



# PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

## PEER Lifelines Geotechnical Virtual Data Center

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## ABSTRACT

This report describes in detail the technical specifications and results of the COSMOS/PEER-LL 2L03 project. The main goal of this project was to implement a fully functional online “Geotechnical Virtual Data Center” (GVDC), employing the most current geotechnical and geophysical (geosciences) data standards and web-based dissemination technology. The GVDC is intended to operate as a public, private, or possibly commercial web-based, one-stop center for sharing and disseminating geosciences data in accordance with the policy requirements of each entity that shares data via the GVDC. These entities—referred to as *Data Providers*—may consist of government agencies, private companies, and other data distribution centers or services that wish to share their geosciences data with other Data Providers and/or the public via the GVDC. The GVDC functions as a hub rather than an archive, whereby end (Internet) users can selectively search for, identify, and download data of interest, leaving *Data Providers* in full control over the primary storage and/or archiving of their own data.

This report begins with an overview of the results of previous phases (I and II) of COSMOS/PEER Projects 2L01 and 2L02, and how these efforts provided the functional and technical foundation for the outcome of Project 2L03. The data standards integrated into the GVDC system are presented. Initially, a complete set of modifications were made to the COSMOS XML Schema and Data Dictionary that were developed in Project 2L02. In Phase III, the COSMOS XML Schema was replaced with the Data Interchange for Geotechnical and Geoenvironmental Specialists (*DIGGSml*) data exchange format. This report includes the rationale for using *DIGGSml* and for the development of an additional interim standard—referred to as the *cosmosDIGGS* schema—that is now fully implemented in the GVDC. The *cosmosDIGGS* schema was devised as a temporary solution to demonstrate the operability of the GVDC system at present and to meet the development schedule for the project in the absence of an immediately deployable (i.e., ratified by scientific community consensus) version of the *DIGGSml* standard.

In addition, this report contains exhaustive information about the development of critical software components of the system architecture: the GVDC or *GVDC Server*, and those developments that specifically support *Data Provider* Servers. These server-side and client-side developments were deemed necessary to support both the use of *DIGGSml* and, by extension, the

GVDC website data discovery functionalities. Specifically, this report documents modifications of the following GVDC-server components: the database structure, the back-end system architecture, and the tools and features on the GVDC website. New applications created to support *Data Providers* include translation programs for converting legacy geotechnical and geophysical data into the DIGGS format (or *DIGGSml* files), and the development and integration of the GVDC's metadata exchange format—referred to as *MetaDIGGS*—for harvesting and storing small amounts of textual information about each record or “asset” (i.e., borehole) a *Data Provider* wishes to share. A clear outline of the requirements for a *Data Provider* to participate in the GVDC is then provided.

Also, during this project the GVDC-Server website (web pages) and related applications developed in Project 2L02 were migrated from a proprietary Microsoft technology stack (i.e., Microsoft Active Server Pages (ASP) scripting language with Windows IIS and MS Access) to an open source technology stack (i.e., PHP, JavaScript, and AJAX with Apache and PostgreSQL). In addition, a complete migration to Google Maps technology was executed as the sole *GVDC-Server* web-mapping application. An example dialog of the Internet-user experience is presented to demonstrate the general workflow for a typical end user of the GVDC website.

This document concludes with a look at relevant existing geosciences data and asset center business models and recommends principles for a viable future implementation and business model suitable for “official” launching of the GVDC. Suggested interim (i.e., two years) management and maintenance, including projected costs, are also provided.

## ACKNOWLEDGMENTS

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Loren Turner, of Caltrans, has participated in the project from the beginning as a member of the project team and has provided valuable intellectual leadership for the research. Loren has additionally performed the role of liaison between the project and the Transportation Pooled Funds Project, which is developing the *DIGGSml* standard.

Finally, we want to thank Caltrans for independently supporting the development of several specific technical elements of the GVDC and for coordinating with the project as a database provider organization. The value of these individual and organizational contributions for the success of the project cannot be overstated.

## DISCLAIMER

The files in this archive supplement the discussion of the *cosmosDIGGS* schema contained within Appendix II of the report entitled, “PEER Lifeline Geotechnical Virtual Data Center” (Stepp et al. 2009).

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Contents of this distribution:

1. *cosmosdiggs.xsd* — schema file for the *cosmosDIGGS* schema. Version as of 9/1/2009.
2. *cosmosDIGGS\_example.xml* — sample xml instance document.
3. *cosmosdiggs.xsd.html* — XML schema documentation for *cosmosDIGGS* in html format.  
This document is viewable/printable via any web browser.
4. *images* — a folder of graphic files used for the documentation.

This folder and the file *cosmosdiggs.xsd.html* must reside within the same directory/folder for proper viewing.

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# 1 Introduction

Many large federal and state government organizations, local government organizations, and private sector companies acquire vast amounts of geotechnical data annually in the course of developing infrastructure projects. Generally, data are acquired to support a specific infrastructure project and then placed in the organization's geotechnical database archive. This practice severely limits the economic value of the data for use in the sponsoring organization's business enterprise as a whole because of the excessive cost of accessing it in a usable format for planning and implementing future infrastructure projects. Recently improved data collection and archiving technologies and the desire to extend the use of their data archive for their larger business enterprise have motivated many organizations to undertake the development of computer-based tools aimed at providing more cost-efficient access to their internal database archives. To expand access to the vast geotechnical data and assets that currently reside in the archives of many organizations would be invaluable. Recognition of the high value of a web-based infrastructure system that not only archives and disseminates geotechnical data but *links* these archives together motivated this research.

## 1.1 SUMMARY OF PREVIOUS WORK RESULTS

### 1.1.1 Phase I

The work described in this report is the culmination of research conducted during the past ten years, with the goal of developing an Internet-based infrastructure system for archiving and web dissemination of geotechnical data. The work was performed in three phases. Phase I organized and conducted a workshop for the purpose of compiling ongoing efforts aimed at archiving geotechnical data in digital format, understanding the state of web-based technologies for disseminating archived databases, and identifying infrastructure and technical issues that

required resolution. The results of Phase I (Swift et al. 2001) provided the basis for developing the scope of work for Phase II of the project.

### **1.1.2 Phase II**

Participants in the Phase I workshop recommended a follow-on research program, with the goal of designing a pilot web-based geotechnical data dissemination system, initially linking a few databases. Phase II of the project accomplished this goal with the COSMOS Pacific Earthquake Engineering Research Center Lifelines Geotechnical Virtual Data Center (COSMOS/PEER LL GVDC) (Swift et al. 2004). The design of the pilot GVDC was based on responses to a questionnaire sent to geotechnical *Data Provider* organizations and users of geotechnical data regarding how these organizations archive data and subsequently obtain data from archives for use in business practice. The development of the GVDC system design involved a large number of academic and practicing specialists, including specialists in acquisition and use of geotechnical data for both practice and research purposes, as well as geotechnical data archiving and dissemination specialists. four geotechnical *Data Providers*, the California Geological Survey (CGS) the California Department of Transportation (Caltrans), the U.S. Geological Survey (USGS), and the Pacific Gas and Electric Company (PG&E), collaborated with the project and served as resources for their data types and their data archiving and dissemination practices.

The research was divided among three working groups. Working Group 1 established the basic requirements for the system design based on uses of geotechnical data and on *Data Providers'* practices for archiving and disseminating data. Working Group 2 developed a geotechnical data dictionary standard for exchange of data in a common format. Working Group 3 performed the system code development and integration required to implement the Pilot GVDC architecture. The resulting system design specifically responded to *Data Providers'* individual data dissemination policies by allowing multiple *Data Providers* to make their data available through a single web-based portal while accommodating each *Data Provider's* data archiving policies. The system allows participating database providers to retain full possession and control of their data. A user can view and download data from multiple organizations in a uniform file format with one-stop access at the Pilot GVDC (Swift et al. 2004).

### 1.1.3 Phase III

The Phase II Pilot GVDC system linked geotechnical databases of four organizations: the CGS, Caltrans, PG&E, and the USGS. To obtain user feedback, the system was presented and reviewed in a workshop held on June 21–23, 2004. The workshop was co-sponsored by the U.S. Federal Highway Administration (FHA) and included participation by the United Kingdom Highways Agency (UKHA), the Association of Geotechnical and GeoEnvironmental Specialists (AGS), the U.S. Army Corp of Engineers, and a number of state transportation departments, county building code officials, and representatives of academic institutions and private sector geotechnical companies.

The feedback from workshop participants concluded that the Pilot GVDC was sufficiently mature to be considered an operational system, but recommended four enhancements to improve its functionality:

1. Modify and extend the data exchange standard to promote broader international acceptance. Specifically, it was recommended to merge the *COSMOSxml* data exchange standard and the *AGSml* standard.
2. Modify the GVDC system and tools for compatibility with the revised data exchange standard. A number of changes to the server-side and client-side of COSMOS/PEER-LL Pilot GVDC system architecture were recommended to support new versions of the COSMOS/PEER-LL XML Schema to be developed in the project.
3. Expand the Pilot GVDC Data Dictionary to include data standards for shear wave velocity profiles, laboratory geotechnical testing, and *in situ* testing such as SASW.
4. Identify requirements for long-term operation and maintenance (O&M) of the COSMOS/PEER LL GVDC.

Phase III of the project implemented a scope of work designed to accomplish these recommendations, with the exception of the recommendation to extend the *COSMOSxml* data exchange standard by merging it with the *AGSml* standard. Six months following initiation of work on Phase III, it came to the attention of the research team that a Transportation Pooled Fund Study (TPF) had been initiated with the goal of developing an international consensus standard for the exchange of geotechnical data (<http://www.diggsml.com/>). The TPF is a collaborative effort of international, federal, and state agencies, including the FHA, a number of state departments of transportation, the UKHA, and the AGS. Existing data exchange formats—

the *COSMOSxml*, the *AGSml*, and the Florida Department of Transportation format—were adopted as the starting inputs for development of a new international consensus data exchange schema. The name—“Data Interchange for Geotechnical and GeoEnvironmental Specialists (DIGGS)”—was adopted for the new data exchange schema. The COSMOS/PEER LL GVDC team agreed to collaborate with the TPF and adopt the new schema as the data exchange standard for the COSMOS GVDC. While collaboration required essentially putting the Phase III development work on hold until the DIGGS schema became accepted, it was concluded that the benefit of adopting a consensus international data exchange standard would be worth the delay. Thus, the completion of the Phase III work was delayed from mid 2005 to late 2008, when the draft *DIGGSml* standard was issued for comment.

The draft DIGGS *v1.0a* standard is currently undergoing an extensive review (Turner et al. 2009). The latest project schedule anticipates that the review and the subsequent work to address identified technical issues may take until the end of 2010 before the DIGGS *v2.0* standard is issued. Consequently, the initial implementation of the COSMOS GVDC described in this report uses a modified version of the DIGGS *v1.0* schema, which has limited data types, but is sufficient to complete the operability of the system. This modified version—referred to as the *cosmosDIGGS* schema—was developed by the COSMOS team in order to meet the development schedule for completing the GVDC in the absence of a deployable version of DIGGS. During the next two years, until the consensus standard is approved and deployed, a short-term strategy is proposed for maintaining the COSMOS GVDC (presented in detail in Chapter 5 of this report).

Chapter 2 of this report describes the integration of the DIGGS standard for interim implementation of the COSMOS GVDC. Chapter 3 describes the architecture of the GVDC. Chapter 4 describes the database provider and system user interactions. Chapter 5 presents a strategy and a set of governing principles for implementation of the COSMOS GVDC, together with a plan for interim maintenance of the system, until the deployable version of the DIGGS exchange standard becomes available.

## **2 Integration of Data Interchange for Geotechnical and Geoenvironmental Specialists (DIGGS) for Archiving and Dissemination of Geotechnical Data**

### **2.1 MODIFICATION OF GVDC DATA DICTIONARY**

During Phase II of this project (Task 2L02), the COSMOS-PEER LL program developed the Pilot data model to be flexible so that it could be readily extended to accommodate standard geotechnical engineering practice and research, as well as geologic, environmental, and hydrologic data elements. As part of initiating Phase III (Task 2L03), the Phase II Pilot GVDC Data Dictionary was expanded to include data standards for shear wave velocity profiles, laboratory geotechnical testing, and *in situ* testing. A Data Dictionary Working Committee, consisting of experts in the geotechnical community, completed this first revision in 2005. The expanded portion of the GVDC Data Dictionary and an example data-mapping exercise from the original site table to XML is provided in Appendix I of this report, entitled “Data Dictionary Tables and Sample Mapping From Site Table To Xml.” Full details on the original Pilot GVDC Data Dictionary elements can be found in Section 3 of Swift et al. (2004).

The COSMOS-PEER LL built its Pilot Data Dictionary on principles of modularity, separation of objects, tightly controlled definitions in both data dictionary items and values of enumerated lists, and on extensibility. As discussed in Chapter 1 of this report, in 2005 a large team of researchers began an international collaborative project to develop a consensus data exchange standard by merging data dictionaries from the following entities: the AGS, COSMOS-PEER LL, and the University of Florida (UF) under the auspices of the Florida Department of Transportation (FDOT). Merging these data dictionaries and respective formats was the starting point for developing the new international data exchange schema.



The research team implemented the COSMOS-PEER LL principles cited above in order to ensure that the dictionary would be usable by many groups and accommodate standard engineering practice, and also be applicable to engineering research, geologic, environmental, hydrologic data (ultimately), and evolving technologies. In order to meet the critical objective of extensibility, the common goal for new dictionary and schema was to structure the dictionary so that processes and activities were separated from observations and test results, and tests were defined as independent modules—referenced to holes (or sampling stations) or to samples (specimens)—that could be plugged into an existing schema. Not only would such a structure provide extensibility, but it would also facilitate the assessment of data quality through inclusion of metadata fields pertinent to sites, holes, samples, and tests. This comprehensive data dictionary and schema became DIGGS. An overview is presented next.

## 2.2 INTRODUCTION TO DIGGS

The DIGGS project, initiated in order to develop an international standard interchange format for geotechnical data, is a collaborative effort, composed of government agencies, universities, and industry partners whose primary focus is to create and maintain an international data transfer standard for transportation-related data (DIGGS 2009). The coalition came into existence through a coordinated effort led by the FHA, which sponsored meetings and eventually formed a pooled fund study project administered by the State of Ohio, Department of Transportation (<http://www.diggsml.com/pooled-fund-project>). Multiple states pooled funds to support this larger project from which all receive benefits.

The DIGGS project has a governance structure for developing the base schema, as well as Special Interest Groups (SIG) to create extensions. The result of the project is the DIGGS schema. Thus far, this initial base schema was developed from the AGS, COSMOS-PEER LL, and UF geotechnical data dictionary formats, and covers borehole, soil testing, site information and other related geotechnical data. At present, the first “DIGGSml” SIG extended the schema to include geoenvironmental testing. The DIGGS standard version **1.0a** is available for review and comment at <http://www.diggsml.com/schemas>.

### **2.2.1 Anticipated Impact on Geotechnical Engineering Data Exchange**

Though the main focus of DIGGS is to develop an international data transfer standard for transportation-related data, it is expected that the convenience of having a single data interchange format over the long term will have an extremely broad appeal to not only the geotechnical community, but also to industry, government, and academic institutions involved in the earth sciences. The DIGGS standard is already in the process of being adopted or incorporated as a data interchange format in geotechnical engineering software such as gINT (<http://www.gintsoftware.com/>). It can be safely assumed that in the near future, stable versions of the DIGGS standard will be adopted. Because of the potential applicability and universality of this standard, it is anticipated that its use will be mandated by U.S. government agencies such as the FHA, Caltrans, and others. Thus the COSMOS-PEER LL project can be viewed as a very early successful developer of this international collaborative effort, promoting and investing in the latest data interchange technology.

### **2.2.2 Summary of Advantages and Disadvantages**

To summarize some the principal benefits of implementing DIGGS in the GVDC, the advantages related to expediting digital exchange of valuable data include:

- The modular design of the GVDC components that integrate the DIGGS standard facilitates updating of the system as new versions are released.
- Savings in staff time in multiple working environments; previously inaccessible, archived data can now be easily retrieved.
- Savings in storage space, as the detailed data are maintained in formats requiring minimal computer resources, such as text-based files.
- Increased ability to keep up to date with data production and versioning.
- Savings in user's time; data retrieval and dissemination is fast.
- Interactive online map applications can be readily developed to facilitate user discovery.
- Ability to produce tailored and/or standardized previews for logs, etc., or other data reports.
- Data sets are held only once in organizations, therefore less duplication.

The most significant disadvantage experienced to date is the delay in technological integration of the standard into the GVDC as part of Phase III of this project. To coordinate with each new version of DIGGS, it will be necessary to allocate staff time for website and application integration and testing, and perhaps periodic database structure updates. To address this issue, the GVDC applications that may need modification have been kept to a minimum and were designed so that modifications can be easily made.

## **2.3 INTERIM SCHEMA DEVELOPED AND IMPLEMENTED WITHIN GVDC**

The initial implementation of the GVDC described in this report uses a modified version of the DIGGS *1.0a* schema (with very limited data types) in order to demonstrate the operability of the system. This modified version—referred to as the *cosmosDIGGS* schema—was developed by the COSMOS team in order to meet the development schedule of the GVDC in the absence of a deployable version of DIGGS. Initially, a deployable version of DIGGS was anticipated within the timeframe of the GVDC project. Unfortunately, unanticipated technical issues within the DIGGS effort (DIGGS 2009) led to significant delays, making it impossible to align the completion of a DIGGS standard with the schedule of deliverables for the GVDC project.

The *cosmosDIGGS* schema has attempted to implement many of the suggestions resulting from the June 2009 evaluation of DIGGS *1.0a* conducted by Galdos Systems and Compusult Limited (Burggraf 2009; Mitten 2009). Compared against DIGGS *1.0a*, *cosmosDIGGS* has a simpler structure with a limited hierarchy, more consistent object patterning and element naming, more specificity, and clearer documentation, but still retains GML compliance and much of the flexibility and extensibility intended for DIGGS *1.0a*. The DIGGS data dictionary was used to define most elements in *cosmosDIGGS*, although some names and the organization of elements were changed as needed.

Although the *cosmosDIGGS* schema adopts many elements and constructs from the existing DIGGS *1.0a*, this modified schema is much more limited in terms of content. Specifically, in the *cosmosDIGGS* schema:

- Piling, monitoring, and environmental elements in DIGGS are not included, although these elements could be integrated in a consistent fashion if a similar data model were to be used in a revised version of DIGGS.

- In-situ tests are limited to geophysical logs (inheriting data constructs from witsml and using witsml data types), CPT, and dynamic penetration tests (e.g., SPT).
- Laboratory tests are limited to particle size, density/moisture/porosity tests, and Atterberg tests.
- Locations are limited to holes and sampling stations.
- The DIGGS' robust capability for handling samples, sampling activities, and geologic/geotechnical observations remains.

The end result is a single schema file that easily validates with all common XML parsers. The schema was tested to work with Altova, Oxygen, and Stylus XML tools, where “blank” XML files could be readily generated. The *cosmosDIGGS* schema has a conceptual basis more in line with a RDBMS, so database mapping is anticipated to be much easier than with the DIGGS *1.0a* schema. Complete documentation of the *cosmosDIGGS* schema can be found in Appendix II of this report, “Interim ‘DIGGS’ Borehole Data Schema.”

## **2.4 RECOMMENDATIONS FOR SUPPORTING FUTURE VERSIONS OF DIGGS**

It is recommended that the COSMOS-PEER LL GVDC fully support future versions of DIGGS, especially since several U.S. government entities are currently fully invested in its development and usage. Thus it is recommended that all follow-on work on the *GVDC Server* fully integrate the GVDC web application for use with current, stable versions of DIGGS.

### 3 Architecture of Geotechnical Virtual Data Center

The COSMOS-PEER LL GVDC is a publicly available web application that acts as a “broker” for geotechnical data (Ponti and Turner 2009). Data are held by registered *Data Providers* who maintain their data in their own proprietary systems. Only the data they choose to share are made available by the GVDC. Data are transmitted to the end user via the GVDC in the standard DIGGS Extensible Markup Language (XML) format (see Chapter 2). Data contained in files formatted according to the DIGGS *standard* are hereafter referred to as *DIGGSml* files.

There are two major components to the system architecture: the GVDC (or *GVDC Server*) and the *Data Provider Servers* (see Fig. 3.1). It is assumed that *Data Providers* will be government agencies, industry (geotechnical engineering, oil companies, etc.), or academia.

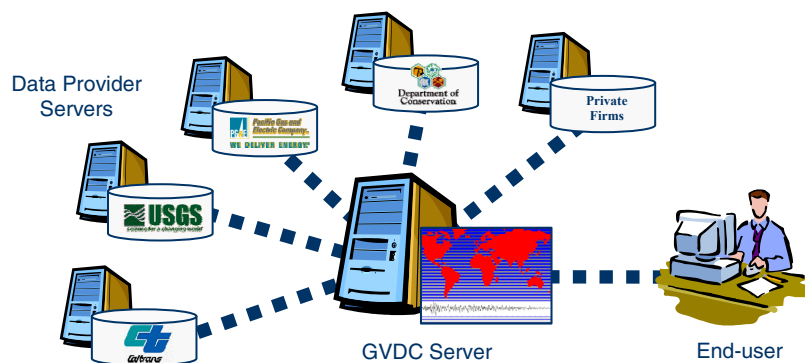


Fig. 3.1 Overview of GVDC System Architecture showing example *Data Providers*.

The Phase II GVDC accomplished metadata harvesting through the implementation of OAIB (Open Archives In-A-Box), which required establishing a communication link between the GVDC's database and the *Data Provider's* database. In the Phase III version of the GVDC system architecture, the function of OAIB was replaced with a modular (and thus more easily modifiable) approach, and the *GVDC-Server* applications previously created to work with COMSOS-PEER LL Data Dictionary were redesigned to be compatible with DIGGS.

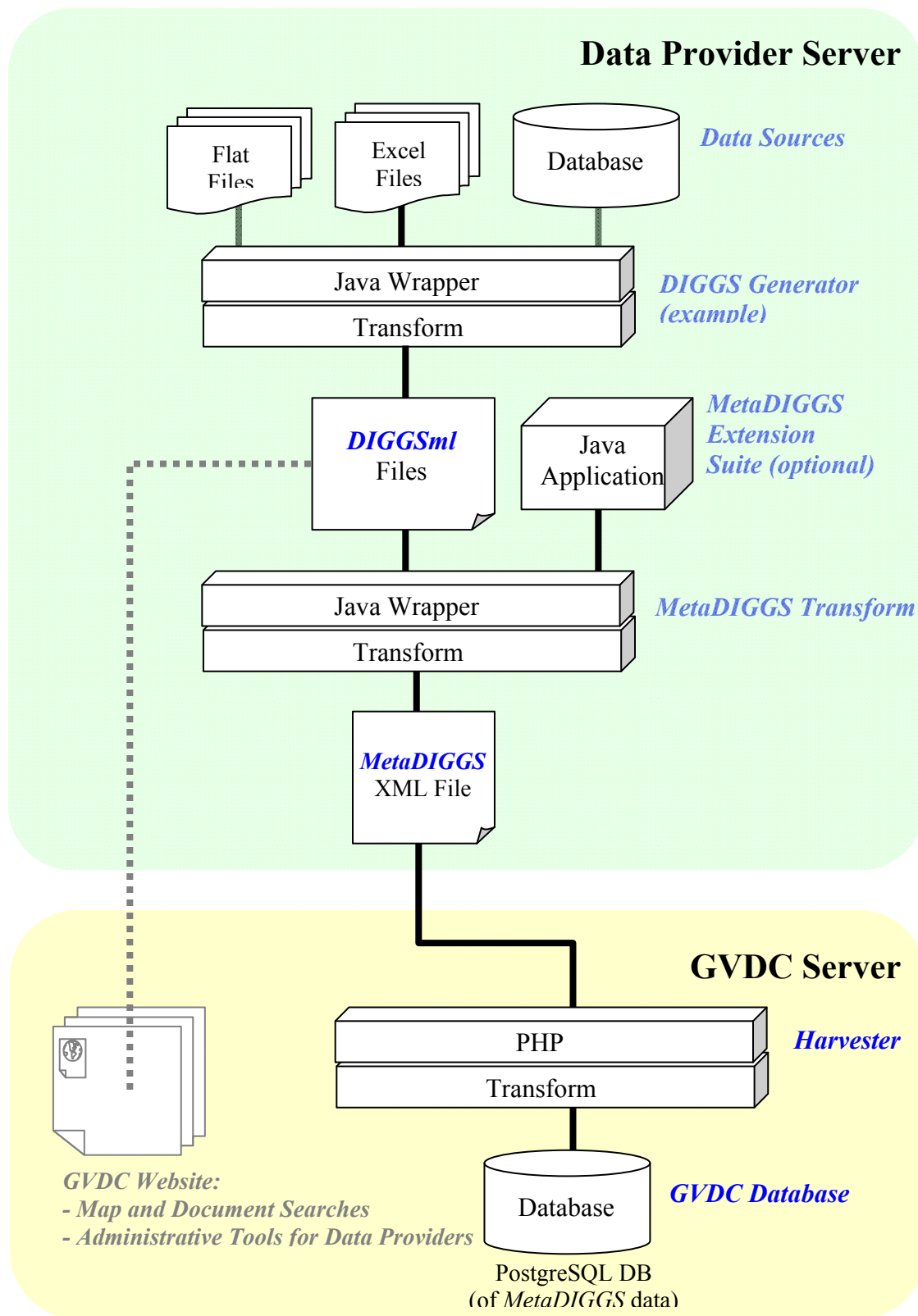
The *GVDC Server* provides web hosting for the GVDC's website, maintains a database containing only metadata about available data sets, harvests metadata from *Data Providers*, hosts the GVDC web application map and text based search interfaces, delivers *DIGGSml* data sets to end users, manages *Data Provider* and end-user accounts, and tracks the data usage statistics of end users.

The *Data Provider Server* functions as either a web server or a FTP server. It hosts the collection of available *DIGGSml* files, or, alternatively, a server-side application that automatically generates *DIGGSml* files on demand. It also hosts a single *MetaDIGGS* file (Metadata from *DIGGSml*) that can be harvested by the GVDC and stored in the GVDC database. Depending on the requirements of the *Data Provider(s)*, the *Data Provider Server* may also host the *Data Provider's* data in their original form (e.g., database, flat files, Excel files, gINT files, etc.), data transform applications, and *MetaDIGGS file* generators; however, this is not a requirement. In order to participate as a *Data Provider* for the GVDC, a *Data Provider* need only host the *DIGGSml* files and the *MetaDIGGS* file and provide access to the *GVDC Server*.

### **3.1 OVERVIEW OF GVDC HARVESTING SYSTEM ARCHITECTURE**

To summarize how the GDVC works, at present the delivery of geotechnical data to end users accessing the *GVDC Server* is accomplished through the following steps, illustrated in Figure 3.2:

- The *Data Provider* generates *DIGGSml* instance documents from their own data sets, utilizing the DIGGS Generator, or a custom application created by the *Data Provider*. If static, *DIGGSml* instances are text-based XML data files, which should not be resource-intensive for the *Data Provider* to maintain.



**Fig. 3.2** Overview of *Data Provider Servers* and *GVDC Server* system architectures.

- The *Data Provider* either:
  - Hosts their own *DIGGSml* files on their *Data Provider* web (or FTP) Server. These can be static files on the server, or they can be generated dynamically, depending upon the *Data Provider's* specific system and preferences; or
  - In some cases, *Data Providers' DIGGSml* files may be hosted from the GVDC Server.
- The *Data Provider* utilizes the *MetaDIGGS Transform* software application to automate metadata generation of the geotechnical information (repository) they wish to make available via the GVDC, creating a single metadata file in the form of a *MetaDIGGS* (XML file). This *MetaDIGGS* file contains the URL where the *Data Provider's DIGGSml* files are stored for each data asset (e.g., borehole).
- The *Data Provider* hosts the *MetaDIGGS* file on their *Data Provider* web (or FTP) Server.
- The *Data Provider* executes the GVDC Harvester application so that the GVDC Server can discover and load the *Data Provider's MetaDIGGS* file into the GVDC Server database.
- An end user accesses the GVDC-Server web application (e.g., by navigating on the online web-mapping application to find any local geotechnical data near a location of interest). When the end user requests a particular data set, the GVDC utilizes the information in the *Data Provider's MetaDIGGS* file to retrieve the requested data from the *Data Provider's DIGGSml* file, providing *DIGGSml* data to the user as a download in their original format, as an Excel file or in a graphical preview such as a borehole log.

Scheduled to be completed at a later date, the *MetaDIGGS Transform Suite* application will be an optional application for geotechnical *Data Providers* that will facilitate the generation of metadata in the *MetaDIGGS* XML standard. As described in Section 3.3.2 on the *MetaDIGGS Transform*, the metadata-generating functionality is available only in an “immediate-mode,” meaning a user generates metadata by running an executable application. The design and implementation specifics for this application are described below in Section 3.3.3.

The next phase of the project will develop a data previewer application so that end users can dynamically view borehole, CPT, and other (i.e., geophysical) logs. This will be



accomplished by creating a core web application that will transform specific attributes in *DIGGSml* file into a visual log represented in html. Different types of logs could be generated based on data type information (i.e., borehole, CPT) obtained during the dynamic data mapping portion of the *Previewer* application execution of *DIGGSml* to another XML file that the previewer can process (*CosmosLog*). *CosmosLog*, discussed in more detail in Section 3.3.5. is designed to be very flexible, so virtually any kind of data can be represented symbolically on a log. It is expected that the data previewer software executable will reside on the *GVDC Server*.

## **3.2 GVDC DATA TRANSMISSION FORMAT: *METADIGGS***

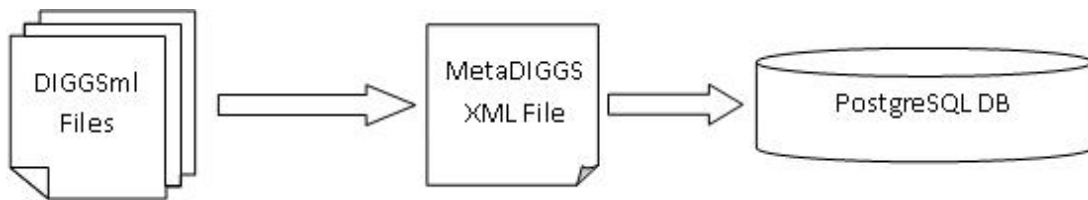
### **3.2.1 General**

To participate in the GVDC, a *Data Provider* is required to generate a single *MetaDIGGS* file that contains the metadata (or information describing their data) for the entire data repository the *Data Provider* wishes to make available online via the GVDC. A single standard application, the *MetaDIGGS Transform*, was designed to accomplish this, which can be used by any *Data Provider* to extract metadata from their collection of *DIGGSml* files (see Section 3.3.2).

### **3.2.2 *MetaDIGGS* XML and XSD**

The main objective in creating *MetaDIGGS* (*Metadata from DIGGS*) was to facilitate the transmission of basic information about a *Data Provider's* repository to the GVDC. Where a *DIGGSml* file contains all information and data about a particular data asset, the *MetaDIGGS* file contains only the information needed to query the Data Provider information. Specifically, *MetaDIGGS* contains the following attributes that coincide with key indexing fields in the *GVDC Server's* PostgreSQL database (see Fig. 3.3).

- ID
- Name
- Naming System
- Project ID
- Primary Asset Type
- Start Date
- End Date
- Longitude
- Latitude
- Spatial Reference ID
- Depth
- Orientation
- Project Purpose
- Data Source
- Date Last Modified
- XML URL
- Reference
- Asset Tests
- Hole



**Fig. 3.3** *MetaDIGGS* file information is extracted from *DIGGSml* files and stored in *GVDC-Server* database.

*MetaDIGGS* files are formatted as an XML file with the filename extension “.xml”. The format and structure of the XML file is defined by a XML Schema Definition (XSD) file (metadiggs.xsd). The XML file data structure comprise a collection of *asset* elements, which are locations where observations or tests are conducted (such as a borehole or sampling station). The *MetaDIGGS* xml instance document contains information about all of the assets that a *Data Provider* wishes to “expose” to the GVDC. Each asset element also contains child asset test elements that identify what kinds of geotechnical tests and/or observations were conducted at that location. A *MetaDIGGS* file may contain records from multiple individual *DIGGSml* files. For example, a *Data Provider* may host thousands of DIGGS files, each containing data from single boreholes, but would host a single *MetaDIGGS* file containing the compilation of indexing information for all of those DIGGS files. Examples of *MetaDIGGS* XML files are provided in Appendix III, “*MetaDIGGS* Data Transmission Examples.”

### 3.3 GVDC APPLICATIONS

Based on feedback from end users obtained during the Phase I and Phase II workshops (Swift et al. 2001; Swift et al. 2004), several new software applications were developed and implemented in the GVDC during Phase III. The objective of these applications was to streamline the data “harvesting” functionality of the GVDC system architecture such that *Data Provider* participation in the GVDC is facilitated and the end-user experience is improved in regards to ease of obtaining data via the GVDC web application. These new applications include the *DIGGS Generator*, *MetaDIGGS Transform*, *MetaDIGGS Extension Suite*, and the *Harvester*, described in detail below.

#### 3.3.1 DIGGS Generator

In order to participate in the GVDC, all *Data Providers* are required to generate *DIGGSml* files for their data sets. Using the *DIGGS Generator* application is one possibility, however this can be accomplished in a variety of ways; the *DIGGS Generator* is very specific to the particular *Data Provider*. In fact, the *DIGGS Generator* may be a stand-alone application, a function of another application, a web service, or some other form. In its simplest implementation, this could be an export function in commercial logging software, such as giNT (i.e., that exports geotechnical data as *DIGGSml* files). Another possibility is that a *Data Provider* captures data in an Excel spreadsheet and exports it to a *DIGGSml* compatible file.

This step could take the form of a data mapping application that converts flat files, Excel files, or other file types to *DIGGSml* files. The data mapping application or transform code created may be wrapped within another application and used to automate the creation of *DIGGSml* files. Some *Data Providers* might choose to batch convert and just host the resulting static *DIGGSml* files, while others might choose not to host static files and, instead, create the *DIGGSml* files only when requested by end users accessing the *GVDC Server*. Because each *Data Provider* is unique in the way they store and manage their data, the *DIGGS Generator* functionality will need to be developed and implemented by the *Data Provider*.

### 3.3.2 *MetaDIGGS Transform*

The purpose of the *MetaDIGGS Transform* software application is to offer simple automated metadata generation functionality for *Data Providers*. The application produces a metadata file—in the form of *MetaDIGGS XML*—that summarizes a *Data Provider*'s geotechnical information. The general objectives of the *MetaDIGGS Transform* application include:

- **Data Transformation:** The application invokes the transformation of data from the *DIGGSml* to the GVDC's MetadataDIGGS format. The actual transformation is executed by a separate XSLT file that can be easily modified to accommodate new versions of the DIGGS schema.
- **Standard Application for all Data Providers:** The *MetaDIGGS Transform* comprises a standard stand-alone Java application that all *Data Providers* can download and install on their server. The *MetaDIGGS Transform* can be executed manually to create a single metadata XML file that reflects the Data Provider's entire repository index at the time of execution. Alternatively, the *MetaDIGGS Transform* can be executed in the background, called by customized server scripts (which would need to be created by the Data Provider to meet their specific needs).
- **Installation:** The *MetaDIGGS Transform* is packaged with a platform-independent installer. Although it can remain platform independent, the application requires system resources for storing configuration and log files.
- **Graphical User Interface and Command Line:** The *MetaDIGGS Transform* also includes a command line interface as well as a Graphical User Interface (GUI) for executing metadata generation. Parameters for data sources and target file will be passed to the application this way.

The specific details of the development the *MetaDIGGS Transform* application are as follows:

- The application is written and compiled in Java so as to be platform independent.
- The transformation executable has been designed such that data sources, target file, and other settings can be passed in at runtime through both the command line interface and the GUI interface.

- A Graphical User Interface (GUI) was designed to use the Java Swing and AWT libraries, to allow the user to execute a transform visually; i.e., the GUI contains a local file browser.
- A command line interface, which can be installed for the appropriate operating system (OS), is designed to allow the user to execute a transform as an OS command.
- An executable JAR installer was created to walk a user through the installation process, building the necessary directories and files, and setting any environment variables, etc.

