United States Department of Agriculture	**Natural Resources Conservation Service**	**11 Campus Boulevard Suite 200 Newtown Square, PA 19073**

Subject: SOI -- Ground-Penetrating Radar Assistance **Date:** February 28, 2001

To: Richard D. Babcock
State Conservationist
USDA, NRCS
Federal Building
2 Madbury Road
Durham, NH 03824-2043

PURPOSE:
The purpose of this study was to use ground-penetrating radar (GPR) to help characterize the depth of organic materials and the composition of soil map units within peatlands.

PARTICIPANTS:
Jim Doolittle, Research Soil Scientist, NRCS, Newtown Square, PA
Karen H. Dudley, Soil Scientist, USDA-NRCS, Concord, NH
Steven J. Hundley, State Soil Scientist, USDA-NRCS, Durham, NH
Don Keirstead, WAE Soil Scientist, USDA-NRCS, Concord, NH
Don Richard, GIS Specialist, USDA-NRCS, Concord, NH
Kathy Swain, Soil Specialist Database, USDA-NRCS, Concord, NH
Peter B. Whitcomb, Soil Survey Project Leader, USDA-NRCS, Concord, NH

ACTIVITIES:
All field activities were completed during the period of 12 to 15 February 2001.

STUDY SITES:
All study sites were in bogs located within southern Merrimack County, New Hampshire. The bogs were located in areas that have been mapped as part of the update of Merrimack County. These bogs are in areas that have been mapped as Greenwood mucky peat (M.U. 295), Chocorua mucky peat (M.U. 395), or Greenwood and Ossippee soils, ponded (M.U. 97). The Greenwood series consists of very deep, very poorly drained soils formed in organic deposits more than 51 inches thick. The Greenwood series is a member of the dysic, frigid Typic Haplohemists family. The Chocorua and Ossippee series consist of very deep, very poorly drained soils formed in organic accumulations. Chocorua soils are underlain by stratified sand and gravel. Loamy sediments underlie Ossippee soils. The Chocorua series is a member of the sandy or sandy-skeletal, mixed, dysic, frigid Terric Haplohemists family. The Ossippee series is a member of the loamy, mixed, dysic, frigid Terric Haplohemists family.

Site 1 is an area of Chocorua mucky peat that is located on Bog Road in Concord Township. Shallow depths to the organic/mineral interface, poor resolution of subsurface features, and multiple bands of background noise plagued radar profiles at Site 1. As a consequence, only a portion of the radar data was interpretable and documented in this report. Site 2 is an area of Greenwood mucky peat that is located along Swamp Road in New Rye. Site 3 is an area of Greenwood mucky peat and Greenwood and Ossippee soils, ponded that is located in Bear Brook State Park in Allenstown Township. Site 4 is an area of Greenwood mucky peat located along State Road 129 about 2 miles north of Loudon. Site 5 (Lola Reese's property) is an area of Greenwood and Ossippee soils, ponded located along State Road 129 about 1.2 miles southwest of Loudon. A stream passes through Site 5 and has deposited multiple layers of mineral soil materials. The organic/mineral soil interface could not be reliably traced laterally across Site 5, and most of the radar files are not documented in this report. Sites 6 is in area of Greenwood and Ossippee soils, ponded near Crooked Pond on Bear Hill Road. A detailed GPR survey was conducted at this bog and two- and three-dimensional plots were prepared from the collected data. Site 7 is in an area of Greenwood and Ossippee soils, ponded located along State Road 129. This bog is in close proximity to Site 5. Site 8 is an area Chocorua mucky peat along US

Highway 4 near Boscawen (Jim Colby's Tree Farm). Site 9 is an area Greenwood mucky peat along US Highway 4 near Joe Colby's Tree Farm in Boscawen.

MATERIALS AND METHODS

Equipment:

The radar unit is the Subsurface Interface Radar (SIR) System-2000, manufactured by Geophysical Survey Systems, Inc.[1] Morey (1974), Doolittle (1987), and Daniels (1996) have discussed the use and operation of GPR. The SIR System-2000 consists of a digital control unit (DC-2000) with keypad, VGA video screen, and connector panel. A 12-volt battery powered the system. This unit is backpack portable and, with an antenna, requires two people to operate. A 70 MHz antenna was used in this study. The 70 MHz antenna was graciously loaned to us from Geophysical Survey Systems, Inc. of North Salem, New Hampshire. A scanning time of 340 ns were used with the 70 MHz antenna. The scanning rate was 32 scan/second.

Field Methods:

Areas of organic soils are considered most crossable for soil transects work during winter months when the upper part of the soil is frozen. However, as witnessed during this survey, a deep snow cover makes radar work impractical without snowshoes. A heavy snowstorm occurred during the preceding week. Melting and rains during the ensuing week had compacted the snow and facilitated the use of snowshoes.

Radar traverses were conducted across each study site. Along most traverse line, observation points were spaced at an interval of about 50 feet. At Site 6, because of the small size of the delineation, observation points were spaced at intervals of 10 to 15 feet. As the study was conducted through wooded areas, all traverses were completed with the GPR control unit carried in a backpack and the antenna carried by hand. As the antenna passed each observation point, the operator impressed a dashed vertical line on the radar record.

The location of observation points and the upland boundary of the bog at Site 6 were obtained with Rockwell Precision Lightweight GPS Receivers (PLGR).[1] The receiver was operated in the continuous and the mixed satellite modes. The Universal Transverse Mercator (UTM) and the Latitude/Longitude coordinate systems were used. Horizontal datum is the North American 1983. For UTM, horizontal units are expressed in meters.

CALIBRATION OF GPR

Ground-penetrating radar measures the time it takes electromagnetic energy to travel from an antenna to an interface (i.e., soil horizon, water table, stratigraphic layer) and back. To convert travel time to depth requires knowledge of the velocity of pulse propagation. Several methods are available to determine the velocity of propagation. These methods include use of table values, common midpoint calibration, and calibration over a target of known depth. The last method is considered the most direct and accurate method to estimate propagation velocity (Conyers and Goodman, 1997). The procedure involves measuring the two-way travel time to a known reflector on the radar profile and calculating the propagation velocity by the following equation (after Morey, 1974):

$$V = 2D/T \qquad [1]$$

Equation [1] describes the relationship of the average propagation velocity (V) to the depth (D) and two-way pulse travel time (T) to a reflector. At eight sampling points, the two-way radar pulse travel time was compared to the measured depth to the organic/mineral interface and used with equation [1] to estimate the velocity of propagation. The measured depth to the organic/mineral interface ranged from 0.66 to 1.3 meters. It would have been preferable if several observations had been made to greater depths. However, the depth of observation was limited to a six-foot auger.

