Preliminary Report on the Geophysical Investigation of the McConnell Road Aquifer Prospect, Brandon,VT

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Executive Summary

Introduction

The Vermont Geological Survey (VGS) conducted a geophysical investigation of the McConnell Road aquifer prospect on 22-24 April 2008. This preliminary report presents an interpretation of the geophysical data collected. This interpretation is then integrated with a previous theoretical model of the McConnell Road aquifer prospect.

Prior study of available water well logs and surficial geologic mapping during 2005-2006 indicated the McConnell Road area might represent a viable overburden aquifer prospect (De Simone, 2006, De Simone and Becker, 2007). The VGS proposed to investigate the overburden aquifers of Brandon in 2006 and presented a draft proposal to investigate the McConnell Road prospect in 2007.

The surficial mapping and water well log interpretation indicated there was some water bearing gravel and sand within the sediments filling a possible buried bedrock channel traversed by McConnell Road. The well log data, however, presented conflicting information on the nature of the sediment filling the channel. Well logs suggested there was generally more hardpan in western portions of the valley with more permeable sand and gravel in eastern portions of the valley. Additionally, the well logs indicate there are hardpan units within the sand and gravel in some places and no hardpan units in other places. Additionally, the well data indicated a thick fine grained lacustrine silt and clay unit prevailed in the south while there was sand and gravel or mixed hardpan and sand and gravel to the north in the valley.

To provide data to address these uncertainties, geophysical surveys were conducted in order to assess the overburden stratigraphy and depth to bedrock. A seismic survey was originally proposed and the report of this survey is included as Appendix A. In addition, the VGS conducted a gravity survey as an independent method to assess the overburden stratigraphy and aid in determination of depth to bedrock. The gravity method also serves to cross check the seismic survey. The report on this survey is included as Appendix B. Finally, the previous interpretation of well log data as used in the preparation of stratigraphic cross sections is included as Appendix C.

Results

The seismic survey data for lines S1, S2 and S3 all indicate the presence of a low velocity surface layer consistent with an unsaturated sand and gravel unit ranging from 12-19 ft thickness across the area surveyed. This is consistent with surficial mapping and water well data that are interpreted to indicate a shallow water lacustrine sand unit with an upper surface representing a beach profile developed in Glacial Lake Coveville that existed approximately from 13,400 – 13,200 years ago.

The seismic survey indicates there is an underlying layer of saturated sand and gravel in the west portion of line S1 while the east portion is seismically faster and somewhat more consistent with a finer grained lacustrine silt layer. This could be the same layer or a denser layer is present as layer 2 in both lines S2 and S3. Water well records indicate more hardpan beneath a surface sand unit in the west portion of the valley and more persistent sand and gravel in the east portion of the valley. However, it should be noted that the seismic lines all were really located in the area originally referred to as the east portion of the valley with the west portion of the valley continuing beyond the extent of this survey. So, the bottom line is there appears to be buried gravel and sand in the *central* portion of the valley identified along the western portion of the agricultural field where the surveys were conducted. The seismic data is supported by the newer well located in the edge of the clearing just north of the eastern end of line S3. The log for this well indicates hardpan beneath the surface lacustrine and beach sand unit. Therefore, it is concluded there must be a hardpan unit that extends into the valley from the east along a sloping bedrock surface tilting from east down to the west. This is suggested as a possibility in the interpretation of cross sections in Appendix C. The integration of the seismic and well log data still supports the existence of a relatively thick sand and gravel unit in the valley fill, especially in the vicinity of seismic line S1 and in the central portion of the valley.

The highest values (in milligals) in the gravity survey were measured in the northwest corner of the agricultural field. This gravity high may be explained two ways: 1) bedrock is closer to the surface, or 2) surficial materials in this area are either thicker or denser than those in surrounding areas. Since the seismic refraction survey demonstrated that bedrock was >200’ deep here, hypothesis #1 can be discounted. The seismic survey also indicates that layer 2 beneath seismic line 2 was thicker and denser than layer 2 beneath seismic line #1. By integrating the seismic data with the gravity data in the northwestern quadrant of the study area, we suggest that the thicker and denser surficial deposits in layer 2 are likely responsible for the elevated gravity readings.

