Research Proposal

Site Characterization and Site-Specific Seismic Ground Motions Analyses for Transportation Infrastructure in Wyoming

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Project Abstract

The Jackson-Wilson bridge over the Snake River is expected to be replaced in the FY 2022. This site has a moderate to high seismic hazard and unknown depth of soil above the bedrock. The operational importance of structures deemed critical or essential may require site specific analysis depending on soil classification and seismic design category. Recently a bridge completed over the Snake River under Project N104083 was considered an essential structure. Currently the Bridge department at the Wyoming Department of Transportation (WYDOT) uses the general procedure in the AASHTO Guide Specification for LRFD Seismic Design (2015, 2016) to determine the seismic design forces for the structure. However, the AASHTO (2015, 2016) specifications allow for a more advanced analyses that may result in a better prediction of the seismic forces needed to design the structure. In order for WYDOT bridge engineers to perform a site specific ground motion analyses a proof-of-concept project is proposed. This project will be used to establish the procedures, steps and training required for WYDOT personnel to perform site specific ground motion analyses. This two year project is co-sponsored by the geology and bridge departments at WYDOT and will include 1) measurement of the shear wave velocity for the Jackson-Wilson bridge site 2) a site specific ground motions analyses and, 3) Training of WYDOT Personnel on how to use shear wave velocity profiles to determine soil site classification and perform site specific ground motion analysis.

Note that WYDOT does not currently have the capability to perform shear wave velocity measurements, and these are required for potential high seismic regions. WYDOT will not have the equipment necessary to perform these measurements in future. However interpretation of a shear wave velocity profile is critical in determining soil site classification, and will be included in the training portion of this research project.

In order to perform a site specific ground motion analyses a soil constitutive model and the depth of the soil above bedrock must be developed from in-situ measurements. These measurements will be made using the multi-channel analysis of surface waves (MASW) and microtremor array measurement (MAM) procedures. The data from these measurements will be used to determine the shear wave velocity of the near surface soils as well as the total depth of the soil above bedrock.

The site specific ground motion analyses also require input ground motions. These motion will be identified and scaled or spectrally matched to represent the hazard at the site. Once the analyses are complete a detailed procedure will be developed and provided in a report along with a few training seminars and presentations. When this project is completed it is expected that bridge engineers at WYDOT will be able to perform site specific ground motion analyses for future projects. It is anticipated that these analyses will result in a better prediction of the ground motions expected at the site during an earthquake event.

Brief Review of Literature

A complete literature review for surface wave testing and site specific ground motion analyses would require separate sections for collection of seismic data, dispersion analyses, inversion procedure, method of analyses, input ground motions, and dynamic soil properties. Because the depth and breadth of covering these subjects would require multiple pages only a brief review is include here. Seismic testing techniques include both borehole and surface wave testing. Surface wave testing has gained in popularity in the past 25 years (Socco et al. 2010, Foti et al. 2011). In general, the surface wave testing requires three main steps; 1) field data acquisition, 2) dispersion processing, and 3) shear wave velocity inversion (Stokoe et al. 1994, Foti et al. 2011, Cox et al. 2014). Data acquisition involves measuring wave fields using arrays of receivers and includes both passive and active testing (Griffiths et al. 2016). Dispersion processing involves developing a relationship between surface wave phase velocity and the frequency. A number of strategies are available to extract the experimental dispersion data from active- and passive-source measurements (Aki 1957, Capon 1969, Stokoe et al. 1994, Park et al. 1998, Zywicki 1999). Inversion is the most complicated and involved part of surface wave testing. In general a guess and check type of procedure paired with global and/or local search algorithms is used to find a layered earth model that provides a suitable match to the measured data. Numerous procedures exist to perform inversion analyses including; Socco and Boiero (2008), Wathelet et al. (2004), Molnar et al. (2010), Maraschini and Foti (2010), and others. A more complete list can be found in Griffiths at al. (2016).

The first 1D equivalent linear computer program, SHAKE (Schnabel et al. 1972), modeled the propagation of shear waves from the bedrock to the surface. This program preceded SHAKE 91 (Idriss and Sun 1992), and a number of different 1D equivalent linear software programs have been developed by researchers and practitioners including Strata (Kottke and Rathje 2009), and DEEPSOIL (Hashash et al. 2011), just to name a few. Other methods and models have also been developed and can be classified by a number of different criteria including; (1) computation in the frequency vs time domain, (2) complexity of the analyses type, either equivalent linear or fully nonlinear, (3) use or neglect of pore water pressure generation employing either total or an effective stress analyses and (4) dimension of the model space used in the analyses (i.e. one, two or three dimensions) (Matasovic and Hashash 2012). Input ground motions and the uncertainty associated with them have also been researched extensively and a review of the influence of input ground motions can be found in Rathje et al. (2010). Dynamic soil properties are also a necessary part of the computer models and much research has been done using both laboratory and field testing to determine these properties reliable including work done by Seed and Idriss (1970), Vucetic and Dobry (1991), EPRI (1993), Darendeli (2001), and Menq (2003), among others.

Project Description

Seismic hazard in Wyoming

The seismic hazard for the contiguous United States, with a zoomed view of Wyoming, is shown in Figure 1. Along the western portion on Wyoming there is a potential for moderate to high peak ground accelerations as shown by the orange zone within Figure 1. This high hazard area runs through the Teton, Lincoln, and Uinta counties and is governed by a number of faults systems including the Teton, Star Valley, Rock Creek, Bear River and other fault systems (Case et al. 2002a, 2002b and 2002c). A major earthquake in the area, the magnitude 7.3 Hebgen Lake earthquake occurred in 1959 just west of Yellowstone National Park. The quake caused 28 fatalities and $11 million in damage to highways and infrastructure. (Stover and Coffman, 1993). These faults are capable of producing damaging earthquakes with magnitudes that range from 6.5-7.5 (Case et al 2002a,b,c). Along the western portion of the state earthquakes with magnitudes less than 2.0 are experienced regularly. (http://earthquaketrack.com/p/united-states/wyoming/recent). While these low-intensity earthquakes generally do not pose a threat to infrastructure or people the seismic activity indicates that these faults are active. Therefore, it is possible that transportation infrastructure in this area will be subject to demanding seismic forces within their design life.

Lessons learned from past earthquakes, over the last 50 – 60 years, has greatly improved the professions ability to design transportation infrastructure that is more resilient to earthquake induced damage. However, there is still a great deal of uncertainty involved with seismic design. Two main factors contribute to these uncertainties including; 1) earthquake ground motions and 2) sub-surface soil properties and layering. Despite the uncertainties associated with seismic design site specific ground motion analyses can be used to try and account for these uncertainties.

Although not many strong ground motions have been recorded in western Wyoming, ground motions from similar active tectonic environments from around the world can be used to develop a suite of design ground motions. The Pacific Earthquake Engineering Research Center (PEER) has a database of ground motions that will be accessed and used to find ground motions that are similar (magnitude, distance, fault type, ect…) to those expected in Western Wyoming. Despite having ground motions that come from a similar tectonic environment the ground motions may still need to be scaled or spectrally matched to be consistent with the seismic hazard level expected in western Wyoming. Although AASHTO (2015) requires only three ground motions be used in site specific ground motion analyses, Rathje et al. (2010) recommended at least ten input ground motions be used to accurately predict a standard deviation of the surface response spectrum.

