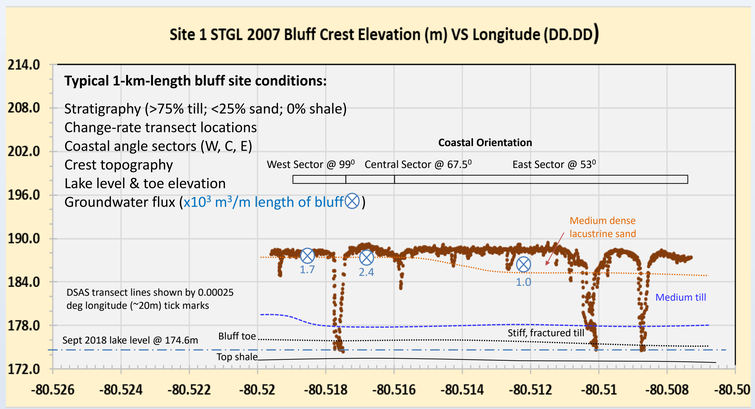
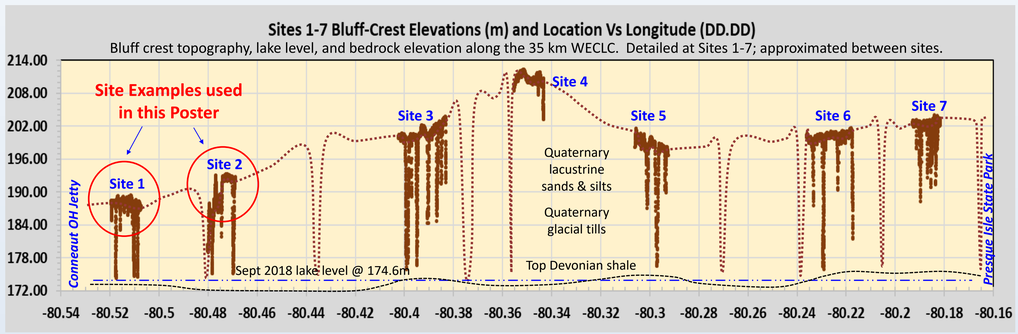
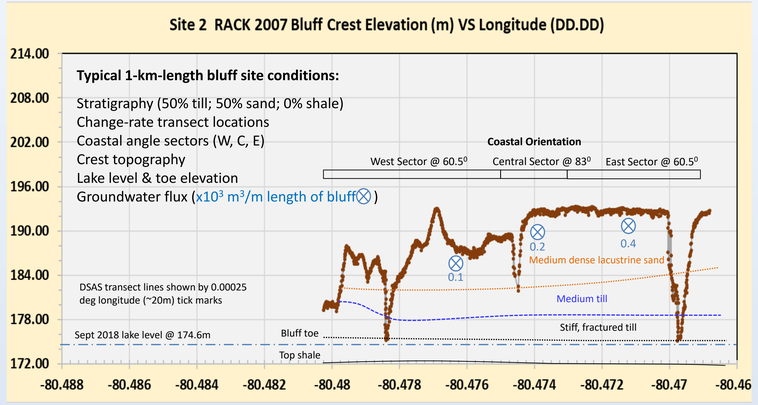
Bluff Retreat and Sediment Input to a Sand-Starved Littoral System on Pennsylvania's Lake Erie Coast, USA

A.M. Foyle, Department of Environmental Science, Penn State Erie – The Behrend College, Erie PA 16563 (#1556)

M.A. Rutter, Dept. Mathematics, Penn State Erie - The Behrend College, Erie PA, mar36@psu.edu; **K. Schuckman**, Dutton e-Education Inst., Penn State University, University Park, PA, kls505@psu.edu







1 PROJECT GOALS

- Build a multivariate Bayesian network model of bluff retreat for the western Erie County littoral cell (WECLC) to identify dominant forcings, explain recent-to-historical average annual bluff retreat rates (AARR), and help estimate future magnitudes and patterns.
- Generate new LiDAR-derived estimates of bluff-sourced littoral sediment input to the WECLC and downdrift littoral cells.
- Improve understanding of bluff processes and hazards on the Pennsylvania coast by linking physical forcing and landscape response.