One possible interpretation of the gravity data suggests that the depth to bedrock in the prospect area generally increases to the south and this supports the surficial mapping and well log data. Alternatively, the lower gravity values as one moves southward may also reflect less dense surficial materials.

Well log data suggests that the overburden may contain ovoid shaped lenses of hardpan within an otherwise layered sequence of sand and gravel as indicated by the drillers’ logs.

An integrated approach is used to suggest a general location for drilling based upon these results. Drilling and accurate logging of the sediment encountered will best reveal the actual nature of the overburden sediment. The search should target a drill location that is most likely to reveal a thicker saturated sand and gravel unit.

Drilling prospect

The small stream that drains Smalley Swamp and empties in to Mill Pond may serve as a source of direct recharge by leakage through its bed into the underlying sand and gravel sediment. Accordingly, a drilling site closer to this stream in the agricultural field may have a better chance of producing a large yield well than a drilling site farther away from this stream.

In the northwestern quarter of the prospect, both the gravity and seismic signatures are consistent with a thick section of denser surficial material. Based on the seismic data and well logs, the depth to bedrock increases moving north and south from seismic line #1 (form 50-90’ to >200’). The seismic and gravity data also support a transition from less dense saturated sand and gravel beneath seismic line 1 to more dense till or lacustrine silt and clay beneath seismic line 2. We believe that the saturated sand and gravel would be a more attractive drilling prospect.

Thus, the selection of a drilling site must be a compromise between the indications of the gravity survey, the seismic survey, well logs and desired nearness to the Smalley Swamp outflow stream.

Accordingly, we suggest a test drilling site be chosen somewhere within a rectangular area marked on the east by a line drawn to connect the west ends of seismic lines S1 and S2. The north and south edges of this rectangular area are gravity lines 103 and 99, respectively. The west boundary of the drilling area is chosen to be the edge of the shaded gravity map. This rectangle is shown on Figure 1. The actual drilling site should take into consideration the future needs of the land owner and other practical measures.

The VGS plans to revisit the data and other factors above before suggesting a specific drill site within the identified rectangle. The data from a test drilling will greatly assist in the evaluation of the McConnell Road overburden aquifer prospect.

Acknowledgements

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References

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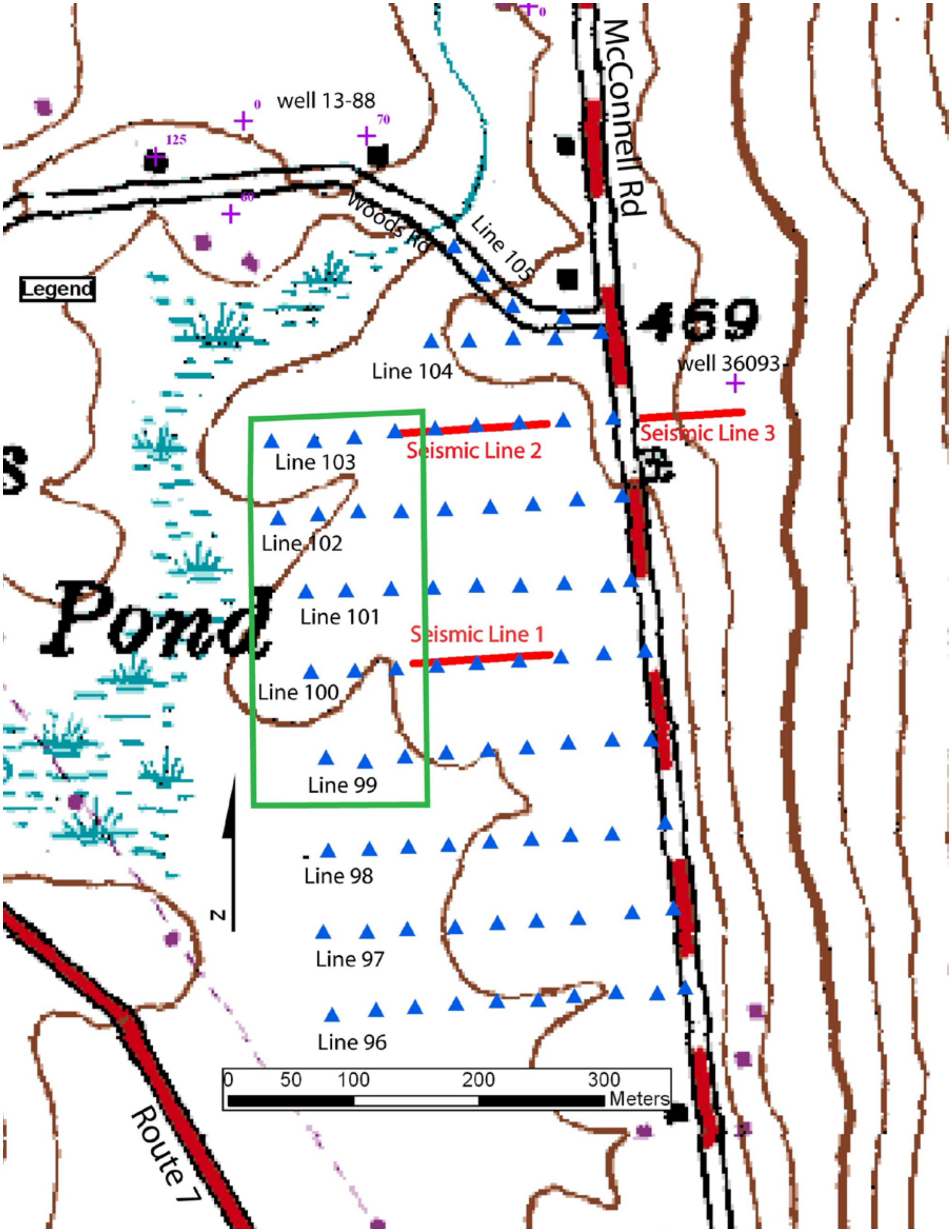

