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: 14 October 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

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 water table depths. 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 5 October 1998.

Equipment:
The radar unit is the Subsurface Interface Radar (SIR) System-2, manufactured by Geophysical Survey Systems, Inc.[1] The SIR System-2 consists of a digital control unit (DC-2) with keypad, VGA video screen, and connector panel. A 12-volt battery powered the system. This unit is backpack portable and requires two people to operate. A 200 mHz antenna was used in this study. The scanning time was 190 nanoseconds (ns); the scanning rate was 32 scan/second were used in this survey.

Discussion:
At the time of this survey, the water table was, on average, the lowest that I have observed it. Radar surveys were conducted by pulling the 200 mHz antenna by hand along the four interior traverse lines. The five traverse lines located on roads were accessible by 4WD vehicle. These traverse lines were surveyed with the antenna towed behind the 4WD vehicle.

Water levels at sixteen monitoring wells were measured immediately following the radar survey. Radar traverses were conducted along the two lines containing the monitoring wells. The measured depths were compared with the interpreted depths to the water table. These data were used to confirm the dielectric permittivity and velocity of propagation of electromagnetic energy through the coarse-textured materials. This information was used to depth scale for the radar profiles and predict water table depths at all observation points.

---

[1] Manufacturer's names are provided for specific information; use does not constitute endorsement.

The measured and the interpreted (from radar imagery) depths to the water table at the sixteen monitoring wells (two radar interpretations were made at well 7B) were compared. At these wells, the depth to the water table ranged from 1.37 to 10.14 meters. The coefficient of determination (r2) between the measured depth and interpreted depth was 0.994. At the sixteen wells, differences between measured and interpreted depths to the water table averaged 0.18 m, and ranged from -0.01 to 0.41 m.

Based on the averaged round-trip travel time to the water table, the velocity of propagation was estimated to be 0.1495 m/ns. The dielectric permittivity was estimated to be about 4.0.

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, with a scanning time of 190 ns and velocity of propagation of 0.1495 m/ns, the maximum, theoretical observation depth was about 14.2 m.

Table 1
Summary of Basic Statistics
Jasper County Site

	# of WELL OBS.	MIN. DEPTH	MAX. DEPTH	R2	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
May 1998	16	0.00	8.71	0.986	0.65	0.1242	5.8
Aug. 1998	16	0.78	9.28	0.99	0.18	0.1366	4.8
Oct. 1998	16	1.37	10.14	0.994	0.41	0.1495	4.0

The correlations between observed and interpreted depths to the water table are high (r2 ranged from 0.993 to 0.999). The continued 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 interpreted depth to the water table was 0.65 m (May 1998).

Table 2
Average Predicted Water Table Depth

Month	Depth (m)
May 1997	2.01
July 1997	2.23
September 1997	3.03
January 1998	2.51
May 1998	1.66
August 1998	2.49
October 1998	3.24

Velocity of propagation varied with the time of the year and the antenna used. Velocities, though rather uniform, varied from 0.1190 to 0.1465 m/ns. Differences are principally dependent on changes in soil moisture contents within the surface layers. Within the study site, the dielectric permittivity of the sandy soil materials above the water table ranged from 4.2 to 6.6. These permittivities conform to tabled values for dry sands.

Temporal fluctuations in the water table can be summarized by averages. Based on GPR interpretations, the average predicted water table depth for the study site are shown in Table 2.

Summary:

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 have been forwarded to Byron Jenkinson under a separate cover letter.

2. Byron Jenkinson will present the results of this study next week at the Annual Meeting of the American Society of Agronomy in Baltimore, Maryland.

3. The next radar survey will be conducted in January or February 1999.

With kind regards,

James A. Doolittle
Research Soil Scientist

cc:

J. Culver, Acting Director, 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

C. Olson, National Leader, Soil Survey Investigations, 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.

The water table is not always discernible at shallow soil depths. In May 1997, the water table was not discernible within depths of 0.93 m of the surface. In July 1997, the water table was not discernible within depths of 0.96 m of the surface. In September 1997, the water table was observable at all observation points. In January 1998, the water table could not be seen within depths of 0.67 m of the soil surface. In May 1998, the water table could not be interpreted within depths of 0.38 m of the soil surface. Ponded conditions are represented as 0.02 m. In August and October 1998, the water table was observable at all observation points.

