New testing technologies used to determine insitu density and moisture content of compacted soil used for construction purposes

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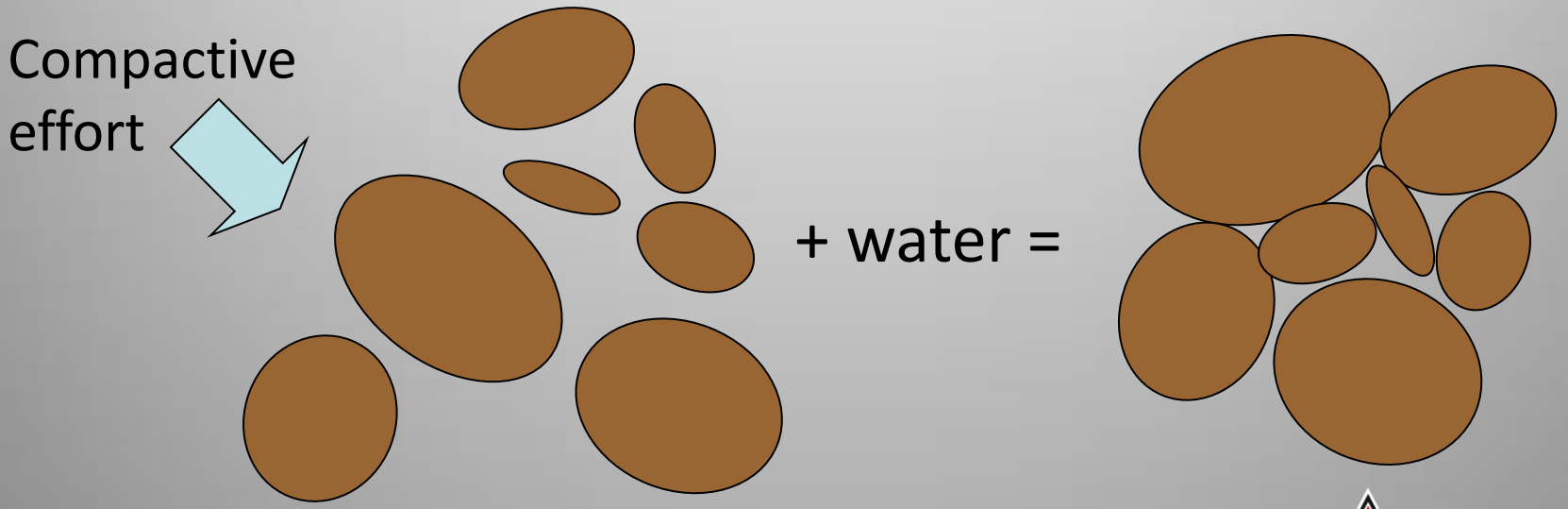
What is Compaction?

A simple ground improvement technique, where the soil is densified through external compactive effort.



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Why Compact Soil?

Increases load-bearing capacity

Prevents soil settlement and frost damage

Provides stability

Reduces water seepage, swelling and contraction

Reduces settling of soil

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Field Compaction

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Compaction Testing

Evaluation of density as a result of compactive efforts with rollers and other equipment

Standard quality control measurement on all soil material types at construction sites

Density of a compacted soil is measured and compared to a density previously determined in laboratory tests

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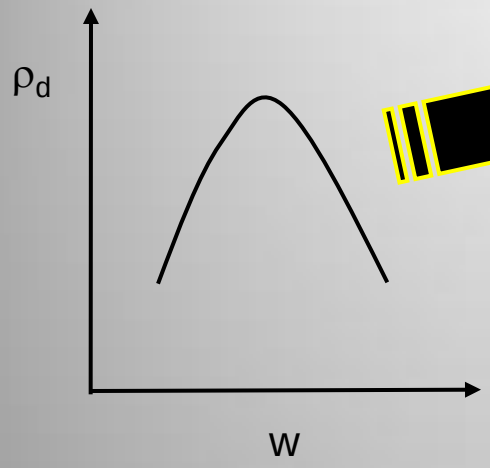
Compaction Control Test



Compaction specifications

$\rho_{d,field}$ = ?

w_{field} = ?

Compare!

Compacted ground

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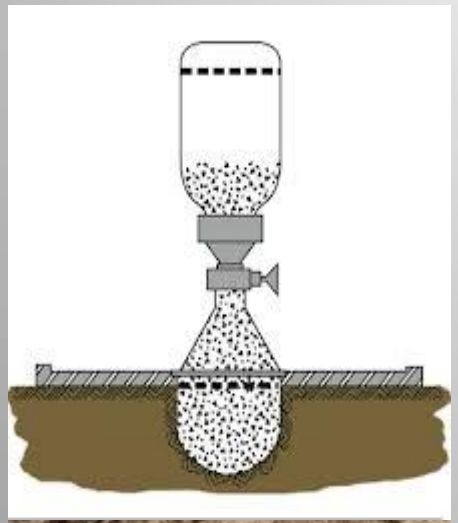
Compaction

Field Density Tests



Sand Cone Test (ASTM D1556-90)

A small hole (6" x 6" deep) is dug in the compacted material to be tested. The soil is removed and weighed, then dried and weighed again to determine its moisture content. The specific volume of the hole is determined by filling it with calibrated dry sand from a jar and cone device. The dry weight of the soil removed is divided by the volume of sand needed to fill the hole.

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Field Density Tests

Nuclear Density (ASTM D2292-91)

Nuclear Density Meters are a quick and fairly accurate way of determining density and moisture content. The meter uses a radioactive isotope source at the soil surface (backscatter) or from a probe placed into the soil (direct transmission). The isotope source gives off energy (usually Gamma and Neutron rays) which radiate back to the meter's detectors on the bottom of the unit.

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Field Density Tests

ASTM D7698 – 11 Standard Test Method for In-Place Estimation of Density and Water Content of Soil and Aggregate by Correlation with Complex Impedance

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Electrical Density Gauge H-4114SD.3F

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EDG Development

The product development spanned over 15 years of work from the initial research to the commercialization of a new geotechnical engineering technology for the determination of in-situ density and moisture content of soil for use in civil engineering

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EDG Development

The research was based on three primary principals of applied geophysics:

1- Conrad and Marcel Schlumberger (1930)

2- G.E. Archie's 1941 work

3- Tixier (1949) and Wyllie and Rose (1950)

Three principals combined and expanded

EDG Development

The objective of the equipment is to provide on-site and immediate in-situ density data for soil materials used in construction.

