CHAPTER 5 – DATA PROCESSING

The processing flow for the EM31-3 data involved fourteen steps, as follows:

1. Download EMI and GPS data from the handheld data logger to the laptop computer.
2. Import data into the Multi31 software package developed by GeoMar Software Inc.
3. Split the data for each coil separation, apply GPS positioning and export data in ASCII format.
4. Analyze latency test files to determine proper latency correction.
5. Apply latency correction to all data sets.
6. Check daily background test data to determine if instrument drift has occurred. (Shift baseline values if necessary.)
7. Reformat data for upload into the Emigma ™ software package developed by Petros Eikon Inc.
8. Once the best starting model has been determined, the EM31-3 data were inverted for each profile section; that is, each lane. The geo-electric section is then comprised of a series of 1-D depth soundings spaced about 1 m apart along the length of the road surveyed.
9. The output from the Emigma inversion program yields modeled layer thickness and resistivity (inverse of conductivity) values for each closely spaced 1-D sounding.
10. To improve the profile interpretation, interval conductance values (conductivity multiplied by thickness) were calculated for each 0.5 m depth interval.
11. Interval conductance values were imported into Geosoft Oasis and gridded to produce color cross-section (profile) plots.
12. The interval conductance from 1.0 to 1.5 m was stripped out of the profile and plotted on the plan with FHWA-CFLHD stationing, topography and cultural features.
13. The conductivity and interval conductance values were used to determine if any correlation exists between soil conductivity and other physical soil properties (e.g., plasticity index, liquid limit, plastic limit, etc.).
14. All output data were imported into AutoCAD for scaling and fitting to the FHWA P & P design drawings.

5.1 EMI MODELING

The EMI data were modeled using Emigma™ software, commercially available from Petros Eikon, Inc. Emigma is a profile data interpretation program for interpreting electromagnetic conductivity sounding data acquired using Geonics EM31, EM34, EM38 or similar instruments, in terms of layered earth (1-D) models.

Figure 6 shows a hypothetical example of the derivation of interval conductance from the raw (field) apparent conductivity data. Two cases are shown in the figure, a *conductive* and a *resistive* case. The first window box labeled “Raw Data, Multiple Configurations” represents the individual apparent (or terrain) conductivity values versus effective investigation depth for each instrument orientation. The effective investigation depth is a function of coil spacing, dipole orientation, frequency and instrument height above the ground surface. The apparent, or terrain, conductivity measured by each instrument is the average or "bulk" conductivity of all the material from the surface to the effective depth of investigation. The next window box labeled "Model from Inverted Data" shows the1-D model results from inversion of the raw apparent conductivity data. The next window box labeled "Total Conductance" shows the cumulative increase in total conductance with depth. The last window box labeled "Interval Conductance" shows the calculated conductance over 0.5 m (1.6 ft) intervals as determined from the layered model. In this last window box we attempted to match the color scheme with the color contouring used for all the final plots. The station-to-station variability in the inverted layered models (plotted in conductivity) can be relatively large due to the limited number of data points and the degrees of freedom in the 1-D modeler. The station-to-station variability in the total conductance is much less because the layer thickness is introduced. The calculation of interval conductance (layers shown in color) allows the gridding of vertical profiles and provides a means to smooth out the station-to-station variations inherent in the inverted data. In doing so, the dynamic range is slightly reduced in proportion to the thickness of the depth interval selected.

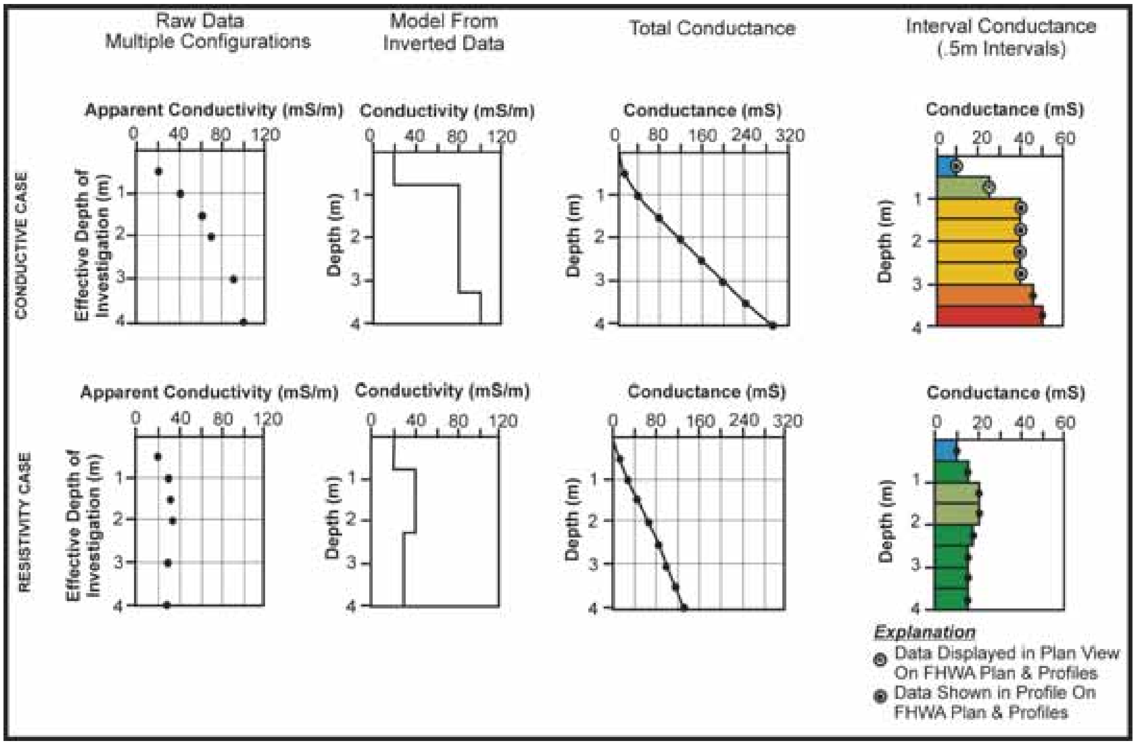

Figure 6. Charts. Hypothetical Example of Derivation of Interval Conductance.