ABSTRACT

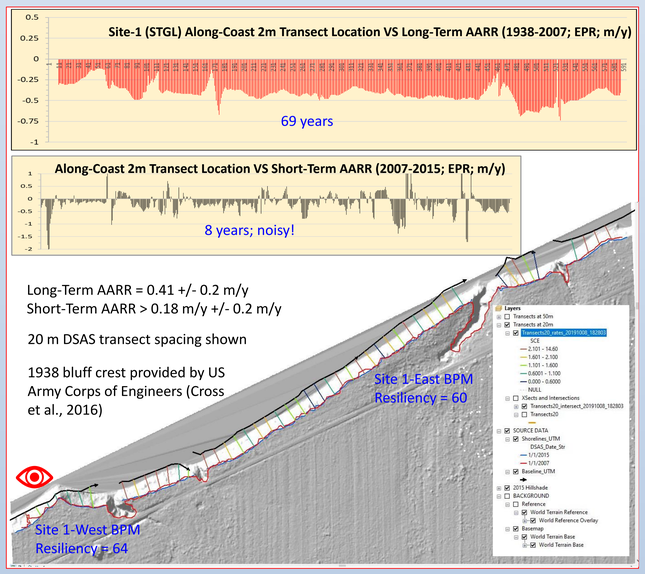
Coastal bluff retreat is a significant hazard for the eight US states on the North American Great Lakes. Highstands in Lake Erie water levels during 2019 broke long-term records on the Pennsylvania coast, which raised public awareness of coastal hazards and will likely lead to enhanced bluff retreat due to wave-driven steepening of the coastal profile. While building-loss frequencies are low compared to urbanized areas on the Pacific coast, the 123 km Pennsylvania coast currently has ~$66M of near-bluff property at risk through 2100.

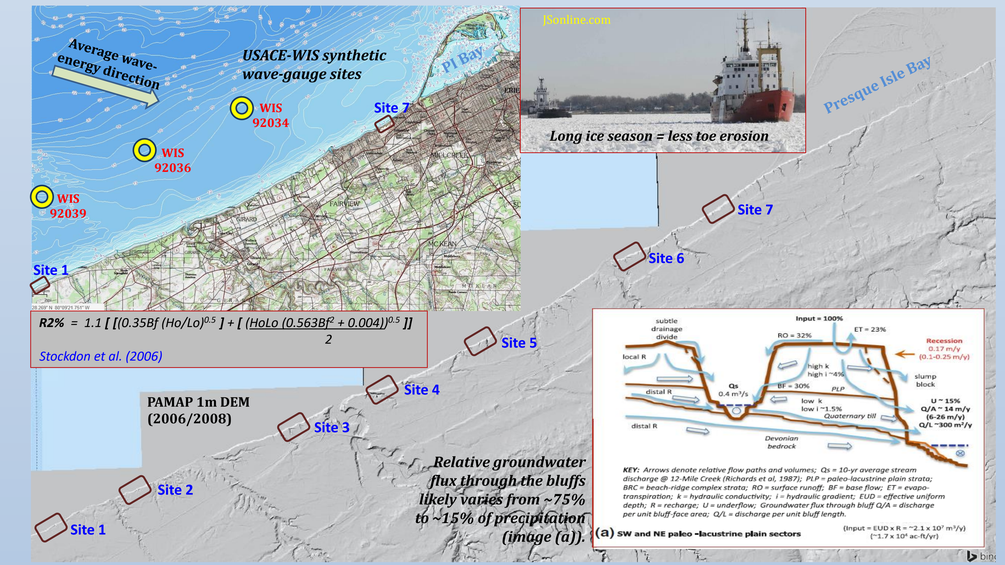
Using T-Sheet and LiDAR derived bluff-crest data from 1938, 2007, and 2015, a Bayesian network model of bluff retreat is being developed for the westernmost of three littoral cells that define the Pennsylvania coast. The model will identify the relative importance of wave attack; groundwater flux; and stratigraphy, elevation, and slope in controlling bluff retreat. Additionally, bluff-face topographies from 2007 and 2015 are being used to map bluff sediment contribution to the littoral system. Bluffs are a principal sediment input to a littoral zone that hosts Presque Isle State Park, which is the state's largest coastal-resource attraction. The project covers the 35 km-long Western Erie County littoral cell (WECLC), about half of Pennsylvania's bluff coast. Seven sites are being used to model bluff retreat and are integrated with cell-wide surface-difference mapping to quantify bluff sediment contributions to the sediment budget.

