CONFLICTS OF INTEREST

No City Officer or employee, during his or her tenure or for one year thereafter, shall have any interest, direct, or indirect, in this IGA or the proceeds thereof. No board of director member or employee of the OSU, during his or her tenure or for one year thereafter, shall have any direct financial interest in the IGA or the proceeds thereof. No City Officer or employees who participated in the award of this IGA shall be employed by the OSU during this IGA.

23. COUNTERPARTS

This IGA shall be signed in two (2) or more counterparts, each of which shall be deemed an original, and which, when taken together, shall constitute one and the same IGA.

CITY OF PORTLAND

____
Michael Stuhr, P.E.
Portland Water Bureau Administrator

____
Date

APPROVED AS TO FORM:

____
City of Portland
City Attorney

____
Date

OREGON STATE UNIVERSITY

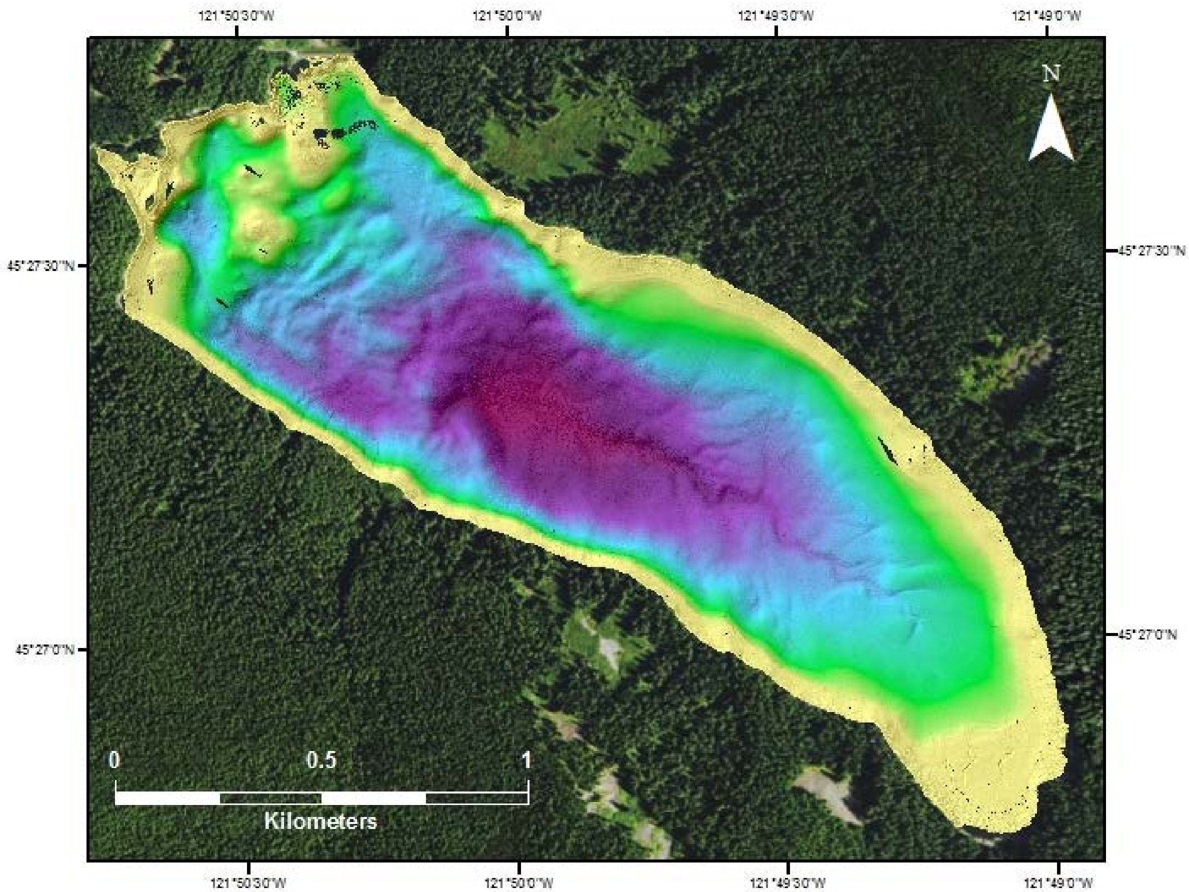
____
Zach Gill
Director Proposal and Award Administration

____
Date

Marine and Lacustrine Turbidite Records: Testing Linkages and Estimating Ground Motions at Bull Run Watershed, Central Cascadia Margin, USA

PI C. Goldfinger, Oregon State University (OSU)

Submitted to
Portland Water Bureau (PWB)



SIGNIFICANCE OF THE PROJECT

The Cascadia Subduction Zone (CSZ) is a megathrust fault system extending from Northern California to British Columbia that has repeatedly produced earthquakes above a magnitude 9 on the Richter scale in the last ~10,000 years. The recurrence interval for an event greater than magnitude 8 (M>8) is ~320 years. The last mega quake (M>9) occurred on Jan. 26, 1700 A.D.

The main evidence for recurring earthquakes at the Cascadia Subduction Zone exists through paleoseismology; however, we have a poor understanding of the magnitudes and spatial extents of prehistoric earthquakes and therefore the future seismic hazards and ground shaking levels in Pacific Northwest population centers. The overarching goal of this investigation is estimation of ground shaking at Bull Run Lake induced by Cascadia Subduction Zone earthquakes.

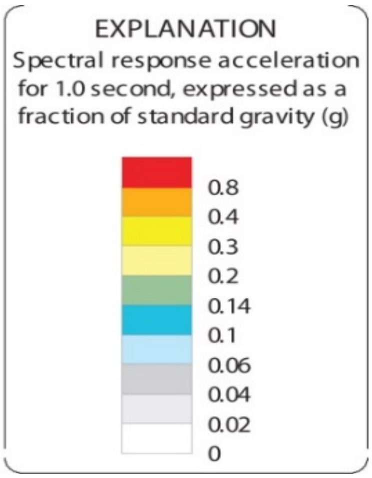
A major undetermined factor at this site is the minimum PGA (peak ground acceleration) required to form a discernable paleoseismic signal in local lacustrine sediment sites. This project is a unique opportunity to study paleoseismic records over a large distance and compare the shaking levels between onshore and offshore environments along similar latitude by linking the Bull Run Lake sedimentary records with the existing marine paleoseismic correlations. It also offers the opportunity to compare geologic evidence to model based estimations such as those currently used in the USGS National Seismic Hazard maps shown in Figure 1.