The data can then be uses for Quality Control and Quality Assurance purposes.

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EDG Development

ASTM Approval May 2011

ASTM D7698 – 11 Standard Test Method for In-Place Estimation of Density and Water Content of Soil and Aggregate by Correlation with Complex Impedance

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EDG Theory

Every soil type has a unique geo-electric signature. When the geo-electric signature is researched and established for a given soil type and integrated with physical properties, that data can then be used to determine the geotechnical field characteristics of the soil under test.

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EDG Theory

The soil electrical parameters of current (Is), voltage (Vs), and phase (Ps) are recorded

From the electrical soil measurements, the software then calculates resistance (Rs) and capacitance (Cs), the quotient Cs/Rs, and real impedance (Zs)

EDG Theory

As the soil density and moisture content values change, the equivalent soil values for R, C and Z will also change

Reported physical properties of the soil – density and moisture content - will also change

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EDG Theory

The EDG determines these electrical properties of the soil by transmitting a 3.0 MHz radio frequency voltage to the soil through a set of steel probes (darts) driven into the soil.

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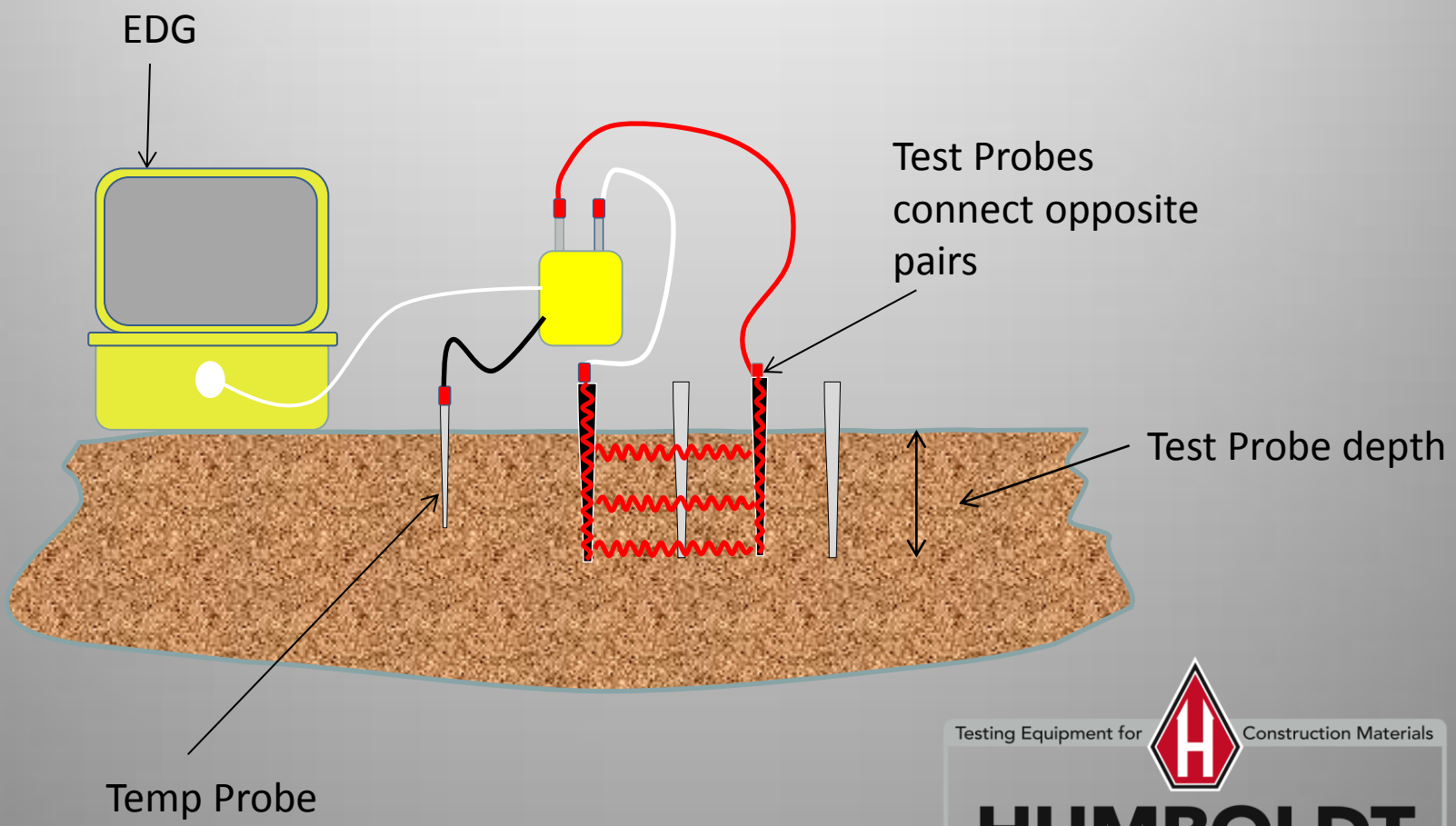
EDG Theory

Electrical Density Test



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EDG in Practice

The radio frequency current that is passing through the probes into the soil and the voltage that appears across the probes are measured electronically

Additionally, the electrical phase relationship between the soil current and the probe-to-probe voltage is determined