		Y	X		May-97	Jul-97	Sept.-97	Jan-98	May-98	Aug-98	Oct-98
		NORTHING	EASTING	ELEV.	Predicted	Predicted	Predicted	Predicted	Predicted	Predicted	Predicted
LINE 3		MID-N/S ROAD									
S	1	4555853	501391	214.89	0.93	1.08	1.89	1.23	0.38	1.25	1.79
	2	4555820	501391	214.76	0.93	1.03	1.74	1.23	0.38	1.25	1.63
	3	4555787	501391	214.81	0.93	1.03	1.74	1.31	0.38	1.32	1.87
	4	4555754	501390	214.86	0.93	1.13	1.74	1.31	0.38	1.32	2.04
	5	4555720	501389	215.43	0.93	1.11	1.99	1.31	0.5	1.44	2.36
	6	4555686	501387	215.47	0.93	1.11	2.23	1.31	1.34	1.32	2.52
	7	4555652	501386	215.96	1.32	1.84	2.43	2.28	0.98	2.33	2.77
	8	4555618	501386	215.02	0.93	1.52	2.28	1.71	0.92	1.79	2.36
	9	4555585	501385	215.04	0.93	1.31	1.99	1.63	0.38	1.63	2.60
	10	4555552	501384	215.01	0.93	1.03	1.79	0.99	0.38	1.21	1.87
	11	4555519	501383	214.92	0.93	0.96	2.03	0.91	0.38	1.09	1.71
	12	4555487	501382	214.82	0.93	0.96	1.89	0.67	0.38	0.93	1.71
N	13	4555470	501382	214.79	0.93	0.96	1.79	0.67	0.62	1.01	1.71

		Y NORTHING	X EASTING	ELEV.	May-97 Predicted	Jul-97 Predicted	Sept.-97 Predicted	Jan-98 Predicted	May-98 Predicted	Aug-98 Predicted	Oct-98 Predicted
LINE 4		NORTH-E/W ROAD									
EAST	1	4555851	501778	215.41	0	0.96	2.03	0.59	0.38	0.86	2.12
	2	4555848	501746	216.26	1.85	2.2	3.31	2.32	1.4	2.57	3.01
	3	4555848	501683	218.51	3.47	3.65	3.94	5.09	3.19	4.43	5.77
	4	4555849	501651	218.15	3.15	3.12	4.48	4.61	2.89	4.2	4.63
	5	4555850	501617	217.39	2.43	2.45	3.7	3.56	2.29	3.34	3.74
	6	4555850	501584	215.95	1.58	1.64	2.52	1.55	1.16	1.63	2.68
	7	4555851	501552	215.44	0.93	1.16	1.99	1.39	0.68	1.32	2.28
	8	4555852	501509	215.59	1	1.54	2.13	1.55	0.74	1.59	2.60
	9	4555852	501489	214.91	0.93	0.96	1.74	0.95	0.38	1.01	1.95
	10	4555853	501456	214.72	0.93	0.96	1.79	0.71	0.38	0.93	1.71
	11	4555854	501423	214.99	0.93	0.96	1.89	0.67	0.38	1.17	1.63
	12	4555854	501391	214.89	0.93	0.96	1.79	0.67	0.38	1.01	1.71
	13	4555854	501366	215.01	0.93	0.96	1.89	0.59	0.38	1.25	2.28
	14	4555856	501336	214.89	0.93	0.96	1.89	0.71	0.38	1.09	1.95
	15	4555857	501306	214.98	0.93	0.96	2.08	0.71	0.38	1.25	2.04
	16	4555857	501277	214.88	0.93	0.96	1.74	0.71	0.38	1.25	1.63
	17	4555858	501247	214.94	0.93	0.96	1.84	0.71	0.38	1.09	1.87
	18	4555859	501217	214.9	0.93	0.96	1.79	0.67	0.38	1.17	2.20
	19	4555861	501181	215	1.13	1.2	2.38	1.55	0.38	1.4	3.90
	20	4555861	501155	217.53	1.78	1.99	3.75	4.45	2.71	2.88	7.55
	21	4555861	501125	222.07	6.99	6.75	7.02	7.66	6.48	7.46	8.36
	22	4555861	501114	223.03	7.78	7.79	8.15	8.47	7.37	8.01	9.01
	23	4555862	501101	223.21	7.19	7.21	7.66	8.87	7.43	8.47	8.45
	24	4555862	501093	222.89	6.15	6.12	6.49	8.55	6	7.85	7.07
	25	4555863	501060	221.28	4.26	4.33	5.21	7.26	4.56	6.61	5.77
W	26	4555863	501030	219.71	2.82	2.86	3.75	6.14	2.83	5.6	3.74

