United States Department of Agriculture	**Natural Resources Conservation Service**	**5 Radnor Corporate Center, Suite 200 Radnor, PA 19087-4585**

Subject: SOI -- Wet-Soils Monitoring Project -- Jasper County, Indiana

Date: 12 January 1998

To: Warren C. Lynn
Research Soil Scientist
NSSC, MS 41
USDA Natural Resources Conservation Service
100 Centennial Mall North, Room 152
Lincoln, Nebraska 68508-3866

Don P. Franzmeier
3-330 Lilly Hall
Department of Agronomy
Purdue University
W. Lafayette, Indiana 47907

Philip J. Schoeneberger
Research Soil Scientist
NSSC, MS 41
USDA Natural Resources Conservation Service
100 Centennial Mall North, Room 152
Lincoln, Nebraska 68508-3866

Purpose:

The purpose of this investigation was to provide data on the depths to water table. This study supports the Wet Soil Monitoring Project in Jasper County, Indiana.

Participants:

Jim Doolittle, Research Soil Scientist, USDA-NRCS, Radnor, PA
Byron Jenkinson, Research Assistant, Purdue U., Lafayette, IN

Activities:

All field activities were completed on 7 January 1998.

Equipment:

The radar unit was the Subsurface Interface Radar (SIR) System-2, manufactured by Geophysical Survey Systems, Inc. The SIR System-2 consists of a digital control unit (DC-2) with keypad, VGA video screen, and connector panel. The system was powered by a 12-volt battery. This unit is backpack portable and requires two people to operate. A 200 mHz antenna was used in the investigation. A scanning time of 190 nanoseconds (ns) and a scan rate of 32.0 scan/second were used in this survey.

Discussion:

At the time of this survey, the water table was rising in soil profiles. The roads were not accessible to even a 4WD vehicle. Radar surveys were conducted by pulling the 200 mHz antenna by hand along all traverse lines.

Hunters had removed several survey flags. These survey flags and observation points were reestablished using a Rockwell Precision Lightweight GPS Receiver (PLGR+96 FEDERAL).

Sixteen monitoring wells were used to assess water table depths. Water levels in the sixteen monitoring wells were measured at the time of the radar survey. Radar traverses were conducted along two lines containing the monitoring wells. Water table depths, measured at each observation well, were used to verify and scale the radar imagery. These data were used to determine the dielectric permittivity and velocity of propagation of electromagnetic energy through the coarse-textured materials. This information was used to construct a depth scale for the radar profiles.

The measured depths to the water table and the scaled radar imagery at the sixteen monitoring wells (two radar interpretations were made at well 7B) were compared. At these wells, depths to the water table ranged from 0.63 to 9.86 meters. The coefficient of determination (r^2) between the measured and interpreted depths to this interface was 0.988. At the sixteen well sites, differences between measured and interpreted depths to the water table ranged from 0.0 to 0.28 m.

Based on the averaged round-trip travel time to the water table, the velocity of propagation was estimated to be 0.1410 m/ns. The dielectric permittivity was estimated to be about 4.55.

The maximum depth of observation was estimated by the equation:

$$D = VT/2$$

Where D is the depth of observation, V is the velocity of propagation, and T is the two-way travel time of a radar pulse. According to this equation and with a scanning time of 190 ns, the maximum observation depth on dunes was about 13.4 m.

Summary of of the first year surveys

Four, ground-penetrating radar surveys of the Jasper County site have been completed. These surveys were completed in May, July, and September of 1997, and January of 1998. Surveys were completed with a 300 mHz (May 1997), 200 mHz (July 1997 and January 1998), and 120 mHz antenna (September 1997). Velocity of signal propagation, resolution and penetration depth varies with antenna. The following table summarizes the data collected at the well sites.

	# of WELL *OBSERVATIONS*	MIN. *DEPTH*	MAX. *DEPTH*	R^2	MAXIMUM *DIFFERENCE*	AVERAGE *VELOCITY*	DIELECTRIC *PERMITTIVITY*
May 1997	7	0.00	9.73	0.993	0.43	0.1245	5.9
July 1997	15	0.75	9.22	0.995	0.22	0.1465	4.2
Sept. 1997	16	1.50	9.46	0.998	0.50	0.1190	6.6
Jan 1998	16	0.63	9.86	0.998	0.28	0.1410	4.6

Observed and interpreted or predicted water table depths were compared at the well monitoring sites. The number of comparisons made at the well monitoring sites varied. In May, the 300 mHz antenna was unable to resolve the water table at shallow depths (less than 1 m). Therefore only the seven deepest water table measurements could be used in May. In July, the depth to the water table was not observed (measured) at one well monitoring site.