Last, in order to utilize the *MetaDIGGS Transform*, a *Data Provider Server* must meet the following requirements:

- Java Runtime Environment (JRE).
- A Web Server or FTP Server to host metadata files for GVDC harvesting. If the Data Provider is using a Web Server, it should be HTTP1.1-compliant to support a conditional GET.
- DIGGS data source files or a service (i.e., DIGGS Generator application, see Section 3.3.1) that can dynamically produce *DIGGSml* from an alternate data source, such as a relational database.

### 3.3.3 *MetaDIGGS* Extension Suite

The *MetaDIGGS Extension Suite*, which is slated to be developed in the next phase of this project, seeks to extend the “stateless, immediate-mode” functionality of the *MetaDIGGS Transform* application with “persistence,” via application configuration, and “scheduled” and “on-demand” modes of metadata generation. The general objectives of the *MetaDIGGS Transform* application include:

- **Configurable:** Data Providers should be able to configure the application to identify both data sources and a target file for metadata generation with an executable “wizard-like” graphical user interface. Changes to the application state would then be stored in a configuration file on the local system. Data sources may include static *DIGGSml* files or dynamic services that generate the *DIGGSml*.
- **Scheduling:** As an extension to an “immediate-mode” transformation of the *MetaDIGGS Transform*, the *MetaDIGGS Extensions* provide a “scheduled” transformation through a

scheduling module. The module includes a graphical interface for configuring scheduled transformations, allowing *Data Providers* to produce metadata for changing data sources without having to worry about retransforming every time their data changes.

- **Web Service Integration:** In addition to the “scheduled” transformation is an “on-demand” mode, capable of invoking metadata generation from an HTTP request. This involves “wrapping” the *MetaDIGGS Transform* application with a Java Servlet, allowing a transform to be invoked from an HTTP GET request. The resulting metadata XML would then be returned in the subsequent HTTP response. For this version of the design specification, the only supported web service framework will be the Servlet specification. Another version may be amended to include support for CGI and .NET frameworks.
- **Conditional Execution:** The execution of a scheduled or HTTP-invoked metadata generation should be conditional on the presence of changes to the data sources from the last generation of metadata. For data sources composed of static DIGGSml files, the application must be able to determine if files have been added or deleted to the source directories. Data Providers using a SQL database must provide a JDBC driver, connection parameters, and an executable SQL file. The SQL file will be used to determine if data have changed. It should execute a single query that returns a Boolean value of true if the source data have changed and metadata should be regenerated.
- **Logging:** Because the application may run scheduled tasks, the software should be able to log metadata generation transactions in a log file.
- **Installation:** The application comes with an installer. The application requires system resources for storing configuration and log files. These resources shall be specified at installation. As new versions of the software or its dependencies become available, they will be designed to be installable/updateable in such a way that the application’s state may still be maintained in the configuration files and unchanged components need not be recompiled.

The specific details of the development the *MetaDIGGS Transform Suite* application are as follows:

- The application will be written and compiled in Java to be platform independent.

- The configuration file(s) will be stored in a simple XML format beneath the installation directory along with the log file.
- A Graphical User Interface (GUI) will be designed, using the Java Swing and AWT libraries, to walk a user through configuration and scheduling.
- An executable JAR installer will be created to walk a user through the installation process, building the necessary directories and files, and setting any environment variables such as class paths.
- The application will be designed so that the reference to the *MetaDIGGS Transform* engine is flexible enough to allow for an updated transformation executable to be swapped seamlessly.
- The application will leverage Java's logging utilities to maintain a log file of metadata generations, and any errors or warning conditions, e.g., a data source file is missing, etc.
- The web-based "on demand" execution will be implemented through a Java Servlet. This portion of the application may require additional external configuration per the Servlet specification.
- The conditional transformation for SQL data sources will be evaluated using the JDBC libraries for database connectivity.

In order to utilize the *MetaDIGGS Transform Suite*, a *Data Provider Server* must meet the following requirements:

- Java Runtime Environment (JRE).
- A Web Server or FTP Server to host metadata files for GVDC harvesting. If the provider is using a Web Server, it should be HTTP1.1-compliant to support a conditional GET (same as required for the *MetaDIGGS Transform*).
- DIGGS data source files or a service that can dynamically produce DIGGSml from an alternate data source, such as a relation database (same as required for the *MetaDIGGS Transform*).
- Apache Tomcat or another Servlet Container that complies with the Java Servlet Specification. The Servlet Container is required only if the *Data Provider* needs the web-based, "on-demand" mode of execution.

- JDBC driver and SQL file are required in instances where the *Data Provider* wishes to transform metadata conditional on changes to an SQL database. The SQL file is to be executable and will return a single Boolean field of true if data have changed.

### 3.3.4 Harvester

The *GVDC Server* runs an application titled the *Harvester*, which retrieves the *MetaDIGGS* file from the *Data Provider* and absorbs that data into the *GVDC Server's* database (Figs. 3.2 and 3.3). The *Harvester* does not support versioning of metadata; each time the application is run, the *Harvester* completely replaces that *Data Providers'* data in the GVDC's PostgreSQL to include only the data requested at the time of the last *Harvester* execution. The general objectives of the *Harvester* include:

- **Data Retrieval:** When initiated by a Data Provider through the GVDC website interface, the application will retrieve MetaDIGGS XML files from Data Providers. Data will be retrieved only if the Data Provider's MetaDIGGS XML has a different creation/modification date from the last file retrieved.
- **Data Transformation:** Invoke the transformation of data from MetaDIGGS XML to the GVDC's PostgreSQL database. All metadata from a particular Data Provider will be removed from the GVDC's PostgreSQL database and replaced with the newly retrieved data.
- **Data Backup:** When a *Data Provider's MetaDIGGS* file is harvested, the application will invoke a routine to create a backup of the deleted database records.

The *Harvester* application and transforms are written entirely in PHP to be platform independent. In order to run the *Harvester*, the *GVDC Server* has been modified to meet the following conditions:



- Supports the *MetaDIGGS* schema, described in Section 3.2.2.
- *MetaDIGGS* data are stored in a PostgreSQL database, which is also integrated with the GVDC web-mapping application.

### 3.3.5 Data Previewers

Data previewers that will allow end users utilizing the web-mapping feature to preview various types of data in a log format are currently being developed. The data or tests supported will include, but not be limited to, CPT and borehole logs. The end user will simply click on any available “preview” link to render the graphics. At present, Canvas software is being used as the development tool to code this application. The <canvas> element is used for displaying graphics on a web page. The canvas element is part of HTML5 and allows for dynamic scriptable rendering of bitmap images.

The main goal of the data previewers is to include all the necessary attributes required to provide graphical previews (logs) for available data that can be represented as logs. The previewer application extracts the necessary information from a DIGGS xml instance and transforms that information to another XML format—referred to as *CosmosLog*—that contains the necessary information for drawing the graphic. The graphic log itself is then generated dynamically on the client via a XSL transform. Initially, a standard log format will be supported, but the application can be designed such that a user can specify what kinds of information are displayed as well as specific formats (e.g., column order, font, scale, etc.).

The *CosmosLog* schema has already been designed and tested, along with the required XSL transform and CSS style sheets to render a *CosmosLog* on the screen. The core application and its extensions are expected to be completed in the next phase of this project. This core application may be contained in a single module into which values for different data types (i.e., CPT, borehole, SPT, etc.) contained in the *CosmosLog* file could be dropped and rendered on-the-fly using pop-up windows or browser tabs.

Say the user wanted a borehole log to be drawn dynamically in a browser tab or new window, he/she would do so by utilizing the following GVDC components:

- *CosmosLog* files consist of attributes to be plotted (derived from DIGGSml), including specific element types. A *CosmosLog* file also defines the order of log columns, depending on the availability of relevant details.

- A file called the Dictionary XML file, which contains paths to graphic symbols used in rendering the various types of logs. While the GVDC Server will offer a standard set of symbols, each *Data Provider* could provide their own dictionary and symbols (i.e., include their own logos).
- ViewerXSL and ViewerCSS files have already been created to support the conversion of CosmosLog XML to html in browser windows. A single ViewerXSL and ViewerCSS support the core previewer application. These files were created in JavaScript to draw or graphically render the data in columns using <canvas> elements in HTML 5.

### 3.4 WEBSITE/FRONT-END UPDATES

A number of changes to the server-side and client-side of COSMOS/PEER-LL Pilot GVDC system architecture were implemented to support DIGGS. In addition to those discussed above regarding the *Harvester* and the replacement of the COSMOS-PEER LL Data Dictionary with DIGGS, the following GVDC system components were modified as part of Phase III:

- GVDC-Server database structure.
- GVDC-Server back-end system architecture and administrative website.
- GVDC-Server front-end website.
- GVDC web application online documentation, including a User's Manual.

In accordance with these recommendations, the *GVDC Server* has been modified to support the following technology framework and web application functionalities:

- Operating Systems: Windows Server 2003 and Apache.
- PostgreSQL database for storing *MetaDIGGS* data, including support for PostGIS (geospatial capability).
- Web-page scripting: Hypertext Processor (PHP), JavaScript & Asynchronous JavaScript and XML (AJAX).
- Java Servlets have been created to perform various GVDC-Server tasks.
- Canvas (HTML 5 element) is being utilized to develop the data (log) previewer applications.
- XSLT transforms for data translation and delivery in different formats are being developed.

- Google Maps web-mapping application for end users, for easy navigation and location of overlying data (i.e., seismologic, geotechnical, geophysical) point layer(s).
- Clustering of geotechnical data points on the web-mapping application.
- Selection box tool for the web-mapping application so that users can select multiple data points to review and/or download data.
- Google Map overlays, such as satellite and hybrid (html overlaying satellite images) base layers.
- On the search form, leveled data type selection is implemented using AJAX.
- On the search results page, data types are explained via tool tips, and flowing Google Map pop-ups provide information on any location of an asset the end user selects.
- Drop-down menus are implemented throughout the website.
- Nearly full functional text editor embedded in the Data Providers' disclaimer management webpage for editing disclaimers.
- On the *Data Providers'* statistics report page, there are now four types of *Period* (time) *Groupings*; on the report results page, shorter *Period Groupings* can be grouped further if convenient, as long as statistics exist.
- Menu option under Subscriber Home has changed; download history for the subscriber is shown as usual.

### 3.4.1 Migration of Front-End Interface to PHP and Java

As part of Phase III, the *GVDC-Server* website (web pages) and related applications were migrated from Microsoft Active Server Pages (ASPs) scripting language to PHP, JavaScript, and AJAX with the following goals in mind:

- To make the GVDC-Server application platform independent, ensuring that the entire website could be hosted on all major operating systems.
- There is a significant open source community of users utilizing PHP, JavaScript, and AJAX; in particular, there is an enormous culture of “sharing” code by developers who implement Google Maps applications via these scripting languages. This means that there is a readily obtainable pre-existing code that could be useful for this project from a multitude of free online sources. One example of this is the code utilized in the

“Clustering” functionality mentioned in the previous section, already implemented in Phase III.

### **3.4.2 Integration of Google Maps Feature**

The Phase II mapping application hosted on the GVDC Server was ESRI’s ArcIMS, which was fully implemented in ASP. Because the price of the yearly license for ArcIMS has significantly increased over the years since the initiation of this project in 2000 and as of 2009 ESRI has ceased supporting ArcIMS with a plan to discontinue it in the near future, Phase III included a complete migration to Google Maps technology as the sole *GVDC-Server* web-mapping application. Utilizing Google Maps technology also has the following additional benefits:

- Google Maps applications can also be designed to be platform independent; again, it is possible that the entire web-mapping functionality could be hosted on other operating systems and not be restricted to Windows.
- Google Maps code, images, and API (Application Programming Interface) is open source, meaning that it is free to develop Google Maps applications and integrate Google Maps into any website.
- There is a vast open source community of users utilizing Google Maps, thus pre-existing code is readily available, some of which has already been utilized in the development the web-mapping application integrated into the GVDC Server.

### **3.4.3 Change to PostgreSQL/PostGIS**

During Phase III, the open source database software PostgreSQL (<http://www.postgresql.org/>) was fully integrated into the *GVDC Server*, completely replacing the Phase II implementation of MySQL. The decision to carry out this migration was motivated by the following significant advantages to using PostgreSQL:

- PostgreSQL is platform independent and object relational.
- PostgreSQL supports object-oriented data and programming (which MySQL does not), through PostGIS (<http://postgis.refrations.net/>). This amounts to direct support for geographic objects, which “spatially enables” the PostgreSQL server, allowing it to be

used as a back-end spatial database for geographic information systems (GIS), much like ESRI's SDE or Oracle's Spatial extension.

- PostGIS follows the OpenGIS “Simple Features Specification for SQL” and has been certified as compliant with the “Types and Functions” profile.

### **3.5 ANTICIPATED UPDATES**

The updates and improvements anticipated for implementation include the following:

- To enable the continued development of the GVDC, the 2L03 project team authored an interim schema, referred to as *cosmosDIGGS*, which is essentially a pared-down version of the full DIGGS schema that will be suitable for transferring most types of geotechnical data collected by the core GVDC members; for more details, see Section 2.3. Once a production-ready version of the DIGGS schema is released, the GVDC Server will switch all affected applications to support DIGGS.
- Development and implementation of borehole, CPT, and other data previewers for viewing data via the GVDC-Server web-mapping application.
- Completion of XSLT, XSLT2 transforms for data translation from DIGGS to formats most convenient/requested by end users.
- GUI for harvesting.

## 4 Contributor and User Interactions

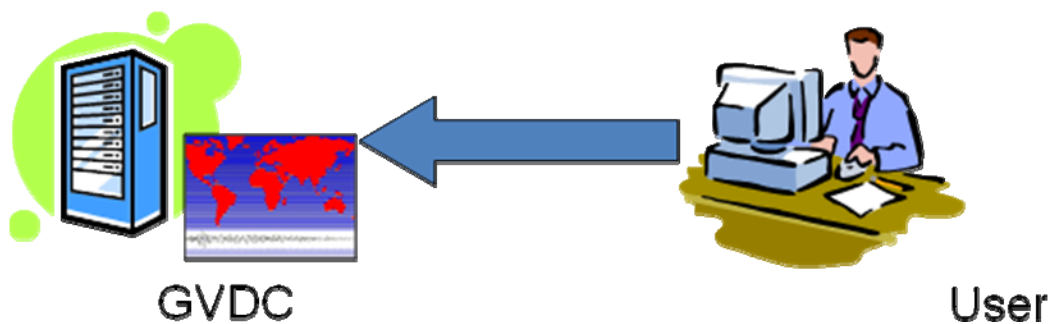
The COSMOS-PEER LL GVDC web application is specially geared toward both the *Data Providers* who contribute and share data through the system and the end users who utilize the GVDC to locate and download data. The workflows commonly experienced by both entities are outlined herein. The *GVDC Server* website roll-out with limited data sets is currently scheduled for September 2009.

### 4.1 DATA PROVIDER WORKFLOW

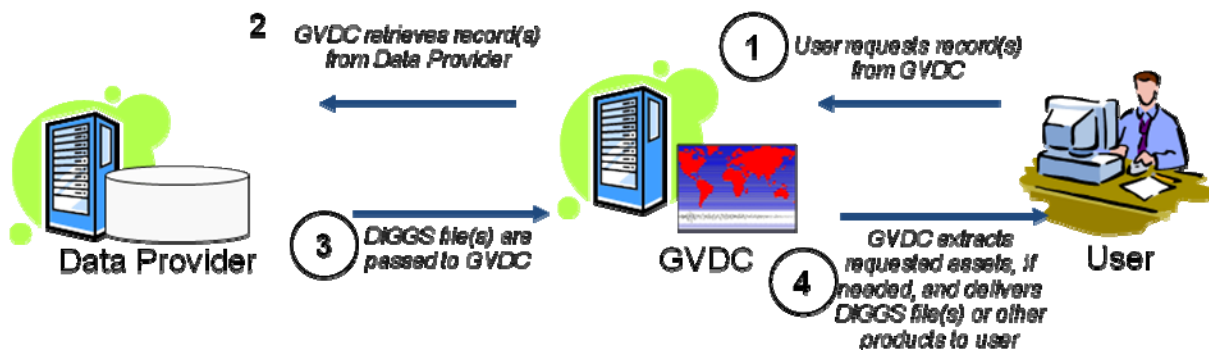
The following steps comprise a brief outline of the requirements of a *Data Provider* to participate in the GVDC (described in detail in Chapter 3 of this report; see Fig. 3.2 for an overview of the entire system):

- The Data Provider is required to generate DIGGSml files for their data sets. This can be accomplished in a variety of ways; however, the Data Provider will need to develop this component, as described in Chapter 3 of this report. Using a DIGGS Generator application is one possibility.
- The Data Provider also needs to generate a single *MetaDIGGS* file in XML format that contains the metadata for their entire data repository, which must include the URL to where the *Data Provider's* DIGGSml files are stored. A single standard application, the *MetaDIGGS Transform*, is designed to accomplish this (Fig. 4.1). This application can be used by any *Data Provider* to extract metadata from a collection of DIGGSml files. The application is accessed through the GVDC website as an embedded Java applet within a web browser.

- The *Data Provider* hosts their own *MetaDIGGS* and *DIGGSml* files on a *Data Provider* (web or FTP) Server (Fig. 4.1). In some cases, the *Data Provider's DIGGSml* files may be hosted from the GVDC Server.
- The Data Provider executes the GVDC Harvester application so that the GVDC Server can discover and load the Data Provider's *MetaDIGGS* file into the GVDC-Server database (Fig. 4.2).



**Fig. 4.1** High-level example of a *Data Provider* generating *MetaDIGGS* files as XML (Ponti and Turner 2009).



**Fig. 4.2** High-level example of a *Data Provider* generating *MetaDIGGS* files and running *Harvester* application to load information into *GVDC Server* database (Ponti and Turner 2009).

To facilitate the *Data Provider's* ease in using the *MetaDIGGS Transform*, a graphical user interface (GUI) was created to facilitate the generation of a *MetaDIGGS* file without complex data management systems in place. For example, a *Data Provider's* system administrator might have a collection of *DIGGSml* files that were generated manually using a

giNT export tool (giNT 2009). These *DIGGSml* files could be placed in a directory on the system administrator's web server and made accessible to the *GVDC Server*. In order to participate in the GVDC, however, a *MetaDIGGS* file must be created and hosted on the *Data Provider's* server.

To accomplish this, the Data Provider's system administrator logs onto the GVDC website, initiates the *MetaDIGGS Transform* function, and inputs the following information:

- Parent directory where *DIGGSml* files are stored.
- Directory where the *MetaDIGGS* file is to be written.
- Base URL address to provide to the GVDC Server to retrieve *DIGGSml* files.



Fig. 4.3 Example usage of *MetaDIGGS Transform* data input dialog box (GUI).

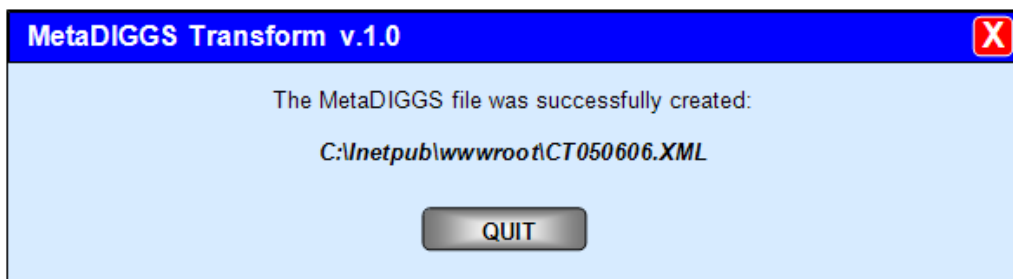


Fig. 4.4 Example message from *MetaDIGGS Transform* application.



In the example shown in Figure 4.3, the *Data Provider* entered the following information:

<i>Path to DIGGSml files:</i>	<i>C:\Inetpub\wwwroot\DIGGSfiles\</i>
<i>Path to MetaDIGGS file:</i>	<i>C:\Inetpub\wwwroot\</i>
<i>Base URL to DIGGSml files:</i>	<i>http://dot.ca.gov/geotechnical/</i>

Upon clicking the “CREATE MetaDIGGS File” button on the *MetaDIGGS Transform* GUI (Fig. 4.3), the *MetaDIGGS* file is generated. The confirmation window shown in Figure 4.4 is presented before the application closes.

In the example above, the *Data Provider* already had *DIGGSml* files on their server. In some cases the *Data Provider* may not have direct access to their own *Data Provider* (web or FTP) *Server*. In such cases, the *Data Provider* runs the application locally on his/her PC and generates the *MetaDIGGS* file. That *MetaDIGGS* file, in addition to the *Data Provider*’s collection of *DIGGSml* files, are then placed on their web server by the webmaster or system administrator. The *Data Provider* data manager running the application would only need to know the base URL to those *DIGGSml* files they wish to upload in order to run the *MetaDIGGS Transform* application.

For instance, the resulting XML file from the *MetaDIGGS Transform* might look something like this:

```
<MetaDIGGS>
  <hole id=“123”>
    <url=“http://dot.ca.gov/geotechnical/meta123.xml”>
    .....
    .....
  </hole>
  <hole id=“124”>
    <url=“http://dot.ca.gov/geotechnical/meta123.xml”>
    .....
    .....
  </hole>
  <hole id=“125”>
    <url=“http://dot.ca.gov/geotechnical/meta123.xml”>
    .....
    .....
  </hole>
</MetaDIGGS>
```

Note that the *MetaDIGGS* file lists the key metadata for each hole or borehole.

For *Data Providers* that want to generate *DIGGSml* files dynamically and don't want to host a collection of static files, a special configuration is required. The *Data Provider's* server needs to be set up to return a list of URLs that would invoke an application to generate *DIGGSml* files dynamically (on-the-fly). The *MetaDIGGS Transform* is still used; however, instead of providing a file path to static *DIGGSml* files, a URL is provided to invoke a service to generate a virtual directory listing of available *DIGGSml* files.

For example, assume Caltrans generates the *DIGGSml* files dynamically. The *MetaDIGGS Transform* on the Caltrans server makes a query to determine a list of available *DIGGSml* files. The parameters provided to *MetaDIGGS Transform* (Fig. 4.3) could look like this:

<i>Path to DIGGSml files:</i>	<i>http://dot.ca.gov/geotechnical/giveMeAll.jsp</i>
<i>Path to MetaDIGGS file:</i>	<i>C:\Inetpub\wwwroot\</i>
<i>Base URL to DIGGSml files:</i>	<i>http://dot.ca.gov/geotechnical/</i>

In this example, *giveMeAll.jsp* provides the service which returns the following response:

```
<allRecord>
<hURL> http://dot.ca.gov/geotechnical/1231</hURL>
<hURL> http://dot.ca.gov/geotechnical/1232</hURL>
<hURL> http://dot.ca.gov/geotechnical/1233</hURL>
<hURL> http://dot.ca.gov/geotechnical/1234</hURL>
<hURL> http://dot.ca.gov/geotechnical/1235</hURL>
</allRecord>
```

Note that the schema included above is just an example to illustrate how this scenario could work. The *MetaDIGGS Transform* still processes each URL as it would for static data.

When a *Data Provider* executes the *Harvester* application, the *MetaDIGGS Transform* application extracts metadata from the *DIGGSml* files or database behind the scenes and loads the information into the *GVDC Server* (Fig. 4.2). This operation consists of the following:

- A simple database dump and replace, where the *Data Provider's* previous (old) *MetaDIGGS* information contained in the *GVDC Server* is first backed up, then replaced in the *GVDC-Server* database with the newly harvested *MetaDIGGS* file data.
- The *Harvester* application should be completely controlled by the *Data Provider*, i.e., it can be run on schedule or on-demand manually or automatically via custom coding by the *Data Provider's* system administrator.

More details on the technical specifications of the *Harvester* application can be found in Chapter 3 of this report.

## 4.2 END-USER EXPERIENCE

The following discussion provides a general workflow for a typical end user of the *GVDC Server* (Fig. 4.5). To begin with, an end user visits the *Server* website to search for data, for instance, geotechnical and/or geophysical data. In general, end users will search the website using the web-mapping application and make requests to download and/or preview the record(s) returned by the search process (Fig. 4.6). The main webpage on the *GVDC Server* and the entry point for all end users, as well as *Data Provider* system or data administrators, are shown in Figure 4.7.

The next step for an end user who wishes to search for and request data would be to log in to the website, as illustrated in Figure 4.8. If the end user is a “new” user, then the user should first register with the website, and an email confirmation will be sent to the user upon successful registration. The login page is the same for data administrators.

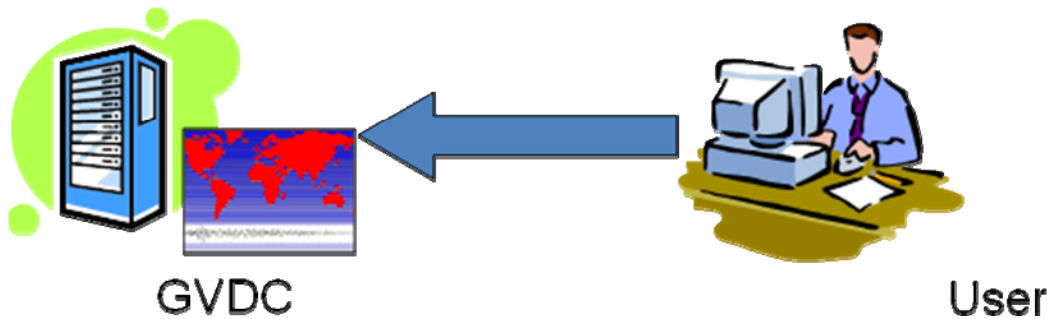


Fig. 4.5 End users access *GVDC-Server* website via Internet.

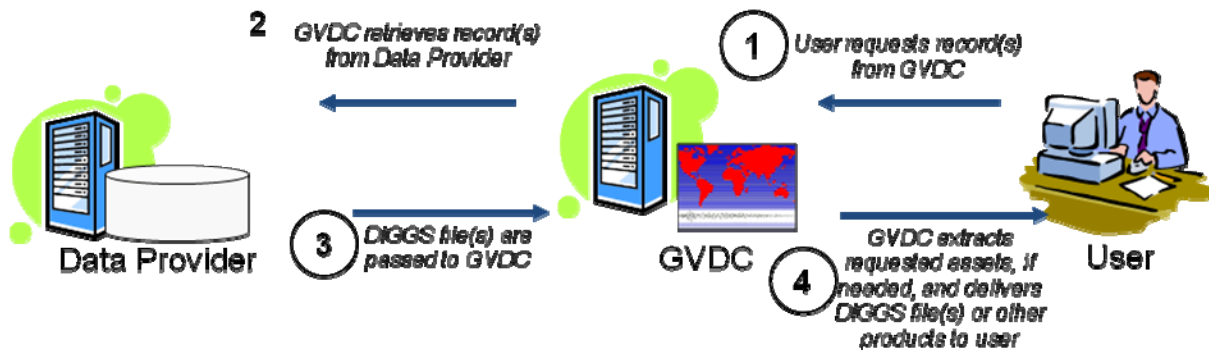


Fig. 4.6 Overview of end-user experience using *GVDC-Server* website to retrieve data.

Figure 4.9 shows an example of an end user's "subscriber Home" page, which provides links to different features within the website, as well as a list or "Download History" of data downloaded during all previous sessions or logins. Figure 4.10 demonstrates the Google Maps web-mapping application integrated into the Search feature of the website.

End users can search the web-mapping application by navigating the map as in any Google Maps application. Data provided by *Data Providers*, such as boreholes, as well as seismic data such as locations of strong-motion earthquake records, are shown as points (blue "+" signs and orange boxes, respectively) on the map. Below the map the "Document Search" functionality allows an end user to search for and make requests for specific data sets based on filters, which include:

- Data Provider name
- Project date, range
- Asset name, such as the name of a borehole
- Project name
- Borehole depths of interest
- Bounding latitudes and longitudes, defining a rectangular box or area to search within



Fig. 4.7 "Home" webpage of GVDC Server.

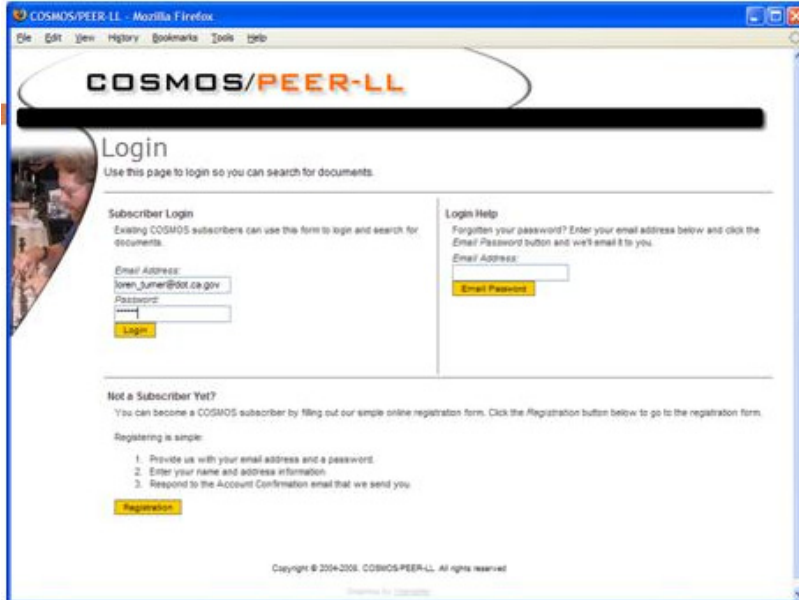


Fig. 4.8 Main *GVDC-Server* login page for both *Data Providers* and end users.

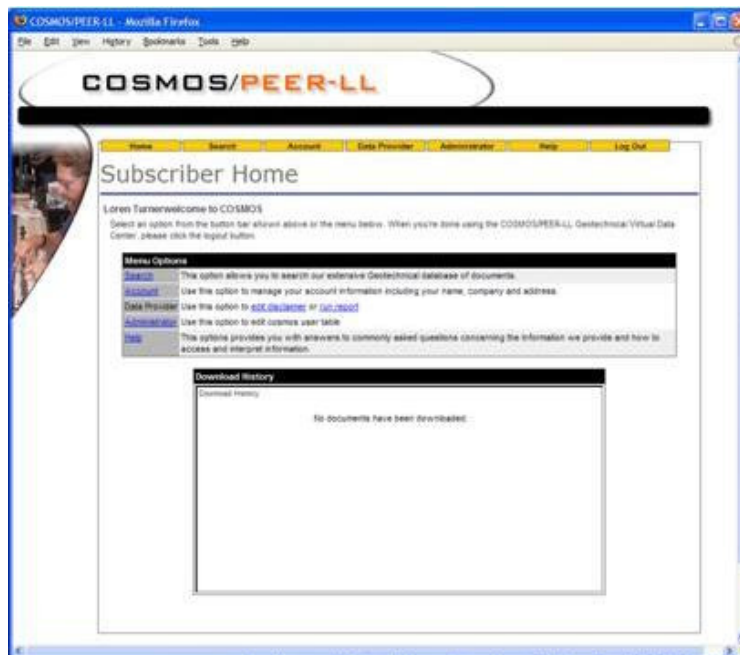
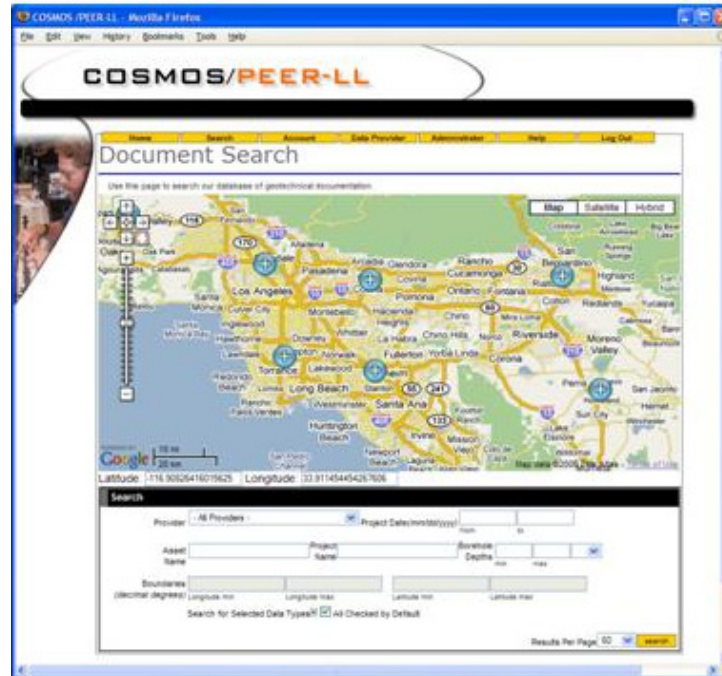


Fig. 4.9 Example of “Subscriber” home page of *GVDC-Server* website.



**Fig. 4.10** *GVDC-Server* web-mapping application and “Document Search” functionality.

If end users click on a point of interest, they will see a pop-up balloon (see Fig. 4.11). The balloon provides a list of all the records (from *MetadatDIGGS* files) in the *GVDC-Server* database for data sets (*DIGGSml* files) located in proximity to the point. The list provides the names of the available data sets or “assets,” such as geotechnical boreholes or geophysical log data. If displayed at the bottom of a balloon, the list of assets can be expanded by clicking on the link “Click to list all data in this cluster.” If the end user wishes to view all the available assets in a particular location on the map, the user can zoom-in to cluster, such that all the data sets in the vicinity will be displayed as separate points (flags) (see Fig. 4.12). The *GVDC-Server* database (and, therefore, the map application) also includes strong-motion records that can be viewed by the end user, such as the example shown in Figure 4.13.

The end user can click on the data point (orange box)—which brings up a balloon providing basic information about the strong motion record—and then can click on the link at the top of the balloon to be taken directly to the data source (Fig. 4.14). The *GVDC* website information balloon provides the name of the strong-motion record, the address (if available), and the original source of the data (the latter at the top of each balloon).



**Fig. 4.11** Example of user clicking on cluster of data points represented by blue “+” sign on map, showing \ list of available data according to asset name.




**Fig. 4.12** Example of zooming in to map to view assets that were previously clustered, and of clicking on one asset (flag), such as a borehole, as shown in Fig. 4.11.





**Fig. 4.13 Example of clicking on strong ground motion data point (orange box), which provides information on name, location, and source of particular record.**

One of the most significant additions to the functionality of the GVDC-mapping application is the select box feature, whereby end users can filter data of interest based solely on location (Fig. 4.15). In the example shown in Figure 4.15, the end user first clicks on the “Show/Hide Selector Box” , which is located to the lower right of the Google Maps navigation arrows/boxes in the upper left corner of the map. A transparent red box opens that allows the user to move freely about the map by clicking and dragging, or he/she can resize the map by dragging the lower right corner. For instance, as the user moves the box about the map, the latitude and longitude boundaries displayed in the Search fields below the map are automatically updated according to the values where the corners land on the map. The user can expand the “Search for Selected Data Types,” and also the sublists of data types under the major headings below (Fig. 4.15). The user may then select all Data Types or only those of interest. When the end user clicks on the orange “Search” button at the bottom of the Search, a brief summary of results lumped by *Data Provider* is presented in a new “Document Search Results” window (see Fig. 4.16).



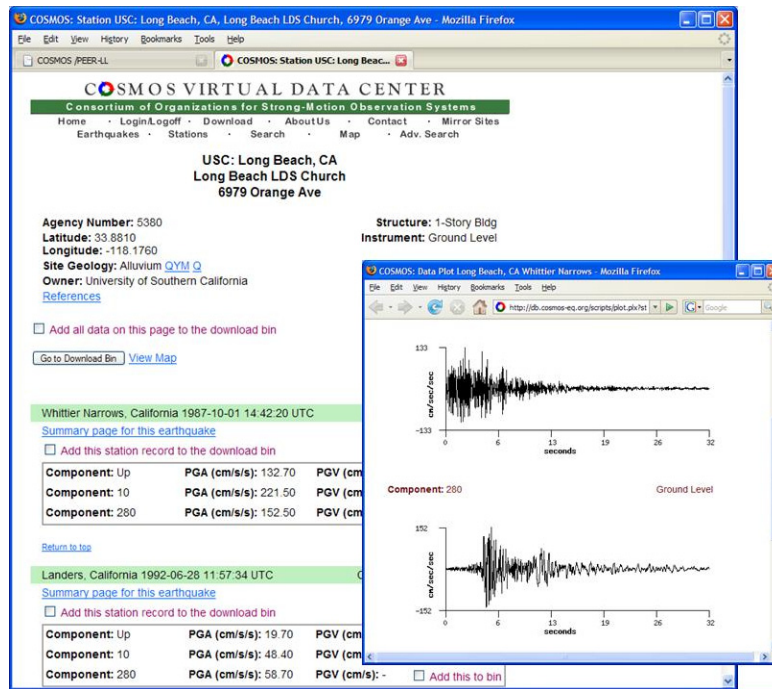


Fig. 4.14 Example of strong-motion data on COSMOS Virtual Data Center website, which can be accessed directly from GVDC web-mapping application.