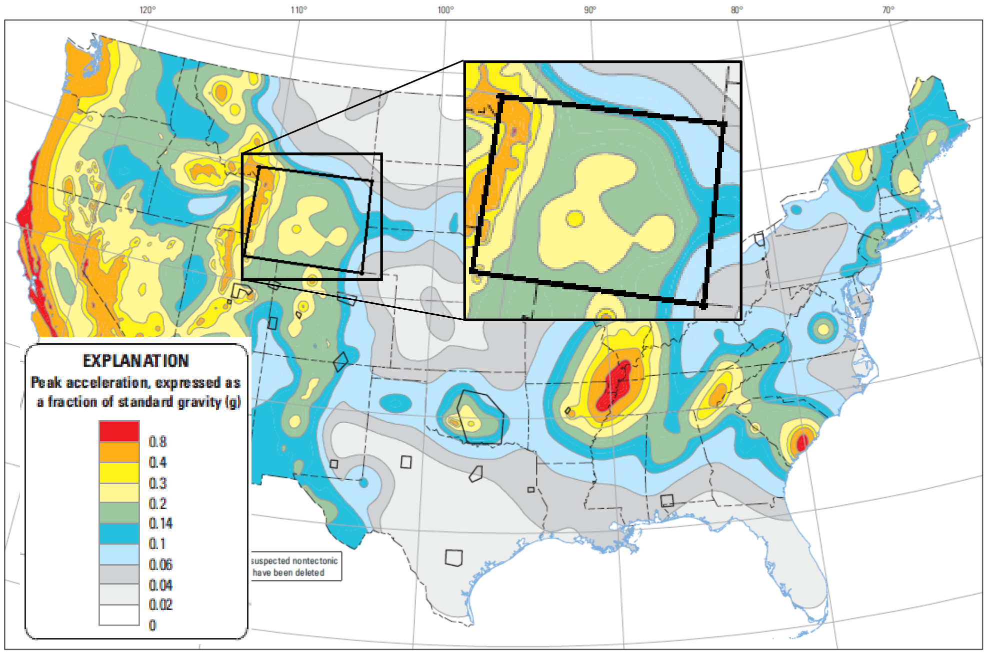

Figure 1. Location of the state of Wyoming superimposed in a map of expected peak ground acceleration (PGA) in the United States with a 2% probability of being exceeded in 50 years (modified from www.usgs.gov using data from the 2014 hazard map).

The geologic conditions of Western Wyoming are made up of mountains and valleys consistent with the basin and range formations throughout the intermountain west. This results in soil deposits that vary widely. In some instances, the sub-surface under bridge abutments may consist of a very thin soil layer over bedrock and in others the soil deposits may be so deep that the depth to bedrock is never reached with conventional drilling and sampling methods

Though unlikely, it is even possible for these extreme differences to exist at opposite ends of the same bridge. From previous earthquakes we have learned that the thickness and stiffness of near-surface soils play an important role in the amplitude and frequency content of ground motions. Events such as the 1985 Mexico City, 1989 Loma Prieta, 1994 Northridege, 1995 Kobe, and 1999 Chi-Chi earthquakes have brought this knowledge to the attention of earthquake engineers and taught the profession much about the importance of considering local soil/geologic conditions in seismic design (Hashash et al. 2010). In fact, the AASHTO design guidelines recognize the importance of near surface soil and state that *"site conditions may also warrant a site-specific ground motion evaluation…….These conditions can include very deep soil deposits or thin soil deposits over rock"* (AASHTO 2015). The code goes on to say that when a design response spectra is developed, and very deep soil deposits aren't accounted for, long period bridges may be under-designed and short period bridges may be over-designed. Furthermore, the code states that *"when the soil over rock is less than 40-50 feet, significant amplification of ground motions can occur at period of less than 0.5 sec"* (AASHTO 2015).

Code based procedures

Design of transportation infrastructure in the U.S. is governed by the AASHTO LRFD Bridge Design Specifications (AASHTO 2016), which is often accompanied with the AASHTO Guide Specifications for LRFD Seismic Bridge Design (AASHTO 2015). These codes specify how to develop the generic response spectrum to use in design. However, before the generic design response spectrum can be developed a seismic site classification must be determined. This is done by assigning the site one of six generalized site classifications (A through F). Which letter classification depends on the sub-surface soil stiffness and thickness. In general the site classes range from “hard rock” (site class A) to “soft soil” (site class E), as shown in Table 1. Notice, that site class F is reserved for soft highly plastic clays, or liquefiable soils. For site class F soils a site-specific ground motion response analyses is required. While the best determination of site class is obtained by directly measuring the stiffness or shear wave velocity (Vs) of the site it is also possible to determine the site class using the undrained shear strength or the standard penetration test (SPT) blow count information as seen in Table 1.

Table 1. Seismic site class definitions according to AASHTO (2015).

Site Class	Soil Type and Profile
A	Hard rock with measured shear wave velocity, $\bar{v}_s > 5000$ ft/sec
B	Rock with 2500 ft/sec < $\bar{v}_s$ < 5000 ft/sec
C	Very dense soil and soil rock with 1200 ft/sec < $\bar{v}_s$ < 2500 ft/sec, or with either $\bar{N} > 50$ blows/ft or $\bar{s}_u > 2.0$ ksf
D	Stiff soil with 600 ft/sec < $\bar{v}_s$ < 1200 ft/sec, or with either 15 blows/ft < $\bar{N}$ < 50 blows/ft or 1.0 ksf < $\bar{s}_u$ < 2.0 ksf
E	Soil profile with $\bar{v}_s$ < 600 ft/sec, or with either $\bar{N}$ < 15 blows/ft or $\bar{s}_u$ < 1.0 ksf, or any profile with more than 10 ft of soft clay defined as soil with $PI > 20$, $w > 40\%$, and $\bar{s}_u < 0.5$ ksf
F	Soils requiring site-specific ground motion response evaluations, such as: • Peats or highly organic clays ($H > 10$ ft of peat or highly organic clay, where H = thickness of soil) • Very high plasticity clays ($H > 25$ ft with $PI > 75$) • Very thick soft/medium stiff clays ($H > 120$ ft)

Exceptions:

Where the soil properties are not known in sufficient detail to determine the site class, a site investigation shall be undertaken sufficient to determine the site class. Site Class E or F should not be assumed unless the authority having jurisdiction determines that Site Class E or F could be present at the site or in the event that Site Class E or F is established by geotechnical data.

where:

$\bar{v}_s$ = average shear wave velocity for the upper 100 ft of the soil profile as defined in Article 3.4.2.2

$\bar{N}$ = average standard penetration test (SPT) blow count (blows/ft) (ASTM D 1586) for the upper 100 ft of the soil profile as defined in Article 3.4.2.2

$\bar{s}_u$ = average undrained shear strength in ksf (ASTM D 2166 or D 2850) for the upper 100 ft of the soil profile as defined in Article 3.4.2.2

PI = plasticity index (ASTM D 4318)

w = moisture content (ASTM D 2216)

The site classification is used to account for the effects of different soil conditions (depth and stiffness) on the design response spectrum. For the proposed bridge site the depth above bedrock has been identified as “deep” within the “As built” plans, which makes it an ideal candidate for further testing. A design acceleration response spectrum (Figure 2) is a simple way of visualizing the dynamic forces exerted on structures by an earthquake. The vertical axis (spectral acceleration) is generally displayed in units of g's (the acceleration of gravity) whereas the horizontal axes represents the natural period (T) of the "structure" in seconds. Conceptually, the spectral acceleration (Sa) gets multiplied by the weight of the structure to determine the horizontal static force exerted on the structure by the earthquake load (realistically, the process is more complex but is built on the same concept). The natural period of the "structure" is directly related to the building height (or bridge length). For visualization purposes, one can consider the horizontal axis as buildings of different heights (or bridges of different lengths), with increasing building height corresponding to increasing period. In fact, a simple rule of thumb for determining the approximate natural period of a concrete structure is to divide it's number of stories by 10 (i.e., T ~ 0.5 sec for a 5-story structure).