The observed depths to the water table varied with the seasons. The minimum water table depth measured was 0.0 m. This measurement was recorded in May in a low-lying inter-dune area. The maximum water table depth measured was 9.86 m. This measurement was recorded in January on the crest of a dune.

The correlations between the observed and the interpreted depths to the water table were high (r^2 ranged from 0.993 to 0.998). The strength of these correlations confirms the uniform velocity of signal propagation through these coarse-textured soils to the water table. The maximum difference between observed and predicted depth to the water table was 0.5 m. The maximum difference was measured in September with the 120 mHz antenna.

The 120 mHz antenna provides the poorest resolution of subsurface features. Resolution was better in July (0.22 m) and January (0.28 m) when the 200 mHz antenna was used. All subsequent surveys will be completed with the 200 mHz antenna.

Velocity of propagation varied with the time of the year and the antenna used. The dielectric permittivity of the sandy soil materials above the water table ranged from 4.2 to 6.6. These values conform to tabled values for dry sands.

All radar data have been plotted in SURFER for Windows by Byron Jenkinson. His three dimensional surface net diagrams of the water table have captured the fluctuation of the water table across this eighty acre site. The extent of different water table depth classes at different times of the year is evident in Byron's computer simulations. It is hoped that these maps will allow the forward and backward modeling of water table depths across the site from well data alone.

Results:

1. All radar imageries have been stored on disc. At each observation point, the depth to the water table has been predicted from the radar imagery. Hard copies of the radar profile were prepared and given along with the data set to Byron Jenkinson.

2. Unless otherwise directed, GPR surveys will be continue at a three month interval. The next radar survey of the site has been tentatively scheduled for April 1998.

3. Unless otherwise directed, this survey will continue through 1998 and 1999.

4. Metal stakes will be inserted in the ground at each observation point to provide a more permanent marker.

5. The wet soil monitoring team should assess the results of this survey. Phil Schoeneberger has slides that summarize the results of the first three survey months. Additional copies of these slides have been requested by the participants. If results are favorable, additional GPR studies should be considered on sand mantled landscapes in other portions of the United States.

6. An EM38 meter (Serial number 8906008) has been loaned to Byron Jenkinson for wet soil monitoring work at the Muscatatuck National Wildlife Refuge in Jennings County, Indiana.

Jim Doolittle

With kind regards,

James A. Doolittle
Research Soil Scientist

cc:

J. Culver, Supervisory Soil Scientist, USDA-NRCS, National Soil Survey Center, Federal Building, Room 152, 100 Centennial Mall North, Lincoln, NE 68508-3866

W. Hosteter, Assistant State Soil Scientist, USDA-NRCS, RR #2, Box 90, Frankfort, IN 46041

J. Kimble, Supervisory Soil Scientist, USDA-NRCS, National Soil Survey Center, Federal Building, Room 152, 100 Centennial Mall North, Lincoln, NE 68508-3866

B. Jenkinson, Graduate Student, Agronomy Department, Purdue University, West Lafayette, IN 47907

T. Neely, State Soil Scientist/MO Leader, USDA-NRCS, Indianapolis, IN

The following tables list the observation points, surface elevations, and depths to water table as predicted from interpretation of GPR records. All measurements are in meters. Tables are arranged by traverse lines.

Readings of "0" indicate ponded conditions. In May, the water table was not discernible within depths of 0.93 m of the surface. In July, with the 200 mHz antenna, the water table was not discernible within depths of 0.96 m of the surface. In September, the water table was observable at all observation points. In January, the water table could not be seen within depths of 0.59 m of the soil surface.