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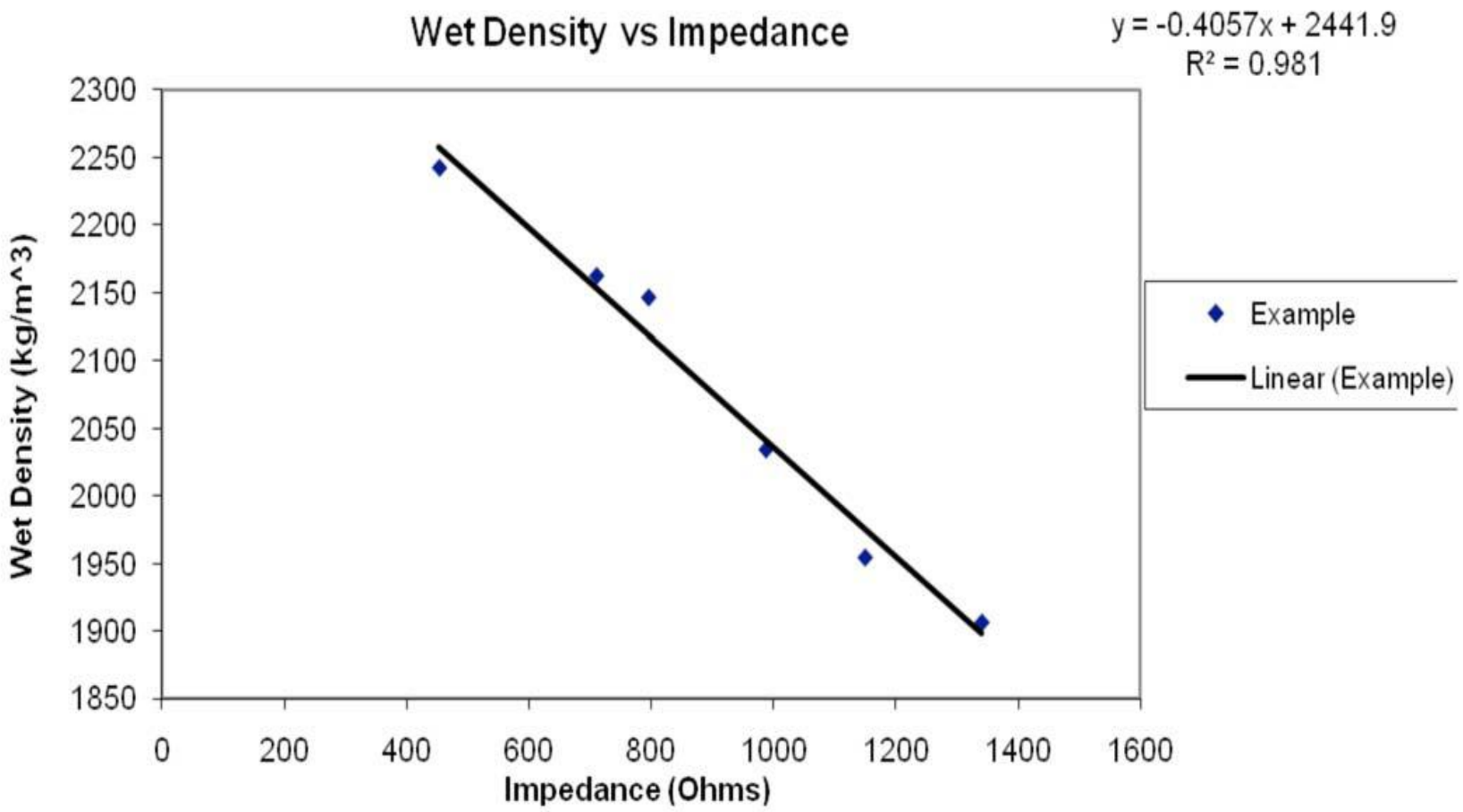
EDG in Practice

Material constants are established by conducting pre-construction geotechnical tests.

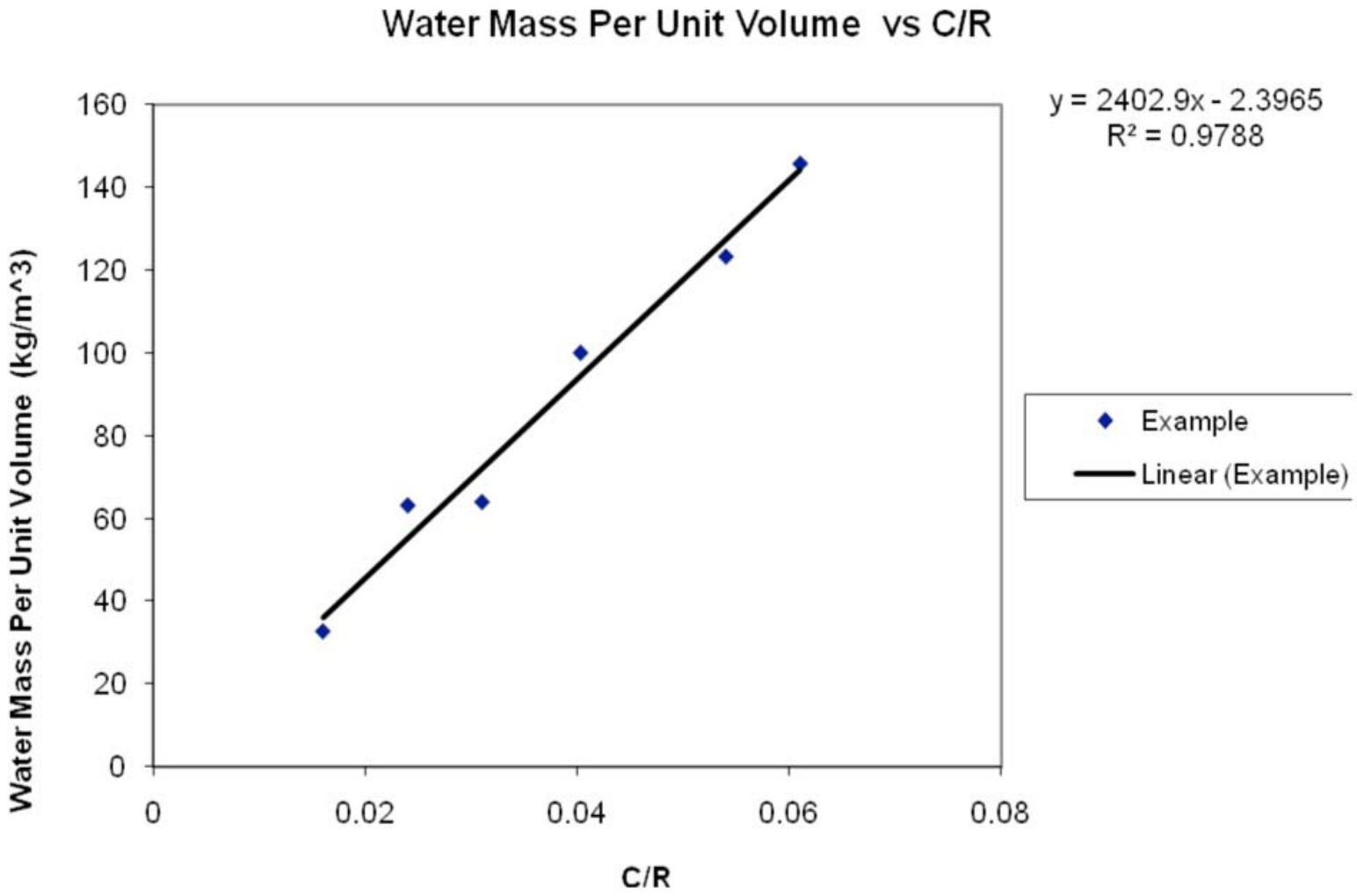
A series lab tests or side-by-side tests are performed to establish the soil characteristics constants within an acceptable confidence level.