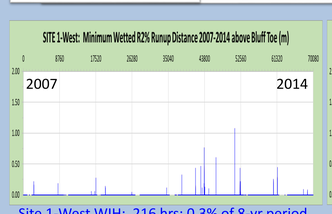
Project results will allow improved understanding of the relative importance of factors driving bluff erosion, enhance scientific understanding of bluff failure processes, aid science-based decision-making by coastal resource managers, and increase hazard-awareness among coastal residents.

2 METHODS

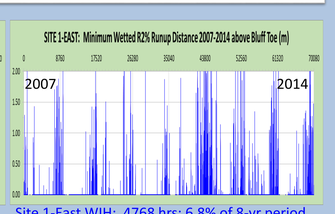
- A Bayesian network (in R) will relate initial conditions (stratigraphy, height, slope); 69-yr bluff retreat rate; and forcings (wave impact; groundwater flux) to explain bluff retreat.
- Differencing of LiDAR data (2007, 2015) will map bluff sediment input to the littoral zone.
- Bluff geodata are being mapped at seven sites and/or using available data from industry.
- 69-yr and short-term 8 yr bluff retreat rates are being mapped for 1938, 2007, and 2015.
- Wave impact at the bluff toe uses an R2% run-up elevation statistic (Stockdon et al., 2006).
- Relative groundwater flux through the bluff uses watershed area and precipitation trends



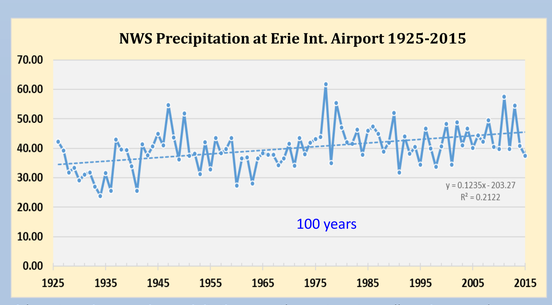




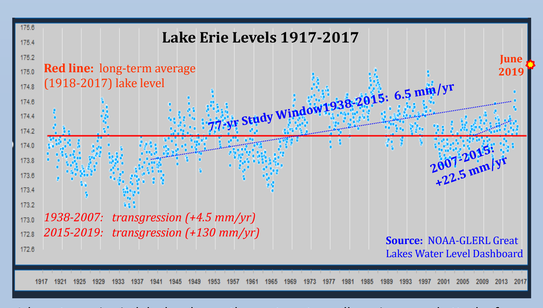
Site 1-West WIH: 216 hrs; 0.3% of 8-yr period



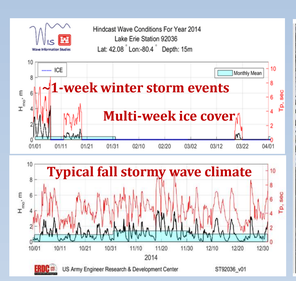
Site 1-East WIH: 4768 hrs; 6.8% of 8-yr period

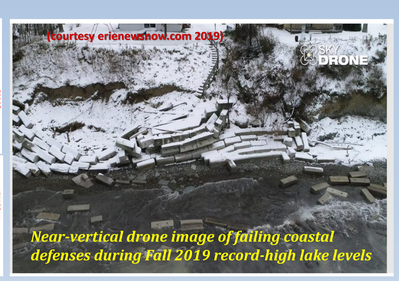


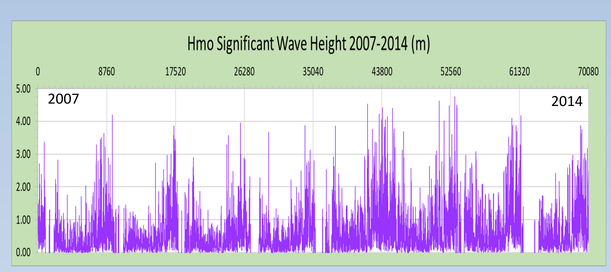
A long-term increase in precipitation over the past century allows increased recharge of surficial aquifers that crop out at the bluff face