SIGNIFICANCE TO THE PORTLAND WATER BUREAU

The Testing Linkages and Estimating Ground Motions at Bull Run Watershed Project (Project) supports the continuation of extensive paleoseismology work conducted by the Oregon State University Active Tectonics and Seafloor Mapping Laboratory on the Cascadia Subduction Zone. Our study of the Cascadia Subduction Zone directly impacts engineering techniques that have been successfully applied to Cascadia, as well as around the world, aimed at estimating the level of shaking inland across Portland and Mount Hood, which will be in part derived from work conducted at Bull Run Lake.

The Portland Water Bureau (PWB) provides water to approximately one-quarter of the population of Oregon, roughly 958,000 people. In collaborating with the PWB and other state agencies, Oregon State University (OSU) strives to mitigate the availability water hazards for Oregonians before, during, and after a Cascadia megaquake event. OSU shall do this by investigating two current unknowns: **1) shaking levels at Bull Run Lake during prehistoric earthquakes, and 2) the present-day vulnerabilities of Bull Run Lake and of its greater watershed.**

Less severe impacts are expected for Oregonians living in areas of lower projected ground shaking; however, many citizens living in areas of lower seismic hazards still rely upon resources from the more seismically vulnerable regions. Ensuring that the PWB has the necessary data to establish water security during 'The Big One' is an important goal. Understanding likely shaking levels at Bull Run Lake during an earthquake also provides insight regarding the response of the remainder of the Bull Run Watershed during a seismic event. A significant amount of research has gone into mapping prehistoric landslides around Bull Run Watershed, nonetheless little is known about underwater landslides within the lake.



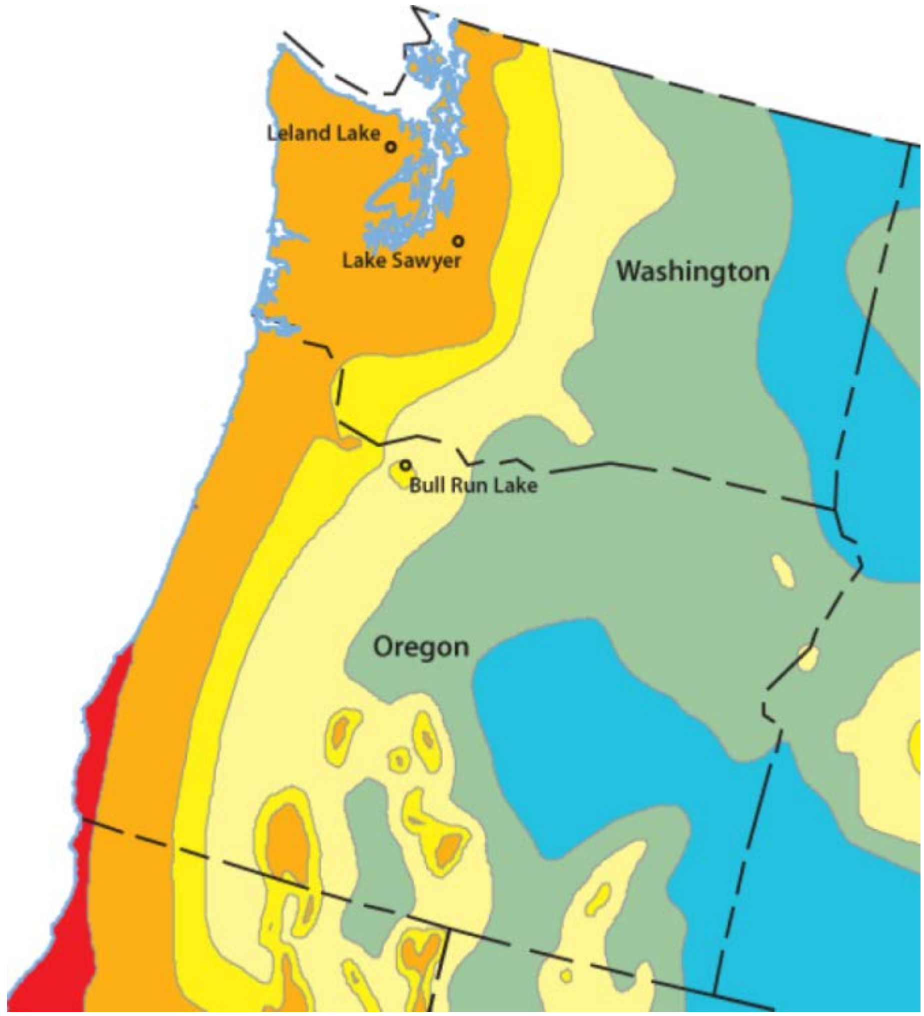


Fig. 1. *USGS National Seismic Hazard map from Petersen et al. (2014) showing the 2% probability of exceedance in 2,500 years from aggregated sources. The 0.3g PGA contour passes through the Mt. Hood area near Bull Run Lake.*

PRELIMINARY WORK

The Cascadia Marine Paleoseismic Record

Marine and Lacustrine paleoseismology has been applied in Cascadia (Adams, 1990; Goldfinger et al.., 2003a,b; 2007; 2008; 2009; 2011a; 2012a, 2012b; Karlin et al., 2004) and other settings, including Chile, Switzerland, and Japan, highlighting its growing acceptance as a tool for investigating geological conditions of past and future earthquakes. Marine turbidite paleoseismology has opened a window ~10,000 years into the history of the Cascadia Subduction Zone. Chris Goldfinger, along with the Active Tectonics and Seafloor Mapping Laboratory group have analyzed ~ 200 sediment cores from the Oregon and Washington coastlines containing numerous signals of CSZ earthquake in the form of a turbidites. The paleoseismic record comes in the form of a sediment signal that is called a seismoturbidites; a turbidite is a geologic deposit of a turbidity current, which is a type of sediment flow and in Cascadia can travel hundreds of kilometers through marine canyon systems. The amount of energy required to destabilize a sediment flow the size of those observed can only be from a large earthquake event. Once OSU has the cores split and separated, the turbidite beds are distinguished between seismic and non-seismic using two primary techniques: 1) Determination of event origin through sedimentological analyses; and 2) Regional correlation between sites to test for direct linkages or lack-thereof. Independent methods used for correlation are 1) subsurface physical property correlations; 2) radiometric dating methods and, 3) high-resolution seismic correlations.