Figure 1: Gravity and seismic survey data collection locations. Blue triangles denote the gravity stations along the 10 numbered gravity survey lines shown. Seismic lines 1-3 are also shown in red. The purple + symbol denotes the location of the newer water well just north of the end of seismic line S3. The green rectangle outlines a suggested area for drilling to further investigate the aquifer prospect.

APPENDIX A

Seismic Refraction Investigation, Brandon, Vermont
By George Springston

Methods

A seismic refraction study was undertaken to determine variations in thickness of subsurface layers in the unconsolidated deposits and to determine the depth to bedrock. An EG&G Geometrics Model ES-1225 12-channel engineering seismograph was used with a 110 meter seismic cable with 10 meter spacing between geophones. Seismic energy was supplied by striking an aluminum plate with an 8 pound sledgehammer. The field procedures are described in detail in Redpath (1973).

Three seismic lines were completed. Line S1 is along the southern edge of the unplowed field along Gravity Survey Line 100. Line S2 is in the unplowed field along Gravity Survey Line 103. Line S3 is on the east side of McConnell Road and is an extension of Line S1. All three seismic lines were shot in forward and reverse directions. In addition, offset shots and center shots were made on lines S1 and S2.

The layers are labeled from the surface downward, starting with Layer 1. Velocities are similarly labeled. Note that this nomenclature differs from that of some seismic refraction manuals in which the upper (surface) layer is called Layer 0.

All velocities were derived from plotting first arrival times of P-waves on T-X graphs after the methods described in Redpath (1973). In each case, the velocities for Layer 1 are derived from arithmetic means of forward and reverse velocities (and center velocities where available) and the Layer 2 and Layer 3 velocities are derived from harmonic means of forward and reverse velocities.

The analyses of thicknesses are made using the intercept time method as described in Redpath (1973), with additional constraints on interpretation as described by Ackerman and others (1986). Delay times calculated for the thickness of Layer 1 on Line S1 were in substantial agreement with the intercept time calculations.

