Award Number G12AC20211

Detailed Surficial Geologic Mapping for the Weldon Spring, Chesterfield, Manchester, House Springs and Maxville 7.5-minute quadrangles as a Portion of the St. Louis Area Earthquake Hazard Mapping Project (SLAEHMP)

Collaborative Research with:
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Earthquake Hazards Program Office
and
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Abstract

The Missouri Department of Natural Resources' (MoDNR) Division of Geology and Land Survey (DGLS) proposed and has produced detailed geologic maps of surficial materials for the Weldon Spring, Chesterfield, Manchester, House Springs and Maxville 7.5-minute USGS quadrangles as part of the St. Louis Area Earthquake Hazard Mapping Project (SLAEHMP). Surficial materials mapping comprises the first phase of seismic hazard assessment by reducing the uncertainty in the three dimensional distribution of surficial material units and their related physical properties.

In addition DGLS produced a depth to bedrock model for the remaining 12 quadrangles located in the western portion of the SLAEHMP study area. This model includes information on shear wave velocity, depth to groundwater, elevation, depth to bedrock and uncertainty values for depth to bedrock data. Existing data from multiple sources was compiled and correlated to characterize the study area. The maps were produced in the Geographic Information System (GIS) spatial database format to reduce file size and to improve the quality and functionality of the final product.

Introduction

The goal of the project for fiscal year 2013 (FY13) was to complete new detailed surficial geologic maps for the Weldon Spring, Chesterfield, Manchester, House Springs and Maxville 7.5-minute quadrangles. This work completes surficial material mapping of the SLAEHMP study area (figure 1). A depth to bedrock model, required to assess the aerial variability of earthquake hazards, was created for the remaining 12 quadrangles in the SLAEHMP area. Depth to groundwater was addressed by the SLAEHMP Technical Working Group (TWG) to rectify the true potentiometric surface. Shear wave velocity (Vs) data collected by the Missouri Department of Transportation (MoDOT) in 2010, USGS in 2007 and Missouri University of Science and Technology (MS&T) in 2008 were also used to characterize surficial material units.

Mapping for this project was completed using available subsurface data and stratigraphic profiles developed for the St. Louis surficial materials database created by DGLS as part of the National Earthquake Hazard Reduction Program (NEHRP), data from the St. Louis database developed by Missouri University of Science and Technology (MS&T), correlations with published, small-scale surficial maps (Goodfield, 1965; Lutzen and Rockaway, 1971; and Brill, 1991) and supplemental drilling by MoDOT to collect depth-to-bedrock data. Existing small-scale maps and reports indicate these areas have surficial material units that vary from Paleozoic bedrock exposures and residuum to early Quaternary loess and alluvium with highly variable grain size. Boring data was incorporated to determine the three-dimensional spatial variation of the surficial material unit properties. This analysis will be used by others to assess the response of the alluvial column, the liquefaction potential and the potential for site amplification in response to different magnitude earthquakes. The information will improve accuracy of the earthquake hazard maps prepared by the SLAEHMP TWG.