Lacustrine Paleoseismology- inland lakes

Recent studies show evidence of inland lakes as being credible recorders of both subduction zone and crustal earthquakes (Karlin and Abella,1992, 1996; Karlin et al.., 2004, and Morey et al., 2013, Strasser et al., 2006). Bull Run Lake is one of three lakes being studied in this investigation. The two other sites are within different PGA categories within the state of Washington; Leland Lake and Lake Sawyer were both analyzed in 2013-2016 and contain seismoturbidites linked to CSZ earthquakes using radiocarbon dating and linkages to known events from the offshore record (Goldfinger et al., 2014). The larger scope of this project is to determine the level of ground motion across two separate transects one along the latitude of Seattle and of Portland. For more details on the seismic correlations between the Washington lakes and the offshore record please refer to figure 3 above.

Ideally, OSU anticipates that it may be possible to bracket ground shaking near Seattle and Portland by calculating the minimum PGA values for a range of slope angles and establishing minimums for the range: what is the minimum amount of energy needed for a seismoturbidite deposit? The most stable slopes that failed will set the minimum-maximum.

Bull Run Lake

Sub-bottom profiling and Sidescan Surveys

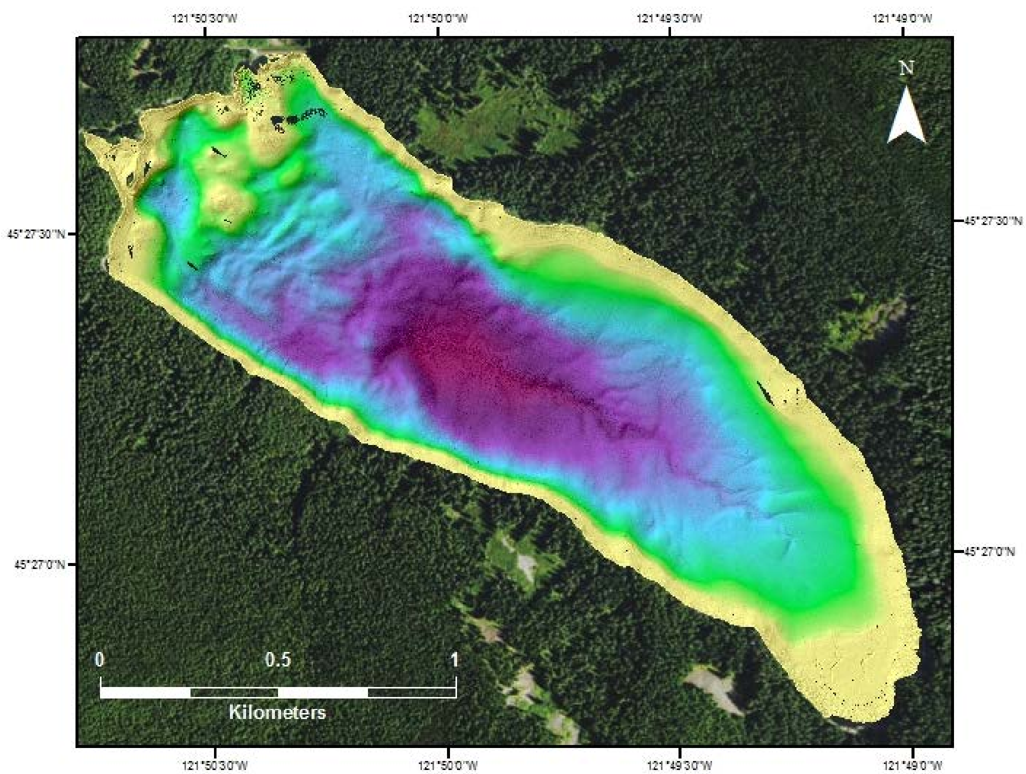


Fig. 2. Bathymetry map of Bull Run Lake. Created by the OSU Active Tectonics and Seafloor Mapping Lab during summer 2015.

In 2015 we collected full coverage high resolution multibeam and backscatter data, along with a high resolution grid of CHIRP sub-bottom profiles during summer 2015. The 3D bathymetry map provides simple visualization of the environment of the lake bed.

OSU finds that the turbidite record in the lake is well imaged in the high-resolution chirp data, and is found throughout the lake, including at least one basin isolated from the main basin. The continuity of the turbidite record shows little or no relationship to the minor stream inlets, suggesting the disturbance beds are not likely to be storm related. Subtle channels from north and south sides of the lake feed an axial channel that terminates at the eastern shore. Lake side wall failures are evident on the north and south walls, and occur with and without imageable tabular blocky slide debris where sedimented slopes exceed ~ 22-25 degrees. Smaller failures visible in backscatter data are found on slopes as low as 12 degrees. OSU conducted diver investigations of several of the landslide areas, collecting hand push core samples and in-situ vane shear torquemeter measurements. Initial slope stability models