The process of establishing the material constants is called the “Soil Model”

Linear regression – Wet Density



Linear regression – Moisture



EDG Field Test

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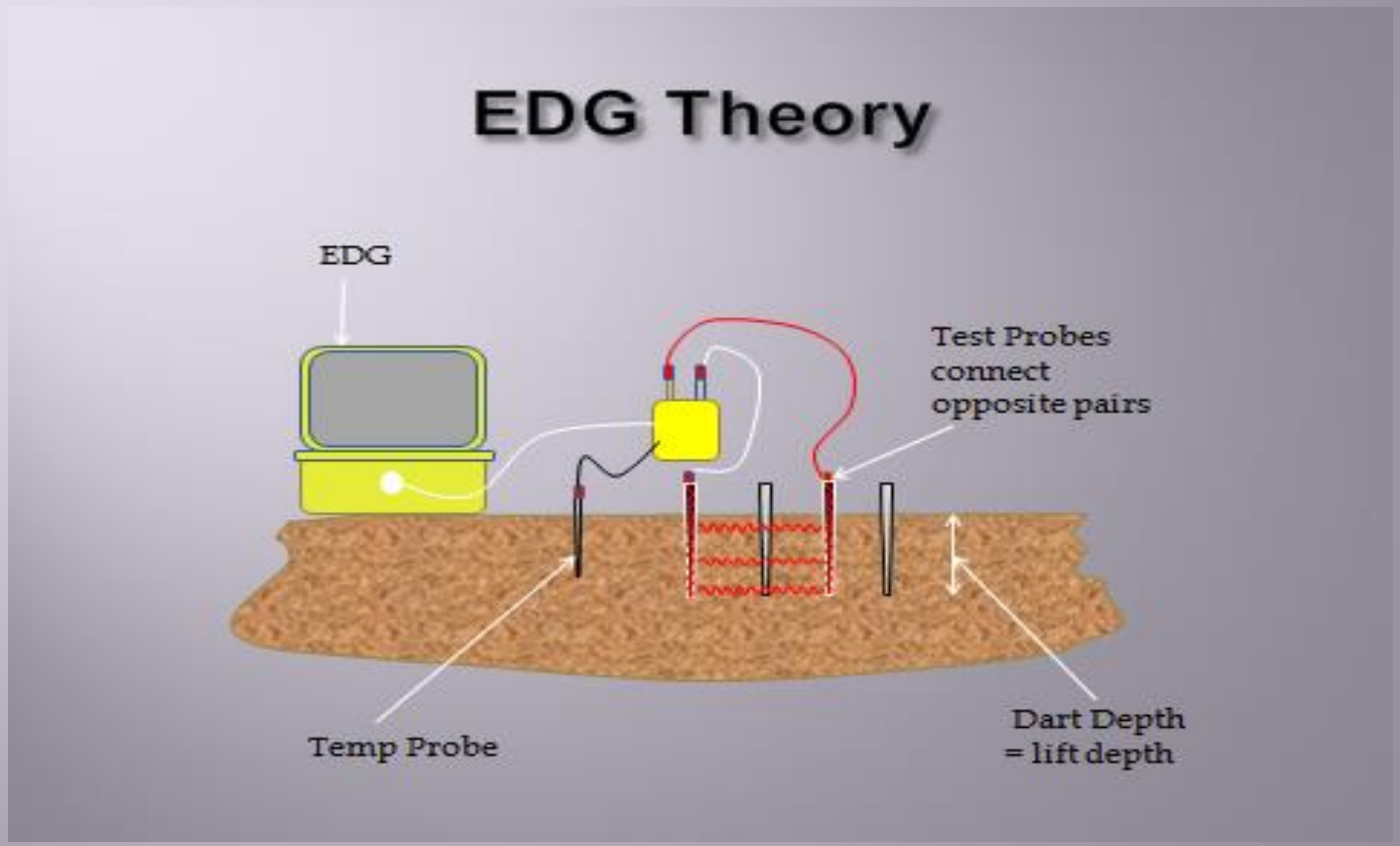
EDG Schematic



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Actual Depth of Measurement

Steel darts of
5 lengths:

4 inch
6 inch
8 inch
10 inch
12 inch

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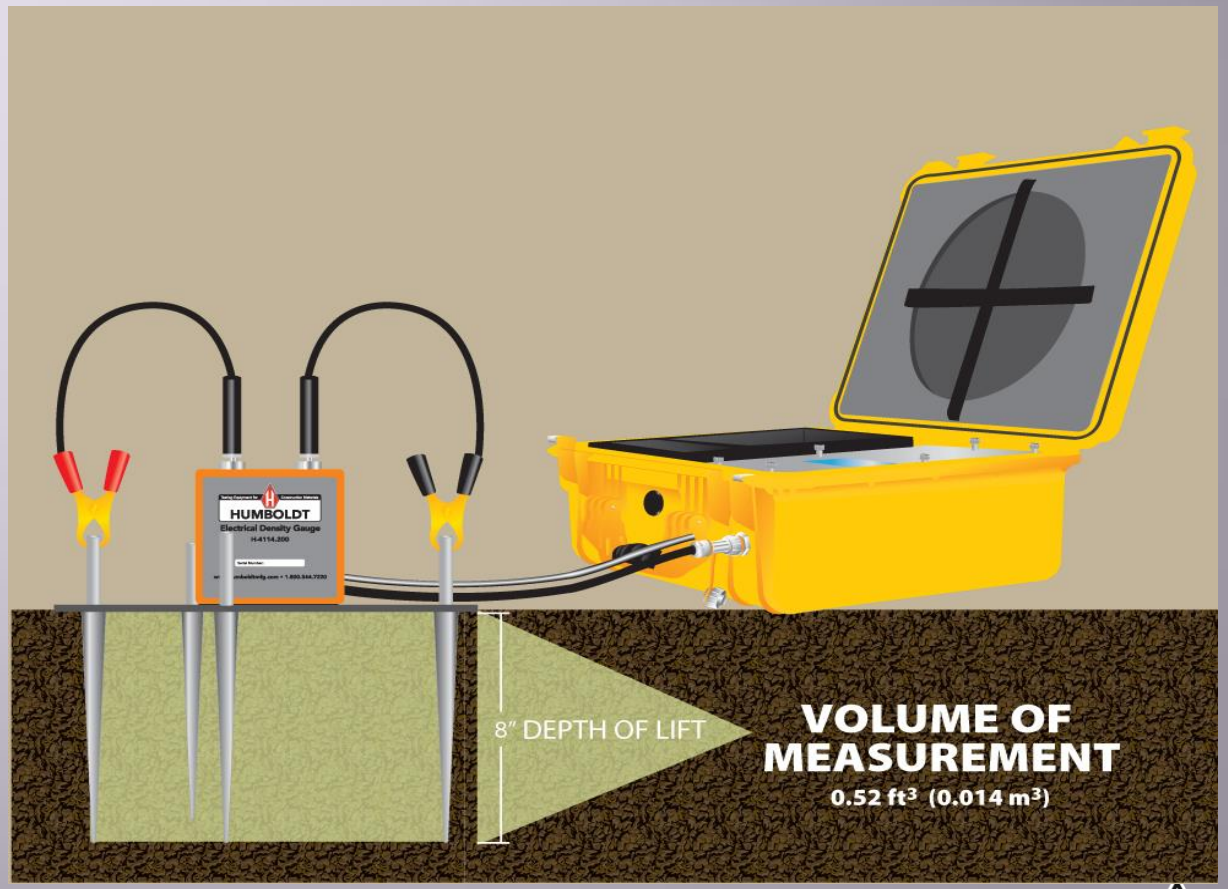
Lift-thickness Specifications

Lift thickness	State DOTs
6-inch	MA, MT, ND
6-inch (compacted)	CT, KY, NY
8-inch	AL, AZ, CA, DE, FL, ID, IL, IN, IA, KS, ME, MN, MS, MO, OR, SC, VT, VA, WI
12-inch	LA, NH, NJ, OH, TX

EDG Schematic



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EDG Reported Values

The EDG reports:

- Wet Density
- Moisture Content

and by calculation:

- Dry Density
- Relative % compaction

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Verification Data

The data for verification of the EDG was taken over a 3 year period from 230 tests from 34 different sites

Compared to NDG results, the EDG shows a variation of +/- 2.65% for density and +/-1.55% for moisture content

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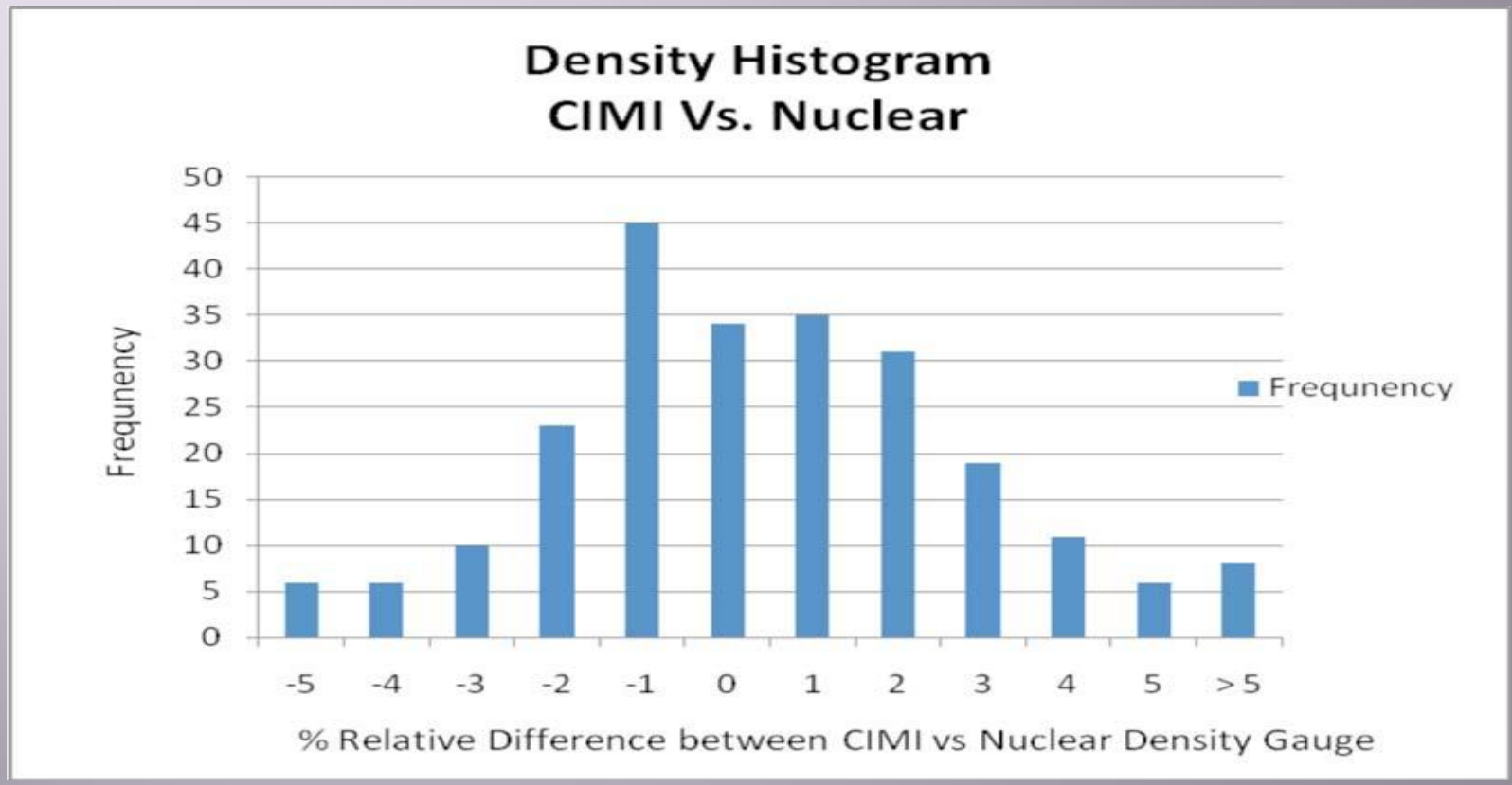
Verification Data



