APPENDIX A

RESEARCH PLAN

To accomplish the objectives, a research plan consisting of five tasks was developed and is presented below.

Task 1— Review and Information Gathering

In this task, the research team will become familiar with MDOT’s current and historical processes/procedures for selecting MR and k values for the design of flexible and rigid pavements. The research team will also obtain information from MDOT that is needed for the other tasks in this study. These include:

1. The locations of FWD tests that were conducted in the past and the availability of the measured deflection data and the pavement cross-section data that existed at the time of testing.
2. The depth of frost penetration especially in the northern part of the Lower Peninsula and in the Upper Peninsula.
3. The repeated load triaxial test data that were obtained as part of research projects that were sponsored by MDOT from 1975 to 1979. The data will be digitized and tabulated along with the roadbed soil type and will be used in later tasks.
4. Traffic data in terms of average daily traffic (ADT) and percent commercial.

The effort of this task should produce:

1. Tabulation of the procedures used by the various Regions for selecting MR and k values and the basis of such selection. Based on the information, differences and similarities in these procedures will also be tabulated.
2. Tabulation of the range and typical MR and k values used by the regional soil engineers for the various soil types.
3. A brief summary of the background and the development of the SSV-resilient modulus chart provided in Figure 2.2.
4. Assessment of the adequacy and sufficiency of the existing process for estimating MR and k values to be used in the new M-E PDG.
5. For all available deflection data, tabulation of the locations of all FWD tests that were conducted in the past and the pavement cross-sections that existed at the time of testing.
6. A map or a chart showing the depth of frost penetration where data are available.
7. Tabulation of the cyclic stress, confining pressure, vertical and horizontal deformations and strains, and the resilient modulus of the various roadbed soils included in the MDOT sponsored research projects during the period of 1975 to 1979.

Task 2— Partitioned State Map

Based on the MDOT Field Manual of Soil Engineering, the information obtained from the various regions in Task 1, the trunkline locations, and the soil maps of the US Soil Conservation Services (USCS), the state will be partitioned into geological zones for the purpose of field testing and soil sampling. The state will be divided into a maximum of 15 coarse clusters where the soil within any given cluster would have similar range of engineering and physical characteristics. Each coarse cluster will then be divided into areas to narrow the range of the soil characteristics. A maximum of 99 areas will be produced. The results will be presented to members of the Research Advisory Panel (RAP) for review and possible modification. The main use of the partitioned soil map is to determine the locations of field testing and soil sampling.

Task 3— Field and Laboratory Testing and Soil Sampling

In this task, the research team will finalize the field sampling and the laboratory testing plans based upon the information obtained in Tasks 1 and 2. The total number of tests to be conducted will be based purely on cost and available budget. The field sampling and the laboratory testing plans are presented in three subtasks below.

Subtask 3.1 - Soil Sampling Plan

From each area on the State Partitioned map, soil samples will be obtained. In areas where the roadbed soil is predominantly sand, only disturbed bag samples will be collected. In clay areas, both disturbed and undisturbed thin Shelby tube samples will be obtained. In total, 75 disturbed roadbed soil samples and 12 undisturbed (Shelby tube) samples will be collected. All samples will be transported to the laboratory for testing as presented in Subtask 3.2 below.

Subtask 3.2 – Laboratory Testing Plan

The laboratory plan consists of moisture content, sieve, Atterberg limits, and cyclic load triaxial tests. All tests will be conducted according to MDOT, AASHTO, or ASTM standard test procedures. Results of the laboratory testing will be analyzed (see Task 4) to determine:

1. Soil classification - For each of the 75 disturbed samples (bag samples), the soil will be subjected to sieve analyses to determine the breakdown between sand and clay/silt particles. Any sample where the fine fraction (passing sieve number 200) is more than seven percent, plastic and liquid limit tests will also be conducted. Results of the sieve analyses and Atterberg limit tests will be used to:

   - Classify the soil according to the USCS and the AASHTO soil classification systems.
   - Develop, if possible, statistical correlations between the resilient modulus of the roadbed soils and the gradation and Atterberg limits of the material.

2. Cyclic load triaxial tests - For each location where Shelby tubes are collected, repeated load triaxial tests will be conducted. The samples will be tested at three moisture contents to simulate the effects of seasonal changes on the resilient modulus of the soils. The water content of the samples will be changed to the desired level by either drying or by using back pressure technique in the triaxial cell. For sand roadbed soils, the test specimens will be compacted at three moisture contents and subjected to cyclic load triaxial tests. Since the resilient moduli values of sand roadbed soils are heavily dependent upon the deviatoric stress; the laboratory tests will be conducted at three stress states which will be estimated through mechanistic analyses to simulate the probable in-situ field conditions.

Subtask 3.3 –Field Test Plan

This plan consists of Falling Weight Deflectometer (FWD) tests. The FWD tests will be conducted at the network- and project-levels. At the network level, one FWD tests will be conducted at 500 foot intervals along the state trunkline. At the project level, 20 FWD tests will be conducted within ± 50 ft from all locations where Shelby tubes (undisturbed soil samples) will be extracted.

All FWD tests will be conducted in the spring and in the late summer – early fall seasons. For those areas where FWD tests were conducted in the past and the deflection and pavement cross-section data are available at MDOT, the data will be used and the number of FWD tests (to be conducted in those areas in this study) will be reduced depending on the availability of spring and fall deflection data.

It should be noted that analyses of various damage models including AASHTO indicate that the two point FWD testing (spring and fall seasons) is adequate to assess the relative pavement damage caused by the roadbed soil due to different degrees of saturation.

Task 4 – Data Analyses

The data analysis, in this study, will be accomplished according to the three subtasks presented below. First, it should be noted that for all soil types, the relationship between the MR and k found in the M-E PDG was used. Since the relationship applies to all MR and k values, the analyses stated in the subtasks below will be conducted on the MR values and the results will be converted to k values.

Subtask 4.1 – Backcalculation of Layer Moduli

All deflection data, whether collected during this study or other studies, will be used (depending on the availability of the pavement cross-section data) to backcalculate the layer moduli using the MICHBACK computer program. Although the moduli of all pavement layers will be backcalculated, only the resilient modulus of the roadbed soils will be subjected to further analyses. The moduli of the pavement layers will be reported without further analyses. For each test area on the partition map, two sets of moduli will be backcalculated; one set will be based on the spring deflection data and the other on the late summer - early fall data. The two sets will be further analyzed to estimate the seasonal damage factor as presented in task five below.

Subtask 4.2 – Laboratory Test Data

Results of the cyclic load tests conducted on Shelby tube and reconstituted bag samples at three moisture contents will be analyzed to determine the laboratory values of the resilient modulus of the roadbed soil. Results of the analyses will be used to assess the impact of moisture (season) on pavement damage and to compare the values to those obtained from backcalculation.

In addition, the digitized cyclic stress-strain data of those research studies that were sponsored by MDOT from 1975 to 1979 will be analyzed. This pool of information will be used as a supplement to verify the relationships or to increase the pool of data to develop more accurate relationships. The Atterberg limits (liquid limit, plastic limit, and plasticity index) and sieve analysis data will be used to classify the soil and to develop correlations to MR whenever possible. Correlations will also be developed between the laboratory and the backcalculated MR values.

Task 5— Damage Assessment Analyses

The damage assessment analyses (noted in subtask 4.1) will be conducted based on the seasonal MR and k values obtained from the backcalculation of the FWD deflection data. The purpose of the analyses is to determine the effective MR and k values to be used in the design and rehabilitation of flexible and rigid pavements. The effective roadbed resilient modulus is an equivalent modulus that would result in the same damage as if the various seasonal resilient modulus values were used (Huang 2004). In the analyses, three methods will be used as follows:

1. The existing AASHTO 1993 damage model shown below.

$$u_f = 1.18 \times 10^8 \times (MR)^{-2.32} \qquad \text{Equation A.1}$$

Where, u_f = relative seasonal damage

2. The existing damage model in the M-E Design Guide, which is based on Miner's hypothesis of cumulative damage represented by the following equation.

$$D_r = \sum \frac{n_{ijklmn}}{N_{ijklmn}} \qquad \text{Equation A.2}$$

Where, D_r = damage ratio, n_{ijklmn} = actual number of load repetitions, N_{ijklmn} = allowable number of load repetitions, for the i^{th} age, the j^{th} season, the k^{th},axle combination, the l^{th},load level, the m^{th} temperature and the n^{th} traffic path.

3. Mechanistic analyses of stresses and strains induced in the roadbed soil due to traffic load. The magnitudes of the induced stresses and strains for various roadbed moduli will be compared as to arrive at a damage model or to verify the above models.

APPENDIX B

LITERATURE REVIEW

Early in this study, an extensive literature review was conducted to study and summarize the results reported by previous investigators regarding:

- The advantages and shortcomings of the laboratory and field test procedures used to determine the MR values of roadbed soils.
- The relationships between the laboratory determined and the backcalculated resilient modulus using deflection data.
- The resilient characteristics of various types of roadbed soils.
- The factors affecting the MR values of roadbed soils including moisture content (seasonal effects), particle size, Atterberg limits, and grain size distribution.
- The reported correlations between MR values and the modulus of subgrade reaction (k) of roadbed soils.
- The reported correlations, if any, between the results of simple tests such as Atterberg Limits, grain size distribution, pocket penetrometer, and hand held shear vane and the MR values of the roadbed soils.

Results of the literature review are summarized below.

B.1 RESILIENT MODULUS AND THE SOIL CLASSIFICATION SYSTEMS

There are currently several common soil classification systems. The most popular of these are the United States Department of Agriculture (USDA), the Unified Soil Classification System (USCS), and the AASHTO soil classification system (Holtz and Kovacs 1981). Table B.1 provides comparison between the three classification systems. Such comparison chart is important because it allows the users of one highway authority to compare their roadbed soils to another agency that uses a different classification system.

Nevertheless, several correlations between the soil classification systems and the resilient modulus of the roadbed soils can be found. These include:

- The data in Figure 2.2, which is used mainly by MDOT.
- The data in Table 2.3 from the AASHTO mechanistic-empirical pavement design procedure (M-E PDG), which provide ranges and typical values of the resilient modulus of roadbed soils based on their AASHTO and USCS classification.
- The data in Table B.1, which provide estimates of various roadbed soil parameters based on their AASHTO and USCS classification systems (NHI 1998).

Although the data in Table 2.3 and Figure B.1 provide, for each soil classification, a range of values, the exact value to be used in the pavement design process is a decision that must be made by the engineer on the job.

Table B.1 Comparison between three soil classification systems (USDA 1992)

USDA texture	Classification		Percent passing sieve number				Liquid limit	Plastic limit
	USCS	AASHTO	4	10	40	200		
Muck	PT	A-8	100	100	90-100	40-100	0-14	NP
Sand	SP-SM, SM, SP, GP, GP-GM, GM	A-2-4, A-3, A-1-b, A-2, A-3, A-2	40-100	25-100	15-90	0-35	<25	NP
Loamy sand	SM, SC-SM, ML, CL-ML, SP-SM, SP	A-2, A-4, A-1-b, A-1, A-2-4, A-3	85-100	60-100	30-90	3-55	<30	NP
Silty loam	ML, CL, CL-ML, SC, SM, CH	A-4, A-6, A-7, A-2	95-100	85-100	60-100	30-95	<45	NP/P
Sandy loam	SM, SC-SM, ML, CL-ML, SC, CL	A-2-4, A-4, A-2, A-1, A-1-b, A-6	70-100	60-100	35-90	15-75	<35	NP
Clay loam	CL, CL-ML, SC, SC-SM	A-6, A-4, A-7, A-2	95-100	75-100	70-100	35-90	25-45	NP/P
Loam	CL, CL-ML, ML	A-4, A-6, A-7	90-100	75-100	70-100	50-90	15-45	NP/P
Mucky sand	SM, SP, SP-SM	A-1-b, A-2-4, A-3	95-100	75-100	30-70	0-15	0-14	NP
Clay	CH, CL	A-6, A-7-6	90-100	85-100	65-95	45-95	30-65	P
Silty clay	CL, SC, CL-ML	A-4, A-6, A-7	85-100	60-100	50-100	30-90	25-50	NP/P
NP = non-plastic, plastic limit<10 P = plastic soil, plastic limit>10								

B.2 LABORATORY TESTING

The resilient modulus (MR) of a soil is an index that describes its stress-strain relation under cyclic loads (Maher et. al 2000). Mechanistic-based pavement and overlay design procedures require the roadbed soil MR values as input to determine the layer thicknesses and the overall system response to traffic loads.

MR values can be obtained in the laboratory and from the backcalculation of nondestructive deflection test (NDT) data. The laboratory determination of the MR values of roadbed soils is reviewed below, along with factors that affect the MR values.

B.2.1 Resilient Modulus Test Procedure

In general, laboratory test procedures for the determination of MR values are essentially based on the existing cyclic triaxial test methods used for the determination of soil properties under repeated loads. A schematic of the test apparatus for conducting MR tests is shown in

Figure B.2. Figure B.3 shows a typical hysteresis loop output (stress-strain of one load unload cycle)

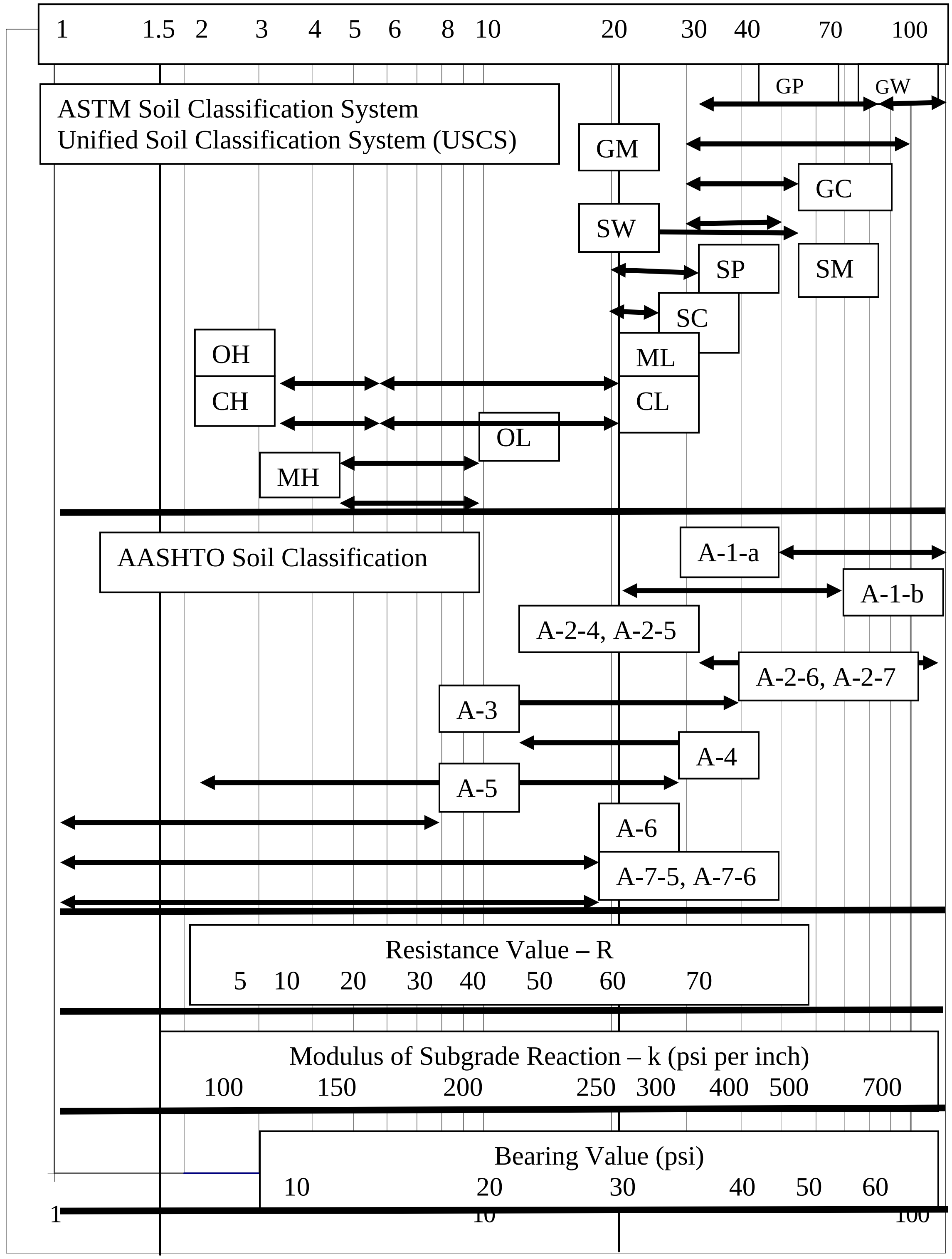


Figure B.1 Soil classification related to strength parameters (NHI 1998)

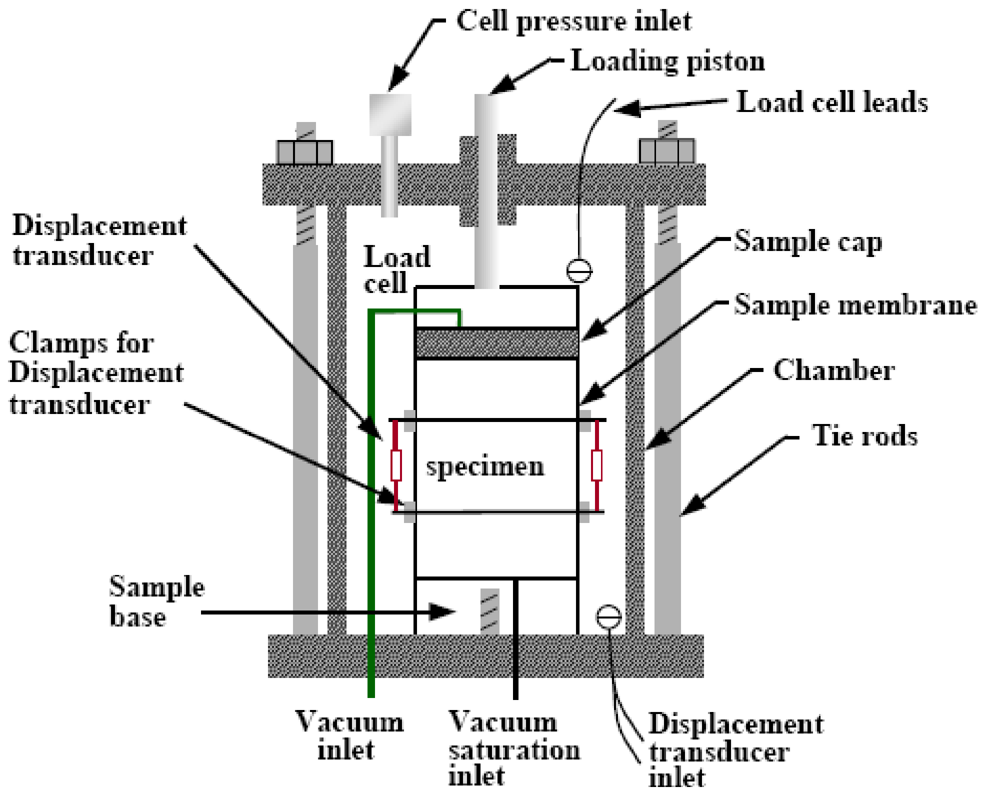


Figure B.2 Resilient modulus testing apparatus for soils (NHI 1998)

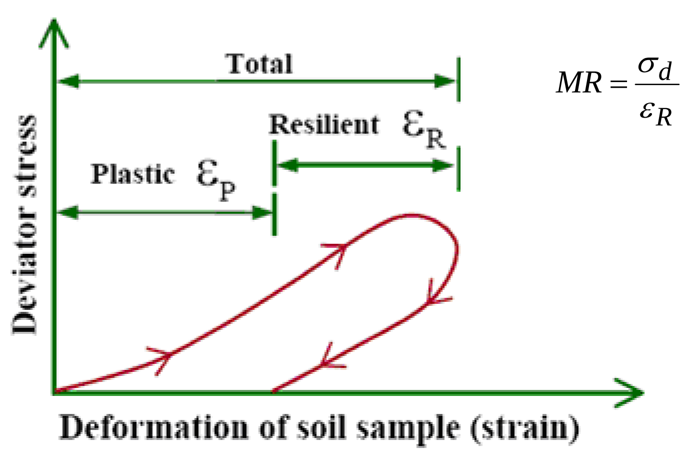


Figure B.3 Resilient modulus concept (NHI 1998) used in the calculation of MR values (NHI 1998). Figure B.3 also shows the recoverable (ε_R) and plastic (ε_P) portions of the axial strain of the sample and the equation for calculating the MR values of the soil. Guidelines for conducting laboratory MR testing are given in the 2001 AASHTO T 307 standard test procedure. The procedure calls for placing a compacted soil sample in a triaxial test apparatus, applying confining pressure and a sustained load to the sample, and then applying a repeated axial load and measuring the resulting vertical deformations (AASHTO 2001). The history of the development of the AASHTO T 307 standard test procedure traces back to the Strategic Highway Research Program (SHRP) protocol P 46-94 "Resilient Modulus of Unbound Base/Subbase Materials and Subgrade Soil." The protocol is based on determining MR values in a repeatable, practical, and productive way. After eight years of implementation, the protocol was adopted in 1992 by AASHTO as test method T 294 replacing its predecessor T 274-82. The procedure has further evolved to incorporate additional technical requirements and currently is labeled AASHTO T 307 standard test procedure (Groeger et al. 2003). According to Maher et al, (2000), some of the most recognized changes from the AASHTO T 274-82 and T 294-92 procedures to the most recent AASHTO T 307 are:

1. The number of loading sequences has been decreased from 27 to 15 and the number of loading cycles per loading sequence has been decreased from 200 to 100 cycles. The decrease in testing sequences and load cycles led to a reduction in the sample deformation and testing time from approximately five hours to two.
2. The maximum axial stress range was changed from 1.0 to 20.0 pounds per square inch (psi) to 3.0 to 40.0 psi for base and subbase materials, and from 1.0 to 10.0 psi to 2.0 to 10.0 psi for roadbed materials.
3. There was a change of confining stress in the subbase testing sequence from 0 to 2.0 psi.
4. The implementation of a constant sustained stress of 10% of the applied deviatoric stress (the difference between the axial stress and the confining pressure) to ensure full contact between the loading piston and the sample.

Granular soils (Type I) are tested using a sample size of 6.0 inches in diameter and, 12.0 inches high. Cohesive soils (Type II) are tested using a sample size of 2.8 inches in diameter and 5.6 inches high.

B.2.2 Issues with Current Test Standards

The AASHTO requirement to apply and remove the deviator load in 0.1 seconds is difficult and costly. It requires high performance servo-valves and fast electronics. It is believed that dynamic effects may become significant for 12 inch high specimens with stiffness less than 20,000 psi and for 6 inch high specimens with stiffness less than 10,000 psi (Marr et al. 2003). While the rapid loading rate is used to model moving vehicles on a pavement system, it is not clear that this fast loading rate is necessary. The test would be simpler to run and the equipment less expensive if the loading period is increased to 0.5 seconds.

Accurate measurements of the axial deformations are essential in obtaining reliable MR results. The AASHTO requirements for such measurements have been changed from two linear variable differential transducers (LVDT) mounted internally at 180° along the specimen's axis, to two LVDTs clamped to the loading rod inside the triaxial chamber to one LVDTs externally mounted to the loading piston and resting on a rigid surface. These changes have made the test procedure manageable. It should be noted that using the average of two LVDTs mounted at 180^o would decrease measurement error if the sample is subjected to a slight rocking motion.

B.3 FIELD TESTING

Field testing for determining or estimating the MR values is divided into two categories; destructive and nondestructive.

B.3.1 Destructive Testing

Results from the following five destructive tests are often used to estimate MR or k values.

B.3.1.1 California Bearing Ratio

The California Bearing Ratio (*CBR*) is the ratio between the soil's resistance to 0.1 inch penetration of a standard piston to the resistance of a well graded and crushed stone to the same penetration. The test can be conducted in the field and the laboratory as described in the AASHTO T193 standard test procedure (AASHTO 2001). The 1993 AASHTO Pavement Design Guide uses Equation B.1 to estimate the MR from the CBR values (AASHTO 1993). It should be noted that the 1500 constant in Equation B.1 can vary from 750 to 3000 (NHI 1998).

$$MR = 1500(CBR) \qquad \text{Equation B.1}$$

Whereas the new M-E PDG recommends the use of Equation B.2 for estimating the MR value (NCHRP 2004).

$$MR = 2555(CBR)^{0.64} \qquad \text{Equation B.2}$$

B.3.1.2 Dynamic Cone Penetrometer

The Dynamic Cone Penetrometer (*DCP*) shown in Figure B.4 is a graduated rod with a metal cone on one end and a mass which is repeatedly lifted and dropped to drive the cone into the soil. The *DCP* is an efficient and inexpensive way to estimate the in-place *CBR*. The cone's penetration rate (*PR*) is measured after every drop and is labeled the *DCP* index. The *DCP* index (*DCP* = mm/blow) correlates well to CBR for fine grained soils up to a *CBR* value of about 15 percent. Equation B.3, from the M-E PDG, provides a correlation between the *CBR* and the *DCP* index (NCHRP 2004).

$$CBR = \frac{292}{DCP^{1.12}} \qquad \text{Equation B.3}$$

Equations B.2 and B.3 are combined in Equation B.4.

$$MR = 96658\left(\frac{1}{DCP}\right)^{0.72} \qquad \text{Equation B.4}$$

Equation B.5 provides another correlation between the *CBR* and the penetration rate (*PR*) of a 60° cone (NHI, 1998).

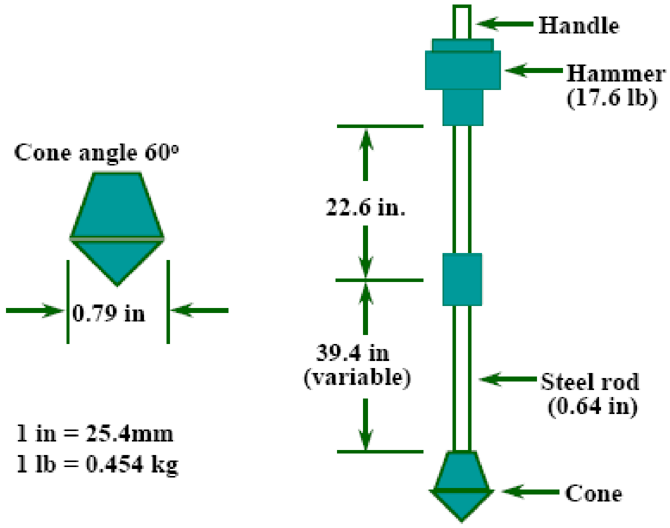


Figure B.4 Schematic of a dynamic cone penetrometer (NHI 1998)

$$CBR = \frac{405.3}{PR^{1.259}} \qquad \text{Equation B.5}$$

Where, *PR* = penetration rate (mm per blow)

B.3.1.3 Plate Load Test

Plate load testing of roadbed soils is not commonly used because it is a laborious and slow destructive test that requires the removal of segments from the pavement surface and base layers (Yoder 1959). It is, nonetheless, a direct method for determining the modulus of subgrade reaction, which is a required input in the current AASHTO concrete pavement design procedure. Figure B.5 depicts a photo of the plate load testing apparatus. Guidelines for repetitive static plate load testing are given in ASTM D1195 "Standard Test Method for Repetitive Static Plate Load Tests of Soils and Flexible Pavement Components" for use in evaluation and design of airport and highway pavements, and in AASHTO T 221 standard test procedure (AASHTO 2001). The static elastic k value is calculated as the ratio of the applied pressure to the elastic deformation, which is the recoverable portion of the total measured deformation (Yoder 1959).

B.3.1.4 Pocket Penetrometer

The pocket penetrometer is a small hand held device with a spring loaded probe at one end. The probe is pushed to penetrate the soil 0.25 inches; the spring measures the resistance of the soil to penetration. The pocket penetrometer is used to estimate the unconfined compressive strength of the soil. Since the MR value is a nonlinear elastic soil property it is logical to assume that there is a relationship between soil strength and MR value (Han et al. 2006). Thompson and Robnett (1979) proposed estimating the MR value from the unconfined compressive strength using Equation B.6.

Figure B.5 Photo of plate load testing apparatus (NHI 1998)

$$MR = 0.86 + .307 q_u \qquad \text{Equation B.6}$$

Where, MR = resilient modulus (ksi) and q_u = unconfined compressive strength (psi)

B.3.1.5 Pocket Vane Shear Tester

The pocket shear tester is used to estimate the undrained shear strength of the soil. The shear tester is inserted 0.25 inches into a flat soil surface and rotated until failure. The maximum pressure required to cause failure is the s_u value. Sukermaran et al (2002) suggested a relationship between the undrained shear strength and MR value.

$$MR = 100 - 500 s_u \qquad \text{PI>30} \qquad \text{Equation B.7}$$

$$MR = 500 - 1500 s_u \qquad \text{PI<30} \qquad \text{Equation B.8}$$

Where, MR = resilient modulus (psi), S_u = undrained shear strength (psi), and PI = plasticity index

B.3.2 Nondestructive Testing

Several nondestructive test procedures and equipment are being used to evaluate the engineering characteristics of roadbed soils. These include:

- Ground penetrating radar (GPR) to estimate the pavement layer thicknesses
- Nondestructive deflection tests (NDT) to measure the pavement response to load

Literature review regarding NDT and the use of the deflection data in pavement evaluation processes are addressed in the next sections.