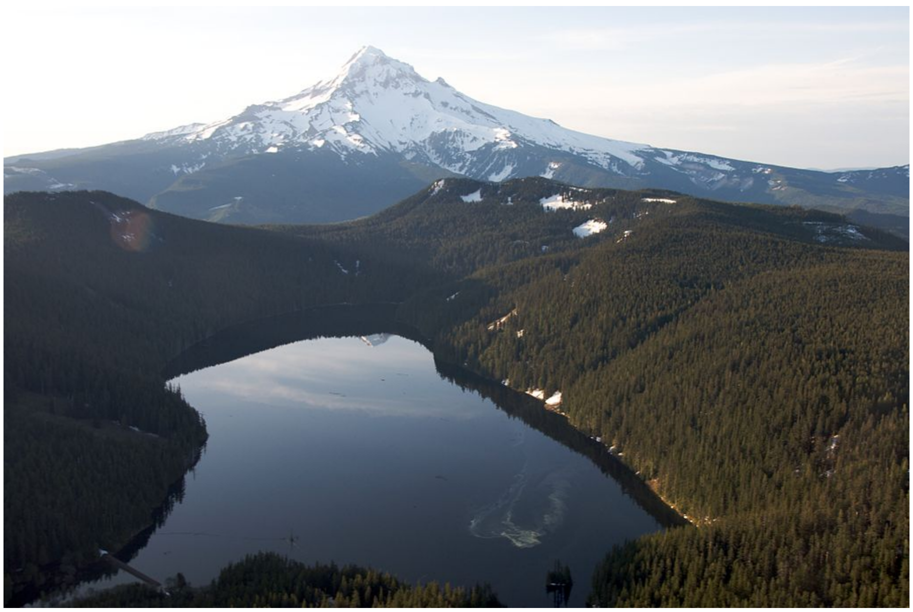


Fig. 3. Photo of Bull Run Lake, looking east. Picture is courtesy of Sam Beebe.

suggest that slopes less than ~ 25 degrees are statically stable. OSU is investigating the levels of ground motion required to destabilize surface sediments around the lake, and radiocarbon dating the disturbance events for comparison to other paleoseismic records, including new offshore cores at similar latitudes.

Coring

In July 2015 OSU collected 7 cores in 9 attempts using a gravity coring system and winch from a barge supplied by the PWB. The core sites are shown in Figure 4. OSU CT scanned some of the cores, and show some preliminary correlation diagrams in Figure 2 and 3. The cores contain a series of observed turbidites, two ash layers, and many faint laminae that may contain a storm record. In addition to the

Mazama ash, a second twin ash layer is found in the upper part of all cores. This twin ash may correlate to the Timberline ash found in Elk Meadow and thought to be ~ 1200 years old (cal radiocarbon age BP 1950).

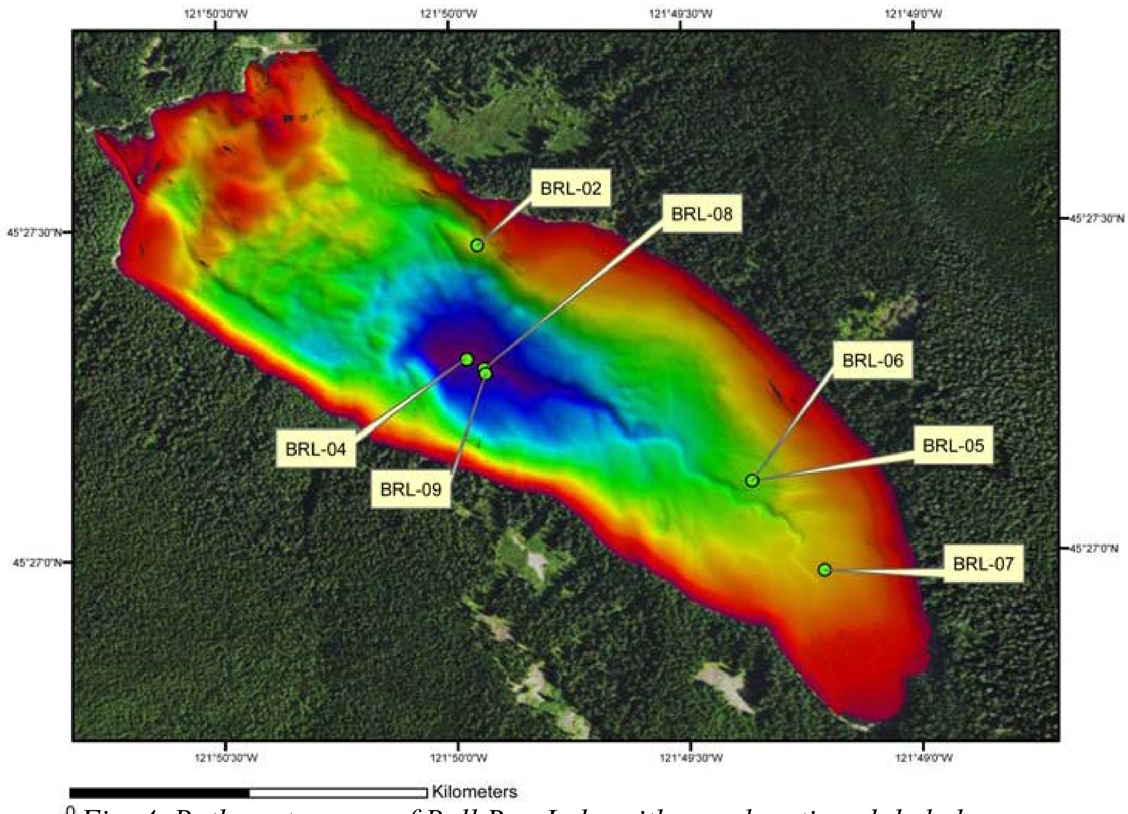


Fig. 4. Bathymetry map of Bull Run Lake with core locations labeled.

Most of the cores bottomed in the Mazama ash, previously identified in earlier work and verified with the new cores (Figure 5). The core stratigraphy verifies that the coarser stratigraphy observed in the sub-bottom profiles can be correlated around the lake, a key test of seismic-vs non-seismic origin. Internal lake sliding or external inputs to the lake would be unlikely to correlate throughout the lake, except earthquakes that affect all parts of the lake simultaneously. Conversely, non-correlable turbidites would be expected from local effects, artesian ground failures, random landslides, storm input from the drainage stream on the east end of the lake etc. An image of the CT scanned cores is shown in Figure 5.