EMI conductivity sounding curves were acquired along profiles using three different coil separations and two dipole orientations collected from two passes with the instrument down each profile lane (see table 2). The software can only invert data that is acquired at discrete station locations. Due to the necessity of acquiring large volumes of data over large areas rapidly, it is not possible to repeatedly occupy and record EMI measurements at discrete station locations; that is, at the exact same location for every instrument configuration for every pass in the lane.

To obtain data at discrete locations for entry into the inversion program, the following data preparation steps were followed using the Emigma™ software:

1. Merge common data sets into a single profile.
2. Divide the profile into approximately straight-line segments.
3. Sort on data locations.
4. Filter spatial positions to smooth profile locations.
5. Interpolate data to obtain common data positions.
6. Decimate data back to approximately 1 m spacing.

The data were then inverted using the Emigma™ inversion routine. The starting model used 8 layers. The layer thickness for layers 1 through 7 was fixed at 0.5 m (1.6 ft). Layer 8 was a half-space. The starting resistivity for layer 1 was 50 Ohm-m to approximate the pavement and the sub grade immediately below the pavement. The resistivity value assigned to layers 2 through 7 for the starting model was 10 Ohm-m representing clay-rich materials. Layer 8 was assigned a starting resistivity value of 20 Ohm-m representing the native materials. All of the inversion sets were subdivided to correspond to the individual P & P drawings provided by CFLHD

5.2 GROUND TRUTH

To provide ground truth information, 20 locations were selected for soil boring sampling and analysis. The boring locations were identified based on the EMI P&P data, in terms of measured soil conductivity using a prioritization scheme that classified areas along the 16 km (10 mi) roadway as low (4 borings), moderate (7 borings) or high (9 borings) potential clay content. Geotechnical drilling, sampling and lab analyses were performed in accordance with specifications used by CFLHD for similar highway investigations (i.e., geotechnical design needs). Enviro-Drill, Inc., performed the boring and sampling, and Western Technologies, Inc., performed lab analyses under ASTM standards C136, D4318, C566, and D2487. All the lab data were included in the unpublished Phase II Report. Table 3 lists the definitions of the Atterberg Limits of Soils properties samples tested during the analysis or calculated from results of the analysis. The locations of the borehole are shown on the P & P plots in appendix A and are listed in table 4.

Table 3. Definitions of Atterberg Limits of Soils Properties.

Sieve Analysis	Percentage of material finer than NO. 200.
Liquid Limit (LL)	The water content corresponding to an arbitrary limit between the liquid and plastic states of consistence of a soil (3).
Plastic Limit (PL)	The water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistence of a soil (3).
Plasticity Index (PI)	The numerical difference between the liquid limit and the plastic limit, or, synonymously, between the lower plastic limit and the upper plastic limit (3).
Moisture Content (MC)	Percentage of water present by mass of a given soil sample (4).
Liquidity Index (LI)	Dependent on the water content with respect to the liquid limit and plastic limit (5).

Table 4. Dulce Borehole Locations.

Borehole ID	Approximate Meters North of Mile Marker	FHWA X	FHWA Y	Offset from Center Line (approx.)
04P-EM01	774.3 m N of MM45	35666	64697.9	1.8 m left
04P-EM02	959.1 m N of MM45	35656.5	64881.8	1.8 m right
04P-EM03	1253.6 m N of MM45	35684.9	65175.4	1.8 m right
04P-EM04	1481.9 m N of MM46	35707.6	65401.5	1.8 m left
04P-EM05	19.7 m N of MM46	35713.7	65547.5	1.8 m left
04P-EM06	361.6 m N of MM46	35715.7	65888.3	1.8 m left
04P-EM07	613.6 m N o MM46	35779	66132.4	1.8 m left
04P-EM08	858.2 m N of MM46	35841.1	66369	1.8 m left
04P-EM09	978.8 m N of MM46	35871.7	66485.6	1.8 m right
04P-EM10	1459.1 m N of MM50	35994	66950.1	1.8 m right
04P-EM11	596.6 m N of MM50	38068.5	72035.5	1.8 m right
04P-EM12	933.5 m N of MM50	38066	72372.4	1.8 m left
04P-EM13	1228.9 m N of MM50	38018.4	72661.3	1.8 m right
04P-EM14	461.9 m N of MM52	36662.6	74526.5	1.8 m left
04P-EM15	178.8 m N of MM53	36204.8	75767.6	1.8 m left
04P-EM16	713.8 m N of MM52	36192.6	76303	1.8 m left
04P-EM17	898.5 m N of MM53	36159.3	76483.9	1.8 m left
04P-EM18	1010.3 N of MM53	36127.1	76590.2	1.8 m left
04P-EM19	63.9 m N of MM54	35778.1	77159	1.8 m left
04P-EM20	1019.5 m N of MM54	35334.4	77995.2	1.8 m left

Borehole Identification Legend
04 - Year Drilling occurred
P - Pavement
EM - Electromagnetic Survey
01 - Borehole Number