B.3.2.1 Nondestructive Deflection Tests

The nondestructive deflection test (NDT) is the most popular test used in pavement evaluation. Relative to destructive testing, NDT is fast and requires minimal lane closure time. In recent years, the use of NDT has become an integral part of the structural evaluation and rehabilitation of pavement structures. The next section summarizes available NDT equipment.

B.3.2.2 NDT Devices

Several NDT devices have been developed. The features of each device and its advantages and disadvantages are thoroughly reviewed by Tariq Mahmood (1993), and are summarized below:

- Static deflection equipment including: the Benkelman Beam, which is shown in Figure B.6, (Moore et al 1978; Asphalt Institute 1977; Epps et al 1989), the plate bearing test (Moore et al 1978; Nazarian et al 1989), the Dehlen Curvature Meter (Gouzheng 1982), the Pavement Deflection Logging Machine (Keneddy et al 1978), and the C.E.B.T.P. Curviameter (Paquet 1978).

Figure B.6 Benkelman Beam

- Automated deflection equipment including: the La Croix Deflectograph, which is shown in Figure B.7, (Hoffman et al 1982; Keneddy 1978), and the California Travelling Deflectometer (Roberts 1977).
- Steady-State dynamic deflection equipment including: the Dynaflect, which is shown in Figure B.8, the Road Rater, the Cox Device, the Waterways Experiment Station (WES) Heavy Vibrator, and the Federal Highway Administration (FHWA) Thumper (Scrivner et al 1969; Smith et al 1984; Moore et al 1978).

Figure B.7 La Croix Deflectograph

Figure B.8 Dynaflect

- Impulse deflection equipment including: the Dynatest FWD, KUAB FWD, shown in Figure B.9, and the Phoenix FWD (Nazarian et al 1989; Hoffman et al 1981; Bohn et al 1972; Crovetti et al 1989; Claessan et al 1976).

Figure B.9 KUAB Falling Weight Deflectometer

The KUAB brand FWD is used by several state agencies, including MDOT and other agencies around the world. The system applies a dynamic impulse load to the pavement surface with a two mass system that simulates a moving tire load. Seismometers set at specific distances along the pavement surface measure acceleration and double integrate to determine vertical deformation or deflection. The entire system is housed in a trailer and can be operated remotely from the truck cab, which allows for quick and easy execution of tests in any weather.

Various types of NDT equipment are available including the Road Rater, Kuab, and Dynaflect Falling Weight Deflectometer (FWD). NDT devices are used by state highway agencies to apply patterns of loading and record deflection data along the pavement surface. The deflection data measured along the pavement surface at different distances from the center of the load are typically used to backcalculate the modulus values of the various pavement layers and the roadbed soil. Numerous backcalculation software packages are available either in the public domain or can be purchased. Most of these use more or less the common procedures presented in the next sections.

The NDT results (the pavement deflections at various distances from the center of the load) are used to:

- Backcalculate the pavement layer moduli
- Assess the variability of the pavement response to loads along and across the pavement and hence, the variability of the pavement structural capacity
- Estimate load transfer efficiency of dowel bars
- Evaluate the presence of voids beneath the pavement surface
- Design the thickness of pavement overlays

B.3.2.3 Falling Weight Deflectometer (FWD) Test

Falling Weight Deflectometers (FWD) are used to apply load to the pavement and measure deflection on the pavement surface at several longitudinal distances from the applied load. The FWD is often preferred over laboratory testing for several reasons including: the nondestructive nature of the tests, low operational cost per test, short test duration, tests can be designed to provide more coverage of the pavement network, and the roadbed soils are being tested under in-situ boundary conditions. The disadvantages include the difficulty to determine or control the water content of the roadbed soils, determine the roadbed soil density, and to control the applied normal and shear stress levels (Houston et. al 1992).

The FWD operates on two basic assumptions; the force of impact due to a falling load is considered a static load, and the roadbed soil acts as an elastic body. The weight of the falling mass can be calculated as follows, as presented in (Kim et al 2006).

$$W_1\left(H + \delta_{\max}\right) - .5K\delta^2_{\max} = 0 \qquad \text{Equation B.9}$$

Where, W_1 = weight corresponding to the mass M, H = height M was dropped from, δ_{max} = maximum pavement deflection, and K = spring constant, δ_{max}/δ_{st} = the impact factor, which can be found by equation B.10.

$$\delta_{\max}/\delta_{st} = 1 + \left(1 + \left(\frac{2H}{\delta_{st}}\right)\right)^{\frac{1}{2}} \qquad \text{Equation B.10}$$

Where, δ_{st} = static deflection

The impact load is calculated using equation B.11, by multiplying the static load by the impact factor.

$$P_{dyn} = W_1\left(1 + \left(1 + \left(\frac{2H}{\delta_{st}}\right)\right)^{\frac{1}{2}}\right) \qquad \text{Equation B.11}$$

Due to the difficulty in measuring impact load, force is calculated by multiplying weight by height.

$$F = WH \qquad \text{Equation B.12}$$

Where, F = force

The uniformly distributed load can be obtained from equation B.13.

$$q = \frac{F}{A} \qquad \text{Equation B.13}$$

Where, q = applied load to plate, A = loading plate area

A series of FWD tests are usually preformed in order to obtain more accurate results. Consecutive tests are conducted at regular intervals along a pavement surface. At each interval four drops of the weight are conducted. The first drop is not used in analysis, and the following three are averaged to create one set of data for each interval. This allows for average values along the pavement to be calculated. Averages are taken in order to capture the range of deflections as well as the most common values over a pavement section. The variations in deflection are due to non-constant roadbed soils and construction practices which often result in varying densities and thicknesses of the pavement layers. A typical asphalt concrete (AC) surface can range from plus or minus 1 inch of thickness from the design thickness. This can affect MR results because a constant layer thickness and Poisons' ratio are used for the entire pavement section tested. An example of how measured deflections at each sensor vary along a pavement section is shown in Figure B.10.

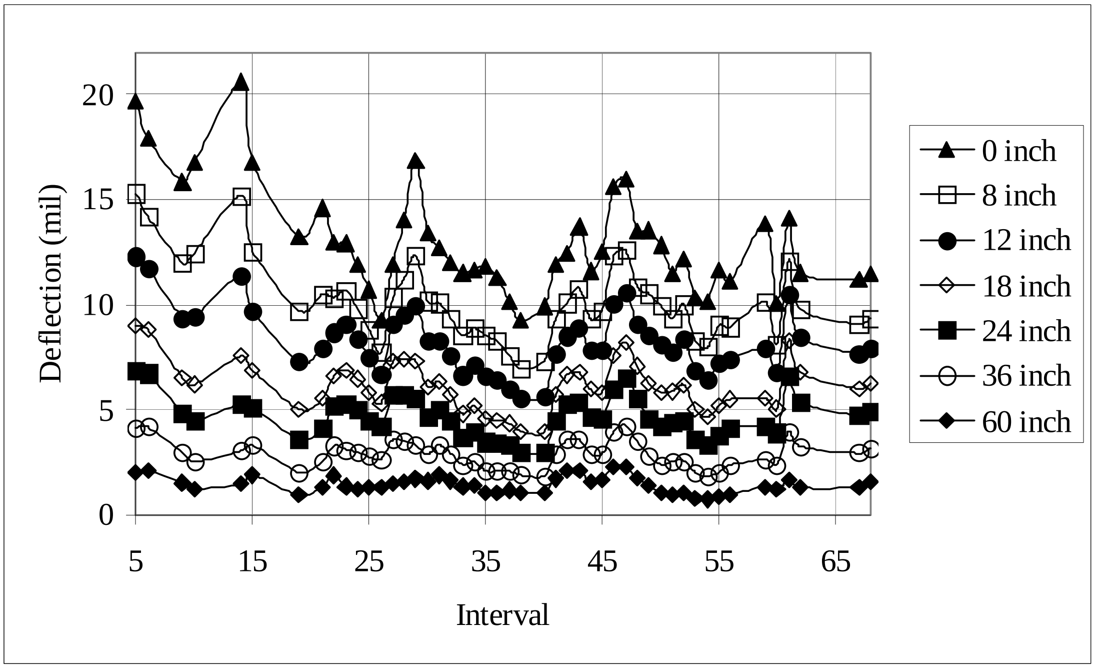


Figure B.10 Typical deflections at all sensors

B.4 BACKCALCULATION OF LAYER MODULI OF FLEXIBLE PAVEMENT

Flexible pavement layer moduli are backcalculated using deflection data from FWD tests. Deflection data is analyzed using computer programs to iteratively forward calculate deflection based on layer moduli, Poisson ratios, thicknesses, and load magnitude. Then the layer moduli are incremented until the calculated deflection is very close to the measured deflection. When the absolute or Root Mean Squared (RMS) error between the measured and calculated deflection is minimized, the results are the most accurate. There are 5 categories of assumptions that have been used to create the various computer programs; linear elastic-static, nonlinear elastic-static, linear-dynamic using frequency domain fitting, linear-dynamic using time domain fitting, and nonlinear-dynamic (Uzan 1994). Each category utilizes different assumptions and techniques.

B.4.1 Backcalculation Methods for Flexible Pavement

The roadbed soil modulus can be determined by using the pavement surface deflection measured at distances of 48 inch or more from the center of the load. Because of arching effects, at these distances, the pavement surface deflection is influenced mainly by the roadbed soils. Hence, the roadbed soil MR values can be backcalculated from a single deflection measurement. The most widely used routine to backcalculate the roadbed soil MR values from a single deflection measurement is the Boussinesq equation (George 2003).

$$d_r = \frac{CP(1-\nu^2)}{\pi r MR} \text{ or } MR = \frac{CP(1-\upsilon^2)}{\pi r d_r} \qquad \text{Equation B.14}$$

Where, d_r = the surface deflection (in) at a distance r (in) from the load, P = applied load (lbs), C = correlation/adjustment factor that accounts for the difference between the backcalculated and the laboratory obtained MR value, MR = resilient modulus (psi), and ν = poison's ratio of the asphalt layer

By assuming a Poisson's ratio of 0.5, equation B.14 can be reduced to the following equation (AASHTO 1993).

$$MR = \frac{0.24CP}{d_r r} \qquad \text{Equation B.15}$$

AASHTO recommends the use of a *C* value of no greater than 0.33.

The minimum distance (r) in Equations B.14 and B.15 is given by the following relationship.

$$r = 0.7\sqrt{a_2 + \left(D \times \sqrt[3]{\frac{E_p}{MR}}\right)} \qquad \text{Equation B.16}$$

Where, a_2 = radius of load plate (in), D = total thickness of pavement layers above the roadbed (in), andE_p = effective modulus of all layers above the roadbed (psi)

E_p in equation B.16 can be calculated by using Equation B.17:

$$\frac{MR \times d_o}{q \times a} = 1.5\left\{\frac{1}{\sqrt{1+\left[\frac{D}{a}\sqrt[3]{\frac{E_p}{MR}}\right]^2}} + \frac{1-\frac{1}{\sqrt{1+\left(\frac{D}{a}\right)^2}}}{\left(\frac{E_p}{MR}\right)}\right\} \qquad \text{Equation B.17}$$

Where, d_o = deflection measured at the center of the load plate after adjustment to temperature of 68 ^oF, *q* = pressure on load plate (psi), *D* = total thickness of pavement layers above the roadbed soil (inch), and E_p = effective modulus of all layers above the roadbed soil (psi)

The Washington State Department of Transportation (WSDOT) developed, for asphalt pavements, Equations B.18 through B.20 and, for concrete pavements, Equation B.21 to estimate the roadbed soil modulus from deflection sensors located at various distances from the center of the load (Pierce 1999).

$$MR\ (psi) = 9000\frac{0.2892}{24d_{24}}$$ Equation B.18

$$MR\ (psi) = -466 + 9000\frac{0.00762}{d_{36}}$$ Equation B.19

$$MR\ (psi) = -198 + 9000\frac{0.00567}{d_{48}}$$ Equation B.20

And for concrete pavements,

$$MR\ (psi) = -111 + 9000\frac{0.00577}{d_{48}}$$ Equation B.21

Where, d_{24}, d_{36}, and d_{48} are the pavement surface deflections (mil) measured at 24, 36, and 48 inches from the center of the load

There are several different computer programs that utilize the before mentioned backcalculation methods, each with varying assumptions, routines, and methods. Table B.2 lists many of the available backcalculation programs.

B.4.2 MICHBACK

The program for backcalculation of layer moduli of flexible pavement used in this report is MICHBACK, developed at Michigan State University (MSU). MICHBACK uses the Chevronx (a multilayer elastic program) as the forward engine to calculate the pavement deflections for a given set of data (layer moduli and Poisson ratios, layer thicknesses, and load magnitude). The MICHBACK program utilizes a modified Newtonian algorithm to increment the layer modulus values based on differences between the measured and the backcalculated pavement deflections (George 2003).

A brief summary of the MICHBACK program procedure is presented below. A detailed flow-sheet can be found in (Mahmood 1993).

- Input initial data (pavement location, file name, layer information, etc...)
- Upload FWD file, or manually input deflection data
- Input modulus seed values and stiff layer depth
- Perform backcalculation
- View or print results

MICHBACK uses a linear-elastic model, as mentioned previously. In order for the program to work correctly, and converge, the deflection basin must be uniform with an elastic system. The main contributing factor leading to non-convergence is the degree of irregularity of the deflection basin. For the backcalculation of layer moduli to be successful, the shape of the deflection basin must be smooth and compatible with the elastic layer theory. Highly irregular measured deflection basins (such as that shown in Figure B.11) cannot be matched to that calculated using the layer elastic theory. Irregularities in the deflection basins could be caused by an uneven contact between one or more deflection sensors and the pavement surface, debris (such as sand particles) between the deflection sensors and the pavement surface, and/or cracks or other structural distresses in the pavement that adversely impact the continuity of the stress dissipation with depth and distance from the load.

Table B.2 Backcalculation programs

Program name	Develop By	Forward calculation method	Forward calculation subroutine	Backcalculation subroutine	Non-linear analysis	Seed modulus	Comments
BISDEF	A. Bush USACE-WES	Multi-Layer elastic theory	BISAR	ITERATIVE	Non-linear analysis	Required	Sensitive to seed modulus. Uses gradient search method
BOUSEDEF	Zhou, et al.	Equivalent layer thickness	MET	ITERATIVE	Yes	Required	Program logic similar to BISDEF
CHEVDEF	A. Bush USACE-WES	Multi-Layer elastic theory	CHEVRON	ITERATIVE	Non-linear analysis	Required	Sensitive to seed modulus
COMDEF	M Anderson	Multi-Layer elastic theory	DELTA	DATA BASE	Non-linear analysis	Required	For composite pavements only
DBCONPAS	M. Tia, et al.	Finite element	FEACONSIII	DATA BASE	Yes		For rigid pavements only
ELMOD	P. Ulidtz	Equivalent layer thickness	MET	ITERATIVE	Yes roadbed only	Not required	Fast, but has limitation inherent to MET program
ELSDEF	Texas A&M University	Multi-Layer elastic theory	ELSYM5	ITERATIVE	No	Required	Sensitive to seed modulus
EMOD		Multi-Layer elastic theory	CHEVRON	ITERATIVE	Yes roadbed only	Required	

Table B.2 (cont'd)

Program name	Develop By	Forward calculation method	Forward calculation subroutine	Backcalculation subroutine	Non-linear analysis	Seed modulus	Comments
EVERCALC	Mahoney, J., et al.	Multi-Layer elastic theory	CHEVRON	ITERATIVE	Yes	Not required for up to 3 layers	Primarily for flexible pavements.
FPEDDI	W. Uddin	Multi-Layer elastic theory	BASNIF	ITERATIVE	Yes	Not required	
ISSEM4	P. Ulidtz	Multi-Layer elastic theory	ELSYM5	ITERATIVE	Yes	Required	Uses deflections at five points to calculate moduli for three layers.
MICHBACK	Michigan State University	Multi-Layer elastic theory	CHEVRON	ITERATIVE	No	Required	
MODOMP2	L. Irvin	Multi-Layer elastic theory	CHEVRON	ITERATIVE	Yes	Required	More oriented for research work.
MODULUS	J. Uzan	Multi-Layer elastic theory	WESLEA	DATA BASE	Yes	Required	Used in an expert system frame work.
PADAL	S. F. Brown	Finite element		ITERATIVE	Yes	Required	
RPEDDI	W. Uddin	Multi-Layer elastic theory	BASINR	ITERATIVE	Yes	Not required	For rigid pavements only.
WESDEF	USACE-WES	Multi-Layer elastic theory	WESLEA	ITERATIVE	No	Required	Sensitive to seed modulus.

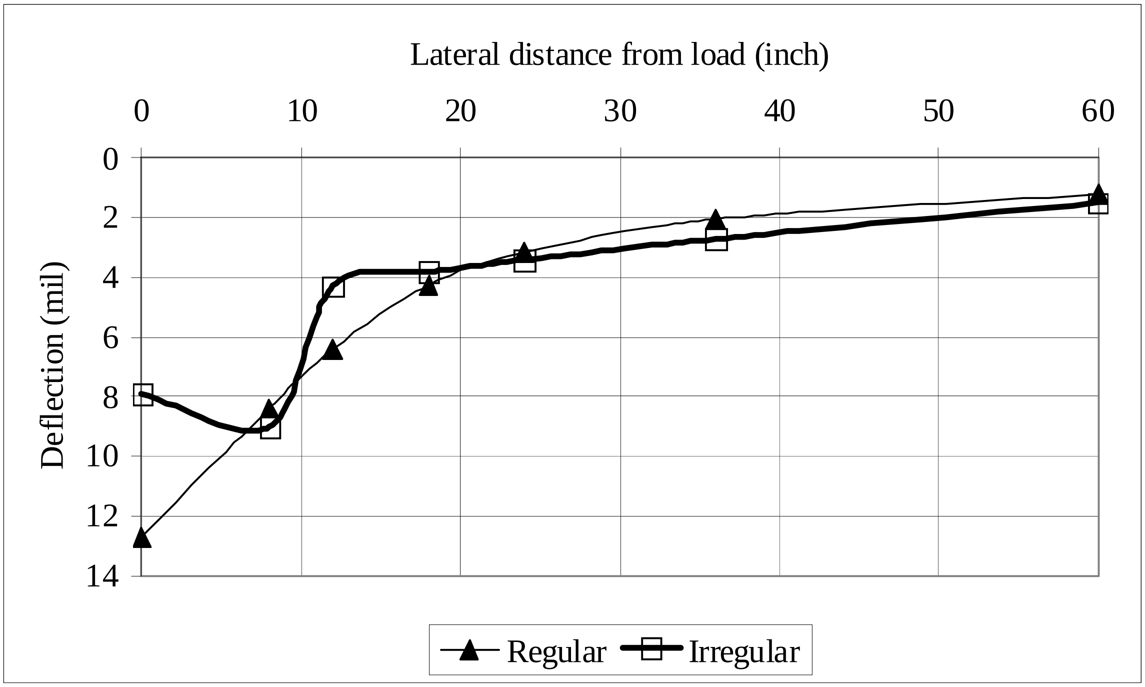


Figure B.11 Regular and irregular deflection basins

B.4.3 Flexible Pavement Temperature Effect on Resilient Modulus

The Asphalt Concrete (AC) layer MR values of a pavement system are greatly affected by temperature. It is common for the temperature of the AC layer to vary by 30° F in a given day. This temperature fluctuation can result in a 500,000 psi variation in AC MR values, which will significantly affect the MR values of other pavement layers when backcalculating. The ideal AC temperature for FWD testing is between 40° and 100° F. It can be difficult to backcalculate AC stiffness when the MR values are above 2,000,000 or below 200,000 psi, therefore flexible pavements should only be FWD tested within the recommended temperatures (Kathleen et al 2001).

A procedure was developed by (the Asphalt Institute 1977) to correct for temperature of AC pavement layers. This process requires the following data: The high and low temperature for the previous 5 days leading up to the NDT, pavement surface temperature at exact time of NDT, frequency of loading and time duration of load impulse, as well as percent asphalt content by weight. If all of this data is available, then AC temperature at the top, middle, and bottom of the layer can be determined, and the mean of the three temperatures is used as the corrected pavement temperature.

B.4.4 Depth to Stiff Layer Effect on Resilient Modulus

Roadbed soil is assumed to be uniformly stiff and infinitely thick, when using linear elastic models such as the one utilized by MICHBACK. This assumption is incorrect as roadbed soil tends to become denser with depth, due to stress increases. At some depth a “stiff layer” will be present, which can be composed of either bedrock or a very dense layer of roadbed soil. To account for this, an additional layer is incorporated in the backcalculation procedure. A stiff layer can be included in several ways:

- Assignment of a very high modulus to the lowest layer in the pavement system; however the depth to this layer will be unknown.
- Assignment of a 20 ft. depth to stiff layer for all FWD analyses (Bush 1980).
- Use of measured velocity of compression waves and frequency of loading (Uddin et al 1986).
- Application of trial and error method carried out until a minimum RMS error is reached (Chou 1989).

The above mentioned methods make various assumptions about depth, which is often unknown. Regression models have also been developed to estimate depth to stiff layer from deflections and layer thicknesses (Brown 1991). This method is used in MODULUS and EVERCALC, but does not accurately predict depth for medium to deep layers (Rohde and Scullion 1990; Mahoney et al 1993). The MICHBACK program uses a regression equation developed by (Baladi 1993) which iteratively improves the depth as described in (Mahmood 1993).

B.5 BACKCALCULATION OF LAYER MODULI OF RIGID PAVEMENT

The modulus of subgrade reaction (k) can be determined from deflection testing conducted at the center of a Portland Cement Concrete (PCC) slab. An empirical set of equations known as the AREA method can be used to backcalculate k as well as the elastic modulus (E_c) of the concrete. Correlation equations have been developed to convert k to MR values (AASHTO 1993).

B.5.1 Backcalculation Methods for Rigid Pavement

The AREA method for calculating the radius of relative stiffness and dynamic foundation k is presented in this subsection. Various other versions of the method exist; however the method developed by Smith et al. (1997), was used in this research and is presented below.

The method for backcalculation of layer moduli of rigid pavement used in this study is based on (Frabizzio 1998). The method is based on calculating the area of the deflection basin, the radius of relative stiffness (*l*), the elastic modulus of the concrete (E_c), and the modulus of subgrade reaction using the measured deflection data as shown in equations B.22 through B.26.

$$AREA = \left[4 + 6\left(\frac{\delta_8}{\delta_0}\right) + 5\left(\frac{\delta_{12}}{\delta_0}\right) + 6\left(\frac{\delta_{18}}{\delta_0}\right) + 9\left(\frac{\delta_{24}}{\delta_0}\right) + 18\left(\frac{\delta_{36}}{\delta_0}\right) + 12\left(\frac{\delta_{60}}{\delta_0}\right)\right] \qquad \text{Equation B.22}$$

$$l = \left[LN\left(\frac{60 - AREA}{289.708}\right) / (-0.698)\right]^{2.566} \qquad \text{Equation B.23}$$

$$E_c = \frac{12(1-\nu^2)Pl^2\delta_r^*}{\delta_r h^3} \qquad \text{Equation B.24}$$

$$\delta_r^* = a\exp^{\left[-b\exp^{(-cl)}\right]} \qquad \text{Equation B.25}$$

$$k = \frac{E_c h^3}{12(1-\nu^2)l^4} \qquad \text{Equation B.26}$$

Where, AREA = deflection basin area (inch), δ_r = deflection of the r[th] sensor (inch), l = radius of relative stiffness (inch), E_c = elastic modulus of the concrete (psi), υ = Poisson's ratio for concrete = .15, P = FWD load (pounds), δ_r^* = non-dimensional deflection coefficient at distance "r", h = concrete slab thickness (inch), *a, b and c* = regression coefficients (see Table B.3), and k = modulus of subgrade reaction (pci)

Table B.3 Regression coefficients for δ_r^*

Radial distance, r (inch)	a	b	c
0	0.12450	0.14707	0.07565
8	0.12323	0.46911	0.07209
12	0.12188	0.79432	0.07074
18	0.11933	1.38363	0.06909
24	0.11634	2.06115	0.06775
36	0.10960	3.62187	0.06568
60	0.09521	7.41241	0.06255

AREA is the cross-sectional area of the deflection basin between the center of the FWD load plate and the outer most deflection sensor. The radius of relative stiffness (l) characterizes the stiffness of the slab-foundation system. It should be noted that the final elastic modulus of the concrete slab is the average of the seven elastic modulus values (one for each deflection sensor) obtained from equation B.24 (Frabizzio 1998).

Equation B.27 is used in the AASHTO pavement design guide to convert k values into MR.

$$MR = k * 19.4 \qquad \text{Equation B.27}$$

B.5.2 Rigid Pavement Temperature Effect on Resilient Modulus

Temperature can play a huge roll in the accuracy of deflection testing of concrete pavements. A concrete slab experiencing a temperature gradient can curl and come out of contact with the underlying material. Curling is more likely to occur on slabs supported by high-strength stabilized bases than those supported by soft bases. To avoid possible slab curling, testing the middle of the slab should be avoided during the day when the surface is hotter than the bottom of the slab and upward curling is taking place. Likewise, testing the corners and edges of the slab should be avoided at night when the slab surface is colder than the bottom of the slab and downward curling is taking place (Kathleen et al 2001).

B.5.3 Slab Location Selection for NDT

Conducting NDT at different positions on a PCC slab can be done to test for different pavement properties and conditions. Discussion of mid-slab, edge, and corner slab loading follows.

B.5.3.1 Mid-Slab Loading

The middle of the slab, in the outer lane, is usually where FWD tests are conducted for backcalculation of roadbed k values. An infinite horizontal layer is assumed when considering rigid pavements, due to the evenly distributed load under a loaded slab. However, the standard 12-ft highway lane width is smaller than that required for the assumption of an infinite horizontal layer, but this is often ignored. The middle of the slab is tested to create the largest distance from pavement joints and edges, and from any distresses at these locations (Kathleen et al 2001).

B.5.3.2 Joint Loading

Loading near the joint of a concrete slab is usually done to calculate Load Transfer Efficiency (LTE). One sensor can be placed on the loaded slab and all others on the unloaded slab. The ratio between the approach and leave slab deflection is used in calculation of LTE. The deflection measured from the 60-inch sensor can be used for roadbed MR backcalculation (Kathleen et al 2001).

B.5.3.3 Edge Loading

Loading the edge of a concrete slab is done to estimate the slab support to its adjacent structure, shoulder, or lane, as well as the presence of voids underneath the slab. This testing location is not normally used for backcalculation purposes.

B.6 CORRELATIONS BETWEEN BACKCALCULATED MODULUS, LABORATORY-BASED MODULUS, DCP, AND SOIL PHYSICAL PROPERTIES

Many correlations exist to convert laboratory modulus to backcalculated modulus. There are also correlations between soil properties and their MR values. An introduction to these correlations can be found below.

B.6.1 Correlations between Laboratory and Backcalculated Resilient Modulus

The primary purpose of establishing relationships between backcalculated FWD modulus and laboratory modulus is for the design of pavement overlays. The laboratory MR values are stress dependent. Therefore, in order to compare the different modulus values, the stress state in which the FWD test was performed must be known (George 2003).

Whether the laboratory modulus or field modulus of the roadbed soil is used in the pavement design and analysis depends on the input required for the model being used. For example, the original American Association of State Highway Officials (AASHO) road test was calibrated to the laboratory MR values of the soil. Therefore, when using the 1993 AASHTO pavement design or overlay procedures, the appropriate input for the roadbed soil is the laboratory MR value (AASHTO 1993).

MR values obtained from laboratory tests may be considerably lower than the backcalculated MR values due to differences in the magnitudes of the deviatoric stress, confining pressure, and loading rate (George 2003). Similarly, field MR values for fine grained soils, obtained by backcalculation from FWD deflections, have been reported in a number of studies to exceed the laboratory resilient modulus values by factors between 3 and 5 (AASHTO 1993).

Layer theory was employed for the analysis of the stress state under a 9,000 pound FWD load. It was found that a reasonable correlation exists between FWD backcalculated moduli and the laboratory moduli based on the in-situ conditions with identical stress states (Ping et al. 2002).