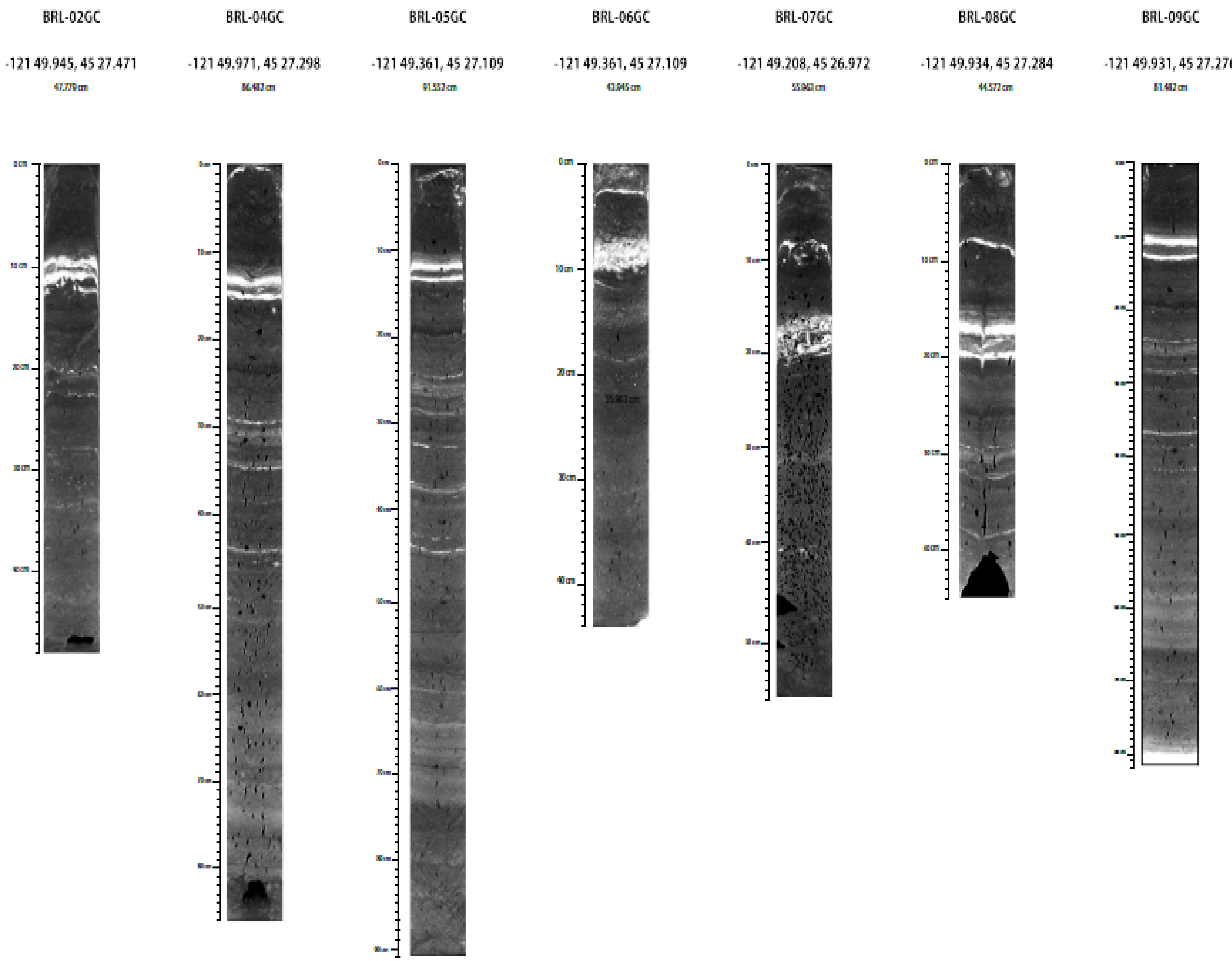


Figure 5. CT scans of Bull Run Lake cores.

