Station Database: Updates on $V_{S30}$ Assignments

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Outline

• New information based on site visits
• Reconciling geologic sources
• Analysis of site terms
• Identification of potentially misclassified sites using site terms
• Next steps
**Codes for $V_{s30}$ assignment:**

0  Measurement at site  
1  Known site condition (typically from site visit), $V_{s30}$ measurement on that known condition  
2  P-wave seismogram method & $V_{s30} > 760$ m/s  
3  Hybrid slope-geology proxy & $V_{s30} > 760$ m/s  
4  Weighted average of proxies, including p-wave seismogram  
5  Weighted average of proxies, p-wave seismogram not available

**New Information**

$V_{s30}$ recommendations provided by John Adams

- 40 stations in Canada  
- Each site visited by a geologist (Code 1)  
- Correspondence with:  
  - CGS: Tim Cote, Jim Hunter and Didier Perret  
  - UQAM: Fiona Darbyshire  
- Information from literature:  
  - Murphy and Eaton (2005). POLARIS stations  
New Information

Breakdown of recommendations

• Unchanged: 11 stations
  – 6 stations already had the recommended $V_{s30}$ with code 1
  – 5 stations had code 0 measurements that did not match recommendations

• Changed: 29
  – 21 stations with original $V_{s30}$ assignments made via code 3 (hybrid slope-geology proxy) and 5 (weighted proxies)
  – 8 stations with original $V_{s30}$ assignments made via code 1 (these remain code 1 and $V_{s30}$ changed after examining the two sources).

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Geologic Map Resources for CENA

• Surface materials maps
  – Fulton (1996): Canada
  – Fullerton et al. (2003): US
  – Used by Kottke et al. (2012) for geology-based $V_{s30}$ proxy
• Surface materials and sediment thickness
  – Used by Thompson and Silva (2013) for hybrid slope-geology proxy
• Local maps
  – Potentially useful for checking sites where classification errors expected

Fullerton et al. (2003)

• USGS Geologic Investigations Series I-2789
• Scale: 1:2,000,000. CEUS (east of 102 deg)
• Compiled from 31 published maps in the USGS Quaternary Geologic Atlas of the United States map series (USGS Miscellaneous Investigations Series I-1420)
• Many maps units. Two major categories: surface deposits and residual materials
• Bedrock sites: mapped as saprolites, or chemically weathered rock
Fulton (1996)

- GSC Map 1880 A
- Scale: 1:5,000,000. All of Canada
- Surficial materials in Canada, including land and some offshore areas
- Broad generic categories: alluvium, lacustrine, marine, glacial, and bedrock.
- Units subdivided according to:
  - Texture (e.g., marine mud vs. marine sand)
  - Thickness (e.g., till blanket vs. till veneer)
  - Landform (e.g., glaciofluvial plain vs. glaciofluvial complex).
Soller and Reheis (2004, 2009)

- USGS OFR 03-275. GIS shape files updated 2009
- Scale: 1:5,000,000. Entire US.
- CEUS: surface materials based on Fullerton et al. (2003) with condensed # categories.
- Bedrock sites: descriptions differ from Fullerton et al. (2003).
  - Units assigned to surficial materials category appropriate for rock composition;
  - e.g., a sedimentary limestone unit assigned as "Residual materials developed in limestone and other carbonate rocks."
- Sediment thickness estimates
  - Provided for each map category. Not mapped spatially within categories
Relatively Local Geologic Sources

- Quaternary Geologic Atlas of the US map series
  - USGS Miscellaneous Investigations Series I-1420
  - Applies for surficial materials
  - Scale: 1:1,000,000
  - Bedrock units mapped as such
- State-wide geologic maps
  - Access through USGS National Geologic Map Database (NGMDB)
  - Variable scales
Example: New Hope, SC

Kottke et al. (2012): Lacustrine, Marine and Marsh, mean $V_{530}=290 \text{ m/s}$

MB: Beach and near-shore deposits

Fullerton et al. (2003)
Holocene to Pleistocene coastal zone sediments, < 30 m thick

Soller and Reheis, 2004

Qpc, Quaternary clayey sand and clay

USGS Miscellaneous Investigations Series I-1420
Weems et al. (1997)
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Residuals

• Total residual, $R_{ij}$:
  $$ R_{ij} = \ln(Y_{ij}) - \mu_{lnIM}(M_i, R_{rup,ij}, V_{S30}) $$

  $i$: event, $j$: recording, $Y$: IM from data, $\mu_{lnIM}$: median GMPE.