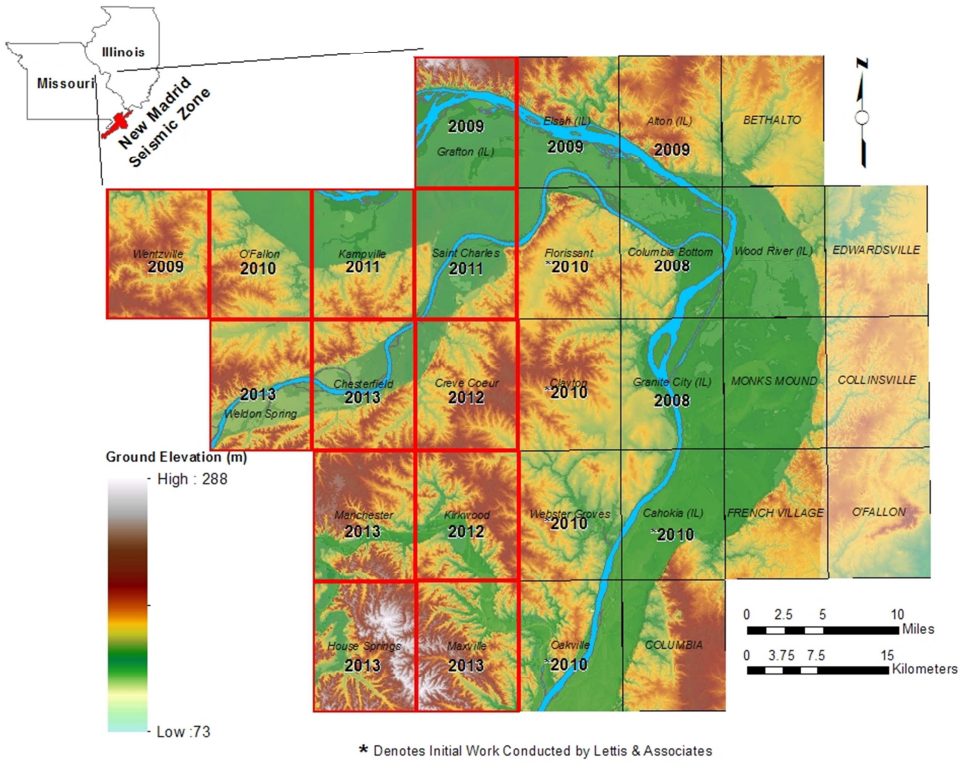

Figure 1. SLAEHMP study area. Years listed on quadrangles denote completion dates. The western 12-quadrangle area is marked by red outline.

Methods

Borehole data derived from DGLS's St. Louis surficial material database was supplemented by the MS&T St. Louis database. Geotechnical information was compiled and correlated with DGLS water well databases to identify inconsistencies in depth to bedrock measurements. Corrected data was then imported into a DGLS geodatabase created for this project. Additional depth-to-bedrock information was collected from outcrop location maps generated during recent bedrock-mapping projects as well as from four borings to bedrock completed by MoDOT during February 2013.

The Geographic Information System (GIS) geodatabase format is preferred over the GIS shapefile format. This format increases productivity and functionality while reducing file size. Individual geodatabase structures include feature data sets of major layer groups that include feature classes of specified data. An example of this structure is depicted in figure 2. The five-quadrangle mapping area geodatabase contains seven feature data sets housing their corresponding feature classes. The geodatabase also has a raster catalog that contains map imagery such as a 10 meter Digital Elevation Model (DEM).