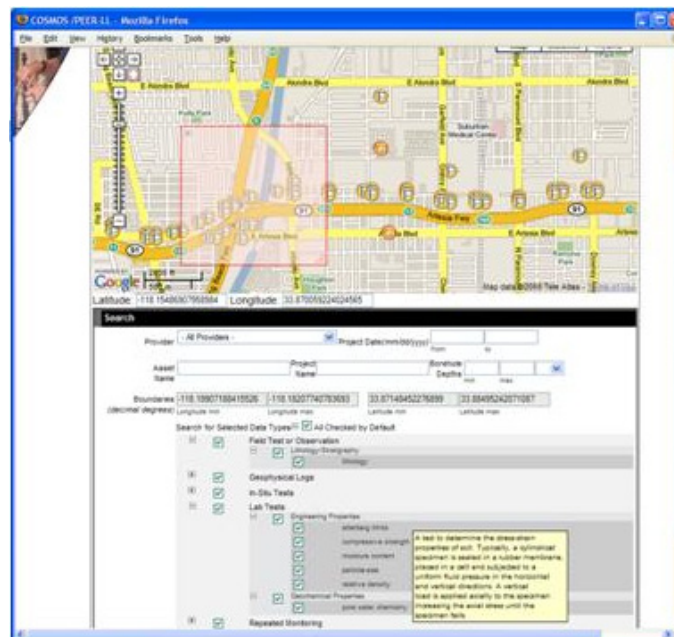
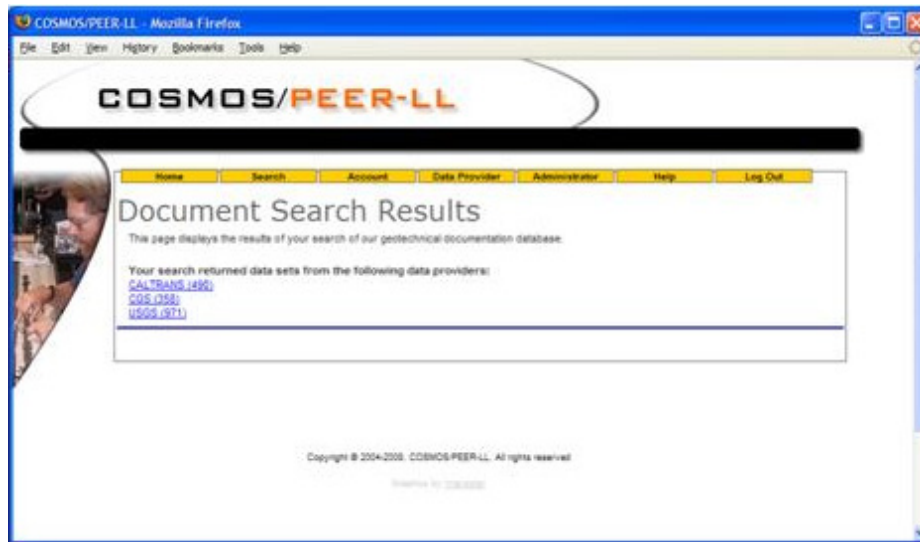


Fig. 4.15 Example of using “Show/Hide Selector Box” tool, and various Data Types that can be searched for in data sets within data points falling within box drawn on map.



**Fig. 4.16 “Document Search Results” window showing results of end-user request (shown in Fig. 4.15) grouped according to *Data Provider’s* name.**

Next, a user can see more details of their search results by clicking on one of the links (Fig. 4.16). A new window containing information on all of the records (from *MetaDIGGS* files) in the GVDC database that fell within the end user’s selection box on the map (Fig. 4.17) pops up. The records listed may be downloaded by checking off the boxes on the far right of the list under the column heading “Download.” Passing the mouse over any one of the data records (assets) will provide an instant summary pop-up text of the Data Types (types of tests) available for download within a given record (*DIGGSml* file) (see Fig. 4.17). Clicking on any one record produces a Google Map pop-up view, zoomed into the asset’s exact location.

A data previewer application that will allow end users to preview various types of data (i.e., borehole, geophysical, CPT) in a log format (see Fig. 4.19) is currently being developed. A user would access a data preview (log) by clicking on a link, either within a given record (asset) listed in list of “Document Search Results” and/or within the Google Maps pop-up balloon belonging to a given asset. It is anticipated that the data previewer application will be completed in the next phase of the project.

Asset Name	Project Name	Measured Depth	Date	Download
000002_00040_0011706	ARCQ Former Station No. 100	40 ft vertical	1989-12-10	<input checked="" type="checkbox"/>
000002_00040_0011706	Shel Station	20 ft vertical	1989-12-10	<input checked="" type="checkbox"/>
000002_00040_0011706	Exxon Station 7-2314	30 ft vertical	1989-12-10	<input checked="" type="checkbox"/>
000002_00040_0011801	Texas U.S.A.	40 ft vertical	1989-12-10	<input checked="" type="checkbox"/>
000002_00040_0011706	Mobile Service Station No. 114086	51.5 ft vertical	1989-12-10	<input checked="" type="checkbox"/>
000002_00040_0011801	Gateway Channel	21.5 ft vertical	1989-12-10	<input checked="" type="checkbox"/>
000002_00040_0011706	Williams Valve	40 ft vertical	1989-12-10	<input checked="" type="checkbox"/>
000002_00040_0011706	Nutley	50 ft vertical	1989-12-10	<input checked="" type="checkbox"/>
000002_00040_0011706	Pomona Bus Company	50 ft vertical	1989-12-10	<input checked="" type="checkbox"/>
000002_00040_0011706	Fast Fuel Station No. 971	20 ft vertical	1989-12-10	<input type="checkbox"/>
000002_00040_0011706	Fast Fuel Station No. 971	31.5 ft vertical	1989-12-10	<input type="checkbox"/>
000002_00040_0011801	Berger Brumley Drug Company	20 ft vertical	1989-12-10	<input type="checkbox"/>
000002_00040_0011706	Q and W Dr. (20076)	10 ft vertical	1989-12-10	<input type="checkbox"/>
000002_00040_0011801	Unocal Station No. 8086	10 ft vertical	1989-12-10	<input type="checkbox"/>
000002_00040_0011706	Los Angeles County Club	50 ft vertical	1989-12-10	<input type="checkbox"/>
000002_00040_0011706	Perry Owens State	31.5 ft vertical	1989-12-10	<input type="checkbox"/>
000002_00040_0011706	Park L. Davis Co.	31 ft vertical	1989-12-10	<input type="checkbox"/>
000002_00040_0011706	Home Service Station	31 ft vertical	1989-12-10	<input type="checkbox"/>
000002_00040_0011706	El Bandido Trucking Co.	40 ft vertical	1989-12-10	<input type="checkbox"/>
000002_00040_0011801	Kraft General Foods	24 ft vertical	1989-12-10	<input type="checkbox"/>
000002_00040_0011706	Mall - La Habra	50.5 ft vertical	1989-12-10	<input type="checkbox"/>
000002_00040_0011801	Former Chevron Station 2240	31.5 ft vertical	1989-12-10	<input type="checkbox"/>
000002_00040_0011706	COOT Site Assessment	30 ft vertical	1989-12-10	<input type="checkbox"/>
000002_00040_0011706	Chevron Station No. 9-0400	31.5 ft vertical	1989-12-10	<input type="checkbox"/>

Fig. 4.17 Example list of data records (assets) located in end user's selection (i.e., box on map) available for download from one *Data Provider*. Pop-ups showing test or data types within each asset are accessed dynamically simply by mousing-over each record.

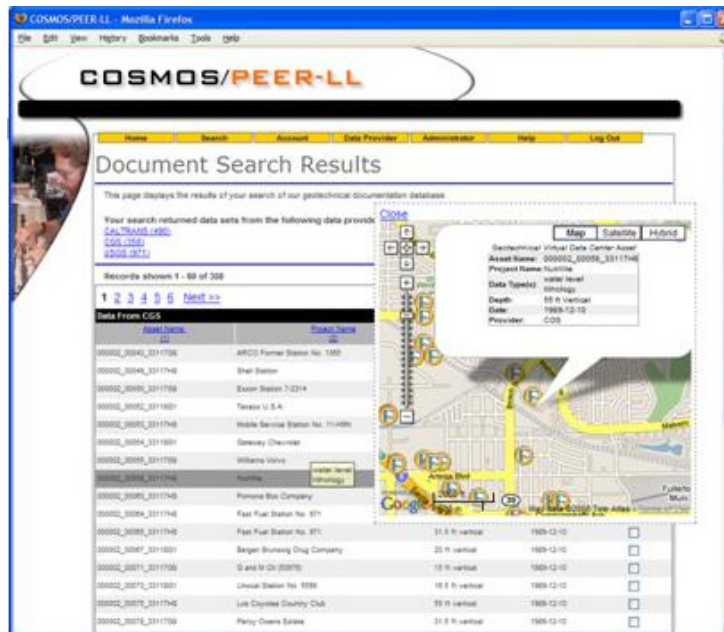
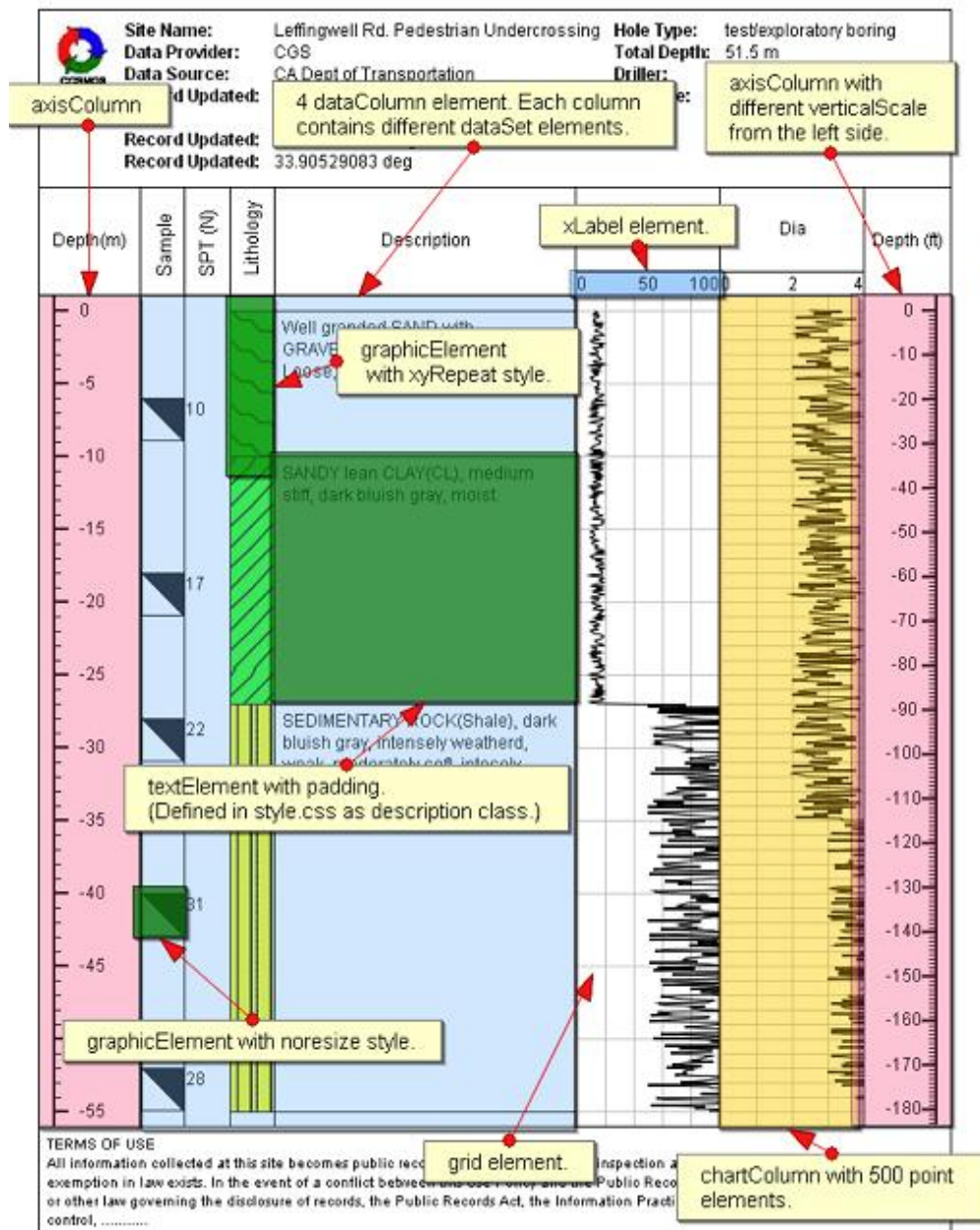
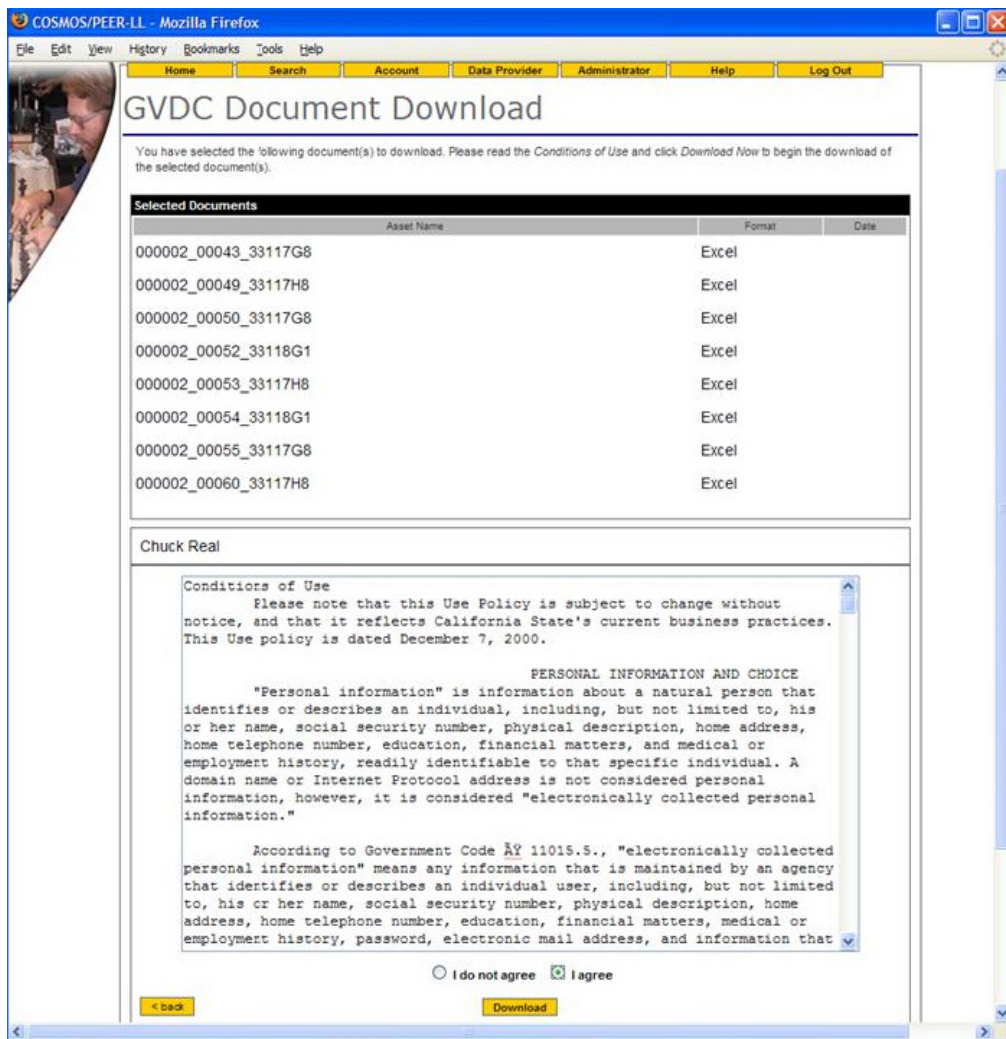


Fig. 4.18 Clicking on any record in “Document Search Results” list provides dynamic pop-up map showing location of selected data set, identical in functionality to mapping application on main search page.

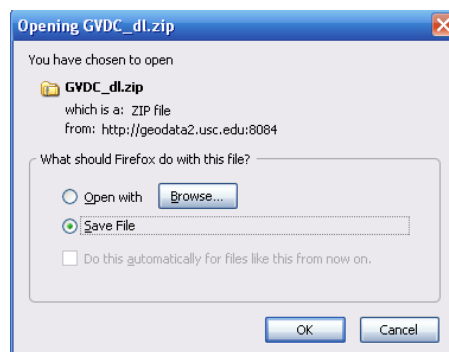


**Fig. 4.19 Detailed example of borehole preview result; previewer application is yet to be completed. Log-style previews of various types of data will be available by clicking on record (asset) of interest either in “Document Search Results” or in asset’s map pop-up information balloon (Ponti and Turner 2009).**





**Fig. 4.20** Example of *Data Provider* disclaimer that end user must agree to in order to download any data via *GVDC Server*.



**Fig 4.21** Example of final step in downloading a zipped set of requested assets.

After selecting data records (assets) to download (e.g., Fig. 4.17), the user clicks on the orange button “Download Data From This Provider” at the lower right corner of the “Document Search Results” page. A new window will pop-up called the “GVDC Document Download,” which lists only the asset selected for download and the particular *Data Provider’s* disclaimer agreement (Fig. 4.20). The end user must accept the *Data Provider’s* disclaimer prior to downloading any data via the *GVDC Server*. If the end user clicks “I agree,” then the user can click on the orange “Download” button at the bottom of this window. Behind the scenes, the *GVDC Server* then requests assets (*DIGGSml*) from the *Data Provider* and dynamically compresses them all into one ZIP file and passes them to the user. A small dialog box opens, which is all the user sees (i.e., Windows, Fig. 4.21), indicating that they should download or open the ZIP file to their own personal media (i.e., hard drive). The user then can unzip and utilize the requested *DIGGSml* files on their own media.

### 4.3 ANTICIPATED UPDATES

The anticipated updates and improvements that will directly affect the *Data Provider* and end-user experiences include the following:

- Completion of a GUI for MetaDIGGS file harvesting to be used by Data Providers.
- Development and implementation of borehole, CPT, and other data previewers for use by end users to view data via the GVDC-Server web-mapping application.
- Completion of XSLT, XSLT2 transforms for data translation and delivery in formats most convenient for/requested by end users.

It is anticipated that these updates will be completed and implemented in the next phase of this project.

## 5 Recommendations and Conclusions

### 5.1 INTRODUCTION

One of the tasks of Phase III was to develop governance and management strategies for implementation of the GVDC. The GVDC consists of an Internet-based server system that can provide efficient one-stop user access to geotechnical data and information from multiple geotechnical database providers. For the purpose of developing strategies for implementation, it is useful to envision the GVDC as a digital nervous system that provides high-value flow of geotechnical information to stimulate and facilitate collaboration throughout the geotechnical community. The core business of the GVDC then is to provide a value-added service to both geotechnical data and information providers, and to the users of the data and information that improves their efficiency and reduces their costs of doing business. Added value accrues through efficient, timely, and cost-effective access to the vast geotechnical data resources currently being held by the multitude of organizations that constitute the geotechnical community. Significant efficiencies and cost savings in the business processes of planning and executing infrastructure projects accrue through timely and continuous access to existing geotechnical data during project planning stages. These efficiencies translate directly into more informed, efficient planning and overall cost savings.

The GVDC has adopted the international geotechnical information exchange open source standard—the *DIGGSml* standard ([www.DIGGSml.com/](http://www.DIGGSml.com/))—for data exchange. Consequently, a necessary element of the GVDC implementation strategy is a proper interface with the organization that takes stewardship of the *DIGGSml* standard. One viable governance strategy would be to incorporate governance of the *DIGGSml* standard maintenance into the GVDC implementation, where a *DIGGSml* standard Special Interest Group (SIG) would maintain the standard under the overall GVDC governance structure. The governance structure would assure

proper representation in the SIG of the various stakeholder communities. Alternatively, maintenance of the *DIGGSml* standard could be established under a separate governance structure—an existing professional standards organization, for example. Adopting this strategy would require establishing agreements and a structure for assuring ongoing coordination between the management of the GVDC and maintenance of the *DIGGSml* standard.

The draft *DIGGSml* standard currently is undergoing review. The review schedule projects that a deployable **v2.0** standard issued in about two years. Consequently, the initial implementation of the GVDC uses the *DIGGSml* exchange schema with very limited data types in order to complete the operability of the system. We propose a short-term strategy for maintaining the GVDC during the estimated two-year time frame while the **v1.0** *DIGGSml* standard is in review.

## **5.2 BUSINESS AND GOVERNING PRINCIPLES FOR GVDC IMPLEMENTATION**

The following business and governing principles for implementation of the GVDC are intended to achieve the following strategic vision: *that the business will provide high-value geotechnical data and information access services for the broad geotechnical community.*

1. Implement the GVDC as a service business that adds value to the geotechnical community's scope of activities and processes;
2. Establish governance processes that establish and maintain a strong service culture;
3. Unite geotechnical data and information developers, providers, and users through a collaborative infrastructure for open, efficient, and value-added sharing of geotechnical data and information;
4. Serve as an open environment for geotechnical information developers, providers, and users to resolve common geotechnical information, sharing infrastructure needs to enhance their business processes;
5. Keep pace with technological advancements that can leverage people, investment capital, and the value of data through a continually evolving, increasingly efficient data sharing infrastructure;
6. Continually serve as a cost-efficient, trusted source for geotechnical information that enhances geotechnical community business processes; and



7. Interactively coordinate with the organization that assumes stewardship of and manages the maintenance and evolution of the open international geotechnical information exchange standard: the *DIGGSml* standard.

In addition to the above business and governing principles, the implementation strategy must provide for sustaining the business over the long term. A review of the most relevant data center governance and business models provide some useful guidance.

### **5.3 RELEVANT EXISTING GEOSCIENCES DATA AND ASSET CENTER BUSINESS MODELS**

The geotechnical community's need for reliable, efficient, and cost-effective access to geotechnical data and information assets to improve their business processes was the fundamental motivation for undertaking the development of the GVDC System. From the beginning, the goal has been to implement an Internet-based server system that links geotechnical data developers, *Data Providers*, and data users in an efficient infrastructure that serves their individual and collective needs for reliable, cost-efficient, and ongoing access to geotechnical data and asset information. Implementation of the GVDC as a sustainable business is the final step in achieving this goal.

Although unable to find an operational server system operational business model that is a complete analog of the GVDC, operational models with similar features exist. Among them, the IRIS DMC has governance and management features that could be applied to the GVDC. The governance and management of the IRIS DMC is summarized in some detail below. Overviews of two other geosciences data and asset archive and distribution services that incorporate many features of the GVDC are also presented below.

#### **5.3.1 Incorporated Research Institutions for Seismology Data Management Center (<http://www.iris.edu>)**

**Business Focus:** The principal business of the Incorporated Research Institutions for Seismology Data Management Center (IRIS DMC) is to archive seismogram waveforms obtained from the IRIS Global Seismic Network (GSN) and install temporary experimental networks deployed to support various focused experiments managed by IRIS, and provide day-to-day servicing of

users' requests for downloading waveforms from the archive. In addition to seismograms from the GSN and IRIS temporary experimental seismograph networks, the DMC also archives and acts as a one-stop distribution point for seismograms recorded by many other seismograph networks around the world, as well as for seismograms from temporary networks deployed to support focused studies conducted by other organizations. In addition to archiving seismograms, the DMC maintains seismograph network, station, instrument, and earthquake metadata. In summary, the overall business focus of the DMC is to provide efficient access to the resource of seismogram waveforms recorded by the worldwide seismological community.

Three dramatic measures of the value of the DMC's service to the seismological community are:

1. A vast amount of data—a large majority of the seismograms recorded—are continuously submitted to the DMC and maintained in the archive. Currently, the DMC archives contain approximately 50 terabytes of data from more than 1100 seismograph stations. Data are acquired from the participating seismograph stations in real time, adding about 9 terabytes of data each year.
2. The number of seismogram waveform requests serviced by the DMC is in the tens of millions annually and continues to grow. The DMC provides a variety of tools to simplify access and assist users' requests for waveform and metadata, and continues to evolve this important service under the leadership of the IRIS DMS Standing Committee.
3. IRIS relies on institutional membership and has strong institutional support. The membership consists of approximately 125 voting members (from universities in the United States), approximately 120 Foreign Affiliates (from universities throughout the world), and approximately 25 institutional members in other affiliate classifications.

**Governance and Management:** The IRIS DMC is one of ten programs of IRIS for which the IRIS Board of Directors provides policy level governance. The IRIS governance and the management of its ten programs are designed to ensure participatory involvement of member institutions. Member institutions' representatives participate at the policy level (as members of the nine-member Board of Directors) and at the program level (as members of one of the ten program committees that report to the Board of Directors). The president of IRIS, a full-time executive, implements the Board's policies and manages the day-to-day business of the Organization, including the activities of the ten program committees.

The DMS Standing Committee, composed of representatives from the eight voting-member organizations, is charged with governance of the DMC. The DMC Standing Committee sets policies and standards for the DMC business operation, including overall maintenance of the DMC archive, data quality standards, user services, and so on. The DMC Program Manager implements policies established by the DMC Standing Committee and manages the day-to-day business of the DMC with a staff of twenty, organized as follows:

- Director of Operations
- Administrative Assistant
- Director of Projects
- Two Systems Administrators
- Director of Software Engineering
- Six Software Engineers
- Seven Data Control Technicians
- Information Services Coordinator

**Sources of Funding:** IRIS is a not-for-profit 503b corporation. Voting Members and U.S. Affiliates pay a one-time membership fee of \$2,500.00 upon being admitted to membership. Affiliate Members do not pay a membership fee. There is no individual membership category. The National Science Foundation is the primary source of funding, which is provided by two different primary mechanisms: (1) a direct-funding agreement, which must be renewed with a new proposal every five years and (2) NSF-funded large scientific studies that are administered by IRIS. In addition, membership participation in the various IRIS Programs appears to be highly significant for the long-term sustainability of the organization.

### **5.3.2 Energy Libraries Online, Inc. (<http://www.enerlib.net>)**

**Business Focus:** The business of Energy Libraries Online, Inc. (EOL) is to preserve and make available by Internet-access oil-well geological and geophysical logs, and associated metadata sets from Oklahoma's vast historical collections. These documents are now stored in a number of collections that contain records up to 100 years old, which cannot be cost effectively accessed in a usable format. The ELO is scanning these logs and preserving them in a digital archive. Users access the archive by an Internet-based server and obtain the complete existing set of geological and geophysical logs for any defined geographic area within the State of Oklahoma.

**Governance and Management:** EOL is chartered as a non-profit charitable (501c(3)) corporation. A six-member Board of Directors, constituted of representatives from the *Data Provider* and user communities, sets policies and has general governance and oversight responsibility for the corporation. An Executive Director manages the business of the corporation under the direction of the Board. A seven-member Technical Advisory Committee provides ongoing interaction between the Executive Director and users of the archive. The EOL currently is in the implementation phase, focusing on scanning geological and geophysical logs and entering them into the archive. Full implementation will require staffing for user support, quality control, and software engineering (personal communication with Tim O. Brown, EOL Executive Director)

**Sources of Funding:** Funding for the development of the system is being provided by a grant through the Tulsa Community Foundation. Sustained funding for operation will be through annual membership fees.

### 5.3.3 DrillingInfo, Inc. (<http://www.drillinginfo.com>)

**Business Focus:** DrillingInfo, Inc. (DI) archives a broad array of petroleum industry data and asset information, and manages Internet-based user access to their archive. Their archive contains a digital library of more than one million historical oil-well geological and geophysical logs, up-to-date royalty leasing information for much of the central United States, and up-to-date regulatory information. Users are able to download archived data and data products in the map-based formats generally used by the petroleum industry. In addition to archived data and assets, the company offers web-based software as a service, consisting of an integrated suite of map-based oil field data evaluation tools and custom mapping tools, in addition to providing knowledgeable management services to assist subscribers with making oil and gas upstream investments and business decisions.

**Governance and Management:** DrillingInfo, Inc. is a for-profit corporation, functioning under the governance of a Board of Directors lead by the Chairman and Chief Executive Officer. The company president, supported by an executive staff, is responsible for day-to-day management of the company's business.

**Sources of Funding:** DI's revenue stream is primarily from subscriptions to its archives and services. The company has been in business for about ten years and currently has more than

1000 subscribing members, including major oil companies, large and small independent oil companies, oil field service companies, consultants, mineral royalty purchasers, mineral royalty owners, law firms, banks, and investment professionals (<http://www.businesswire.com>, May 30 2002). The company offers two levels of subscription: full subscribers have unlimited access to all of the company's archived data and asset information, and basic subscribers have access to archived assets tailored to their specific needs. In 2002, DI ranked second in page views among non-government oil and gas information websites.

#### **5.4 COORDINATION WITH DEVELOPMENT OF *DIGGSml* STANDARD**

In 2005, as part of the Phase III implementation, a decision was made to adopt the “Data Interchange for Geotechnical and GeoEnvironmental Specialists (*DIGGSml*) Standard” as the schema for exchange of geotechnical data through the *GVDC Server*. This decision was motivated by the perceived benefit of broadening access to users throughout the world with a consensus international geotechnical data exchange format. The development of *DIGGSml* was initiated early in 2005 as a Transportation Pooled Fund Study (TPF) coordinated by the Ohio Department of Transportation (Turner et al. 2009). The TPF project focused on integrating existing geotechnical data dictionaries, including the COSMOS data dictionary, to create a new international data exchange format. Developmental work on PEER LL Project 2L03, which was approximately 70 percent completed at that time, was delayed in anticipation of using the consensus *DIGGSml* standard, maintenance of coordination with the development of the *DIGGSml* exchange standard being the only continuing activity on the Project. The level of effort and time needed to develop *DIGGSml* has proved to be much greater than originally perceived. *DIGGS v.1* has now been released for review. A recent project status review following the comment period concluded that a substantial amount of work still remains (Turner et al. 2009). This assessment was further supported in an independent review of *DIGGS* conducted by Galdos Systems, where the author states, “The *DIGGS 1.0a* schemas are currently not ready to be deployed in anything other than an experimental environment.” (Burggraf 2009). The development of a final consensus standard will likely take two more years to complete.

Given this assessment, the COSMOS PEER LL Project team decided to complete the *GVDC-server* system using a variant of the *DIGGSml* schema with fewer types of data (*cosmosDIGGS*). This approach allows for interim implementation of a functional server system,

with the opportunity to later expand the system's data translators to include all the geotechnical data types contained in the consensus *DIGGSml* standard when it is deployed. Attendant to this decision is the need to maintain ongoing participation in the *DIGGSml* standard development activities.

## **5.5 RECOMMENDED GVDC BUSINESS MODEL**

Compliance with the business and governing principles described in Section 5.2 will assure a business model for the GVDC that focuses strongly on providing services to users that will add significant value to their business activities. The successes of IRIS DMC and DrillingInfo, Inc. emphasize the importance of this business focus. Accordingly, for the long term it is recommended that GVDC should be implemented as a not-for-profit 503b corporation, with governance and management consistent with the principles described in Section 5.2.

**Governance and Management:** Governance of the GVDC should be under the direction of a Board of Directors constituted of appropriate representation from geotechnical database providers and the geotechnical data user community. The Board should provide decisive leadership for formulating program level policies that focus on services to users and should provide oversight to ensure that high-value services to users are being implemented and maintained.

Initial management and staffing for implementation of the GVDC should include the following:

1. A general manager, responsible for day-to-day management of the business and for marketing the business to the user community;
2. A software engineer responsible for maintaining the GVDC and upgrading the system to incorporate additional data types as the *DIGGSml* standard evolves, and who serves as coordinator with the *DIGGSml* governance organization;
3. A data quality and user services administrator to interface with database providers and service user requests; and
4. An administrative assistant and office manager. It is recommended that a User Services Committee should be established at the outset of the business implementation and that the committee should perform a highly participatory function for developing and maintaining user services.

**Sustainability:** To be sustainable in the long term, the geotechnical community must accept the GVDC as a service that enhances their business practices. A funding model based on the principal funding source being a government agency (e.g., NSF and the IRIS DMC) seems highly improbable of success. The alternative is a funding model based on membership subscriptions similar to the very successful DrillingInfo, Inc. business model discussed in Section 5.3. It is believed there is high potential in the long term for the GVDC to service a large number of geotechnical *Data Providers*. As the number of *Data Providers* linked to the system increases, the value of membership also will increase. In the short term, however, an aggressive and effective marketing effort to promote use of the system will be required. Even the most sound and high-value services do not flourish without a dedicated marketing effort. Start-up funding will be required to implement this strategy.

## 5.6 GVDC MAINTENANCE DURING *DIGGSml*/REVIEW

As discussed in Section 5.4, it is currently projected that the *DIGGSml* schema will not be fully deployable for another two years. During the interim, the data types available through the GVDC will be very limited; therefore, the system is not expected to be able to initially offer sufficient value to attract user members. We recommend that during this transition phase, the *GVDC-server* technologies should be maintained and upgraded to incorporate new technology developments. In addition, close coordination with the *DIGGSml* development activities must be maintained, and the capability of the system must be expanded in pace with the evolution of the *DIGGSml* data exchange standard. During this transition phase, it is also recommended that a system software engineer be employed to maintain the GVDC, with the participatory involvement of a Technical Working Group consisting of *Data Provider* representatives who have appropriate expert knowledge about the *DIGGSml* exchange schema, knowledge about their own and user business needs, and a strong interest in having the system fully implemented. Potential sources of funding for the transition phase are the TPF Project and/or a corporate funding through the PEER LL Program by highly committed *Data Provider* organizations.

**Estimated Cost:** It is estimated that the total cost of maintaining the GVDC and enhancing the system as needed to incorporate technological advances to be \$220,000. This estimate is based on the following cost assumptions.

**Table 5.1 Estimated costs for maintaining and enhancing GVDC.**

<b>Cost Item</b>	<b>Annual Cost Estimate</b>	<b>Total</b>
PI/Software Engineer	<b>50,000</b>	<b>100,000</b>
Participatory Working Group Meetings and Travel	<b>10,000</b>	<b>20,000</b>
Technical Services	<b>30,000</b>	<b>60,000</b>
Materials and Equipment	<b>10,000</b>	<b>20,000</b>
Total	<b>100,000</b>	<b>200,000</b>
Plus Overhead @ 10%	<b>110,000</b>	<b>220,000</b>



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# **Appendix I: Data Dictionary Tables and Sample Mapping from Site Table to XML**

**by J. Benoît, J. I. Bobbitt, and D. J. Ponti**

## **INTRODUCTION**

An expandable data dictionary standard has been developed as part of a project sponsored by the Consortium of Organizations for Strong-Motion Observation Systems (COSMOS) and by the Pacific Earthquake Engineering Research Center Lifelines Program (PEER) to link databases from various agencies such as the California Department of Transportation (Caltrans), the California Geological Survey (CGS), the U.S. Geological Survey (USGS) and Pacific Gas and Electric (PG&E) through a single virtual data center interface. The data model and data dictionary from this pilot COSMOS-PEER project 2L02 on Archiving and Web Dissemination of Geotechnical Data included several laboratory and in situ geotechnical tests [COSMOS-PEER, 2004].