		Y	X		May-97	Jul-97	Sept.-97	Jan-98	May-98	Aug-98	Oct-98
		NORTHING	EASTING	ELEV.	Predicted	Predicted	Predicted	Predicted	Predicted	Predicted	Predicted
LINE 3		WEST-N/S ROAD									
N	1	4555862	501000	217.44	2.82	2.84	3.6	3.72	2.83	3.27	3.74
	2	4555843	500999	218.61	3.87	3.75	4.58	4.69	3.79	4.82	4.88
	3	4555828	500999	218.78	4.06	3.77	4.63	4.85			
	4	4555811	500999	218.37	4.52	4.72	5.36	5.82	4.27	4.51	4.88
	5	4555780	500998	218.9	5.56	6.19	6.73	7.42	5.64	5.29	5.93
	6	4555749	500996	219.82	3.87	3.87	4.68	5.01	3.85	7.07	7.72
	7	4555719	500995	218.08	2.56	2.68	3.45	3.56	2.53	4.59	5.04
	8	4555695	500994	216.5	2.63	3.04	3.75	3.81	2.65	3.11	3.58
	9	4555676	500993	216.76	1.13	1.84	2.52	2.04	1.16	3.58	4.23
	10	4555655	500993	215.01	0.93	1.18	1.99	1.15	0.38	2.02	2.68
	11	4555624	500991	214.25	0.93	1.2	2.03	0.91	0.38	1.25	2.36
	12	4555593	500991	214.1	0.93	0.96	2.18	0.67	0.38	1.01	1.71
	13	4555562	500990	214.11	0.93	0.96	1.99	6.3	0.38	1.09	1.63
	14	4555531	500988	213.97	0.93	0.96	1.99	0.67	0.38	0.93	1.63
	15	4555500	500987	214.07	0.93	0.96	1.99	0.67	0.38	0.93	1.71
S	16	4555472	500986	213.84	0.93		1.99	0.67	0.38	0.78	1.63

		Y NORTHING	X EASTING	ELEV.	May-97 Predicted	Jul-97 Predicted	Sept.-97 Predicted	Jan-98 Predicted	May-98 Predicted	Aug-98 Predicted	Oct-98 Predicted
LINE 4		SOUTH-E/W ROAD									
W	1	4555472	500986	213.84	0.93	0.96	1.99	0.67	0.38	0.78	1.63
	2	4555470	501010	214.26	0.93	0.96	1.74	0.91	0.38	1.17	1.71
	3	4555468	501040	214.29	0.93	0.96	1.79	0.91	0.38	1.01	1.71
	4	4555466	501071	214.71	0.93	1.36	2.28	1.31	0.38	1.56	2.36
	5	4555464	501102	214.88	0.93	1.61	2.43	1.79	0.38	1.71	2.44
	6	4555462	501133	215.28	1.58	1.92	2.67	2.2	1.34	2.49	3.09
	7	4555460	501162	217.72	3.67	3.55	4.38	4.85	3.25	4.28	4.96
	8	4555458	501192	217.78	3.54	3.85	4.72	5.09	3.13	4.59	5.12
	9	4555456	501222	214.8	1	1.16	2.38	1.55	0.74	1.71	2.77
	10	4555454	501252	214.66	0.93	1.16	2.08	1.31	0.38	1.4	2.68
	11	4555452	501283	214.58	0.93	1.11	1.79	1.03	0.38	1.17	1.95
	12	4555450	501313	214.6	0.93	1.06	1.84	0.95	0.38	1.17	1.87
	13	4555448	501344	214.57	0.93	1.08	1.79	0.91	0.38	1.17	1.79
	14	4555447	501373	214.72	0.93	1.08	1.89	1.23	0.38	1.25	1.79
	15	4555445	501404	214.92	1	1.31	2.08	1.31	0.68	1.4	1.95
	16	4555443	501435	215.75	1.45	1.82	2.62	2.12	1.4	2.02	2.60
	17	4555442	501466	215.82	1.45	1.99	2.67	2.36	1.52	2.26	2.77
	18	4555441	501497	217.45	3.08	3.12	3.89	3.89	2.89	3.65	4.06
	19	4555438	501528	219.34	5.36	5	5.75	6.22	4.68	5.52	6.01
	20	4555436	501559	220.97	6.99	7	7.37	7.99	6.78	7.38	7.80
	21	4555433	501590	216.87	2.17	2.61	3.8	4.37	2.18	3.34	4.06
	22	4555431	501622	215.9	1.52	2.12	2.87	2.6	1.58	2.64	3.33
	23	4555428	501652	214.73	1	1.38	2.13	1.31	0.62	1.48	2.93
	24	4555427	501682	214.34	0.93	0.96	1.99	0.99	0.38	0.93	2.20
	25	4555425	501712	214.43	0.93	0.96	1.94	0.63	0.38	0.78	1.79
	26	4555423	501742	214.31	0.93	0.96	1.89	0.59	0.38	0.78	1.87
E	27	4555421	501778	214.5	0.93	0.96	1.74	0.59	0.8	0.78	1.79