• Partition residuals (mixed effects analysis):
  $$ R_{ijl} = c_k + \eta_{Ei} + (\eta_S)_l + \varepsilon_{ijl} $$

  $l$: site, $c_k$: mean bias for GMPE $k$, $\eta$: fixed effects (event, site), $\varepsilon_{ijl}$: remaining residual
Partitioning Residuals – Event Terms

- Total residuals can be partitioned using mixed effects modeling, in which multiple error terms are kept track of based on identifying information
- One example of this is isolating an event term, defined as the misfit between the data from a well-recorded event and the average GMPE prediction for that event:

\[ R_{ij} = c_k + \eta_{Ei} + \epsilon_{ij} \]

where \( c_k \) is the mean misfit of model \( k \), \( \eta_{Ei} \) is the event term, and \( \epsilon \) is the within event residual

Interpreting the Fixed Site Effect

Residual expression can be re-arranged as:

\[ \ln(Y_{ij}) = R_{ij} + \mu_{\ln(IM)}(M_i, R_{rup,ij}, V_{S30}) \]

\[ F_S = c \ln \left( \frac{V_{S30}}{V_{ref}} \right) \]

\( (\eta_S)_i \)

Site components:

Sum of \( (\eta_S)_i \) and \( F_S \) is the observed site response; misfit of one affects the other
Interpreting the Fixed Site Effect

Trend of $c$ term (courtesy J. Hollenback):

Suppose a site has $V_{s30}=300$ m/s, but was mischaracterized. $F_s$ would be in error by amounts shown for assigned $V_{s30}$ of 150 m/s, 900 m/s

If site does not have unusual features, this would cause ($\eta_3$) to trend in an equal and opposite way

Computation of Site Terms

- PEER model GMPE for Fourier amplitudes
- Site term results provided by JH
- Site terms were calculated for stations meeting two conditions: (1) $R_{rup} < 300$ km; (2) not located in Gulf coast region
- 306 such stations (out of 1379)
- 297 stations have data recorded at greater than 15 Hz, leaving 29 with no data at $f > 15$Hz
**Compilation of site terms conditional on frequency range**

**Examples**

Frequency dependence of the site term for an apparently correctly classified site in the CENA (SSN 71). Plot: Justin Hollenback.

Example of site terms with shape similar to that of $V_{30}$ scaling coefficient, suggesting possible mis-classification. SSN=270. Plot: Justin Hollenback.
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Overview

• We consider mean bias and slope of site terms (in frequency space)
• ‘Scores’ assigned to each based on percentiles
• The two scores are averaged
• The higher the average score, the greater the potential for misclassification of $V_{s30}$
Slope Criterion

- Slopes calculated over one log cycle of frequency (100 points)
- Least-squares regression
- The maximum absolute value of slope is taken for each station

Site term for station 2, plotted with the lines of best fit for each successive set of 100 data points. Maximum slope of 0.68. Total weight is 0.6595.

Slope Score

- > 90th percentile: Score = 1.0
- < 10th percentile: Score = 0
- Intermediate percentiles linearly interpolated

Site term for SSN= 9, a site with a low maximum slope (~0.27). Total weight is 0.004.
Bias Criterion

- Bias is the mean of $\eta_S$ for each site $l$
- Computed over usable frequency range

Site term for SSN=113, a site with a high bias (~0.8). Total weight is 0.9

Bias Score

- > 90th percentile: Score = 1.0
- < 10th percentile: Score = 0
- Intermediate percentiles linearly interpolated

Site term for SSN=41, a site with a low bias (~0.1). Total weight is 0.002
Summary of Results

Histograms of site bias and slope absolute values. Red lines represent the 10th and 90th percentiles.

Next Steps

• Provide site list (with scores) to TI team
• Address station $V_{s30}$ assignment in order of highest to lowest score
• For each high-score site:
  – Compare geologic classifications using existing resources (e.g., two surface unit maps)
  – Look up sites on local maps using USGS NGMDB as needed
  – Google earth look-up
• Modify assigned $V_{s30}$ as applicable
Next Steps

• Re-examine profile database (originally developed by Kottke et al. 2012)

• Some data quality control steps required (per J. Harmon, UIUC)

• Re-do proxy analysis with PDB, update weights used for $V_{S30}$ assignment for code > 1 sites

References


• Fulton, RJ, compiler, 1996, Surficial Materials of Canada, Geological Survey of Canada, Map 1880 A


• Soller, DR, and PH Packard, 1998. Digital representation of a map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains.