From Equation B.28 the FWD backcalculated moduli were about 1.65 times higher than the laboratory MR values. The ratio is in agreement with the suggestion by the AASHTO design guide (AASHTO 1993), that the FWD backcalculated moduli are approximately two to three times higher than the laboratory determined moduli, considering that the AASHTO relationships were based primarily on clay soils. In addition, for this comparison the FWD tests were performed under in-situ soil conditions and the laboratory determined MR values were obtained from the reconstituted soil samples; simulating the in-situ moisture and density conditions under identical states of stress. The possible causes for the difference between the lab MR values and backcalculated values as reported in this study (Ping et al. 2002) were:

$$MR_{FWD} = 1.6539 MR_{lab} \qquad \text{Equation B.28}$$

- The FWD backcalculation program is based on the linear elastic theory of multiple layer pavement structures while the pavement materials are not elastic.
- The FWD backcalculation method is not a unique solution method; therefore, different layer moduli could be obtained from the same FWD data.
- The lab specimens were tested almost immediately after they were compacted, and the confining pressure for the triaxial test was applied by air; the in-situ soil had been there for a long time, and the confining pressure was caused by vertical load and soil weight.

Von Quintus and Killingsworth believed the reasons for the differences in the laboratory and field moduli were related to the inability of the laboratory tests to simulate the actual in-situ confinement and effect of the surrounding materials in both the lateral and vertical direction (1998).

For rigid pavements, the dynamic k value obtained from backcalculation is about two times greater than the static elastic k value that would be obtained from plate load testing of the same soil. This is due to the difference in the soil’s response to dynamic and static loads. Correlations have been developed to estimate the k value as a function of CBR, density, and soil classification. Additional correlations between soil properties (gradation, density, moisture content), soil classification, CBR, DCP penetration rate, and MR values are available in the literature.

B.6.2 Relationship between Laboratory and Backcalculated Resilient Modulus and Physical Soil Properties

Many research studies (George 2003; George 2004; George et al. 2004; Janoo et al. 2003; Janoo et al. 1999; Maher et al. 2000; Rahim and George 2003; Yau and Von Quintus 2002) are available in the literature which investigated correlating the laboratory or backcalculated MR values to soil indices or physical properties.

Correlations have been developed to estimate soil k value as a function of CBR, density, and soil classification. Several of these correlations are summarized in Table B.4. Additional correlations between soil properties such as gradation, density, moisture content, soil classification, CBR, DCP penetration rate, and MR values are given in the Illinois Department of Transportation's Guidelines on Subgrade Inputs and Subgrade Stability Requirements for Local Road Pavement Design (Hall et al. 2001).

Table B.4 Range of k values for soil type, density, and CBR (Hall et al. 2001)

AASHTO class	Soil description	USCS classification	Dry density (lb/ft^3)	CBR (%)	Static k value (psi/inch)
Coarse grained soils					
A-1-a, well graded	Gravel	GW, GP	125 - 140	60 - 80	300 - 450
A-1-a, poorly graded			120 - 130	35 - 60	300 - 400
A-1-b	Coarse sand	SW	110 - 130	20 - 40	200 - 400
A-3	Fine sand	SP	105 - 120	15 - 25	150 - 300
A-2 soils (granular materials with high fines)					
A-2-4, gravelly	Silty gravel	GM	130 - 145	40 - 80	300 - 500
A-2-5, gravelly	Silty sandy gravel				
A-2-4, sandy	Silty sand	SM	120 - 135	20 - 40	300 - 400
A-2-5, sandy	Silty gravelly sand				
A-2-6, gravelly	Clayey gravel	GC	120 - 140	20 - 40	200 - 450
A-2-7, gravelly	Clayey sandy gravel				
A-2-6, sandy	Clayey sand	SC	105 - 130	10 - 20	150 - 350
A-2-7, sandy	Clayey gravelly sand				
Fine grained soils					
A-4	Silt	ML, OL	90 - 105	4 - 8	25 - 165
	Silt/sand/gravel mix		100 - 125	5 - 15	40 - 220
A-5	Poorly graded silt	MH	80 - 100	4 - 8	25 - 190
A-6	Plastic clay	CL	100 - 125	5 - 15	25 - 225
A-7-5	Moderately plastic elastic clay	CL, OL	90 - 125	4 - 15	25 - 215
A-7-6	Highly plastic elastic clay	CH, OH	80 - 110	3 - 5	40 - 220

It should be noted that the k value of fine grained soil is highly dependent on the degree of saturation. Adjustments to the k value are required for embankments less than 10 feet thick over a softer roadbed, and/or for bedrock at a depth within 10 feet.

B.7 SEASONAL CHANGES

Pavement layers have varying properties and characteristics dependant on the time of the year. Pavements residing in areas that undergo freeze-thaw cycles are subject to seasonal effects. A pavement system can become very weak during the spring thaw season, then rapidly recover strength leading into summer, slowly recover over the summer and fall, and then reach a maximum stiffness when frozen during the winter (Shepherd and Vosen 1997). A typical annual range in deflection is shown in Figure B.12.

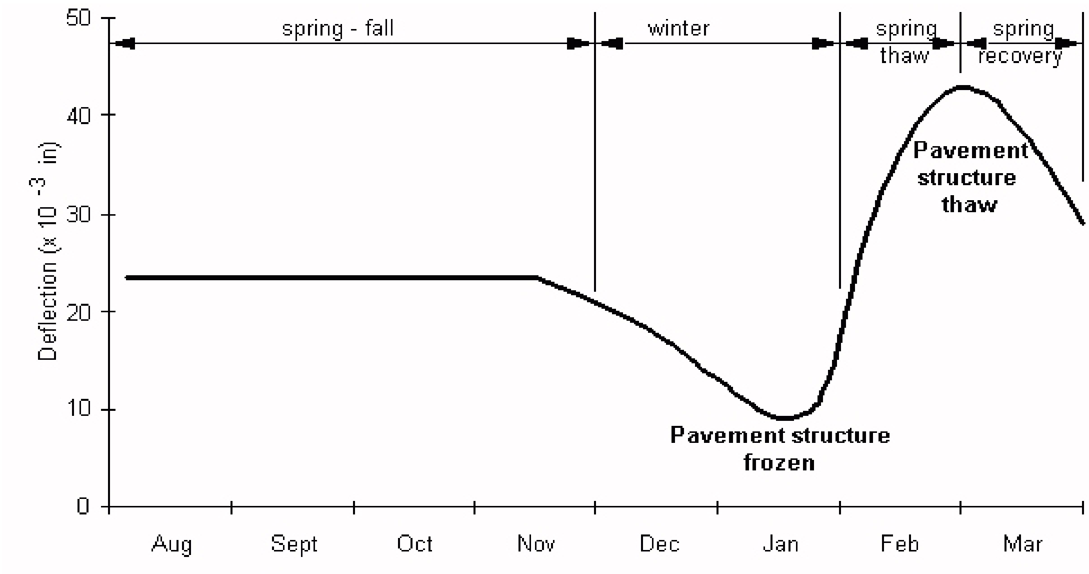


Figure B.12 Typical pavement deflections illustrating seasonal pavement strength changes (PTC 2008)

B.7.1 Spring Season

During the winter season, un-drained water within the pavement, along with water from shallow water tables, can freeze and create ice lenses. Due to this, the surface can experience frost heave. When the spring season begins, and the lenses start to melt, the pavement layers can become saturated if not properly drained. Also, additional water can enter the system from rain and snow melt. All pavement layers can experience a reduction in bearing capacity as a result of this. It is estimated that 90% of damage to pavements occurs during the spring thaw season (Janoo and Greatorex 2002). A diagram showing the formation of ice lenses can be seen in Figure B.13.

B.7.2 Summer Season

The summer season is considered to start after the conclusion of the spring-thaw season which is defined by the time when moisture conditions, within the pavement system, return to normal and the ambient temperatures begins to rise. The date when this occurs changes from year to year and from location to location. The summer-fall season ends when the ground starts to freeze, but is often considered to last until the spring-thaw season begins and the ice starts to melt. In Michigan, summer season is typically from May to December.

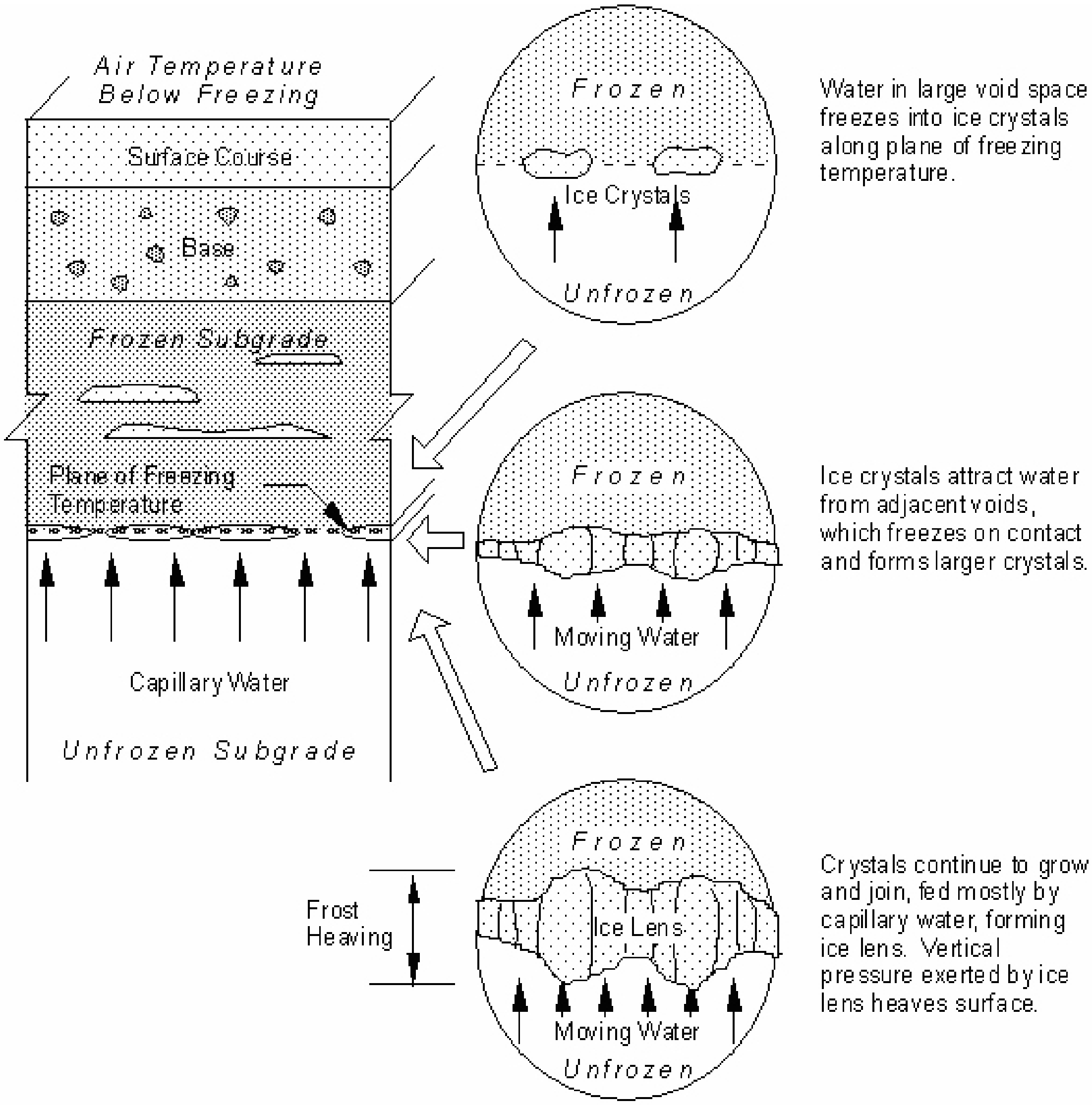


Figure B.13 Formations of ice lenses in a pavement structure (PTC 2008)

APPENDIX C

SOIL CLASSIFICATION SYSTEMS

Table C.1 AASHTO soil classification system (Holtz and Kovacs 1981)

General classification	Granular materials (35% or less passing 0.075 mm)							Silt-clay materials (more than 35% passing 0.075 mm)				
Group classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7	
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5	A-7-6
Sieve analysis, percent passing:												
2.00 mm (No. 10)	50 max	-	-	-	-	-	-	-	-	-	-	-
0.425 mm (No. 40)	30 max	50 max	51 min	-	-	-	-	-	-	-	-	-
0.075 mm (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min	36 min
Characteristics of fraction passing 0.425 mm (No. 40)												
Liquid limit	-	-	-	40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min	41 min
Plasticity index	6 max	6 max	NP	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min	11 min
Usual types of significant constituent materials	Stone fragments, gravel, and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils		

Figure C.1 AASHTO Atterberg limit ranges (Holtz and Kovacs 1981)

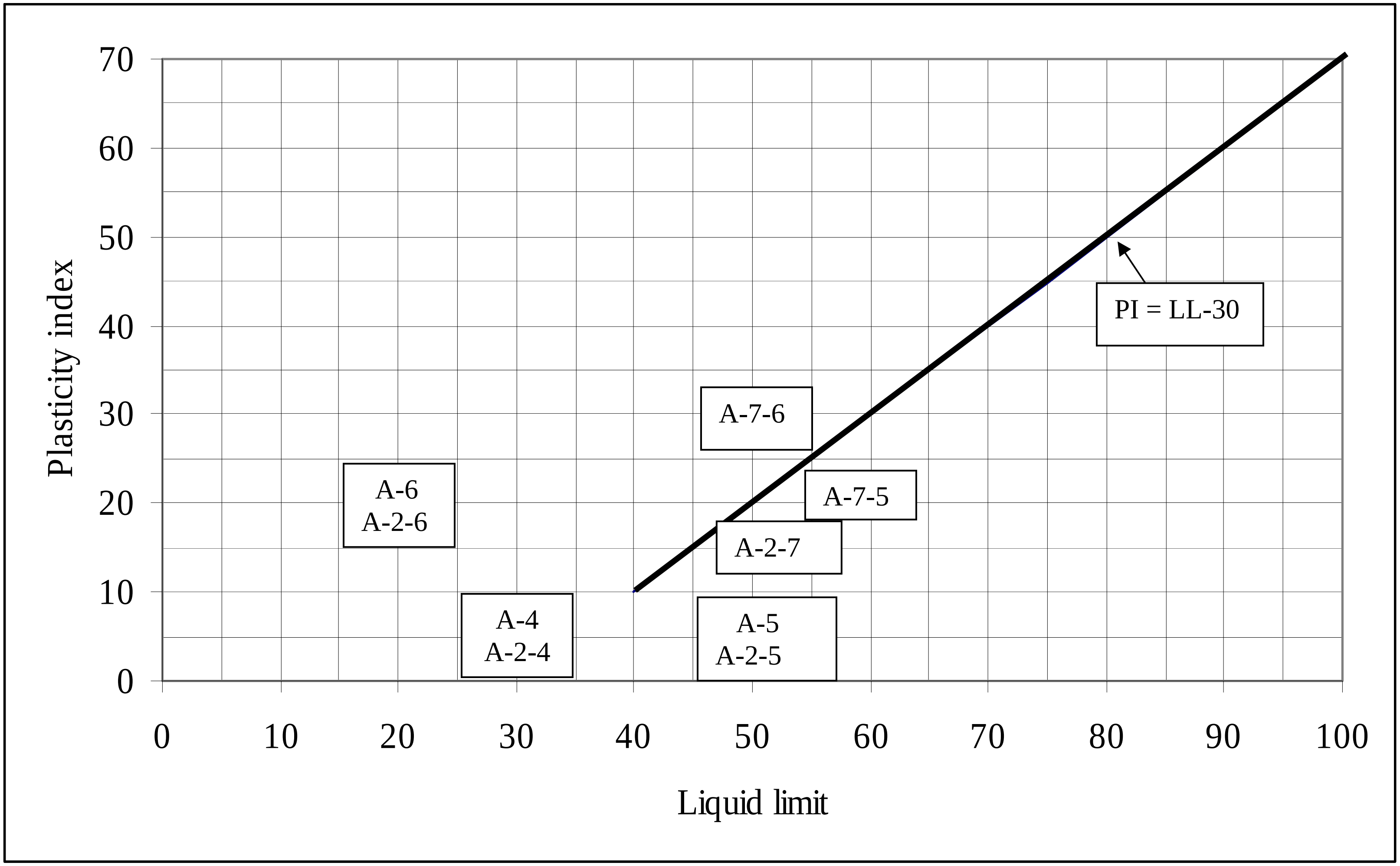


Figure C.2 Casagrande's plasticity chart (Holtz and Kovacs 1981)

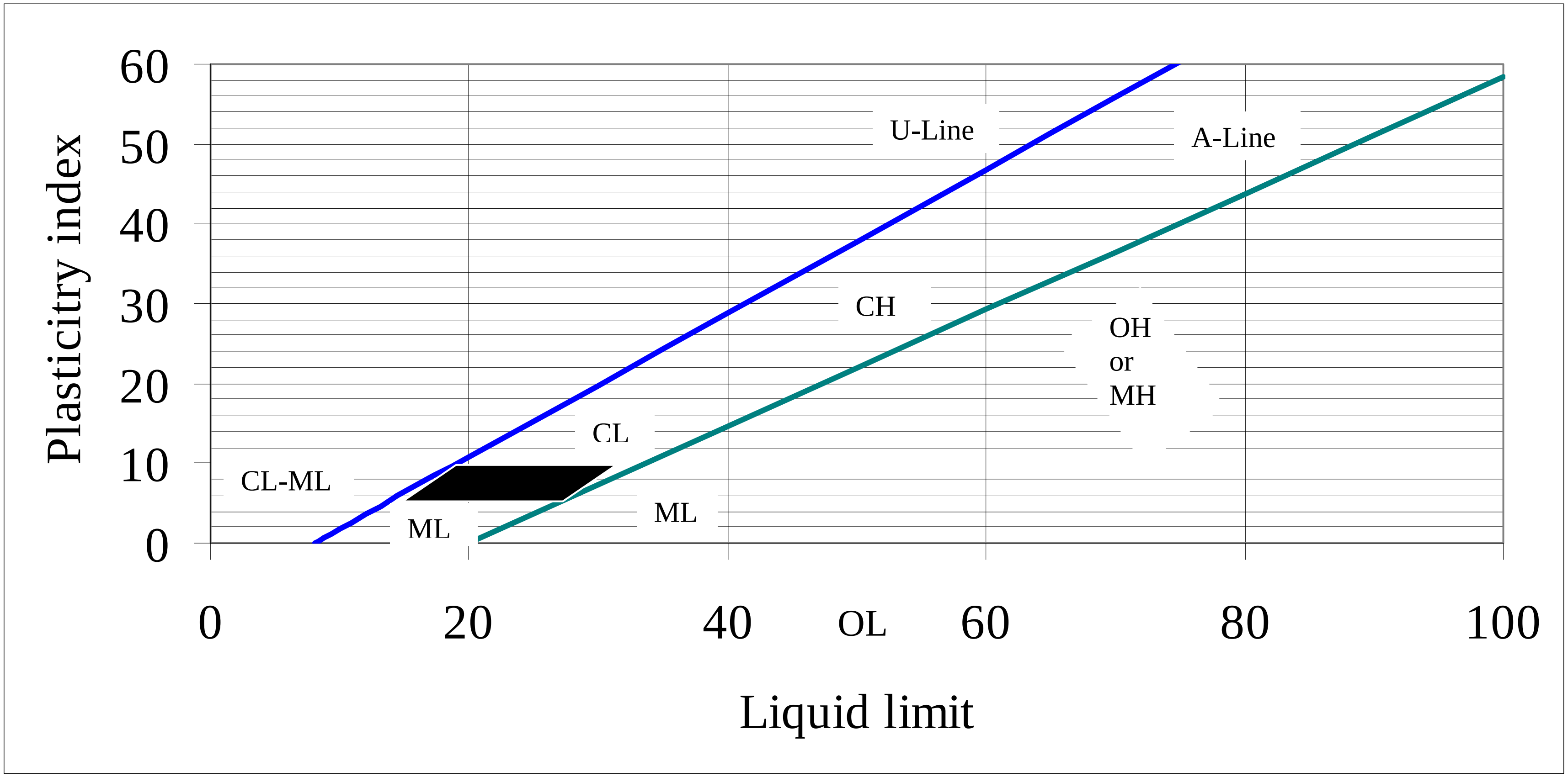


Figure C.3 USCS coarse grained soil classification (Holtz and Kovacs 1981)

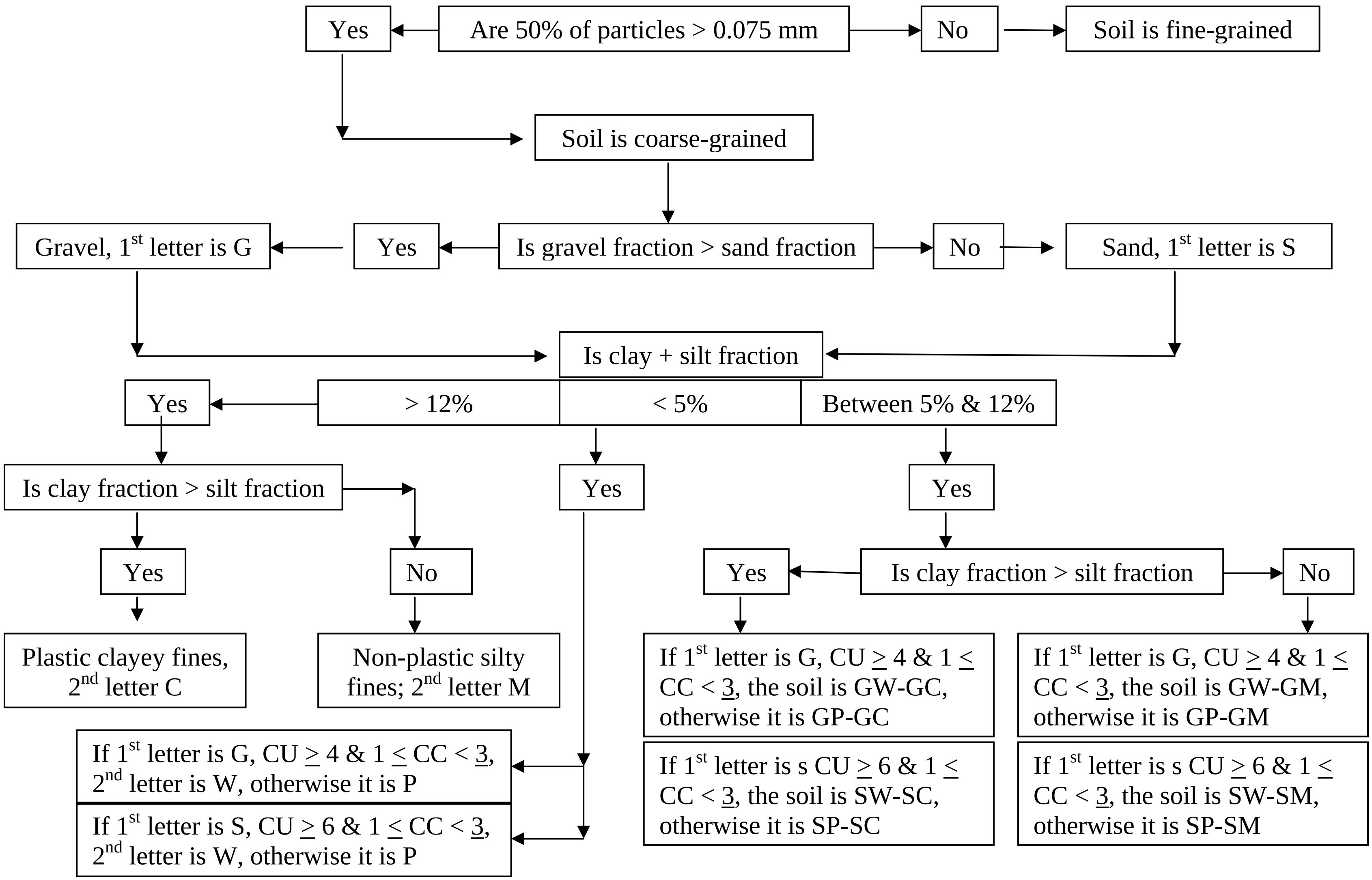


Figure C.4 USCS fine grained soil classification (Holtz and Kovacs 1981)

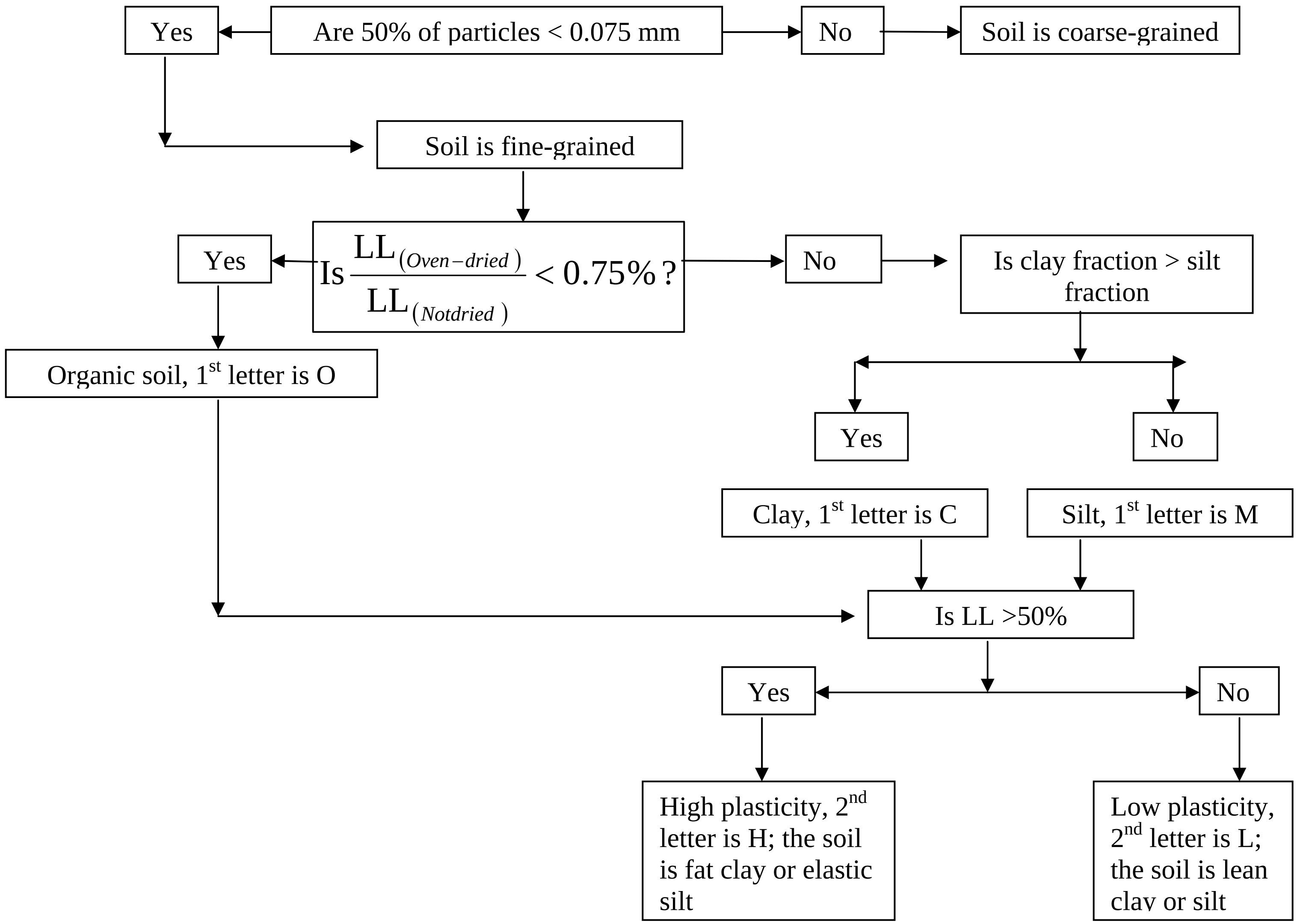


Table C.2 Possible AASHTO soil classifications relative to the USCS (Holtz and Kovacs 1981)

USCS group	Possible AASHTO classification
SP	A-3, A-1-b, A-1-a, A-2-4, A-2-5, A-2-6, A-2-7
SG	A-3, A-1-b, A-1-a, A-2-4, A-2-5, A-2-6, A-2-8
SM	A-1-b, A-2-4, A-2-5, A-2-7, A-2-6, A-4, A-5, A-6, A-7-5, A-7-6
SC	A-2-6, A-2-7, A-2-4, A-2-6, A-4, A-7-6, A-7-5
CL	A-6, A-7-6, A-4
ML	A-4, A-5, A-6, A-7-5
SP-SM	A-3, A-1-a, A-1-b, A-2-4, A-2-4, A-2-6, A-2-7
SC-SM	A-4, A-5, A-2-4, A-2-5, A-1-a, A-1-b

Table C.3 Possible USCS relative to the AASHTO classification (Holtz and Kovacs 1981)