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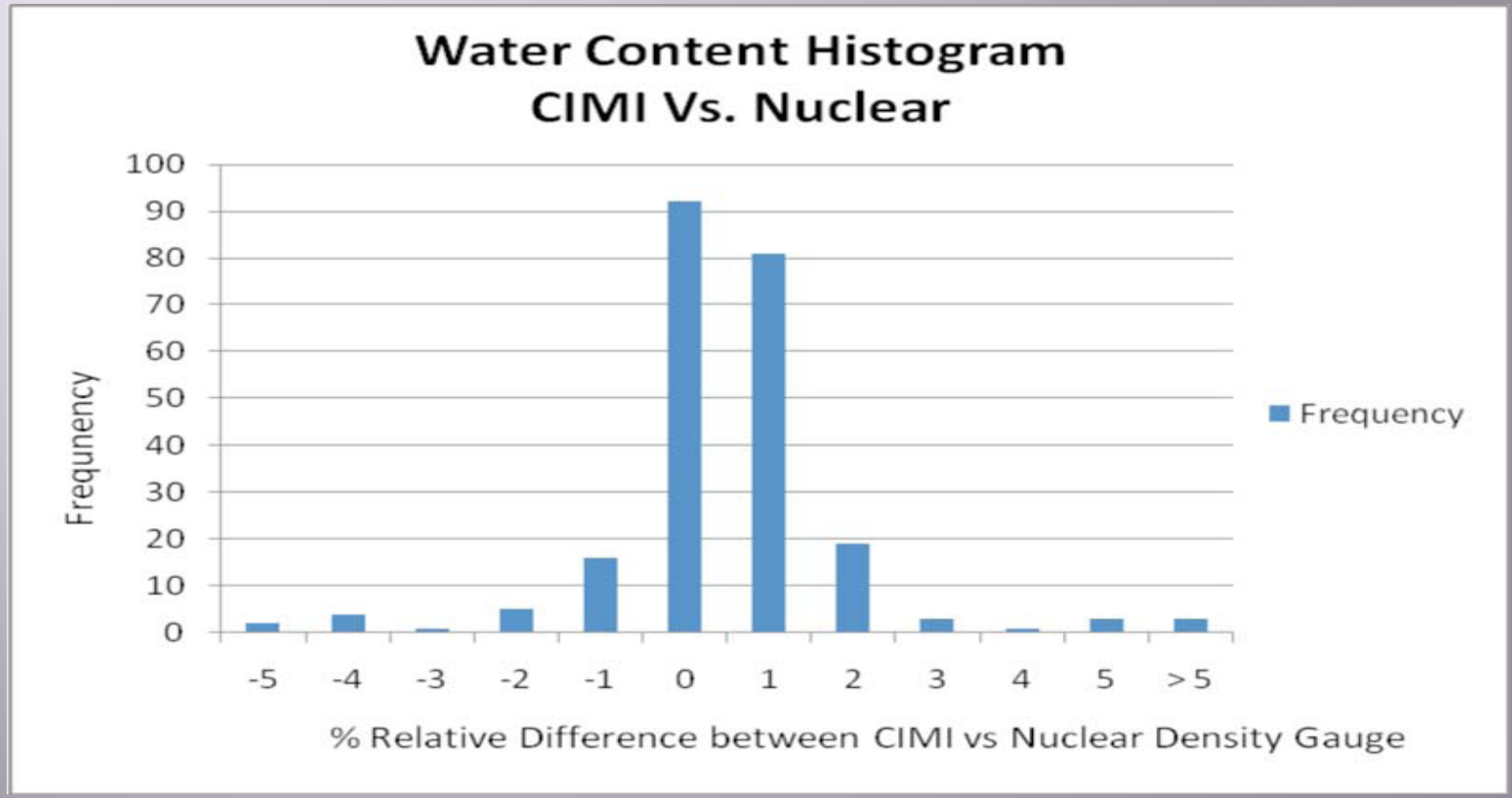
Verification Data



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In-Situ Density Comparison – SRD/NDM
BS 1377-9:1990/ASTM D7698-11

Material: Crushed Concrete			Specification: 6P1	
Date	SRD		EDG	
	Bulk Density Mg/m^3	Moisture %	Bulk Density Mg/m^3	Moisture %
19/03/13	2.09	9.5	2.115	9.3
19/03/13	2.13	9.3	2.121	9.3
19/03/13	2.13	9.5	2.125	9.3
20/03/13	2.09	9.5	2.157	9.2
20/03/13	2.16	9.8	2.156	9.2
20/03/13	2.11	9.7	2.159	9.2
23/03/13	2.17	9.0	2.162	9.2
23/03/13	2.09	9.9	2.141	9.2
23/03/13	2.15	9.8	2.165	9.2

In-Situ Density Comparison – SRD/NDM
BS 1377-9:1990/ASTM D7698-11

Material:	Brown Sand		Specification:	1A		
Date	SRD		NDM		EDG	
	Bulk Density Mg/m^3	Moisture %	Bulk Density Mg/m^3	Moisture %	Bulk Density Mg/m^3	Moisture %
21/06/13	1.821	10.3	1.791	11.3	1.849	10.9
21/06/13	1.890	12.0	1.845	12.3	1.865	11.5
21/06/13	1.689	7.5	1.668	7.6	1.636	7.5