Simplified procedures exist in the code to obtain a generic design acceleration response spectrum for any location in the U.S. for Site Classes A-E. For example, design response spectra for Site Classes A-E have been developed for Lander, Wyoming (Figure 2) using the generic procedures outlined in AASHTO (2015). The design spectral accelerations for Lander consistently increase in amplitude and effect longer period structures as the local site conditions change from hard rock (Site Class A) to soft soil (Site Class E). This is a logical progression (meaning, seismic design forces consistently increase as the site gets softer, and taller/longer structures are more adversely affected when founded on softer sites). However, this trend only exists when the input rock accelerations at the base of the soil column are relatively small. For example, code-based design response spectra for Site Classes A-E have also been developed for Jackson, Wyoming (Figure 3), which is much closer to the active faults (notice the difference in scale between Figures 2 and 3). Figure 3 illustrates that the soil response is more complex when high intensity ground motions are input at the bottom of a soft soil site. While the soft soil site (Site Class E) response spectrum drops below the Site Class D spectra at short periods (T < 0.6 sec), it significantly exceeds the Site Class A-D spectra at long periods (T > 0.6 sec). This means that stiff, short bridges with natural periods of vibration less than about 0.6 sec will actually be subjected to lower seismic forces if they are built on Site Class E soils rather than on Site Class D soil. However, longer, more flexible bridges with natural periods greater than about 0.6 sec will be subjected to higher seismic forces if they are built on Site Class E soils. These simple examples illustrate the complex nature of estimating seismic design forces. One must consider the intensity of the input rock motions, the local soil conditions, and the period of the structure in order to obtain a safe design.

Simplified procedures do not exist for sites that classify as Site Class F. As indicated in Table 1, these soils require site specific ground motion analyses because their dynamic response can be too complex to predict with simplified code-based procedures. It will also be noted here that AASHTO (2015) removed liquefiable soils from the list of automatic conditions that result in a designation of Site Class F. This condition still exists in the ASCE 7-10 Minimum Design Loads for Buildings and Other Structures (ASCE 2016). AASHTO (2015) recognizes the important role site-specific evaluations play for liquefiable soils, but removed them from mandatory consideration in the code because such analyses are *"difficult to conduct"*. Nonetheless, AASHTO (2015) also acknowledges that site-specific evaluations for liquefiable soils should be considered if the designer wishes to *"avoid excessive conservatism in assessing bridge inertia*

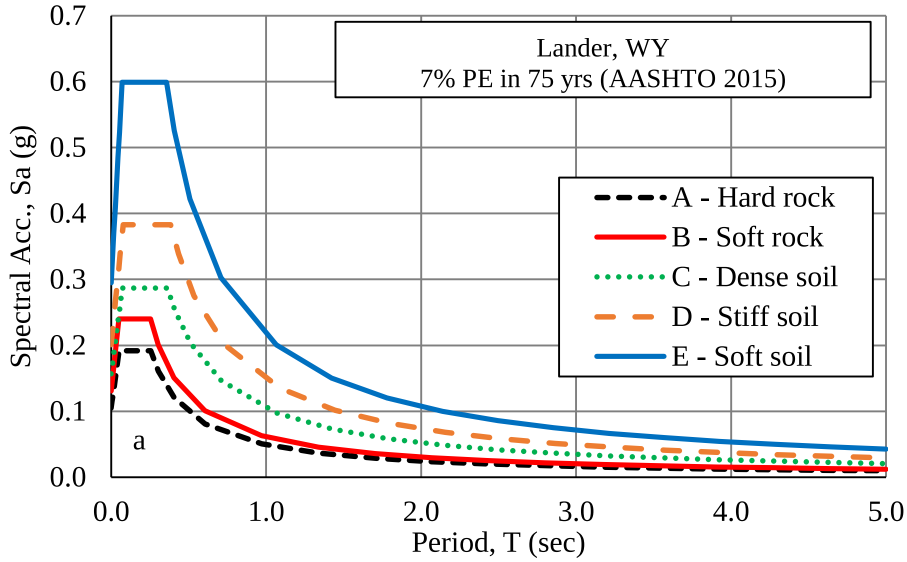

Figure 2. Response spectra for a 7% probability of exceedance in 75 years for varies site classes near Lander, WY.

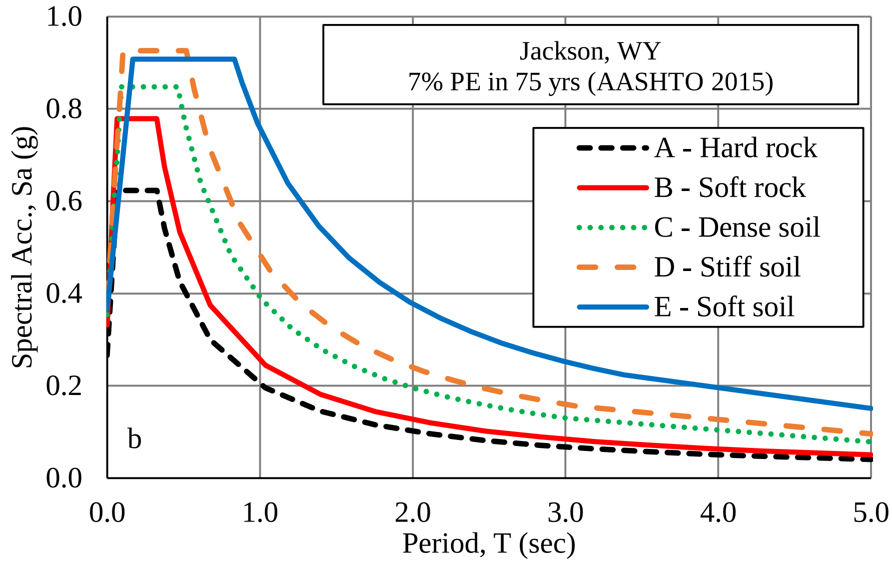

Figure 3. Response spectra for a 7% probability of exceedance in 75 years for varies site classes near Jackson, WY.

loads when liquefaction occurs". The proposed procedure for site specific ground motion analyses can be used to determine a design response spectra when Site Class F or liquefiable soils are encountered.

Site response methodology

Site specific ground motion analyses can be used to analyze the site specific response of a soil to ground shaking from an earthquake event. The process involves; 1) developing a soil constitutive model, 2) selecting appropriate acceleration time histories, and 3) using a software program to model the shear waves as they travel from the bedrock to the ground surface. Figure 4 shows a schematic of the site specific ground motion analyses procedure.

A soil constitutive model consists of a shear wave velocity (Vs) profile and dynamic soil properties. The shear wave velocity can be obtained using a variety of surface wave or borehole methods, in either case these tests must be performed at the proposed site. More details concerning seismic testing methods and how to determine a shear wave velocity profile can be found in Foti et al. (2011), Cox et al. (2014) and Garofalo et al. (2016) among others. Along with the shear wave velocity profile, the dynamic soil properties (shear-stress and shear-strain) must also be considered. These dynamic soil properties can be measured from undisturbed samples. However, the complexity and cost of testing these samples make this a viable option only for unique and high profile projects. More often the soil plasticity, effective vertical stress, over-consolidation ratio and other soil properties are used to determine dynamic soil properties from published relationships such as those proposed by Seed and Idriss (1970), Vucetic and Dobry (1991), EPRI (1993), Darendeli (2001), and Menq (2003).

Determination of appropriate ground motions to use in site specific ground motion analyses is not a trivial matter. Since the input ground motions have been shown to have a large effect on the predicted response (Rathje et al. 2010) care must be taken to find ground motions that are representative of the magnitude, distance, fault type, bedrock conditions and site hazard. This is accomplished by developing a target response spectrum that accounts for the seismic hazard, and then searching for motions using the Pacific Earthquake Engineering and Reacher Center (PEER) strong motion database (Ancheta et al. 2013) to find motions that match the magnitude, distance and fault type. It is often the case that the ground motions from the database do not match the target response spectrum at the design period. In these cases the ground motions must be scaled or spectrally matched to better approximate the hazard level at the site.