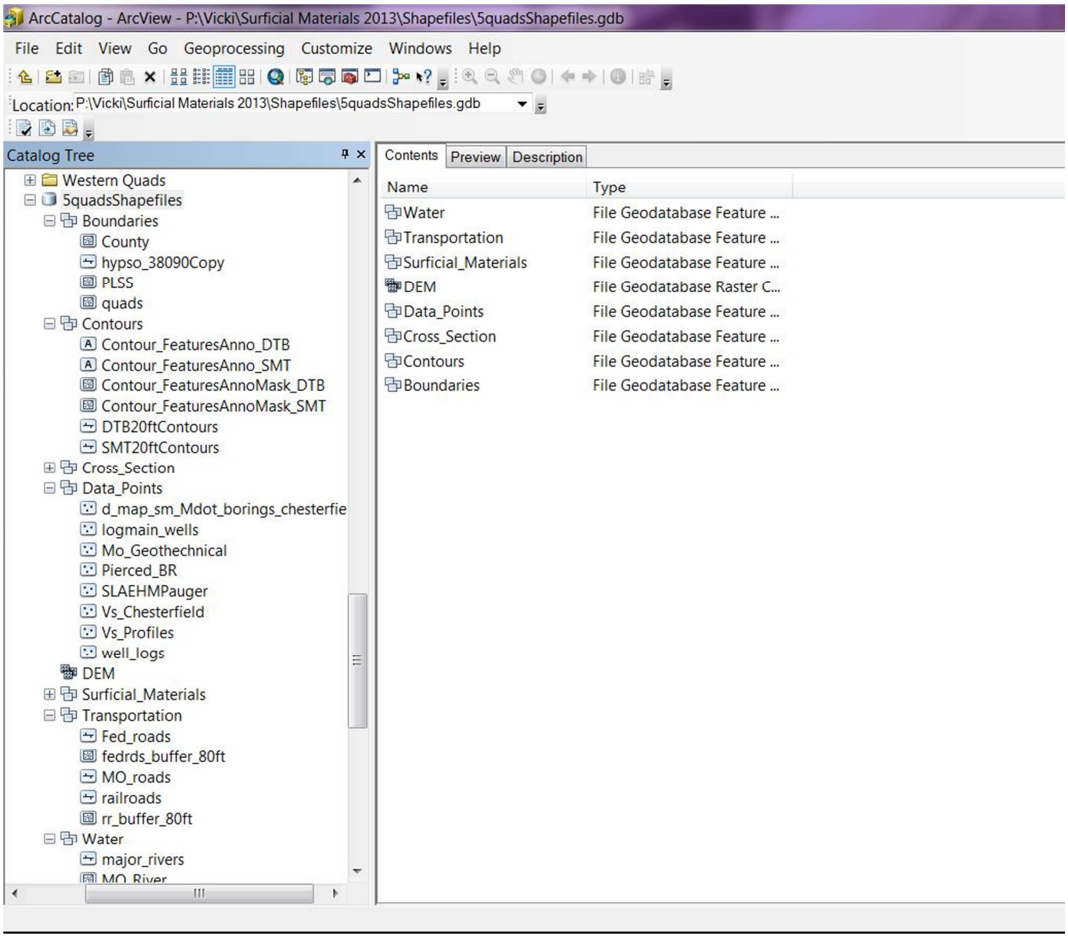

Figure 2. Screen shot of the structure of the five-quadrangle mapping area geodatabase as viewed in ArcCatalog. Feature data sets are shown on the right; feature classes contained in the data sets are shown on the left.

The map layout comprises a 1:65,000-scale surficial material geologic map, a 1:65,000-scale cross section, a 1:145,000-scale Surficial Material Thickness map with material thickness contours overlying a USGS 10-meter DEM, a 1:145,000-scale depth to bedrock map with bedrock elevation contours overlying a USGS 10-meter DEM and a 1:145,000-scale Data Point Location map showing the spatial distribution and types of data used to produce the map. Geologic descriptions of the surficial material units and a shear wave velocity profile data are also displayed on the map. An example of the surficial material geologic map in GIS format is shown in figure 3.