AASHTO group	Possible USCS classification
A-1-a	GW, GP, SW, SP, GM, SM
A-1-b	SW, SP, GM, SM, GP
A-3	SP, SW, GP
A-2-4	GM, SM, GC, SC, GW, GP, SW, SP
A-2-5	GM, SM, GW, GP, SW, SP
A-2-6	GC, SC, GM, SM, GW, GP, SW, SP
A-2-7	GM, GC, SM, SC, GW, GP, SW, SP
A-4	ML, OL, CL, SM, SC, GM, GC
A-5	OH, MH, ML, OL, SM, GM
A-6	CL, ML, OL, SC, GC, GM, SM
A-7-5	OH, MH, ML, OL, CH, GM, SM, GC, SC
A-7-6	CH, CL, ML, OL, SC, OH, MH, GC, GM, SM

APPENDIX D

LABORATORY RESULTS

Figure D.1 Clusters of State of Michigan

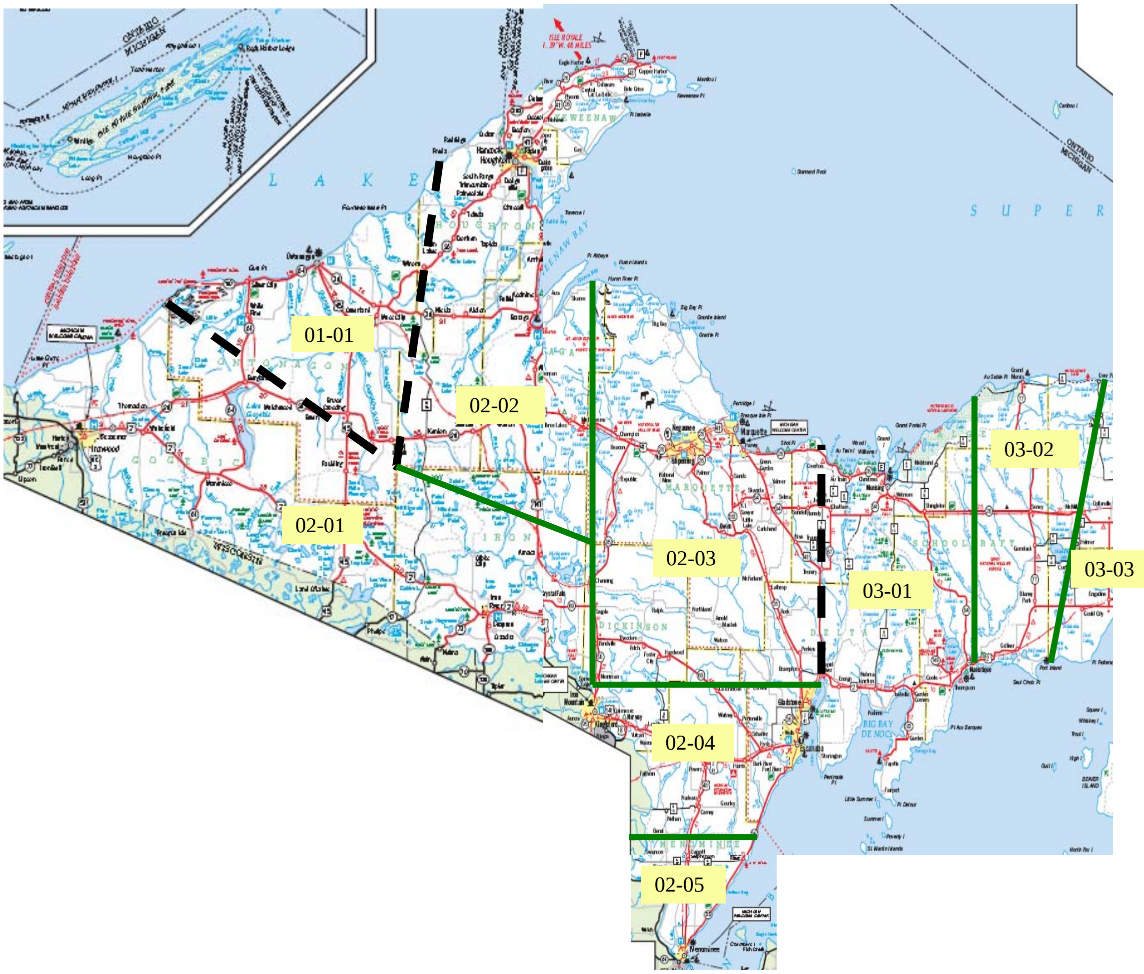


Figure D.2 Cluster and area boundaries in the State of Michigan

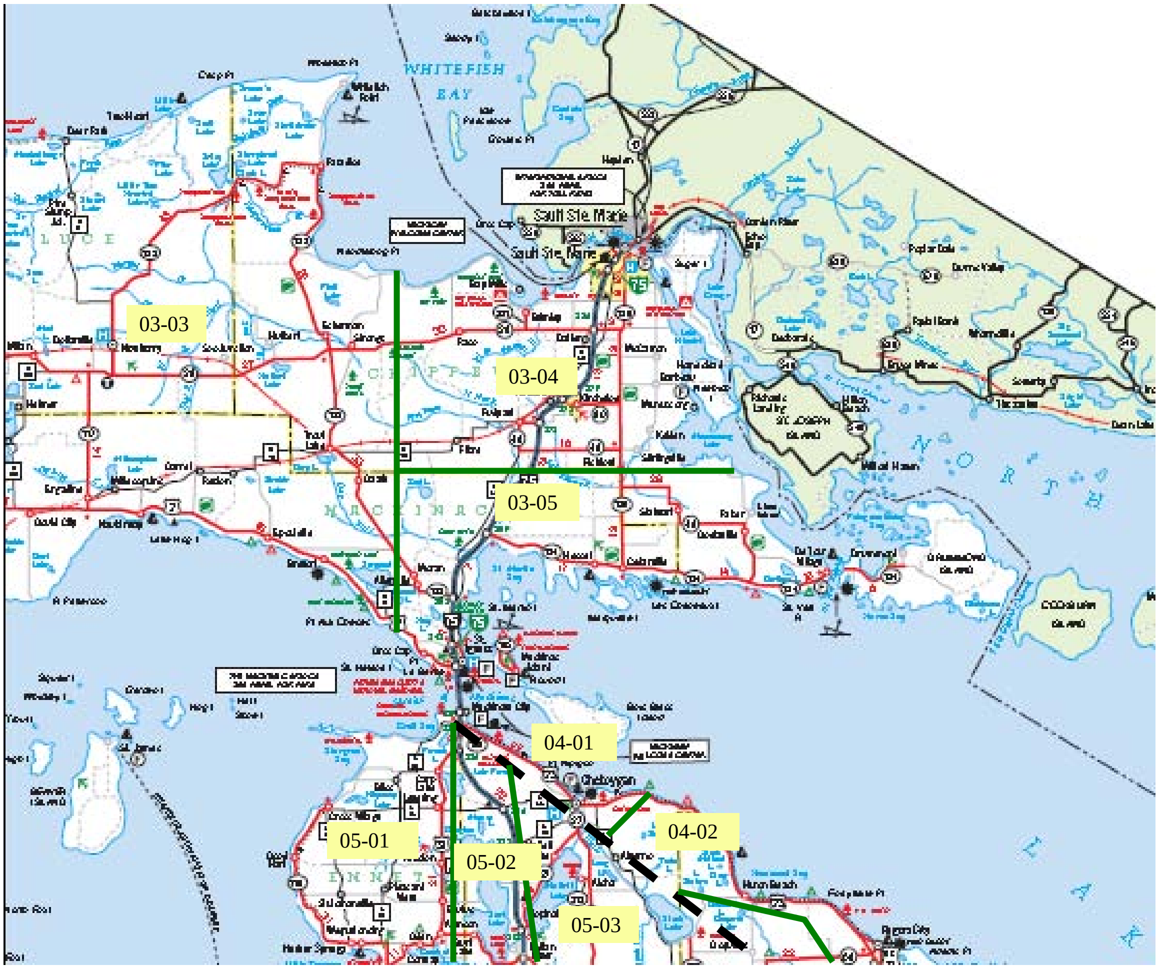


Figure D.2 (cont'd)

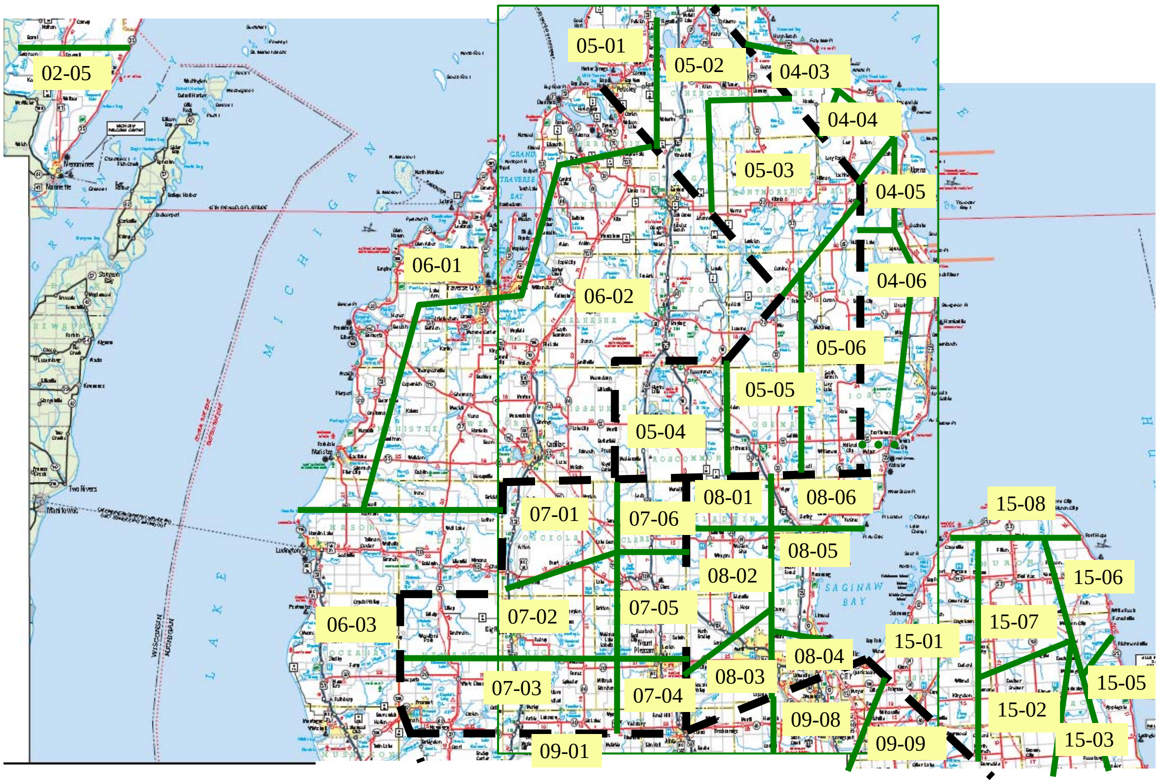


Figure D.2 (cont'd)

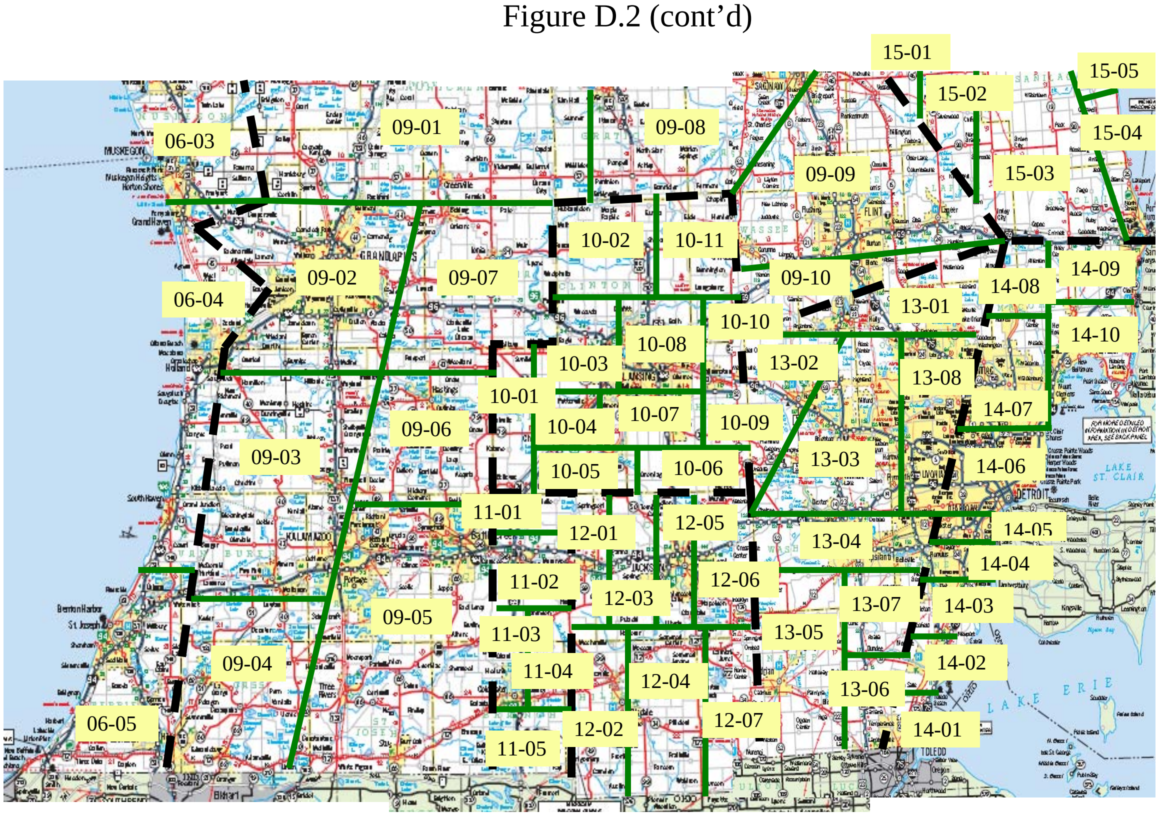


Figure D.2 (cont'd)

All data in tables D.1, D.2, D.3, and D.5 are listed in order of the cluster-area number. Whereas, the data in table D.4 is listed by soil type.

Table D.1 Soil percentages for each area within the 15 clusters

Cluster	Area	Muck (%)	Sand (%)	Loamy sand (%)	Silty loam (%)	Sandy loam (%)	Clayey loam (%)	Loam (%)	Mucky sand (%)	Clay (%)	Silty clay (%)	Proposed sampling
01	01	NO DATA										X
02	02	12.8	18.6	38	18.7	9						X
	03	24.3	30.6	12	3	13.4	9.1					X
	04	24.2	12	9.4	9.3	24.9	18.3					
	05	25	12.8	15.3	5.6	28.1	12.5					
	01	NO DATA										X
03	01	21	37	9.2	7.3	6.7	11.3					X
	02	20	29.1	8.6	12.2	5.3	14.8					
	04	9.2	8	16	63							X
	05	14.8	37	33.1	13							X
	03	29.2	29.6	9.4	11.5	16						
04	06	20	13.2	9.4		37.4			10			X
	02	25	15.2	34.4	16.2							
	01	58.4	33.3	4.1								X
	05	37.4	35	4.4	10	6.5						X
	03	16.1	50			28.4						X
	04	24.8				59.9		14.5				X

Note: empty cells indicate 0 percent of that soil type.

* Loam contains sand, silt and clay. The breakdown of the loam is unknown at this point.

Table D.1 (cont'd)

Cluster	Area	Muck (%)	Sand (%)	Loamy sand (%)	Silty loam (%)	Sandy loam (%)	Clayey loam (%)	Loam (%)	Mucky sand (%)	Clay (%)	Silty clay (%)	Proposed sampling
05	01	22	5	72.4								X
	02	13.1	41.5	39.3								X
	03	14.3	74.7	7.8		2						
	04	26.3	51.4	17.4								
	05		97.9	1.7								X
	06	4.4	14.4	25.2		13		39.2				X
06	01	3.3	53.5	30.4		9.3						X
	02	8.1	71.8	7.5		8.2						X
	03	8.1	75.6	5.9		4.7						X
	04		25.7	39.5		8		26				X
	05		23.6	41.6		12.2		17.1				
07	04		14.9	6.8		11.4		65.3				X
	02		63.2	7					25.1			X
	05	2	18.4	18.6		7.9		48				X
	03	6.2	53.9	26.3		12.7						X
	01	15.1	32.1	28.6		10		10.1				X
	06	13	34.3	36.6		7.5		7.1				

Note: empty cells indicate 0 percent of that soil type.

* Loam contains sand, silt and clay. The breakdown of the loam is unknown at this point.

Table D.1 (cont'd)

Cluster	Area	Muck (%)	Sand (%)	Loamy sand (%)	Silty loam (%)	Sandy loam (%)	Clayey loam (%)	Loam (%)	Mucky sand (%)	Clay (%)	Silty clay (%)	Proposed sampling
08	03		2	24.9				72.1				X
	04		2	8.6		2.6		86.8				X
	01		12.4	15.6		11.3		58.8				X
	05		15	29.2		6.1		49.7				
	02		29.8	44.9				21.1				X
	06	19.2	39.4	22.2		11		8				X
09	10			8.2	43.3	3.2	9.6	33.4				X
	01	16	6.7	64.4		3.3		7.3				X
	08		12.1	19.1		3.4		62.8				X
	05	8.9				6.4		83				X
	03	33.4		19.4		18.1		21.4				X
	02		22.8	40.5		10.1	6.3	12.4				X
	09	4.3	14.8	43.3		22.4		9.6				
	07	4.8	3	11.2		23.2		52				X
	04	12.2		22.5		28.3		32.9				
	06	2.2		8.6		44.5		41.9				

Note: empty cells indicate 0 percent of that soil type.

* Loam contains sand, silt and clay. The breakdown of the loam is unknown at this point.

Table D.1 (cont'd)

<table>
<tr><th>Cluster</th><th>Area</th><th>Muck (%)</th><th>Sand (%)</th><th>Loamy sand (%)</th><th>Silty loam (%)</th><th>Sandy loam (%)</th><th>Clayey loam (%)</th><th>Loam (%)</th><th>Mucky sand (%)</th><th>Clay (%)</th><th>Silty clay (%)</th><th>Proposed sampling</th></tr>
<tr><td rowspan="11">10</td><td>08</td><td></td><td></td><td></td><td></td><td>4.1</td><td></td><td>94.8</td><td></td><td></td><td></td><td rowspan="2">X</td></tr>
<tr><td>10</td><td></td><td></td><td>8.5</td><td></td><td>12.7</td><td></td><td>75.8</td><td></td><td></td><td></td></tr>
<tr><td>11</td><td></td><td></td><td></td><td></td><td>13.2</td><td>11.8</td><td>73.8</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>06</td><td>10.8</td><td></td><td>11.5</td><td></td><td>15.3</td><td></td><td>60.9</td><td></td><td></td><td></td><td rowspan="2">X</td></tr>
<tr><td>05</td><td>3.7</td><td></td><td>11.4</td><td></td><td>29.3</td><td></td><td>55</td><td></td><td></td><td></td></tr>
<tr><td>09</td><td>30.1</td><td></td><td>27.6</td><td></td><td>29.8</td><td></td><td>11.1</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>04</td><td>16.7</td><td></td><td></td><td></td><td>31.3</td><td></td><td>48.5</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>03</td><td>10.6</td><td></td><td>11.1</td><td></td><td>34.4</td><td></td><td>38.1</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>01</td><td></td><td></td><td>6.2</td><td></td><td>34.4</td><td></td><td>57.5</td><td></td><td></td><td></td><td rowspan="3">X</td></tr>
<tr><td>07</td><td>3.2</td><td></td><td>8</td><td></td><td>39.9</td><td></td><td>46.1</td><td></td><td></td><td></td></tr>
<tr><td>02</td><td>7.1</td><td></td><td></td><td></td><td>40.6</td><td></td><td>48.4</td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">11</td><td>01</td><td>17</td><td></td><td>34.5</td><td></td><td>27.6</td><td></td><td>15.6</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>02</td><td>6.9</td><td></td><td>5.8</td><td></td><td>54.8</td><td></td><td>25.3</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>05</td><td>11.4</td><td></td><td>11.6</td><td></td><td>65.4</td><td></td><td>10.3</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>03</td><td></td><td></td><td></td><td></td><td>67.2</td><td></td><td>30.5</td><td></td><td></td><td></td><td rowspan="2">X</td></tr>
<tr><td>04</td><td>6</td><td></td><td></td><td></td><td>72.6</td><td></td><td>18.5</td><td></td><td></td><td></td></tr>
</table>

Note: empty cells indicate 0 percent of that soil type.

* Loam contains sand, silt and clay. The breakdown of the loam is unknown at this point.

Table D.1 (cont’d)

<table>
<tr><th>Cluster</th><th>Area</th><th>Muck (%)</th><th>Sand (%)</th><th>Loamy sand (%)</th><th>Silty loam (%)</th><th>Sandy loam (%)</th><th>Clayey loam (%)</th><th>Loam (%)</th><th>Mucky sand (%)</th><th>Clay (%)</th><th>Silty clay (%)</th><th>Proposed sampling</th></tr>
<tr><td rowspan="7">12</td><td>01</td><td>9.2</td><td>3.9</td><td>18.2</td><td></td><td>36.4</td><td></td><td>24.7</td><td></td><td></td><td></td><td rowspan="2">X</td></tr>
<tr><td>02</td><td>7.9</td><td>9.2</td><td>5.6</td><td>11.4</td><td>53.2</td><td></td><td>9.4</td><td></td><td></td><td></td></tr>
<tr><td>06</td><td>22.7</td><td>17.4</td><td></td><td></td><td>34.3</td><td>17.9</td><td></td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>04</td><td>5.4</td><td></td><td>12</td><td></td><td>16.5</td><td>26.5</td><td>37.6</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>07</td><td>6.2</td><td></td><td></td><td></td><td>7</td><td></td><td>84</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>03</td><td>18.5</td><td></td><td></td><td></td><td>56.5</td><td></td><td>17.7</td><td></td><td></td><td></td><td rowspan="2">X</td></tr>
<tr><td>05</td><td>9.2</td><td></td><td>5.8</td><td></td><td>62.5</td><td></td><td>19</td><td></td><td></td><td></td></tr>
<tr><td rowspan="8">13</td><td>08</td><td></td><td>4.4</td><td>5.7</td><td></td><td>28.1</td><td>39.8</td><td>14.8</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>07</td><td></td><td>5.1</td><td>28.5</td><td></td><td>30.5</td><td>28.8</td><td>5.8</td><td></td><td></td><td></td><td rowspan="2">X</td></tr>
<tr><td>06</td><td></td><td>7.2</td><td>36.2</td><td></td><td>34.3</td><td>17.9</td><td>4.4</td><td></td><td></td><td></td></tr>
<tr><td>05</td><td></td><td></td><td></td><td></td><td>6.6</td><td>37.8</td><td>55.5</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>04</td><td>6.2</td><td></td><td>4</td><td>13.6</td><td></td><td>14.2</td><td>60</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>02</td><td>12</td><td></td><td>11.6</td><td></td><td>37.1</td><td></td><td>34.3</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>03</td><td>13.1</td><td></td><td>4.3</td><td>28.6</td><td>20</td><td>24.9</td><td></td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>01</td><td>12.4</td><td></td><td>31.4</td><td></td><td>44</td><td></td><td>4.8</td><td></td><td></td><td></td><td>X</td></tr>
</table>

Note: empty cells indicate 0 percent of that soil type.

* Loam contains sand, silt and clay. The breakdown of the loam is unknown at this point.

Table D.1 (cont'd)

Cluster	Area	Muck (%)	Sand (%)	Loamy sand (%)	Silty loam (%)	Sandy loam (%)	Clayey loam (%)	Loam (%)	Mucky sand (%)	Clay (%)	Silty clay (%)	Proposed sampling
14	01	8.2		29		20.3	18.7	14.8				X
	02	9.5	3	28.4		21.4	35.5					X
	03	5.2		11	25.5		53.2	3.5				X
	04				28.4		13.2	50				X
	07		21.4	7.2	12.3	28.9	13.5	12.9				X
	08			9		36.7		50.9				X
	09		11.2	3.5		16.2		64.3				
	10			5.8	4.6	9	57			7	12.5	X
	05	NO DATA										X
	06	NO DATA										X
15	04		7.4	6.1	22.5	4.9	33.7	17.7				X
	06		5.1	13.8	3.8	7		62.8				X
	02	20.9	6.4	5.5	14.9	15.3		33.1				X
	07			36		16.2		39.1				X
	01		15	28		23.5		31				
	03			4.8	60.3	23.9		8.5				X
	08			7.8	10.4	37.5		37				X
	05			4.4		38.6		56				

Note: empty cells indicate 0 percent of that soil type.

* Loam contains sand, silt and clay. The breakdown of the loam is unknown at this point

Table D.2 Locations and results of pocket penetrometer and vane shear tests

Sample number	Location	Vane shear test (psi)	Pocket penetrometer (psi)
M-045-S (01-01)	405 feet South of Ontonagon River	did not fail	did not penetrate
U-002-E (02-01)	385 feet East of M-45	2	2.3
M-028-W (02-02)	~1000 feet West of M-141	4	3.5
M-028-W (02-03)	~2000 feet East of M-35	0.25	1.4
U-002-E (02-04)	765 feet East of Spalding Rd	did not fail	did not penetrate
U-002-E (03-01)	400 feet East of Hwy 13	0.26	0.4
M-028-W (03-02)	1500 feet North of M-77	0.5	0.7
M-028-W (03-03)	500 feet West of Basnau Rd	0.25	3
U-002-E (03-03)	200 feet East of M-117	1	1.3
I-075-N (03-04)	mile marker 380	0.25	0.4
I-075-N (03-05)	mile marker 368	did not fail	did not penetrate
U-023-S (04-01)	320 feet North of F 05 Co Rd	0.5	0.9
M-068-W (04-02)	180 feet West of US-23	0.5	2
M-068-W (04-03)	150 feet West of Little Ocqueoc River	0.5	0.9
M-065-S (04-04)	160 feet South of Elm Hwy	did not fail	did not penetrate
M-032-W (04-05)	220 feet East of Herron Rd	3	5.1
U-131-N (05-01)	200 feet South of Michigan Fisheries Visitor Center	0.25	1
U-127-N (05-04)	120 feet North of Co Rd 300	0.25	0.4
M-033-S (05-05)	750 feet South of Peters Rd	did not fail	did not penetrate
M-072-W (05-06)	330 feet West of M-32	6	3.7
M-132-N (06-01)	1000 feet North of Addis Rd (paved rd)	0.75	1.4

Table D.2 (cont'd)

Sample number	Location	Vane shear test (psi)	Pocket penetrometer (psi)
I-075-N (06-02)	160 feet North of Co Rd 662	0.25	1.8
U-031-N (06-03)	307 feet North of M-46		
I-196-N (06-05)	110 feet North of Schmuhl Rd	1	3.3
M-020-W (07-02)	~.5 mile East of 13 Mile Rd		
M-020-E (07-03)	~500 feet East of Cottonwood Ave		
U-127-N (07-04)	100 feet North of Jefferson Rd	did not fail	did not penetrate
U-127-N (07-05)	65 feet North of Vernon Rd	5	3.6
M-061-E (07-06)	420 feet East of left hand turn on M-61 (off US-127)		
M-061-E (08-02)	165 feet West of Hockaday	0.5	0.6
U-010-W (08-03)	65 feet West of bridge before Stark Rd	did not fail	2.3
U-010-W (08-04)	145 feet West of Mackinaw Rd	did not fail	did not penetrate
I-075-S (08-05)	115 feet South of Prevo Rd	did not fail	did not penetrate
I-075-N (08-06)	80 feet North of bridge after exit 195	1.7	2.1
U-131-S (09-01)	160 feet South of Lake Montcalm Rd		
I-096-W (09-02)	141 feet West of Morse Lake Ave		
U-131-S (09-03)	105 feet South of 110th Ave	0.5	1.1
U-131-S (09-05)	60 feet South of 'Reduce Speed 55 MPH' sign right where it turns from interstate to freeway	0.5	1.1
M-044-E (09-07)	Station 137+10		
I-075-S (09-08)	650 feet South of Wadsworth Rd		
M-024-S (09-09)	20 feet North of Burley Rd	1.25	1.9

Table D.2 (cont'd)

Sample number	Location	Vane shear test (psi)	Pocket penetrometer (psi)
I-069-E (09-10)	172 feet East of Grand River Rd	0.5	1
I-069-N (10-01)	75 feet North of Base Line Hwy	3	4
I-096-W (10-03)	210 feet West of bridge before exit 97	1	1.3
I-069-N (10-04)	150 feet North of Island Hwy	1.75	4
I-069-N (10-05)	100 feet North of Five Points Hwy	2.5	3.2
I-096-W (10-09)	140 feet West of Dietz Rd	2.7	3.1
I-069-E (10-10)	120 feet East of Britton Rd	did not fail	did not penetrate
M-021-E (10-11)	800 feet East of Shepards Rd	3	2.6
I-069-N (11-01)	160 feet North of mile marker 42		
I-094-W (11-02)	132 feet West of exit 110 on ramp	1.5	2.5
M-060-W (11-03)	135 feet West of Southbound I-69 overpass	3	5.5
I-069-S (11-05)	95 feet South of Bridge after exit 10		
I-094-W (12-01)	95 feet West of 29 Mile Rd	1	2.6
I-094-W (12-03)	36 feet West of bridge after exit 135	1	1.5
U-012-E (12-04)	100 feet East of Emarld Rd	did not fail	6
I-094-W (12-06)	53 feet West of Mt Hope Rd	3	3.5
U-012-E (12-07)	120 feet West of Person Hwy	0.5	0.9
M-024-S (13-01)	250 feet North of Best Rd	3.5	5
M-059-W (13-02)	Station 131+29		
M-014-W (13-03)	255 feet West of Napler Rd	did not fail	4.5