A continuing effort, sponsored by COSMOS-PEER project 2L03, aimed at expanding the current Geotechnical Virtual Data Center (GVDC) Data Dictionary to include various seismic velocity tests and geophysical tests as well as additional laboratory and *in situ* tests. A group of experts in the specific types of data to be captured by the revised data dictionary were invited to a workshop on the Expansion of the COSMOS Data Dictionary standard, which was held on July 27–28, 2005, at the Westin San Francisco Airport Hotel in California. Prior to the workshop, participants were asked to develop draft data dictionary tables for the various tests for discussion via e-mail. Some of those tables used information from existing data dictionaries such as that developed for the National Geotechnical Experimentation Sites (NGES) program (Benoît et al. 1994).

The workshop agenda included presentations from leading experts on various geophysical and seismic field tests such as the crosshole test, downhole and borehole geophysical tests, PS-logging and SASW, as well as seismic laboratory tests including triaxial testing, torsional ring shear, resonant column and torsional shear testing, and laboratory shear wave techniques. Following the presentations, participants were divided into working groups in an effort to reach consensus on the various data dictionary tables by the end of the workshop. Additional discussions and refinements to the tables took place in the ensuing months, integrating results from a newly developed collaboration between COSMOS, the Geotechnical Management System (GMS) (which is a group constituting representatives from various state DOTs, the FHWA, the Army Corps of Engineers, the EPA, the USGS and the UK Highway Agency), the University of Florida, the UK Association of Geotechnical and Geoenvironmental Specialists (AGS), and the UK Construction Industry Research and Information Association (CIRIA) in an effort to reconcile the various existing geotechnical data dictionaries and data models. The creation of a common data dictionary will result from this collaboration between the COSMOS-PEER LL 2L03 project and the Transportation Pooled Funds project (TPFP) 918.

The various presentations and the resulting data dictionary tables are included in this report. We would like to thank the workshop participants as well as others unable to attend for their active participation and most valuable contributions to the COSMOS Data Dictionary.

## REFERENCES

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## Workshop

### Expansion of the COSMOS Data Dictionary Standard

COSMOS-PEER LL Project 2L03 - Carl Stepp, PI  
West n San Francisco Airport Hotel, CA  
July 27-28, 2005

## Overview of the COSMOS-PEER Pilot System for Web Dissemination of Geotechnical Data – 2L02 Project

### Project Objective:

- Develop a pilot web-based Geotechnical Virtual Data Center linking example geotechnical data sets from:
  - California Department of Transportation (Caltrans)
  - Pacific Gas and Electric Company (PG&E)
  - California Geological Survey (CGS)
  - United States Geological Survey (USGS)

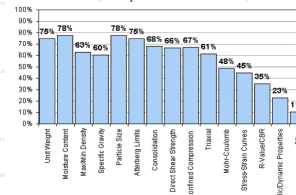
- These organizations also are participating as vital partners in the project

## Scope of Pilot System Project

- Task 1:** Define geotechnical data user and data use scenarios for a pilot geotechnical virtual data center system
  - Conduct an online Geotechnical Data User Survey
- Task 2:** Develop an expanded data dictionary standard for the pilot system to link multiple databases
  - Translate into Web Markup Language for ease of programming
- Task 3:** Develop pilot system architecture based on data user and data use scenarios
  - Link CGS, Caltrans, PG&E and USGS geotechnical data sets, using Harvester Architecture
- Task 4:** Plan and implement a workshop structured to obtain geotechnical community consensus and deliver a proceeding that will serve as an expanded implementation plan
  - COSMOS-PEER-LL - RIWA Workshop held in Newport Beach, CA on June 21-23, 2004

## Task 2 Objectives

- Define Entities for Data Dictionary
- Develop Data Model
- Classify Geotechnical Information Based on User Scenarios Survey



- Develop tables for pilot data dictionary
- Develop Data Model Standard

## Data Model and Data Dictionary

- Data Model
  - Information content
  - Structure
  - Relationships
- Data Dictionary
  - Specifies meaning of various attributes
  - Used to develop Schema

## Data Dictionary Table: Metadata

Parameter	Definition
Cone Penetration Test Parameters	The cone penetration test (CPT) consists in determining the resistance to penetration of a conical pointed penetrometer into subsurface soils. Standard testing procedures are described in ASTM D5778. Relevant testing parameters are described in this table.
Name	Definition
Note	The hole of which these CPT parameters are apart. The CPT parameters must be related to whole. The value is a foreign key that should select an instance of Hole based on the ID value of the table.
Cone Type	The type of cone penetrometer used for testing. The following provides a list of available cone penetrometers: a) mechanical cone, b) electric cone, c) piezoelectric cone, d) seismic piezoelectric cone, e) dynamic cone, f) dynamic cone, g) acoustic cone, h) resistivity cone, i) vibratory cone, j) miniature cone, or k) other.
Cone Manufacturer	The business name of the company manufacturing the cone penetrometer. For example: Fugro, Hogenbjerger, Delft, etc.
Tip Area	The conical base area of the penetrometer tip. Typical values are 10 cm <sup>2</sup> and 15 cm <sup>2</sup> .
Tip Apex Angle	The apex angle of the conical point of the penetrometer tip. The standard value is 60 degrees.
Friction Sleeve Area	The surface area of the friction sleeve located immediately behind the penetrometer tip. Typical values are 150 cm <sup>2</sup> for the 10 cm <sup>2</sup> and 200 cm <sup>2</sup> for the 15 cm <sup>2</sup> .
Distance Tip to Sleeve	The distance between the tip and the center of the friction sleeve.
Piezoelectric Type	The type of piezoelectric is defined in part by the position of the filament. The types include the following: a) Type 1 (on the tip), b) Type 2 (on the sleeve), c) Type 3 (on the sleeve), d) Type 4 (on the sleeve), e) Type 5 (on the sleeve), f) Type 6 (on the sleeve), g) Type 7 (on the sleeve), h) Type 8 (on the sleeve), i) Type 9 (on the sleeve), j) Type 10 (on the sleeve), k) Type 11 (on the sleeve), l) Type 12 (on the sleeve), m) Type 13 (on the sleeve), n) Type 14 (on the sleeve), o) Type 15 (on the sleeve), p) Type 16 (on the sleeve), q) Type 17 (on the sleeve), r) Type 18 (on the sleeve), s) Type 19 (on the sleeve), t) Type 20 (on the sleeve), u) Type 21 (on the sleeve), v) Type 22 (on the sleeve), w) Type 23 (on the sleeve), x) Type 24 (on the sleeve), y) Type 25 (on the sleeve), z) Type 26 (on the sleeve), aa) Type 27 (on the sleeve), ab) Type 28 (on the sleeve), ac) Type 29 (on the sleeve), ad) Type 30 (on the sleeve), ae) Type 31 (on the sleeve), af) Type 32 (on the sleeve), ag) Type 33 (on the sleeve), ah) Type 34 (on the sleeve), ai) Type 35 (on the 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## Data Dictionary Table: Data

Cone Penetration Test Data	
The cone penetration test (CPT) consists of determining the resistance to penetration of a conical penetrometer into subsurface soils. Standard testing procedures are described in ASTM D 5778. Cone Penetration Test data are presented in this table.	
Name	Definition
Cone Penetration Test Parameters	The Cone Penetration Test Parameters, of which the CPT data are apart, the CPT data must be related to a Cone Penetration Test Parameters. This value is a foreign key that should select an instance of Cone Penetration Test Parameters based on the id value of the Cone Penetration Test Parameters.
Tip Depth	The depth of measurement at the penetrometer tip.
Tip Resistance	The end-bearing component of penetration resistance in units of stress referred to as $q_c$ (uncorrected or net area ratio).
Friction Sleeve Resistance	The friction component of penetration resistance in units of stress developed on a friction sleeve referred to as $f_s$ .
Penetration Pore Pressure	Fluid pressure measured during the cone penetration test.
Inclination	Inclination of the penetrometer during advance in degrees.
Remarks	A text descriptor providing additional information relevant to the CPT data and results.
Date Last Updated	The date of the last update to the data in this table.

## Expansion of the Data Dictionary Standard 2L03 Project

### Objectives

1. Select tests to be included in Data Dictionary based on User Scenarios and other needs:
  - Laboratory Geotechnical Tests
  - In Situ Geotechnical Tests
  - Geophysical/Seismic Field Tests
2. Update data model
3. Define metadata/data for each test entity
4. Develop expanded data dictionary
5. Modify and expand schema

## Entities for Pilot System Data Dictionary

2L02	2L03
<ul style="list-style-type: none"> <li>Business Associate</li> <li>Site</li> <li>Coordinate Reference System</li> <li>Hole</li> <li>Hole Test Association</li> <li>Hole Tests</li> <li>Alias</li> <li>Core</li> <li>Layer</li> <li>Component</li> <li>Specimen</li> <li>Moisture</li> <li>Atterberg Limits</li> <li>Particle Size Parameters</li> <li>Particle Size</li> <li>Standard Penetration Test Parameters</li> <li>Standard Penetration Test Data</li> <li>Cone Penetration Test Parameters</li> <li>Cone Penetration Test Data</li> <li>Cone Penetration Dissipation Test</li> </ul>	<ul style="list-style-type: none"> <li>Specific Gravity</li> <li>Triaxial Test Parameters</li> <li>Triaxial Test Data</li> <li>Triaxial Test Series - Parameters</li> <li>Triaxial Test Series - Data</li> <li>1-D Consolidation Test Parameters</li> <li>1-D Consolidation Test Data</li> <li>1-D Consolidation Time Deformation</li> <li>Direct Shear (NGES)</li> <li>Hydraulic Conductivity (NGES)</li> <li>Field Vane Shear Test Parameters</li> <li>Field Vane Shear Test Data</li> <li>Prebored Pressuremeter Parameters</li> <li>Prebored Pressuremeter Test Data</li> <li>Flat Dilatometer Test Parameters</li> <li>Flat Dilatometer Test Data</li> <li>Flat Dilatometer Dissipation Test</li> </ul>

## Pooled-Fund Study Expansion of the Data Dictionary Standard

Results from 2L02, 2L03 and from this workshop will be used as part of a collaboration between COSMOS, the Geotechnical Management System (State DOTs, FHWA, Army Corps of Engineers, EPA, USGS) UK Highway Agency, U of Florida, UK Association of Geotechnical and Geoenvironmental Specialists (AGS), UK Construction Industry Research and Information Association (CIRIA) in an effort to reconcile various geotechnical data dictionaries and data model.

## Workshop Objective

- Expand the current Geotechnical Virtual Data Center (GVDC) Data Dictionary to include geophysical/seismic tests for the development of shear-wave velocity profiles and other seismic geotechnical and geophysical properties:
- Crosshole Test
  - Downhole and Borehole Tests
  - PS-Logging
  - SASW
  - Cyclic Triaxial
  - Torsional Shear
  - Resonant Column

## Expansion of the Data Dictionary Standard

### Major requirements for implementation and use:

Independent of implementation  
Clear (unambiguous)  
Expandable  
Flexible  
Realistic (degree of completeness)

Acquisition period:  
Legacy data (limited metadata)  
Data already in electronic format  
Future data

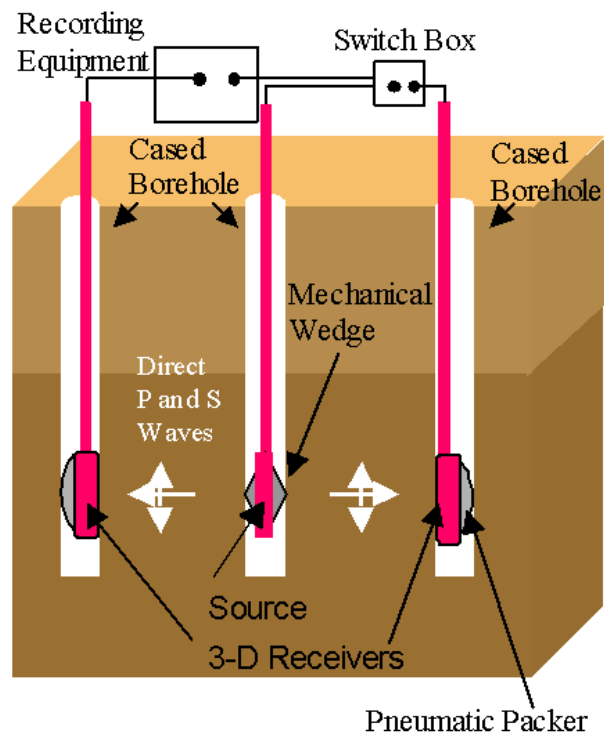
## Data Dictionary Table - Example

A1	B1	C1	D1	E1
Field Vane Shear Test Parameters				
A2	B2	C2	D2	E2
<b>Field Vane Shear Test Parameters</b>	The field vane shear test method is designed to determine the undrained shear strength of saturated clays. Standard testing procedures are described in ASTM D 2573. Relevant testing parameters are described in this table.			
<b>Name</b>	<b>Definition</b>	<b>Data Type</b>	<b>Example</b>	<b>Optional/Mandatory</b>
4	<b>Hole</b>	side	The hole, at which these field vane parameters is a part. The field vane parameters must be related to a part. This value is a foreign key value that select an instance of hole based on the id value of the hole.	Mandatory
5	<b>Vane Manufacturer</b>	text	The business name of the company manufacturing the field vane. For example, Geonor, Nelson, Asahi, etc.	
6	<b>Vane Type</b>	text	The type of vane used for testing. For example, Vane Borer, remikrakes, etc.	
7	<b>Vane Shape</b>	text	The shape of the four-bladed vane used for testing. Available vane shapes include: a) rectangular, b) single tapered, c) double tapered, or d) other.	
8	<b>Vane Size</b>	quantity	The height of the four-bladed vane.	
9	<b>Vane Diameter</b>	quantity	The diameter of the four-bladed vane.	
10	<b>Vane Blade Thickness</b>	quantity	The thickness of the four-bladed vane.	
11	<b>Torque Device</b>	text	The device used to apply torque to the vane. For example, spring drive, torque wrench, etc.	Mandatory
12	<b>Vane Rotation Rate</b>	quantity	The rate at which the vane is rotated during shear testing. This standard rate is 0.1 degree/second. The standard can accept a range of 0.05 to 0.2 degree/second.	
13	<b>Last Calibration Date</b>	date	The date of the last calibration of the vane shear apparatus. Specify how much time the vane was used since the last calibration.	
14	<b>Remarks</b>	text	A text descriptor providing additional information related to the Field Vane Shear Test Parameters and equipment especially if those differ from standard requirements.	
15	<b>Date Last Updated</b>	date	The date of the last update to the data in this table.	

## GEOPHYSICAL AND SEISMIC FIELD TESTS

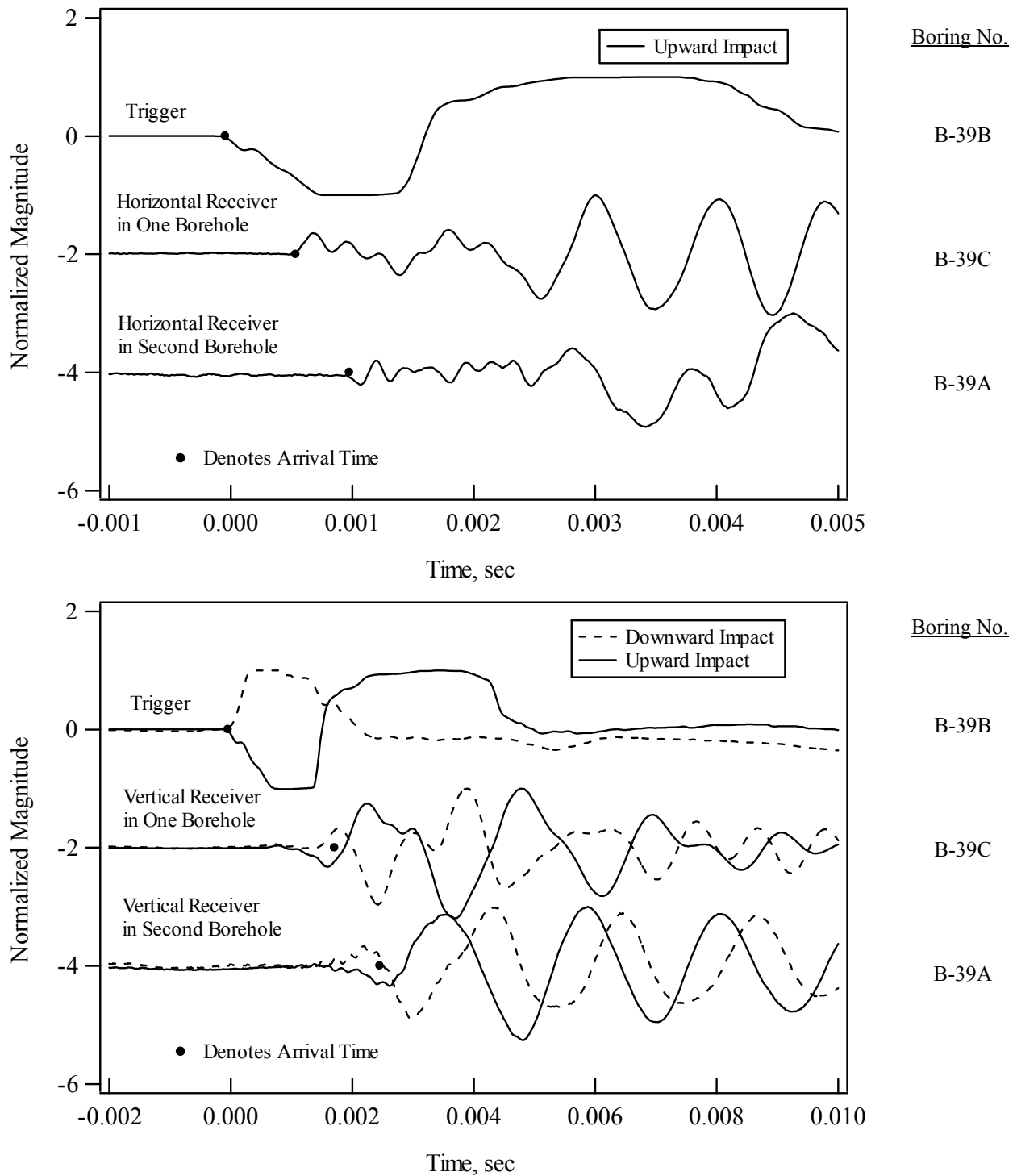
### CROSSHOLE SEISMIC TESTING BY K. STOKIE

#### Testing Arrangement



**Fig. A1.1** Simplified schematic of crosshole seismic testing with three boreholes.

### Typical Crosshole Records



**Fig. A1.2 Typical seismic waveforms recorded at a depth of 110 ft (~34 m) at Site 1: (a) SV-wave records; and (b) P-wave records in the two receiver boreholes.**



## Meta Data

1. Company Performing Test
2. Site Name and/or Test Name
3. Site Location:
  - Owner
  - City
  - State
  - GPS Coordinates
4. Test Date(s)
5. Weather Conditions
6. Description of Site Profile
  - Layer Depths and Material Types
  - Depth to Water Table
7. Range of Test Depths
8. General Borehole Information
  - Number of Boreholes
  - Names of Boreholes
  - Depths of Boreholes
  - Borehole Drilling Procedure
  - Borehole Diameter
  - Cased or Uncased Boreholes
    - type of casing
    - OD of casing
    - wall thickness of casing
    - casing grouted in place
    - type of grout
  - Borehole Conditions
    - dry
    - borehole (or casing) full of water
    - depth to water in borehole if not full
9. Inclination of Boreholes
  - Company Performing Test
  - Manufacturer and Model No. of Inclinator
  - Date of Traceable (by NIST traceable equipment and an independent company) Calibration
  - Date of In-House Calibration
  - Measurement Depth Interval
  - Resolution and/or Accuracy

## 10. Arrangement of Boreholes for Seismic Testing

- Orientation of Array
  - in line (linear array)
  - $\sim 90^\circ$  angle in array
  - other (describe)
  - orientation of array
- Distance Between Adjacent Boreholes (with borehole names)
- Wave Travel Paths Used During Testing
- Type of Measurement Along Each Travel Path
  - true interval (receiver-to-receiver)
  - direct (source-to-receiver)
  - pseudo-interval (sometimes used with two-channel recorder and three boreholes)

## 11. Seismic Source

- P-Wave Source
  - impact or explosive
  - mechanical, electro-mechanical, hydraulic, etc.
  - loading direction
  - one direction or reversible
  - wireline or oriented
  - if oriented, orientation mechanism
- S-Wave Source
  - impact or explosive
  - mechanical, electro-mechanical, hydraulic, etc.
  - loading direction
  - one direction or reversible
  - wireline or oriented
  - if oriented, orientation mechanism

## 12. Seismic Recorder

- Manufacturer and Model No.
- Number of Channels
- Maximum Frequency Range or Minimum Digitization Time Interval
- Amplitude Resolution (digitization bites for minimum voltage level)
- Time Averaging
- Filtering and Ranges Used
- Company Performing and Date of Calibration:
  - independent NIST-traceable calibration
  - in-house calibration with NIST-traceable standards
  - in-house calibration with “local” standards
  - if in-house calibration, date standards were calibrated and company performing calibration
- Field Calibration of Recorder
  - none
  - independent waveform generator
  - manufacturer and model no. of waveform generator
  - date when waveform generator was last calibrated

### 13. Seismic Receivers

- Geophones or Accelerometers
- Manufacturer and Model No.
- 1D, 2D or 3D Receivers
- Number of 1D, 2D or 3D receivers
- Company Performing and Date of Calibration:
  - independent NIST-traceable calibration
  - in-house calibration with NIST-traceable standards
  - in-house calibration with “local” standards
  - if in-house calibration, date standards were calibrated and company performing calibration
- Calibration of Receivers
  - frequency range
  - calibration constant and/or calibration curve
- Method of Locking Receivers in Borehole
  - metal spring
  - inflatable bladder
  - other
  - none (freely hanging)
- Method of Orienting Horizontal Receivers if Using 2D or 3D Packages
  - none
  - rods to the ground surface
  - locking and rotating system
  - none (freely hanging)

## Measurement Data

**Table A1.1 Results of the field calibration of the Agilent Dynamic Signal Analyzer performed December 13, 2002.**

Instrument	Agilent Dynamic Signal Analyzer 35670A, Serial No.MY41005676			
Equipment Used	Hewlett Packard Function Generator Model 3314A, Serial No. 2836A11170 NIST Traceable Calibration through 3/15/2003			
Calibration Date	12/13/02			
Frequency Span	12.0 kHz			
Input	Square Wave			
Frequency	100, 200 Hz			
Frequency Hz	Input Amplitude V	Expected $\Delta t$ ms	Measured $\Delta t$ ms	Channel No.
100	1.0	10.00	10.0098	1
100	1.0	10.00	10.0098	2
100	1.0	10.00	10.0098	3
100	1.0	10.00	10.0098	4
200	1.0	5.00	5.0049	1
200	1.0	5.00	5.0049	2
200	1.0	5.00	5.0049	3
200	1.0	5.00	5.0049	4

**Table A1.2 Source/receiver calibration factors as measured in the field.**

3-D Receiver	Geophone Orientation	Calibration Factor (ms)
GRC01 (Orange-Cabled)	Vertical	-0.160
	Horizontal 1	-0.229
	Horizontal 2	-0.229
GRC02 (Black-Cabled)	Vertical	-0.160
	Horizontal 1	-0.229
	Horizontal 2	-0.229

**Table A1.3 Borehole separations, Northings and Eastings for U-7 boreholes.**

Depth (ft)	Distance between U-7AR & U-7BR (ft)	U-7AR		U-7BR	
		Northing (ft)	Easting (ft)	Northing (ft)	Easting (ft)
2.1	9.99	31321.74	55718.56	31311.78	55717.83

**Table A1.4 Crosshole test results: horizontally propagating waves at Site 1 measured between borings 39B and 39C.**

**Wave Velocities from Boring 39B to Boring 39C**

**Crosshole Site 1**

Shear Wave Calibration Time (ms) = -0.160  
P Wave Calibration Time (ms) = -0.229

Meas. Depth (ft)	Path Length (ft)	Travel Time		Corrected Travel Time*		Velocity		Poisson's Ratio
		Shear Wave (ms)	P Wave (ms)	Shear Wave (ms)	P Wave (ms)	Shear Wave (fps)	P Wave (fps)	
5	9.576	4.623	1.679	4.783	1.908	2002	5019	0.41
7.5	9.564	3.586	1.373	3.746	1.602	2553	5970	0.39
10	9.580	3.449	1.205	3.609	1.434	2654	6680	0.41
12.5	9.601	3.464	1.083	3.624	1.312	2649	7318	0.42
15	9.625	3.067	0.839	3.227	1.068	2983	9012	0.44
17.5	9.686	2.502	0.809	2.662	1.038	3639	9331	0.41
20	9.700	2.258	0.763	2.418	0.992	4012	9779	0.40
25	9.724	2.304	0.717	2.464	0.946	3946	10279	0.41
30	9.699	2.121	0.717	2.281	0.946	4252	10253	0.40
35	9.645	1.877	0.626	2.037	0.855	4735	11281	0.39
40	9.558	1.785	0.671	1.945	0.900	4914	10620	0.36
45	9.488	1.602	0.610	1.762	0.839	5385	11309	0.35
50	9.371	1.556	0.580	1.716	0.809	5461	11584	0.36
55	9.269	1.572	0.595	1.732	0.824	5352	11249	0.35
60	9.192	1.617	0.610	1.777	0.839	5173	10956	0.36
70	9.067	1.602	0.595	1.762	0.824	5146	11004	0.36
80	9.096	1.755	0.610	1.915	0.839	4750	10841	0.38
90	8.831	1.755	0.610	1.915	0.839	4611	10525	0.38
100	8.450	1.755	0.580	1.915	0.809	4412	10445	0.39
110	8.152	1.755	0.580	1.915	0.809	4257	10076	0.39
115	7.896	1.541	0.473	1.701	0.702	4642	11248	0.40
120	7.620	1.434	0.443	1.594	0.672	4780	11339	0.39
125	7.425	1.419	0.412	1.579	0.641	4703	11584	0.40
130	7.204	1.297	0.412	1.457	0.641	4945	11239	0.38
140	6.697	1.099	0.366	1.259	0.595	5319	11256	0.36
150	6.175	1.312	0.351	1.472	0.580	4195	10646	0.41

\* Corrected Travel Time = [Travel Time measured from the source-to-receiver] - [Calibration Time]

## BOREHOLE GEOPHYSICS DATA DICTIONARY BY W. OWEN

### COSMOS Data Dictionary Workshop

#### Borehole Geophysics Data Dictionary

Bill Owen, CEG, RGP  
California Department of Transportation  
Geophysics and Geology Branch

### Borehole Geophysical Logs

#### Why Log?

- Collect unbiased continuous and in-situ data
- Sample a larger volume than core and cuttings
- Correlate between boreholes
- Provide information on unsampled boreholes

### Borehole Geophysical Log Interpretation

- No unique interpretation of a single geophysical log
- Multiple logs are collected and interpreted together
- Qualified with lithologic logging, sampling and laboratory testing
- Most geophysical interpretations are qualitative instead of quantitative

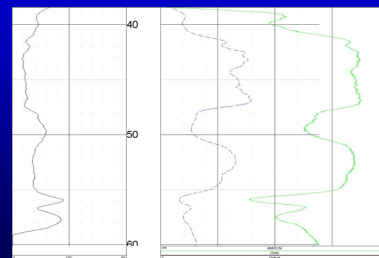
### Cost Savings Using Borehole Geophysics

- More thorough site characterization
- Reduce the number of required borings
- Reduce the number of laboratory sample analysis
- At Caltrans, cost savings realized through use of in-house expertise for routine geophysical services

### Typical Logs Available

- Typical Borehole Logs
  - PS Log
  - Caliper
  - Natural Gamma
  - Induction
  - Acoustic Televiwer
  - Full Waveform Sonic
  - Resistivity
  - Density

### Example: Conductivity Log



### Existing Standards

- LAS – CWLS  
– ASCII
- WITSML – POSC  
– XML Schema

### Proposed Dictionary

- Based on LAS version 2.0
- Version 3.0 compatibility also needed
- Easy to convert to POSC XML Schema

### Proposed Logs for Inclusion

- Caliper
- Natural Gamma
- Resistivity
- Conductivity
- SP

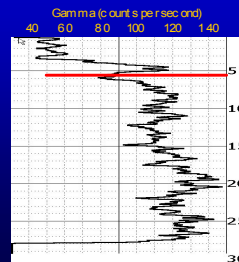
### Other Logs

- Neutron Porosity
- Gamma Density
- Delta-Time (slowness)
- Velocity
- Sonic Porosity

### Not Proposed

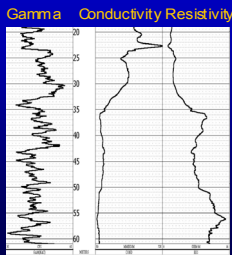
- Acoustic Televiwer  
– Extracted fracture and bed attitudes may be capable of inclusion
- Sonic Waveforms
- Linear graph data better adapted to format

### Natural Gamma



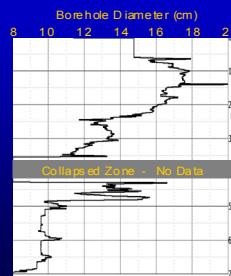
- Coarse grain, thick bedded sands and gravels from surface to 4 m bgs
- Fine grain, thin bedded silts and clays below 4 m bgs

## Induction



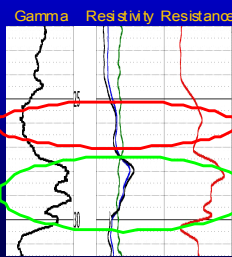
- Log collected in PVC cased boring
- Material change from soft/wet soil to rock noted by increase in resistivity at 35.5 m bgs
- Spike in conductivity at 23 m probably due to saline groundwater

## Caliper



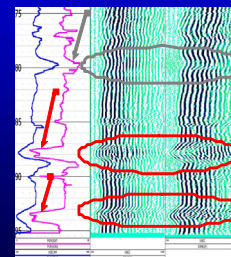
- Nominal boring diameter 9.4 cm
- Washouts to 35.5 m bgs
- Collapsed borehole in fractured rock 35.5 m to 43 m, fractured rock to 49 m bgs

## Resistivity



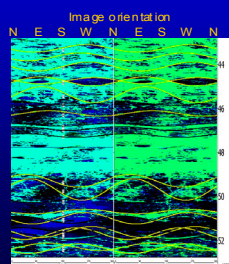
- Low gamma and elevated resistivity suggest coarse grained material at 25.5 m to 27 m bgs
- Elevated gamma and elevated resistivity suggest sand derived from granite at 27.5 m to 30 m bgs

## Full Wave Form Sonic Log



- Collected in open borehole
- Porosity, Slowness, Waveform quality
- Decreased porosity at 88 m and 94 m bgs
- Increased porosity at 79.5 m bgs

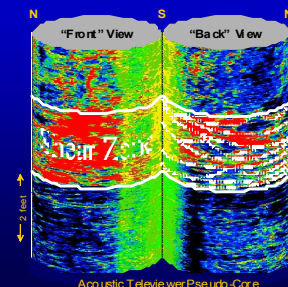
## Acoustic Televiewer



- Harder rock shown as darker color
- In this example, bedding appears as low amplitude sine waves and fractures appear as high amplitude sine waves that cross other features

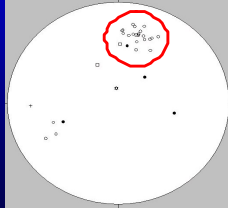
## Acoustic Televiewer Log

- Fracture/Bedding Orientation
- Stratigraphic Delineation
- Compressional-Wave Velocity
- Borehole Deviation
- Borehole Eccentricity

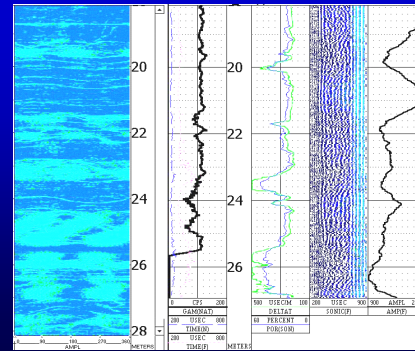




## Stereonet Plot of Acoustic Televiewer picks



- Stereonet plot of features picked as bedding, plotted as poles-to-planes
- Preferred orientation of south dipping bedding planes



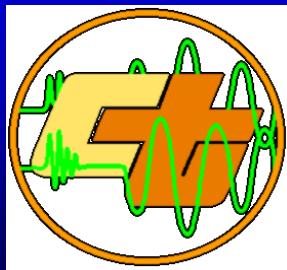
## PS Suspension Log

- Compressional and Shear-Wave Velocities
- Stratigraphic Delineation
- Shear Modulus Determination
- Density Estimation
- Input for Earthquake Ground Response Modeling

## Seismic Ground Response Analysis

- Standard Acceleration Response Spectrum (ARS)
  - Typical Soil/Rock Profiles
  - MCE Range 6.5-8.0
- Site-Specific ARS
  - Liquefiable soils
  - significant organic soils/soft clays

**Geophysicist's Role:**  
 Acquire seismic velocity data needed to develop site-specific ground response models  
 Derive Shear and Bulk Moduli from Velocity Data



## SASA SEISMIC TESTING BY K. H. STOKE

### Testing Arrangement

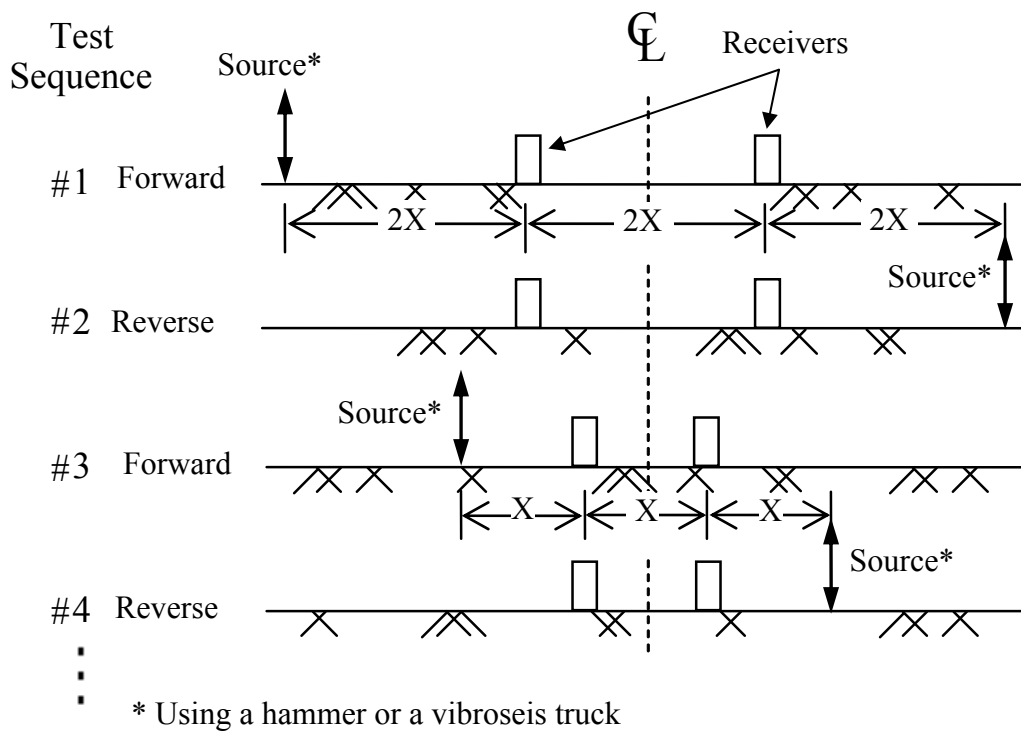


Fig. A1.3 Common receivers-midpoint geometry often used in SASW testing.