The estimated velocity of propagation determined at each observation point is shown in Table 1. The velocity of propagation and the dielectric permittivity (E_r) were variable among the sampling points. The calculated velocity ranged from 0.039 m/ns to 0.049 m/ns at the eight points. The estimated dielectric permittivity ranged from 38 to 58.

---

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

To interpret the depth to the organic/mineral interface at all
observation points, a predictive equation based on the depth and the two-way travel times to the organic/mineral interface was developed. The measured depth and the two-way travel time to the organic/mineral interface at the eight sampling points were compared. A strong relationship (r = 0.95) was found to exist between the two-way travel time of the radar pulse and the measured depth to this interface. A least square line was fitted to the data and used to predict the depth to organic/mineral interface at all observation points. The predictive equation used during this investigation is:

$$D = -0.0795 + (0.0241*T) \qquad [2]$$

Where D is the depth and T is the two-way travel time to the organic/mineral interface.

At the eight sampling points, using equation [2] and the two-way travel time the average difference between the measured and the predicted depth to the organic/mineral interface was 0.07 m with a range of -0.10 to 0.09 m (see residuals in Table 1).

Table 1 – Basic Statistics for the Sampling Points. The velocity of propagation (V) was determined using the two-way travel time (T), the measured depth to the organic/mineral interface, and equation [1]. Velocity is expressed in m/ns. The dielectric permittivity (E_r) of the organic layers was determined from the equation $E_r = (0.296/V)^2$ (after Morey, 1974).

Measured				**Predicted**	
Depth (m)	**T**	**V**	**Er**	**Depth (m)**	**Residuals**
1.30	54.6	0.048	40	1.24	0.06
1.30	54.6	0.048	40	1.24	0.06
0.66	33.6	0.039	58	0.73	-0.07
0.79	37.8	0.042	51	0.83	-0.04
0.94	38.6	0.049	38	0.85	0.09
1.12	53.9	0.042	52	1.22	-0.10
0.86	42.2	0.041	54	0.94	-0.08
0.73	30.5	0.048	39	0.66	0.07

RESULTS

Twenty-two transects were completed with GPR. However, three transects and portions of another were discarded because of the poor interpretative quality of the radar profiles. The remaining nineteen transects provided a total of 376 observations. The average thickness of the organic deposits was about 2.48 m, with an range of 0.56 to 8.12 m. On half of the observations had organic materials between 1.33 to 3.05 m thick. A recorded depth of 8.12 m represents the maximum depth of penetration with the 70 MHz antenna and a scanning time of 340 ns. Because of this factor, a recorded depth of 8.12 m at an observation point signifies that the depth to the organic/mineral interface was equal to or (most likely) greater than 8.12 m.

Table 2 shows the frequency distribution of peat thickness along each radar traverse. The critical depth of 1.3 m separates the Terric from the Typic taxonomic subgroups. With the exception of map unit 395, Chocorua mucky peat, peatlands are predominantly composed of soils with organic layers greater than 1.3 m (51 inches) thick. Table 3 lists the interpreted depth to the organic/mineral soil interface at each observation point. The coordinates (latitude and longitude) of each observation point are also given in Table 3.

A detailed investigation was conducted at Site 6. The purpose of this investigation was to prepare two- and three-dimensional plots and determine the volume of this small area organic soil that had been mapped as Greenwood and Ossippee soils, ponded. Similar plots can be easily prepared for wetland classification, mitigation, and carbon sequestration studies.

The survey required less than one hour to complete. Forty-six radar observations points were obtained within the bog. The coordinates of an additional 38 reference points defined the outline of the bog. The average thickness of organic materials within the bog is about 2.2 m with an range of 0.79 to 4.95m. One-half the observations had organic materials between 1.25 and 3.05 m thick.

The GPR data from Bog 6 were processed through the Surfer7 program developed by Golden Software, Inc. [2.] Figure 1 contains two and three-dimensional simulations of the bog. The bog contains two deeper kettle holes. It has an area of about 21,450 square m (about 5.3 acres) and a volume of 6,321 cubic meters. Taxonomically, the bog is 70 % Typic Haplohemist and 30 % Terric Haplohemist.

CONCLUSIONS:

1. Transect work is infrequently carried out in areas of organic soils because of wet and often ponded soil conditions that provides poor footing and little support to soil scientists. This field study provided an excellent learning experience for the handling of GPR surveys in peatlands during winter months. Fieldwork demonstrates the utility of using snowshoes. With good snowshoes, the speed and quantity of data increased greatly. Based on the accomplishments of this survey, additional GPR surveys of peatlands are encouraged in ensuing years.

2. Nineteen transects were completed with GPR. These transects provided a total of 376 observations. The average thickness of the organic deposits was about 2.48 m, with an interpreted range of 0.56 to 8.12 m. Data listed in Tables 2 and 3 can be used by soil scientists to document the composition of map units within Merrimack County, New Hampshire.

3. The 70 MHz antenna, which was graciously loaned to the USDA-NRCS by Geophysical Survey Systems, Inc. (North Salem, NH), was immeasurably easier to operate and provide superior penetration depths than the 120 MHz. Based on this study, the 70 MHz antenna is considered highly suitable for the determinations of organic thickness. Without this antenna, fieldwork would be decidedly more arduous, requiring more people and producing less data. This antenna should be well suited to bedrock, geomorphic and stratigraphic investigation. It is recommended that the National Soil Survey Center purchase a 70 MHz antenna.

4. The survey party is commended for their fine organization, preparation, and management of this field study.

It was my pleasure to work in New Hampshire and with members of your fine staff.

With kind regards,

James A. Doolittle
Research Soil Scientist

cc:
R. Ahrens, Director, USDA-USDA, National Soil Survey Center, Federal Building, Room 152,100 Centennial Mall North, Lincoln, NE 68508-3866
S. J. Hundley, State Soil Scientist, USDA-NRCS, Federal Building, 2 Madbury Road, Durham, NH 03824-2043
C. Olson, National Leader for Soil Investigations, USDA-USDA, National Soil Survey Center, Federal Building, Room 152,100 Centennial Mall North, Lincoln, NE 68508-3866
H. Smith, Director of Soils Survey Division, USDA-NRCS, Room 4250 South Building, 14th & Independence Ave.