A long-term rise in lake level over the past century allows increased attack of the bluff toe by hydrodynamic forces (waves)







The 8-yr wave-climate record (hind-cast) shows fall storms, and a reduction in significant wave height (Hmo -> zero) due to ice cover during winter seasons (data: wis.usace.army.mil)

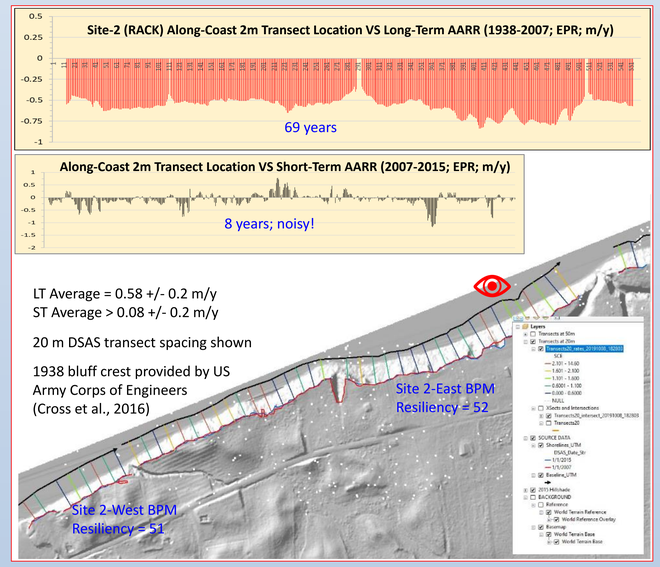
Lithologic BPM Resiliency of Bluff Face Units

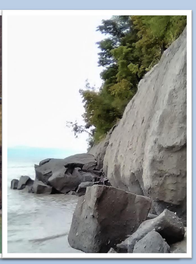
Highstand gravels @ 20 BPM
Transgressive lacustrine sands @ 33 BPM
Medium till @ 65 BPM
Stiff, fractured till @ 82 BPM
Devonian shale bedrock @ 825 BPM

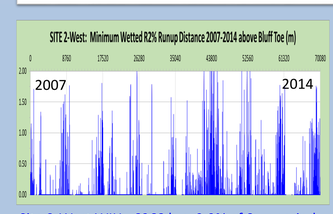
Weighted BPM Resiliency Value

WECLC Range:
Minimum 50
Maximum 100

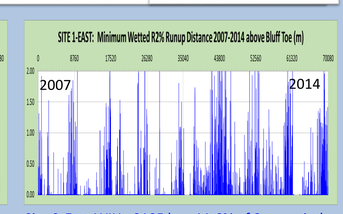
BPM = Standard Penetration Blows/Meter
BPM determined by stratigraphy







Site 2-West WIH: 6968 hrs; 9.9% of 8-yr period



Site 2-East WIH: 8105 hrs; 11.6% of 8-yr period

3 PRELIMINARY RESULTS & NEXT STEPS

- Prior to developing the Bayesian network, no obvious correlation was seen between bluff retreat and groundwater flux, crest elevation, and BPM resiliency individually.
- Qualitatively, a correlation is seen with wave-impact hours (runup), coastal orientation, and bedrock presence/absence.
- The 7-yr retreat rates (for model validation) show more variability than the 69-yr rates: the former data are undergoing QA/QC to remove false progradation.
- Bayesian network-building (in R) and slope-differencing (in LP360) are underway.

4 RELEVANT LITERATURE

Cross, W., Morang, A., Frey, A., Mohr, M.C., Chader, S., and Forgette, C.M. 2016. Historical sediment budget (1860s to present) for the United States shoreline of Lake Erie. ERDC/CHL TR-16-15.
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