Many computer programs are available to perform site specific ground motion analyses. These include; SHAKE2000 (Ordonez, 2000), DEEPSOIL (Hashash et al., 2011), STRATA (Kottke and Rathje 2010), DMOD2000 (Matasovic and Ordonez, 2007) and many others. The analyses can be performed in one, two, or three dimensions, the equivalent linear or nonlinear domain and can include advanced pore water pressure models to simulate the effects of liquefaction. Some of the above mentioned software programs are available for free download and can be used to perform both equivalent linear and fully nonlinear analyses. The differences between the types of analyses can be significant and it has been shown that, contrary to popular belief, the nonlinear analyses may not produce realistic results at high shear strains (Griffiths et al. 2016).

The most common, equivalent linear, type of analyses has been used since the 1970's. However, many programs that use a very similar model have been developed in recent years. These programs have been developed as research tools, and are available free of charge to interested parties. Alternatively, there are some commercially available software packages, but these will not be used for this research project. While the analyses relies upon a computer to perform the analyses, there are some protocols and indicators that the analyses may not be producing realistic results. By checking these indicators it is possible to protect against a "black box" type of analyses. Also, often results from one software package can be checked against another to ensure that realistic results are obtained.

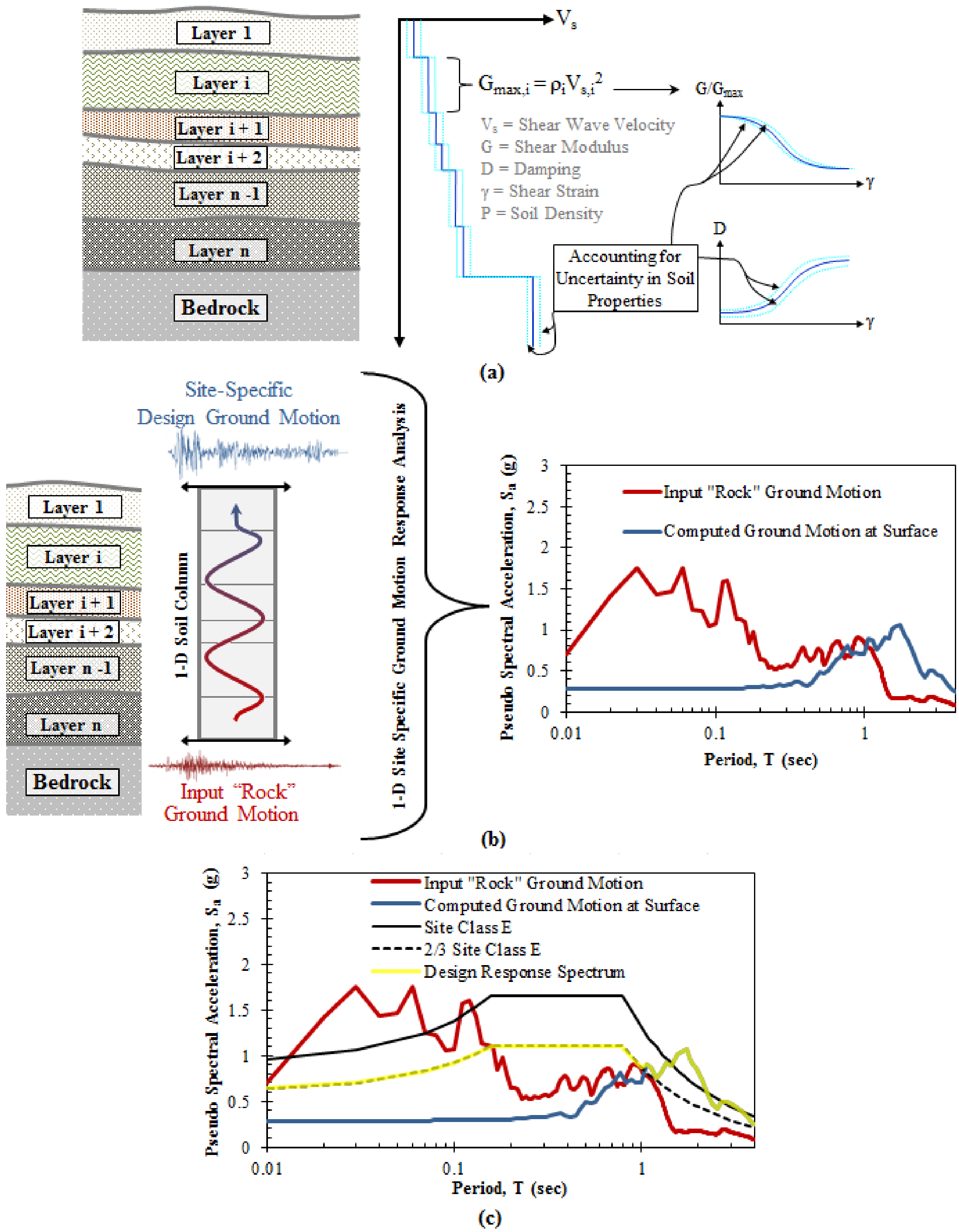

Figure 4. Schematic of site specific ground motions response analyses a) discretized soil profile and dynamic soil properties, b) use appropriate ground motions and computer software to develop a surface response, and c) develop the design response spectrum based on AASHTO (2015) code based allowances from Cox et al. (2012).

If a site specific ground motion analyses is performed and results in a reduction of the predicted response at the site, the AASHTO (2015) code allows the owner of the structure to reduce the ground motions by as much as 2/3 of the generic site class design response spectrum. This is illustrated in Figure 4c for a generic site. It should be mentioned that even a modest decrease in the design spectral acceleration can have a dramatic impact on the horizontal forces used for seismic design.

Research Plan

The proposed project is expected to run for two years. The project tasks are divided into four main tasks with each of the four tasks expected to take approximately six months. Task 1 will be developing a target response spectrum and finding input ground motions to use in the site specific analyses, this includes scaling or spectrally matching the ground motions if necessary. Task 2 will be to collect surface wave data at the sight and determine the shear wave velocity profile. Task 3 will be developing the soil constitutive model and performing the site specific ground motion analyses using a freely available software program. Task 4 will be to develop training material, any scientific journal publications and a final report which will serve as a reference guide for WYDOT personal to perform site specific ground motion analyses for future projects.

<u>Task 1</u>

In order to find acceleration time histories for use in the site specific ground motion analyses a target response spectrum that is consistent with the seismic hazard for a probability of exceedance of 7% in 75 years must be determined. This will be accomplished using tools from the United States Geological Survey (USGS) to develop a uniform hazard spectrum and in accordance with the allowances in AASHTO (2015). The ground motions that will be used for the analyses will be a subset of the acceleration time histories within the PEER strong motion database. The acceleration time histories will be obtained by using similar fault, distance and magnitude characteristics as those expected for the Jackson-Wilson bridge site. Once obtained the input ground motions may be scaled or spectrally matched to the target spectrum at the periods of the Jackson-Wilson bridge for use in further analyses. Obtaining correct magnitude and distance information will be accomplished by performing a deaggregation of the site using one of the USGS tools available online. It is expected that this task will take approximately six months. This task can be performed prior to any data collection and will commence as soon as funds are approved. Task 1, is expected to be completed by July 31st 2017.

It is understood that the period of the bridge will not be known until after the initial bridge design, which is dependent on the design strategy (i.e. seismic isolation, hinging, ect…). While scaling ground motions to a specific period of the uniform hazard spectrum is ideal, a ballpark estimate of the bridge period will be sufficient to scale input ground motions initially. As part of this research project a sensitivity analyses will be performed to determine the effects of scaling the input ground motions to different periods. This will help determine which periods should be used for scaling ground motions in future projects.