Abbreviations:

m	meters
S	seconds
mS	milliseconds
m/S	meters per second

Data

Line S1 (West of McConnell Road along southern edge of unplowed field)
Length: 110 m
Velocities:

V1: 264 m/S (arithmetic mean of forward, reverse, and center velocities)
V2: 1573 m/S (harmonic mean of forward and reverse velocities)
V2 (east half): 1843 m/S (harmonic mean of forward and center-reverse velocities)

V2 (west half): 1507 m/S (harmonic mean of reverse and center-forward velocities)
V3: 3098 m/S (harmonic mean of forward and reverse velocities)

Thicknesses:

Layer 1
East end: 5.1 m = 16.7 feet
West end: 3.6 m = 11.9 feet

Layer 2
East end: 10.2 m = 33.5 feet
West end: 26.0 m = 85.2 feet

Depth to Bedrock:
East end: 15.3 m = 50 feet
West end: 29.6 m = 97 feet

Line S2 (West of McConnell Road along Gravity Survey Line 103)
Length: 110 m
Velocities
V1: 282 m/S (arithmetic mean of forward, reverse, and center velocities)
V2: 2211 m/S (harmonic mean of forward and reverse velocities)
V2 (east half): 2118 m/S (harmonic mean of forward and center-reverse velocities)
V2 (west half): 2018 m/S (harmonic mean of reverse and center-forward velocities)

Thicknesses:

Layer 1
East end: 3.8 m = 12.4 feet
West end: 5.7 m = 18.6 feet

Layer 2
West end: greater than 62 m or 204 feet

Depth to Bedrock:
West end much greater than 200 feet

Line S3 (East of McConnell Road in line with Line S2)
Length: 95 m
Velocities
V1: 279 m/S (arithmetic mean of forward, reverse, and center velocities)
V2: 2135 m/S (harmonic mean of forward and reverse velocities)

Thicknesses:

Layer 1
East end: 7.0 m = 23.1 feet
West end: 4.4 m = 14.3 feet

Layer 2
East end greater than 17.1 m or 56 feet

Depth to Bedrock:
East end greater than 89 feet

Interpretations

The Layer 1 velocities are typical of P-wave velocities in unsaturated surficial deposits at shallow depths. For comparison, the mean velocity for similar materials from 6 stratified drift aquifer study sites in New England is 320 m/S (Haeni, 1995, Table 3).

The Layer 2 velocities on Line S1 are consistent with saturated sands or gravels. For comparison, the mean velocity for saturated stratified drift at 6 sites in New England is 1540 m/S (Haeni, 1995, Table 3).

Layer 2 velocities on Lines S2 and S3 appear to be high for saturated sand and gravel. The velocities are more consistent with stiff fine-grained lacustrine silt or clay or dense till. A seismic refraction profile across an unnamed tributary of Furnace Brook about 1.25 miles northeast of Pittsford Mills shows has a second layer that is interpreted to be lacustrine silt and clay with velocities ranging from 1800 to 2100 m/S (Stewart, 1972, Figure 18).

The Layer 3 velocity on Line S1 is consistent with bedrock velocities from other seismic refraction studies that have been undertaken in the area. For example, the seismic refraction profile across the Neshobe River about three fourths of a mile north-northeast of Brandon cited in Stewart (1972, Figure 19) had a bedrock velocity of about 4600 m/S to 4900 m/S and the profile across an unnamed tributary of Furnace Brook cited in the previous paragraph had bedrock velocities of 3,300 and 3,700 m/S (Stewart, 1972, Figures 18).

The possibility does exist that some of the Layer 2 material could be weathered bedrock, which could be expected to have velocities well below 3,000 m/S. This cannot be resolved from the available seismic refraction data.

References

Ackerman. H.D., Pankratz, L.W., and Dansereau, Danny, 1986, Resolution of ambiguities of seismic refraction travel time curves: Geophysics, v. 51, p. 223-235.

Haeni, F.P., 1995, Application of surface-geophysical methods to investigations of sand and gravel aquifers in the glaciated northeastern United States: U.S. Geological Survey Professional Paper 1415-A, 70p.

Redpath, B.B., 1972, Seismic refraction exploration for engineering site investigations: U.S. Army Engineer Waterways Experiment Station Explosive Excavation Research Laboratory Report TR E-73-4, Livermore, Calif., 51p.

Stewart, D.P., 1972, Geology for environmental planning in the Rutland-Brandon region, Vermont: Vermont Geological Survey, Environmental Geology Report No. 2, Montpelier, 40p. plus 7 plates.