[2.] Trade names have been used to provide specific information and do not constitute endorsement by the authors.

SW, Washington, DC 20250
B. Thompson, MO Team Leader, USDA-NRCS, 451 West Street, Amherst, MA 01002-2995
P. Whitcomb, USDA-NRCS, The Concord Center, 10 Ferry Street, Box 312, Concord, NH 03301-5081

References

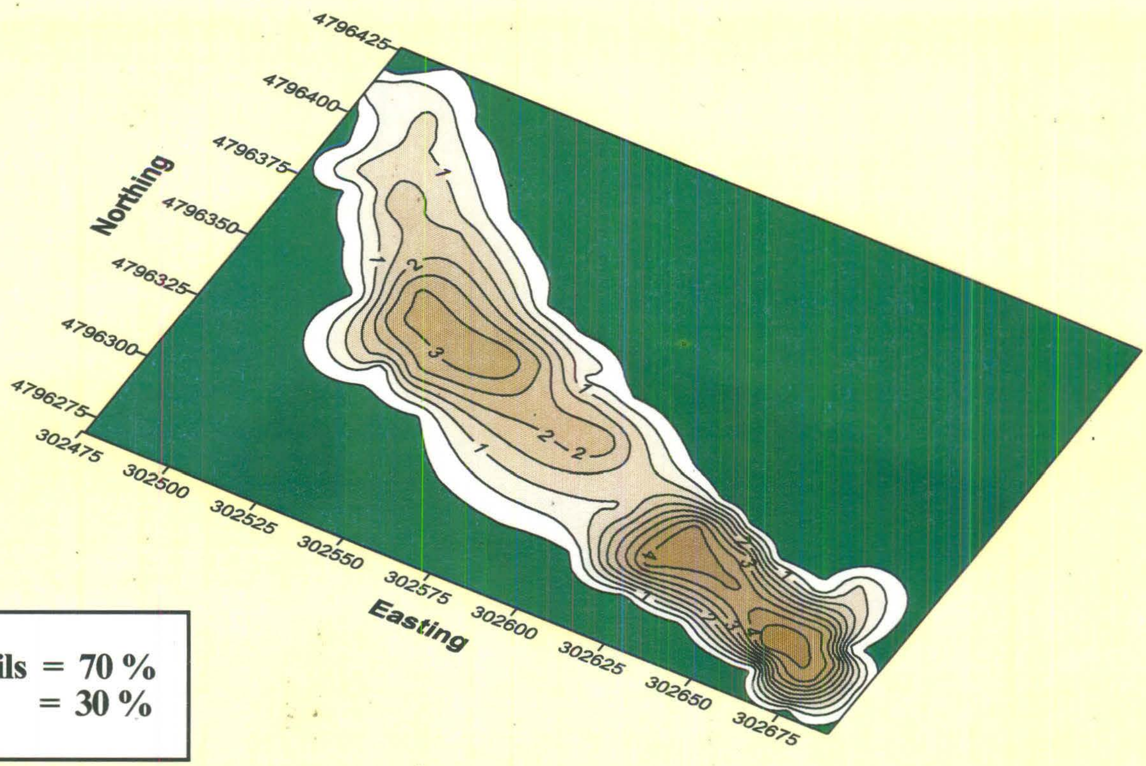
Conyers, L. B., and D. Goodman. 1997. Ground-penetrating Radar; An introduction for archaeologists. AltaMira Press, Walnut Creek, CA. 232 pp.

Daniels, D. J. 1996. Surface-Penetrating Radar. The Institute of Electrical Engineers, London, United Kingdom. 300 p.

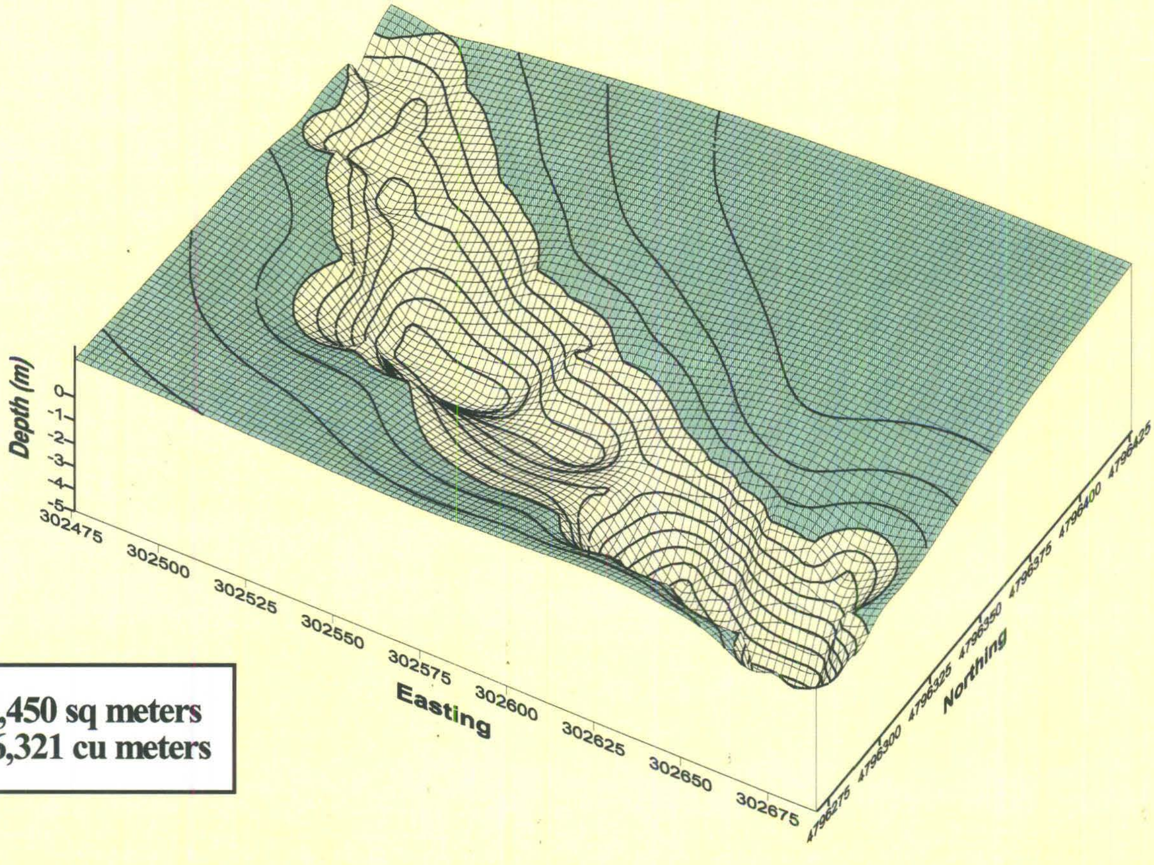
Doolittle, J. A. 1987. Using ground-penetrating radar to increase the quality and efficiency of soil surveys. pp. 11-32. In: Reybold, W. U. and G. W. Peterson (eds.) Soil Survey Techniques, Soil Science Society of America. Special Publication No. 20. p. 98