<u>Task 2</u>

Task 2 is the site characterization for the Jackson-Wilson bridge over the Snake River. The site characterization will include surface wave testing using passive (MAM) and active (MASW) methods. Site characterization is a major component of the site specific ground motion analyses and includes data acquisition and analyses. Data acquisition will be performed on site and will be accomplished by deployment of seismic sensors. Specifically, trillium compact broadband seismometers will used to collect MAM and 4.5 Hz geophones and a Geode seismograph will be used to collect the MASW data. It is anticipated that the site visit will take place in August or September of 2017 when the river level is low. This will enable testing to be performed at multiple locations around the bridge substructure and potential around bridge bents. The testing will likely take 1-3 day's with two days of travel required for travel to Jackson from Laramie and back again.

Once the data has been collected it will be analyzed to determine the shear wave velocity of the near-surface soil structure. Analyzing surface wave data is not a trivial matter. Due to the nonlinear, ill-posed and mix-determined nature of inversion it is possible to obtain multiple shear wave velocity profiles for the same data set. Despite these and other challenges, it is possible to obtain an acceptable shear wave velocity profile using the most recent data analyses techniques (Cox and Teague, 2016). Due to the complex nature of the data analyses it is anticipated that six months is a realistic timeframe for the collection and analyses of the data collected at the proposed bridge site. It is expected that task 2 will begin in August of 2017 and be completed by December 31st 2017.

Task 3

Task 3 will use the collected shear wave velocity data to build a soil constitutive model in one of the free software programs available. The scaled and spectrally matched ground motions will be used within the software program to perform the site specific ground motion analyses. The results will be determined and compared with the AASHTO general procedure to determine a design response spectrum. This task is expected to take 6 months beginning in January of 2018 and will be completed by July 31st of 2018.

Once a design response spectrum has been developed the seismic design category can be determined. While the site specific ground motion analyses has the potential to reduce the design ground motions it does not change the procedure to determine and use a seismic design category (except that the long period spectral acceleration [S_1] may be lower for a site specific ground motion analyses, which may change the seismic design category).

Task 4

Task 4 will be to develop a report that can be used as a manual for future site specific ground motions analyses. One of the major outcomes of this research will be the training of WYDOT personal to be able to perform theses analyses for future projects. Accordingly, this six months will be used to develop a training manual and presentation for WYDOT employees. Including a training seminar at the WYDOT offices where both Geology and Bridge personal will be invited. This task will begin in August of 2018 and is expected to be complete by December 31st 2018.

Technology Transfer

In order to ensure that the proposed analyses is implemented and used for future bridge design processes it is anticipated that at least one and possible more training sessions will be scheduled with the Bridge and Geology departments at WYDOT. These may include several "lectures" over the course of a few weeks or months or possible a single half day training session. The training sessions will be scheduled in consultation with Jeff Booher and Kirk Hood with dates and times that are compatible with the departments of interest and the project investigator.

Training sessions will cover the determination of input ground motions, building of a soil model, and performing a site response analyses. To be most effective these sessions will be designed to be hands on so that participants can learn how to perform the analyses, ask questions and receive feedback as the information as it is taught. These training sessions/session will be held at a mutually beneficial location which will enable the teaching of the concepts and software can be most beneficial to WYDOT personal.

Implementation

Jeff Booher the assistant state bridge engineer for WYDOT will be responsible for the implementation of the proposed research results within the bridge department at WYDOT. It is anticipated that at the successful completion of the proposed project WYDOT engineers will have all the tools and training material necessary to perform site specific ground motion analyses for future bridge designs. Since this analyses is not currently part of the bridge design process, it can be implemented for future bridge designs in high seismically active locations within the state.

The proposed project will not likely alter any of the current codes used by the bridge department, however using the AASHTO (2015) Guide specifications there are allowances for the maximum reduction that can be obtained when performed site specific ground motions analyses. These reductions, and other specifics are included in section 3.4.3.2 of the AASHTO guide specifications (2015).

Outcomes

Benefits to WYDOT

At the completion of this project it is expected that the employees of the WYDOT bridge department will have a framework and example of how to perform site specific ground motion analyses. This analyses is more robust than the general code based design procedure currently being used by the WYDOT bridge department, and will result in a greater degree of confidence in the design spectral accelerations. Furthermore, the AASHTO guide specifications (2016) encourage bridge designers to account for uncertainties in design ground motions and soil properties, which is difficult to do without performing a site specific ground motions analyses. Once the bridge department at WYDOT knows how to perform these analyses a better prediction of the design spectral accelerations can be used in further design.

This same procedure can be used to determine design peak ground accelerations (PGA) for liquefaction susceptibility or retaining wall design. Often site specific ground motion analyses yield a reduced PGA for deep and/or soft soil sites, and may yield an increased PGA for stiff and/or very shallow soil over bedrock sites. In either case the predicted PGA is more likely to represent the PGA expected during an earthquake event than that from the general procedure in AASTHO (2015). As part of the proposed project the surface wave data will be collected and used to determine the shear wave velocity of the sub-surface. This data by itself will be helpful in determining the generalized site classification used in seismic design. Furthermore, it is possible that site specific ground motion analyses may result in a reduction in the design ground motions resulting in cost savings in the design and construction of the bridge.

Broader Impacts

While site specific ground motion analyses are regularly performed in many seismically active regions throughout the world, regions near large population centers tend to receive more attention. Performing site specific ground motion analyses in a rural state like Wyoming may provide insights and guidance to other rural states, especially concerning the potential cost-effectiveness of performing advanced site characterization and more advanced analyses. Also, it is anticipated that findings from this project will be incorporated in a graduate course at the University of Wyoming (CE 5640 Geotechnical Earthquake Engineering). Do to the expected soil conditions at the Jackson-Wilson bridge it is possible that the shear wave velocity profiles may need to be extended to great depths. Using surface wave methods to sample to these extreme depths is a topic of national concern and it is expected that a national audience will be interested in the findings from this project.

Graduate students participating in this project will gain valuable communication and technical problem solving skills, which will carry the benefits of this project into the future. Additionally, hiring an undergraduate student will result in a valuable introduction to earthquake engineering for the younger student and mentoring opportunity for both the undergraduate and graduate student.

Budget

Tabulated budget information is included as Tables 2 and 3 for each year of the project. The budget for the proposed project is $79,727 for year one and $60,773 for year two. This sums to a total of $140,500 (sum of line L in Tables 2 and 3) for the total cost over two years. The budget justification for each year is included below.

1st Year

The Costs associated with the second year of the proposed project are included below and in Table 2.

Personal

Budget for personal is a major component of the overall budget. 1.5 months of summer salary for the principal investigator is included for the supervision of a graduate student. This includes one month per student per year (1st year project so 1 months summer salary) and 0.5 months for the time to organize, plan and participate in the field testing required to determine the shear wave velocity profile. During the others months of the year the salary for the principal investigator is covered by the University of Wyoming. The support of one graduate Ph.D. student for one year (12 months) is also included with an adjustment of 3% cost increase included. Also included is $1000 to support an undergraduate student, who will be identified and hired hourly to help collect and possible analyze surface wave data. This results in a total personal cost of $37,750 (A+B in Table 2).

Table 2. Budget information for year one of the propose WYDOT project.