APPENDIX B

By Jonathan Kim

Brief Gravity Summary

<u>Corrections Completed:</u>

1. Temperature
2. Drift
3. Free air
4. Bougeur
5. Latitude
6. Terrain corrections were not deemed to be necessary by George and me.

<u>Gravity Observations:</u>

-The total milligal difference between highest and lowest readings in the prospect area is 1.06 milligals so this is “microgravity”.

-No matter how the data are contoured (Inverse Distance Weighted, Spline, or Kriging) the contour pattern is generally the same. IDW and Kriging are more similar to each other than Spline is to either. IDW is shown.

-The highest gravity readings are in the northwestern quadrant of the prospect.

-Gravity readings generally decrease moving north to south.

-The 2006 well (well 36093) at the east end of Seismic Line 3 has a total depth of 162’and an overburden thickness of 145’ with 31’ of sand overlying 114’ of hardpan. Yield is listed at 60 gpm. This well brings the 200’ isopach much farther to the west.

-The closest well to the northern end of the prospect is well 13-88 and has a total depth of 200’ and an overburden thickness of 70’. Yield is listed at 5 gpm.

<u>Preliminary Gravity Interpretations:</u>

-The gravity high in the NW part of the prospect could be explained as a bedrock ridge beneath the surface; this agrees somewhat with what may be bedrock topographic contours on the western side of the prospect. However, this does not jibe with the seismic refraction data that suggests bedrock depths > 200’ along seismic line 2. If this bedrock ridge were shallower, we would see it with seismic.

-The generally monotonic decrease in gravity values moving to the south is consistent with a bedrock surface dipping gently to the south.

-The gravity contrasts both NW-SE and N-S could be explained by lateral and vertical variation (facies) in surficial materials. DeSimone indicates that sand content increases to the east and north because of the Lake Coveville shoreline and inputs of sand to the lake being from the north and east. He also said that till content in the surficial section increases from east to west in the northern half of the prospect.