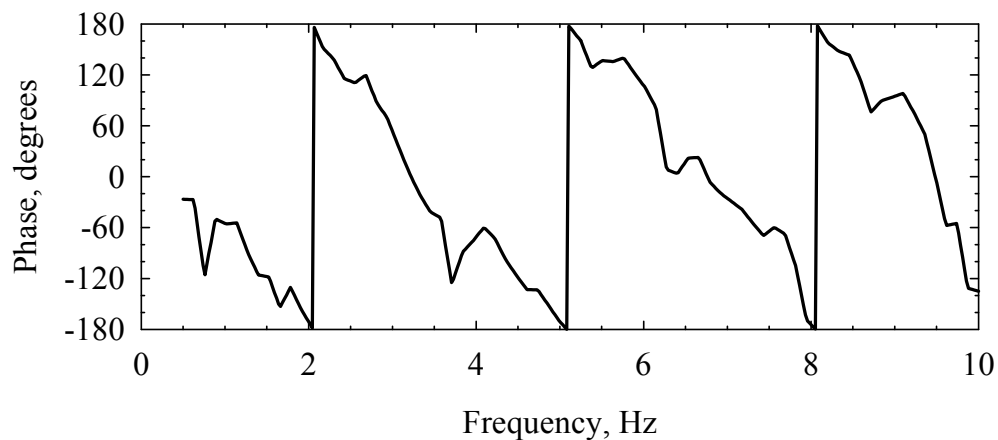


Fig. A1.4 Phase plots measured by SASW testing with 750-ft receiver spacing at Site YM 1.

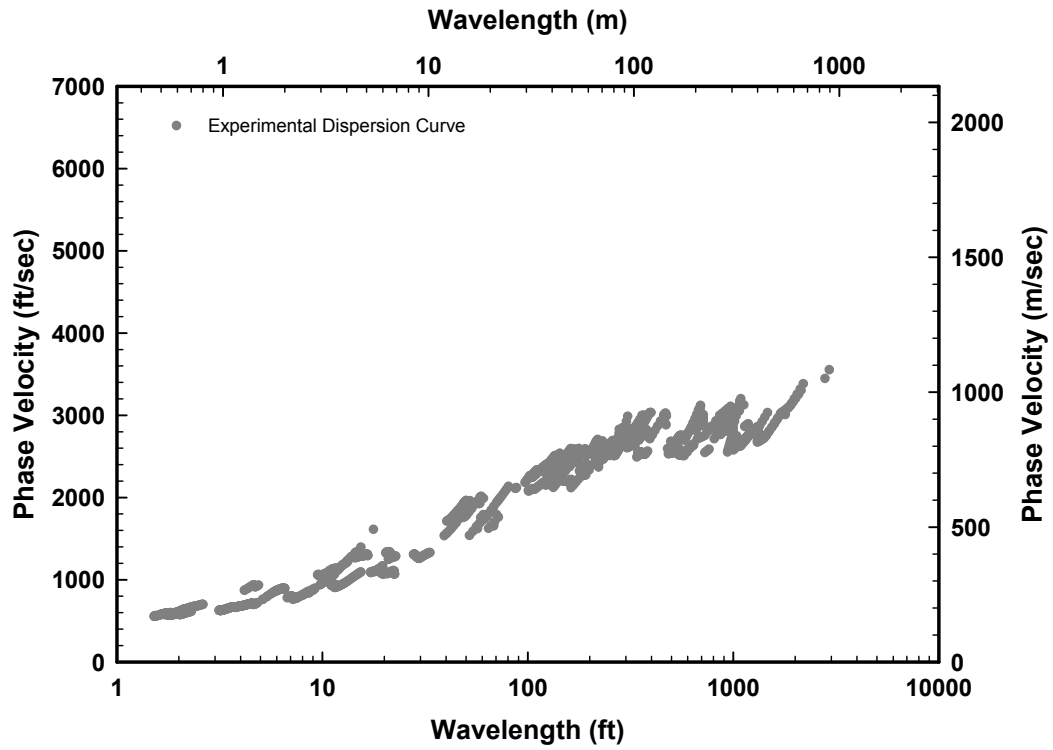
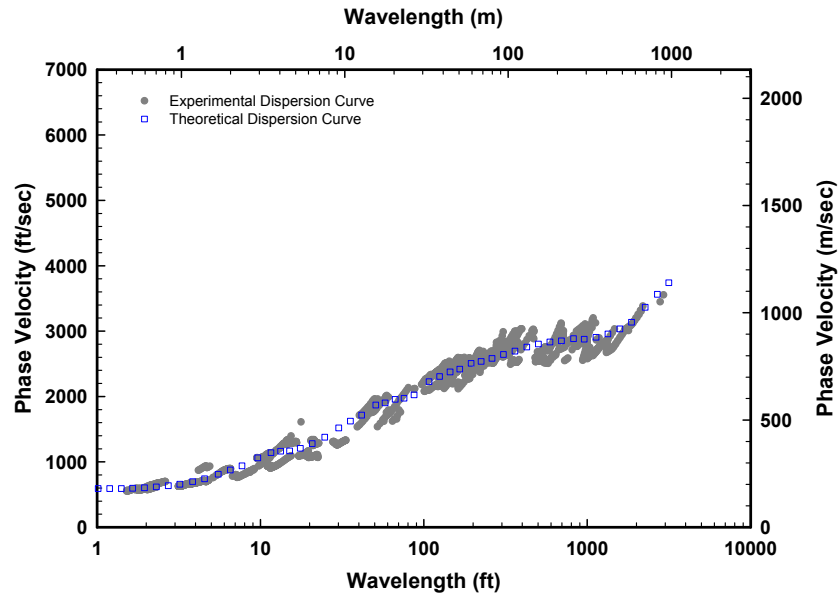


Fig. A1.5 Experimental dispersion curve measured at YM 1.

## Typical Data Analysis (Forward Modeling or Inversion) and Results



**Fig. A1.6 Experimental and theoretical dispersion curves from YM 1.**

**Table A1.5 Profile parameters used to develop theoretical dispersion curve at Site YM 1.**

Layer No.	Thickness, ft	Depth to Top of Layer, ft	S-Wave Velocity, ft/s	Assumed Poisson's Ratio	P-Wave Velocity, ft/s	Assumed Mass Density, pcf
1	1.4	0	630	0.30	1179	120
2	1	1.4	830	0.30	1553	120
3	0.5	2.4	1100	0.30	2058	120
4	7	2.9	1300	0.30	2432	120
5	17	10	2000	0.30	3742	130
6	10	26	2300	0.30	4303	130
7	30	36	2600	0.30	4864	130
8	130	66	3150	0.30	5893	130
9	350	196	3300	0.30	6174	130
10	400	546	3000	0.30	5613	130
11	520	946	4800	0.30	8980	130

## Meta Data

1. Company Performing Test
2. Site Name and/or Test Name
3. Site Location:
  - Owner
  - City
  - State
  - GPS Coordinates
4. Test Date(s)
5. Weather Conditions
6. Description of Site Profile if Available
  - Layer Depths and Material Types
  - Depth to Water Table
7. Range of Wavelengths or Frequencies Measured
8. Arrangement of SASW Array
  - Orientation of Array
    - in line (linear array)
    - geometrical pattern
    - other (describe)
    - orientation of array
  - Minimum and Maximum Lengths of Array
  - All Sets of S-R1 and R1-R2 Distances
9. Seismic Recorder
  - Manufacturer and Model No.
  - Number of Channels
  - Maximum Frequency Range or Minimum Digitization Time Interval
  - Amplitude Resolution (digitization bites for minimum voltage level)
  - Time Averaging or Frequency Averaging
  - Filtering and Ranges Used
  - Company Performing and Date of Calibration:
    - independent NIST-traceable calibration
    - in-house calibration with NIST-traceable standards
    - in-house calibration with “local” standards
    - if in-house calibration, date standards were calibrated and company performing calibration
  - Field Calibration of Recorder
    - none
    - independent waveform generator
    - manufacturer and model no. of waveform generator
    - date when waveform generator was last calibrated
10. Seismic Sources
  - Hand-Held Hammers
    - sizes
  - Electro-Magnetic Shaker
    - size

- Bulldozer
  - size
- Vibroseis
  - size
- Other

#### 11. Seismic Receivers

- Geophones or Accelerometers
- Manufacturer and Model No.
- 1D, 2D or 3D Receivers
- Number of 1D, 2D or 3D receivers
- Company Performing and Date of Calibration:
  - independent NIST-traceable calibration
  - in-house calibration with NIST-traceable standards
  - in-house calibration with “local” standards
  - if in-house calibration, date standards were calibrated and company performing calibration
- Calibration of Receivers
  - frequency range covered
  - calibration constant and/or calibration curve
- Method of Vertically Orienting Receivers
  - “by eye”
  - level bubble
  - other

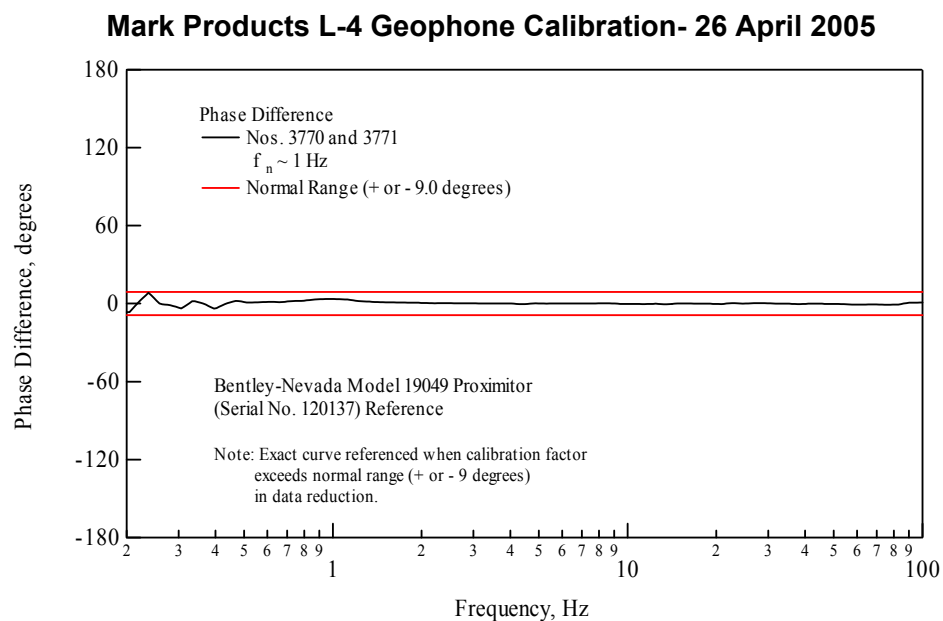
#### 12. Analysis of Dispersion Curve

- Simplified/Empirical
  - describe
- Forward Modeling
  - software name
  - only fundamental mode
  - all modes and wave types
  - global analysis
  - array-based analysis
- Inversion
  - software name
  - only fundamental mode
  - all modes and wave types
  - global analysis
  - array-based analysis
  - resolution matrix

## Measured Data

**Table A1.6 Results of field calibration of the Agilent Dynamic Signal Analyzer performed December 13, 2002.**

Instrument	Agilent Dynamic Signal Analyzer 35670A, Serial No.MY41005676			
Equipment Used	Hewlett Packard Function Generator Model 3314A, Serial No. 2836A11170 NIST Traceable Calibration through 3/15/2003			
Calibration Date	12/13/02			
Frequency Span	12.0 kHz	} this will change		
Input	Square Wave			
Frequency	100, 200 Hz			
Frequency Hz	Input Amplitude V	Expected $\Delta t$ ms	Measured $\Delta t$ ms	Channel No.
100	1.0	10.00	10.0098	1
100	1.0	10.00	10.0098	2
100	1.0	10.00	10.0098	3
100	1.0	10.00	10.0098	4
200	1.0	5.00	5.0049	1
200	1.0	5.00	5.0049	2
200	1.0	5.00	5.0049	3
200	1.0	5.00	5.0049	4



**Fig. A1.7 Phase difference between Mark Products L4 Geophones 3770 and 3771, 1-Hz resonant frequency; calibrated relative to Bently-Nevada Model 19049 Proximator (Serial No. 120137) - 26 April 2005.**



**Table A1.7 Calibration curve of “matched” receiver pair.**

<b>Phase Difference (degree)</b>	<b>Frequency (Hz)</b>
0.562923	1.99412
0.516249	2.03704
0.458246	2.08088
0.399112	2.12566
0.339978	2.17141
0.280843	2.21814
0.291211	2.26588
0.312082	2.31464
0.332953	2.36446
0.353824	2.41534
0.330936	2.46732
0.298978	2.52042
0.267016	2.57467
0.235057	2.63008
0.222669	2.68668
0.215549	2.7445
0.208429	2.80356
0.201311	2.8639
0.188156	2.92554
0.172965	2.9885
0.15777	3.05281
0.142578	3.11851
0.135415	3.18563
0.131579	3.25419
0.127745	3.32422
0.123907	3.39576
0.112874	3.46884
0.0982411	3.5435
0.0836075	3.61976
0.0689753	3.69766
0.0541742	3.77724
0.0392733	3.85853
0.024373	3.94157
0.00947167	4.0264
-0.0661402	4.11305
-0.184669	4.20157
-0.303197	4.29199

**Table A1.8 Tabulated experimental (“field”) dispersion curve of Site YM 2 (total 2106 data points from 14 test spacings).**

<b>S - R1 (ft)</b>	<b>R1 - R2 (ft)</b>	<b>V<sub>R</sub>(fps)</b>	<b>Frequency (Hz)</b>	<b>Wave Length (ft)</b>
75	75	3098.9	20.9875	147.655
		3070.02	22.8125	134.576
		3425.33	24.6375	139.029
		3181.5	26.4625	120.227
		3309.81	28.2875	117.006
		3015.77	30.1125	100.15
		3157.05	32.12	98.2894
		2834.25	33.945	83.4954
		2760.32	35.77	77.1686
		3121.4	37.595	83.0271
		3168.22	39.42	80.3708
		3250.83	41.245	78.8175
		3426.18	43.07	79.5492
		3284.46	44.895	73.1588
		3143.92	46.72	67.2928
		3063.92	48.545	63.115
		2901.03	50.37	57.5945
		2830.76	51.465	55.0037

**Table A1.9 Theoretical dispersion curve that matches the field dispersion curve.**

<b>Wave Length (ft)</b>	<b>V<sub>R</sub> (fps)</b>
1.01	593
2.30	618
5.51	812
13.29	1165
30.11	1520
66.80	1957
144.57	2376
307.02	2644
694.63	2852
1581.65	3034
3157.28	3741

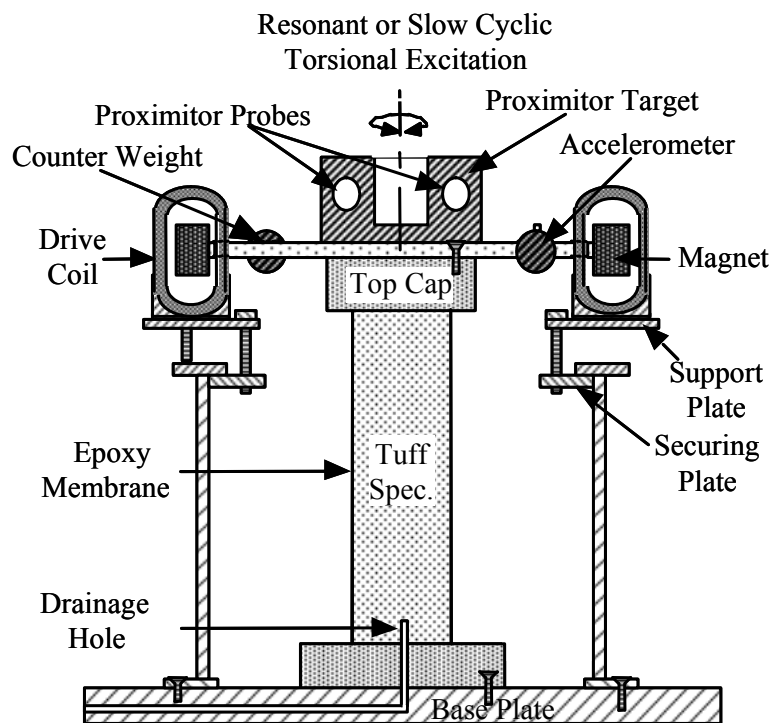
**Table A1.9 Profile parameters used to develop theoretical dispersion curve at Site YM 1.**

<b>Layer No.</b>	<b>Thickness, ft</b>	<b>Depth to Top of Layer, ft</b>	<b>S-Wave Velocity, ft/s</b>	<b>Assumed Poisson's Ratio</b>	<b>P-Wave Velocity, ft/s</b>	<b>Assumed Mass Density, pcf</b>
1	1.4	0	630	0.30	1179	120
2	1	1.4	830	0.30	1553	120
3	0.5	2.4	1100	0.30	2058	120
4	7	2.9	1300	0.30	2432	120
5	17	10	2000	0.30	3742	130
6	10	26	2300	0.30	4303	130
7	30	36	2600	0.30	4864	130
8	130	66	3150	0.30	5893	130
9	350	196	3300	0.30	6174	130
10	400	546	3000	0.30	5613	130
11	520	946	4800	0.30	8980	130

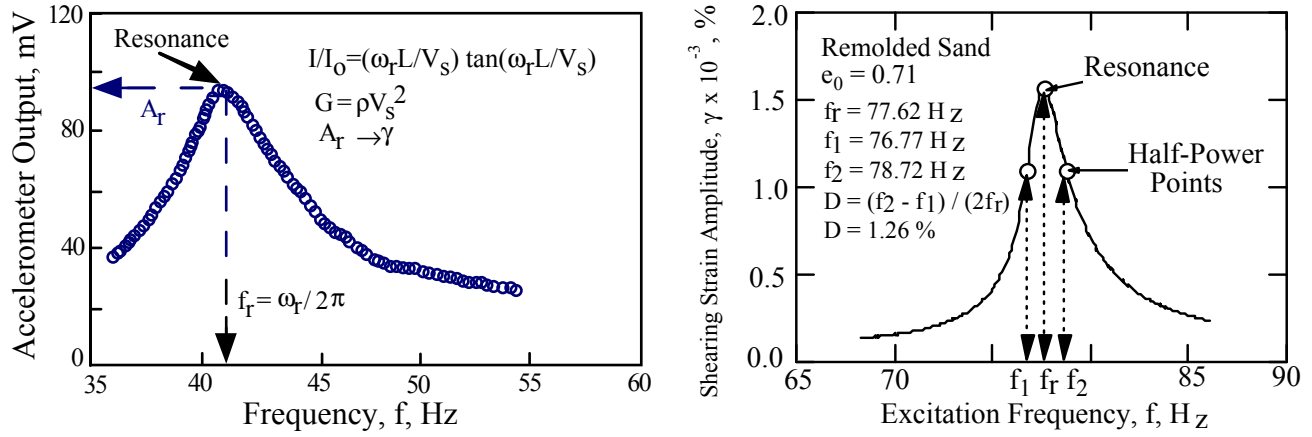
## SEISMIC LABORATORY TESTS

### RESONANT COLUMN AND TORSIONAL SHEAR TESTING BY K. H. STOKIE

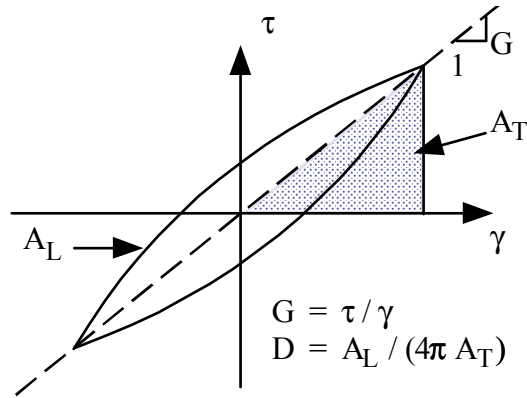
#### Test Configuration and Equipment



**Fig. A1.8 Combined resonant column and torsional shear device (confining chamber not shown).**

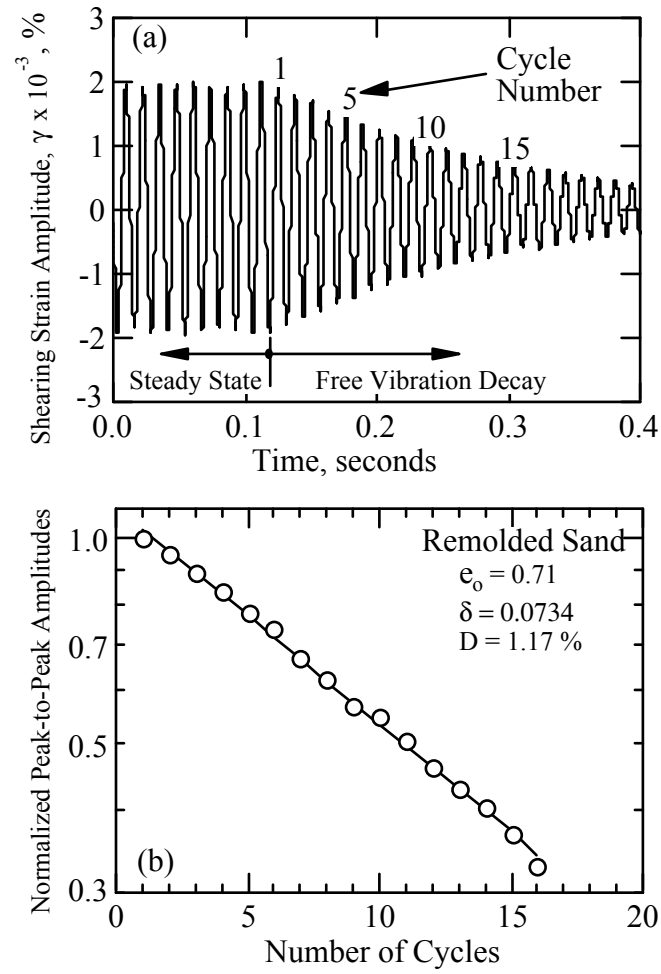


(a) Dynamic Response Curve Measured in the RC Test

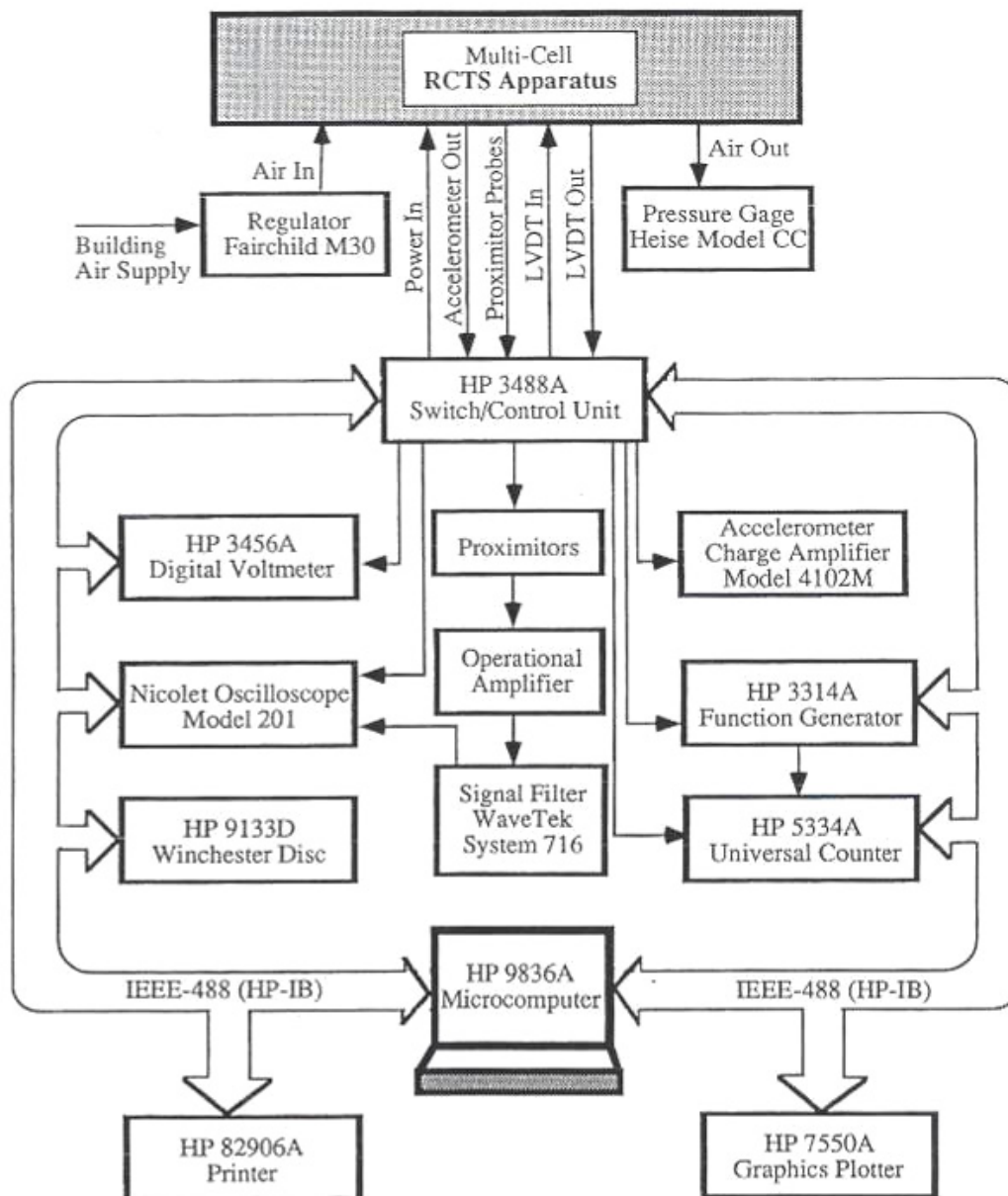


(b) Hysteresis Loop Measured in the TS Test

**Fig. A1.9 Examples of measurements performed in the resonant column and torsional shear tests.**



**Fig. A1.10 Material damping measurement in the resonant column test using the free-vibration decay curve.**



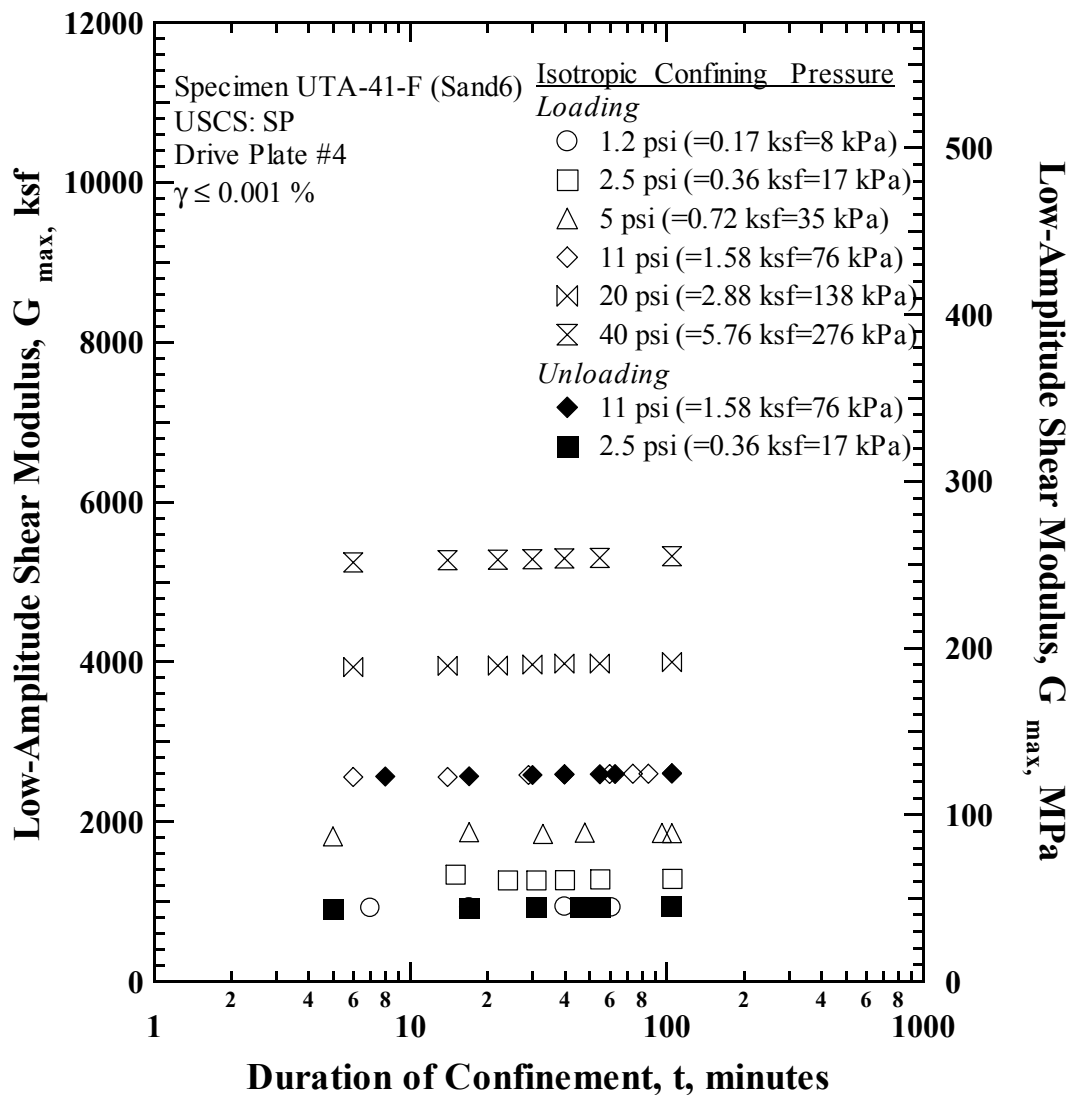
**Fig. A1.11 Configuration of computerized RCTS equipment.**

**Table A1.11 List of equipment for resonant column and torsional shear testing calibrated at the University of Texas at Austin.**

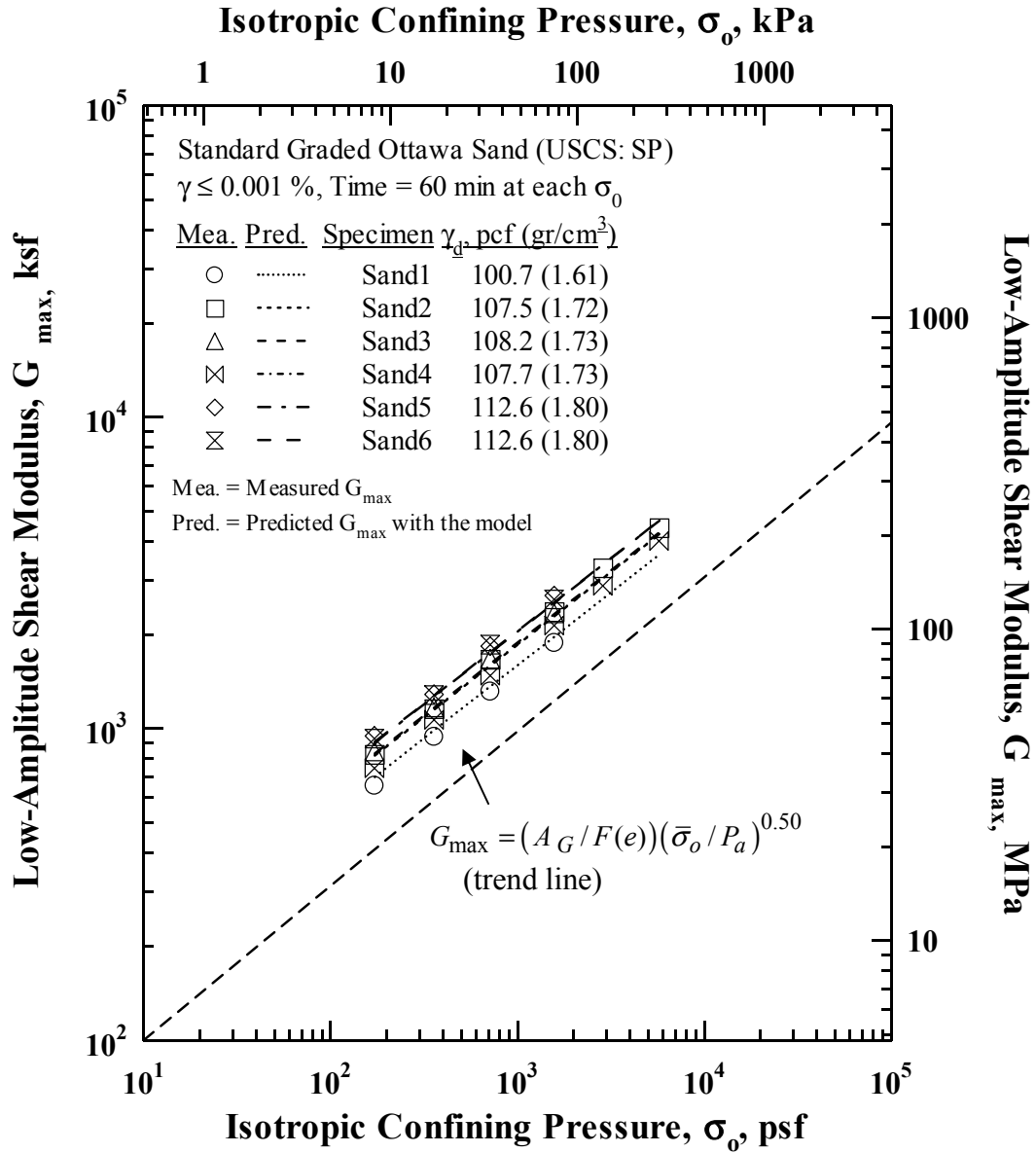
EQUIPMENT	DESCRIPTION	SERIAL NUMBER	CALIBRATION NUMBER	CALIBRATION DATE	EXPIRATION DATE
Sauter RC 4021hp	Weight Balance	UT617925	2005-01	6/16/2005	6/16/2006
HP 3314A	Function Generator	2141A02471	2005-02	6/16/2005	6/16/2006
HP 3458A	Digital Multimeter	2823A12370	2005-03	6/16/2005	6/16/2006
HP 5334A	Universal Counter	2350A00797	2005-04	6/17/2005	6/17/2006
Columbia Model 4102M	Charge Amplifier	480	2005-05	6/27/2005	6/27/2006
Columbia Model 302-6	Accelerometer (No. 1)	3878	2005-06	6/27/2005	6/27/2006
Columbia Model 302-6	Accelerometer (No. 2)	2919	2005-07	6/27/2005	6/27/2006
Ashcroft (0-100psi)	Pressure Gage (No.	UT279327	2005-08	6/28/2005	6/28/2006
Ashcroft (0-600psi)	Pressure Gage	UT289551	2005-09	6/28/2005	6/28/2006
Heise CM-60750 (0 -14psi)	Vacuum Gage	UT409547	2005-10	6/28/2005	6/28/2006
L.S. Starrett 763	Micrometer	1	2005-11	6/29/2005	6/29/2006
Brown and Sharpe	Micrometer	2	2005-12	6/29/2005	6/29/2006
Mitutoyo	Digital Caliper	5204589	2005-13	6/29/2005	6/29/2006
Bently Nevada 330100--50-05	Proximitior (4-Y and 5-Y)	FEB G106073	2005-14	6/30/2005	6/30/2006
Bently Nevada 330100--50-05	Proximitior (4-R and 5-R)	FEB G106076	2005-15	6/30/2005	6/30/2006
Columbia Model SH-200-S3R	LVDT	7907	2005-16	6/30/2005	6/30/2006
Columbia Model SH-200-S3R	LVDT	77002	2005-17	6/30/2005	6/30/2006
University of Texas (TC)	2.5 in. Stainless Steel Top	1	2005-18	7/1/2005	7/1/2006
University of Texas (TC)	2.5 in. Stainless Steel Top	2	2005-19	7/1/2005	7/1/2006
University of Texas (TC)	2.5 in. Stainless Steel Top	3	2005-20	7/1/2005	7/1/2006
University of Texas (TC)	2.5 in. Stainless Steel Top	4	2005-21	7/1/2005	7/1/2006
University of Texas (TC)	2.5 in. Stainless Steel Top	5	2005-22	7/1/2005	7/1/2006
University of Texas (TC)	2.8 in. Aluminum Top Cap	6	2005-23	7/1/2005	7/1/2006
University of Texas (TC)	2.0 in. Aluminum Top Cap	7	2005-24	7/1/2005	7/1/2006
University of Texas (TC)	2.0 in. Stainless Steel Top	8	2005-25	7/1/2005	7/1/2006
University of Texas (TC)	2.8 in. Stainless Steel Top	9	2005-26	7/1/2005	7/1/2006
University of Texas (TC)	2.0 in. Aluminum Top Cap	10	2005-27	7/1/2005	7/1/2006
University of Texas (TC)	2.0 in. Aluminum Top Cap	11	2005-28	7/1/2005	7/1/2006
University of Texas (CP)	Stainless Steel Calibration	1	2005-29	7/1/2005	7/1/2006
University of Texas (CP)	Stainless Steel Calibration	2	2005-30	7/1/2005	7/1/2006
University of Texas (CP)	Stainless Steel Calibration	3	2005-31	7/1/2005	7/1/2006
University of Texas (DP)	Drive Plate	4	2005-32	7/4/2005	7/4/2006
University of Texas (DP)	Drive Plate	5	2005-33	7/7/2005	7/7/2006
HP 3478A	Digital Multimeter	2520A19650	2005-34	6/17/2005	6/17/2006
Nicolet Model 201	Oscilloscope	UT337671	2005-35	6/20/2005	6/20/2006
Tektronix AM 501	Operational Amplifier	UT309931	2005-36	6/21/2005	6/21/2006
HP 6824A	Power Supply Amplifier	1716A02655	2005-37	6/22/2005	6/22/2006
Lambda Model LL-903	Regulated Power Supply	UT238462	2005-38	6/21/2005	6/21/2006
University of Texas (DC-	DC-Shifter	1	2005-39	6/23/2005	6/23/2006
Wavetek System 716	Digital Signal Filter	UT416434	2005-40	6/24/2005	6/24/2006
University of Texas (TC)	1.5 in. Stainless Steel Top	12	2005-41	7/1/2005	7/1/2006
University of Texas (TC)	1.5 in. Stainless Steel Top	13	2005-42	7/1/2005	7/1/2006
University of Texas (TC)	1.5 in. Aluminum Top Cap	14	2005-43	7/1/2005	7/1/2006
University of Texas (TC)	1.5 in. Aluminum Top Cap	15	2005-44	7/1/2005	7/1/2006
Agilent 33120A	Function Generator	UT761757	2005-45	6/16/2005	6/16/2006
MB Dynamics SS530	Power Supply Amplifier	UT625383	2005-46	6/22/2005	6/22/2006