Table D.2 (cont'd)

Sample number	Location	Vane shear test (psi)	Pocket penetrometer (psi)
I-094-W (13-04)	Station 75+02		
U-012-E (13-05)	Between Maple Rd and Industrial Ave	did not fail	did not penetrate
U-023-N (13-07)	60 feet North of Sherman	0.75	1.6
M-010-E (13-08)	Station 38+00	did not fail	3.5
I-075-S (14-01)	60 feet South of Gaynier Rd	3	3.5
I-075-S (14-02)	40 feet South of Nadeau Rd	4.5	3.5
U-024-S (14-03)	~1000 feet South of Ready Rd	4.5	5
U-024-S (14-04)	150 feet North of Pardee	0.25	0.5
I-075-S (14-04)	Station 23+00		
I-094-W (14-05)	300 feet West of Monroe Blvd	3.5	4.3
M-153-E (14-06)	~800 feet East of Greenfield Rd	did not fail	4.5
M-053-S (14-07)	1500 feet South of Canal Rd		
I-094-W (14-09)	350 feet West of Wadhams Rd	2.5	3
I-094-W (14-10)	227 feet West of Palms Rd	did not fail	4
M-053-S (15-02)	300 feet South of M-46	2	2.3
M-090-E (15-03)	210 feet East of Murray Rd	0.5	0.7
M-090-E (15-04)	200 feet East of Bobcock St 37 feet East of Village Limit sign	did not fail	did not penetrate
M-025-S (15-05)	200 feet North of Day Rd	1.5	2.8
M-25-N (15-06)	170 feet North of North Huron Dr	1.3	2.2
M-019-S (15-07)	650 feet South of Thompson Rd 1 mile South of M-142	1.5	2.7

Table D.3 Laboratory test results

Sample number	Shelby tube	Natural water content (%)	Sample weight (g)	Percent passing sieve #							Atterberg limits			D_{10}	D_{30}	D_{60}	$C_U = D_{60}/D_{10}$	$C_C = D_{30}^2/(D_{60})(D_{10})$	Classification	
				3/8 inch	4	10	20	40	100	200	LL	PL	PI						AASHTO	USCS
				9.500	4.750	2.000	0.850	0.425	0.150	0.075										
M-045-S (01-01)		11.5	298.8	99.5	99.3	98.9	96.8	96.7	77.2	66.7	26	16	10	0.0030	0.006	0.040	13.33	0.30	A-6	CL
U-002-E (02-01)		16.8	303.3	99.1	97.8	96.6	92.3	68.1	46.4	39.2	18	-	NP	0.008	0.040	0.300	37.50	0.67	A-4	SM
M-028-W (02-02)		21.0	200.0	100.0	99.4	98.0	93.4	83.2	64.5	56.1	23	-	NP	0.0080	0.024	0.110	13.75	0.65	A-4	ML
M-028-W (02-03)		6.6	535.8	100.0	99.3	97.2	92.1	81.8	23.4	6.1	16	-	NP	0.091	0.175	0.285	3.13	1.18	A-1-b	SP-SM
U-002-E (02-04)		10.8	200.0	100.0	99.4	98.0	93.4	83.2	64.5	54.1	19	-	NP	0.0100	0.050	0.110	11.00	2.27	A-4	ML
U-002-E (03-01)		5.0	525.3	100.0	99.8	99.6	98.5	92.6	15.8	6.5	13	-	NP	0.130	0.190	0.275	2.12	1.01	A-3	SP-SM
M-028-W (03-02)		3.1	519.1	99.9	99.6	99.3	97.9	89.7	14.0	3.0	NA	NA	NP	0.150	0.190	0.280	1.87	0.86	A-3	SP
U-002-E (03-03)		13.1	222.9	100.0	96.8	93.7	88.7	77.8	31.7	25.1	15	-	NP	0.002	0.120	0.300	150.00	24.00	A-2-4	SM
M-028-W (03-03)		4.8	520.2	94.1	87.5	82.6	71.2	45.5	11.1	6.4	21	-	NP	0.140	0.285	0.600	4.29	0.97	A-3	SP-SM
I-075-N (03-04)		9.4	549.2	99.9	99.8	99.5	98.4	91.3	10.0	1.5	NA	NA	NP	0.160	0.200	0.280	1.75	0.89	A-3	SP
I-075-N (03-05)		21.2	197.8	100.0	99.9	94.1	92.4	80.9	60.3	48.2	55	22	33	0.001	0.002	0.150	150.00	0.03	A-7-6	SC
U-023-S (04-01)		22.0	547.2	98.8	98.8	98.5	96.4	90.3	10.3	4.3	NA	NA	NP	0.170	0.200	0.280	1.65	0.84	A-3	SP
M-068-W (04-02)		4.0	205.0	99.9	98.6	91.0	51.3	25.2	16.0	14.1	18	12	6	0.040	0.500	1.000	25.00	6.25	A-2-4	SC-SM
M-068-W (04-03)		33.3	515.6	100.0	100.0	99.7	98.7	89.8	14.3	3.7	NA	NA	NP	0.160	0.190	0.280	1.75	0.81	A-3	SP
M-065-S (04-04)		8.1	201.5	99.3	95.4	91.3	87.5	72.7	30.4	21.5	30	-	NP	0.001	0.150	0.300	300.00	75.00	A-2-4	SM
M-032-W (04-05)		9.6	203.4	100.0	99.8	99.6	99.0	95.0	64.6	48.7	19	12	7	0.001	0.006	0.130	130.00	0.28	A-4	SC-SM
U-131-N (05-01)		13.1	199.4	99.8	99.2	96.4	95.0	78.7	43.5	29.2	14	-	NP	0.016	0.140	0.280	17.50	4.38	A-2-4	SM
U-127-N (05-04)		8.9	527.6	91.8	84.4	79.1	73.3	53.6	6.4	3.7	NA	NA	NP	0.180	0.260	0.500	2.78	0.75	A-3	SP
M-033-S (05-05)		3.5	525.7	63.1	57.5	45.4	35.7	26.7	7.8	4.6	NA	NA	NP	0.185	0.510	6.000	32.43	0.23	A-1-a	SG
M-072-W (05-06)		14.3	201.0	100.0	99.6	98.8	97.3	91.4	56.1	39.9	22	11	11	0.0070	0.035	0.160	22.86	1.09	A-6	SC
M-132-N (06-01)		15.0	521.7	99.5	99.0	98.5	96.8	78.7	8.8	4.2	NA	NA	NP	0.160	0.220	0.320	2.00	0.95	A-3	SP
I-075-N (06-02)		3.4	518.0	95.1	93.7	92.8	90.4	63.4	5.8	4.1	NA	NA	NP	0.170	0.260	0.400	2.35	0.99	A-3	SP
U-031-N (06-03)		5.8	1060.3	99.5	99.1	98.4	97.4	87.2	7.9	0.5	NA	NA	NP	0.170	0.210	0.300	1.76	0.86	A-3	SP
I-196-N (06-05)		10.5	1085.6	99.6	98.4	96.2	91.2	84.4	26.5	5.9	15	-	NP	0.089	0.160	0.275	3.09	1.05	A-2-4	SP-SM
M-020-W (07-02)		4.2	1003.7	99.6	99.3	98.7	97.9	88.0	2.1	0.8	NA	NA	NP	0.180	0.220	0.300	1.67	0.90	A-3	SP
M-020-E (07-03)		4.5	513.3	99.2	97.9	96.8	94.5	89.6	21.2	3.3	NA	NA	NP	0.110	0.190	0.280	2.55	1.17	A-3	SP
U-127-N (07-04)		10.9	200.8	100.0	98.8	96.6	95.4	90.3	38.3	26.9	22	12	10	0.001	0.100	0.230	230.00	43.48	A-2-6	SC
U-127-N (07-05)	X	11.2	203.9	100.0	98.3	92.6	87.3	79.9	53.7	40.5	23	14	9	0.0011	0.006	0.190	172.73	0.17	A-6	SC
U-127-N (07-05)		14.4	213.7	99.8	98.2	85.2	81.0	74.8	52.1	43.7	24	14	10	0.0010	0.008	0.210	210.00	0.30	A-6	SC
M-061-E (07-06)		22.1	198.5	100.0	98.8	93.3	84.7	59.3	23.7	17.9	19	-	NP	0.040	0.190	0.430	10.75	2.10	A-2-4	SM
M-061-E (08-02)		20.3	223.1	100.0	99.7	93.9	77.8	51.9	26.1	23.2	11	-	NP	0.050	1.000	0.520	10.40	38.46	A-2-4	SM
U-010-W (08-03)		21.4	200.2	100.0	100.0	99.8	99.7	97.6	61.0	55.2	32	14	18	0.001	0.002	0.140	140.00	0.02	A-6	CL
U-010-W (08-04)		8.2	200.1	99.9	99.9	98.8	96.6	84.5	48.8	36.7	29	13	16	0.001	0.011	0.200	200.00	0.61	A-6	SC

Table D.3 (cont'd)

Sample number	Shelby tube	Natural water content (%)	Sample weight (g)	Percent passing sieve #							Atterberg limits			D_{10}	D_{30}	D_{60}	$C_U = D_{60}/D_{10}$	$C_C = D_{30}^2/(D_{60})(D_{10})$	Classification	
				3/8 inch	4	10	20	40	100	200	LL	PL	PI						AASHTO	USCS
				9.500	4.750	2.000	0.850	0.425	0.150	0.075										
U-010-W (08-04)	X	15.0	205.1	98.0	98.9	96.5	95.8	80.3	42.5	33.3	27	13	14	0.0009	0.018	0.200	222.22	1.80	A-6	SC
I-075-S (08-05)		8.9	201.0	100.0	99.9	97.7	94.5	69.4	40.3	33.5	25	12	13	0.001	0.011	0.300	300.00	0.40	A-2-6	SC
I-075-N (08-06)		11.8	201.5	100.0	99.2	96.8	93.7	85.4	36.6	26.2	17	10	7	0.001	0.011	0.270	270.00	0.45	A-2-4	SC-SM
U-131-S (09-01)		4.6	1056.3	99.0	98.0	97.4	97.0	83.7	2.5	0.5	NA	NA	NP	0.180	0.220	0.300	1.67	0.90	A-3	SP
I-096-W (09-02)		9.9	206.2	100.0	99.0	97.3	93.8	82.7	40.9	30.5	17	13	4	0.001	0.075	0.240	240.00	23.44	A-2-4	SC-SM
U-131-S (09-03)		1.9	530.4	100.0	100.0	99.9	99.8	97.2	6.0	0.4	NA	NA	NP	0.180	0.200	0.290	1.61	0.77	A-3	SP
U-131-S (09-05)		3.6	1025.6	97.5	90.2	80.8	69.5	45.8	3.1	1.3	NA	NA	NP	0.185	0.295	0.605	3.27	0.78	A-3	SP
M-044-E (09-07)		8.7	206.5	100.0	99.5	97.7	94.1	85.5	37.7	26.7	14	-	NP	0.020	0.110	0.250	12.50	2.42	A-2-4	SM
I-075-S (09-08)		20.2	216.1	99.1	96.1	91.8	89.7	85.5	62.3	45.8	31	14	17	0.001	0.004	0.140	140.00	0.11	A-4	SC
M-024-S (09-09)		13.3	198.6	100.0	99.6	97.6	95.4	93.2	45.0	24.1	20	-	NP	0.012	0.090	0.200	16.67	3.38	A-2-4	SM
I-069-E (09-10)		7.1	527.8	98.3	93.4	83.0	66.3	36.8	5.2	3.1	NA	NA	NP	0.190	0.340	0.700	3.68	0.87	A-3	SP
I-069-N (10-01)		10.1	534.1	94.9	88.7	81.1	67.6	49.2	16.7	8.0	16	11	5	0.093	0.230	0.600	6.45	0.95	A-3	SP-SM
I-096-W (10-03)		14.7	199.7	100.0	98.4	93.9	90.1	82.0	29.5	17.5	29	14	15	0.0600	0.150	0.280	4.67	1.34	A-2-6	SC
I-069-N (10-04)		11.1	198.5	100.0	99.3	94.1	86.4	74.9	30.1	17.6	16	-	NP	0.010	0.150	0.200	20.00	11.25	A-2-4	SM
I-069-N (10-05)		24.0	204.0	100.0	100.0	97.8	87.6	54.9	43.2	37.3	19	-	NP	0.010	0.070	0.500	50.00	0.98	A-2-4	SM
I-096-W (10-09)		15.1	200.9	100.0	99.6	93.7	91.0	61.1	38.0	30.4	19	-	NP	0.006	0.075	0.410	68.33	2.29	A-2-4	SM
I-069-E (10-10)		12.8	204.9	98.0	96.1	92.4	90.5	84.7	57.2	37.7	26	15	11	0.001	0.009	0.170	170.00	0.48	A-6	SC
M-021-E (10-11)		15.0	230.2	99.4	92.1	85.9	79.5	72.2	46.3	33.8	23	14	9	0.001	0.030	0.270	270.00	3.33	A-2-4	SC
I-069-N (11-01)		9.1	1032.9	90.3	87.1	83.0	77.8	63.9	15.9	6.9	14	-	NP	0.120	0.210	0.390	3.25	0.94	A-3	SP-SM
I-094-W (11-02)		7.1	1022.7	95.0	91.7	87.1	77.5	51.2	6.2	2.7	NA	NA	NP	0.170	0.270	0.510	3.00	0.84	A-3	SP
M-060-W (11-03)		10.5	199.3	99.7	99.0	97.4	90.6	67.0	37.6	31.1	22	15	7	0.004	0.025	0.330	82.50	0.47	A-2-4	SC-SM
I-069-S (11-05)		6.6	201.1	100.0	99.1	93.9	86.9	77.3	49.3	38.6	15	11	4	0.002	0.034	0.210	105.00	2.75	A-4	SC-SM
I-094-W (12-01)		8.6	199.8	100.0	95.2	81.8	73.9	51.8	26.5	20.0	16	12	4	0.038	0.180	0.560	14.74	1.52	A-2-4	SC-SM
I-094-W (12-03)		13.2	527.4	97.4	95.4	91.6	83.0	68.3	18.7	7.4	16	-	NP	0.095	0.195	0.345	3.63	1.16	A-3	SP-SM
U-012-E (12-04)		4.9	200.4	99.9	98.9	94.2	89.4	73.7	36.6	23.0	16	-	NP	0.003	0.110	0.300	100.00	13.44	A-2-4	SM
I-094-W (12-06)		12.1	213.7	100.0	99.8	92.2	90.5	86.0	35.2	23.8	15	-	NP	0.005	0.130	0.250	50.00	13.52	A-2-4	SM
U-012-E (12-07)		7.0	513.8	67.5	57.0	42.2	25.8	16.0	10.0	8.1	18	-	NP	0.160	1.000	6.000	37.50	1.04	A-1-a	SG
M-024-S (13-01)		10.6	196.0	100.2	98.4	93.4	90.2	85.2	59.4	45.1	18	15	3	0.001	0.013	0.150	150.00	1.13	A-4	SM
M-059-W (13-02)		11.6	1033.3	99.4	97.9	95.1	91.2	65.7	8.9	1.7	NA	NA	NP	0.160	0.220	0.380	2.38	0.80	A-3	SP
M-014-W (13-03)		9.3	198.1	100.0	99.1	94.0	90.0	85.7	62.7	49.2	22	13	9	0.001	0.006	0.130	130.00	0.28	A-4	SC
I-094-W (13-04)		8.0	1005.6	98.1	95.8	90.5	82.8	65.9	13.1	3.5	NA	NA	NP	0.140	0.210	0.390	2.79	0.81	A-3	SP

Table D.3 (cont'd)

Sample number	Shelby tube	Natural water content (%)	Sample weight (g)	Percent passing sieve #							Atterberg limits			D_{10}	D_{30}	D_{60}	$C_U = D_{60}/D_{10}$	$C_C = D_{30}^2/(D_{60})(D_{10})$	Classification	
				3/8 inch	4	10	20	40	100	200	LL	PL	PI						AASHTO	USCS
				9.500	4.750	2.000	0.850	0.425	0.150	0.075										
U-012-E (13-05)		14.9	205.0	100.0	99.9	99.0	97.8	95.5	65.6	56.7	33	17	16	0.001	0.002	0.100	111.11	0.04	A-6	CL
U-023-N (13-07)		9.8	529.5	94.1	83.4	66.2	53.5	43.3	12.0	5.7	13	-	NP	0.130	0.280	1.350	10.38	0.45	A-3	SP-SM
M-010-E (13-08)		14.0	201.0	100.0	99.7	98.1	95.0	90.8	74.3	59.9	24	14	10	0.0010	0.003	0.075	75.00	0.12	A-6	CL
M-010-E (13-08)	X	12.3	207.0	100.0	98.0	95.6	93.5	88.3	72.6	54.8	23	14	9	0.0009	0.015	0.090	100.00	2.78	A-6	CL
I-075-S (14-01)	X	18.4	204.5	100.0	99.9	89.4	87.9	67.6	54.2	48.2	42	21	21	0.0090	0.015	0.250	27.78	0.10	A-7-6	SC
I-075-S (14-01)		25.4	200.6	100.0	96.9	78.9	76.2	68.4	47.8	41.2	45	19	26	0.0007	0.003	0.270	385.71	0.05	A-7-6	SC
I-075-S (14-02)		18.7	201.0	100.0	98.3	97.6	92.6	85.5	64.1	46.1	41	19	22	0.001	0.003	0.190	211.11	0.06	A-7-6	SC
U-024-S (14-03)		19.2	202.3	100.0	99.4	98.8	91.8	79.7	55.3	41.4	40	13	27	0.001	0.003	0.190	271.43	0.07	A-6	SC
I-075-S (14-04)		15.8	200.8	100.0	99.9	99.8	99.7	96.4	59.4	46.9	34	17	17	0.001	0.003	0.260	288.89	0.04	A-6	SC
U-024-S (14-04)		22.2	543.7	100.0	100.0	99.8	99.6	96.3	23.3	2.5	NA	NA	NP	0.100	0.170	0.255	2.55	1.13	A-3	SP
I-094-W (14-05)		21.6	199.0	99.7	97.6	97.5	89.7	78.0	56.7	46.7	34	21	13	0.001	0.013	0.160	160.00	1.06	A-6	SC
M-153-E (14-06)	X	26.0	209.4	100.0	99.8	99.0	98.3	92.7	70.1	51.1	51	19	32	0.0090	0.018	0.100	11.11	0.36	A-7-6	SC
M-153-E (14-06)		21.6	202.9	100.0	100.0	98.4	98.1	94.1	64.4	49.9	52	20	32	0.0007	0.001	0.140	200.00	0.02	A-7-6	SC
M-053-S (14-07)		5.9	529.1	93.1	87.5	81.5	70.3	55.0	9.3	4.7	NA	NA	NP	0.170	0.240	0.500	2.94	0.68	A-3	SP
I-094-W (14-09)	X	26.3	205.1	100.0	100.0	98.5	97.9	85.2	59.8	55.8	42	23	19	0.0010	0.010	0.150	150.00	0.67	A-7-6	CL
I-094-W (14-09)		21.9	197.3	99.7	99.2	97.7	96.6	90.8	66.8	60.9	44	21	23	0.0010	0.002	0.075	75.00	0.05	A-7-6	CL
I-094-W (14-10)		21.5	198.9	100.0	99.5	93.3	91.6	80.3	65.2	56.3	42	19	23	0.001	0.002	0.100	166.67	0.07	A-7-6	CL
M-053-S (15-02)		17.2	200.4	100.0	99.5	96.8	94.4	87.5	42.8	26.2	14	-	NP	0.008	0.100	0.210	26.25	5.95	A-2-4	SM
M-090-E (15-03)		38.0	204.1	100.0	99.9	98.8	96.1	90.7	73.1	55.8	35	20	15	0.001	0.005	0.088	88.00	0.28	A-6	CL
M-090-E (15-04)		12.4	199.6	100.0	99.7	97.4	95.0	90.6	67.4	52.8	24	15	9	0.0010	0.006	0.100	100.00	0.36	A-4	CL
M-025-S (15-05)		4.4	532.8	99.3	98.7	98.2	97.3	84.4	1.9	1.1	NA	NA	NP	0.180	0.210	0.300	1.67	0.82	A-3	SP
M-25-N (15-06)		16.4	206.4	100.0	98.9	94.0	90.8	85.1	54.2	42.3	24	13	11	0.001	0.007	0.190	190.00	0.26	A-4	SC
M-019-S (15-07)		11.4	199.4	99.9	95.1	83.9	76.4	61.5	29.0	17.2	14	-	NP	0.065	0.160	0.400	6.15	0.98	A-2-4	SM

Table D.4 Laboratory and MR test results

Sample number	Sample type		Classification		Dry unit weight (lb/ft^3)	Water content for cyclic test	Saturation	MR at cyclic stress (psi)	
	Shelby tube	Disturbed	AASHTO	USCS				10.0	15.0
M-028-W (02-03)		X	A-1-b	SP-SM	113.4	8.5	47.3	19,195	17,845
U-002-E (03-01)		X	A-3	SP-SM	108.7	4.5	22.1	22,787	19,592
M-028-W (03-03)		X	A-3	SP-SM	105.5	2.0	9.0	16,895	15,941
I-196-N (06-05)		X	A-2-4	SP-SM	111.5	3.7	19.5	23,009	21,964
I-069-N (10-01)		X	A-3	SP-SM	116.1	9.9	59.2	15,858	15,682
I-069-N (11-01)		X	A-3	SP-SM	118.0	7.0	44.2	30,701	28,120
I-094-W (12-03)		X	A-3	SP-SM	121.6	11.4	79.8	18,122	15,961
U-023-N (13-07)		X	A-3	SP-SM	115.4	6.5	38.2	22,608	20,574
M-068-W (04-03)		X	A-3	SP	100.9	20.0	80.6	9,969	10,004
M-020-W (07-02)		X	A-3	SP	110.5	11.5	59.2	29,418	28,566
M-059-W (13-02)		X	A-3	SP	107.7	9.0	43.1	24,840	23,788
M-059-W (13-02)		X	A-3	SP	104.4	7.9	34.6	23,195	NA
U-127-N (05-04)		X	A-3	SP	112.6	6.9	37.5	37,123	29,921
I-075-N (03-04)		X	A-3	SP	111.7	6.9	36.6	26,115	24,378
I-094-W (11-02)		X	A-3	SP	116.7	6.2	37.7	44,479	27,346
I-094-W (13-04)		X	A-3	SP	114.3	6.0	34.2	21,449	18,842
U-024-S (14-04)		X	A-3	SP	108.2	10.0	48.5	22,768	21,924
M-020-W (07-02)		X	A-3	SP	109.2	5.3	26.4	30,244	24,872

* It should be noted that the shaded rows indicate the results of those tests that were conducted to verify the developed resilient modulus prediction models.

Table D.4 (cont'd)

Sample number	Sample type		Classification		Dry unit weight (lb/ft^3)	Water content for cyclic test	Saturation	MR at cyclic stress (psi)	
	Shelby tube	Disturbed	AASHTO	USCS				10.0	15.0
I-069-E (09-10)		X	A-3	SP	116.9	5.1	31.2	28,636	26,070
M-132-N (06-01)		X	A-3	SP	112.9	4.7	25.8	31,711	28,970
M-053-S (14-07)		X	A-3	SP	113.9	3.9	22.0	25,714	22,275
U-023-S (04-01)		X	A-3	SP	117.8	3.3	20.7	23,039	21,715
U-031-N (06-03)		X	A-3	SP	111.5	3.3	17.4	31,870	29,609
M-020-E (07-03)		X	A-3	SP	113.0	3.2	17.6	32,666	28,156
M-025-S (15-05)		X	A-3	SP	110.3	3.0	15.4	40,115	35,447
U-131-S (09-01)		X	A-3	SP	110.6	2.7	13.9	28,766	27,706
I-075-N (06-02)		X	A-3	SP	110.2	2.0	10.2	32,457	31,187
U-131-S (09-05)		X	A-3	SP	117.3	1.0	23.3	38,423	35,319
M-028-W (03-02)		X	A-3	SP	104.0	1.3	5.7	22,959	22,494
U-131-S (09-03)		X	A-3	SP	108.6	0.5	2.4	30,340	27,995
M-020-W (07-02)		X	A-3	SP	109.1	0.2	1.0	31,460	28,705
M-020-W (07-02)		X	A-3	SP	104.1	0.2	0.9	19,692	20,267
M-020-W (07-02)		X	A-3	SP	107.6	0.2	1.0	24,319	24,552
U-002-E (02-01)		X	A-4	SM	109.3	9.5	47.4	15,352	13,818
U-002-E (03-03)		X	A-2-4	SM	111.5	7.7	40.7	15,969	15,818
M-065-S (04-04)		X	A-2-4	SM	94.6	7.6	26.3	11,932	11,898
U-131-N (05-01)		X	A-2-4	SM	112.9	5.4	29.6	24,627	23,092
M-061-E (07-06)		X	A-2-4	SM	96.0	17.0	60.8	11,480	12,958
M-061-E (08-02)		X	A-2-4	SM	118.6	5.5	35.3	32,200	31,733
M-044-E (09-07)		X	A-2-4	SM	128.8	7.6	66.6	18,416	19,636

Table D.4 (cont'd)

Sample number	Sample type		Classification		Dry unit weight (lb/ft^3)	Water content for cyclic test	Saturation	MR at cyclic stress (psi)	
	Shelby tube	Disturbed	AASHTO	USCS				10.0	15.0
M-024-S (09-09)		X	A-2-4	SM	102.9	9.8	41.5	15,142	15,839
I-069-N (10-04)		X	A-2-4	SM	124.2	8.4	63.6	19,172	18,945
I-069-N (10-05)		X	A-2-4	SM	100.2	23.7	93.9	5,290	5,641
I-096-W (10-09)		X	A-2-4	SM	117.9	14.1	88.7	9,509	11,383
U-012-E (12-04)		X	A-2-4	SM	108.0	3.9	18.8	19,152	18,377
I-094-W (12-06)		X	A-2-4	SM	123.2	10.3	75.7	19,406	19,305
I-094-W (12-06)		X	A-2-4	SM	116.7	8.7	52.9	13,363	NA
I-094-W (12-06)		X	A-2-4	SM	115.1	8.7	50.6	9,610	NA
M-024-S (13-01)		X	A-4	SM	110.3	9.5	48.6	17,933	16,160
M-053-S (15-02)		X	A-2-4	SM	114.0	8.5	48.0	18,325	18,043
M-019-S (15-07)		X	A-2-4	SM	113.7	9.2	51.6	22,213	19,482
M-068-W (04-02)		X	A-2-4	SC-SM	117.5	2.2	13.7	30,928	24,740
M-032-W (04-05)		X	A-4	SC-SM	106.3	8.1	37.4	19,255	18,161
I-075-N (08-06)		X	A-2-4	SC-SM	131.3	9.2	87.7	15,783	16,562
I-096-W (09-02)		X	A-2-4	SC-SM	108.0	1.2	5.8	22,142	19,579
M-060-W (11-03)		X	A-2-4	SC-SM	107.0	8.4	39.5	19,812	16,639
I-069-S (11-05)		X	A-4	SC-SM	132.6	6.4	63.9	27,276	25,621
I-094-W (12-01)		X	A-2-4	SC-SM	128.8	8.5	74.5	27,610	23,849

Table D.4 (cont'd)