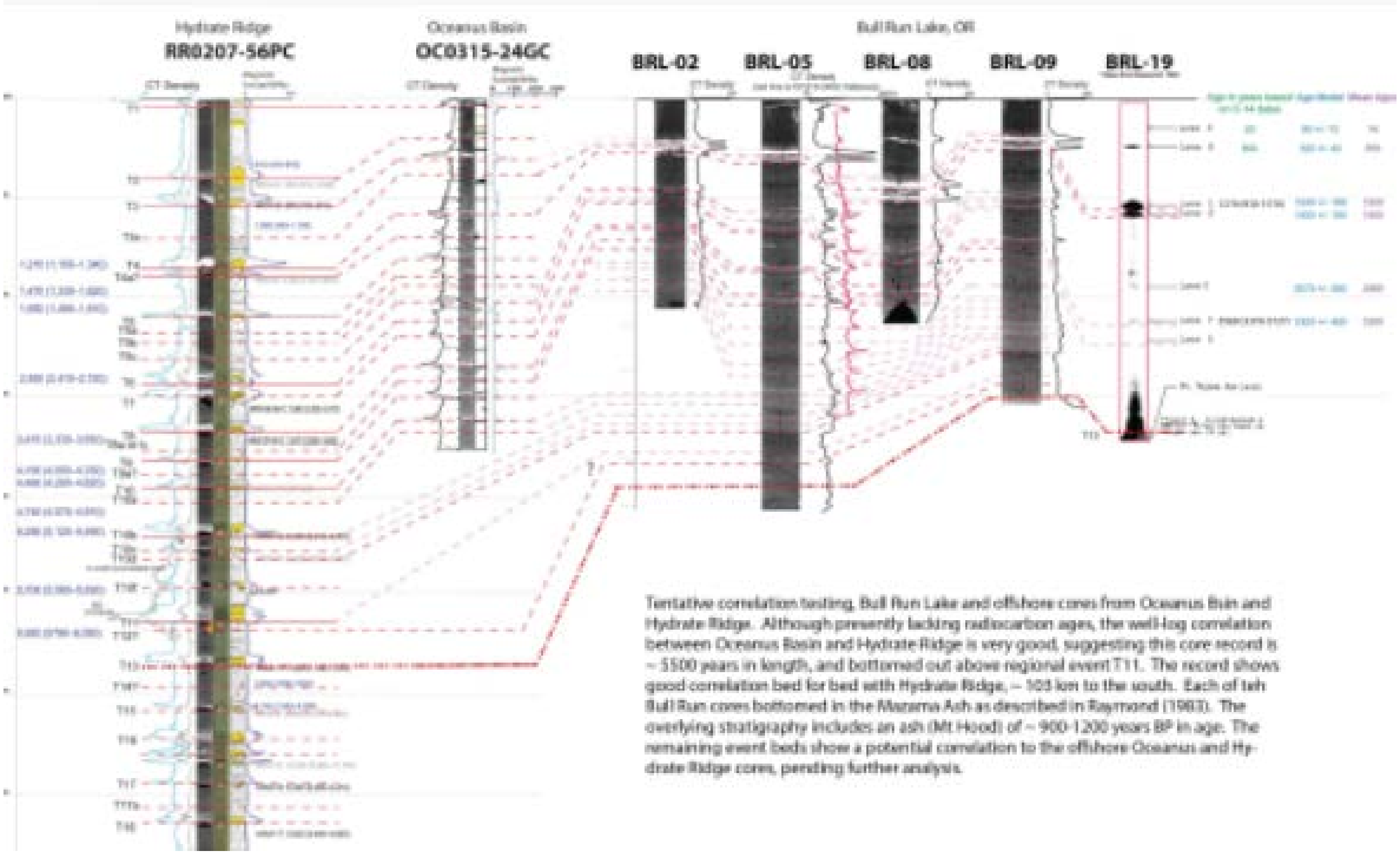


Fig. 6. Preliminary correlations between Bull Run cores and several marine cores (Hydrate Ridge and Oceanus Basin).

Figures 6 and 7 shows a tentative correlation diagram with several of the Bull Run cores and possible correlation to offshore cores at Hydrate Ridge and Oceanus basin, a new core also collected in 2015. We use common industry well-log correlation methods, described in detail in Goldfinger et al. (2015). The stratigraphy is linked by the common Mazama ash shown by the heavy read line. Offshore, the ash is delivered by an earthquake triggered turbidite (commonly this is T13). Onshore the ash is an airfall deposit, and thus the ages of these deposits are different: 7625 +/- 50 onshore, and the average T13 age is ~ 7150 +/- 80 offshore. The difference is the time between the actual eruption and the following earthquake. The Mazama eruption age is nearly identical to the age of offshore turbidite T14 (Goldfinger et al. (2012).

Figure 6 shows that the number of significant turbidites in Bull Run Lake is roughly the same as the turbidite count offshore. Between the significant turbidites, many thin laminae and inter-event lake sediment, dark gyttya, make up the rest of the core stratigraphy.

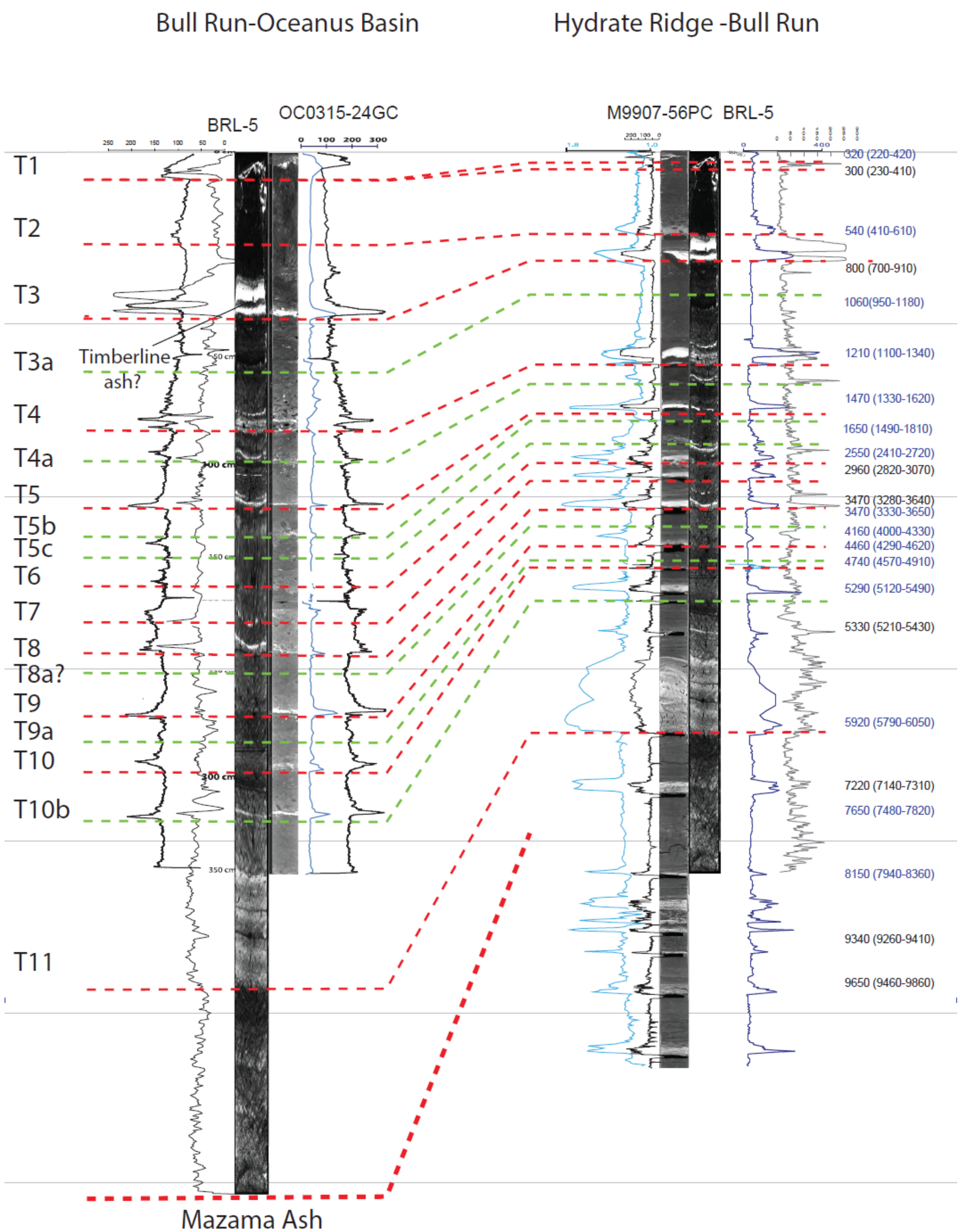


Figure 7. Closer view of offshore cores and Bull Run core and mutual correlation. Radiocarbon ages shown at right for Hydrate Ridge core, ages pending for Bull Run and Hydrate Ridge. Turbidites previous linked to full margin (red) and segmented rupture (green) from Goldfinger et al. (2012) are shown in dashed red and green lines. Sequence tied by Mazama ash and large regional event T11 anchor the correlation.