Middle Road: South to North

Observation	Elevation	MAY'97	JUL'97	SEP'97	JAN'98
1	214.89	0.93	1.08	1.89	1.23
2	214.76	0.93	1.03	1.74	1.23
3	214.81	0.93	1.03	1.74	1.31
4	214.86	0.93	1.13	1.74	1.31
5	215.43	0.93	1.11	1.99	1.31
6	215.47	0.93	1.11	2.23	1.31
7	215.96	1.32	1.84	2.43	2.28
8	215.02	0.93	1.52	2.28	1.71
9	215.04	0.93	1.31	1.99	1.63
10	215.01	0.93	1.03	1.79	0.99
11	214.92	0.93	0.96	2.03	0.91
12	214.82	0.93	0.96	1.89	0.67
13	214.79	0.93	0.96	1.79	0.67

North Road: East to West

Observation	Elevation	MAY'97	JUL'97	SEP'97	JAN'98
1	215.41	0.00	0.96	2.03	0.59
2	216.26	1.85	2.20	3.31	2.32
3	218.51	3.47	3.65	3.94	5.09
4	218.15	3.15	3.12	4.48	4.61
5	217.39	2.43	2.45	3.70	3.56
6	215.95	1.58	1.64	2.52	1.55
7	215.44	0.93	1.16	1.99	1.39
8	215.59	1.00	1.54	2.13	1.55
9	214.91	0.93	0.96	1.74	0.95
10	214.72	0.93	0.96	1.79	0.71
11	214.99	0.93	0.96	1.89	0.67
12	214.89	0.93	0.96	1.79	0.67
13	215.01	0.93	0.96	1.89	0.59
14	214.89	0.93	0.96	1.89	0.71
15	214.98	0.93	0.96	2.08	0.71
16	214.88	0.93	0.96	1.74	0.71
17	214.94	0.93	0.96	1.84	0.71
18	214.90	0.93	0.96	1.79	0.67
19	215.00	1.13	1.20	2.38	1.55
20	217.53	1.78	1.99	3.75	4.45
21	222.07	6.99	6.75	7.02	7.66
22	223.03	7.78	7.79	8.15	8.47
23	223.21	7.19	7.21	7.66	8.87
24	222.89	6.15	6.12	6.49	8.55
25	221.28	4.26	4.33	5.21	7.26
26	219.71	2.82	2.86	3.75	6.14

West Road: North to South

Observation	Elevation	MAY'97	JUL'97	SEP'97	JAN'98
1	217.44	2.82	2.84	3.60	3.72
2	218.61	3.87	3.75	4.58	4.69
3	218.78	4.06	3.77	4.63	4.85
4	218.37	4.52	4.72	5.36	5.82
5	218.90	5.56	6.19	6.73	7.42
6	219.82	3.87	3.87	4.68	5.01
7	218.08	2.56	2.68	3.45	3.56
8	216.50	2.63	3.04	3.75	3.81
9	216.76	1.13	1.84	2.52	2.04
10	215.01	0.93	1.18	1.99	1.15
11	214.25	0.93	1.20	2.03	0.91
12	214.10	0.93	0.96	2.18	0.67
13	214.11	0.93	0.96	1.99	6.30
14	213.97	0.93	0.96	1.99	0.67
15	214.07	0.93	0.96	1.99	0.67
16	213.84	0.93	0.00	1.99	0.67

South Road: West to East

Observation	Elevation	MAY'97	JUL'97	SEP'97	JAN'98
1	213.84	0.93	0.96	1.99	0.67
2	214.26	0.93	0.96	1.74	0.91
3	214.29	0.93	0.96	1.79	0.91
4	214.71	0.93	1.36	2.28	1.31
5	214.88	0.93	1.61	2.43	1.79
6	215.28	1.58	1.92	2.67	2.20
7	217.72	3.67	3.55	4.38	4.85
8	217.78	3.54	3.85	4.72	5.09
9	214.80	1.00	1.16	2.38	1.55
10	214.66	0.93	1.16	2.08	1.31
11	214.58	0.93	1.11	1.79	1.03
12	214.60	0.93	1.06	1.84	0.95
13	214.57	0.93	1.08	1.79	0.91
14	214.72	0.93	1.08	1.89	1.23
15	214.92	1.00	1.31	2.08	1.31
16	215.75	1.45	1.82	2.62	2.12
17	215.82	1.45	1.99	2.67	2.36
18	217.45	3.08	3.12	3.89	3.89
19	219.34	5.36	5.00	5.75	6.22
20	220.97	6.99	7.00	7.37	7.99
21	216.87	2.17	2.61	3.80	4.37
22	215.90	1.52	2.12	2.87	2.60
23	214.73	1.00	1.38	2.13	1.31
24	214.34	0.93	0.96	1.99	0.99
25	214.43	0.93	0.96	1.94	0.63
26	214.31	0.93	0.96	1.89	0.59
27	214.50	0.93	0.96	1.74	0.59