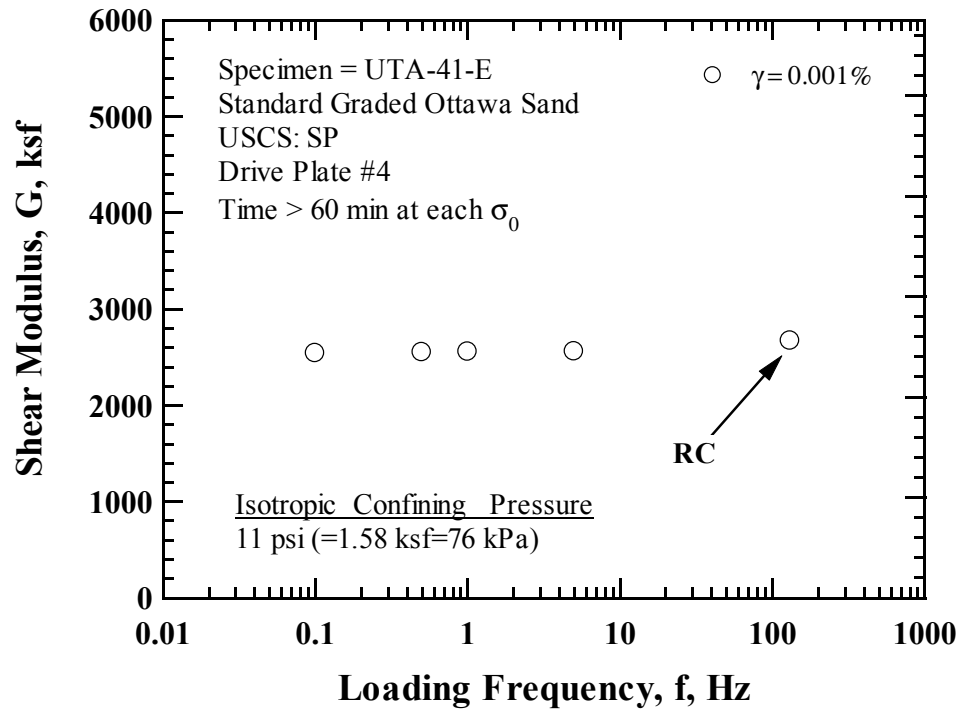
## Typical Measurements



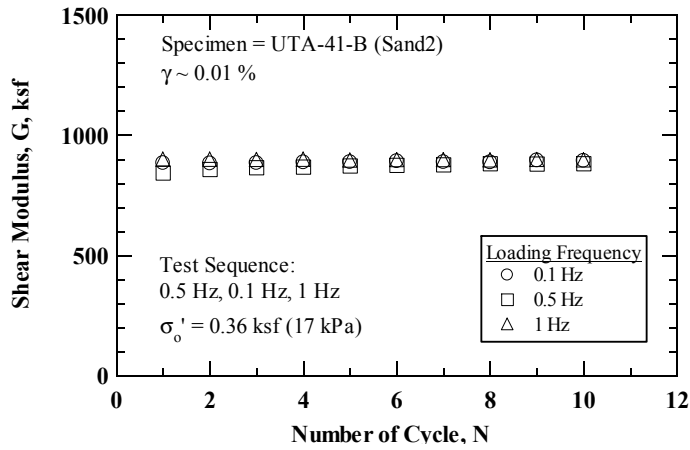
**Fig. A1.12 Variation in low-amplitude shear modulus with magnitude and duration of isotropic confining pressure from resonant column tests of Specimen UTA-41-F (Sand6).**



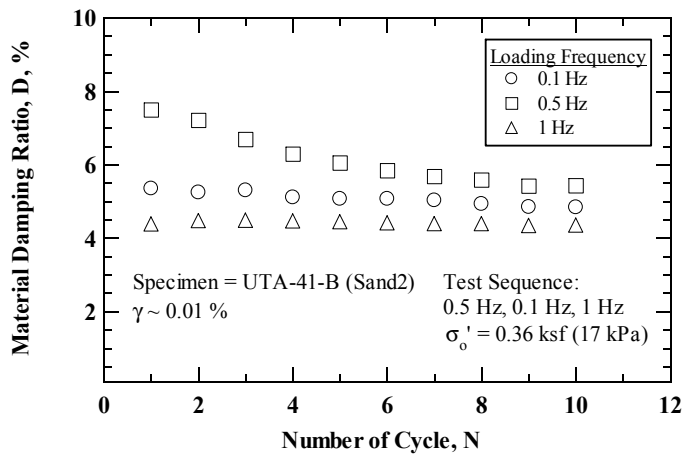
**Fig. A1.13** Variation in low-amplitude shear modulus with isotropic confining pressure of the six, standard graded Ottawa sand specimens as determined from resonant column tests.



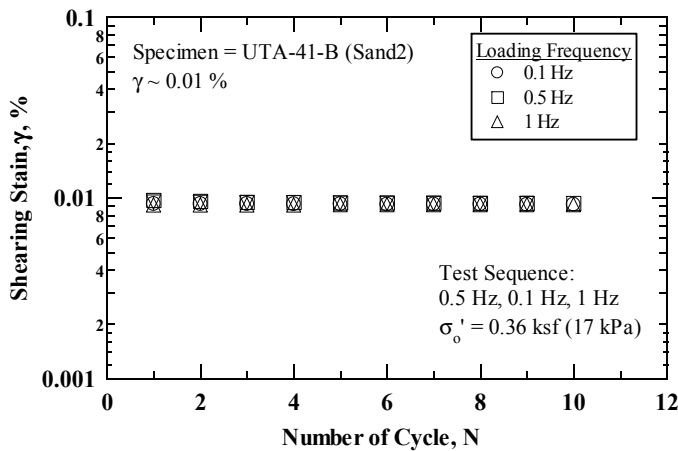
**Fig. A1.14 Comparison of the Variation in Shear Modulus with Loading Frequency at an Isotropic Confining Pressure of 11 psi (= 1.58 ksf = 76 kPa) from the Combined RCTS Tests of Specimen UTA-41-F (Sand6).**



(a) Shear Modulus, G

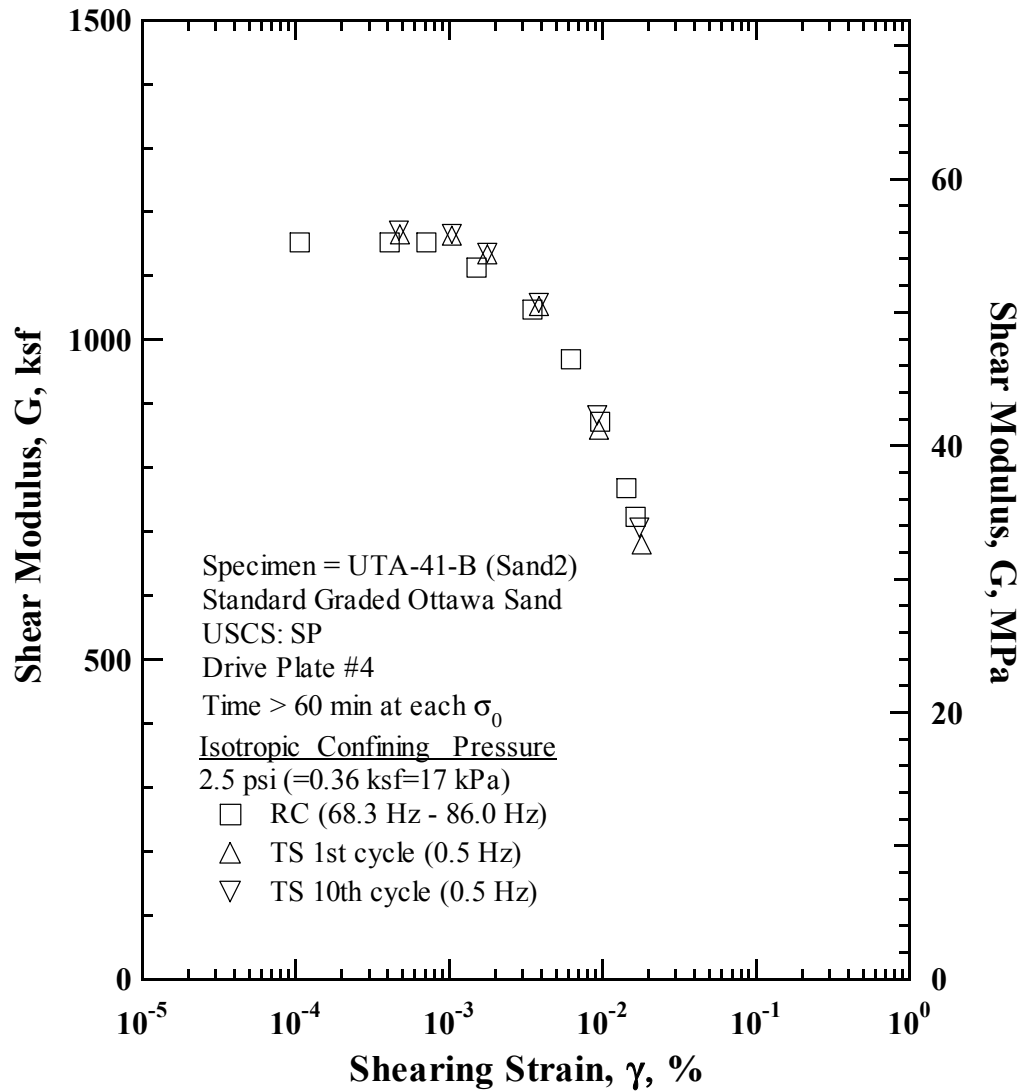


(b) Material Damping Ratio, D

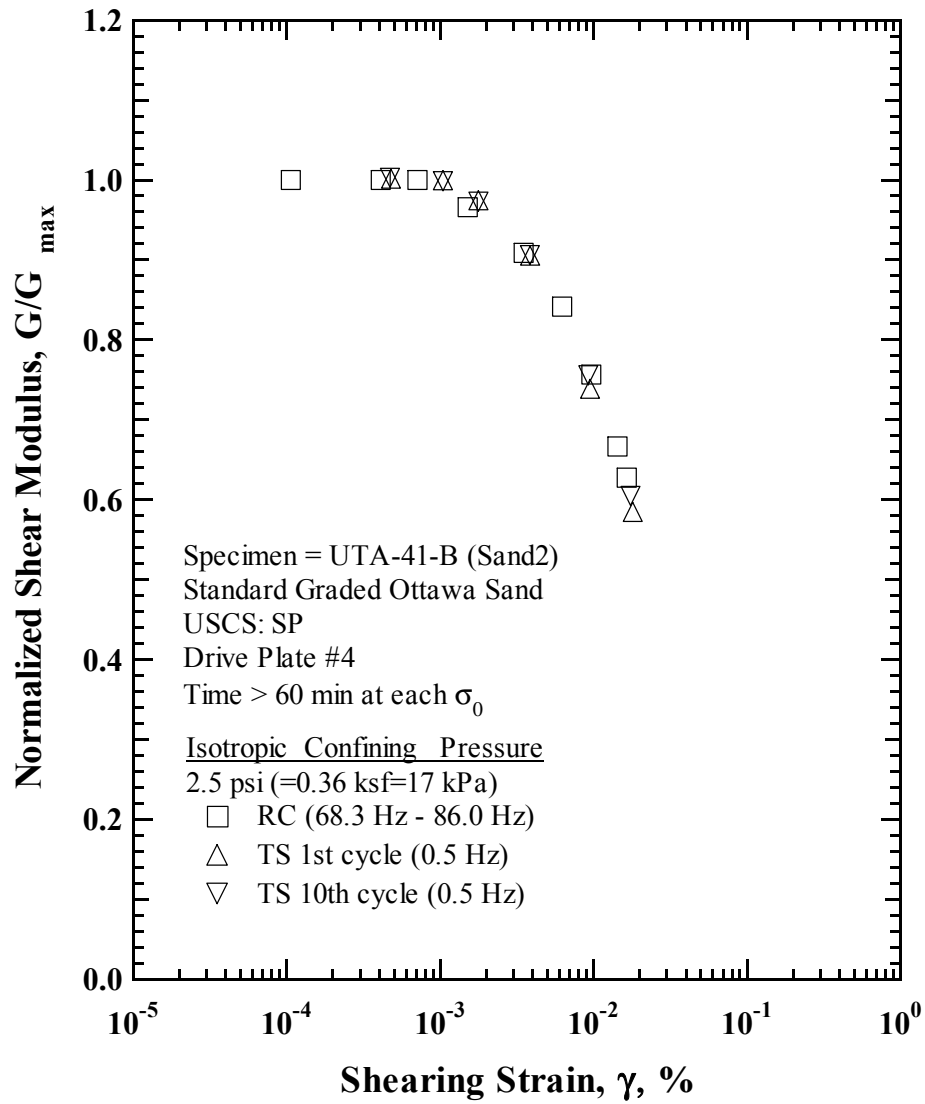


(c) Shearing Strain,  $\gamma$

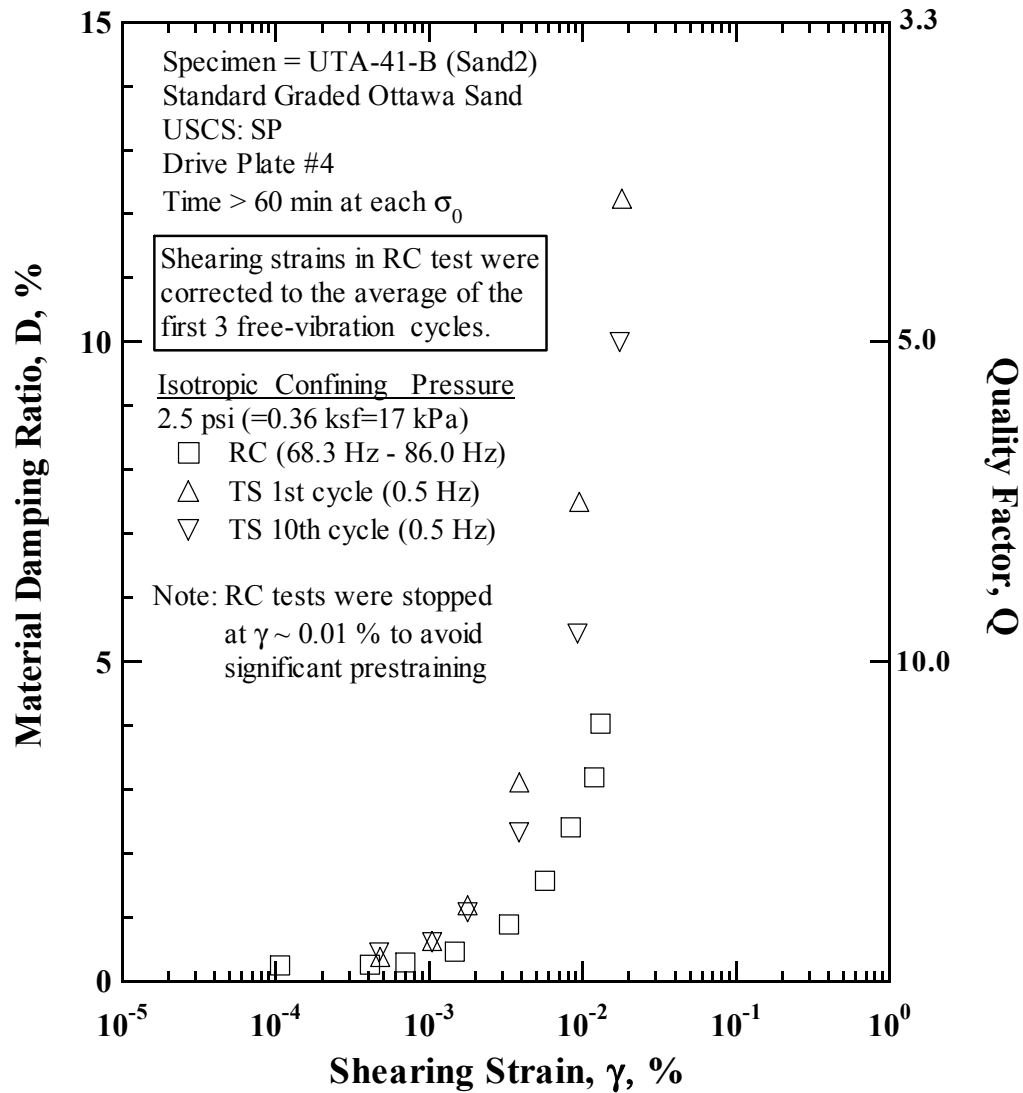
**Fig. A1.15 Variation of (a) shear modulus; (b) material damping ratio; and (c) shearing strain at an isotropic confining pressure of 0.36 ksf (17 kPa) with number of cycles in large-strain range from the torsional shear tests of Specimen UTA-41-B (Sand2).**



**Fig. A1.16 Comparison of the variation in shear modulus with shearing strain at an isotropic confining pressure of 0.36 ksf (17 kPa) from the combined RCTS tests of Specimen UTA-41-B (Sand2).**



**Fig. A1.17 Comparison of the variation in normalized shear modulus with shearing strain at an isotropic confining pressure of 0.36 ksf (17 kPa) from the combined RCTS tests of Specimen UTA-41-B (Sand2).**



**Fig. A1.18** Comparison of the variation in material damping ratio with shearing strain at an isotropic confining pressure of 0.36 ksf (17 kPa) from the combined RCTS tests of Specimen UTA-41-B (Sand2).

## Meta Data

1. Company Performing Test
2. Location of Company
3. RC and/or TS Equipment
  - Manufacturer and Model No.
  - Frequency Range and/or Digitization Time Interval
  - Amplitude Resolution (digitization bites for minimum voltage level)
  - Filtering and Ranges Used
  - Company Performing and Dates of Calibrations:
    - independent NIST-traceable calibration
    - in-house calibration with NIST-traceable standards
    - in-house calibration with “local” standards
    - if in-house calibration, date standards were calibrated and company performing calibration
4. Soil or Rock Specimen
  - Site Location
  - Description of Site Profile
  - Type of Sampling Method
5. Characteristics of Test Specimen
  - Intact or Remolded
  - Description of Soil/Rock
    - LL, PL,  $C_u$ ,  $e$ ,  $\dots$ , etc
    - grain size curve
6. Testing Sequence
  - i. Staged or Unstaged
    - a. number of pressure stages
    - b. isotropic or anisotropic confinement
    - c. order of pressure stages
    - d. low-amplitude test pressures
    - e. high-amplitude test pressures



**Table A1.12 Summary of tests performed at the University of Texas at Austin on standard graded Ottawa sand specimens.**

Spec. No.	Specimen ID	Initial Specimen Size		Isotropic Test Pressures		
		Height in. (cm)	Diameter in. (cm)	Low-Amplitude RC and TS Tests ksf (kPa)	High-Amplitude RC Tests ksf (kPa)	High-Amplitude TS Tests ksf (kPa)
Sand1	UTA-41-A	5.50	2.76	0.17, 0.36, 0.72, 1.58, 2.88, 5.76, 1.58, 0.36	1.58, 5.76	1.58, 5.76
		(14.0)	(7.0)	(8, 17, 35, 76, 138, 276, 76, 17)	(76, 276)	(76, 276)
Sand2	UTA-41-B	5.60	2.81	0.17, 0.36, 0.72, 1.58, 2.88, 5.76, 1.58, 0.36	0.36, 1.58, 5.76, 1.58, 0.36	0.36, 1.58, 5.76, 1.58, 0.36
		(14.2)	(7.1)	(8, 17, 35, 76, 138, 276, 76, 17)	(17, 76, 276, 76, 17)	(17, 76, 276, 76, 17)

### Measured Data

1. Effects of Parameters on  $G_{\max}$  and  $D_{\min}$ 
  - confinement time
  - excitation frequency
  - number of loading cycles
  - confining pressure
  - void ratio
  - several loading and unloading cycles
  - dry density

**Table A1.13 Variation in low-amplitude shear wave velocity, low-amplitude shear modulus, low-amplitude material damping ratio and estimated void ratio with duration of isotropic confining pressure from RC tests of Specimen UTA-41-A (Sand1).**

Time	Low-Amplitude Shear Modulus, $G_{\max}$		Low-Amplitude Shear Wave Velocity, $V_s$	Low-Amplitude Material Damping Ratio, $D_{\min}$	Estimated Void Ratio, $e$
(min.)	(ksf)	(MPa)	(fps)	(%)	
2	502150	24073	9784	0.32	0.0186
9	501680	24050	9780	0.30	0.0186
14	502060	24069	9784	0.31	0.0186
19	501670	24050	9780	0.30	0.0185
27	502050	24068	9784	0.31	0.0185
37	502060	24069	9784	0.30	0.0185

**Table A1.14 Variation in low-amplitude shear wave velocity, low-amplitude shear modulus, low-amplitude material damping ratio and estimated void ratio with magnitude of isotropic confining pressure from RC tests of Specimen UTA-41-A (Sand1).**

Isotropic Confining Pressure, $\sigma_o'$			Low-Amplitude Shear Modulus, $G_{\max}$		Low-Amplitude Shear Wave Velocity, $V_s$	Low-Amplitude Material Damping Ratio, $D_{\min}$	Total Unit Weight, $\gamma_t$
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	(%)	(pcf)
18	2592	124	497700	23860	9746	0.40	169
37	5328	255	498260	23886	9750	0.38	169
75	10800	518	497930	23871	9745	0.33	169
150	21600	1035	502050	24068	9784	0.31	169
300	43200	2071	502770	24103	9785	0.31	169

## 2. Effect of Parameters on G and D

- number of loading cycles
- shearing strain
- confining pressure
- elastic threshold strain
- dry density

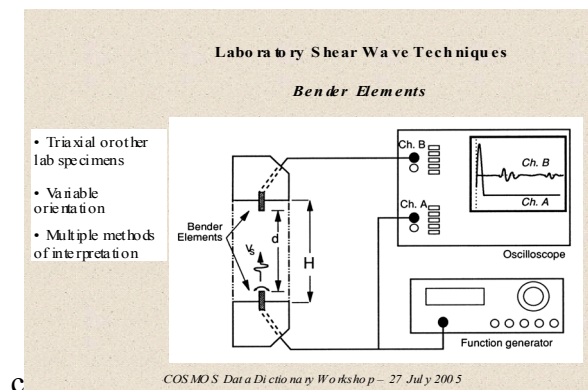
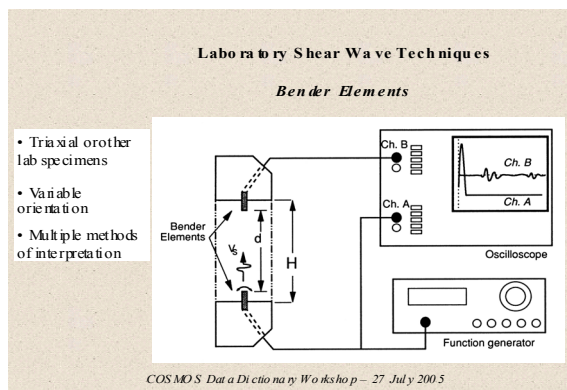
**Table A1.15 Variation in shear modulus, normalized shear modulus and material damping ratio with shearing strain from RC rests of Specimen UTA-41-A (Sand1); confining pressure (loading),  $\sigma'_o$  =11 psi(= 1.58 ksf = 76 kPa).**

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, $G/G_{\max}$	Average <sup>+</sup> Shearing Strain, %	Material Damping Ratio <sup>x</sup> , D, %
7.19E-05	498350	1.00	7.06E-05	0.29
1.43E-04	498350	1.00	1.41E-04	0.30
2.82E-04	497770	1.00	2.76E-04	0.30
5.84E-04	498340	1.00	5.73E-04	0.30
1.08E-03	498360	1.00	1.06E-03	0.31
2.12E-03	497840	1.00	2.08E-03	0.31
3.94E-03	498330	1.00	3.86E-03	0.34
7.52E-03	494760	0.99	7.34E-03	0.39
1.29E-02	491290	0.99	1.25E-02	0.47
1.98E-02	487680	0.98	1.91E-02	0.58
2.96E-02	484160	0.97	2.83E-02	0.75

Notes: <sup>+</sup>Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

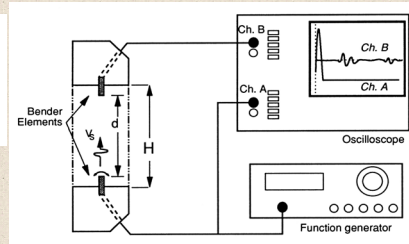
<sup>x</sup>Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

## LABORATORY SHEAR WAVE TECHNIQUES BY M. RIEMER



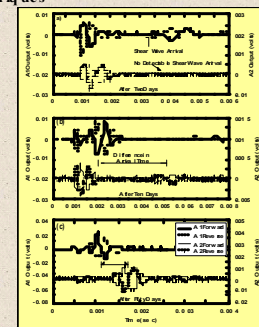
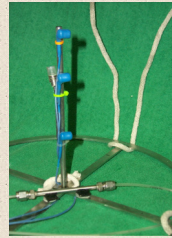
### *Bender Elements*

- Triaxial or other lab specimens
- Variable orientation
- Multiple methods of interpretation



*COSMOS Data Dictation Workshop – 27 July 2005*

### Arrays in Scale Models



*COSMOS Data Dictionary Workshop – 27 July 2005*

[illegible]

*COSMOS Data Dictionary Workshop – 27 July 2005*

## **OTHER PRESENTATIONS**

### **NEES@UCSB: XML TOOLS AND STANDARDS FOR DATA REPOSITORIES BY H. RATZESBERGER**

#### **The NEES Data Repository and XML Technologies**

Last year, at the COSMOS-Peer Lifelines conference for Archiving and Web Dissemination of Geotechnical Data, I presented an outline of the NEES repository and its data models. At the time, the repository software was incomplete and even among the NEES equipment sites there was some confusion about its use. The NEES and its data repository began its operational phase last October, and since that time has evolved. Its primary focus is the curation of experiment data and the ability to evaluate and reproduce experiment results. There are few published projects, but most require a login to view them: <http://central.nees.org/>

Technologies and practices have also evolved since the data repository was first specified, and NEES programmers are adapting the repository to them and the following briefly explains them. In general, the changes are to make the repository more compatible with the COSMOS Geotechnical exchange format, and it continues to be a goal of the NEES@UCSB team to publish geotechnical data directly to the COSMOS GVDC and to make the tools developed available so that other NEES sites can also do the same.

#### **State of XML Technologies**

XML is ubiquitous and even programmers sometimes ask why. The answer, to quote J. P. Bardet, is the World Wide Web. HTML, the presentation language of the Web was published about ten years ago and XML attempts to accomplish for data what HTML accomplished for presentation. As important as the features of a programming language its adoption by developers. In that regard, XML is one of the most thoroughly supported specifications in terms of programming languages, related standards, commercial acceptance and adoption by researchers.

The COSMOS GVDC format is an XML file format. The benefits of this decision are becoming more evident as programs that work with XML mature. Besides the XML Schema

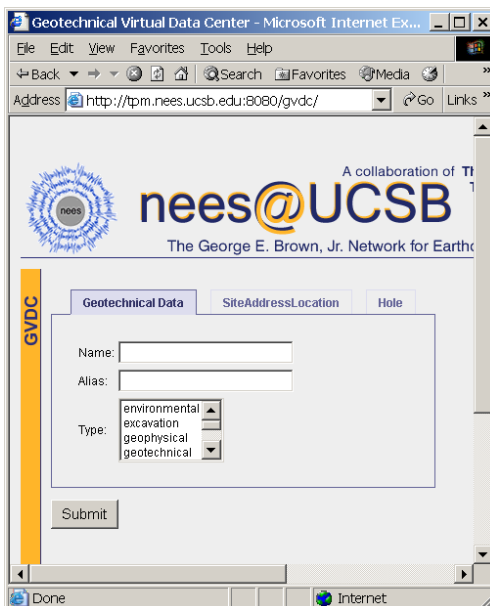
format which precisely describes the elements there are the following World Wide Web Consortium specifications:

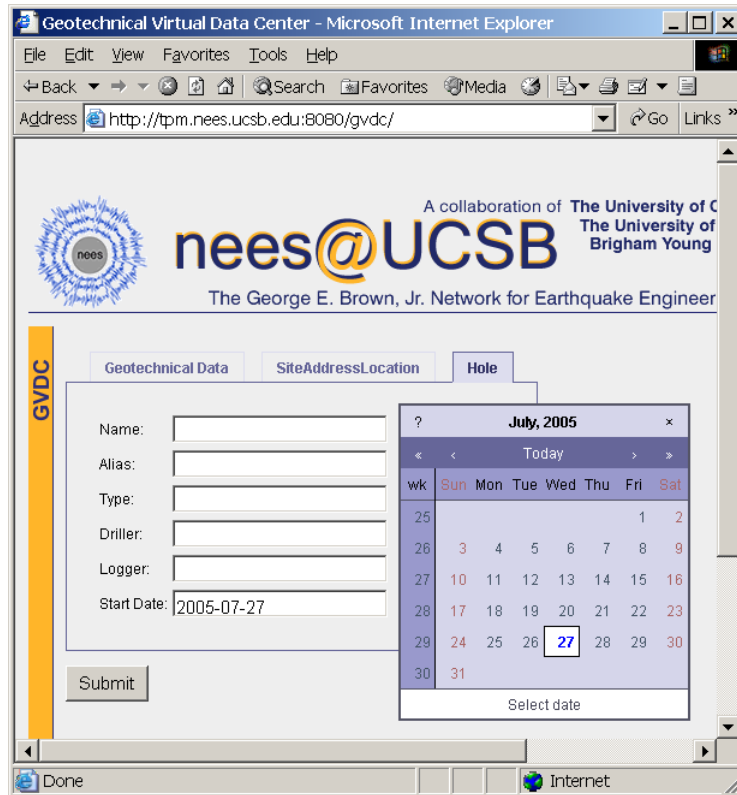
- **XML**, the Extensible Markup Language is a specification for “semi-structured data.” We all have probably seen more of the <angle bracket> demarked text than we wished to. Although the text is humanly readable, it is not necessarily intended to be, but it provides structure to data and allows numeric values to be transferred from computer to computer regardless of the hardware architecture, operating system or software program.
- **XML Schema** precisely describes what valid content for an XML file is. Such files can be difficult to read and viewing/editing programs are very helpful when evaluating Schema files.
- **XPath**, the XML Path Language is a syntax to select data from XML files by traversing the hierarchy assumed by nested elements. The most recent version, 2.0, also provides important functions such as date and time conversions, string manipulation and even math functions. Indeed, the specification can be extended with domain specific functions such as unit conversion.
- **XQuery**, the XML Query Language is an evolving standard intended to overcome the limitations of XPath by providing a richer query syntax that has some resemblance to SQL.
- **XSLT**, the XML Transformation Language lets programs convert XML to text, html or other xml files.
- **XForms** is a markup for input/editing of XML data. The standard has been published for only a few years and browsers and other programs are beginning to support it.

In addition to the above World Wide Web Consortium standards, there are a number of commercial and open source applications to complete the production of robust, large-scale applications. For example, XML databases store and index XML documents and directly support the XPath and XQuery languages. This eliminates the need to translate or “shred” XML documents so they can be stored as table relations. Lastly, Java and other programming languages as well as desktop software such as Excel support XML files. This universal support is a statement to the completeness of the specification and the skill of the members of the W3C.

## XML in Practice

From a production point of view—the tasks necessary to acquire, store, search and publish data—the fewer files that must be altered to implement a change or extension the better. Ideally, a change to schema file would be all that is necessary to change the input/edit form, the database, and perhaps even reporting and exchange features. NEES@UCSB hoped to demonstrate exactly this possibility, but could not devote all the resources to this effort at this time. Even so, we conclude that it is possible to use XSLT to transform XML Schema files into XForms. In our example, we took the COSMOS Geotechnical Schema file and created an XForms template compatible with the open source Java servlet program, Orbeon Presentation Server, which supports XForms through server side Java and client side JavaScript. Our example is incomplete and we are some ways from a functioning application, but we think the results are very promising: <http://tpm.nees.ucsb.edu:8080/gvdc/>. The team at NEES@UCSB expect that we will be able to create web enabled forms through two or three XSLT scripts, but that we will need to annotate the schemas to achieve all the functionality of XForms.





Finally, there is the issue of publishing XML data. The NEES is adopting a strategy for this called Representational State or REST. REST has the distinction both of being based on a Ph.D. thesis and having the groundswell support of the web programming community. Indeed, REST style web services are simply the standard use of the http protocol and URL's (or URI's, Universal Resource Identifiers) and a set of standard parameters. Accessing documents or fragments of documents from a REST style web service is very similar to using XPath. A few examples may best explain this:

<http://geodata.cosmos-data.org/GeotechnicalData?id=qwerty>

Get the document identified by the unique id "qwerty"

[http://geodata.cosmos-data.org/GeotechnicalData/Site\[id=qwerty\]/Hole\[depth>20\]/](http://geodata.cosmos-data.org/GeotechnicalData/Site[id=qwerty]/Hole[depth>20]/)

Get the documents for the site "qwerty" with Holes greater than 20. (The units would need to be specified as a parameter.)

REST proposes some standard parameters such as mime-type. The default mime-type is "text/xml" but if the parameter supplied were "&mime-type=text/html" then the server would return formatted, humanly readable, html. Requesting the borehole logs for a certain site, created by a particular company and delivered as an Excel spreadsheet is for the requesting program or



browser, simply a matter of a correctly specified URL. The groundswell support for XML technologies continues and the specifications and tools are becoming very mature. Designs that follow the tree format of XML Schema are better supported than those following the OWL/RDF Triple format.

## **Status of OWL Model**

OWL, the Objects for the Web Language continues to have the support of Tim Berners-Lee, one of the inventors of the World Wide Web. The OWL models developed by J. P. Bardet, Jennifer Swift, et al., are remarkably thorough, but the software development tools to utilize the OWL format are not fully mature. If I can offer my own simplification, OWL attempts to create data representations that can be programmatically linked with others. In other words, items in one data set can be linked with others by programs, not manual translations. For example, if J.P. has a dataset of people, including Socrates, and Jennifer has another dataset of human properties, such as being mortal then programmatically, an OWL program can tell us that Socrates is indeed mortal. In the NEES knowledge domain, these linkages would be in domains such as velocity profiles and structural resonances. One possibility is to restructure the OWL model to reference the Schema based repository. A REST style repository can provide a URI for any XML fragment. The OWL model can refer to these fragments.