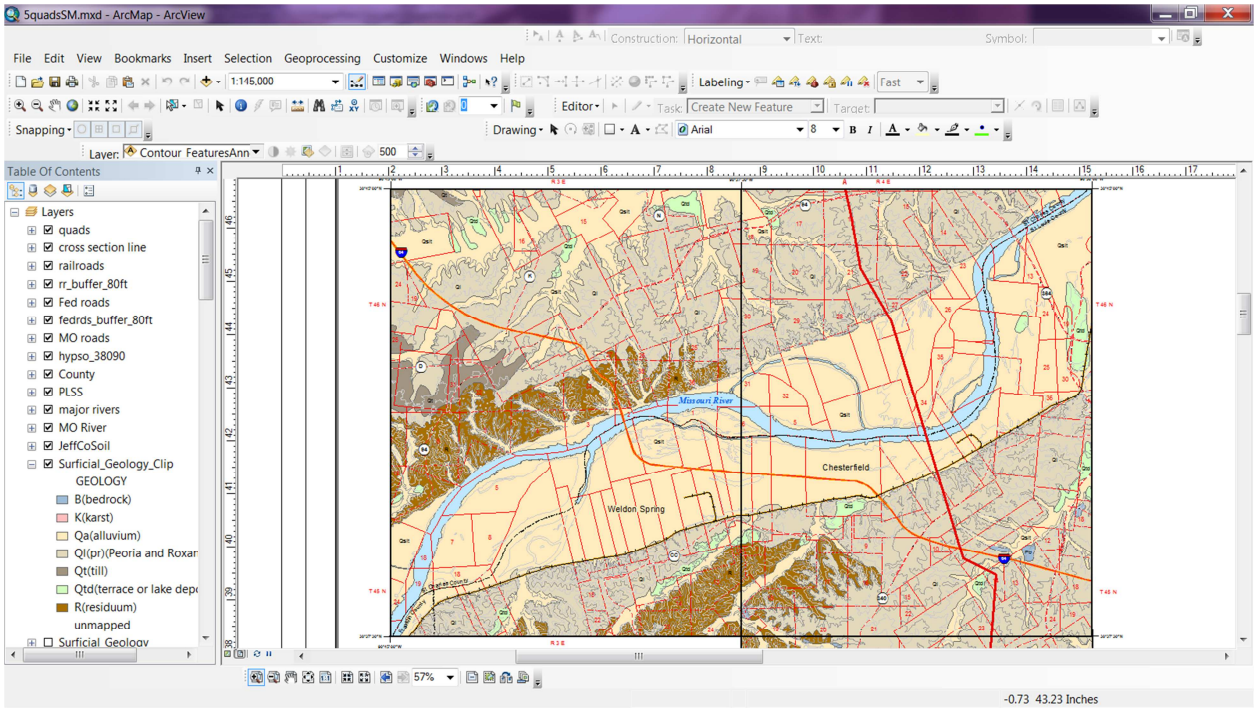

Figure 3. Screen shot of surficial material geologic map. The layered structure of the map geodatabase is visible on the left; an example of the map in progress is on the right.

The surficial material geologic map is in a layered format that includes all relevant base map information. The base mapping was created at DGLS using surficial material unit shapefiles and surface elevation contours at 50-foot intervals. Transportation, water and boundary features were added to complete the map. Surficial material units and their characteristics, including age and interpretation of the material, are described in the attribute table (figure 4).

Table

Surficial_Geology_Clip

Shape *	OBJECTI	ABBREV	UNIT	AGE	INTERPRET_	DESCRIPT_	OCCURRENCE	STATE	GEOLOGY
Polygon	508	B	near-surface	preglacial (Paleozoic)	bedrock	shale, sandstone, limestone, dolomite		Missouri	B(bedrock)
Polygon	549	B	near-surface	preglacial (Paleozoic)	bedrock	shale, sandstone, limestone, dolomite		Missouri	B(bedrock)
Polygon	550	B	near-surface	preglacial (Paleozoic)	bedrock	shale, sandstone, limestone, dolomite		Missouri	B(bedrock)
Polygon	565	B	near-surface	preglacial (Paleozoic)	bedrock	shale, sandstone, limestone, dolomite		Missouri	B(bedrock)
Polygon	236	K	Peoria and Roxan Si		Karst	depression or sinkholes, cave openings and solution pinnacles	carbonate bedr	Missouri	K(karst)
Polygon	237	K	Peoria and Roxan Si		Karst	depression or sinkholes, cave openings and solution pinnacles	carbonate bedr	Missouri	K(karst)
Polygon	238	K	Peoria and Roxan Si		Karst	depression or sinkholes, cave openings and solution pinnacles	carbonate bedr	Missouri	K(karst)
Polygon	239	K	Peoria and Roxan Si		Karst	depression or sinkholes, cave openings and solution pinnacles	carbonate bedr	Missouri	K(karst)
Polygon	496	Qa		Holocene and Pleistocene(Wi	alluvium	clay, silt, sand, gravel and boulders(3~25m)	Floodplain of riv	Missouri	Qa(alluvium)
Polygon	566	Qa		Holocene and Pleistocene(Wi	alluvium	clay, silt, sand, gravel and boulders(3~25m)	Floodplain of riv	Missouri	Qa(alluvium)
Polygon	582	Qa		Holocene and Pleistocene(Wi	alluvium	clay, silt, sand, gravel and boulders(3~25m)	Floodplain of riv	Missouri	Qa(alluvium)

(0 out of 161 Selected)

Surficial_Geology_Clip

Figure 4. Screen shot of the surficial geology attributes table showing data types contained in the table.

The 1:65,000-scale cross section (figure 5) was constructed to display the same features as the surficial material geologic map. The cross section line was drawn through pierced bedrock data points where possible to better show geomorphic characteristics of the mapping area. The topographic surface was generated from a 10-meter DEM. The bedrock surface was interpreted from borings that intersect bedrock and from surface outcrops. Due to changes in topography from the dissected uplands to the floodplain, a 20X vertical exaggeration was chosen so areas of low relief could be recognized and mapped accordingly.