Sample number	Sample type		Classification		Dry unit weight (lb/ft^3)	Water content for cyclic test	Saturation	MR at cyclic stress (psi)	
	Shelby tube	Disturbed	AASHTO	USCS				10.0	15.0
M-045-S (01-01)		X	A-6	CL	120.8	10.2	69.8	36,543	31,503
M-010-E (13-08)	X		A-6	CL	118.8	15.0	96.8	9,714	8,235
M-010-E (13-08)		X	A-6	CL	122.1	10.4	73.9	17,150	16,572
M-010-E (13-08)	X		A-6	CL	128.5	5.7	49.5	44,634	41,942
M-010-E (13-08)	X		A-6	CL	122.3	12.3	88.0	15,561	9,553
I-094-W (14-09)	X		A-7-6	CL	101.7	10.5	43.2	73,444	70,095
I-094-W (14-09)		X	A-7-6	CL	101.6	11.3	46.3	60,247	60,327
I-094-W (14-09)	X		A-7-6	CL	96.4	26.3	95.0	9,955	8,080
M-090-E (15-04)		X	A-4	CL	109.5	10.6	53.1	67,778	62,006
M-072-W (05-06)		X	A-6	SC	116.2	10.7	64.2	26,492	27,193
U-127-N (07-05)	X		A-6	SC	120.5	11.2	75.9	7,323	6,925
U-127-N (07-05)	X		A-6	SC	117.5	14.2	88.4	4,713	5,338
U-127-N (07-05)	X		A-6	SC	126.7	6.7	54.9	54,737	53,030
U-127-N (07-05)	X		A-6	SC	115.3	16.6	97.2	3,984	5,382
U-127-N (07-05)		X	A-6	SC	117.7	10.3	64.5	36,047	27,746
U-010-W (08-04)	X		A-6	SC	111.5	15.0	79.3	5,879	5,105
U-010-W (08-04)	X		A-6	SC	113.8	16.7	93.8	4,134	5,268
I-096-W (10-03)		X	A-2-6	SC	108.3	11.6	56.4	43,783	37,688
I-075-S (14-01)	X		A-7-6	SC	115.7	8.8	52.1	32,569	29,839
I-075-S (14-01)	X		A-7-6	SC	108.7	18.4	90.3	7,187	8,386
I-075-S (14-01)	X		A-7-6	SC	106.2	20.9	96.2	6,069	4,007

Table D.4 (cont'd)

Sample number	Sample type		Classification		Dry unit weight (lb/ft^3)	Water content for cyclic test	Saturation	MR at cyclic stress (psi)	
	Shelby tube	Disturbed	AASHTO	USCS				10.0	15.0
I-075-S (14-01)		X	A-7-6	SC	99.8	18.8	73.8	18,147	17,831
M-153-E (14-06)	X		A-7-6	SC	96.6	26.0	99.1	3,731	3,015
M-153-E (14-06)	X		A-7-6	SC	92.5	30.4	99.9	4,430	3,921
M-153-E (14-06)		X	A-7-6	SC	101.8	10.7	44.1	40,864	44,442
M-028-W (02-02)		X	A-4	ML	106.2	11.0	50.6	53,824	41,516
M-028-W (02-02)		X	A-4	ML	108.4	17.6	85.7	5,707	NA
M-028-W (02-02)		X	A-4	ML	97.2	24.3	90.6	1,768	NA
U-002-E (02-04)		X	A-4	ML	113.0	10.7	58.8	37,012	33,191

Table D.5 Laboratory resilient modulus results

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
M-045-S (01-01)	A-6	CL	100	31.6	2.304	35,043	36,543	49.0	3.740	31,266	31,503
			200	32.1	2.202	36,823		50.3	3.774	31,862	
			500	32.2	2.262	36,639		50.1	3.663	31,747	
			800	32.5	2.205	37,056		50.1	3.817	31,297	
			1000	32.8	2.227	35,934		50.4	3.872	31,465	
U-002-E (02-01)	A-4	SM	100	32.5	3.729	13,894	15,352	50.3	5.850	12,872	13,818
			200	32.9	3.592	14,285		50.1	5.727	13,150	
			500	32.7	3.442	15,044		50.4	5.551	13,686	
			800	32.7	3.325	15,708		50.4	5.496	13,826	
			1000	33.3	3.415	15,305		49.9	5.364	13,942	
M-028-W (02-02)	A-4	ML	100	32.0	1.741	48,422	53,824	50.7	2.777	45,310	41,516
			200	32.5	1.650	50,092		51.0	2.801	44,090	
			500	32.7	1.569	53,892		51.3	2.969	42,510	
			800	32.7	1.600	53,350		51.3	3.047	41,331	
			1000	33.0	1.598	54,230		51.3	3.087	40,707	
M-028-W (02-02)	A-4	ML	NA	NA	NA	NA	5,707	NA	NA	NA	NA
			NA	NA	NA	NA		NA	NA	NA	
			NA	NA	NA	NA		NA	NA	NA	
			NA	NA	NA	NA		NA	NA	NA	
			NA	NA	NA	NA		NA	NA	NA	

Table D.5 (Cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulu s (psi)	Average MR (psi) at load cycles 500, 800 and 1000
M-028-W (02-02)	A-4	ML	NA	NA	NA	NA	8,145	NA	NA	NA	NA
			NA	NA	NA	NA		NA	NA	NA	
			NA	NA	NA	NA		NA	NA	NA	
			NA	NA	NA	NA		NA	NA	NA	
			NA	NA	NA	NA		NA	NA	NA	
M-028-W (02-03)	A-1-b	SP-SM	100	33.9	2.675	19,996	19,195	51.4	4.042	16,997	17,845
			200	33.8	2.698	20,013		51.4	3.956	16,510	
			500	33.7	2.821	19,057		52.6	3.873	17,649	
			800	33.8	2.796	19,502		51.7	3.733	17,942	
			1000	34.0	2.792	19,025		51.5	3.774	17,945	
U-002-E (02-04)	A-4	ML	100	32.8	2.499	31,653	37,012	50.0	3.944	29,991	33,191
			200	32.8	2.471	33,225		49.8	3.855	30,881	
			500	33.7	2.322	36,319		50.0	3.724	31,614	
			800	33.1	2.219	36,874		50.1	3.560	33,569	
			1000	33.1	2.207	37,843		50.5	3.516	34,390	
U-002-E (03-01)	A-3	SP-SM	100	33.3	2.393	22,822	22,830	51.0	4.295	18,193	19,629
			200	33.9	2.412	23,466		50.2	4.135	18,644	
			500	33.9	2.441	23,426		51.6	4.005	19,685	
			800	34.1	2.522	22,465		52.0	4.114	19,323	
			1000	34.6	2.560	22,598		51.7	3.990	19,880	

Table D.5 (Cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulu s (psi)	Average MR (psi) at load cycles 500, 800 and 1000
M-028-W (03-02)	A-3	SP	100	33.1	2.429	22,556	23,003	50.3	3.861	20,301	22,536
			200	33.3	2.428	22,706		50.9	3.783	21,157	
			500	34.1	2.460	23,286		51.3	3.731	21,613	
			800	33.9	2.374	23,167		51.3	3.644	22,811	
			1000	33.8	2.483	22,555		52.0	3.582	23,185	
M-028-W (03-03)	A-3	SP-SM	100	32.7	3.357	15,294	16,911	49.8	5.258	14,150	15,956
			200	33.4	3.283	16,085		50.3	5.113	14,855	
			500	33.0	3.059	16,876		50.5	4.774	15,866	
			800	33.8	3.094	16,885		50.9	4.876	15,840	
			1000	33.9	3.175	16,971		50.9	4.722	16,162	
U-002-E (03-03)	A-2-4	SM	100	31.7	3.230	15,364	15,984	50.3	5.163	14,590	15,833
			200	32.2	3.208	15,857		50.5	5.056	15,302	
			500	32.7	3.167	16,240		50.3	4.973	15,412	
			800	32.7	3.251	15,919		51.1	4.873	15,966	
			1000	32.6	3.286	15,793		51.0	4.793	16,120	
I-075-N (03-04)	A-3	SP	100	33.8	2.198	25,827	26,140	51.4	3.419	24,035	24,401
			200	33.8	2.255	25,821		51.9	3.423	24,209	
			500	34.0	2.203	25,887		51.7	3.456	24,040	
			800	34.3	2.156	26,592		52.3	3.402	24,474	
			1000	34.2	2.263	25,940		52.3	3.348	24,689	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulu s (psi)	Average MR (psi) at load cycles 500, 800 and 1000
U-023-S (04-01)	A-3	SP	100	33.6	2.390	23,852	23,060	51.5	3.757	21,584	21,735
			200	33.9	2.392	24,136		51.7	3.775	21,768	
			500	33.7	2.472	23,456		51.5	3.807	21,526	
			800	33.8	2.440	22,395		51.7	3.700	21,852	
			1000	33.7	2.508	23,330		51.7	3.814	21,828	
M-068-W (04-02)	A-2-4	SC-SM	100	34.1	2.034	29,159	30,958	51.3	3.595	22,151	24,764
			200	33.0	2.006	28,338		52.3	3.505	23,435	
			500	34.1	1.883	30,987		52.1	3.377	24,481	
			800	34.4	1.861	30,960		51.6	3.383	24,598	
			1000	34.6	1.980	30,927		51.9	3.299	25,212	
M-068-W (04-03)	A-3	SP	100	29.4	5.139	8,572	9,979	46.6	8.078	8,440	10,013
			200	30.7	4.944	9,491		47.1	7.723	8,966	
			500	31.3	4.879	9,725		48.6	7.368	9,822	
			800	31.7	4.685	10,215		48.8	7.052	10,308	
			1000	31.6	4.806	9,996		48.5	7.166	9,910	
M-065-S (04-04)	A-2-4	SM	100	31.7	4.463	10,722	11,943	48.7	6.850	10,728	11,909
			200	31.5	4.383	10,903		49.7	6.524	11,210	
			500	32.1	4.101	11,945		50.0	6.427	11,637	
			800	32.3	4.157	11,833		50.3	6.268	11,995	
			1000	32.5	4.190	12,050		49.6	6.038	12,096	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
M-032-W (04-05)	A-4	SC-SM	100	32.5	2.880	17,806	19,255	50.5	4.474	16,758	18,161
			200	32.3	2.805	17,979		50.7	4.478	17,269	
			500	32.9	2.739	18,915		50.6	4.283	18,002	
			800	33.2	2.725	19,303		50.9	4.267	18,269	
			1000	33.1	2.708	19,546		50.7	4.208	18,211	
U-131-N (05-01)	A-2-4	SM	100	32.1	2.263	23,769	24,651	51.4	3.311	24,414	25,604
			200	32.2	2.284	23,491		51.3	3.281	24,858	
			500	33.3	2.257	24,948		51.4	3.239	26,201	
			800	33.6	2.314	24,548		50.9	3.247	25,241	
			1000	33.8	2.266	24,456		51.9	3.298	25,370	
U-127-N (05-04)	A-3	SP	100	34.1	1.757	35,135	37,158	52.6	2.846	29,879	29,949
			200	34.3	1.708	36,388		51.9	2.861	29,921	
			500	34.5	1.687	37,843		52.9	2.866	30,325	
			800	35.3	1.727	36,438		51.9	2.901	29,588	
			1000	35.2	1.766	37,194		52.6	2.850	29,935	
M-072-W (05-06)	A-6	SC	100	30.6	3.211	22,916	26,492	48.9	4.652	24,395	27,193
			200	31.3	3.095	24,442		49.0	4.593	25,076	
			500	31.7	2.941	26,104		49.8	4.403	26,622	
			800	31.9	2.888	27,204		49.8	4.321	27,183	
			1000	31.2	2.958	26,168		50.2	4.252	27,774	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
M-132-N (06-01)	A-3	SP	100	33.8	2.004	27,798	31,741	52.1	3.079	26,746	28,997
			200	33.9	2.055	29,008		52.7	3.027	27,574	
			500	34.1	1.984	30,874		52.6	2.977	28,591	
			800	34.4	1.960	31,899		53.2	2.989	29,341	
			1000	34.0	1.857	32,449		52.0	2.917	29,059	
I-075-N (06-02)	A-3	SP	100	33.4	1.616	26,603	32,450	51.6	2.882	26,762	31,187
			200	33.3	1.535	28,072		51.9	2.855	28,300	
			500	33.8	1.461	32,068		52.3	2.552	31,485	
			800	34.5	1.499	32,023		52.1	2.508	31,026	
			1000	34.4	1.417	33,260		52.7	2.450	31,049	
U-031-N (06-03)	A-3	SP	100	34.1	1.933	30,572	31,867	52.5	2.814	29,633	29,636
			200	33.8	1.884	31,084		52.1	2.832	29,692	
			500	34.6	1.808	32,659		52.6	2.897	29,123	
			800	35.0	1.908	31,347		52.9	2.861	30,084	
			1000	35.4	1.937	31,594		52.6	2.842	29,701	
I-196-N (06-05)	A-2-4	SP-SM	100	33.5	2.456	22,276	23,030	51.9	3.650	21,630	21,985
			200	33.7	2.428	23,097		51.7	3.641	21,694	
			500	34.2	2.386	23,190		51.5	3.618	22,017	
			800	33.6	2.395	22,525		51.7	3.675	21,801	
			1000	33.9	2.371	23,375		52.1	3.637	22,136	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
M-020-W (07-02)	A-3	SP	100	33.6	2.112	26,636	31,489	51.2	3.135	25,897	31,766
			200	33.8	2.001	29,046		51.6	3.012	27,403	
			500	34.3	1.969	30,442		51.8	2.891	28,918	
			800	34.0	1.902	31,795		52.5	2.649	33,296	
			1000	34.1	1.893	32,230		52.7	2.550	33,084	
M-020-W (07-02)	A-3	SP	100	32.8	2.029	27,192	30,272	50.6	3.326	23,445	24,896
			200	33.6	2.032	28,722		50.5	3.436	23,201	
			500	33.8	1.969	30,147		51.7	3.361	25,035	
			800	34.0	1.971	30,271		51.7	3.315	24,950	
			1000	33.9	1.965	30,399		51.6	3.408	24,702	
M-020-W (07-02)	A-3	SP	100	33.7	2.016	28,992	29,446	51.2	3.080	25,785	28,593
			200	33.9	2.064	28,380		51.3	3.000	27,443	
			500	33.9	1.961	29,237		51.4	2.948	28,001	
			800	34.0	2.042	29,357		51.6	2.893	28,741	
			1000	34.3	1.984	29,743		51.7	2.938	29,037	
M-020-W (07-02)	A-3	SP	100	33.2	1.883	19,618	19,693	51.0	3.025	16,754	20,257
			200	33.1	1.884	19,462		51.0	2.949	18,301	
			500	33.6	1.901	20,010		52.1	2.779	19,917	
			800	33.8	1.922	19,736		52.0	2.722	20,529	
			1000	33.6	1.876	19,334		51.7	2.723	20,325	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
M-020-W (07-02)	A-3	SP	100	31.7	2.516	20,521	24,320	49.5	4.178	17,679	24,552
			200	32.8	2.321	22,926		50.3	3.959	19,876	
			500	33.1	2.329	24,360		51.4	3.364	23,953	
			800	33.3	2.344	24,091		51.3	3.310	24,799	
			1000	33.8	2.284	24,508		51.4	3.307	24,904	
M-020-E (07-03)	A-3	SP	100	33.9	1.963	29,497	32,696	52.6	3.106	27,496	28,182
			200	34.0	1.935	30,737		52.2	2.999	27,797	
			500	34.4	1.881	32,158		51.9	2.992	28,321	
			800	34.3	1.941	31,958		52.3	3.019	27,995	
			1000	34.2	1.810	33,972		51.9	3.081	28,230	
U-127-N (07-05)	A-6	SC	100	42.5	11.329	3,466	3,984	72.2	15.047	4,432	5,481
			200	43.7	10.944	3,698		73.5	7.386	4,716	
			500	44.3	10.593	3,897		75.1	6.798	5,246	
			800	44.4	10.260	4,015		75.4	6.602	5,455	
			1000	44.2	10.170	4,041		75.4	12.596	5,742	
U-127-N (07-05)	A-6	SC	100	52.0	2.068	47,427	54,737	82.9	3.013	49,924	53,030
			200	51.7	1.926	50,103		82.3	2.944	50,430	
			500	52.8	1.878	53,735		81.6	2.806	51,951	
			800	51.5	1.860	54,842		82.5	2.821	53,516	
			1000	52.3	1.860	55,634		82.0	2.761	53,623	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
U-127-N (07-05)	A-6	SC	100	46.3	6.202	7,133	7,323	75.8	10.783	6,642	6,925
			200	46.7	6.185	7,244		76.7	10.605	6,765	
			500	46.7	6.248	7,223		77.2	10.557	6,875	
			800	47.2	6.196	7,353		77.5	10.534	6,936	
			1000	47.9	6.195	7,395		77.9	10.543	6,965	
U-127-N (07-05)	A-6	SC	100	44.7	9.544	4,319	4,713	74.4	14.108	4,852	5,358
			200	45.8	9.458	4,487		75.7	13.880	5,081	
			500	46.2	9.290	4,651		75.8	13.294	5,339	
			800	46.5	9.278	4,718		75.7	13.131	5,338	
			1000	46.4	9.113	4,770		76.4	13.119	5,398	
U-127-N (07-05)	A-6	SC	100	30.4	2.658	31,474	36,054	47.9	4.349	28,993	27,729
			200	30.9	2.535	33,999		48.7	4.299	30,151	
			500	31.5	2.333	36,628		49.1	4.290	27,523	
			800	31.6	2.285	36,290		49.0	4.221	27,851	
			1000	32.5	2.231	35,243		50.2	4.333	27,814	
M-061-E (07-06)	A-2-4	SM	100	28.0	7.229	10,631	11,483	41.8	12.878	11,660	12,907
			200	28.6	7.191	10,855		42.3	12.581	11,834	
			500	29.3	6.855	11,362		43.2	12.189	13,155	
			800	29.6	6.630	11,709		44.2	11.636	12,831	
			1000	28.8	6.826	11,377		44.2	11.476	12,736	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
M-061-E (08-02)	A-2-4	SM	100	33.1	1.937	29,999	32,231	51.2	2.807	30,104	31,763
			200	32.9	1.864	30,417		51.7	2.743	30,517	
			500	33.8	1.897	32,344		52.1	2.713	31,551	
			800	33.8	1.930	32,106		51.9	2.701	31,719	
			1000	34.0	1.875	32,242		52.3	2.728	32,020	
U-010-W (08-04)	A-6	SC	100	41.4	10.662	3,592	4,134	70.9	14.499	4,516	5,268
			200	42.3	10.310	3,829		71.7	13.972	4,771	
			500	42.9	9.824	4,076		72.8	13.214	5,099	
			800	43.2	9.691	4,164		73.7	12.850	5,323	
			1000	42.9	9.608	4,163		73.8	12.675	5,382	
U-010-W (08-04)	A-6	SC	100	43.2	7.759	5,212	5,873	71.7	13.897	4,831	5,106
			200	44.4	7.585	5,439		72.2	13.671	4,937	
			500	45.6	7.430	5,791		73.0	13.508	5,049	
			800	45.9	7.266	5,946		73.6	13.342	5,130	
			1000	46.1	7.252	5,884		73.4	13.283	5,138	
I-075-N (08-06)	A-2-4	SC-SM	100	32.4	3.493	14,265	15,798	51.1	4.992	15,346	16,577
			200	32.9	3.499	14,932		50.9	4.807	15,758	
			500	33.3	3.406	15,448		51.4	4.785	16,290	
			800	33.3	3.297	15,986		51.2	4.676	16,606	
			1000	33.1	3.263	15,960		51.3	4.594	16,836	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
U-131-S (09-01)	A-3	SP	100	33.8	2.123	26,881	28,793	52.3	3.220	26,018	27,732
			200	33.9	2.126	27,797		52.8	3.183	26,982	
			500	34.5	2.127	29,155		52.8	3.200	27,204	
			800	34.3	2.052	29,674		52.6	3.078	27,868	
			1000	34.6	2.152	27,550		53.2	3.081	28,124	
I-096-W (09-02)	A-2-4	SC-SM	100	33.5	2.694	20,127	22,163	52.0	4.254	18,607	19,597
			200	33.8	2.624	21,049		51.6	4.205	18,942	
			500	33.7	2.566	21,588		51.5	4.164	19,295	
			800	34.0	2.530	22,509		52.0	4.085	19,756	
			1000	33.8	2.473	22,392		51.2	3.999	19,740	
U-131-S (09-03)	A-3	SP	100	33.9	1.997	28,736	30,368	51.1	3.381	23,393	28,022
			200	34.3	2.019	29,283		51.9	3.341	24,843	
			500	34.9	1.990	30,848		52.1	3.006	27,525	
			800	34.0	1.948	30,648		52.4	3.010	27,615	
			1000	34.4	1.983	29,608		52.6	2.953	28,925	
U-131-S (09-05)	A-1-b	SP	100	34.0	2.036	36,835	38,498	52.5	2.817	33,838	35,390
			200	33.9	2.070	37,497		52.0	2.833	34,449	
			500	34.5	1.978	38,818		52.5	2.776	35,389	
			800	34.9	1.943	38,902		52.5	2.796	35,440	
			1000	34.8	2.007	37,773		52.5	2.856	35,340	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
M-044-E (09-07)	A-2-4	SM	100	33.4	2.943	17,969	18,434	51.4	4.275	18,433	19,654
			200	33.5	2.928	18,261		52.0	4.175	19,068	
			500	33.9	2.948	18,534		51.6	4.086	19,511	
			800	33.7	2.841	18,744		51.6	4.043	19,663	
			1000	34.0	3.046	18,023		51.9	4.041	19,788	
M-024-S (09-09)	A-2-4	SM	100	33.1	3.415	15,148	15,156	50.4	5.279	14,639	15,854
			200	33.1	3.421	15,097		50.5	5.143	15,004	
			500	33.6	3.458	15,204		50.6	4.889	15,786	
			800	32.9	3.427	14,945		50.8	4.853	15,880	
			1000	33.3	3.378	15,318		51.0	4.891	15,897	
I-069-E (09-10)	A-3	SP	100	34.0	1.985	29,263	28,663	52.2	3.321	25,428	26,095
			200	34.1	2.074	29,172		52.2	3.248	25,709	
			500	34.4	2.071	28,746		52.3	3.163	26,255	
			800	34.3	2.079	29,232		51.9	3.231	25,802	
			1000	34.8	2.160	28,012		52.4	3.192	26,227	
I-069-N (10-01)	A-3	SP-SM	100	33.5	3.483	14,917	15,873	51.2	4.732	16,473	17,394
			200	33.5	3.542	14,864		51.1	4.694	16,512	
			500	33.1	3.344	15,551		51.3	4.485	17,528	
			800	33.8	3.457	15,312		50.8	4.533	17,144	
			1000	34.0	3.162	16,756		51.7	4.526	17,509	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
I-096-W (10-03)	A-2-6	SC	100	32.9	2.180	41,549	43,824	50.1	3.266	40,469	37,712
			200	33.4	2.210	42,092		50.5	3.275	41,776	
			500	33.8	2.175	43,219		51.5	3.167	42,767	
			800	34.1	2.196	44,499		49.2	3.779	34,806	
			1000	34.1	2.203	43,754		48.7	2.686	35,563	
I-069-N (10-04)	A-2-4	SM	100	33.4	2.846	18,890	19,190	51.4	4.400	18,049	18,963
			200	33.5	2.771	19,221		51.8	4.330	18,293	
			500	33.5	2.839	19,530		51.0	4.232	18,653	
			800	33.4	2.862	19,049		51.5	4.107	18,952	
			1000	33.9	2.802	18,990		51.6	4.076	19,284	
I-069-N (10-05)	A-2-4	SM	100	25.4	8.607	4,273	5,295	37.6	15.895	3,469	5,646
			200	25.9	8.326	4,542		41.3	12.494	4,766	
			500	27.0	7.715	5,123		43.1	11.611	5,377	
			800	27.2	7.630	5,241		43.7	11.104	5,712	
			1000	27.6	7.381	5,521		43.8	11.027	5,850	
I-096-W (10-09)	A-2-4	SM	100	30.1	5.580	8,027	9,518	47.9	7.602	9,168	11,394
			200	30.9	5.176	8,832		48.1	7.430	9,504	
			500	31.2	5.002	9,361		49.5	6.721	10,908	
			800	31.0	4.917	9,419		49.5	6.363	11,495	
			1000	31.6	4.875	9,775		49.8	6.307	11,778	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
I-069-N (11-01)	A-3	SP-SM	100	32.9	1.119	30,534	30,733	51.7	1.595	29,788	28,147
			200	33.8	1.119	32,960		52.0	1.567	30,484	
			500	34.0	1.063	30,406		52.0	2.994	28,203	
			800	34.0	1.119	30,967		52.2	2.974	28,154	
			1000	34.8	1.119	30,827		51.9	2.995	28,083	
I-094-W (11-02)	A-3	SP	100	33.6	1.694	36,073	44,521	51.2	3.205	25,752	27,372
			200	33.3	1.627	37,965		52.2	3.144	26,314	
			500	34.1	1.487	45,141		52.8	3.102	27,442	
			800	32.6	1.432	42,908		51.9	3.136	26,857	
			1000	34.1	1.453	45,513		52.6	3.020	27,817	
M-060-W (11-03)	A-2-4	SC-SM	100	31.9	2.614	19,615	19,812	50.2	4.354	17,216	16,639
			200	31.3	2.561	19,255		50.7	4.426	17,262	
			500	32.0	2.553	19,808		50.8	4.481	16,817	
			800	32.4	2.561	19,861		50.7	4.560	16,601	
			1000	32.2	2.563	19,768		50.9	4.669	16,498	
I-069-S (11-05)	A-4	SC-SM	100	33.7	2.252	23,451	27,303	52.3	3.358	24,923	25,645
			200	33.8	2.220	24,393		52.6	3.317	25,291	
			500	34.0	2.095	25,903		52.5	3.274	25,489	
			800	34.2	2.014	26,908		51.6	3.267	25,632	
			1000	34.3	1.931	29,098		52.2	3.245	25,814	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
I-094-W (12-01)	A-2-4	SC-SM	100	33.3	1.963	28,024	27,636	51.3	3.519	22,990	23,872
			200	32.5	2.028	27,129		52.0	3.594	23,024	
			500	34.1	2.041	28,985		51.8	3.438	23,554	
			800	33.6	2.129	26,615		52.0	3.414	24,001	
			1000	33.9	2.113	27,308		52.4	3.534	24,060	
I-094-W (12-03)	A-3	SP-SM	100	33.6	2.783	19,527	18,139	50.8	4.851	15,566	15,977
			200	33.6	2.766	19,827		50.9	4.881	15,796	
			500	33.4	2.814	18,886		50.4	4.789	16,090	
			800	33.9	3.021	17,820		50.8	4.831	15,893	
			1000	34.1	3.066	17,711		50.8	4.798	15,947	
U-012-E (12-04)	A-2-4	SM	100	33.3	2.862	18,848	19,234	50.8	4.340	18,416	18,343
			200	33.3	2.930	19,047		51.3	4.323	18,683	
			500	33.6	2.781	19,237		51.2	4.264	18,191	
			800	34.1	2.881	19,210		51.4	4.312	18,324	
			1000	34.1	2.766	19,255		51.3	4.266	18,515	
I-094-W (12-06)	A-2-4	SM	100	33.9	2.675	19,996	19,425	51.4	4.042	19,797	21,382
			200	33.8	2.698	20,013		51.4	3.956	20,110	
			500	33.7	2.821	19,357		52.6	3.873	21,249	
			800	33.8	2.796	19,802		51.7	3.733	21,552	
			1000	34.0	2.792	19,115		51.5	3.774	21,346	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
I-094-W (12-06)	A-2-4	SM	NA	NA	NA	NA	9,610	NA	NA	NA	NA
			NA	NA	NA	NA		NA	NA	NA	
			NA	NA	NA	NA		NA	NA	NA	
			NA	NA	NA	NA		NA	NA	NA	
			NA	NA	NA	NA		NA	NA	NA	
I-094-W (12-06)	A-2-4	SM	10 psi		13 psi		NA	18 psi		21 psi	
			13,363		12,463			11,233		10,929	
M-024-S (13-01)	A-4	SM	100	34.4	3.172	17,093	17,950	51.9	5.000	15,746	16,175
			200	34.0	3.101	17,359		50.0	4.846	15,814	
			500	34.8	3.149	17,853		51.5	4.878	16,213	
			800	34.6	3.049	17,891		51.6	4.844	16,042	
			1000	35.1	3.052	18,106		51.8	4.844	16,271	
M-059-W (13-02)	A-3	SP	100	33.6	2.042	28,216	24,863	51.7	3.362	23,959	23,810
			200	33.5	2.112	27,648		51.9	3.351	24,234	
			500	33.9	2.186	26,464		52.1	3.478	23,699	
			800	33.9	2.368	24,623		51.7	3.453	23,882	
			1000	33.8	2.439	23,502		51.9	3.436	23,849	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
M-059-W (13-02)	A-3	SP	NA	NA	NA	NA	23,195	NA	NA	NA	NA
			NA	NA	NA	NA		NA	NA	NA	
			NA	NA	NA	NA		NA	NA	NA	
			NA	NA	NA	NA		NA	NA	NA	
			NA	NA	NA	NA		NA	NA	NA	
I-094-W (13-04)	A-3	SP	100	32.8	2.693	20,399	21,470	51.2	4.441	17,533	18,859
			200	32.5	2.615	20,565		50.7	4.353	17,856	
			500	33.2	2.592	21,384		50.8	4.245	18,355	
			800	33.5	2.589	21,598		50.8	4.133	18,836	
			1000	33.4	2.648	21,427		51.2	4.040	19,387	
U-023-N (13-07)	A-3	SP-SM	100	34.0	2.515	22,197	22,629	51.6	3.907	20,649	20,593
			200	33.8	2.443	23,009		51.4	3.846	20,641	
			500	34.0	2.573	22,214		51.2	3.961	20,201	
			800	33.9	2.428	22,768		52.4	3.910	20,900	
			1000	34.7	2.477	22,904		52.2	3.952	20,678	
M-010-E (13-08)	A-6	CL	100	29.7	4.124	16,710	17,012	45.5	6.531	16,006	16,345
			200	30.1	4.182	16,898		46.1	6.637	15,991	
			500	30.2	4.256	16,855		46.3	6.562	16,218	
			800	30.7	4.226	16,995		46.5	6.433	16,417	
			1000	30.5	4.202	17,186		46.6	6.492	16,399	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
M-010-E (13-08)	A-6	CL	100	48.6	3.375	14,374	15,561	77.7	7.441	9,934	9,553
			200	49.6	3.334	15,053		78.1	7.453	9,867	
			500	49.6	3.271	15,423		78.2	7.743	9,627	
			800	49.8	3.258	15,631		78.2	7.779	9,528	
			1000	49.8	3.257	15,629		78.3	7.849	9,504	
M-010-E (13-08)	A-6	CL	100	51.5	1.331	31,968	44,641	83.3	1.796	36,929	41,989
			200	51.8	1.291	36,534		82.8	1.731	38,488	
			500	52.7	1.218	43,564		82.5	1.808	40,155	
			800	52.3	1.211	45,089		82.2	1.629	42,399	
			1000	51.8	1.152	45,271		82.4	1.793	43,414	
M-010-E (13-08)	A-6	CL	100	39.6	7.658	8,407	9,713	46.6	8.078	8,440	8,280
			200	41.3	7.157	9,399		47.1	7.723	8,966	
			500	42.2	6.971	9,004		48.6	7.368	8,822	
			800	43.5	6.473	9,818		48.8	7.052	8,108	
			1000	44.0	6.376	10,317		48.5	7.166	7,910	
I-075-S (14-01)	A-7-6	SC	100	30.3	2.283	11,369	18,221	48.9	3.899	14,813	17,842
			200	31.0	2.259	13,560		48.7	3.804	15,893	
			500	31.3	2.074	17,389		48.9	3.721	16,938	
			800	31.7	1.971	18,449		49.6	3.586	18,253	
			1000	32.0	2.067	18,825		49.6	3.573	18,336	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
I-075-S (14-01)	A-7-6	SC	100	51.3	2.172	32,901	32,510	82.3	2.390	32,808	29,860
			200	51.2	1.994	36,098		82.8	2.299	31,287	
			500	52.3	1.815	31,799		82.7	2.045	29,226	
			800	52.3	1.481	32,377		82.4	1.858	30,295	
			1000	51.7	1.417	33,354		82.3	1.668	30,060	
I-075-S (14-01)	A-7-6	SC	100	35.0	10.936	5,114	7,187	61.1	14.155	6,907	8,386
			200	35.9	9.896	5,982		61.6	13.624	7,285	
			500	36.6	9.349	7,441		62.5	12.617	7,928	
			800	36.7	8.808	7,284		63.5	12.002	8,545	
			1000	37.3	8.616	6,835		64.1	11.896	8,685	
I-075-S (14-01)	A-7-6	SC	100	NA	NA	5,907	6, 069	NA	NA	4,037	4,007
			200	NA	NA	5,929		NA	NA	3,976	
			500	NA	NA	5,911		NA	NA	3,872	
			800	NA	NA	5,878		NA	NA	3,845	
			1000	NA	NA	5,907		NA	NA	3,846	
M-153-E (14-06)	A-7-6	SC	100	33.8	2.378	38,348	40,902	51.2	3.050	42,427	44,483
			200	34.4	2.254	39,970		51.5	2.964	42,728	
			500	34.5	2.223	40,365		51.4	3.004	43,684	
			800	34.0	2.119	41,453		51.5	2.965	44,394	
			1000	33.7	2.120	40,889		52.2	2.876	45,372	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
M-053-S (14-07)	A-3	SP	100	33.6	2.237	25,772	25,738	51.5	3.727	21,646	22,296
			200	33.6	2.150	25,870		51.7	3.731	21,643	
			500	33.9	2.249	26,465		51.9	3.688	22,217	
			800	34.0	2.258	25,493		52.0	3.646	22,403	
			1000	33.7	2.315	25,255		51.8	3.622	22,268	
I-094-W (14-09)	A-7-6	CL	100	49.1	5.308	8,870	9,955	77.2	9.347	7,782	8,080
			200	49.1	5.217	9,211		77.2	9.253	7,846	
			500	49.2	4.966	9,690		77.1	9.107	7,995	
			800	48.8	4.777	9,943		77.8	9.010	8,089	
			1000	49.2	4.675	10,234		77.8	8.918	8,156	
I-094-W (14-09)	A-7-6	CL	100	51.2	2.114	45,953	73,344	81.9	2.609	57,985	70,094
			200	51.1	1.853	52,917		82.8	2.466	61,580	
			500	52.2	1.602	67,009		82.5	2.327	67,663	
			800	52.7	1.426	75,719		82.2	2.190	70,504	
			1000	51.2	1.383	77,304		81.8	2.205	72,116	
I-094-W (14-09)	A-7-6	CL	100	33.0	1.604	53,229	60,217	50.7	2.211	57,722	60,303
			200	32.7	1.585	55,517		51.7	2.228	59,950	
			500	33.8	1.530	60,326		51.7	2.152	60,448	
			800	34.1	1.462	60,280		51.8	2.104	60,142	
			1000	34.2	1.459	60,046		52.3	2.044	60,318	