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In-Situ Density Comparison – SRD/NDM
BS 1377-9:1990/ASTM D7698-11

Material:	Brown Sand & Gravel				Specification:	6N
Date	SRD		NDM		EDG	
	Bulk Density Mg/m^3	Moisture %	Bulk Density Mg/m^3	Moisture %	Bulk Density Mg/m^3	Moisture %
23/06/13	2.03	6.8	2.009	7.0	1.990	7.2
23/06/13	-	-	2.002	7.1	1.997	7.3
23/06/13	-	-	1.959	7.7	1.992	7.3

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In-Situ Density Comparison – SRD/NDM
BS 1377-9:1990/ASTM D7698-11

Material: Chalk			Specification: Class 3			
Date	SRD		NDM		EDG	
	Bulk Density Mg/m^3	Moisture %	Bulk Density Mg/m^3	Moisture %	Bulk Density Mg/m^3	Moisture %
23/06/13	1.96	20.4	1.898	22.6	1.902	22.6
23/06/13	-	-	1.901	24.3	1.890	23.7
23/06/13	-	-	1.871	23.6	1.877	24.0

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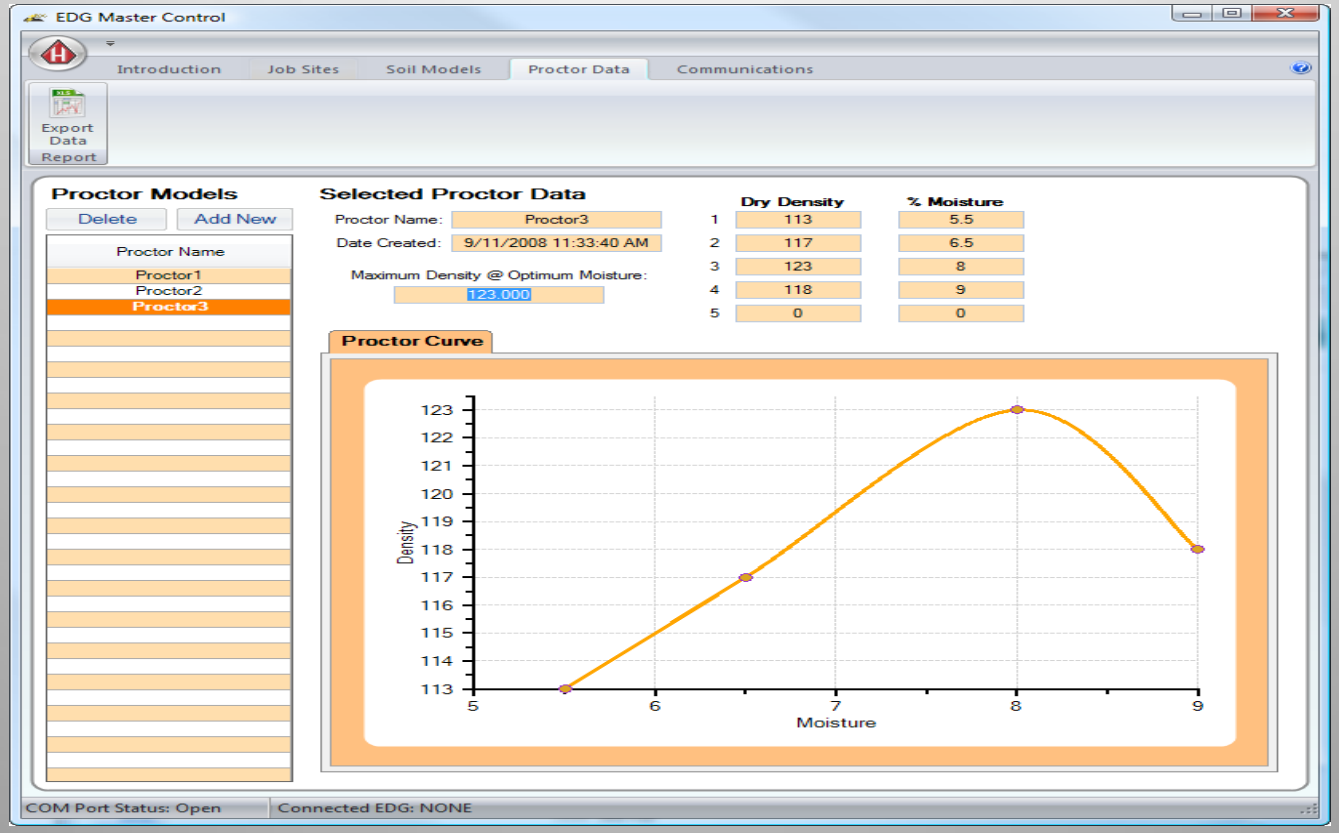
Moisture/Density Curve