Morey, R. M. 1974. Continuous subsurface profiling by impulse radar. pp. 212-232. IN: Proceedings, ASCE Engineering Foundation Conference on Subsurface Exploration for Underground Excavations and Heavy Construction, held at Henniker, New Hampshire. Aug. 11-16, 1974.

Thickness and Subsurface Topography of Organic Deposits within a Bog located in Merrimack County, New Hampshire



Greenwood soils = 70 %
Ossippee soils = 30 %



Area = 21,450 sq meters
Volume = 6,321 cu meters

Table 2

Frequency Distribution of Organic Soil Material Thickness by Soil Map Unit
(All depths are in meters; "#" signifies number of observations)

Soil Map Unit 97 - Greenwood and Ossipee soils, ponded

File#15 M.U. 97

Depth	#	frequency	
0 to 1.3	3	0.33	terric
1.3 to 2	6	0.67	
2 to 4	0	0.00	
4 to 6	0	0.00	
6 to 8	0	0.00	
>8	0	0.00	
SUM	9		

File#24 M.U. 97

Depth	#	frequency	
0 to 1.3	14	0.30	terric
1.3 to 2	12	0.26	
2 to 4	13	0.28	
4 to 6	7	0.15	
6 to 8	0	0.00	
>8	0	0.00	
SUM	46		

File#28 M.U. 97

Depth	#	frequency	
0 to 1.3	6	0.13	terric
1.3 to 2	10	0.22	
2 to 4	12	0.26	
4 to 6	14	0.30	
6 to 8	1	0.02	
>8	3	0.07	
SUM	46	0.00	

File#26 M.U. 97

Depth	#	frequency	
0 to 1.3	1	0.08	terric
1.3 to 2	2	0.17	
2 to 4	6	0.50	
4 to 6	3	0.25	
6 to 8	0	0.00	
>8	0	0.00	
SUM	12		

File#29 M.U. 97

Depth	#	frequency	
0 to 1.3	1	0.04	terric
1.3 to 2	4	0.15	
2 to 4	12	0.46	
4 to 6	6	0.23	
6 to 8	3	0.12	
>8	0	0.00	
SUM	26		

Table 2 (continued)

Frequency Distribution of Organic Soil Material Thickness by Soil Map Unit
(All depths are in meters; "#" signifies number of observations)

Soil Map Unit 295 - Greenwood mucky peat

File#12 M.U. 295

Depth	#	frequency	
0 to 1.3	4	0.27	terric
1.3 to 2	0	0.00	
2 to 4	1	0.07	
4 to 6	4	0.27	
6 to 8	3	0.20	
>8	3	0.20	
SUM	15		

File#13 M.U. 295

Depth	#	frequency	
0 to 1.3	1	0.14	terric
1.3 to 2	1	0.14	
2 to 4	1	0.14	
4 to 6	1	0.14	
6 to 8	2	0.29	
>8	1	0.14	
SUM	7		

File#14 M.U. 295

Depth	#	frequency	
0 to 1.3	2	0.25	terric
1.3 to 2	3	0.38	
2 to 4	3	0.38	
4 to 6	0	0.00	
6 to 8	0	0.00	
>8	0	0.00	
SUM	8		

File#16 M.U. 295

Depth	#	frequency	
0 to 1.3	2	0.15	terric
1.3 to 2	11	0.85	
2 to 4	0	0.00	
4 to 6	0	0.00	
6 to 8	0	0.00	
>8	0	0.00	
SUM	13		

File#17 M.U. 295

Depth	#	frequency	
0 to 1.3	5	0.42	terric
1.3 to 2	4	0.33	
2 to 4	3	0.25	
4 to 6	0	0.00	
6 to 8	0	0.00	
>8	0	0.00	
SUM	12		

File#20 M.U. 295

Depth	#	frequency	
0 to 1.3	1	0.05	terric
1.3 to 2	16	0.76	
2 to 4	4	0.19	
4 to 6	0	0.00	
6 to 8	0	0.00	
>8	0	0.00	
SUM	21		

File#21 M.U. 295

Depth	#	frequency	
0 to 1.3	1	0.04	terric
1.3 to 2	6	0.23	
2 to 4	19	0.73	
4 to 6	0	0.00	
6 to 8	0	0.00	
>8	0	0.00	
SUM	26		

File#22 M.U. 295

Depth	#	frequency	
0 to 1.3	10	0.48	terric
1.3 to 2	5	0.24	
2 to 4	4	0.19	
4 to 6	0	0.00	
6 to 8	2	0.10	
>8	0	0.00	
SUM	21		

Table 2 (continued)
Frequency Distribution of Organic Soil Material Thickness by Soil Map Unit
(All depths are in meters; "#" signifies number of observations)

Soil Map Unit 295 - Greenwood mucky peat

File#23 M.U. 295

Depth	#	frequency	
0 to 1.3	1	0.03	terric
1.3 to 2	7	0.19	
2 to 4	28	0.78	
4 to 6	0	0.00	
6 to 8	0	0.00	
>8	0	0.00	
SUM	36		

File#31 M.U. 295

Depth	#	frequency	
0 to 1.3	2	0.13	terric
1.3 to 2	12	0.80	
2 to 4	1	0.07	
4 to 6	0	0.00	
6 to 8	0	0.00	
>8	0	0.00	
SUM	15		

File#32 M.U. 295

Depth	#	frequency	
0 to 1.3	1	0.17	terric
1.3 to 2	5	0.83	
2 to 4	0	0.00	
4 to 6	0	0.00	
6 to 8	0	0.00	
>8	0	0.00	
SUM	6		