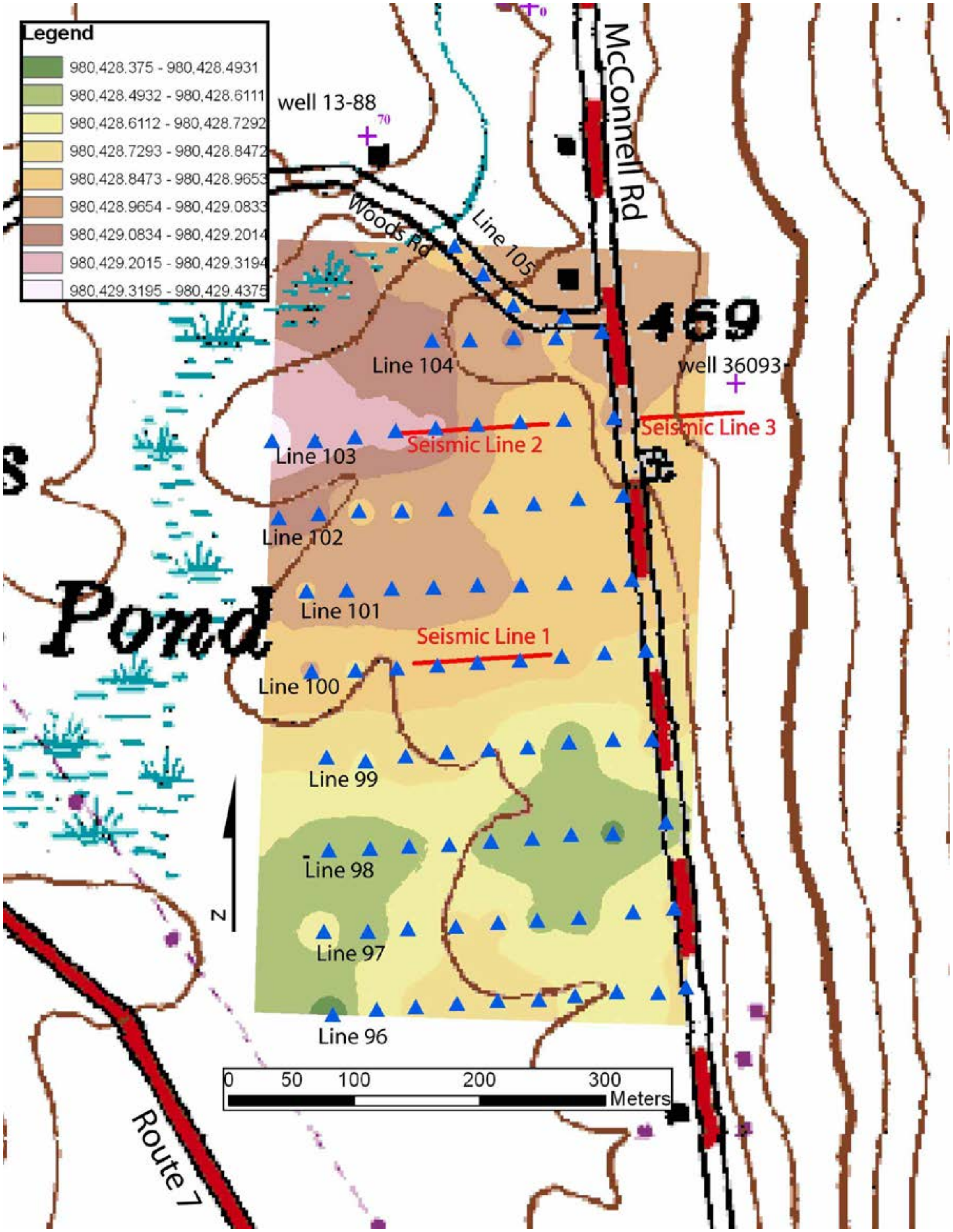

Figure 2: Results of the gravity survey (values in milligals).

APPENDIX C

By David De Simone

Interpretation of Cross Sections Through the McConnell Road Area

SECTION AA': Depth to bedrock data suggest a glacially over-deepened trough as depicted in the contoured map. The line of section starts on the flank of a bedrock ridge, however, and not in the valley bottom. Gravel wells used in the section terminate in a basal gravel unit whose extent through the section is not known with certainty. Adjacent well logs report either sand and gravel overlying sand or a thick section of hardpan or hardpan with boulders. This is reconciled by depicting a lens of hardpan. Drilling is needed to positively identify the stratigraphy along portions of this section. The distal southern portion of the section is dominated by finer grained lacustrine sediments and not by the coarser gravel and sand units to the north. The coarser grained sediments are sourced in the north where the ice margins stood and where, later, the Neshobe contributed sediment to the lake. The clay and gravel and boulder sand units in the upper portion of the stratigraphy may represent sediment flow diamictons, perhaps flows from the surrounding mountain flanks which occurred shortly after the drop from Quaker Springs to Coveville level. Above these diamictons, there is lacustrine sand capped by a Lake Coveville beach.

SECTION BB': A basal till unit is reported in 3 well logs used for this section. If present, this suggests that more of the deeper southern portion of Section AA' would be composed of the hardpan shown only as a lens in that previous section. However, the till does not persist across to the eastern half of section BB' where a detailed sequence composed of basal ice contact gravel is overlain by sand, sand and gravel, and finally boulder sand. The boulder sand unit in the eastern half of the section could be underlain by an undetermined thickness of till or might persist to bedrock. This ground moraine unit is shown as inter-fingering with the lacustrine units in the deep portion of the section. The inter-fingering is possibly accomplished by numerous sediment flow diamictons within the ground moraine unit that could have formed as sediment sloughed off the ground moraine and flowed into the lake. Coveville beach sediment forms a thin veneer over the shoreline portions on both sides of the section. The western beach is a sand spit exposed in a quarry.

SECTION CC': Till is shown at the base of this section only to conform to the reported till in section BB'. Its presence needs to be confirmed. The deep part of the section is similar to that of section BB' in having a water-bearing basal gravel overlain by sand, gravel and finally by finer grained lacustrine sediments. The well logs reported a clay, gravel and boulder unit beneath the lacustrine sands and this is represented as the inter-fingering sediment flow diamictons discussed in section BB'. They may be more discontinuous than represented on the section but the section follows the reported well logs as closely as possible.