Work Plan

The work conducted thus far has given significant confidence that Bull Run Lake very likely contains a record of the Cascadia earthquake sequence that is recorded by offshore cores and coastal marsh sites (e.g. Atwater, 1987). In order to test this potential record, and to use the results to establish ground motion criteria for Bull Run Lake, a number of steps are required. First, OSU shall acquire ~ 10-12 radiocarbon ages from the stratigraphic sequence to establish age control for the sequence. Although correlations are anchored by the Mazama ash at the core bases, OSU must construct age models for all of the cores to establish age ranges for each event. This shall be done using the Bayesian modeling program OxCal, which can calculate the age of any point in the sequence, given a number of radiocarbon ages to establish sedimentation rates. Microprobe analysis shall be used to examine the upper twin ash and compare it to the Timberline Ash found at Elk Meadow. This has been terrestrially dated using radiocarbon, providing an external age-control link to strengthen the stratigraphic age sequence. Grain size analysis is used to establish the boundaries of the turbidites. While the CT system can commonly image these boundaries, grain size analysis is required to verify these boundaries. The boundaries are critical for developing an accurate age model.
Once the age model has been established, OSU shall then compare to the event ages both offshore and onshore (compiled in Goldfinger et al. 2012, 2016). If these events pass this test of coeval formation with other paleoseismic evidence, OSU shall then proceed to assess levels of ground motion at Bull Run Lake.

If successful, OSU shall complete slope stability assessment of the Bull Run submarine failures imaged in 2015, and estimate minimum ground motions at Bull Run Lake. Slope stability assessments normally yield the minimum levels of ground motion required to destabilize a slope. OSU wishes to assess the maximum levels however, and to do this, OSU uses the lowest failed slope angles mapped in the lake. The minimum values should approach realistic shaking levels for the maximum events experienced at Bull Run Lake. OSU shall use the slope angles for all mappable landslides along the lake walls to assess the distribution and cutoff angle. Preliminary work suggest this angle is 11-12 degrees. Below that angle, we observe no slope failures, suggesting that the slope failures are angle dependent, suggestive at least of most of them being earthquake related. While OSU cannot relate specific slides to specific earthquakes or turbidites in the lake, OSU hypothesize that the lowest slope failure angles are related to the largest ground motions in the lake. OSU shall then compare their results with model based results such as the USGS National Seismic Hazard maps, and other Washington lake data in progress to assess similarities or differences between these different results and approaches. In 2015, OSU collected submarine shear vane measurements with which to constrain the cohesion; that is the shear strength of the upper sediments in question, thus OSU has all the parameters needed to perform what is known as a limit-equilibrium slope stability assessment. OSU shall use the Slide 7.0 software for this purpose.

Timeline and Budget.

Below is the timeline and budget, showing tasks completed and remaining.

<u>2016-2017 PROJECT PLANS</u>

PROJECT PLAN

Month	Work Plan	Description
July 2017	• **XRF analysis of lake cores (data collection complete)**	XRF Core Scanner collects chemical element profiles down the core sections for measuring environmental change and bed provenance.
August 2016 (completed)	• **Laser Particle Size Analyzer (PSA); 0.5 cm intervals** • **Analyze smear slides**	Measures grain size to analyze distribution of beds (turbidites tend to have a larger grain size than stationary lake mud). Smear slides are analyzed under a microscope to detect amorphous materials or minerals present. Smear slides are analyzed to determine which beds to sample from for EMP analyses.
March 2016 **(completed)**	• **Sample preparation for radiocarbon dating.** • **Calibrate and rectify PSA data**	High resolution radiocarbon dating will help tie our investigation together between local and marine datasets. Dating stratigraphic beds gives us the ability to correlate earthquakes across large distances.
July 2017	• **Normalize and rectify XRF data.**	

	• **Sample preparation for electron micro probing- based on PSA results.**	
Summer 2017	• **Possible ROV work at to lake sites to retrieve shear vane measurements for slope stability modelling- SLOPE & MOVE software systems.**	**Optional work if possible to obtain shear vane measurements from deeper lake sites near deep failure zones.**
July 2017	• **Submit radiocarbon samples, acquire additional sample as required**	**Samples submitted to UC Irvine AMS facility**
September-October 2017	• **Develop OxCal age models for all cores**	**Construct "event free" stratigraphy and age models, develop series of event ages.**
November-December 2017	• **Re-calibrate BRL and offshore cores as required using full age models.**	**Detailed re-correlation using age models and all data**
January-February 2018	• **Complete final analyses and develop report**	**Report for Portland Water Bureau**
February-March 2018	• **Develop journal manuscript**	**Likely submission for Bulletin of the Seismological Society of America.**

BUDGET PROPOSAL

Category	***Cost/unit***	***Quantity***	***Total***
PI Name: Chris Goldfinger			
Salaries & Wages			
A) Senior Personnel			
Chris Goldfinger	N/A		N/A
B) Other Personnel			
Senior Technician B Black	4200	0.6	2520.00
C.) Fringe Benefits OPE	61%		1537.20
		Total Fringe	1537.20
		Total Salaries, Wages & Fringe Benefits	4057.20
D) Other Direct Costs			
1. Materials & Supplies		core liners archival	110.00
3. Computer Services	$500/month	0.5	250.00
4. Shipping	$50/shipment	10 samples/shipment	50.00
5. ITRAX X-Ray Fluorescence Spectrometry (XRF)	$30/hour	33 hours	complete
6. Multi-Sensor Core Logger	$55/day	2 days	110.00
7. CT imaging	$55/core	7 cores	385.00
8. Electron Microprobe (EMP)	$60/hour	3 hours	180.00
9. Radiocarbon Ages	$250/sample	12 samples	3000.00
		Total Other Direct Costs	4085.00
		Total Direct	8142.20

Modified Direct (total direct less tuition, sub-award in excess of $25K)	$8,142.20
CLIP Facilities & Administration Costs (formerly Indirect Costs) 25%	$2,035.55
Total	**$10,177.75**

Budget approval not to exceed: $10, 178

Budget Justification

OSU requests .6 months support technician Bran Black, which shall include sediment sampling, grain size analysis, sonar data processing and GIS integration of new data. OSU requests $110 in supplies which includes expendables such as sample containers and standards. OSU requests $250 for computer services @ $500/month, $50 for sample shipping, $110 for MST scanning, and $385 for CT imaging OSU requests $3000 for 12 radiocarbon samples at the UC Irvine AMS facility and $180 for microprobe analysis at CEOAS.