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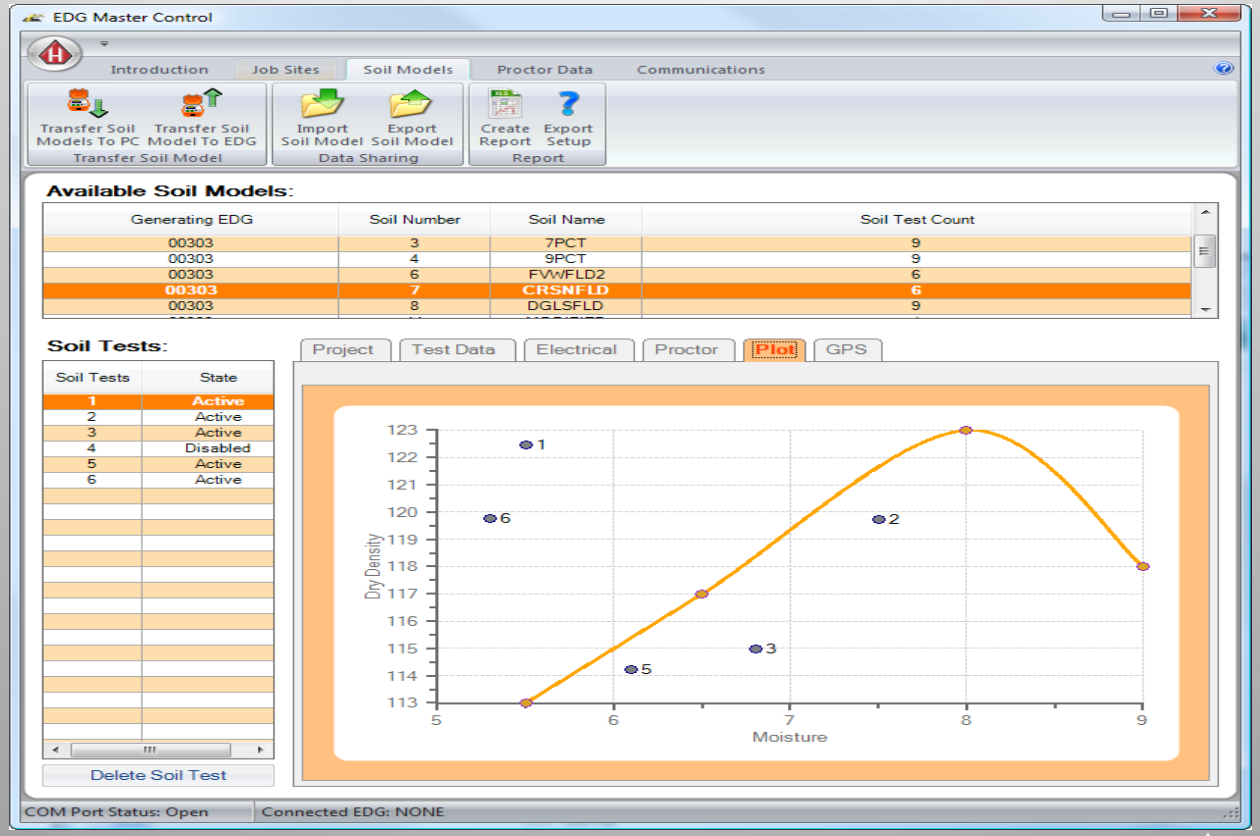
Test Data Plots



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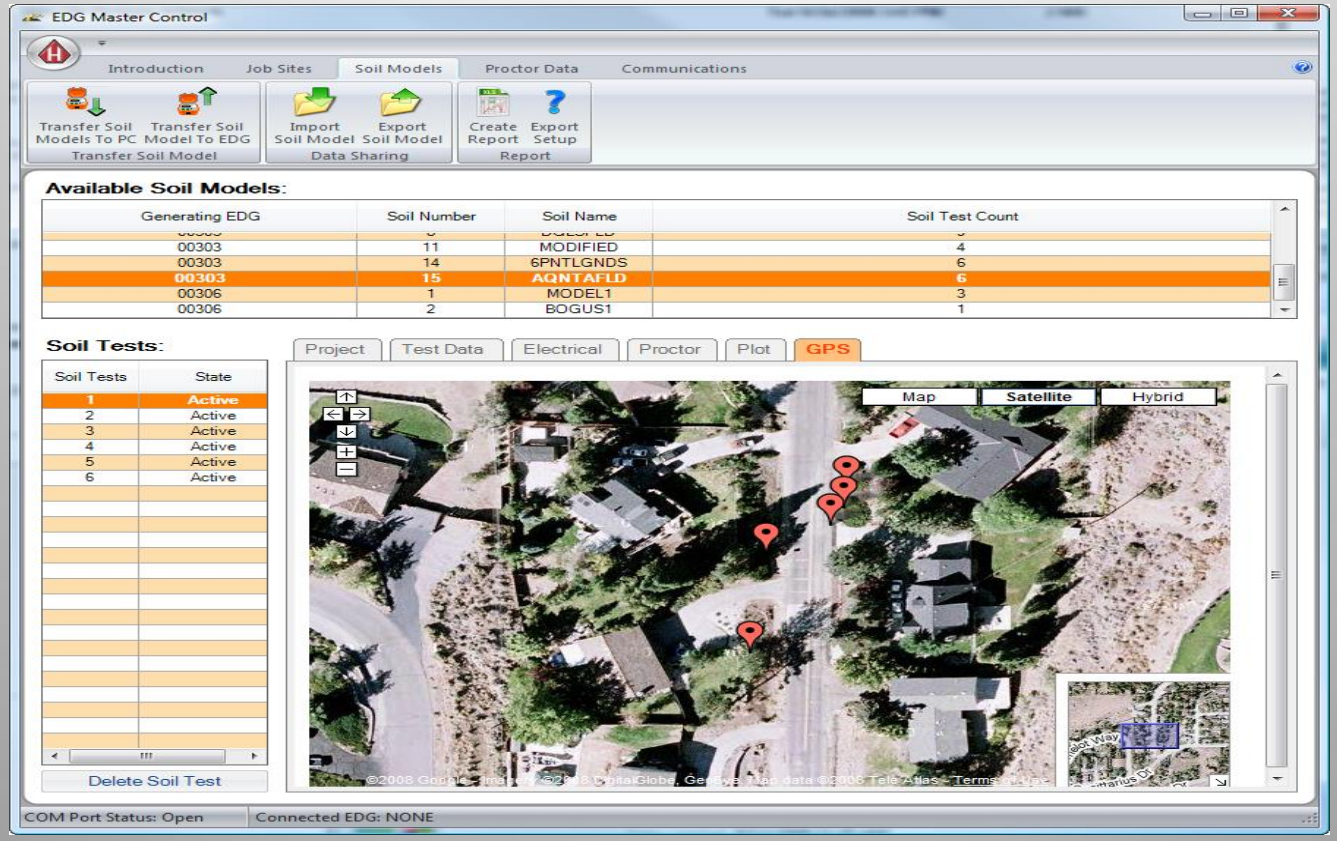
GPS Option



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Summary

- An alternative test method of determining the in-situ density and moisture content of compacted soil
- No restrictions on use
- Direct measurement of full lift depth up to 12 inch (300mm)
- Immediate on site compaction information

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Electrical Density Gauge
H-4114SD.3F

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Electrical Density Gauge
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For more information see

www.humboldtmfg.com

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