## **REFERENCES**

### ***REST Style Web Services:***

- The Beauty of REST. O'Reilly XML.com  
<http://www.xml.com/pub/a/2004/03/17/udell.html>
- Implementing REST Web Services: Best Practices, O'Reilly XML.com  
<http://www.xml.com/pub/a/2004/08/11/rest.html>
- How to create a REST Protocol, O'Reilly XML.com  
<http://www.xml.com/pub/a/2004/12/01/restful-web.html>
- REST Roundup, O'Reilly XML.com  
<http://www.xml.com/pub/a/2002/05/08/deviant.html>
- REST Reporting, O'Reilly XML.com  
<http://www.xml.com/pub/a/2005/02/16/rest-report.html>
- Architectural Styles and the Design of Network-based Software Architectures. Fielding, Roy.  
<http://www.ics.uci.edu/~fielding/pubs/dissertation/top.htm>

### ***W3C XML Standards:***

XForms – The Next Generation of Web Forms

<http://www.w3.org/MarkUp/Forms/>

XML XPath Language

<http://www.w3.org/TR/xpath>

XML Query (XQuery)

<http://www.w3.org/XML/Query>

XML Schema

<http://www.w3.org/XML/Schema>

Extensible Stylesheet Language Family

<http://www.w3.org/Style/XSL/>

### ***AJAX:***

Ajax: A New Approach to Web Applications. Jesse James Garrett.

<http://www.adaptivepath.com/publications/essays/archives/000385.php>

## DATA DICTIONARY TABLES

<b>Borehole Geophysical Data</b>	Borehole geophysical log data contain measurements of numerous different physical properties. As such, multiple measurements may exist for a single geophysical log. The Canadian Well Logging Society has developed the recognized file standard for non-petroleum geophysical logs. Details on the standard are at <a href="http://www.cwls.org/las_info.php">http://www.cwls.org/las_info.php</a> . The data dictionary proposed here is based on Version 2.0 of the CWLS Log ASCII Standard (LAS). The names in the attached table are Mnemonics in the LAS system.
----------------------------------	---

Name	Definition
<b>~Version Information</b>	
VERS.	CWLS LOG ASCII STANDARD VERSION (2.0)
WRAP.	NO WRAP (ONE LINE PER DEPTH STEP)

<b>~Well Information Block</b>	
Name	Definition
STRT.	start depth
STOP.	stop depth
STEP.	step up_hole
NULL.	null value
COMP.	company
WELL.	well
FLD.	field
LOC.	location
CNTY.	county
STAT.	state
SRVC.	service company
DATE.	log date
UWI.	unique well ID
LIC.	license number

~Curve Information Block	
Name	Definition
DEPT.	Depth
GAM(NAT).	Log Type Natural Gamma
COND.	Log Type Conductivity
RES.	Log Type Resistivity
API CODE	Equivalent API Code for Log Type
Curve Location	Column Loc. for Specific Log Type

~Parameter Information Block	
Name	Definition
FILE.	File Type
FIID.	File Type Identifier
VERS.	System Version
SER.	System Serial Number
TRUK.	Truck Calibration Number
TOOL.	Tool Serial Number
TIME.	Time
LAT.	Latitude
LON.	Longitude
LMF.	Log Measured From
DMF.	Driller Measured From
PD.	Permanent Datum
PDEV.	Elevation Permanent Datum
EKB.	Elevation Kelly Bushing
ELEV.DF	Elevation Drill Floor
EGL.	Elevation Ground Level
DRDP.	Driller's Depth
CASD.	Casing Diameter
CASB.	Casing Bottom
CASX.	Casing Type
CAST.	Casing Thickness
TNOC.	Time Circulation Stopped

LOGU.	Logging Unit
RECB.	Recorded By
OSR1.	Other Services 1
OSR2.	Other Services 2
OSR3.	Other Services 3
BS.	Bit Size
MST.	Mean Surface Temperature
TGRD.	Temperature Gradient
MAGN.	Magnetic Declination
MDEN.	Density Matrix
MATR.	Neutron Matrix
DTMT.	Delta T Matrix
DTFL.	Delta T Fluid
MUDS.	Mud Sample Source
MRS.	Mud Resistivity
MTP.	Mud Temperature
MFRS.	Resistivity Mud Filtrate
MFTP.	Temperature Mud Filtrate
MCRS.	Resistivity Mud Cake
MCTP.	Temperature Mud Cake
FTYP.	Fluid Type
FD.	Fluid Density
DFV.	Fluid Viscosity
FPH.	Fluid pH
ELCO.	Resistivity Cutoff

<b>Crosshole Seismic Test Parameters</b>	The seismic crosshole testing method consists in determining the seismic wave velocities of subsurface soils between a minimum of two boreholes. Standard testing procedures are described in ASTM D 5778. Relevant testing parameters are described in this table.
--	---

<b>Name</b>	<b>Definition</b>
Roles	Reference to a business associate (company or person) responsible for conducting the test.
Start Test Date	The date that the first data was collected.
End test Date	The date that the last data was collected.
Source Receiver Information	A description of the source-receiver borehole arrangement and test sequencing.
Source Hole	The hole, of which this crosshole seismic testing parameters is a part. The seismic crosshole test parameters must be related to a source hole.
Receiver Hole	The holes, of which this crosshole seismic testing parameters are a part. The seismic crosshole test parameters must be related to a one or more receiver holes.
Source-Receiver Spacing	Boreholes spacing at surface: source/receivers.
Borehole Preparation Method	The method used to prepare a borehole set for crosshole testing including grout type and proportions, casing type and inside diameter.
Borehole Walls	Borehole walls conditions at the time of testing. For example, cased or uncased.
Borehole Conditions	The condition of the borehole at the time of crosshole testing. For example, dry, borehole full of water, depth to water in borehole (if not full)
Boreholes Inclination	The equipment and method used to accurately survey the verticality of each boreholes to obtain the horizontal distance with depth between boreholes. This includes calibration details, measurement depth and system resolution/accuracy.
Equipment	A description of the equipment used as part of this crosshole test. In this case, equipment covers the P and S wave sources, the P and S wave receivers and, the recording unit types and details including the accuracy of the timing system. The equipment table also provides bench calibration information.
P-Wave Seismic Source	A description of the P-wave source, e.g. impact or explosive, mechanical, hydraulic, electro-mechanical, other. The description should include information regarding loading direction (one direction or reversible), wireline or oriented including orientation method.
S-Wave Seismic Source	A description of the S-wave source, e.g. impact or explosive, mechanical, hydraulic, electro-mechanical, other. The description should include information regarding loading direction (one direction or reversible), wireline or oriented including orientation method.
Field Calibration	Zero or more sets of information about the calibrations that were performed in the field
Receiver Locking System	Method used to lock receiver in borehole, e.g. metal spring, inflatable bladder, none or other.

Receiver Orientation Method	Method used to orient horizontal receivers if using 2D or 3D packages, e.g. rods to ground surface, locking and rotating system, none.
Remarks	A text descriptor providing additional information relevant to the Seismic Crosshole test data and results.
Date Last Updated	The date of the last update to the data in this table

<b>Crosshole Seismic Test Data</b>	The seismic crosshole testing method consists in determining the seismic wave velocities of subsurface soils between a minimum of two boreholes. Standard testing procedures are described in ASTM D 5778. Crosshole Seismic Test data are presented in this table.
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Name	Definition
Crosshole Seismic Test Parameters	The Crosshole Seismic Test Parameters, of which these Crosshole Seismic Test data are a part. The Seismic Crosshole Test data must be related to a Crosshole Seismic Test Parameters. This value is a foreign key that should select an instance of Crosshole Seismic Test Parameters based on the Id value of the Crosshole Seismic Test Parameters.
Measurement Type	Type of measurement along each travel path. Those include true interval (receiver-to-receiver), direct (source-to-receiver) and pseudo-interval (sometimes used with two-channel recorder and three boreholes)
Test Depth	Depth of measurements for P-wave and S-wave.
Path Length	Distance from Source to Receiver at depth of measurement.
P Calibration Time	The P Calibration Time is the trigger delay associated with the equipment used. This is the value to be subtracted from the measured time to derive the corrected travel time.
S Calibration Time	The S Calibration Time is the trigger delay associated with the equipment used. This is the value to be subtracted from the measured time to derive the corrected travel time.
P-wave Travel Time	Corrected compression wave (P-wave) travel time from source to receiver or from receiver to receiver.
S-wave Travel time	Corrected shear wave (S-wave) travel time from source to receiver or from receiver to receiver.
P-wave Velocity	Calculated compression wave velocity.
S-wave Velocity	Calculated shear wave velocity.
Poisson's Ratio	Poisson's ratio for the testing depth. This value, if given, may be assumed.
Remarks	A text descriptor providing additional information relevant to the Seismic Crosshole test data and results.
Date Last Updated	The date of the last update to the data in this table
<b>Wave Form</b>	The normalized magnitude vs. time plots for the trigger and vertical and horizontal receivers in each borehole.

Name	Definition
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Wave Form	The wave form that this data applies to.
Magnitude	The normalized magnitude
Time	The time associated with the normalized magnitude
Impact Direction	The direction of the impact, e.g. downward or upward.

<b>Direct Shear Test Parameters</b>	The Direct Shear Test is designed to evaluate the strength of soils under a prescribed failure plane. Standard testing procedures are described in ASTM D 3080. Relevant testing parameters are described in this table.
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Name	Definition
Specimen	The specimen, of which these direct shear test parameters are a part. The direct shear test parameters must be related to a Specimen. This value is a foreign key that should select an instance of Specimen based on the Id value of the Specimen.
Equipment Manufacturer and Model	Provide name and model number of consolidation test equipment.
Test Date	Date the test was initiated.
Specimen preparation	Describe specimen preparation for intact specimen or compaction procedure for reconstituted specimen.
Shear Box Type	Shear box specimen holder type. Typical types include square, round, ring shear, etc.
Shear Box Dimensions	The diameter or width of the shear box specimen holder.
Initial Specimen Height	The height of the test specimen following application of the normal stress but prior to shear testing.
Initial Water Content	The water content of the test specimen before testing.
Final Water Content	The water content of the test specimen after testing.
Initial Dry Density	The dry density of the test specimen before testing.
Final Dry Density	The dry density of the test specimen after testing.
Remarks	A text descriptor providing additional information relevant to the Direct Shear Test Parameters and equipment especially if those differ from standard requirements.
Date Last Updated	The date of the last update to the data in this table

<b>Direct Shear Test Data</b>	The Direct Shear Test is designed to evaluate the strength of soils under a prescribed failure plane. Standard testing procedures are described in ASTM D 3080. Relevant testing data are described in this table.
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Name	Definition
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Direct Shear Test Parameters	The Direct Shear Test Parameters, of which these Direct Shear Test Data are a part. The Direct Shear Test Data must be related to a Direct Shear Test Parameters. This value is a foreign key that should select an instance of Direct Shear Test Parameters based on the Id value of the Direct Shear Test Parameters.
Initial Normal Stress	The normal stress applied on the test specimen prior to shearing.
Displacement Rate	The shear box displacement rate used for testing.
Elapsed Time	The elapsed time from the beginning of shear testing.
Horizontal Displacement	The horizontal displacement measured or inferred from the elapsed time and displacement rate.
Vertical Displacement	The vertical displacement measured during testing.
Normal Stress	The normal stress corrected for changes in contact area.
Shear Stress	The shear stress corrected for changes in contact area.
Peak Shear	Peak shear stress
Residual Shear	Residual shear stress
Horizontal Displacement at Peak Shear	The horizontal displacement measured at peak shear stress
Horizontal Displacement at Residual Shear	Horizontal displacement measured at residual shear stress.
Remarks	A text descriptor providing additional information relevant to the Direct Shear Test Data.
Date Last Updated	The date of the last update to the data in this table

<b>Direct Shear Test Series - Results</b>	The Direct Shear Test is designed to evaluate the strength of soils under a prescribed failure plane. Standard testing procedures are described in ASTM D 3080. Relevant testing results from a series of direct shear tests on sample of similar initial conditions are described in this table.
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<b>Name</b>	<b>Definition</b>
Direct Shear Test Parameters	The Direct Shear Test Parameters, of which these Direct Shear Test Data are a part. The Direct Shear Test Data must be related to a Direct Shear Test Parameters. This value is a foreign key that should select an instance of Direct ShearTest Parameters based on the Id value of the Direct Shear Test Parameters.
Specimen IDs	The specimens which are part of the series.
Peak Cohesion Intercept	Peak Cohesion Intercept
Peak Friction Angle	Peak Friction Angle
Residual Cohesion Intercept	Residual Cohesion Intercept
Residual Friction Angle	Residual Friction Angle
Stress Range for Cohesion and Friction Angle Reported	Stress Range for Cohesion and Friction Angle Reported
Remarks	A text descriptor providing additional information relevant to the Direct Shear Test Series-Results
Date Last Updated	The date of the last update to the data in this table

<b>Equipment</b>	A generalized structure that can handle equipment, including calibration of the equipment. It is composed of identifiers, classes, and name/value pairs for parameters. The calibration is a set of name/value pairs. A piece of equipment may be part of a larger piece of equipment. No attempt is made to capture the part of hierarchy.
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<b>Name</b>	<b>Definition</b>
Manufacturer	Equipment is characterized by the final manufacturer. This may be part of the identification.
Model Name	A piece of equipment is often characterized by a model number and serial number. This is the model number part.
Serial Number	The serial number is the value assigned to a piece of equipment, which is unique among the manufacturer, model name combination.
G106 Name	A unique name assigned to the piece of equipment. This element is to be used in place of the model name, serial number combination
Class	One or more instances of equipment classes. At a minimum, there should be a classification that gives the type of equipment, such as sensor, pump, battery, etc. This element may be accompanied by a classification system.
Parameter	A general element that can capture any parameter used to describe the equipment. The parameter must have a name and value, and may also have a uom and/or a description.
Calibration	A complex type that can capture calibration information. This calibration is intended to capture calibration of the equipment separate from its calibration at the time of the test. This is often referred to as bench calibration.
Comment	Any comment that may be appropriate about the equipment

<b>Parameter</b>	The general type that will be used to capture any parameter. This is done using name value pairs, along with supplementary information.
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<b>Name</b>	<b>Definition</b>
Name	The name of the parameter
Value	The value of the parameter
Uom	If appropriate, a unit of measure that goes with the value
Description	A free form description of the parameter

<b>Calibration</b>	The information, including free form parameters, to describe the calibration of a piece of equipment. This is intended to cover at a minimum the last calibration performed on the equipment.
<b>Name</b>	<b>Definition</b>
Calibration Date	The date on which the calibration was completed
Calibrated by	The business associate that performed the calibration
Parameter	One or more parameters that give information about the calibration
Comment	Any comment that may be appropriate about the calibration

<b>One-Dimensional Consolidation Test Parameters</b>	The One-Dimensional Consolidation Test is designed to evaluate the amount and rate of compressibility of soils subjected to axial loading under the condition of zero lateral strain. Standard testing procedures are described in ASTM D 2435. Relevant testing parameters are described in this table.
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<b>Name</b>	<b>Definition</b>
Specimen	The specimen, of which these one-dimensional consolidation test parameters are a part. The one-dimensional consolidation test parameters must be related to a Specimen. This value is a foreign key that should select an instance of Specimen based on the Id value of the Specimen.
Test Type	The type of consolidation test. The following provides a list of possible one-dimensional consolidation test types: a) incremental load, b) constant rate of strain, c) constant rate of loading, d) constant pore pressure gradient, e) constant ratio of pore pressure to load, f) swelling test, g) consolidation with back pressure control, or h) other.
Equipment Manufacturer and Model	Provide name and model number of consolidation test equipment.
Test Date	Date the test was initiated.
Ring Type	The type of consolidometer ring used for testing. For example, fixed, floating, or, other.
Specimen Diameter	The diameter of the test specimen.
Specimen Height	The initial height of the test specimen.
Specimen Preparation	The method used to prepare the specimen for testing. Methods include: a) trimming with turntable, b) trimming using a cutting shoe, c) specimen from ring lined sampler (no trimming required), d)reconstituted or e) other.
Initial Water Content	Water content of test specimen before testing.
Final Water Content	Water content of test specimen after testing.
Initial Void Ratio	Void ratio of test specimen before testing
Final Void Ratio	Void ratio of test specimen after testing
Initial Degree of Saturation	Degree of saturation of test specimen before testing.
Final Degree of Saturation	Degree of saturation of test specimen after testing.
Initial Dry Density	Dry density of test specimen before testing
Final Dry Density	Dry density of test specimen after testing
Vertical Effective Stress	Existing vertical effective stress at depth of test specimen.
Remarks	A text descriptor providing additional information relevant to the One-Dimensional Consolidation Test Parameters and equipment especially if

	those differ from standard requirements.
Date Last Updated	The date of the last update to the data in this table

<b>One-Dimensional Consolidation Test Data</b>	The One-Dimensional Consolidation Test is designed to evaluate the amount and rate of compressibility of soils subjected to axial loading under the condition of zero lateral strain. Standard testing procedures are described in ASTM D 2435. One-Dimensional Consolidation Test Data are described in this table.
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Name	Definition
One-Dimensional Consolidation Test Parameters	The One-Dimensional Consolidation Test Parameters, of which these One-Dimensional Consolidation Test Data are a part. The One-Dimensional Consolidation Test Data must be related to a One-Dimensional Consolidation Test Parameters. This value is a foreign key that should select an instance of One-Dimensional Consolidation Test Parameters based on the Id value of the One-Dimensional Consolidation Test Parameters.
Load Increment	The load increment applied to the test specimen.
Void Ratio	The void ratio at the end of the corresponding load increment.
Vertical Strain	The vertical strain at the end of the corresponding load increment.
Height Change Definition	The height change may be calculated using the final deformation for each load increment as: a) end of load increment (24 hours), b) end-of-primary consolidation (d100), or c) other.
Preconsolidation Pressure	The preconsolidation pressure evaluated using the Casagrande method. Other methods should be specified in Remarks.
Compression Index	The compression index ( $C_c$ ) defined as the slope of the virgin compression measure on a graph of void ratio versus the logarithm of vertical effective stress.
Recompression Index	The recompression index ( $C_r$ ) defined as the slope of the recompression curve measure on a graph of void ratio versus the logarithm of vertical effective stress.
Remarks	A text descriptor providing additional information relevant to the One-Dimensional Consolidation Test Data especially if those differ from standard requirements.
Date Last Updated	The date of the last update to the data in this table.

<b>One-Dimensional Consolidation Time-Deformation Test Data</b>	The One-Dimensional Consolidation Test is designed to evaluate the amount and rate of compressibility of soils subjected to axial loading under the condition of zero lateral strain. Standard testing procedures are described in ASTM D 2435. Time-Deformation test data for each load increment are described in this table.
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<b>Name</b>	<b>Definition</b>
One-Dimensional Consolidation Test Data	The One-Dimensional Consolidation Test Data, of which these One-Dimensional Consolidation Time-Deformation Test Data are a part. The One-Dimensional Consolidation Time-Deformation Test Data must be related to a One-Dimensional Consolidation Test Data. This value is a foreign key that should select an instance of One-Dimensional Consolidation Test Data based on the Id value of the One-Dimensional Consolidation Test Data.
Load Increment	The load increment applied to the test specimen.
Elapsed Time	Time elapsed since the application of the load increment corresponding to the measured deformation.
Deformation	The deformation corresponding to the elapsed time. Deformation can be given as: a) deformation readings, b) deformation corrected for apparatus compressibility, c) strain, or) other.
Coefficient of Consolidation	The coefficient of consolidation corresponding to the load increment
Secondary Compression Index	The secondary compression index corresponding to the load increment
Remarks	A text descriptor providing additional information relevant to the One-Dimensional Consolidation Time-Deformation Test Data especially if those differ from standard requirements.
Date Last Updated	The date of the last update to the data in this table

<b>Seismic Downhole Velocity Test</b>	Downhole velocity information are acquired using a source at the ground surface with one or more receivers located in a nearby borehole. Primary data acquired consist of measurement depth and travel time of compression (P) and shear (S) waves at that depth. Interpreted data consist of layer determination and P and S wave velocity of that layer.
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<b>Name</b>	<b>Definition</b>
Hole	The hole, of which this seismic downhole velocity test is a part. The seismic downhole velocity test must be related to a hole. This value is a foreign key that should select an instance of Hole based on the Id value of the Hole.
Roles	Reference to a business associate (company or person) who has a role in the hole.
Equipment	The equipment, used as part of this downhole velocity test. In this case, equipment covers the source, the receivers and the recording unit types and details. The equipment table also provides bench calibration information.
Testing Date	The date when velocity measurements were made.
Borehole Walls	Borehole walls conditions at the time of testing. For example, cased or uncased.
Borehole Condition	The condition of the borehole at the time of testing. For example, dry, filled with water or drilling mud.
P-Source-Receiver Borehole Spacing	Horizontal distance from Compression Wave Source to center of Receiver borehole at ground surface.
S-Source-Receiver Borehole Spacing	Horizontal distance from Shear Wave Source to center of Receiver borehole at ground surface.
Receiver Depth	Depth of receiver in borehole
Slant Length	The slant length is the calculated travel path from source to receiver derived from the Source-Receiver Borehole Spacing and the Receiver Depth.
P Calibration Time	The P Calibration Time is the trigger delay associated with the equipment used. This is the value to be subtracted from the measured time to derive the corrected travel time.
S Calibration Time	The S Calibration Time is the trigger delay associated with the equipment used. This is the value to be subtracted from the measured time to derive the corrected travel time.
P-wave Travel Time S-R	Compression wave (P-wave) corrected travel time from source to receiver.
S-wave Travel time S-R	Shear wave (S-wave) corrected travel time from source to receiver.
P-wave Velocity	Calculated average compression wave velocity.
S-wave Velocity	Calculated average shear wave velocity.
Layer Thickness	The thickness of the layer associated with the P or S wave velocity.
Depth Top of Layer	The depth to the top of the layer from the depth datum



P Velocity	The P wave velocity of the layer. This value is always a parameter.
S Velocity	The S wave velocity of the layer. This value may be a parameter, or may be calculated
Poissons Ratio	Poisson's ratio for the layer. This value, if given, may be assumed
Layer Density	The total density or unit weight of the layer. The value may be assumed.
Remarks	A text descriptor providing additional information relevant to the Seismic Downhole Velocity test data and results.
Date Last Updated	The date of the last update to the data in this table

<b>Surface Wave Test</b>	A surface seismic experiment is run with a source and one or more receivers. The source may be used for more than one shot. The data is a set of seismic traces. The products of the test are phase plots, a phase velocity plot, and an interpreted near surface VS, VP earth model.
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<b>Name</b>	<b>Definition</b>
Site	The site at which this experiment was run
Name	A name for the survey. The name is used to distinguish between Surface Waves tests at the site when more than one survey is run.
Service Company	The company, or business associate, responsible for running the test.
Start Test Date	The date that the first data was collected. This may be different from the date when the site was surveyed, occupied, or set up.
End Test Date	The date that the last data was collected. This may be the same as the Start test date. If this value is missing, it is assumed that the data was collected in a single day.
Shot Receiver Information	A description of the shot-receiver geometry, and sequencing
Source Equipment	A description of the equipment used for the source
Receiver Equipment	A description of the equipment used for the receivers
Recorder Equipment	A description of the equipment used for the recording equipment
Channels Recorded Count	The nominal number of channels recorded for each shot.
Sampling Interval	The sample interval used in recording the seismic traces
Field Calibration	Zero or more sets of information about the calibrations that were performed in the field
Comment	Zero or more comments that may relate to the experiment.

<b>Shot Receiver Information</b>	A complex type that can capture the shooting geometry and patterns. This type assumes (1) a receiver station may be string of receivers that are implanted linearly or bunched, (2) the shot station is in line with the receiver stations, and (3) the receiver stations are inline.
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<b>Name</b>	<b>Definition</b>
Receiver Station	A detailed description of each receiver station that includes an identifier, string orientation, and orientations if the receiver is 3D. The details of the equipment are not given here.
Source Type	The type of source used. The details of the source may be captured in a source equipment object.
Shot Description	A description of each shot. This is used to capture the geometry, and the recording channels

Record Information	For each trace, the shot, receiver, and channel number
<b>Receiver Station</b>	Details of the receiver station element
Identifier	A name, unique within the test, for a receiver station.
Planting Geometry	The geometry of the receiver string. Bunched nest is a set of receivers bunched close to the station. Inline forward is the string planted inline, with one end at the station, and the string running away from the forward source position. Inline reverse has the string running toward the forward source position. Crossline has the string running perpendicular to the source-receiver line, with the station in the middle of the string
Orientation	If the string is 3D, the type and orientations of the geophones
Orientation Method	The method used to vertically orient the geophones
Description	A free form field that allows a description of the receiver station
<b>Shot Description</b>	The details of the shot description element
Identifier	An identification of the shot
Spacing	The distance between the shot and the nearest receiver station. This assumes that the distance is the same between each of the adjacent receiver stations
Shot Receiver Spacing	The distance from the shot to each receiver individually.
Spacing to Receiver	The identifier of the receiver which the distance applies to.
Recording Channel	The channel (or channels) on which the shot is recorded.
<b>Record Information</b>	
Trace id	An identifier for the recorded trace.
Shot	the shot identifier
Receiver	the receiver station identifier
Recording Channel	The channel on which the shot is recorded.

<b>Dispersion Plot</b>	A dispersion plot is phase velocity vs. wavelength.
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Name	Definition
SW Test	The test that this dispersion plot applies to.
Velocity Type	The type of velocity that is being given (S or P)
Velocity uom	The unit of measure symbol for the velocity
Wavelength uom	The unit of measure symbol for the wavelength
Experimental Value Point	Each measured value point will be a pair of values: a velocity and a wavelength.
Theoretical Model Point	Each model value point will be a pair of values: a velocity and a wavelength.
Comment	Describe analysis type, e.g. simplified, empirical, forward modeling, inversion, others. Provide other details relevant to the analysis.

<b>Model Plot</b>	A table of the model. This model generates velocity vs. wavelength values for the dispersion plot.
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Name	Definition
SW Test	The test that this dispersion plot applies to.
Model ID	An identifier for the model. This may be used to differentiate it from other models developed for the same test
Linear uom	The unit of measure symbol for depth and thickness values
Velocity uom	The unit of measure symbol for velocity values
Density uom	The unit of measure symbol for density values
Depth Datum	A description of the vertical datum for which depth = 0.
Row	A row of values for the table

Row Structure	The subelements for each row of data
Layer Number	A value to identify a layer. Generally the layers are identified by successive integers
Thickness	The thickness of the layer
Depth to Top	The depth to the top of the layer from the depth datum
Pvelocity	The P wave velocity of the layer. This value is always a parameter.

Svelocity	The S wave velocity of the layer. This value may be a parameter, or may be calculated
Poissons Ratio	Poisson's ratio for the layer. This value, if given, may be assumed
Mass Density	The density of the layer. The value may be assumed.

<b>Phase Plot</b>	A phase plot is developed for each SW trace. It is a table of phase vs. frequency.
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<b>Name</b>	<b>Definition</b>
SW Test	The test that this phase plot applies to.
Trace	The id of the trace that is recorded.
Phase uom	The unit of measure symbol for the phase
Frequency uom	The unit of measure symbol for the frequency
Value Point	Each value point will be a pair of values: a phase and a frequency

<b>Suspension PS Logging Test Parameters</b>	The OYO Suspension PS Logger is a proprietary logging tool/method used for measurement of shear and compression wave velocities in a single borehole. Following are test parameters for each logged borehole.
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<b>Name</b>	<b>Definition</b>
Hole	The hole, of which this Suspension PS Logger test is a part. The Suspension PS Logger test must be related to a hole. This value is a foreign key that should select an instance of Hole based on the Id value of the Hole.
Roles	Reference to a business associate (company or person) who has a role in the hole.
Equipment	The equipment, used as part of this suspension PS logger test. In this case, equipment covers the probe and the logger/recorder unit types and details. The equipment table also provides bench calibration information.
Testing Date	The date when suspension PS logger measurements were made.
Hole Location (Lat-Lon)	The horizontal location of the top of the logged borehole.
Reference Elevation (elevation at depth=0)	The elevation (sea level reference) of the zero depth reference for this borehole.
Total Depth	The total depth of the logged hole.
Borehole Inclination	The average inclination (degrees) from vertical of the hole. Sometimes the suspension PS logging is done in inclined holes, for example through a dam core. Most of the time the hole will be nominally vertical with inclination = 0 degrees
Cased or Uncased	Was the logging done with or without casing
Drilling Method	The drilling method used
Final Hole Diameter	The final diameter of the drilled borehole, before casing
Casing Diameter	The ID of the casing (if present)
Casing Type	The type of casing
Conductor Casing Depth	The depth of a steel conductor casing, if present. This method will not work through steel casing, so a conductor casing limits the minimum depth of measurement.
Probe ID (Serial Number)	The ID or serial number of the probe used.
Logger/Recorder ID (Model & Serial Number)	The ID or serial number of the logger/recorder used.
Operator (name)	Name of the logger operator responsible for gathering the raw data
Date	Date of the start of the logging

Start Time	Time (local) of the first data sample
End Time	Time (local) of the last data sample
Analyst (name)	Name of the person responsible for the data analysis

<b>Torsional Ring Shear Test Parameters</b>	The torsional shear ring test method is designed to determine the residual shear strength of cohesive soils. Standard testing procedures are described in ASTM D 6467. Relevant testing parameters are described in this table.
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<b>Name</b>	<b>Definition</b>
Hole	The hole, of which these field vane parameters are a part. The field vane parameters must be related to a hole. This value is a foreign key that should select an instance of Hole based on the Id value of the Hole.
Manufacturer	The business name of the company manufacturing the apparatus. For example, Geonor, Nilcon, Acker, etc.
Type	Description of apparatus within a manufacturer inventory or reference to non commercial device
Height	maximum height of test specimen allowable by apparatus
Torque Device	Description of loading system used to applied normal force and torque to loading cell (e.g., controlled displacement or hydraulic controlled, etc)
Description of Ring Shear Cell	
Operators	Name of person that perform the test
Date	Starting date of test
Test Duration	Total duration of the test
Field Sampling Technique	Reference to sampling techniques used to collect samples from the field. Required for undisturbed samples
Laboratory Sample Preparation Method	Description of the method used for preparing the test specimen, including trimming and installation in torsion ring shear device
Reconsolidation Method	Description of the method used for applying initial stress to test specimen, unconsolidated/consolidated
Last Calibration Date	The date of the last calibration of the apparatus. Specify how much the apparatus was used since the last calibration.
Remarks	A text descriptor providing additional information relevant to the Test Parameters and equipment especially if those differ from standard requirements.
Date Last Updated	The date of the last update to the data in this table



<b>Triaxial Test Parameters</b>	The Triaxial Test is used to determine the stress-strain relationships of a cylindrical specimen of either undisturbed or remolded soil. Standard testing procedures are described in ASTM D 2850 for the Unconsolidated Undrained Test and ASTM D 4767 for the Consolidated Undrained Test.
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<b>Name</b>	<b>Definition</b>
Specimen	The specimen, of which these triaxial test parameters are a part.
Manufacturer & Model of Test Equipment	
Operator	Lab technician operating test
Reviewer	Person reviewed test
Date	Date of testing
Calibration Information	Provide details of calibration and certification if available
Visual Description	General description of specimen including color, particle description (sand, silt, clay or mixtures thereof), classification, and moisture
Depth	Depth of Specimen below the ground surface
Test Type	The type of triaxial test.
Specimen Diameter	The average initial diameter of the test specimen.
Specimen Height	The average initial height of the test specimen.
Specimen Preparation	The method used to prepare the specimen for testing. Methods include: a) trimming with turntable, b) trimming using a cutting shoe, c) specimen from ring lined sampler (no trimming required), d) remolded, e) reconstituted, or f) other.
Filter Paper	Presence of filter paper strips to enhance drainage
Specific Gravity	Specific gravity of the soil solids
Initial Water Content	Water content of test specimen before testing.
After Consolidation Water Content	Water content of test specimen following consolidation phase
Initial Void Ratio	Void ratio of test specimen before testing
After Consolidation Void Ratio	Void ratio of test specimen before axial loading is applied
Initial Degree of Saturation	Degree of saturation of test specimen before testing.
After Consolidation Degree of Saturation	Degree of saturation of test specimen before axial loading is applied

Initial Dry Density	Dry density of test specimen before testing
After Consolidation Dry Density	Dry density of test specimen before axial loading is applied
Saturation Method	Indicate which method was used to achieve saturation: wet or dry
Total Back Pressure	The back pressure applied to the specimen
Pore Pressure Parameter (B)	The pore pressure parameter (B) at the end of saturation per ASTM
Lateral Effective Consolidation Stress	The difference between chamber pressure and back pressure prior to shearing
Vertical Effective Consolidation Stress	The lateral effective consolidation stress plus any deviatoric stress applied during consolidation
T <sub>50</sub>	Time to achieve 50% consolidation
Membrane Effect Correction	Have the test values been corrected for membrane effects
Filter Paper Correction	Have the test values been corrected for filter paper stiffness
Loading control	Was loading controlled through stress or strain rates or other
Loading rate	At what rate was loading applied
Remarks	A text descriptor providing additional information relevant to the Triaxial Test Parameters and equipment especially if those differ from standard requirements. Include details regarding the condition of the test specimen prior and after testing.
Photograph	Photograph of failed specimen
Date Last Updated	The date of the last update to the data in this table

<b>Triaxial Test Data</b>	The Triaxial Test is used to determine the stress-strain relationships of a cylindrical specimen of either undisturbed or remolded soil. Standard testing procedures are described in ASTM D 2850 for the Unconsolidated Undrained Test and ASTM D 4767 for the Consolidated Undrained Test.
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<b>Name</b>	<b>Definition</b>
Triaxial Test Parameters	The Triaxial Test Parameters, of which these Triaxial Test Data are a part. The Triaxial Test Data must be related to Triaxial Test Parameters. This value is a foreign key that should select an instance of Triaxial Test Parameters based on the Id value of the Triaxial Test Parameters.
Chamber Pressure	The chamber pressure applied to the specimen
Axial Strain	The axial strain imposed or measured during the test and corresponding to the vertical stress.
Vertical Stress	The vertical stress inferred from the load measured or applied during the test and corresponding to the axial strain.
Excess Pore Pressure	The excess pore pressures measured during the test and corresponding to the axial stress or vertical stress.
Volume Change	Volume change measured during the test and corresponding to the axial strain or vertical stress.
Failure Definition	Failure criteria (e.g. 15% strain, peak, residual, etc.)
Effective Lateral Stress at Failure	Chamber pressure minus pore water pressure at failure -- if measured
Deviator Stress at Failure	Principal stress difference at failure
Axial Strain at Failure	Axial strain at failure corresponding to failure criteria.
Remarks	A text descriptor providing additional information relevant to the Triaxial Test Data especially if those differ from standard requirements.
Date Last Updated	The date of the last update to the data in this table.

<b>Triaxial Test Series Data</b>	The Triaxial Test is used to determine the stress-strain relationships of a cylindrical specimen of either undisturbed or remolded soil. Standard testing procedures are described in ASTM D 2850 for the Unconsolidated Undrained Test and ASTM D 4767 for the Consolidated Undrained Test.
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<b>Name</b>	<b>Definition</b>
Triaxial Test Data	The Triaxial Test Series Parameters, of which these Triaxial Test Series Data are a part. The Triaxial Test Series Data must be related to Triaxial Test Series Parameters. This value is a foreign key that should select an instance of Triaxial Test Series Parameters based on the Id value of the Triaxial Test Series Parameters.
Specimen IDs	The specimens which are part of the series
Effective Stress Friction Angle	Effective Stress Friction Angle
Effective Stress Cohesion	Effective Stress Cohesion
Total Stress Friction Angle	Total Stress Friction Angle
Total Stress Cohesion	Total Stress Cohesion
Date Last Updated	The date of the last update to the data in this table.