		Y NORTHING	X EASTING	ELEV.	May-97 Predicted	Jul-97 Predicted	Sept.-97 Predicted	Jan-98 Predicted	May-98 Predicted	Aug-98 Predicted	Oct-98 Predicted
LINE 5		EAST-N/S ROAD									
S	1	4555421	501778	214.5	0.93	0.96	1.74	0.59	0.38	0.78	1.79
	2	4555439	501780	214.29	0.93	0.96	1.79	0.67	0.38	0.86	1.79
	3	4555470	501784	214.34	0.93	0.96	1.79	0.67	0.38	0.86	1.87
	4	4555501	501787	214.59	0.93	1.01	1.89	0.67	0.38	0.78	1.79
	5	4555531	501791	214.69	0.93	1.36	1.79	0.63	0.38	1.17	1.87
	6	4555561	501794	214.64	0.93	0.96	1.79	0.67	0.38	0.93	1.71
	7	4555591	501797	214.68	0.93	0.96	1.79	0.67	0.38	0.86	1.87
	8	4555621	501799	214.72	0.93	0.96	1.74	0.67	0.38	0.86	1.87
	9	4555653	501802	214.85	0.93	0.96	1.79	0.67	0.38	0.78	2.04
	10	4555685	501807	214.71	0	0.96	1.84	0.67	0.02	0.86	1.95
	11	4555716	501809	214.69	0	0.96	1.89	0.67	0.02	0.86	1.95
	12	4555745	501812	214.77	0	0.96	1.89	0.67	0.02	0.78	1.95
	13	4555776	501815	214.88	0	0.96	1.94	0.67	0.02	0.62	2.04
N	14	4555807	501818	214.85	0	0.96	1.94	0.67	0.02	0.62	2.12

		Y NORTHING	X EASTING	ELEV.	May-97 Predicted	Jul-97 Predicted	Sept.-97 Predicted	Jan-98 Predicted	May-98 Predicted	Aug-98 Predicted	Oct-98 Predicted
LINE 6		INTERIOR-E/W LINE(N)									
E	1	4555653	501802	214.85	0.93	0.96	2.72		2.23	3.5	4.31
	2	4555701	501719	217.3	1.78	2.25	3.26	3.16	2.06	3.03	3.90
	3	4555702	501687	216.94	1.52	1.97	2.82	3.4	1.88	2.88	3.66
	4	4555704	501655	221.66	6.67	6.44	3.06	7.58	1.88	7.15	7.55
	5	4555704	501640	223.22	8.04	7.87	6.88	8.47	7.07	7.85	8.28
	6	4555704	501620	222.67	7.78	7.72	9.18	6.14	8.03	7.93	8.36
	7	4555705	501587	220.03	4.71	4.51	7.85	4.37	7.37	5.6	6.17
	8	4555706	501554	217.88	2.63	3.01	5.65	4.29	4.39	3.42	3.98
	9	4555709	501523	218.37	2.95	3.19	4.09	3.89	2.18	3.89	4.39
	10	4555711	501491	217.59	2.37	2.68	4.04	2.68	2.65	3.65	4.06
	11	4555714	501455	216.87	1.71	2.2	3.89	1.96	2.12	2.49	2.93
	12	4555717	501421	216.33	0.93	1.59	2.87	1.55	1.58	1.79	2.52
	13	4555720	501352	215.21	0.93	1.52	2.28	1.23	1.1	1.94	2.68
	14	4555720	501319	215.03	0.93	1.01	2.13	1.15	0.86	1.25	2.12
	15	4555723	501286	214.91	0.93	1.03	1.74	1.03	0.38	0.86	1.71
	16	4555722	501254	214.82	0.93	0.96	1.94	0.67	0.38	1.01	1.63
	17	4555721	501228	214.72	0.93	0.96	2.08	0.67	0.38	1.01	1.63
	18	4555719	501196	214.79	0.93	0.96	1.94	0.67	0.38	1.01	1.63
	19	4555717	501155	214.8	0.93	0.96	1.74	0.67	0.38	0.78	1.71
	20	4555716	501122	214.77	0.93	0.96	1.79	0.67	0.02	0.78	1.71
	21	4555716	501092	214.81	0.93		1.74	0.67	0.38	0.86	1.87
	22	4555708	501063	214.6	0.93		1.74	0.67	0.38	1.01	2.44
	23	4555661	501044	214.58	0.93		1.74	0.67	0.38	1.01	2.20
W	24	4555695	500994	216.5	2.63	3.04	2.18		2.53	0.86	2.04