File#33 M.U. 295

Depth	#	frequency	
0 to 1.3	3	0.43	terric
1.3 to 2	4	0.57	
2 to 4	0	0.00	
4 to 6	0	0.00	
6 to 8	0	0.00	
>8	0	0.00	
SUM	7		

Table 2 (continued)

Frequency Distribution of Organic Soil Material Thickness by Soil Map Unit
(All depths are in meters; "#" signifies number of observations)

Soil Map Unit 395 - Chocorua mucky peat

File#18 M.U. 395

Depth	#	frequency
0 to 1.3	11	1.00
1.3 to 2	0	0.00
2 to 4	0	0.00
4 to 6	0	0.00
6 to 8	0	0.00
>8	0	0.00
SUM	11	

File#30 M.U. 395

Depth	#	frequency
0 to 1.3	33	0.94
1.3 to 2	2	0.06
2 to 4	0	0.00
4 to 6	0	0.00
6 to 8	0	0.00
>8	0	0.00
SUM	35	

Table 3. Summary of GPR Data

Site	M.U.	File #	Waypoint	Lat.	Long.	Depth (m)
2	295	12	WP001	43.1844	-71.3582	1.02
2	295	12	WP002	43.1844	-71.3582	1.30
2	295	12	WP003	43.1844	-71.3582	3.38
2	295	12	WP004	43.1844	-71.3582	5.47
2	295	12	WP005	43.1844	-71.3582	6.26
2	295	12	WP006	43.1844	-71.3582	8.12
2	295	12	WP007	43.1844	-71.3582	7.91
2	295	12	WP008	43.1844	-71.3582	8.12
2	295	12	WP009	43.1844	-71.3582	8.12
2	295	12	WP010	43.1844	-71.3582	7.39
2	295	12	WP011	43.1844	-71.3582	4.02
2	295	12	WP012	43.1844	-71.3582	1.03
2	295	12	WP013	43.1844	-71.3582	0.64
2	295	12	WP014	43.1844	-71.3582	4.50
2	295	12	WP015	43.1844	-71.3582	5.70
2	295	13	WP016	43.1844	-71.3582	8.12
2	295	13	WP017	43.1844	-71.3582	7.24
2	295	13	WP018	43.1844	-71.3582	6.28
2	295	13	WP019	43.1844	-71.3582	4.83
2	295	13	WP020	43.1844	-71.3582	3.49
2	295	13	WP021	43.1844	-71.3582	1.79
2	295	13	WP022	43.1844	-71.3582	0.84
2	295	14	WP023	43.1823	-71.3587	1.10
2	295	14	WP024	43.1823	-71.3585	1.88
2	295	14	WP025	43.1823	-71.3584	2.27
2	295	14	WP026	43.1823	-71.3582	1.88
2	295	14	WP027	43.1823	-71.3580	2.84
2	295	14	WP028	43.1822	-71.3578	3.05
2	295	14	WP029	43.1823	-71.3576	1.69
2	295	14	WP030	43.1823	-71.3575	0.95

Site	M.U.	File #	Waypoint	Lat.	Long.	Depth(m)
3	97	15	WP031	43.1628	-71.3747	0.98
3	97	15	WP032	43.1626	-71.3747	1.49
3	97	15	WP033	43.1625	-71.3747	1.30
3	97	15	WP034	43.1626	-71.3746	1.37
3	97	15	WP035	43.1627	-71.3745	1.55
3	97	15	WP036	43.1626	-71.3744	1.19
3	97	15	WP037	43.1626	-71.3744	1.44
3	97	15	WP038	43.1628	-71.3739	1.72
3	97	15	WP039	43.1628	-71.3738	1.55
3	295	16	WP040	43.1628	-71.3737	1.76
3	295	16	WP041	43.1628	-71.3735	1.17
3	295	16	WP042	43.1627	-71.3733	1.77
3	295	16	WP043	43.1627	-71.3731	1.46
3	295	16	WP044	43.1627	-71.3729	1.58
3	295	16	WP045	43.1628	-71.3730	1.85
3	295	16	WP046	43.1629	-71.3732	1.53
3	295	16	WP047	43.1630	-71.3733	1.26
3	295	16	WP048	43.1631	-71.3735	1.70
3	295	16	WP049	43.1632	-71.3736	2.66
3	295	16	WP050	43.1633	-71.3737	2.66
3	295	16	WP051	43.1634	-71.3738	1.70
3	295	16	WP052	43.1635	-71.3739	1.88
3	295	16	WP053	43.1636	-71.3740	1.92
3	295	16	WP054	43.1638	-71.3740	1.92
3	295	17	WP055	43.1631	-71.3739	0.95
3	295	17	WP056	43.1631	-71.3738	1.97
3	295	17	WP057	43.1632	-71.3736	2.23
3	295	17	WP058	43.1632	-71.3734	2.98
3	295	17	WP059	43.1632	-71.3732	1.93
3	295	17	WP060	43.1632	-71.3731	1.48
3	295	17	WP061	43.1632	-71.3729	1.14

Site	M.U.	File #	Waypoint	Lat.	Long.	Depth(m)
3	295	17	WP062	43.1632	-71.3727	1.02
3	295	17	WP063	43.1633	-71.3725	1.30
3	295	17	WP064	43.1633	-71.3723	1.03
3	295	17	WP065	43.1634	-71.3722	1.44
3	295	17	WP066	43.1637	-71.3721	2.02

Site	M.U.	File #	Waypoint	Lat.	Long.	Depth(m)
1	395	18	WP067	43.2516	-71.6062	0.59
1	395	18	WP068	43.2516	-71.6061	1.30
1	395	18	WP069	43.2515	-71.6060	1.02
1	395	18	WP070	43.2514	-71.6059	1.00
1	395	18	WP071	43.2512	-71.6057	1.02
1	395	18	WP072	43.2510	-71.6057	0.84
1	395	18	WP073	43.2509	-71.6056	0.73
1	395	18	WP074	43.2508	-71.6057	1.03
1	395	18	WP075	43.2507	-71.6058	0.72
1	395	18	WP076	43.2506	-71.6058	0.72
1	395	18	WP077	43.2505	-71.6058	0.95