East Road - South to North

Observation	Elevation	MAY'97	JUL'97	SEP'97	JAN'98
1	214.50	0.93	0.96	1.74	0.59
2	214.29	0.93	0.96	1.79	0.67
3	214.34	0.93	0.96	1.79	0.67
4	214.59	0.93	1.01	1.89	0.67
5	214.69	0.93	1.36	1.79	0.63
6	214.64	0.93	0.96	1.79	0.67
7	214.68	0.93	0.96	1.79	0.67
8	214.72	0.93	0.96	1.74	0.67
9	214.85	0.93	0.96	1.79	0.67
10	214.71	0.00	0.96	1.84	0.67
11	214.69	0.00	0.96	1.89	0.67
12	214.77	0.00	0.96	1.89	0.67
13	214.88	0.00	0.96	1.94	0.67
14	214.85	0.00	0.96	1.94	0.67

North Interior Line: East to West

Observation	Elevation	MAY'97	JUL'97	SEP'97	JAN'98
2	217.30	1.78	2.25	3.26	3.16
3	216.94	1.52	1.97	2.82	3.40
4	221.66	6.67	6.44	3.06	7.58
5	223.22	8.04	7.87	6.88	8.47
6	222.67	7.78	7.72	9.18	6.14
7	220.03	4.71	4.51	7.85	4.37
8	217.88	2.63	3.01	5.65	4.29
9	218.37	2.95	3.19	4.09	3.89
10	217.59	2.37	2.68	4.04	2.68
11	216.87	1.71	2.20	3.89	1.96
12	216.33	0.93	1.59	2.87	1.55
13	215.21	0.93	1.52	2.28	1.23
14	215.03	0.93	1.01	2.13	1.15
15	214.91	0.93	1.03	1.74	1.03
16	214.82	0.93	0.96	1.94	0.67
17	214.72	0.93	0.96	2.08	0.67
18	214.79	0.93	0.96	1.94	0.67
19	214.80	0.93	0.96	1.74	0.67
20	214.77	0.93	0.96	1.79	0.67
21	214.81	0.93	0.00	1.74	0.67
22	214.60	0.93	0.00	1.74	0.67
23	214.58	0.93	0.00	1.74	0.67

South Interior Line: West to East

Observation	Elevation	MAY'97	JUL'97	SEP'97	JAN'98
2	214.69	0.93	0.00	2.13	0.67
3	214.77	0.93	0.96	1.99	0.67
4	214.76	0.93	0.96	2.33	0.75
5	214.75	0.93	1.11	2.13	0.99
6	215.47	1.06	1.56	2.43	1.71
7	216.08	1.32	2.10	3.11	2.44
8	215.01	0.93	0.96	1.84	1.07
9	215.03	0.93	1.03	2.03	0.91
10	215.03	0.93	1.01	2.03	1.07
11	215.06	0.93	0.96	1.89	1.07
12	215.08	0.93	0.96	1.79	1.27
13	215.22	0.93	0.96	1.99	1.31
14	215.39	0.93	0.96	1.99	1.39
15	215.91	0.93	1.64	2.28	2.04
16	218.43	3.41	3.52	5.51	5.17
17	218.45	3.41	3.57	5.26	5.17
18	218.64	3.60	3.85	4.77	5.33
19	219.82	4.52	4.49	5.12	5.57
20	223.16	8.36	8.25	8.15	9.43
21	224.49	10.06	10.03	9.66	10.72
22	224.26	9.73	9.93	9.52	10.40
23	219.17	4.13	4.36	4.97	5.57
24	215.06	0.93	0.96	2.03	0.75
25	215.08	0.93	0.88	2.03	0.67
26	215.38	0.93	0.83	2.18	0.67