REFERENCES CITED

Adams J. 1990. Paleoseismicity of the Cascadia Subduction Zone: Evidence from Turbidites off the Oregon-Washington Margin. Tectonics, 9(4): 569-583 p.

Atwater, B.F., 1987. Evidence for great Holocene earthquakes along the outer coast of Washington State. Science 236, 942-944.

Goldfinger, C., Nelson, C.H., and Johnson, J.E., 2003a, *Deep-Water Turbidites as Holocene Earthquake Proxies: The Cascadia Subduction Zone and Northern San Andreas Fault Systems*: Annali Geofisica, v. 46, p. 1169-1194.

—, 2003b, *Holocene Earthquake Records from the Cascadia Subduction Zone and Northern San Andreas Fault Based on Precise Dating of Offshore Turbidites*: Annual Reviews of Earth and Planetary Sciences, v. 31, p. 555-577.

Goldfinger, C., Morey, A.E., Nelson, C.H., Gutiérrez-Pastor, J., Johnson, J.E., Karabanov, E., Chaytor, J., Ericsson, A., and shipboard scientific party, 2007, *Rupture lengths and temporal history of significant earthquakes on the Offshore and Northcoast segments of the Northern San Andreas Fault based on turbidite stratigraphy*, Earth and Planetary Science Letters, v. 254, p. 9-27.

Goldfinger, C., Grijalva, K., Burgmann, R., Morey, A.E., Johnson, J.E., Nelson, C.H., Gutierrez-Pastor, J., Karabanov, E., Chaytor, J.D., Patton, J., and Gracia, E., 2008, *Late Holocene Rupture of the Northern San Andreas Fault and Possible Stress Linkage to the Cascadia Subduction Zone*, Bulletin of the Seismological Society of America, v. 98, p. 861-889.

Goldfinger, C., Morey, A., Black, B., Beeson, J. and Patton, J., 2013, *Spatially Limited Mud Turbidites on the Cascadia Margin: Segmented Earthquake Ruptures?* Nat. Hazards Earth Syst. Sci., 13, 2109-2146. doi:10.5194/nhess-13-1-2013

City of Portland Water Bureau. *Bull Run Watershed Conduit Trestles Retrofit Project, Sandy, Oregon.* Prepared by URS, Portland, Oregon. FEMA Project No. PDMC-OR-009. URS Project No. 15702306.

Goldfinger C. 2011. Submarine paleoseismology based on turbidite records. Annual Review of Marine Science, v. 3, 35-66.

Goldfinger, C., Nelson, C.H., Morey, A., Johnson, J.E., Gutierrez-Pastor, J., Eriksson, A.T., Karabanov, E., Patton, J., Gracia, E., Enkin, R., Dallimore, A., Dunhill, G., and Vallier, T., 2012, *Turbidite Event History: Methods and Implications for Holocene Paleoseismicity of the Cascadia Subduction Zone*, USGS Professional Paper 1661-F, Reston, VA, U.S. Geological Survey, p. 184 p, 64 Figures. http://pubs.usgs.gov/pp/pp1661f/

Goldfinger, C., Morey, A., Galer, S., Beeson, J., Erhardt, M.E., 2014, A paleoseismic transect of Forearc Lakes at the Latitude of Seattle, Washington, Seismological Society of America Annual Meeting, Anchorage Alaska, April 30, 2014.

Goldfinger, C., Galer, S., Beeson, J.W., Hamilton, T.S, Black, B., Romsos, C., Patton, J., Nelson, C.H., Hausmann, R., Morey, A., 2016, The Importance of Site Selection, Sediment Supply, and Hydrodynamics: A Case Study of Submarine Paleoseismology on the Northern Cascadia margin, Washington USA, Marine Geology, In Press.

Karlin, R.C., and Abella, S.E.B., 1992, Paleoearthquakes in the Puget Sound region recorded in sediments from Lake Washington, U.S.A.: Science, v. 258, p. 1617-1620.

Karlin, R., and Abella, S.E., 1996, A history of Pacific Northwest earthquakes recorded in Holocene sediments from Lake Washington: Journal of Geophysical Research, v. 101, no. B3, p. 6137–6150.

Karlin, R.E., Holmes, M., Abella, S.E.B., Sylvester, R., 2004. Holocene landslides and a 3500-year record of Pacific Northwest earthquakes from sediments in Lake Washington. Geological Society of America Bulletin 116, 94-108.

Morey A.E, Goldfinger C, Briles C.E, Gavin D.G, Colombaroli D, and Kusler J.E. 2013. Are Great Cascadia earthquakes recorded in the sedimentary records from small forearc lakes? Natural Hazards Earth System Sciences, 13, 2441-2463 p.

Petersen, M.D., Moschetti, M.P., Powers, P.M., Mueller, C.S., Haller, K.M., Frankel, A.D., Zeng, Yuehua, Rezaeian, Sanaz, Harmsen, S.C., Boyd, O.S., Field, Ned, Chen, Rui, Rukstales, K.S., Luco, Nico, Wheeler, R.L., Williams, R.A., and Olsen, A.H., 2014, Documentation for the 2014 update of the United States national seismic hazard maps: U.S. Geological Survey Open-File Report 2014–1091, 243 p.

Raymond R.B. 1983. The Paleolimnology of Bull Run Lake: Disruption and stability in a natural system [dissertation]. Portland State University, 1-127pp.

Strasser M, Anselmetti F.S, Fah D, Giardini D, Schnellmann M. 2006. Magnitudes and source areas of large prehistoric northern Alpine earthquakes revealed by slope failures in lakes. Geology, 34 (12): 1005-1008 p.

Yeats, R.S. 1998. Living with Earthquakes in the Pacific Northwest: A Survivor's Guide. Second edition. Corvallis (OR): Oregon State University Press 390 p.