Site	M.U.	File #	Waypoint	Lat.	Long.	Depth(m)
4	295	20	WP078	43.3080	-71.4352	1.97
4	295	20	WP079	43.3080	-71.4350	2.01
4	295	20	WP080	43.3080	-71.4348	2.64
4	295	20	WP081	43.3080	-71.4347	3.08
4	295	20	WP082	43.3080	-71.4345	3.51
4	295	20	WP083	43.3080	-71.4343	3.17
4	295	20	WP084	43.3080	-71.4341	3.70
4	295	20	WP085	43.3080	-71.4339	3.81
4	295	20	WP086	43.3080	-71.4337	4.62
4	295	20	WP087	43.3080	-71.4335	4.60
4	295	20	WP088	43.3081	-71.4334	3.49
4	295	20	WP089	43.3082	-71.4333	2.75
4	295	20	WP090	43.3081	-71.4331	2.78
4	295	20	WP091	43.3081	-71.4330	4.04
4	295	20	WP092	43.3080	-71.4328	5.14
4	295	20	WP093	43.3080	-71.4326	3.59
4	295	20	WP094	43.3080	-71.4324	3.28
4	295	20	WP095	43.3080	-71.4323	3.17
4	295	20	WP096	43.3080	-71.4321	2.84
4	295	20	WP097	43.3080	-71.4320	2.57
4	295	20	WP098	43.3079	-71.4321	2.33
4	295	21	WP099	43.3078	-71.4320	3.35
4	295	21	WP100	43.3077	-71.4320	3.65
4	295	21	WP101	43.3076	-71.4320	3.40
4	295	21	WP102	43.3075	-71.4320	3.10
4	295	21	WP103	43.3072	-71.4320	2.96
4	295	21	WP104	43.3071	-71.4319	2.84
4	295	21	WP105	43.3070	-71.4320	2.77
4	295	21	WP106	43.3068	-71.4320	2.50
4	295	21	WP107	43.3067	-71.4320	2.57
4	295	21	WP108	43.3066	-71.4320	2.50
4	295	21	WP109	43.3065	-71.4320	2.52
4	295	21	WP110	43.3063	-71.4320	2.45
4	295	21	WP111	43.3062	-71.4321	2.41
4	295	21	WP112	43.3061	-71.4321	2.45
4	295	21	WP113	43.3060	-71.4321	1.99
4	295	21	WP114	43.3059	-71.4321	2.30
4	295	21	WP115	43.3057	-71.4321	2.18
4	295	21	WP116	43.3056	-71.4321	2.01
4	295	21	WP117	43.3055	-71.4320	2.02
4	295	21	WP118	43.3054	-71.4321	2.02
4	295	21	WP119	43.3053	-71.4322	1.90

Table 3 (continued)
Summary of GPR Data

Site	M.U.	File #	Waypoint	Lat.	Long.	Depth(m)
4	295	21	WP120	43.3052	-71.4323	1.97
4	295	21	WP121	43.3051	-71.4322	1.60
4	295	21	WP122	43.3050	-71.4321	1.56
4	295	21	WP123	43.3050	-71.4321	1.55
4	295	21	WP124	43.3049	-71.4321	0.61
4	295	22	WP125	43.3059	-71.4318	2.11
4	295	22	WP126	43.3059	-71.4316	2.17
4	295	22	WP127	43.3060	-71.4314	1.97
4	295	22	WP128	43.3060	-71.4312	2.01
4	295	22	WP129	43.3060	-71.4311	1.97
4	295	22	WP130	43.3060	-71.4309	1.99
4	295	22	WP131	43.3060	-71.4307	1.70
4	295	22	WP132	43.3061	-71.4306	1.53
4	295	22	WP133	43.3061	-71.4304	1.53
4	295	22	WP134	43.3061	-71.4302	1.65
4	295	22	WP135	43.3061	-71.4301	1.67
4	295	22	WP136	43.3061	-71.4299	1.70
4	295	22	WP137	43.3061	-71.4298	1.63
4	295	22	WP138	43.3061	-71.4296	2.15
4	295	22	WP139	43.3061	-71.4294	2.85
4	295	22	WP140	43.3062	-71.4293	5.89
4	295	22	WP141	43.3062	-71.4291	8.12
4	295	22	WP142	43.3062	-71.4290	8.12
4	295	22	WP143	43.3061	-71.4288	4.60
4	295	22	WP144	43.3061	-71.4286	4.07
4	295	22	WP145	43.3061	-71.4284	4.57
4	295	23	WP146	43.3062	-71.4297	1.86
4	295	23	WP147	43.3062	-71.4298	1.58
4	295	23	WP148	43.3062	-71.4300	2.64
4	295	23	WP149	43.3063	-71.4302	1.51
4	295	23	WP150	43.3063	-71.4303	1.25
4	295	23	WP151	43.3064	-71.4305	1.58
4	295	23	WP152	43.3064	-71.4306	1.86
4	295	23	WP153	43.3064	-71.4308	1.92
4	295	23	WP154	43.3064	-71.4310	1.79
4	295	23	WP155	43.3064	-71.4312	2.26
4	295	23	WP156	43.3065	-71.4313	2.38
4	295	23	WP157	43.3065	-71.4315	2.41
4	295	23	WP158	43.3065	-71.4317	2.52
4	295	23	WP159	43.3066	-71.4319	2.52
4	295	23	WP160	43.3066	-71.4320	2.53
4	295	23	WP161	43.3067	-71.4322	2.41
4	295	23	WP162	43.3067	-71.4323	2.41
4	295	23	WP163	43.3068	-71.4325	2.34
4	295	23	WP164	43.3068	-71.4327	2.46
4	295	23	WP165	43.3069	-71.4328	2.39
4	295	23	WP166	43.3069	-71.4330	2.30
4	295	23	WP167	43.3070	-71.4331	2.50
4	295	23	WP168	43.3070	-71.4333	2.39
4	295	23	WP169	43.3070	-71.4335	2.71
4	295	23	WP170	43.3070	-71.4336	2.61
4	295	23	WP171	43.3070	-71.4339	2.57
4	295	23	WP172	43.3071	-71.4339	2.41
4	295	23	WP173	43.3072	-71.4340	2.57
4	295	23	WP174	43.3073	-71.4341	3.03
4	295	23	WP175	43.3074	-71.4342	2.94
4	295	23	WP176	43.3076	-71.4343	2.89
4	295	23	WP177	43.3077	-71.4344	2.71
4	295	23	WP178	43.3077	-71.4345	2.71
4	295	23	WP179	43.3078	-71.4347	2.62
4	295	23	WP180	43.3079	-71.4348	2.73
4	295	23	WP181	43.3080	-71.4349	2.64