	WyDOT Budget		SUMMARY			
		PROPOSAL BUDGET			FOR WYDOT USE ONLY	
	Organization		FY	2017	Proposal No.	DURATION (24 mo)
	UNIVERSITY OF WYOMING					Proposed Awarded
	Principal Investigator				Award No.	
	Dr. Shawn C. Griffiths					
A.	Senior Personnel: PI/PD Co-PI's,	WyDot Funded | Person-mo			Funds	Funds
	Faculty and other Senior Associates	CAL	ACAD	SUMR	Requested	Granted
1	Dr. Shawn C. Griffiths			1.5	13950	
2					0	
3					0	
4					0	
5					0	
6					0	
7	Total Senior Personnel (1-6)	0	0	1.5	13950	
B.	Other Personnel					
1	Post-doctoral Assoc.					
2	Other Professionals					
3	Graduate Student		9	3	22800	
4	Undergraduate Students				1000	
5	Secretarial/Clerical				0	
6	Shop/Tech.				0	
	TOTAL SALARY AND WAGES (A+B)				37750	
C.	Fringe Benefits 52% faculty 0.476% grad, 1.1744	0.52	0.005	0.0117	7374	
D.	PERMANENT EQUIPMENT					
	Total Permanent Equipment				0	
E.	Travel 1. domestic				6000	
	2. foreign				0	
F.	PARTICIPANT COSTS.					
1	Stipend					
2	Travel					
3	Subsidence					
4	Other					
	TOTAL PARTICIPANT COSTS				0	
G.	OTHER DIRECT COSTS					
1	Materials and Supplies				1200	
2	Publication costs				15	
3	Consultant Services				2000	
4	Computer Services				2500	
5	Subcontracts					
6	Tuition and fees	Sem	2		9600	
7	Other					
	TOTAL OTHER DIRECT COSTS				15315	
H.	TOTAL DIRECT COSTS (A-G)				66439	
I.	INDIRECT COSTS					
	General Overhead for Wyoming agency's of 20%					
		0.2			13288	
J.	TOTAL direct and Indirect (H+I)				79727	
K.	Residual Funds					
L.	AMOUNT OF THIS REQUEST for year 1				79727	
PI/PD TYPED NAME AND SIGNATURE		DATE		FOR WyDot USE ONLY		
Shawn C. Griffiths				INDIRECT COST RATE VERIFICATION		
INST. REP. TYPED NAME AND SIGNATURE		DATE		Date Checked	Date of Rate Sheet	Initials -

Fringe Benefits

In accordance with University regulations fringe benefits are charged to supplemental (summer) salary of 52% for non-students and 0.476% for graduate students and 1.11744% for undergraduate students. This results in a total cost of fringe benefits of $7,374 (C in Table 2).

Travel

Travel cost for the proposed project includes costs associated with travel, lodging and meals to the proposed bridge site with the necessary equipment and personal (principal investigator, one graduate student and one undergraduate student) to perform surface wave testing. The travel expenses also include monies for the principal investigator to attend one national conference to present findings associated with the proposed research and collaborate with other researchers with expertise in earthquake engineering. It is expected that the total travel expenses will be $6,000 for the 1st year of the project (E in Table 2).

Other Direct Costs

Other direct costs are included in section G of Table 1. These costs include materials and supplies which covers cost associated with field testing (gloves, safety equipment, shovels, ect...). Also included is the cost to maintain and "rent" the equipment needed to perform field testing. Publication costs for use in printing posters or developing other graphics. Consultant fees are included to hire a consultant to review the data analyses of surface waves which can present challenges for stiff and gravel soil sites. Computer services, which will be used to purchase the hardware and software necessary to record and analyze surface wave data as well as perform site response analyses. Included in this cost is the purchase of the long-term storage equipment to store the raw data recorded at the site. Tuition and fees for the support of one Ph.D. student for two semesters (summer tuition and fees are included in the four semesters). Total direct costs for year one are $15,315 (G in Table 2).

Total Direct Costs

Total direct costs for year one of this project are $66,439 (H in Table 2).

Indirect Costs

In accordance with University of Wyoming policy, state of Wyoming agencies are charged a rate of 20% of the total direct costs. This results in an indirect cost amount of $13,288 (I in Table 2), and a total cost for year one of $79,727.

<u>2nd Year</u>

The Costs associated with the second year of the proposed project are included below and in Table 3.

Personal

The second year of the project includes 1.0 month of summer salary for the principal investigator for the supervision of a graduate student. This includes one month per student per year (1 year of project so 1 months summer salary). During the others months of the year the salary for the principal investigator is covered by the University of Wyoming. The support of one graduate

Table 3. Budget information for year two of the propose WYDOT project.

	WyDOT Budget		SUMMARY			
		PROPOSAL BUDGET			FOR WYDOT USE ONLY	
	Organization		FY	2018	Proposal No.	DURATION (24 mo)
	UNIVERSITY OF WYOMING					Proposed Awarded
	Principal Investigator				Award No.	
	Dr. Shawn C. Griffiths					
A.	Senior Personnel: PI/PD Co-PI's,	WyDot Funded | Person-mo			Funds	Funds
	Faculty and other Senior Associates	CAL	ACAD	SUMR	Requested	Granted
1	Dr. Shawn C. Griffiths			1	9300	
2					0	
3					0	
4					0	
5					0	
6					0	
7	Total Senior Personnel (1-6)	0	0	1	9300	
B.	Other Personnel					
1	Post-doctoral Assoc.					
2	Other Professionals					
3	Graduate Student		9	3	22800	
4	Undergraduate Students				0	
5	Secretarial/Clerical				0	
6	Shop/Tech.				0	
	TOTAL SALARY AND WAGES (A+B)				32100	
C.	Fringe Benefits 52% faculty 0.476% grad, 1.1744	0.52	0.005	0.0117	4945	
D.	PERMANENT EQUIPMENT					
	Total Permanent Equipment				0	
E.	Travel 1. domestic				4000	
	2. foreign				0	
F.	PARTICIPANT COSTS.					
1	Stipend					
2	Travel					
3	Subsidence					
4	Other					
	TOTAL PARTICIPANT COSTS				0	
G.	OTHER DIRECT COSTS					
1	Materials and Supplies				0	
2	Publication costs				0	
3	Consultant Services				0	
4	Computer Services				0	
5	Subcontracts					
6	Tuition and fees	Sem	2		9600	
7	Other					
	TOTAL OTHER DIRECT COSTS				9600	
H.	TOTAL DIRECT COSTS (A-G)				50645	
I.	INDIRECT COSTS					
	General Overhead for Wyoming agency's of 20%					
		0.2			10129	
J.	TOTAL direct and Indirect (H+I)				60773	
K.	Residual Funds					
L.	AMOUNT OF THIS REQUEST for year 2				60773	
PI/PD TYPED NAME AND SIGNATURE		DATE		FOR WyDot USE ONLY		
Shawn C. Griffiths				INDIRECT COST RATE VERIFICATION		
INST. REP. TYPED NAME AND SIGNATURE		DATE		Date Checked	Date of Rate Sheet	Initials -

Ph.D. student for two years (12 months) is also included with an adjustment of 3% cost increase included. This results in a total personal cost of $32,100 (A+B in Table 3).

Fringe Benefits

In accordance with University regulations fringe benefits are charged to supplemental (summer) salary of 52% for non-students and 0.476% for graduate students. This results in a total cost of fringe benefits of $4,945 (C in Table 3).

Travel

Travel costs or year two of the proposed project includes costs associated with travel, lodging and meals for the principal investigator and one graduate student to attend one national conference to present findings associated with the proposed research. It is expected that the total travel expenses will be $4,000 (E in Table 3).

Other Direct Costs

Other direct costs are included in section G of Table 3. These include tuition and fees for the support of one Ph.D. student for two semesters (summer tuition and fees are included). Total other direct costs are $9,600 (G in Table 3).

Total Direct Costs

Total direct costs for year two of this project are $50,645 (H in Table 3).

Indirect Costs

In accordance with University of Wyoming policy, state of Wyoming agencies are charged a rate of 20% of the total direct costs. This results in an indirect cost amount of $10,129 (I in Table 2), and a total cost for year two of $60,773.