		Y	X		May-97	Jul-97	Sept.-97	Jan-98	May-98	Aug-98	Oct-98
		NORTHING	EASTING	ELEV.	Predicted	Predicted	Predicted	Predicted	Predicted	Predicted	Predicted
LINE 7		INTERIOR-E/W LINE(S)									
W	1	4555593	500991	214.1	0.93	0.96	1.99		0.2		
	2	4555595	501031	214.69	0.93		2.13	0.67	0.38	0.86	2.12
	3	4555589	501059	214.77	0.93	0.96	1.99	0.67	0.38	1.25	2.12
	4	4555589	501089	214.76	0.93	0.96	2.33	0.75	0.38	1.01	2.12
	5	4555588	501120	214.75	0.93	1.11	2.13	0.99	0.38	1.25	1.87
	6	4555588	501138	215.47	1.06	1.56	2.43	1.71	0.92	1.87	2.60
	7	4555587	501154	216.08	1.32	2.1	3.11	2.44	1.7	2.41	3.33
	8	4555586	501188	215.01	0.93	0.96	1.84	1.07	0.38	1.32	2.36
	9	4555585	501221	215.03	0.93	1.03	2.03	0.91	0.38	1.25	2.12
	10	4555584	501252	215.03	0.93	1.01	2.03	1.07	0.38	1.17	1.95
	11	4555583	501285	215.06	0.93	0.96	1.89	1.07	0.38	1.17	2.20
	12	4555582	501316	215.08	0.93	0.96	1.79	1.27	0.38	1.17	2.12
	13	4555586	501350	215.22	0.93	0.96	1.99	1.31	0.38	1.25	2.12
	14	4555591	501382	215.39	0.93	0.96	1.99	1.39	0.38	1.17	2.36
	15	4555597	501416	215.91	0.93	1.64	2.28	2.04	0.98	1.79	2.85
	16	4555603	501453	218.43	3.41	3.52	5.51	5.17	3.07	5.99	5.12
	17	4555606	501485	218.45	3.41	3.57	5.26	5.17	3.07	4.28	4.96
	18	4555608	501517	218.64	3.6	3.85	4.77	5.33	3.13	4.51	5.20
	19	4555610	501550	219.82	4.52	4.49	5.12	5.57	4.21	4.98	5.52
	20	4555612	501582	223.16	8.36	8.25	8.15	9.43	7.79	8.47	9.01
	21	4555614	501602	224.49	10.06	10.03	9.66	10.72	8.75	10.18	10.64
	22	4555615	501615	224.26	9.73	9.93	9.52	10.4	8.87	10.03	9.99
	23	4555618	501646	219.17	4.13	4.36	4.97	5.57	3.91	4.98	5.52
	24	4555611	501676	215.06	0.93	0.96	2.03	0.75	0.38	0.93	2.04
	25	4555616	501707	215.08	0.93	0.88	2.03	0.67	0.02	0.86	2.04
	26	4555607	501737	215.38	0.93	0.83	2.18	0.67	0.38	0.78	1.79