Site	M.U.	File #	Waypoint	Lat.	Long.	Depth(m)
6	97	24	WP182	43.2938	-71.4326	1.14
6	97	24	WP183	43.2937	-71.4326	1.77
6	97	24	WP184	43.2937	-71.4325	3.79
6	97	24	WP185	43.2936	-71.4325	3.63
6	97	24	WP186	43.2935	-71.4325	4.34
6	97	24	WP187	43.2934	-71.4325	1.60
6	97	24	WP188	43.2935	-71.4326	3.17
6	97	24	WP189	43.2936	-71.4327	4.95
6	97	24	WP190	43.2936	-71.4328	4.28
6	97	24	WP191	43.2937	-71.4329	4.16
6	97	24	WP192	43.2938	-71.4329	3.05
6	97	24	WP193	43.2938	-71.4329	1.28
6	97	24	WP194	43.2939	-71.4331	1.93
6	97	24	WP195	43.2938	-71.4331	4.18
6	97	24	WP196	43.2937	-71.4331	4.28
6	97	24	WP197	43.2936	-71.4332	4.15
6	97	24	WP198	43.2936	-71.4332	1.26
6	97	24	WP199	43.2936	-71.4333	2.22
6	97	24	WP200	43.2937	-71.4333	1.84
6	97	24	WP201	43.2938	-71.4334	0.96
6	97	24	WP202	43.2938	-71.4335	1.42
6	97	24	WP203	43.2939	-71.4336	2.46
6	97	24	WP204	43.2940	-71.4337	1.63
6	97	24	WP205	43.2941	-71.4337	0.79
6	97	24	WP206	43.2941	-71.4339	2.62
6	97	24	WP207	43.2940	-71.4340	3.51
6	97	24	WP208	43.2939	-71.4341	2.85
6	97	24	WP209	43.2939	-71.4342	2.30
6	97	24	WP210	43.2939	-71.4344	1.37
6	97	24	WP211	43.2940	-71.4344	2.87
6	97	24	WP212	43.2941	-71.4344	3.05
6	97	24	WP213	43.2942	-71.4344	2.01
6	97	24	WP214	43.2943	-71.4344	1.70
6	97	24	WP215	43.2943	-71.4344	1.25
6	97	24	WP216	43.2943	-71.4345	1.44
6	97	24	WP217	43.2943	-71.4346	1.95
6	97	24	WP218	43.2943	-71.4347	0.82
6	97	24	WP219	43.2943	-71.4348	0.96
6	97	24	WP220	43.2944	-71.4348	1.39
6	97	24	WP221	43.2944	-71.4347	1.44
6	97	24	WP222	43.2945	-71.4347	1.02
6	97	24	WP223	43.2945	-71.4347	1.10
6	97	24	WP224	43.2946	-71.4348	1.21
6	97	24	WP225	43.2946	-71.4348	0.84
6	97	24	WP226	43.2946	-71.4350	1.05
6	97	24	WP227	43.2947	-71.4349	0.96

Site	M.U.	File #	Waypoint	Lat.	Long.	Depth(m)
5	97	26	WP292	43.3195	-71.4238	1.76
5	97	26	WP293	43.3195	-71.4237	2.04
5	97	26	WP294	43.3196	-71.4235	1.83
5	97	26	WP295	43.3197	-71.4234	2.11
5	97	26	WP296	43.3197	-71.4232	2.45
5	97	26	WP297	43.3198	-71.4231	3.75
5	97	26	WP298	43.3198	-71.4229	4.51
5	97	26	WP299	43.3199	-71.4228	5.08
5	97	26	WP300	43.3199	-71.4226	5.56
5	97	26	WP301	43.3200	-71.4225	3.88
5	97	26	WP302	43.3201	-71.4224	2.09
5	97	26	WP303	43.3201	-71.4222	1.07

Table 3 (continued)
Summary of GPR Data

Site	M.U.	File #	Waypoint	Lat.	Long.	Depth(m)
7	97	28	WP320	43.3187	-71.4199	1.65
7	97	28	WP321	43.3187	-71.4199	2.02
7	97	28	WP322	43.3187	-71.4199	1.46
7	97	28	WP323	43.3187	-71.4199	1.72
7	97	28	WP324	43.3187	-71.4199	2.15
7	97	28	WP325	43.3187	-71.4199	1.81
7	97	28	WP326	43.3187	-71.4199	1.67
7	97	28	WP327	43.3187	-71.4199	2.01
7	97	28	WP328	43.3187	-71.4199	3.08
7	97	28	WP329	43.3187	-71.4199	3.77
7	97	28	WP330	43.3187	-71.4199	4.39
7	97	28	WP331	43.3187	-71.4199	5.18
7	97	28	WP332	43.3187	-71.4199	5.20
7	97	28	WP333	43.3187	-71.4199	5.33
7	97	28	WP334	43.3187	-71.4199	5.04
7	97	28	WP335	43.3187	-71.4199	5.22
7	97	28	WP336	43.3187	-71.4199	4.21
7	97	28	WP337	43.3187	-71.4199	3.28
7	97	28	WP338	43.3187	-71.4199	2.06
7	97	28	WP339	43.3187	-71.4199	1.74
7	97	28	WP340	43.3187	-71.4199	1.51
7	97	28	WP341	43.3187	-71.4199	1.30
7	97	28	WP342	43.3187	-71.4199	1.48
7	97	28	WP343	43.3187	-71.4199	2.20
7	97	28	WP344	43.3187	-71.4199	5.20
7	97	28	WP345	43.3187	-71.4199	8.12
7	97	28	WP346	43.3187	-71.4199	8.12
7	97	28	WP347	43.3187	-71.4199	6.93
7	97	28	WP348	43.3187	-71.4199	8.12
7	97	28	WP349	43.3187	-71.4199	5.45
7	97	28	WP350	43.3187	-71.4199	5.79
7	97	28	WP351	43.3187	-71.4199	6.00
7	97	28	WP352	43.3187	-71.4199	5.19
7	97	28	WP353	43.3187	-71.4199	4.94
7	97	28	WP354	43.3187	-71.4199	4.44
7	97	28	WP355	43.3187	-71.4199	2.82
7	97	28	WP356	43.3187	-71.4199	3.35
7	97	28	WP357	43.3187	-71.4199	2.64
7	97	28	WP358	43.3235	-71.4164	2.06
7	97	28	WP359	43.3236	-71.4165	1.76
7	97	28	WP360	43.3237	-71.4165	1.32
7	97	28	WP361	43.3238	-71.4165	1.05
7	97	28	WP362	43.3239	-71.4165	0.84
7	97	28	WP363	43.3240	-71.4165	1.09
7	97	28	WP364	43.3241	-71.4164	1.07
7	97	28	WP365	43.3242	-71.4164	0.75
7	97	29	WP366	43.3243	-71.4163	0.77
7	97	29	WP367	43.3245	-71.4162	1.48
7	97	29	WP369	43.3244	-71.4162	2.41
7	97	29	WP370	43.3237	-71.4154	2.75
7	97	29	WP371	43.3235	-71.4155	3.33
7	97	29	WP372	43.3234	-71.4155	3.49
7	97	29	WP373	43.3233	-71.4156	3.21
7	97	29	WP374	43.3232	-71.4156	3.47
7	97	29	WP375	43.3231	-71.4156	4.00
7	97	29	WP376	43.3229	-71.4156	4.34
7	97	29	WP377	43.3228	-71.4156	4.71
7	97	29	WP378	43.3227	-71.4156	6.14
7	97	29	WP379	43.3226	-71.4157	5.77
7	97	29	WP380	43.3224	-71.4157	5.98
7	97	29	WP381	43.3223	-71.4157	6.12
7	97	29	WP382	43.3222	-71.4157	6.39
7	97	29	WP383	43.3221	-71.4158	5.77
7	97	29	WP384	43.3220	-71.4158	3.19
7	97	29	WP385	43.3218	-71.4158	2.89