Table D.5 (cont'd)

Sample number	Soil Type		Cycle number	Cyclic stress (psi)							
				10				15			
	AASHTO	USCS		Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000	Average cyclic load (lbs)	Average deformation (mils)	Average resilient modulus (psi)	Average MR (psi) at load cycles 500, 800 and 1000
M-053-S (15-02)	A-2-4	SM	100	33.3	2.923	18,400	18,342	51.1	4.424	18,022	18,060
			200	33.2	2.914	18,486		51.0	4.470	18,018	
			500	33.4	2.921	18,171		51.4	4.471	17,918	
			800	33.4	2.963	18,372		51.3	4.416	18,113	
			1000	33.4	2.894	18,483		51.0	4.372	18,149	
M-090-E (15-04)	A-4	CL	100	34.6	1.494	65,657	67,841	51.5	2.170	60,204	62,065
			200	34.2	1.492	65,191		51.9	2.192	61,455	
			500	34.6	1.487	67,087		51.7	2.159	61,666	
			800	34.6	1.510	68,335		51.7	2.128	62,105	
			1000	34.5	1.398	68,102		52.0	2.212	62,423	
M-025-S (15-05)	A-3	SP	100	34.0	1.585	37,971	40,152	52.6	2.503	35,506	35,481
			200	34.0	1.601	38,716		52.2	2.445	35,369	
			500	34.1	1.588	39,705		51.7	2.500	35,195	
			800	34.9	1.643	40,506		52.3	2.468	35,680	
			1000	35.0	1.595	40,246		52.0	2.437	35,567	
M-019-S (15-07)	A-2-4	SM	100	34.3	2.740	19,702	22,233	51.3	4.328	18,630	9,500
			200	35.7	2.770	20,960		51.9	4.203	18,904	
			500	35.0	2.584	21,859		51.7	4.118	19,310	
			800	35.2	2.539	22,379		51.4	4.096	19,441	
			1000	34.6	2.572	22,462		53.2	4.183	19,750	

APPENDIX E

FWD RESULTS

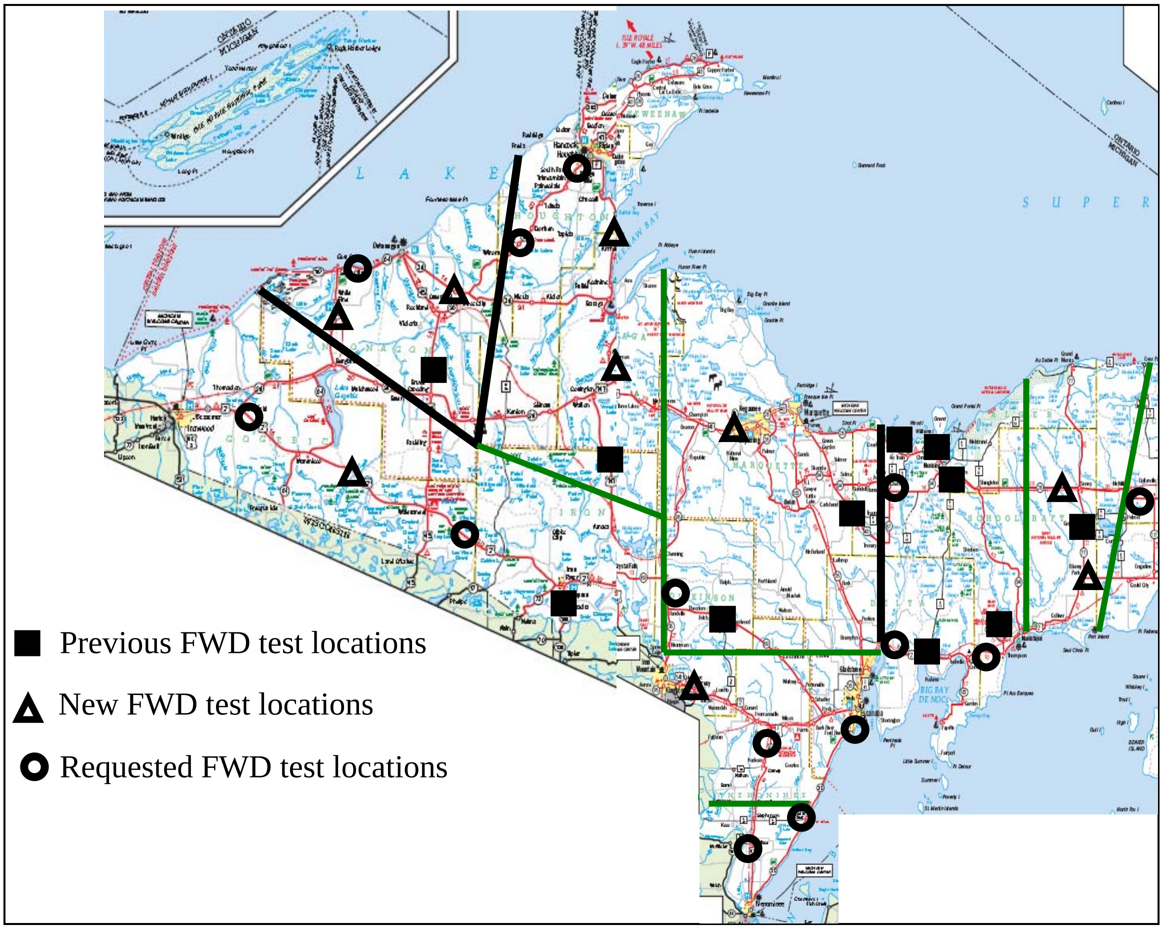
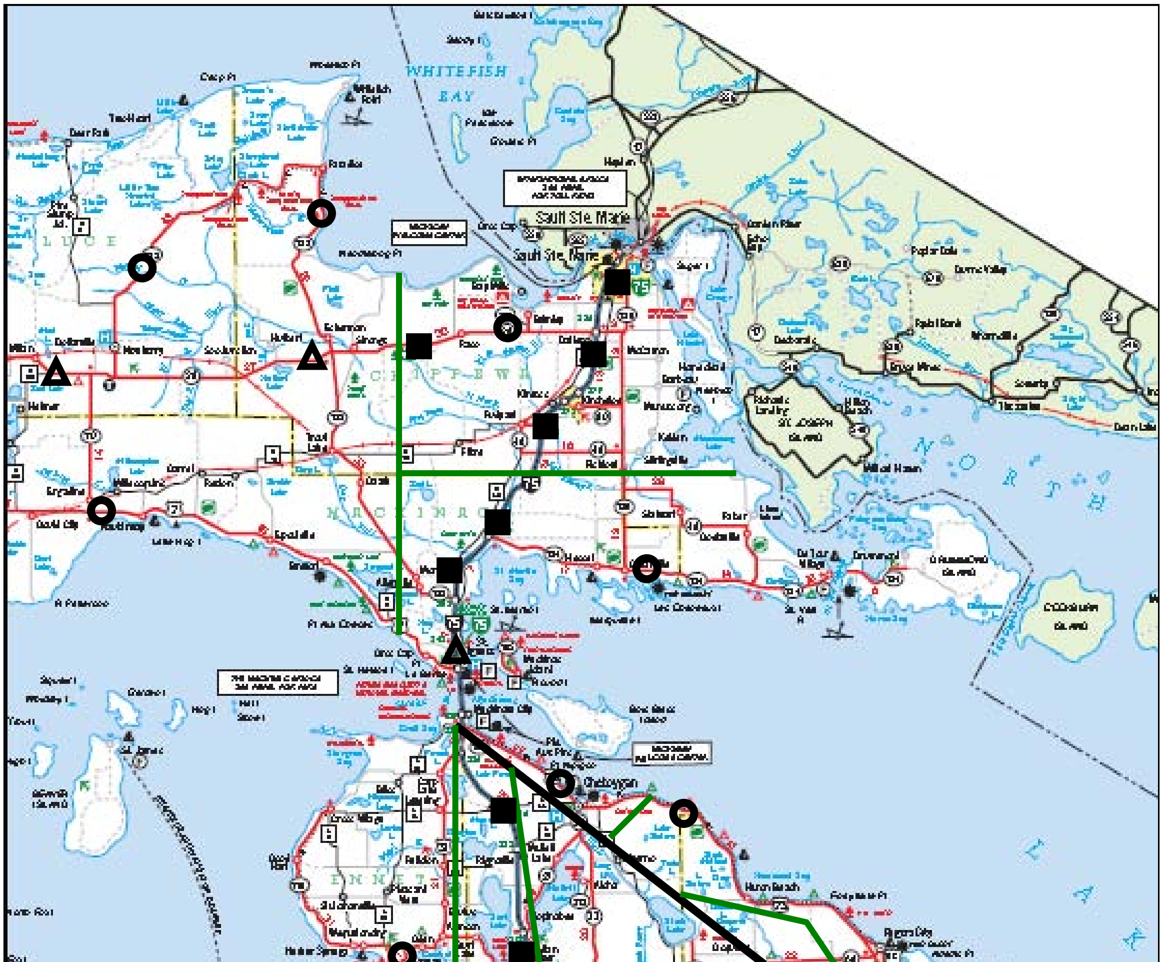


Figure E.1 FWD test locations in the State of Michigan



■ Previous FWD test locations
▲ New FWD test locations
● Requested FWD test locations

Figure E.1 (cont'd)

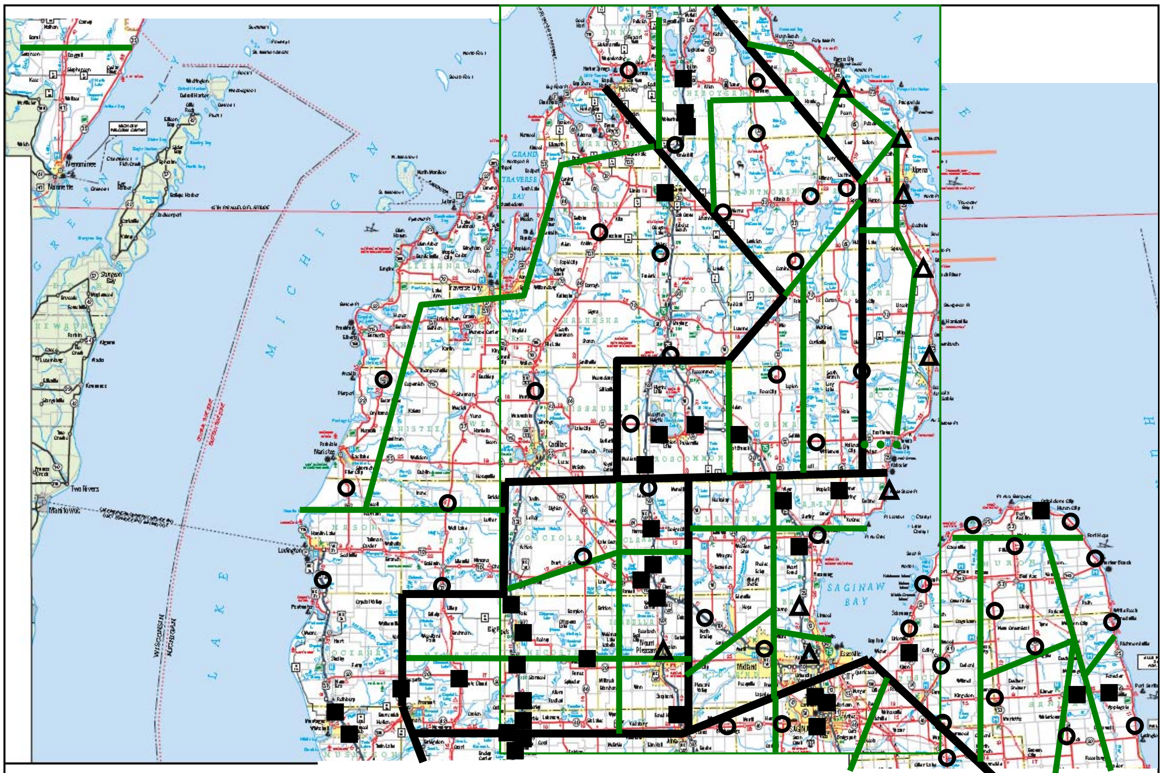


Figure E.1 (cont'd)

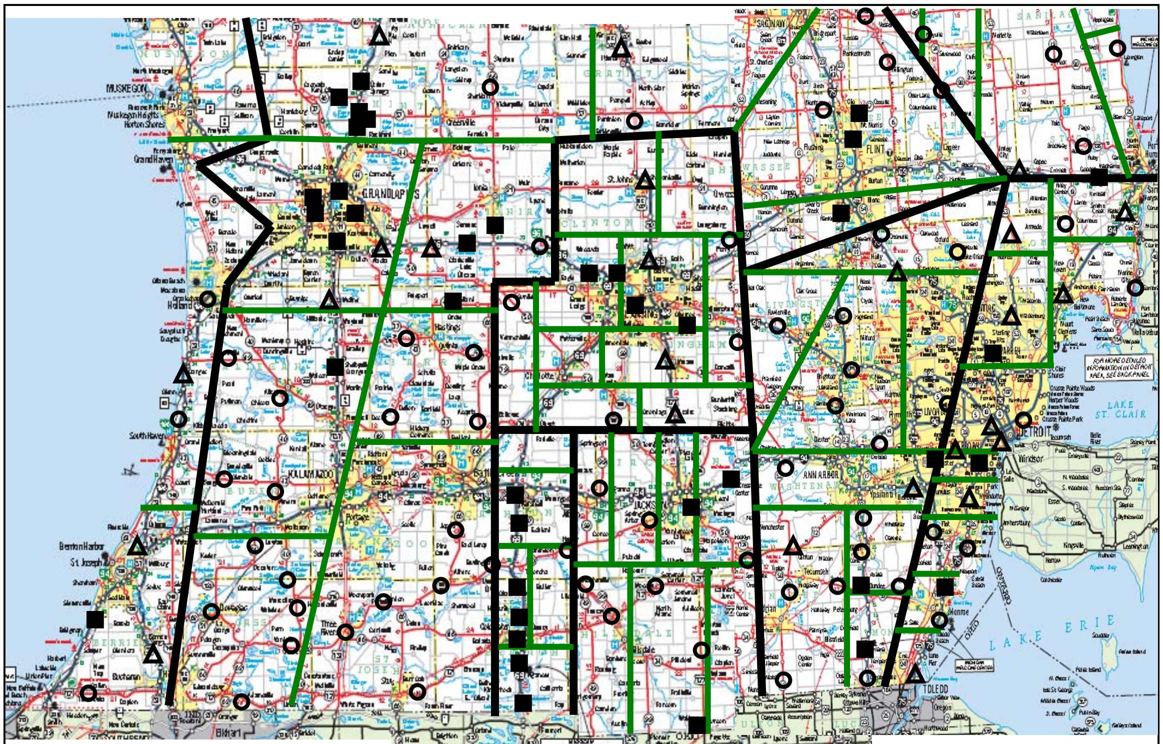


Figure E.1 (cont'd)

Table E.1 New FWD test locations

Region	County	Control Section	Control Section BMP	Location	Pavement Type
Bay	Bay	09035	6.232	North of Beaver Rd	Rigid
Bay	Bay	09101	8.413	2048' West of Mackinaw Rd	Rigid
Bay	Gratiot	29011	13.609	North of Ithaca North City Limit	Rigid
Bay	Isabella	37014		100' North of Vernon Rd	Flexible
Metro	Macomb	50015	5.642	North of the end of the divided hwy (NB direction)	Flexible
Metro	Macomb	50015	5.642	North of the end of the divided hwy (NB direction)	Flexible
Metro	Macomb	50015	5.642	North of the end of the divided hwy (NB direction)	Flexible
Metro	Macomb	50015	5.642	North of the end of the divided hwy (NB direction)	Flexible
Metro	Macomb	50015	5.642	North of the end of the divided hwy (NB direction)	Flexible
Metro	Macomb	50015	5.642	North of the end of the divided hwy (NB direction)	Flexible
Metro	St. Clair	77024	0.000	East of Lapeer/St. Clair Co Line	Rigid
Metro	St. Clair	77024	0.000	East of Lapeer/St. Clair Co Line	Rigid
Metro	St. Clair	77024	0.000	East of Lapeer/St. Clair Co Line	Rigid
Metro	St. Clair	77024	0.000	East of Lapeer/St. Clair Co Line	Rigid
Metro	St. Clair	77024	0.000	East of Lapeer/St. Clair Co Line	Rigid
Metro	St. Clair	77024	0.000	East of Lapeer/St. Clair Co Line	Rigid
Metro	St. Clair	77024	0.000	East of Lapeer/St. Clair Co Line	Rigid
Metro	St. Clair	77111	12.536	450' West of Wadhams Road	Flexible
Metro	St. Clair	77111	12.536	450' West of Wadhams Road	Flexible
Metro	St. Clair	77111	12.536	450' West of Wadhams Road	Flexible
Metro	St. Clair	77111	12.536	450' West of Wadhams Road	Flexible
Metro	St. Clair	77111	12.536	450' West of Wadhams Road	Flexible
Metro	St. Clair	77111	12.536	450' West of Wadhams Road	Flexible
Metro	Wayne	82194	0.000	North of M-39	Rigid

Table E.1 (cont'd)

Region	County	Control Section	Control Section BMP	Location	Pavement Type
Metro	Wayne	82022	7.620	West of M-39	Rigid
Metro	Wayne	82022	15.514	East of Rotunda Dr	Rigid
Metro	Wayne	82111		Station 38+00, 290' North of mile marker 13.2	Rigid
North	Alcona	01052	11.728	0.2 miles South of Black River Rd North	Flexible
North	Alpena	04032	0.000	North of M-32	Flexible
North	Presque Isle	71073	14.481	Cheboygan/Presque Isle Co Line East	Flexible
North	Presque Isle	71073	0.000	West of M-66	Flexible
North	Presque Isle	71073	0.000	West of M-66	Flexible
Southwest	Allegan	03032	0.860	South of Rangeline Rd	Rigid
Southwest	Allegan	03033	0.000	North of Van Buren/Allegan County line	Rigid
Southwest	Allegan	03033	0.000	North of Van Buren/Allegan County line	Rigid
Southwest	Berrien	11057	8.929	North of Berrien Springs	Rigid
Superior	Baraga	07022	1.030	North of M-28 (area with passing lane)	Flexible
Superior	Baraga	07013	3.147	Baraga/Houghton Co Line South	Flexible
Superior	Chippewa	17061	7.250	West of M-123	Flexible
Superior	Gogebic	27022	0.797	East of Pierce St	Flexible
Superior	Mackinac	49025	0.607	North of US-2	Flexible
Superior	Ontonagon	66042	11.654	West of M-26	Flexible
Superior	Schoolcraft	75061	13.250	West of M-77	Flexible
Superior	Schoolcraft	75061	13.250	West of M-77	Flexible
University	Eaton	23063		One slab before sta 1557+00	Rigid
University	Eaton	23063		One slab before sta 1557+00	Rigid
University	Eaton	23063		One slab before sta 1557+00	Rigid
University	Clinton	19034	0.000	M-21 North to end of freeway	Rigid

Table E.1 (cont'd)

Region	County	Control Section	Control Section BMP	Location	Pavement Type
University	Clinton	19034	0.000	M-21 North to end of freeway	Rigid
University	Clinton	19034	0.000	M-21 North to end of freeway	Rigid
University	Monroe	58151		S of Gaynier Rd. truck scales	Rigid
University	Monroe	58151		S of Gaynier Rd. truck scales	Rigid
University	Monroe	58151		S of Gaynier Rd. truck scales	Rigid
University	Monroe	58151		S of Gaynier Rd. truck scales	Rigid
University	Monroe	58151		S of Gaynier Rd. truck scales	Rigid
University	Monroe	58151		S of Gaynier Rd. truck scales	Rigid
University	Monroe	58151		S of Gaynier Rd. truck scales	Rigid