Data management Plan

Various forms of data will be generated as part of the proposed project. Including; sensor recordings from field measurements, data analyses files for the determination of the shear wave velocity profile, ground motions, data files used to perform the site specific ground motion analyses, and program specific files of the completed analyses. The data can be categorized as pre-processed (raw data), post-processed (i.e. engineering units) and analyses files. Appendix A includes the data management plan form that is required for InterAgency Agreement between the Wyoming Department of Transportation and the University of Wyoming.

<u>Data Form and Format</u>

Depending on the sensor used the raw file format of the recorded data will be miniSEED or SEG-2. It is anticipated that these files will be converted into text or Matlab files for use in the analyses. Soil models will be developed using a freely available software program and the data files associated with these programs will stored. It is also anticipated that Matlab scripts to process and manage the data will also be developed and stored. Figures will be developed to help visualize the results and other important data (shear wave velocity profiles, dynamic soil properties, ect…), these files will be stored as *.jpg or Matlab *.fig files.

Storage and Dissemination

It is anticipated that all the data will occupy 10-20 gigabytes of storage space. Long-term storage and backup of the data will be handled at the University of Wyoming. Access to the raw data will be available to engineers at WYDOT upon request. It is not anticipated that the pre-processed or post-processed data will be published or accessible to the broad research community. However, it is anticipated that research findings, figures and some tabulated data will be published in a comprehensive reports, articles, and journals.

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Appendix A

Data Management Plan

Name of Contractor	**Shawn Griffiths**
Name of project	**Site Characterization and Site-Specific Seismic Ground Motions Analyses for Transportation Infrastructure in Wyoming**
Project Duration	**Start date : January 2017** **End: Decemeber 2019**
DMP Version	**One**
Date Amended, if any	**1/2/2017**
Name of all authors, and ORCID number for each author	
WYDOT Project Number	
Any Digital Object Identifier (DOI), including any CROSSREF number, which has been assigned to any peer reviewed publication or data generated by this project	
Name of all peer reviewed publications which have been generated using data from this project	
URLs for all peer reviewed publications which have been generated using data from this project	
RiP RH Display ID Number	
Dataset URL, if available	

What constitutes such data will be determined by the Principle Investigator, Project Champion, and the Research Manager. In general, your plan should address final research data. This includes recorded factual material commonly accepted in the scientific community as necessary to validate research findings. Final research data do not include laboratory notebooks, partial datasets, preliminary analyses, drafts of scientific papers, plans for future research, peer review reports, communications with colleagues, or physical objects, such as gels or laboratory specimens. As part of your research, you may also generate unique data, which are data that cannot be readily replicated. Your DMP should also address unique data that may arise from your research.

WYDOT expects the timely release and sharing of data to be no later than the acceptance for publication of the main findings from the final dataset, unless the Principle Investigator will be embargoing the data. In such a case, the data cannot be embargoed for a period longer than twelve (12) months.

1. Introduction

The purpose of this research project is to:

Perform surface wave tests and site specific ground motion analyses and train WYDOT personal to perform these analyses for future projects.

2. Definitions

a. Code or scripts include code used in the collection, manipulation, processing, analysis or visualization of data, but may also include software developed for other purposes.

b. Copyright is a set of legal rights extended to copyright owners that govern such activities as reproducing, distributing, adapting, or exhibiting original works fixed in tangible forms.

c. Data means the recorded factual material commonly accepted in the scientific community as necessary to validate research findings, but not any of the following: preliminary analyses, drafts of scientific papers, plans for future research, peer reviews, communications with colleagues. Recorded material excludes physical objects (e.g. laboratory samples). Research data also does not include trade secrets, commercial information, materials necessary to be held confidential; and personnel and medical information and similar information the disclosure of which would constitute a clearly unwarranted invasion of personal privacy.

d. Data Archive is a site where machine readable materials are stored, preserved or possibly redistributed to individuals interested in the materials.

e. Data Management Plan is a document that specifies your plans for managing your data and files for a research project.

f. Dataset means collection of data.

g. Metadata refers to structured data about data which helps define administrative, technical, or structural characteristics of the digital content.

3. Data Types and Storage

The types of data and/or datasets generated and/or used in this project include …

The recorded data will be miniSEED or SEG-2. Data collection will be documented using field notebooks and datasheets, which will be scanned and stored with the raw data. The raw collected data is not reproducible and the loss of this data will require field investigations to be repeated. The analyzed data is reproducible and can be produced from the raw data by performing new analyses. If the analyzed data is lost or corrupted new analyses can be performed. It is anticipated that many of the raw files will be converted into text or Matlab files for use in the analyses. Soil models will be developed using a freely available software program and the data files associated with these programs will stored. It is also anticipated that Matlab scripts to process and manage the data will also be developed and stored. Figures will be developed to help visualize the results and other important data (shear wave velocity profiles, dynamic soil properties, ect…), these files will be stored as *.jpg or Matlab *.fig files.

The growth rate of the data depends on the depth of analyses performed. Which is unknown until the analyses are complete. However it is anticipated that all the data will occupy no more than 10-20 gigabytes of storage space for this project. Long-term storage and backup of the data will be handled at the University of Wyoming using local storage devices. Access to the raw data will be available to engineers at WYDOT upon request. It is not anticipated that the pre-processed or post-processed data will be published or accessible to the broad research community. However, it is anticipated that research findings, figures and some tabulated data will be published in a comprehensive reports, articles, and journals.

Pre-existing data includes “as-built” bridge plans from 1958 which are stored and accessible by bridge engineers at WYDOT, these plans may be used to help plan future site investigations. Data gathered in this project may be used for future similar or related projects, or for research purposes which have not yet been identified.

Provide a description of the data that you will be gathering in the course of your project. You should address the nature, scope, and scale of the data that will be collected. Describe the characteristics of the data, their relationship to other data, and provide sufficient detail so that reviewers will understand any disclosure risks that may apply. Discuss value of the data over the long-term. Please provide the name of all repositories where the data will be housed during the lifetime of the project.

Checklist

- o What type of data will be produced?
- o How will data be collected? In what formats?
- o How will the data collection be documented?
- o Will it be reproducible? What would happen if it got lost or became unusable later?
- o How much data will it be, and at what growth rate? How often will it change?
- o Are there tools or software needed to create/process/visualize the data?
- o Will you use pre-existing data? From where?
- o Storage and backup strategy?

3. Data Organization, Documentation and Metadata

The plan for organizing, documenting, and using descriptive metadata to assure quality control and reproducibility of these data include …

Raw data formats include SEG-2 and miniSEED files which are common files types for the collection of data in surface wave testing and geophysics. From these raw files text and data analyses files will be generated. The organization of these generated files will be determined as the files are generated and will be consistent throughout the project. Likely data will be organized based on the project, site, and test number. This structure of folders and subfolders will allow for future identification of the tests performed and data collected can be easily identified if needed. Documentation of how the files structure is made and used will be determined between the graduate assistant and the principal investigator. Data will be generated in formats inluding; txt, jpeg, bmp, matlab fig files. Geopsy, a free inversion and wave analyses software will be used to, develop multiple files for analyses and includes many file types.

There is currently no one single community sharing standard for storing and sharing this type of data however, the SEG-2 and miniSEED file formats are standard and can be shared with others (WYDOT) upon request.

Your DMP should describe the anticipated formats that your data and related files will use. To the maximum extent practicable, and in accordance with generally accepted practices in your field, your DMP should address how you will use platform-independent and non-proprietary formats to ensure maximum utility of the data in the future. If you are unable to use platform-independent and non-proprietary formats, you should specify the standards and formats that will be used and the rationale for using those standards and formats.

NOTE: Attach the Metadata transmittal form or URL for data generated or peer reviewed publications from this project.