<b>Cyclic Triaxial Test</b>	The Cyclic Triaxial Test is used to determine the cyclic stress-strain relationships of a cylindrical specimen of either undisturbed or remolded soil. Standard testing procedures are described in ASTM D 2850 for the Unconsolidated Undrained Test and ASTM D 4767 for the Consolidated Undrained Test.
-----------------------------	--

<b>Name</b>	<b>Definition</b>
Specimen	The specimen, of which these triaxial test parameters are a part.
Visual Description	General description of specimen including color, particle description (sand, silt, clay or mixtures thereof), and moisture
Depth	Depth of Specimen below the ground surface
Test Type	The type of triaxial test.
Specimen Diameter	The diameter of the test specimen.
Specimen Height	The height of the test specimen.
Specimen Preparation	The method used to prepare the specimen for testing. Methods include: a) trimming with turntable, b) trimming using a cutting shoe, c) specimen from ring lined sampler (no trimming required), d) remolded, or e) other.
Filter Paper	Presence of filter paper strips to enhance drainage
Specific Gravity	Specific gravity of the soil solids
Initial Water Content	Water content of test specimen before testing.
Before Shear Water Content	Water content of test specimen before axial loading is applied
Initial Void Ratio	Void ratio of test specimen before testing
Before Shear Void Ratio	Void ratio of test specimen before axial loading in applied
Initial Degree of Saturation	Degree of saturation of test specimen before testing.
Before Shear Degree of Saturation	Degree of saturation of test specimen before axial loading in applied
Initial Dry Density	Dry density of test specimen before testing
Before Shear Dry Density	Dry density of test specimen before axial loading in applied
Saturation Method	Indicate which method was used to achieve saturation: wet or dry
Total Back Pressure	The back pressure applied to the specimen

Pore Pressure Parameter (B)	The pore pressure parameter (B) at the end of saturation
Lateral Effective Consolidation Stress	The difference between chamber pressure and back pressure prior to shearing
Vertical Effective Consolidation Stress	The lateral effective consolidation stress plus any deviatoric stress applied during consolidation
Overconsolidation Ratio	The consolidation stress during prior to shearing divided by the maximum past effective stress, if known
T <sub>50</sub>	Time to achieve 50% consolidation
Membrane Effect Correction	Have the test values been corrected for membrane effects
Filter Paper Correction	Have the test values been corrected for filter paper stiffness
Strain or Stress Control	Was loading controlled through stress or strain rates
Loading Frequency	At what rate was loading applied
Loading Amplitude	Amplitude of each cycle of deviatoric stress
Strain Amplitude	Amplitude of each cycle of axial strain
Young's Modulus	Deviatoric stress / axial strain
Interpreted Shear Modulus	Shear stress / shear strain
Definition of Liquefaction	Criteria for assessing liquefaction occurrence
Cycles to Liquefaction	Number of cycles to reach definition of liquefaction
Remarks	A text descriptor providing additional information relevant to the Triaxial Test Parameters and equipment especially if those differ from standard requirements.
Photograph	Photograph of failed specimen
Date Last Updated	The date of the last update to the data in this table

<b>Shear Wave Velocity Triaxial Test</b>	The Triaxial Test is used to determine the stress-strain relationships of a cylindrical specimen of either undisturbed or remolded soil. Standard testing procedures are described in ASTM D 2850 for the Unconsolidated Undrained Test and ASTM D 4767 for the Consolidated Undrained Test. Shear wave velocity measurement test parameters and data are described in this table.
--	--

<b>Name</b>	<b>Definition</b>
Specimen	The specimen, of which these triaxial test parameters are a part.
Visual Description	General description of specimen including color, particle description (sand, silt, clay or mixtures thereof), and moisture
Depth	Depth of Specimen below the ground surface
Test Type	The type of triaxial test.
Specimen Diameter	The diameter of the test specimen.
Specimen Height	The height of the test specimen.
Specimen Preparation	The method used to prepare the specimen for testing. Methods include: a) trimming with turntable, b) trimming using a cutting shoe, c) specimen from ring lined sampler (no trimming required), d) remolded, or e) other.
Specific Gravity	Specific gravity of the soil solids
Initial Water Content	Water content of test specimen before testing.
Before Shear Water Content	Water content of test specimen before axial loading is applied
Initial Void Ratio	Void ratio of test specimen before testing
Before Shear Void Ratio	Void ratio of test specimen before axial loading in applied
Initial Degree of Saturation	Degree of saturation of test specimen before testing.
Before Shear Degree of Saturation	Degree of saturation of test specimen before axial loading in applied
Initial Dry Density	Dry density of test specimen before testing
Before Shear Dry Density	Dry density of test specimen before axial loading in applied
Saturation Method	Indicate which method was used to achieve saturation: wet or dry
Total Back Pressure	The back pressure applied to the specimen
Pore Pressure Parameter (B)	The pore pressure parameter (B) at the end of saturation

Lateral Effective Consolidation Stress	The difference between chamber pressure and back pressure prior to shearing
Vertical Effective Consolidation Stress	The lateral effective consolidation stress plus any deviatoric stress applied during consolidation
Overconsolidation Ratio	The consolidation stress during prior to shearing divided by the maximum past effective stress, if known
T <sub>50</sub>	Time to achieve 50% consolidation
Total Density	Density including moisture, of specimen following consolidation, prior to Vs testing
Method of Vs Testing	Description of method used to assess shear wave velocity on the laboratory specimen
Travel Distance	distance between sensors in direction of shear wave propagation
Method of Picking Travel Time	method by pick travel time was identified from wave traces of shear disturbance
Travel Time	Time for shear disturbance to travel between sensors
Calculated Velocity	Travel distance / travel time
Frequency of Pulse	Frequency of shear wave
Interpreted Shear Modulus	Interpreted as $G_{max} = (\text{density}) \cdot (V_s)^2$
Remarks	A text descriptor providing additional information relevant to the Lab Shear Wave Test Parameters and equipment especially if those differ from standard requirements.
Photograph	Photograph of failed specimen
Date Last Updated	The date of the last update to the data in this table



<b>Unit Weight</b>	The unit weight of a soil specimen. Unit weight test data are presented in this table.
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<b>Name</b>	<b>Definition</b>
Specimen	The specimen, of which this Unit Weight is a part. The Unit Weight must be related to a Specimen. This value is a foreign key that should select an instance of Specimen based on the Id value of the Specimen.
Total Unit Weight	The total unit weight of a soil specimen. The total unit weight is defined as the total weight (wet weight) of a soil specimen over the total volume occupied by that soil specimen.
Dry Unit Weight	The dry unit weight of a soil specimen. The dry unit weight is defined as the dry weight (weight of solids) of a soil specimen over the total volume occupied by that soil specimen.
Test Method	Description of the test method or evaluation procedure used to determine the total unit weight.
Remarks	A text descriptor providing additional information relevant to the unit weight test method, evaluation or estimation procedure.
Date Last Updated	The date of the last update to the data in this table

# Appendix II: Interim Data Transfer XML Schema for the Geotechnical Virtual Data Center by Daniel J. Ponti

## BACKGROUND

For this phase of the 2L03 project, the Geotechnical Virtual Data Center (GVDC) has committed to using a data transfer XML schema (a model for how data elements are organized), that is being developed by a team of geotechnical experts sponsored by a Federal Highways Administration Transportation Pooled Fund Study [TPF-5(111)]. The COSMOS team members have played an integral role in developing this schema, most specifically to ensure that essential data dictionary elements are incorporated into the new transfer standard. This schema, called DIGGS (Data Interchange for Geotechnical and Geoenvironmental Specialists), is released in beta form, but some technical aspects of the schema design have rendered the schema unsuitable for production use by the GVDC. The DIGGS team is aware of these issues and is working to resolve them. It is anticipated that a “production-ready” DIGGS schema will be available for GVDC use within the next few months.

To enable the continued development of the GVDC, the 2L03 project team authored an interim schema, referred to as *cosmosDIGGS*, which is essentially a pared down version of the full DIGGS schema that will be suitable for transferring most types of geotechnical data collected by the core GVDC members. Once a production-ready version of the DIGGS schema is released, the data center will switch to using it. The *cosmosDIGGS* schema uses the DIGGS data dictionary (more or less) for the objects and tests are included. The schema has a conceptual basis more in line with an RDBMS, which will make database mapping much easier (although not entirely simple) than with the current DIGGS version. Moreover, the structural design of *cosmosDIGGS* appears to solve a number of issues that have been identified with the current

DIGGS beta. As such, this schema design is being offered to the DIGGS team for their consideration as they work toward resolving some of the issues identified with the current beta version of the DIGGS schema.

The *cosmosDIGGS* schema is much more limited in terms of content than the DIGGS beta release. Locations are limited to holes and sampling stations only. The *cosmosDIGGS* has a robust handling of samples, sampling activities, and geologic/geotechnical observations, but *in situ* tests are limited to geophysical logs, CPT, and dynamic penetration tests (e.g., SPT). Laboratory tests are limited to particle size, density/moisture/porosity tests, and Atterberg tests. Although the scope of *cosmosDIGGS* is limited, it should serve the initial core *Data Providers* sufficiently until the full DIGGS schema is ready. Full documentation of the *cosmosDIGGS* schema is available for download from [http://peer.berkeley.edu/publications/peer\\_reports/reports\\_2009/reports\\_2009.html](http://peer.berkeley.edu/publications/peer_reports/reports_2009/reports_2009.html)

## **THE *COSMOSDIGGS* OBJECTS AND GENERAL SCHEMA DESIGN**

The *cosmosDIGGS* schema is a GML 3.1 application schema that uses the DIGGS namespace. It consists of a number of GML (Geographic Markup Language) objects that sit as collections under the root level in an xml instance document.

The primary *cosmosDIGGS* objects fall into one of these categories;

- projects
- locations
- sampling activities
- samples
- zone systems
- *in situ* tests
- laboratory tests

The above objects carry all of the geotechnical data. There are also a number of metadata *cosmosDIGGS* objects that the primary objects can reference:

- associated files
- remarks
- roles
- business associates
- equipment
- specifications
- contracts
- groupings

In addition, there is one root element, Diggs—an extension of a GML feature collection—that is the wrapper for all of the *cosmosDIGGS* objects.

Collections of primary and metadata objects all sit at the root level of an xml instance. As GML objects, they all inherit from AbstractGMLType and carry a gml:id attribute, which serves as the primary identifier for an object. The base AbstractGMLType also contains the following property elements: description, name, and metaDataProperty. In *cosmosDIGGS*, the gml:id is restricted to be mandatory, and name and metaDataProperty are removed by restriction. Name is replaced by a similarly named element in the Diggs namespace for objects that need names – this is done to both allow only one primary name for an object, and also to avoid an apparent “bug” in GML 3.1 whereby many GML name types can substitute for gml:name. It was decided to not use gml:metaDataProperty because time constraints did not allow for the evaluation and incorporation of that structure into the schema; the *cosmosDIGGS* handles metadata in other ways. In general, though, the philosophy was to utilize GML datatypes when such datatypes would serve the purpose, as opposed to developing parallel datatypes within the Diggs namespace.

## **REQUIRED *COSMOSDIGGS* ELEMENTS**

A minimal valid *cosmosDIGGS* xml instance document requires the main Diggs root element. Within this root element is a mandatory fileInformation element, which carries essential information about the xml instance, and a mandatory projects element which itself must contain at least one Project object. That is all that is required for a valid *cosmosDIGGS* file. An example

minimal *cosmosDIGGS* document (with only the required elements) would look like the following:

```
<Diggs gml:id="usgs_doc1"
  xmlns="http://schemas.diggsml.com/1.0a" xmlns:gml="http://www.opengis.net/gml"
  xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:witsml="http://www.witsml.org/schemas/131"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://schemas.diggsml.com/1.0a
  http://schemas.diggsml.com/schemas/1.0a/diggs/cosmosDIGGS.xsd">
  <fileInformation
    <creationDate>2009-07-15</creationDate>
    <diggsVersion>1.0b</diggsVersion>
  </fileInformation>
  <projects>
    <Project gml:id="usgs_p1"/>
  </projects>
</Diggs>
```

## ASSOCIATIONS AND HIERARCHY

Associations among objects in *cosmosDIGGS* are achieved via explicit referencing only, using an `xlink:href` attribute that corresponds to the `gml:id` of the object that is being referenced. Objects reference other objects through use of property elements of type `gml:ReferenceType` which carry the `xlink:href` attribute. The specific referencing elements that an object contains depend on the type of object, which is detailed below.

To use a database analogy, the referencing elements that an object contains are akin to foreign keys in a table—they act as pointers to a “parent” object. The *cosmosDIGGS* objects know which objects they reference (or belong to), but a referenced object does not keep track of what objects reference it. In other words, children know who their parents are, but parents don’t keep track of their children. Again, this is similar to parent-child tables in a RDBMS, where a parent table carries a primary key only (in *cosmosDIGGS*, this is the `gml:id`), and the child tables carry foreign keys to their parents (elements of type `gml:ReferenceType` that holds the `gml:id` of the parent object in their `xlink:href` attribute ). This structure should allow for fairly simple mapping of *cosmosDIGGS* objects into and out of multiple tables of an RDBMS, if that is desired.

The associations among primary *cosmosDIGGS* objects are as follows:

1. (Project: the Project feature is the master parent of all primary *cosmosDIGGS* objects. EVERY primary *cosmosDIGGS* object must reference at least one Project feature, even if the Project feature is not its direct parent. This is done to allow a processing application to determine if there are any orphaned objects (orphaned with respect to the project) in an xml instance. Note also that in *cosmosDIGGS*, an object can “belong” to more than one Project.
2. Locations: all location features must reference at least one Project feature and may serve as parents to sampling activities, zone systems, and in-situ tests.
3. Sampling Activities: all SamplingActivity objects must reference at least one Project feature, and if the activity occurs at a location (such as a borehole), would also reference one location feature. SamplingActivity objects serve as parents to Sample objects.
4. Samples: all Sample objects reference at least one Project feature and one SamplingActivity object. Sample objects serve as parents to laboratory test objects. Sample objects may be optionally referenced by individual zones within a zone system; this referencing is for information only, to provide a source reference for an observation in a zone. For example, if the description of a sample collected from a borehole is used to interpret the lithology of a zone defined in the hole, the sample that provides this data may be referenced by the zone.
5. Zone Systems: all zone system objects must reference at least one Project feature and one location feature. Zone systems are currently not referenced by any other *cosmosDIGGS* object.
6. *In Situ* Tests: all in-situ test objects must reference at least one Project feature and one location feature. *In situ* test objects may be optionally referenced by individual zones within a zone system; this referencing—for information only—provides a source reference for an observation in a zone.
7. Laboratory Tests: all laboratory test objects must reference at least one Project feature and at least one Sample object. Lab test objects may be optionally referenced by individual zones within a zone system; this referencing—for information only—provides a source reference for an observation in a zone.

## LOCATIONS, POSITIONS, AND THE USE OF GML GEOMETRIES

In *cosmosDIGGS*, only location features and the Project feature carry GML geometries and use GML geometry types. For now, *cosmosDIGGS* limits GML geometries to only these two classes of GML objects.

Project features may not have any spatial properties and therefore do not need to carry any geometry. If a project does have a spatial component, it can be expressed in *cosmosDIGGS* with either single or multiple geometries (e.g., a collection of points; a linestring collection that could represent a road network for example, etc.).

Location features, on the other hand, must carry a datum element and optionally a geometry element that defines the location and shape of the location feature (depends on the type of feature). The datum element is a point object that defines the reference datum location for the location feature in geographic space. For a borehole, this might be the  $x,y,z$  location of the borehole collar at the land surface. For a trial pit (not yet implemented), the location would reference some origin position on the trial pit wall. The location datum is the point from which all observations and tests at that location are measured within a local referencing system.

In *cosmosDIGGS*, referencing a measurement or an observation to a specific position on a location feature is done with an element of type `PositionType`, which is a complex type that offers a choice of one-dimensional, two-dimensional or three-dimensional complex elements. Each of these types contains a “from” and a “to” element, representing distances measured from the location datum *within the geometry of the location feature*.

Which choice of from/to element is used is dependent on the type of feature the measurement references. For a borehole, which is a one-dimensional feature in its local reference system, the one-dimensional position is used, and the “from” and “to” elements are just real numbers that represent the measured depth down the borehole. For a trial pit, the two-dimensional position would be used and “from” and “to” elements would be one or more tuples that refer to the  $x$  and  $y$  distances from the datum within the local reference system that defines the plane of the trial pit wall (which is in turn is defined in three-dimensional space by the geometry of the location feature itself). A sample’s position would be represented as a single tuple ( $x$  and  $y$  coordinate) on this plane. A geologic layer boundary would consist of a list of tuples that represent the coordinates of a linestring that represents the intersection of the plane of

the layer boundary on the trial pit wall, and so on, for three-dimensional locations (volumes) where the “from” and “to” elements would represent surfaces within the volume. Were this structure used in DIGGS, it would allow for a simple means for incorporating additional location features into the schemas, such as trenches, outcrops, transects, seismic surveys, etc.

In *cosmosDIGGS*, only two location features are defined: Hole and SamplingStation. A sampling station is a point in space, thus, only a datum is defined. “From” and “to” elements of observations at a sampling station would be 0. For a hole, “from” and “to” correspond to measured depth down hole (assuming that the datum is set at the top of the hole path).

## CODE LISTS AND ENUMERATED LISTS

Constraining vocabularies so that the meaning of data is represented without ambiguity is essential to interoperability. These constraints are managed in *cosmosDIGGS* through a combination of code lists that reference a dictionary or authority, and text string restrictions built into XML schema called enumerated lists. The power of code lists is that they allow for flexibility for the xml instance author to define the terms used; however, this can create difficulty for the xml consumer in terms of understanding (or having a computer understand) the vocabulary of what is being reported. Code lists cannot be validated in schema and the gml:CodeType data type used to reference a code list is not required to supply a valid link to a defining dictionary.

Enumerated lists do allow for more specificity and can be validated by schema, but extending an enumerated list to contain more values requires a schema change, which can be a hindrance. In *cosmosDIGGS*, enumerated lists are used where the team felt it was necessary to control vocabulary to make processing of the xml instance documents easier and more understandable, and where choices should be limited. To hedge against the limitation of enumerated lists, most lists allow the addition of a non-standard text string that starts with the pattern “other:xx”. Processing applications may not be able to understand this value, but it does allow the information to be transferred.

String values that reference code lists in *cosmosDIGGS* use the GML data type gml:CodeType, which consists of an uncontrolled text string plus an optional codeSpace attribute. In *cosmosDIGGS*, the gml:CodeType data type for elements was used where the string value is *intended* to come from a controlled list of values, or where reference to an authority is



useful, but where such use is not mandatory for processing applications to function. As defined in GML, “if the codeSpace attribute is present, then its value *should* (emphasis added) identify a dictionary, thesaurus or authority for the term, such as the organization who assigned the value, or the dictionary from which it is taken.” Code-type elements in *cosmosDIGGS* are used frequently for things like names, or specialized vocabulary that may be understandable to many without reference to a dictionary or authority, but where such specification would be desired (e.g., use of the term “silty sand” as defined by the USCS classification system).

## SUMMARY DESCRIPTION OF *COSMOSDIGGS* OBJECTS

The following are summary explanations of the primary *cosmosDIGGS* objects. Additional documentation is contained in the schema document itself.

**Project:** A Project is a collection of locations, sampling activities, samples, laboratory tests, zone systems and *in situ* tests that constitute a business activity. Note that in *cosmosDIGGS*, other objects can be associated with one or more projects. While in most practice a *cosmosDIGGS* object will likely be associated with only one Project, this flexibility allows for organizations to incorporate data into a project that may have been originally collected for another purpose, while still retaining a reference to the project that produced the data in the first place.

Projects are of type `ProjectType`, which extends `AbstractNamedDiggsFeatureType`, which in turn ultimately derives from `gml:AbstractFeatureType`. The GML elements inherited by Project objects are as follows: (1) `gml:id`, (mandatory); (2) `gml:description` (optional); and (3) `gml:boundedBy` (optional). In addition to property elements specific to the Project feature, Project also contains a group called `PrimaryFeatureMetadataGroup`. Many other *cosmosDIGGS* objects also contain this group. This is a group of elements that allow a Project to reference external files, remarks (either a simple string or reference to a Remark object), or roles.

**Locations:** A location is a place where data are collected, samples are taken, or observations are made. Concrete location feature types substitute for the abstract

\_Location element. All location features extend `AbstractLocationType`, which is an extension of `gml:AbstractFeatureType`. In addition to the same GML elements inherited as with `Project`, and a name element, `AbstractLocationType` contains the following:

1. `aliases` – holds alternative names.
2. `project` – references the associated project feature.
3. `groups` – references group metadata objects that this hole may be associated with.
4. `datum` – a point object that defines the reference location from which the positions of all measurements, observations, etc. are measured.
5. `datumElevation` - the elevation of the location at its datum; this should be referenced to some geodetic datum.

In addition, all location features include the `PrimaryFeatureMetaDataType`.

The *cosmosDIGGS* schema has only two non-abstract location features, `Hole` and `SamplingStation`. `Hole` is defined as a deep, narrow excavation made in the ground, whereas `SamplingStation` is a point where observations or tests are performed, or where samples are collected. With the *cosmosDIGGS* model, locations can be added to the schema by creating non-abstract location features that extend `AbstractLocationType`.

**Sampling Activities and Samples:** In *cosmosDIGGS*, information about the activity that creates or produces a sample, *including its position on a location feature*, is separated from information that is pertinent only to the physical sample itself. Therefore, sample information is contained in two objects in *cosmosDIGGS* – `SamplingActivity`, and `Sample`.

`Sampling Activity` is defined as: “the action taken to obtain or produce a physical sample, although the activity may not produce a sample (e.g., a core run that produces no recovery). This activity typically occurs at a location feature, but may also occur in a laboratory (e.g., production of an aggregate or subsamples). All

Sample objects must refer to a SamplingActivity object". A Sample is defined as: "a specimen of earth material, liquid or gas that is obtained as a result of a sampling activity, for the purpose of testing, observation or description."

Separating samples from the activities that produce them has some distinct advantages. A SamplingActivity object can exist without a Sample, which allows an instance author to report an attempt to collect or produce a sample that failed (e.g., a core run that produces no sample). A sampling activity can also produce more than one physical sample, such a splitting a sample in the lab, or collecting a water sample and then pouring the water into four vials, thus producing four physical samples. Since more than one sample can refer to a single sample activity, there is no need now to repeat the activity information for each separate sample.

Also, since all information about the location of a sample and other means of its production/collection (e.g., depth down a hole, what other materials it may have derived from) is now contained in the SamplingActivity object, it is possible for a *cosmosDIGGS* xml file to transmit sample information to a lab without any information about the sample's origin. This is useful where the identifying information about a sample needs to be kept confidential.

The SamplingActivity object is of type SamplingActivity type, which extends diggs:AbstractNamedDiggsObjectType and ultimately derives from gml:AbstractGMLType. It inherits the gml:id attribute, gml:description property and diggs:name. It also contains the PrimaryFeatureMetadataGroup. SamplingActivity objects must reference a project and must provide information about the type of sample the activity obtains. Derived sample types come from an enumerated list: {'collected'| 'aggregate'| 'subsample'| 'test'| 'none'}. If the activity occurs at a location, there is an optional positionInfo element that contains the reference to the location feature, as well as complex elements to define the position of the sampling activity and derived sample at the location. Other complex type elements provide information on the source samples (if an

aggregate or subsample activity), sampling method and date, and sampling environment.

The Sample object is of type SampleType, which also extends diggs:AbstractNamedDiggsObjectType and inherits those properties. Samples must reference a Project and a SamplingActivity object. As with locations, samples can also belong to groups and reference Group objects. Additional property elements provide information on the physical characteristics of the sample as well as its chain of custody.

**Zone Systems:** Zone systems are logical collections of zones. A zone is defined as a region or interval at a location that contains observations or interpretations. The *cosmosDIGGS* zone systems are composed of several specific categories of zones.

All specific zone systems extend AbstractZoneSystemType. AbstractZoneSystemType itself extends AbstractNamedDiggsObjectType, which adds mandatory elements to reference Project and Location objects, and the PrimaryFeatureMetadataGroup. The *cosmosDIGGS* schema contains seven types of zone systems:

1. **Color zone systems** — A color zone system contains zones that describe the color of materials encountered. All zones within a color zone system must not overlap, although multiple colors can be described within a single zone.
2. **Component zone systems** — Component zone systems describe details of earth materials encountered at a location. Components restricted to a specific lithologic layer are encoded as constituents within lithology zones (another zone system type). Zones within a component zone system may not be continuous and may overlap. Eight types of component zones are currently defined: bioturbation intensity, consistency, diagenetic features, fossils, hydrocarbons, lithology, physical structures, and trace fossils. An “other” type is also allowed for transfer of additional categories or components.

3. **Discontinuity zone systems** — Discontinuity zone systems describe fractures and joints and their spacing within a zone. Individual discontinuities or zone of discontinuities within a discontinuity zone system may overlap.
4. **Lithology zone systems** — Lithology zone systems describe earth materials encountered at a location. Zones within a lithology zone system must not overlap. Lithologies described in a zone can be described either through classification schemes and/or text descriptors, and also may contain structured information on particle geometry and constituents. Constituents are similar to components but are confined to a single lithology zone.
5. **Orientation zone systems** — Orientation zones describe the geometry of planar surfaces encountered at a location; the standard types of orientation zones included in *cosmosDIGGS* are bedding, joints, cross-beds, faults, and fractures. These zones are designed to characterize regions with similar geometries. Individual measurements of planar geometries of boundaries or faults are recorded in Discontinuity or Lithology zones. Zones within an orientation zone system must not overlap.
6. **Property zone systems** — A property zone system contains zones that are defined by numeric values - usually interpreted as a result of some laboratory or in-situ test. Zones within a property zone system must not overlap. Seven standard types of property zones are included in *cosmosDIGGS*: compressional wave velocity, compressive strength, density, porosity, permeability, shear wave velocity, and shear strength.
7. **Stratigraphy zone systems** — Stratigraphy zones are ordered bodies of rock or sediment, such as formations, stages, biostratigraphic units or aquifers. Zones within a stratigraphy zone system must not overlap, and the names of each zone a zone system must be unique within the zone system. Seven types of stratigraphic zones are included in *cosmosDIGGS*: allostratigraphic, biostratigraphic, chronostratigraphic, hydrostratigraphic, lithostratigraphic, magnetostratigraphic, and tectonostratigraphic.

***In Situ Tests:*** *In situ* tests are measurements that are made at a location. To make it easier for processing applications to find data easier, all *in situ* test objects follow

the same structural pattern. A master element for the test derives from `AbstractInSituTestType`, and contains optional metadata and results elements that themselves reference complex elements that hold the metadata and test results, respectively.

The internal structure of the metadata and results complex elements varies depending on the specific *in situ* test. All *in situ* metadata complex elements, however, inherit from `AbstractTestMetaDataType`, which includes `gml:ReferenceType` elements that can reference Equipment and Specifications metadata objects.

Via the `AbstractInSituTestType`, all *in situ* tests must reference at least one Project feature and a Location feature, along with the position (range) of the test at the location, an optional test date and time, and the `PrimaryFeatureMetadataGroup`.

The *cosmosDIGGS* schema contains the following *in situ* tests: (1) CPT; (2) dynamic penetration (e.g., SPT); and (3) geophysical logs. Additional *in situ* tests could be easily added to the schema by following the template described above.

**Laboratory Tests:** Laboratory tests are measurements that are made on samples or groups of samples. The structural pattern for laboratory tests is similar to that of *in situ* tests. A master element for a laboratory test derives from `AbstractLabTestType`, and contains optional metadata and results elements that themselves reference complex elements that hold the metadata and test results, respectively.

As with *in situ* tests, the internal structure of the metadata and results complex elements varies depending on the specific laboratory test, with the metadata complex element inheriting from `AbstractTestMetaDataType`.

Via the `AbstractLabTestType`, all lab tests must reference at least one Project feature and at least one Sample object, along with the test date and time, laboratory, and the `PrimaryFeatureMetadataGroup`.

The *cosmosDIGGS* schema contains the following laboratory tests: (1) Atterberg limits; (2) density/moisture/porosity; and (3) particle size. In *cosmosDIGGS*, the separate DIGGS tests for moisture, density, and porosity were combined into the same test here because *typically* all three parameters are (or can be) derived from a single test procedure. Additional lab tests can be easily added to the schema by following the template described above.

## ***COSMOSDIGGS* META DATA OBJECTS**

The *cosmosDIGGS* metadata objects (AssociatedFile, Remark, Role, BusinessAssociate, Equipment, Specification, Contract, and Group) provide context to the geotechnical data being transferred. These metadata objects are also GML objects and carry a mandatory gml:id. Primary *cosmosDIGGS* objects can reference these objects via elements of gml:ReferenceType or gml:StringOrRefType. The gml:StringOrRefType type, which allows either a string value or a reference to another object, is used for remarks, specifications, equipment, and business associates. This allows an xml instance author to provide a simple remark or description for these elements instead of having to construct and include a metadata object in the xml file. A brief summary of the purpose of the *cosmosDIGGS* metadata objects follow:

**AssociatedFile** objects contain information about digital files that may contain context information or additional data about a primary *cosmosDIGGS* object. Examples of the kinds of associated files may be reports, tables, or photographs. These objects contain information about the file type, source, etc, and can contain a URL link to the online location of the file.

**BusinessAssociate** objects contain information about a person or entity that performs a role or function, or makes a remark in association with any *cosmosDIGGS* object. These objects contain identifying information as property elements that are similar to what is found in a typical contact or address book.

**Remarks** objects contain commentary about a primary DIGGS feature. The comment can optionally contain metadata about who made the comment (a reference to a BusinessAssociate object), and when it was made.

**Role** objects describe the function assumed or the part played by a person or entity with respect to a primary *cosmosDIGGS* object. Role objects hold a reference to a BusinessAssociate that performs the role as well as the time period in which the role is performed.

**Equipment** objects contain descriptive information about test or construction equipment that may be referenced by tests or other objects. Equipment objects also contain an element that can be used to audit calibrations.

**Specification** objects define test, sampling activity or calibration methods, procedures, or specifications.

**Contract** objects define or reference contracts or legal instruments generally associated with *cosmosDIGGS* Project features.

**Group** objects define a logical collection of locations or samples and may optionally define its purpose. For example, a set of closely spaced holes as part of a multiple well installation may form a group, or a suite of samples used for a test or related series of tests may also belong to a group.



## Appendix III: *MetaDIGGS* Application

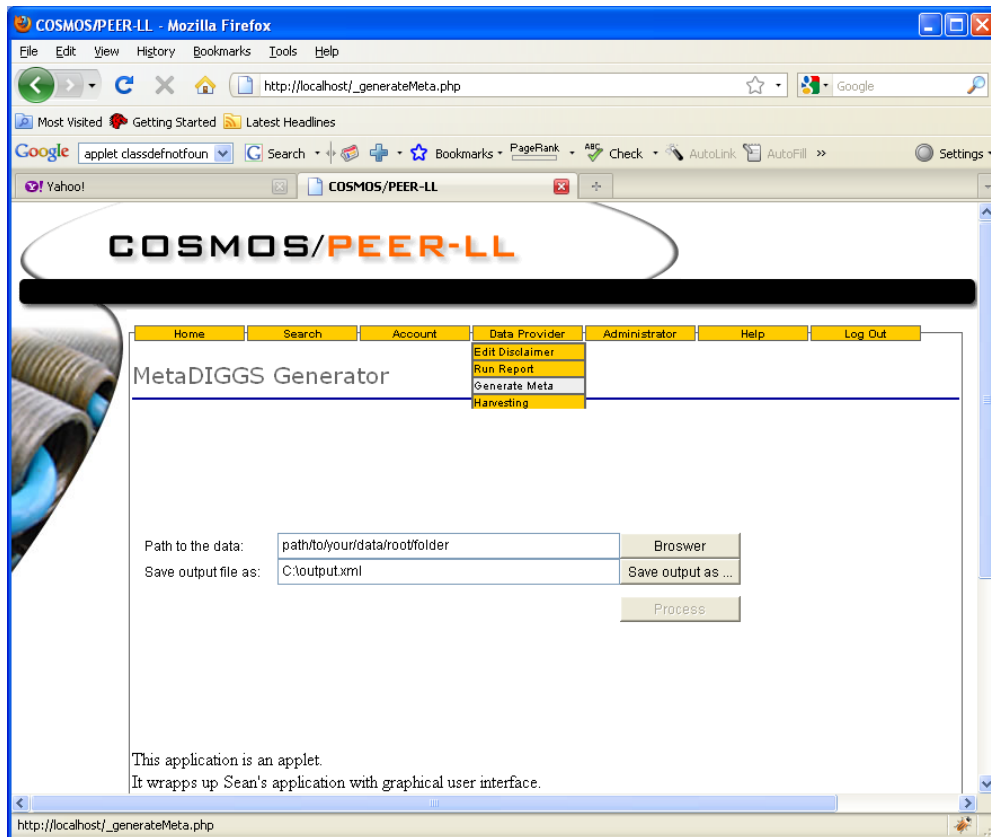
The GVDC *MetaDIGGS* application is a small Java webstart program that extracts metadata from DIGGS locations (e.g., holes and sampling stations) and creates an output xml file that is “harvested” by the GVDC server. The information contained within the file produced by the *MetaDIGGS* application is only that needed to populate the database that serves as the back end for the GVDC website application.

The *MetaDIGGS* application is accessed via the GVDC website. *Data Providers* download and execute the application by choosing the “Generate Meta” item from the *Data Provider* Menu (Fig. 1). To keep the information on the GVDC website up to date, the application should be run whenever any of the *Data Provider*’s DIGGS files have been modified. If the GVDC detects a *MetaDIGGS* output xml file that has been created by the *Data Provider* since the last update, it uses the new *MetaDIGGS* output file to modify the contents of the database.

The *MetaDIGGS* application uses xsl to transform the current DIGGS schema version (currently *cosmosDIGGS*) to the *MetaDIGGS* xml schema. Updates to the *MetaDIGGS* application are handled entirely at the GVDC and will be designed to be compatible with different DIGGS versions as they are released.

### REQUIREMENTS FOR *METADIGGS*

1. *MetaDIGGS* is a Java webstart program that is downloaded to the local client machine, and is platform independent. It will run on any computer using a modern operating system (e.g., Windows, Linux, Unix, MacOS X) that has the Java Runtime Engine (version 1.5 or higher) installed on it. It is recommended that the computer have a minimum of 1 GB of memory.



**Fig. A3.1** *MetaDIGGS* is configured and executed from the GVDC website. This screen is only accessible to those with *Data Provider* access privileges to the site.

2. *MetaDIGGS* must be executed from a *Data Provider's* computer that has access to the directory that contains the DIGGS files the *Data Provider* chooses to make available through the GVDC, and that can also access the directory that will contain the output *MetaDIGGS* xml file that is produced. Typically, execution and file storage will occur on the same computer, but this is not necessary.

## ***METADIGGS* DOCUMENTATION**

Although the current version of *MetaDIGGS* will be maintained on the GVDC server as a Java webstart application, the compiled application, support, and schema files will also be distributed such that the application can be run by the *Data Provider* locally without needing to access the GVDC website. This facility is provided if the *Data Provider* wishes to set up the application to operate automatically on an unattended schedule.

The application and required support files are contained in the distribution available at [http://peer.berkeley.edu/publications/peer\\_reports/reports\\_2009/reports\\_2009.html](http://peer.berkeley.edu/publications/peer_reports/reports_2009/reports_2009.html) This distribution contains the following:

1. The *MetaDIGGS* application (CosmosDiggs2MetaDiggs.jar).
2. The current xsl file (default.xsl).
3. Windows batch and Unix/Linux/MacOS X shell scripts that can be modified to simplify execution (CosmosDiggs2MetaDiggs.bat and CosmosDiggs2MetaDiggs.sh).
4. A directory with a sample *cosmosDIGGS* xml file, the *MetaDIGGS* schema file (metaDIGGS.xsd) and schema documentation.

To install the application, simply place the .jar file and xsl file in an appropriate directory. *MetaDIGGS* is executed by the following commands, typed into a command window or terminal shell, or executed via a batch file or shell script:

```
java -Xms256m -Xmx512m -jar CosmosDiggs2MetaDiggs.jar <path to root directory  
containing DIGGS files> <path to output.xml file> <path to the xsl file>
```

The start heap (-Xms) and maximum heap (-Xmx) memory parameters can be adjusted to account for a large number of DIGGS files in the event that an out-of-memory condition arises during execution.

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