Table E.2 FWD tests conducted on flexible pavement sections

Location			Roadbed type USCS	FWD File Information		Pavement layer thickness (in)		Backcalculation				Resilient modulus (psi)			Physical location
Region	Road	Cluster-area		Date	File title	Asphalt concrete	Base/ subbase	Error RMS (%)	Converged? Yes	Converged? No	Depth to stiff layer (in)	Asphalt concrete	Base/ subbase	Roadbed	
Superior	US-2	02-01	SM	5/20/2008	flex-Su-US2-CS27022-05-20-2008	3.5	26.5	1.47	7	4	250	972815	45256	21132	Start at Pierce St, east side of Wakefield
North	US-131	07-01	SM	5/1/2002	flex-N-US131-CS67017-05-01-2002	7.25	22	0.63	79	14	700	1696003	26912	23263	from S. of 14 Mile (Luther) to N. of US-10 Seg 2
North	I-75	06-02	SP1	11/12/1997	flex-N-I75-CS69014-11-12-1997	6.25	24	1.09	61	36	700	1073344	37124	30358	N. OF M-32 TO VANDERBILT
North	I-75	06-02	SP1	8/3/1999	flex-N-I75-CS69014-08-03-1999	6.25	24	1.34	62	28	700	460044	49111	31074	N. OF M-32 TO VANDERBILT
North	I-75	06-02	SP1	8/3/1999	flex-N-I75-CS69014-08-03-1999-(2)	6.25	24	1.36	61	29	700	516468	55316	40422	N. OF M-32 TO VANDERBILT
North	I-75	06-02	SP1	11/13/1997	flex-N-I75-CS69014-11-23-1997	6.25	24	1.09	71	22	700	976787	38138	30700	N. OF M-32 TO VANDERBILT
North	I-75	06-02	SP1	8/4/1999	flex-N-I75-CS69014-08-04-1999	6.25	24	1.36	65	27	700	364430	48793	30134	Sturgeon Valley Road to M-32
North	I-75	06-02	SP1	8/4/1999	flex-N-I75-CS69014-08-04-1999-(2)	6.25	24	1.53	63	48	700	440817	52962	40183	Sturgeon Valley Road to M-32
Grand	M-120	06-03 07-02	SP1 SP1	7/23/1998	flex-G-M120-CS61012-07-23-1998	7	24	1.43	28	46	700	191605	28836	18572	From M-82 to M-20
Grand	US-131	07-02	SP1	5/13/1998	flex-G-US131-CS54013-08-18-1994	7.25	22	1.26	130	51	700	937313	30697	34067	Osceola-Mecosta Co. Ln. S. to 8 Mile Rd
Grand	US-131	07-03	SP1	8/18/1994	flex-G-US131-CS54013-08-18-1994	7.25	24	1.13	43	22	700	370266	38527	27557	FROM MONTCALM-MECOSTA CO. LINE N. TO 8 MILE ROAD
Grand	US-131	07-03	SP1	8/18/1994	flex-G-US131-CS54013-08-18-1994-(2)	7.5	22	1.49	16	16	700	372701	38341	31242	FROM MONTCALM-MECOSTA CO. LINE N. TO 8 MILE ROAD
Grand	US-131	07-03	SP1	8/18/1994	flex-G-US131-CS54013-08-18-1994-(3)	7.5	22	1.51	18	15	700	351947	38155	30740	FROM MONTCALM-MECOSTA CO. LINE N. TO 8 MILE ROAD
Grand	US-131	07-03	SP1	8/18/1994	flex-G-US131-CS54013-08-18-1994-(4)	7.5	22	1.15	47	18	700	354711	37817	27911	FROM MONTCALM-MECOSTA CO. LINE N. TO 8 MILE ROAD
Grand	US-131	07-03	SP1	8/18/1994	flex-G-US131-CS54013-08-18-1994-(5)	7.5	22	1.52	18	15	700	351862	38153	30744	FROM MONTCALM-MECOSTA CO. LINE N. TO 8 MILE ROAD
Grand	M-37	07-03	SP1	5/18/2000	flex-G-M37-CS62032-05-18-2000	8	25	1.28	25	15	700	433004	21019	20953	3 Mile Rd. to White Cloud S. Village
Grand	M-20	07-03	SP1	4/9/2002	flex-G-M20-CS54041-04-09-2002	6	24	1.09	48	20	700	592526	24492	25668	From Mecosta County Ln. to US-131
Grand	M-57	09-01	SP1	8/23/1994	flex-G-M57-CS41122-8-23-1994	3	26	1.20	81	27	700	2446547	44131	29428	FROM RAMSDELL RD. E. TO YOUNGMAN RD
Grand	M-57	09-01	SP1	5/23/1995	flex-G-M57-CS28021-5-23-1995	3	26	1.38	20	63	700	3871662	33601	32384	FROM RAMSDELL RD. E. TO YOUNGMAN RD
Grand	M-57	09-01	SP1	8/23/1994	flex-G-M57-CS59021-08-23-1994	3	26	1.21	40	13	700	2756285	42908	29943	FROM RAMSDELL RD. E. TO YOUNGMAN RD
Grand	M-57	09-01	SP1	8/23/1994	flex-G-M57-CS59021-08-23-1994-(2)	3	26	1.27	43	10	700	2680244	43546	29965	FROM RAMSDELL RD. E. TO YOUNGMAN RD
Grand	M-57	09-01	SP1	8/23/1994	flex-G-M57-CS59021-08-23-1994-(3)	3	26	1.32	34	20	700	2657574	44229	32430	FROM RAMSDELL RD. E. TO YOUNGMAN RD
Grand	M-57	09-01	SP1	8/23/1994	flex-G-M57-CS59021-08-23-1994-(4)	3	26	1.27	33	20	700	2663880	43749	28829	FROM RAMSDELL RD. E. TO YOUNGMAN RD
Grand	US-131	09-01	SP1	6/25/1998	flex-G-US131-CS59012-06-25-1998	8	24	1.46	20	5	700	529653	38384	29069	Between Tamarack and Cutler Rds.
North	M-55	05-04	SP2	8/20/2001	flex-N-M55-CS77022-8-20-2001	7	23	1.75	32	44	700	253762	29680	23140	near County Road 401
North	M-55	05-04	SP2	8/20/2001	flex-N-M55-CS77022-8-20-2001-(2)	7	23	1.74	35	41	700	250435	29872	22953	near County Road 401
Superior	M-28	03-01	SP-SM	5/21/2008	flex-Su-M28-CS75061-05-21-2008	5.5	24.5	0.65	11	0	700	1719937	27402	21272	East of Shingleton
Superior	US-2	03-01	SP-SM	5/22/2008	flex-Su-US2-CS75021-05-22-2008	5.5	24.5	1.28	10	1	300	3987549	60149	20953	E of Co line, East of Garden Corners
Superior	M-28	03-03	SP-SM	5/22/2008	flex-Su-M28-CS17061-05-22-2008	5	25	0.66	10	0	700	2255609	23293	21652	East of Hulbert Rd to the North CSMP 5.000, Hulbert Corners
North	US-23	04-02	SC-SM	6/3/2008	flex-N-US23-CS4032-06-03-2008	5	25	1.49	9	2	150	2126531	59749	14388	DwnTwn Alpena, US 23 and 2nd street
North	US-23	04-02	SC-SM	6/4/2008	flex-N-US23-CS71073-06-04-2008-(2)	5.5	24.5	1.60	8	3	300	2175426	63071	23691	Center M 68 and US 23
North	US-23	04-02	SC-SM	6/3/2008	flex-N-US23-CS71073-06-04-2008	6.5	23.5	0.87	11	0	700	540464	32021	20721	At Beach hwy to the west
North	US-23	04-02	SC-SM	4/29/2009	flex-N-US23-CS71073-04-29-2009	6.5	23.5	0.69	9	2	700	775934	27420	18584	At Beach hwy to the west

Table E.2 (Cont'd)

Location			Roadbed type USCS	FWD File Information		Pavement layer thickness (in)		Backcalculation				Resilient modulus (psi)			Physical location
								Error RMS (%)	Converged?		Depth to stiff layer (in)				
Region	Road	Cluster-area		Date	File title	Asphalt concrete	Base/ subbase		Yes	No		Asphalt concrete	Base/ subbase	Roadbed	
North	US-23	04-02	SC-SM	6/3/2008	flex-N-US23-CS1052-06-03-2008	3.5	26.5	1.77	6	5	200	1292560	62082	16445	US 23 & Black River Rd.
Superior	I-75	03-05	SC	5/22/2008	flex-Su-I75-CS49025-05-22-2008	7.5	22.5	1.41	4	7	150	783951	35186	55215	At the end of on ramp from US 2
Bay	M-57	09-08	SC	8/30/1994	flex-B-M57-CS29022-08-30-1994	5.5	25	1.41	43	23	700	278977	26637	26310	FROM SAGINAW-GRATIOT CO. LINE TO US-27
Bay	M-57	09-08	SC	8/30/1994	flex-B-M57-CS29022-08-30-1994-(2)	5.5	25	1.39	41	25	700	278587	26544	26385	FROM SAGINAW-GRATIOT CO. LINE TO US-27
Bay	M-57	09-08	SC	8/30/1994	flex-B-M57-CS29022-08-30-1994-(3)	5.5	25	1.70	25	42	700	265828	27872	29292	FROM SAGINAW-GRATIOT CO. LINE TO US-27
Bay	M-57	09-08	SC	8/30/1994	flex-B-M57-CS29022-08-30-1994-(4)	5.5	25	1.69	24	43	700	266435	27982	29611	FROM SAGINAW-GRATIOT CO. LINE TO US-27
Bay	M-57	09-08	SC	1/28/1993	flex-B-M57-CS29022-01-28-1993	5.5	26	1.41	65	69	700	269243	26067	25798	FROM SAGINAW-GRATIOT CO. LINE TO US-27
Bay	M-84	09-08	SC	10/3/2005	flex-B-M84-CS9011-10-03-2005	4	25	1.52	8	8	200	412843	35590	22034	South Test Section (N. of Klaho Road)
Bay	M-84	09-08	SC	5/17/2005	flex-B-M84-CS9011-05-17-2005	4	25	1.07	30	9	300	1058438	24543	19099	
Bay	M-84	09-08	SC	5/17/2005	flex-B-M84-CS9011-05-17-2005-(2)	4	25	1.15	52	17	400	1224141	23099	20129	
Bay	M-84	09-08	SC	10/10/2005	flex-B-M84-CS9011-10-10-2005	4	25	0.97	16	0	275	1179156	34888	25923	Klaho Rd. North Test Section
Bay	M-84	09-08	SC	9/11/2005	flex-B-M84-CS9011-09-11-2005	4	25	1.40	30	2	160	2959369	47342	19575	
Bay	M-84	09-08	SC	9/13/2005	flex-B-M84-CS9011-09-13-2005-(2)	4	25	0.91	16	0	250	774323	32298	27322	South Test Section (N. of Saginaw Valley State College)
University	M-52	10-10	SC	11/13/2002	flex-U-M52-CS33051-11-13-2002	6	24	1.14	39	5	250	776627	23650	23582	Just S. of Rowley Road
Metro	M-53	14-08	CL	4/4/2008	flex-M-M53-CS50015-04-04-2008	8	24	1.07	9	2	300	1122329	16031	22259	Start about 245 feet north of centerline of 32 mile rd
Superior	M-38	01-01	CL	5/21/2008	flex-Su-M28-CS66042-05-20-2008	3.5	26.5	1.58	10	1	350	1468878	32573	18372	Starting in Greenland at 4th street
Metro	M-53	14-08	CL	2/27/2009	flex-M-M53-CS50015-02-27-2009	8	24	0.65	13	0	300	1510899	7153	25317	Start about 245 feet north of centerline of 32 mile rd
Metro	M-53	14-08	CL	3/6/2009	flex-M-M53-CS50015-03-06-2009	8	24	0.95	13	0	300	978866	8909	24319	Start about 245 feet north of centerline of 32 mile rd
Metro	M-53	14-08	CL	3/9/2009	flex-M-M53-CS50015-03-09-2009	8	24	0.84	13	0	300	1349614	8647	24942	Start about 245 feet north of centerline of 32 mile rd
Metro	M-53	14-08	CL	3/13/2009	flex-M-M53-CS50015-03-13-2009	8	24	0.83	13	0	300	1413123	9494	23748	Start about 245 feet north of centerline of 32 mile rd
Metro	M-53	14-08	CL	4/9/2009	flex-M-M53-CS50015-04-09-2009	8	24	1.39	11	2	300	553041	11432	22508	Start about 245 feet north of centerline of 32 mile rd
Metro	I-94	14-09	CL	4/2/2008	flex-M-I94-CS77111-04-02-2008	4.2	17.5	1.78	5	19	100	1937770	11660	4763	Approx 362 feet West of Wadhams RD
Superior	US-141	02-02	ML	5/19/2008	flex-Su-US141-CS7022-05-19-2008	4.5	25.5	1.10	12	1	700	1075462	16677	21265	At South US141 and M28, Covington, to North US 141 and M28
Superior	US-41	02-04	ML	5/19/2008	flex-Su-US41-CS7013-05-19-2008	2.5	27.5	1.28	11	0	150	2059728	29874	10531	At Address of 12188 US41 Hwy

Table E.3 FWD tests conducted on rigid pavement sections

Location			Roadbed type USCS	FWD file information		Concrete slab thickness (in)	Number of tests	Concrete Ec (psi)	Roadbed K (pci)	Roadbed MR (psi)	Physical location
Region	Road	Cluster-area		Date	File title						
Grand	I-96	09-07	SM	6/27/2001	rigid-G-I96-CS34044-06-27-2001	9	21	1,268,974	347	26,950	Between Knox and Keefer Roads
Bay	US-23	09-09	SM	10/21/1998	rigid-B-US23-CS25031-10-21-1998	9	34	4,320,980	437	33,920	S. of Hill Road
Bay	US-23	09-09	SM	5/30/2001	rigid-B-US23-CS25031-05-30-2001	9	46	2,748,666	351	27,250	
Bay	US-23	09-09	SM	8/23/2005	rigid-B-US23-CS25031-08-23-2005-(2)	9	17	1,792,001	392	30,384	N. of Thompson Rd. to US-23 SB ramp
Bay	I-475	09-09	SM	6/26/1997	rigid-B-I475-CS25132-06-26-1997	9	60	3,104,905	283	21,958	BBETWEEN CORNELL AND COLDWATER OVERPASSES
Bay	I-475	09-09	SM	6/24/2001	rigid-B-I475-CS25132-06-24-2001	9	66	2,263,476	307	23,832	N. of Lieth St.
University	I-69	10-04	SM	9/10/2007	rigid-U-I69-CS23063-09-10-2007	10	30	2,199,553	298	23,132	
University	I-69	10-04	SM	3/5/2009	rigid-U-I69-CS23063-03-05-2009	10	33	6,113,085	317	24,606	
University	I-69	10-04	SM	4/17/2009	rigid-U-I69-CS23063-04-17-2009	10	33	6,523,842	222	17,207	
Superior	M-28	03-04	SP1	5/8/2001	rigid-Su-M28-CS17062-05-08-2001	8	80	1,874,921	235	18,226	.9 Miles W. of Ranger Rd. E. 1 Mile
Superior	I-75	03-04	SP1	5/31/2000	rigid-Su-I75-CS17033-05-31-2000	9	49	1,199,440	218	16,931	Chipewa-Mackinac Co. Line to N. edge structure of M-28
Superior	I-75	03-04	SP1	5/25/2000	rigid-Su-I75-CS17034-05-25-2000	9	16	1,330,163	247	19,141	M-28 N. edge to end of median barrier N, of Toll Plaza
Superior	I-75	03-04	SP1	5/22/2000	rigid-Su-I75-CS17034-05-22-2000	9	21	1,523,738	224	17,367	Rest area ramp gore to M-28
North	I-75	05-02	SP1	9/17/2001	rigid-N-I75-CS16091-09-17-2001	9	69	1,501,914	259	20,106	From MC RR to N. edge of Riggsville Rd.
North	I-75	05-02	SP1	10/26/2001	rigid-N-I75-CS16091-10-26-2001	9	53	1,779,633	267	20,708	From N. of Riggsville Road to Indian Rr
North	I-75	05-02	SP1	9/18/2001	rigid-N-I75-CS16092-09-18-2001	9	98	1,283,968	289	22,414	From Riggsville Road to US-31
North	I-75	05-02	SP1	9/27/2001	rigid-N-I75-CS160992-09-27-2001	9	86	1,370,042	273	21,186	From N. of US-31 to Riggsville Road
Grand	US-131	07-03	SP1	4/9/1998	rigid-G-US131-CS59012-04-09-1998	9	22	782,808	338	26,229	M-82 S. ramps N. to Montcalm-Mecosta Co
North	I-75	05-04	SP2	8/30/1997	rigid-N-I75-CS65041-08-30-2001	9	20	1,333,695	304	23,622	From Ski Park Road to Ogemaw-Rosscommon County Line
North	I-75	05-04	SP2	9/14/2001	rigid-N-I75-CS65041-09-14-2001	9	29	1,159,426	245	19,038	Roscommon-Ogemaw County line to Ski Park Road
Bay	US-23	09-10	SP2	8/30/2005	rigid-B-US23-CS25031-08-30-2005	10	19	1,371,563	407	31,592	S. of Thompson Road
Bay	US-23	09-10	SP2	8/23/2005	rigid-B-US23-CS25031-08-23-2005	10	27	1,487,442	386	29,920	S. of Thompson Rd. to US-23 SB ramp
Bay	US-23	09-10	SP2	11/15/2005	rigid-B-US23-CS25031-11-15-2005	10	68	1,082,723	339	26,345	N.of Thompson Road
Bay	US-23	09-10	SP2	11/16/2005	rigid-B-US23-CS25031-11-16-2005	10	31	1,025,612	234	18,134	N.of Thompson Road
Bay	US-23	09-10	SP2	11/16/2005	rigid-B-US23-CS25031-11-16-2005-(2)	10	48	958,993	259	20,107	S.of Thompson Road
University	I-94	13-04	SP2	11/19/2006	rigid-U-I94-CS82021-11-19-2006	10	333	2,764,869	311	24,146	W. of Haggarty Road near MP 191, Belleville
Superior	M-28	03-01	SP-SM	8/23/2001	rigid-Su-M28-CS02041-08-23-2001	10	21	1,288,074	259	20,073	From N. of Portage Street to RR tracks
Superior	M-28	03-01	SP-SM	8/23/2001	rigid-Su-M28-CS02041-08-23-2001-(2)	10	46	1,006,652	209	16,199	From RR tracks to Portage St., Munising
Southwest	I-196	06-04	SP-SM	5/14/2008	rigid-So-I196-CS3033-05-14-2008	9	33	7,774,538	303	23,527	Van Buren/Allegan Co Line Sign, Base line Rd off Rt/Way
Southwest	I-196	06-04	SP-SM	9/11/2007	rigid-So-I196-CS3033-11-09-2007	9	36	5,170,572	445	34,562	Van Buren/Allegan Co Line Sign, Base line Rd off Rt/Way
Southwest	US-31	06-05	SP-SM	10/9/2001	rigid-So-US31-CS11057-10-09-2001	9	28	819,421	194	15,028	Fetween Rangeline and Matthews Roads
Southwest	US-31	06-05	SP-SM	10/30/2001	rigid-So-US31-CS11057-10-30-2001	9	27	1,909,724	192	14,879	Fetween Rangeline and Matthews Roads
Southwest	US-31	06-05	SP-SM	6/6/2003	rigid-So-US31-CS11057-06-06-2003	9	16	1,398,211	240	18,636	Fetween Rangeline and Matthews Roads

Table E.3 (Cont'd)

Location			Roadbed type USCS	FWD file information		Concrete slab thickness (in)	Number of tests	Concrete Ec (psi)	Roadbed K (pci)	Roadbed MR (psi)	Physical location
Region	Road	Cluster-area		Date	File title						
Southwest	US-31	06-05	SP-SM	4/18/2008	rigid-So-US31-CS11057-05-14-2008	9	33	3,943,545	218	16,897	South of Rigeline Rd
Southwest	US-31	06-05	SP-SM	11/9/2007	rigid-So-US31-CS3032-11-09-2007	10	33	2,444,743	390	30,295	South of Rangeline Rd
Bay	I-75	08-06	SC-SM	9/13/2001	rigid-B-I75-CS6111-09-13-2001	9	57	1,617,746	286	22,182	Arnec-Ogemaw Co. Ln. to N Ramps at Sterling Rd.
Southwest	I-94	12-05	SP-SM	11/18/2002	rigid-So-I94-CS11081-11-18-2002	9	84	1,402,982	216	16,759	E. of Crystal Road
Southwest	I-94	12-05	SP-SM	10/28/2004	rigid-So-I94-CS11081-10-28-2004	9	66	1,285,711	223	17,299	between I-94 and W. of Crystal Road
Southwest	I-94	12-05	SP-SM	10/30/2001	rigid-So-I94-CS11081-10-30-2001	9	12	1,247,204	192	14,871	E. of Crystal Road
University	US-23	13-06	SP-SM	9/14/2006	rigid-U-US23-CS58034-09-14-2006	10	79	931,042	365	28,310	near US-223 to N. of Consear Road
Grand	US-131	09-02	SC-SM	11/7/1996	rigid-G-US131-CS41131-07-11-1996-(2)	9	9	2,055,282	313	24,279	US-131 S. OF 54TH ST. N'LY TO N. OF M-11
Grand	M-6	09-02	SC-SM	9/15/2004	rigid-G-M6-CS41064-09-15-2004	10	57	2,657,345	392	30,406	From EB I-196 to W. of M-37
Grand	M-6	09-02	SC-SM	9/8/2004	rigid-G-M6-CS41064-09-29-2004	10	653	6,913,721	262	20,344	From W. of M-37 to I-196
Grand	M-6	09-02	SC-SM	9/8/2004	rigid-G-M6-CS41064-09-08-2004	10	665	6,929,648	262	20,329	From W. of M-37 to I-196
Grand	M-6	09-02	SC-SM	11/15/2001	rigid-G-M6-CS41064-11-15-2001	10	159	3,091,380	253	19,654	I-96 to M-37
University	US-127	10-02	SC-SM	6/15/1998	rigid-G-US27-CS19033-06-15-1998	10	249	3,688,356	222	17,215	Between Price Rd. and I-69
University	US-127	10-02	SC-SM	11/7/2007	rigid-U-US127-CS19034-11-07-2007	10	31	7,943,405	379	29,442	M-21 North to end of freeway
University	US-127	10-02	SC-SM	3/5/2009	rigid-U-US127-CS19034-03-05-2009	10	33	5,676,413	233	18,090	M-21 North to end of freeway
University	US-127	10-02	SC-SM	5/1/2009	rigid-U-US127-CS19034-05-01-2009	10	10	7,720,364	158	12,261	M-21 North to end of freeway
Southwest	I-69	11-03	SC-SM	9/11/2001	rigid-So-I69-CS12034-09-11-2001	9	39	2,551,331	384	29,825	N. of State Road to N. of Hog Creek
Southwest	I-69	11-03	SC-SM	10/8/1998	rigid-So-I69-CS12034-10-08-1998	9	7	1,224,345	342	26,522	Between N. of Newton Road to Branch-Calhoun County Line
Southwest	I-69	11-03	SC-SM	10/9/1998	rigid-So-I69-CS12034-10-09-1998	9	7	1,385,348	313	24,319	Between N. of Newton Road to Branch-Calhoun County Line
Southwest	I-69	11-05	SC-SM	12/18/2001	rigid-So-I69-CS12033-12-18-2001	9	65	2,286,690	253	19,637	N. of Pearl Beach Road
Superior	I-75	03-05	SC	6/13/2000	rigid-Su-I75-CS49025-06-13-2000	9	63	1,751,835	278	21,555	N.edge Portage St. Structure to Mackinac-Chippewa County Line
Superior	I-75	03-05	SC	6/2/2000	rigid-Su-I75-CS49025-06-02-2000	9	40	1,115,443	240	18,646	
Bay	US-127	07-05	SC	12/19/2007	rigid-B-US127-CS37014-12-19-2007	8	45	2,490,183	475	36,844	100' North of Vernon Rd
Bay	I-75	08-04	SC	7/2/2008	rigid-B-I75-CS3035-07-02-2008	9	36	4,624,514	272	21,138	N. of Beaver Rd, at Wellers Rd
Bay	US-10	08-04	SC	12/18/2007	rigid-B-US10-CS9101-12-18-2007	7.3	36	4,976,290	290	22,537	West of Mackinaw Rd
Bay	US-127	09-08	SC	6/27/2008	rigid-B-US127-CS29011-06-27-2008	9	33	5,013,736	255	19,785	Charles Rd centerline under bridge over us127, North Ithaca city limits
Bay	I-75	09-08	SC	8/15/2001	rigid-BI75-CS73101-08-15-2001	9	47	1,249,188	244	18,953	Salzburg Rd. to M-13 Conn.
Bay	I-75	09-08	SC	11/30/1999	rigid-BI75-CS73101-11-30-1999	9	19	2,514,512	257	19,970	M-13 Conn. to Salzburg Road
Bay	I-675	09-08	SC	10/24/2003	rigid-B-I675-CS73101-10-24-2003	9	72	1,298,419	291	22,548	Between Tittabawassee and N. Michigan
Bay	I-675	09-08	SC	5/26/2004	rigid-B-I675-CS73101-05-26-2004	9	49	1,322,471	285	22,091	Between Tittabawassee and N. Michigan Roads
Bay	I-675	09-08	SC	10/14/2004	rigid-B-I675-CS73101-10-14-2004	9	75	986,784	225	17,439	Between Tittabawassee and N. Michigan Roads
Bay	I-675	09-08	SC	12/5/2005	rigid-B-I675-CS73101-12-05-2005	9	63	1,634,031	281	21,767	Between Tittabawassee and N. Michigan Roads

Table E.3 (Cont'd)

Location			Roadbed type USCS	FWD file information		Concrete slab thickness (in)	Number of tests	Concrete Ec (psi)	Roadbed K (pci)	Roadbed MR (psi)	Physical location
Region	Road	Cluster-area		Date	File title						
University	I-69	10-08	SC	6/25/2001	rigid-U-I69-CS19043-06-25-2001	9	14	1,163,467	217	16,805	E. of Lowell Road
University	I-69	10-08	SC	5/14/2002	rigid-U-I69-CS19043-05-14-2002	9	98	1,895,200	326	25,285	Between E. of Old US-27 and Lowell Road
University	I-69	10-08	SC	9/18/1998	rigid-U-I69-CS19042-09-18-1999	9	10	1,687,833	339	26,277	Chandler Road E.
Metro	M-5	13-03	SC	11/29/2006	rigid-M-M5-CS00000-11-29-2006	10	69	2,378,364	304	23,566	Between Pontiac Trail and RR
University	I-75	14-01	SC	12/4/2007	rigid-U-I75-CS58151-12-04-2007	9.3	83	4,002,494	297	23,071	50 ft N. of Mile Marker 7
University	I-75	14-01	SC	2/20/2009	rigid-U-I75-CS58151-02-20-2009	9.3	60	8,686,794	164	12,758	50 ft N. of Mile Marker 7
University	I-75	14-01	SC	3/9/2009	rigid-U-I75-CS58151-03-09-2009	9.3	60	7,214,255	141	10,942	50 ft N. of Mile Marker 7
University	I-75	14-01	SC	3/13/2009	rigid-U-I75-CS58151-03-13-2009	9.3	57	10,395,076	140	10,871	50 ft N. of Mile Marker 7
University	I-75	14-01	SC	4/16/2009	rigid-U-I75-CS58151-04-16-2009	9.3	66	6,582,070	142	11,041	50 ft N. of Mile Marker 7
University	I-75	14-01	SC	3/31/2008	rigid-U-I75-CS58151-03-31-2008	10	57	4,346,544	175	13,580	S. of Gaynier Rd. truck scales
University	I-75	14-01	SC	4/27/2009	rigid-U-I75-CS58151-04-27-2009	9.3	3	5,377,033	150	11,640	S. of Gaynier Rd. truck scales
University	I-75	14-03	SC	10/6/2006	rigid-U-I75-CS58152-10-06-2006	10	21	1,085,465	228	17,695	N. of Post Road
Metro	I-94	14-05	SC	10/6/2005	rigid-M-I94-CS82022-10-06-2005	10	37	2,104,643	340	26,411	
Metro	I-94	14-05	SC	10/13/2005	rigid-M-I94-CS82022-10-13-2005	10	38	2,104,704	327	25,381	
Metro	I-94	14-05	SC	10/26/2005	rigid-M-I94-CS82022-10-26-2005	10	49	2,226,098	320	24,813	
Metro	I-94	14-05	SC	10/31/2005	rigid-M-I94-CS82022-10-31-2005	10	34	2,289,527	354	27,468	
Metro	I-94	14-05	SC	9/30/2005	rigid-M-I94-CS82022-09-30-2005	10	64	2,240,000	303	23,523	
Metro	I-94	14-05	SC	11/1/2005	rigid-M-I94-CS82022-11-01-2005	10	79	1,980,028	258	20,003	
Metro	M-10	14-06	SC	10-3-2007	rigid-M-M10-CS82111-10-03-2007	10	44	2,770,674	663	51,486	Aprox 290 ft N. of MP 13.2
Metro	I-94	14-05	SC	9/16/2008	rigid-M-I94-CS82022-09-16-2008	12.25	78	2,982,552	310	24,056	At the end of gore paint lines from Schafer Hwy to I 94 EB, CSMP aprox 14.642
Metro	I-94	14-06	SC	9/16/2008	rigid-M-I94-CS82022-09-16-2008-(2)	12.5	66	3,536,866	373	28,945	Aprox 385 east of Beach Daily Rd Sta 414+00
Metro	I-75	14-06	SC	9/16/2008	rigid-M-I75-CS82194-09-16-2008	12	62	3,246,240	300	23,300	0n bridge will start at end of ramp from M39 to NB I75 = CSMP = 0.188
Metro	M-14	13-08	CL	11/29/2006	rigid-M-M14-CS82102-11-29-2006	10	66	4,335,070	335	25,963	W. of Beck Road
Metro	I-94	14-09	CL	2/20/2009	rigid-M-I94-CS77111-02-20-2009	11	60	12,944,066	227	17,612	
Metro	I-94	14-09	CL	2/27/2009	rigid-M-I94-CS77111-02-27-2009	11	66	7,542,618	201	15,601	
Metro	I-94	14-09	CL	3/6/2009	rigid-M-I94-CS77111-03-06-2009	11	66	8,492,904	228	17,680	
Metro	I-94	14-09	CL	3/9/2009	rigid-M-I94-CS77111-03-09-2009	11	66	7,435,507	159	12,345	
Metro	I-94	14-09	CL	3/13/2009	rigid-M-I94-CS77111-03-13-2009	11	66	7,559,975	158	12,235	
Metro	I-94	14-09	CL	4/9/2009	rigid-M-I94-CS77111-04-09-2009	11	66	6,091,908	97	7,545	

Table E.3 (Cont'd)

Location			Roadbed type USCS	FWD file information		Concrete slab thickness (in)	Number of tests	Concrete Ec (psi)	Roadbed K (pci)	Roadbed MR (psi)	Physical location
Region	Road	Cluster-area		Date	File title						
Metro	I-69	14-09 15-03	CL	7/2/1997	rigid-M-I69-CS77023-07-02-1997	9	18	2,283,001	233	18,107	
Metro	I-69	15-03	CL	4/2/2008	rigid-M-I69-CS77024-04-02-2008	10	39	2,442,439	118	9,181	At W. St Cair County Line, Sign
Metro	I-69	15-03	CL	2/20/2009	rigid-M-I69-CS77024-02-20-2009	10	39	4,892,153	219	16,979	At W. St Cair County Line, Sign
Metro	I-69	15-03	CL	2/27/2009	rigid-M-I69-CS77024-02-27-2009	10	39	2,908,535	142	11,013	At W. St Cair County Line, Sign
Metro	I-69	15-03	CL	3/6/2009	rigid-M-I69-CS77024-03-06-2009	10	39	2,837,078	174	13,515	At W. St Cair County Line, Sign
Metro	I-69	15-03	CL	3/9/2009	rigid-M-I69-CS77024-03-09-2009	10	39	2,609,827	138	10,728	At W. St Cair County Line, Sign
Metro	I-69	15-03	CL	3/13/2009	rigid-M-I69-CS77024-03-13-2009	10	39	2,669,069	130	10,107	At W. St Cair County Line, Sign
Metro	I-69	15-03	CL	4/9/2009	rigid-M-I69-CS77024-04-09-2009	10	39	2,287,458	94	7,329	At W. St Cair County Line, Sign

The deflection basin data and the backcalculated pavement layer moduli for each of the FWD tests conducted on flexible and rigid pavement structures are listed in Tables E.4 and E.5, respectively.