Checklist

o What standards will be used for documentation and metadata?
o Is there good project and data documentation format/standard?
o What directory and file naming convention will be used?
o What project and data identifiers will be assigned?
o Is there a community standard for metadata sharing/integration?

4. Data and/or Database Access and Intellectual Property

What access and ownership concerns are there…

Because the raw data will not be shared with the broad research community and no business or participants are sharing confidential information there are no concerns about database access. However, password protection will be used on short- and long-term storage devices. Long term data storage will be controlled on-site and controlled by the principal investigator.

Protecting research participants and guarding against the disclosure of identities and/or confidential business information is an essential norm in scientific research. Your DMP should address these issues and outline the efforts you will take to provide informed consent statements to participants, the steps you will take the protect privacy and confidentiality prior to archiving your data, and any additional concerns. If necessary, describe any division of responsibilities for stewarding and protecting the data among Principal Investigators.

If you will not be able to deidentify the data in a manner that protects privacy and confidentiality while maintaining the utility of the dataset, you should describe the necessary restrictions on access and use. In general, in matters of human subject research, your DMP should describe how your informed consent forms will permit sharing with the research community and whether additional steps, such as an Institutional Review Board (IRB), may be used to protect privacy and confidentiality.

Checklist

o What steps will be taken to protect privacy, security, confidentiality, intellectual property or other rights?
o Does your data have any access concerns? Describe the process someone would take to access your data.
o Who controls it (e.g., PI, student, lab, University, funder) ?
o Any special privacy or security requirements (e.g., personal data, high-security data) ?
o Any embargo periods to uphold?

5. Data Sharing and Reuse

The data will be released for sharing in the following way …

The raw data and processed data will not be shared with others except under written consent from the Wyoming Department of Transportation, and those hired to review the data as outlined in the project proposal. Published data from this project will include figures, tables and descriptions of the collected data. The data is likely to be published after the project is complete and in a yet unidentified journal. It is also likely that conference publications may be used to disseminate these results.

Describe who will hold the intellectual property rights for the data created by your project. Describe whether you will transfer those rights to a data archive, if appropriate. Identify whether any copyrights apply to the data, as might be the case when using copyrighted instruments. If you will be enforcing terms of use or a requirement for data citation through a license, indicate as much in your DMP. Describe any other legal requirements that might need to be addressed.

Checklist

o If you allow others to reuse your data, how will the data be discovered and shared?
o Any sharing requirements (e.g., funder data sharing policy) ?

o Audience for reuse? Who will use it now? Who will use it later?
o When will I publish it and where?
o Tools/software needed to work with data?

6. Data Preservation and Archiving

The data will be preserved and archived in the following ways …

Long-term storage of the data will be accomplished using a non-portable storage device. This will reside at the University of Wyoming and will be a backup for the data that is collected in the field as well as the analyzed data. Because much of the data can be reproduced from analyses, long term storage will be backed up to the cloud or a similar on-line tool for the SEG-2 and miniSEED data, which is the most expensive data to collect. All other data can be generated from this data and will not be stored in cloud based archive. The file structure and long-term storage will be maintained by the principal investigator. While the use of an institutional repository to back up all data generated from the project is acceptable, the long term cost associated with monthly/yearly subscriptions make the use of a non-portable storage device much more affordable for most of the generated data.

The dissemination of the research results will also include publications that include persistent identifiers that are maintained by the publishers. Often digital object identifiers are used to reference and find that information. Although a journal has not been identified for publication, it is anticipated that the publisher will maintain a persistent identifier.

Describe how you intend to archive your data and why you have chosen that particular option. You may select from a variety of options including, but not limited to:

- Use of an institutional repository
- Use of an archive or other community-accepted data storage facility
- Self-dissemination

You must describe the dataset that is being archived with a minimum amount of metadata that ensures its discoverability. Whatever archive option you choose, that archive must support the capture and provision of the US Federal Government "Common Core" metadata. In addition, the archive you choose must support the creation and maintenance of persistent identifiers and must provide for maintenance of those identifiers throughout the preservation lifecycle of the data. Your plan should address how your archiving and preservation choices meet these requirements.

Checklist

o How will the data be archived for preservation and long-term access?
o How long should it be retained (e.g., 3-5 years, 10-20 years, permanently) ?
o What file formats? Are they long-lived?
o Are there data archives that my data is appropriate for (subject-based? Or institutional)?
o Who will maintain my data for the long-term?

NOTE:

Researchers evaluating data repositories as the option(s) for storing and preserving their data should examine evidence demonstrating that the repository:

a. Promotes an explicit mission of digital data archiving;
b. Ensures compliance with legal regulations, and maintains all applicable licenses covering data access and use, including, if applicable, mechanisms to protect privacy rights and maintain the confidentiality of respondents;
c. Has a documented plan for long-term preservation of its holdings;
d. Applies documented processes and procedures in managing data storage;
e. Performs archiving according to explicit work flows across the data life cycle;
f. Enables the users to discover and use the data, and refer to them in a persistent way through proper citation;
g. Enables reuse of data, ensuring appropriate formats and application of metadata;
h. Ensures the integrity and authenticity of the data;
i. Is adequately funded and staffed, and has a system of governance in place to support its mission; and
j. Possesses a technical infrastructure that explicitly supports the tasks and functions described in internationally accepted archival standards like Open Archival Information System (OAIS).

**These guidelines are based on the Data Seal of Approval.

METADATA TRANSMITTAL SCHEMA

Title[1]	Human-readable name of the asset. Should be in plain English and include sufficient detail to facilitate search and discovery. A name given to the publication or data element. **All substitute or alternative titles must have a different Metadata Transmittal Schema**
Creator/contact point	An entity/person(s) primarily responsible for making the content of the resource. Contact person's name and email for the asset.
Publication Date(s)	The date associated with the final report/dataset.
Description/Abstract	Human-readable description (e.g., an abstract) with sufficient detail to enable a user to quickly understand whether the asset is of interest. May include abstract, table of contents, reference to a graphical representation of content or a free text account of the content.
Subject and Keywords	The topic of the content of the resource. Tags (or keywords) help users discover your dataset; please include terms that would be used by technical and non-technical users.
Identifier[2] and/or source	A unique identifier for the dataset/publication. Examples: URI, URL, DOI, ISNB, ISSN.
Edition	Most recent date on which the dataset was changed, updated or modified.
Coverage	Spatial location, temporal period, jurisdiction.
Language	The language of the dataset/publication.
Publisher/Distributor	**FHWA and Wyoming Department of Transportation**

[1] *To include alternate title; conference title; and journal title if they are different.*
[2] *To include record numbers; report numbers; NTIS number; TRIS Accession Number; OCLC Number; ISBN; ISSN; contract number; and DOI if available.*
Red Text indicates NTL Required information.

	List all other publishing companies that this publication has been sent to.
Funding agency	**FHWA and Wyoming Department of Transportation**
Access Restrictions	The degree to which this dataset **could** be made publicly-available, *regardless of whether it has been made available*. Choices: public (Data asset is or could be made publicly available to all without restrictions), restricted public (Data asset is available under certain use restrictions), or non-public (Data asset is not available to members of the public).
Intellectual Property and Other Rights	This may include information regarding access or restrictions based on privacy, security, or other policies. This should also serve as an explanation for the selected "accessLevel" including instructions for how to access a restricted file, if applicable, or explanation for why a "non-public" or "restricted public" data asset is not "public," if applicable.
License	The license or non-license (i.e. Public Domain) status with which the dataset or API has been published.
Format	The machine-readable file format. May include media type or dimensions. Used to determine the software, hardware or other equipment needed to display or operate the resources.
Collection	The collection of which the dataset is a subset. Include all identifiers and/or sources.
Related Documents	Related documents such as technical information about a dataset, developer documentation, etc.
Data Organization	
Size of file	