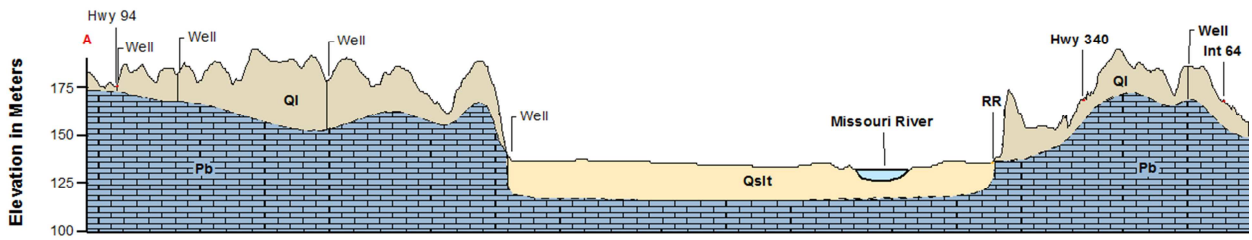

Figure 5. Portion of cross section for five-quadrangle map area.

The map layout contains three smaller scale inset maps showing surficial material thickness, bedrock surface and data point locations of the mapping area. The surficial material thickness map (figure 6) was constructed at 1:145,000-scale with a USGS 10-meter DEM as a base layer. Surficial material thickness was derived from calculating the difference between surface elevation and the elevation at the top of bedrock. A raster interpretation of this difference was generated using ArcGIS software and its Spatial Analyst extension. Contours were generated from the raster data at a 20-foot interval.

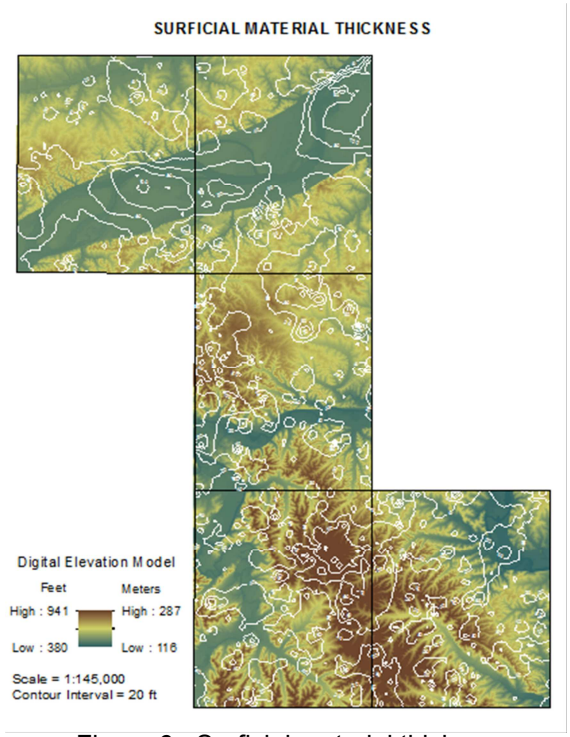

Figure 6. Surficial material thickness map.

The Top of Bedrock inset map (figure 7) was constructed at 1:145,000-scale with a USGS 10-meter DEM as a base layer. The top of bedrock was determined from correlation of drilling logs, shallow seismic surveys and water well data from DGLS databases. Data was manipulated using ArcGIS software and its Spatial Analyst extension. A raster was generated from the data and then contoured at a 20-foot interval.

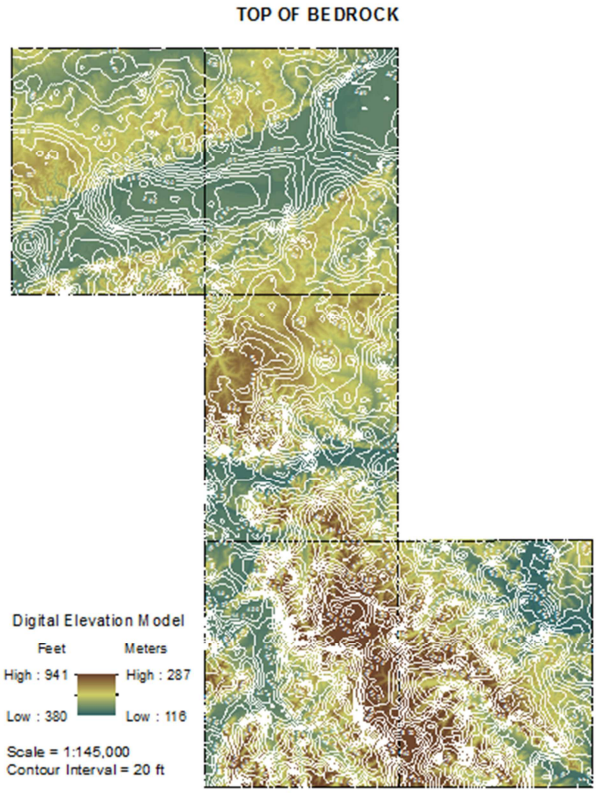

Figure 7. Bedrock surface elevation map.