Site	M.U.	File #	Waypoint	Lat.	Long.	Depth(m
7	97	29	WP386	43.3217	-71.4159	2.13
7	97	29	WP387	43.3216	-71.4159	1.76
7	97	29	WP388	43.3215	-71.4159	1.83
7	97	29	WP389	43.3214	-71.4159	1.77
7	97	29	WP390	43.3213	-71.4160	2.22
7	97	29	WP391	43.3211	-71.4160	2.68
7	97	29	WP392	43.3210	-71.4160	3.74

Site	M.U.	File #	Waypoint	Lat.	Long.	Depth(m)
8	395	30	WP001	43.3533	-71.6740	1.22
8	395	30	WP002	43.3533	-71.6741	1.13
8	395	30	WP003	43.3532	-71.6743	0.94
8	395	30	WP004	43.3534	-71.6743	0.66
8	395	30	WP005	43.3532	-71.6741	0.78
8	395	30	WP006	43.3532	-71.6741	0.99
8	395	30	WP007	43.3531	-71.6739	1.45
8	395	30	WP008	43.3530	-71.6740	1.28
8	395	30	WP009	43.3530	-71.6741	0.66
8	395	30	WP010	43.3530	-71.6741	0.66
8	395	30	WP011	43.3530	-71.6743	0.66
8	395	30	WP012	43.3530	-71.6742	0.77
8	395	30	WP013	43.3529	-71.6741	0.66
8	395	30	WP014	43.3529	-71.6740	1.05
8	395	30	WP015	43.3529	-71.6739	0.94
8	395	30	WP016	43.3529	-71.6738	1.11
8	395	30	WP017	43.3529	-71.6738	1.11
8	395	30	WP018	43.3528	-71.6737	1.22
8	395	30	WP019	43.3527	-71.6738	1.16
8	395	30	WP020	43.3527	-71.6738	1.33
8	395	30	WP021	43.3526	-71.6739	1.22
8	395	30	WP022	43.3526	-71.6737	1.05
8	395	30	WP023	43.3525	-71.6736	0.99
8	395	30	WP024	43.3524	-71.6737	0.99
8	395	30	WP025	43.3524	-71.6738	0.60
8	395	30	WP026	43.3523	-71.6737	0.99
8	395	30	WP027	43.3523	-71.6737	0.94
8	395	30	WP028	43.3523	-71.6735	0.66
8	395	30	WP029	43.3522	-71.6736	0.83
8	395	30	WP030	43.3521	-71.6737	0.66
8	395	30	WP031	43.3521	-71.6736	0.66
8	395	30	WP032	43.3520	-71.6735	0.66
8	395	30	WP033	43.3519	-71.6735	0.60
8	395	30	WP034	43.3519	-71.6737	0.88
8	395	30	WP035	43.3519	-71.6736	0.66

Site	M.U.	File #	Waypoint	Lat.	Long.	Depth(m
9	295	31	WP036	43.3343	-71.6567	1.37
9	295	31	WP037	43.3343	-71.6566	1.25
9	295	31	WP038	43.3344	-71.6564	1.58
9	295	31	WP039	43.3344	-71.6563	1.97
9	295	31	WP040	43.3344	-71.6561	1.63
9	295	31	WP041	43.3344	-71.6561	1.81
9	295	31	WP042	43.3344	-71.6559	1.79
9	295	31	WP043	43.3345	-71.6560	1.86
9	295	31	WP044	43.3346	-71.6561	1.63
9	295	31	WP045	43.3347	-71.6561	1.48
9	295	31	WP046	43.3348	-71.6562	1.88
9	295	31	WP047	43.3349	-71.6562	2.00
9	295	31	WP048	43.3350	-71.6562	1.81
9	295	31	WP049	43.3351	-71.6561	1.37
9	295	31	WP050	43.3352	-71.6561	1.17
9	295	31	WP051	43.3352	-71.6562	0.72
9	295	32	WP052	43.3352	-71.6564	1.44

Table 3 (continued)
Summary of GPR Data

Site	M.U.	File #	Waypoint	Lat.	Long.	Depth(m
9	295	32	WP053	43.3351	-71.6565	1.33
9	295	32	WP054	43.3352	-71.6566	1.60
9	295	32	WP055	43.3351	-71.6568	1.51
9	295	32	WP056	43.3351	-71.6570	1.42
9	295	32	WP057	43.3351	-71.6571	0.63
9	295	33	WP058	43.3351	-71.6571	1.60
9	295	33	WP059	43.3350	-71.6571	1.00
9	295	33	WP060	43.3349	-71.6570	1.60
9	295	33	WP061	43.3348	-71.6570	1.54
9	295	33	WP062	43.3347	-71.6569	1.33
9	295	33	WP063	43.3346	-71.6569	0.56
9	295	33	WP064	43.3344	-71.6569	1.02