The data point location inset map (figure 8) was constructed at 1:145,000-scale and uses the surficial material geology layer as a base map. The map displays the spatial distribution of the data as well as indicating the source of the data: bedrock borings, geotechnical borings and seismic surveys.

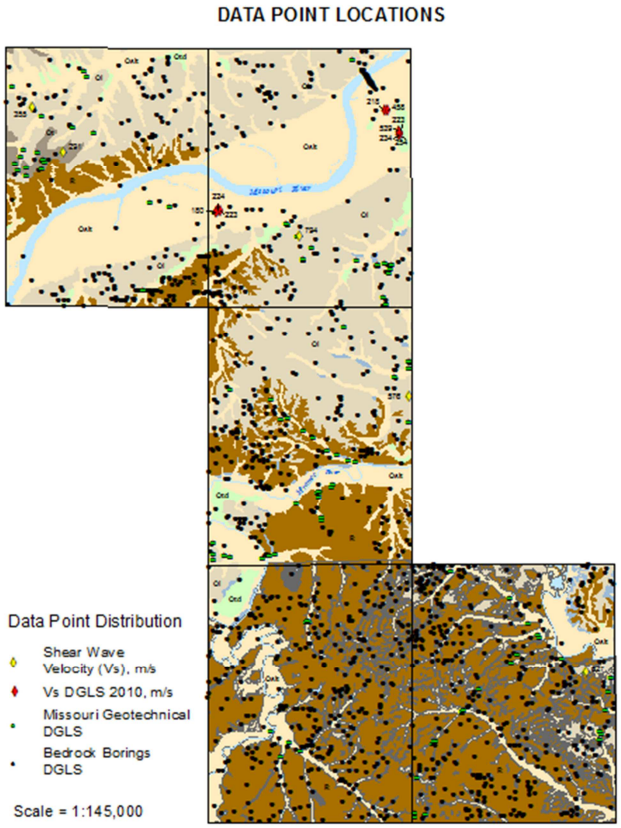

Figure 8. Data point locations

Results

The Weldon Spring and Chesterfield quadrangles include portions of the Missouri River floodplain. The floodplain is up to three miles in width in this area. The Weldon Spring, Chesterfield and Manchester quadrangles include portions of the loess covered uplands and lie within the Dissected Till Plains Section of the Central Lowlands Province of the Interior Plains Physiographic Division. The House Springs and Maxville quadrangles lie within the Salem Plateau Section of the Ozark Plateau Province of the Interior Highlands Physiographic Division. The lowest recorded elevation is 390 feet above mean sea level (msl) and occurs along the Meramec River on the eastern edge of the Maxville quadrangle. The highest recorded elevation is 940 feet above msl and occurs in the northeastern corner of the House Springs quadrangle. Total relief of the five-quadrangle area is approximately 550 feet.

The map area is underlain primarily by Paleozoic-age limestone and shale. The majority of the Chesterfield quadrangle and the northeast portion of the Maxville quadrangle are underlain by Mississippian-age St. Louis, Salem and Warsaw formations. The majority of the Weldon Spring quadrangle through the northwest corner of the Maxville quadrangle is underlain by the Mississippian-age Burlington-Keokuk Limestone (undifferentiated). The southwest corner of the Manchester, majority of the

House Springs, and southwest corner of the Maxville quadrangle are underlain by Ordovician-age St. Peter, Joachim and Plattin formations.

Surficial materials in the five-quadrangle study area are comprised of alluvium, loess, residuum, terrace deposits and glacial till. Areas of bedrock exposure are also present. Descriptions of these units follow:

Alluvium – This unit has been deposited by the Missouri and Meramec rivers. The approximate upper 15 feet comprises silt with variable amounts of clay and organic material. Material below the silt is predominantly sand and gravel to the top of bedrock. Thickness of this unit ranges from 80 to 100 feet. The water table is approximately five to 15 feet below ground surface, resulting in an interval of saturated sand and gravel greater than 80 feet thick.

Loess – This unit is a wind-blown deposit of silt and clayey silt with occasional pockets of clay, sand and gravel. The unit is composed of two separate loess layers, the Roxana below and the Peoria above (Goodfield, 1965). Total thickness of the combined unit may reach 140 feet. The Roxana is has greater clay content and may have a paleosol developed in the uppermost few feet. The contact between the two units forms a potential slide plane in areas of high topographic relief. The loess overlies Mississippian-age bedrock comprised of limestone and shale creating two unique environments. Where the loess is thin, the limestone may be karstic. Where the underlying unit is predominantly shale, water will perch, destabilizing the contact zone. Where the loess rests on shale, slide potential is increased.

Residuum – Areas of residual material are found on the slope and toe slope of high relief areas. Content is dependent on the bedrock parent material but typically has high clay content with fragments of parent material.

Terrace deposits – Terrace deposits in the project area are slightly different than previously mapped terrace deposits (Goodfield, 1965; Brill, 1991; and Harrison, 1997). All were deposited during fluvial events, leaving the terrace above low flow stage of the river. However, terrace deposits in this area have a lacustrine signature of sensitive organic clays approximately 20 feet below the surface. After high stage flow returned to normal, low lying areas within the terrace filled with organic-rich clay material. This zone has a very low shear wave velocity and underlies considerable infrastructure.

Glacial till – Deposits of clayey till are located in the western portion of the Weldon Spring quadrangle. Quaternary till was deposited as a drift blanket during glaciation north of the Missouri River. The till is a mixture of clay, silt, sand, gravel and cobbles that covers the bedrock surface. It varies in thickness from 10 to 25 feet with the thickest deposits inland from the river and in depressions in the bedrock surface.

Areas of bedrock exposure – Locally, surficial materials are absent or insignificant. Bedrock exposures in these quadrangles are typically found in areas of high topographic relief. Bedrock is Paleozoic in age. Lithologies are primarily limestone and shale, but dolomite and sandstone are also present.

Shear wave velocity data collected for the Division of Geology and Land Survey by MoDOT during 2010 is summarized in a table and graph presented with the map. All data was collected on the Chesterfield quadrangle. The averaged shear wave velocities are presented in table 1.

Table 1. Averaged Vs data for sites located on the Chesterfield quadrangle.

Averaged Shear Wave Velocity			
Site	**Vs (m/s)**	**Depth (ft)**	**Depth (m)**
CH-01	224	46.6	14.2
CH-02	223	26.5	8.1
CH-06	180	6.7	2
CH-07	254	53.3	16.2

CH-08	223	49.9	15.2
CH-09	539	40.4	12.3
CH-10	234	53.6	16.3
CH-13	218	30.8	9.4
CH-14	458	43.5	13.3

Conclusion

The surficial material geologic maps for the Weldon Spring, Chesterfield, Manchester, House Springs and Maxville 7.5-minute USGS quadrangles have been completed as deliverables in fulfillment of award number G12AC20211. These maps were compiled using new and existing data derived from the St. Louis surficial material database (previously compiled by DGLS), St. Louis database, shallow seismic surveys, Seismic Cone Penetrometer Testing (SCPT) and from various sources listed in the bibliography.

The maps were constructed in a GIS geodatabase format for improved quality of the finished product, reduced file size and increased storage capacity to facilitate ease of map transfer. Attribute tables are associated with each feature class in the geodatabase for ease of viewing data.

The specific age of mapped units was not determined or depicted; only relative ages are indicated. Considerations were given to small scale maps of the region produced by former DGLS staff. Inset contour maps were developed using a 10-meter DEM and data points across the 22 quadrangle SLAEHMP project site to generate contours based on surficial material thickness and elevation of the top of bedrock. The contour maps depict a 20-foot contour interval and were clipped to each specific quadrangle boundary. A surficial material vector map was utilized as a base map to display the spatial distribution of the point data. The inset maps were created and added to the final map product.

The geologic surficial material mapping and accompanying data are critical base information for seismic hazard analysis. The depth to bedrock, depth to water table and type of surficial material form the fundamental basis for seismic assessment. Analysis of this data is used to assess how the alluvial column will respond to different magnitude earthquakes with respect to liquefaction and site amplification potential. The data compiled for the SLAEHMP surficial material maps improves the accuracy and precision of the earthquake hazard maps being prepared by the SLAEHMP TWG.

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