Finger Lakes LPG Storage, LLC

MEMORANDUM

FROM: Leonard Dionisio
John Istvan

DATE: January 19, 2012

RE: Response to Public Comments regarding geology and underground storage caverns

As the geologists principally responsible for the review of the geology in and around the underground salt caverns proposed for LPG storage on the US Salt property and for the oversight of the geomechanical and other evaluations conducted of those caverns, this memorandum is to respond to certain public comments made regarding geology, geologic faults, seismic concerns, and the ability of the salt caverns to retain the LPG. In support of the underground storage applications submitted to the Department, we have worked on the Reservoir Suitability Report and we have reviewed all of the underlying test results, as well as other information developed over the years for solution mining and natural gas storage activities that have occurred on this site for over 100 years.

Based on our review of the comments and our knowledge of the site, it is our professional opinion based on our decades of experience that the public comments do not in any way raise any concern regarding the suitability of the underground salt caverns to store LPG in a safe, reliable and environmentally sensitive manner. Our specific responses to the comments follow:

Leaching of Cavern Contents into the Lake

Dr. John Halfman submitted a comment letter (letter B32) where he again reiterates that he is worried about migration of brine into the Lake bottom. In April, at the public information session held by Finger Lakes, we spoke with Dr. Halfman and pointed out to him that the underground salt caverns proposed for storage here could not possibly do so since this location is downdip and any brine that might possibly leak out of US Salt caverns (as discussed below, this is not possible) that are not pressurized would stay downdip due to the specific gravity. In addition, less use of road salt has helped to reduce the sodium and chlorides in the lakes.

Most importantly, from a hydraulics point of view, it makes no difference whether there is propane, butane or brine in the proposed storage caverns since all provide hydraulic support to the cavern walls, and the required mechanical integrity test being performed before the cavern is placed into storage, will confirm that the fluids are not leaching into the Lake bottom. In the caverns, no matter what the fluids are, pressures on the roof and cavern walls remains well within the ability of the salt to safely store the hydrocarbons.

The Fate of a Spill into Seneca Lake

A spill from the brine pond into the lake will likely flow to the deepest part of the lake due to the specific gravity of the brine. The existing saline layer in the deep part of the lake does not increase unless there is additional circulation placed in contact with the Salina beds. Further, if there is a spill, the high density brine would sink to the bottom of the lake, but this would minimize the potential damage caused to the upper layer of fresh water that is used for public consumption.

In addition, Wing, et al (1995) and Halfman, et al (2006) pointed out that a large volume of salt reaching the Lakes occurs from road deicing, "mine waste" and other groundwater sources. It should be noted that the mine waste referenced is not referencing anything directly from the salt caverns. Wing further hypothesized that the bottom of Seneca Lake intersects the Salina section and that this contact has increased the amount of sodium and chlorine in the lake. If this hypothesis is correct, then this is a naturally occurring event unrelated to our proposed project. Finally, something not mentioned in these articles are the other chemicals and fertilizers used for agricultural purposes that can add significantly to the run off factor.

Dr. Halfman quotes Jolly, USGS, Reston, Va., who graphed the lake concentration of chloride in ppm for the entire 20th Century, showing that the concentration peaked between 1970 and 1980, declining ever since. Possibly that coincided with the ending of the Morton injection wells. His concern that the additional pressure of LPG on the Finger Lakes caverns would induce seepage into the lake is unfounded since the pressure of the stored hydrocarbon is the same as the brine head in the cavern and since the mechanical testing has shown that the caverns do not leak, there can be no influx of brine into the lake.

Dr. Halfman indicates that his data and graph show that the salinity in the lake has been decreasing and he concludes that this data mimics the declining salt production on the lake. This assumption is in error as the production of salt has been increasing. Salt by its nature is impermeable and will not allow the migration of LPG or brine. The pressure in the caverns will remain the same whether it is filled with brine or LPG.

Faulting and Seismicity

Comment letter A224 (written by an attorney) raised a number of concerns related to faulting and seismicity. However, the alleged inadequacy of the DSEIS to address, analyze and research seismicity are moot since the only thing Finger Lakes can analyze is the historical information, and to understand geologically where the faults may be. Finger Lakes knows where the faults are located from our geological studies, and we are aware of what might or might not happen over time. However, based on company experience, site data and public data, no cavern has ever failed due to geological movements within the salt.

None of the reports Finger Lakes has reviewed show faults in the deeply glacial gouged Seneca or any of the other lakes. One significant point related to faulting is referenced

in the Stone and Webster (S&W) report submitted with public comments as fault 20, the strike-slip fault purported to run north to south on the west side of Seneca Lake. First of all, the fault trace on the S&W map, is not continuous and cannot be traced the entire length.

More specifically, the Structural Map of South-Central New York (figure 2.3-1 in the S&W report) shows a questionable north-south lateral fault on the west side of Seneca Lake and another one just west of Ithaca, New York. The question marks indicate that the faults are interrupted and not known from direct physical evidence. Indeed, in section 2.4 of the report, Structure and Tectonics, page 2.4-1, S&W writes "Another fault, in the Seneca Lake area, shows right lateral offset of hundreds of feet, cuts salt beds, and surface emanations of brine. However there is **no** seismicity associated with the Seneca Lake fault. Information on its association with basement structure is lacking. The Central Stable Region as a whole has been subject to gentle uplift since Paleozoic time. No major tectonic structures of regional extent are considered active or potentially active."

More significantly, if the fault were active, some or all of the water courses/streams that run down the slopes from west to east perpendicular to the fault trace 20 into the lake would be displaced or offset by the fault. There is no displacement of any stream shown on any map all along the west side of the lake. Moreover to raise an issue with regard to fracking wells and seismic events is clearly an attempt to connect that issue with what is proposed and it should be well known by now that this project is not related in any way to that activity.

As has been the case in recent earthquakes in the northeast, no underground pipes, sewers or water lines were affected. Once again, Emergency Shut Down Valves will prevent release of LPG if there is surface damage to the facility as a result of an earthquake. It is worthwhile to note that there has never been a recorded seismic event over 3 on the Richter scale in Schuyler County. See Draft DEC SGEIS, 2011, p. 4-30.

The Jacobi earthquake studies show that few basement faults reach the surface and even those that are inferred have plenty of question marks on the maps and cross-sections where there is no indication of the fault locations. To say that the basement faults have "been repeatedly reactivated" is without evidentiary support since none have been "recent" in geological time.

The Finger Lakes design copiously defines the methods that will be used to reduce or limit the possibility of failure in the brine pond, expulsion of LPG into the atmosphere, or damage to rail and pipeline facilities.

Comment letter A224 (referenced above) references a dissertation prepared by Courtney Lugert. We have obtained a copy of this dissertation and reviewed it. It does not in any way support the notion that there are faults that could have any adverse effect on the caverns that have been in existence for decades on the US Salt property and used for hydrocarbon storage starting in 1964.

The dissertation concentrates on the East side of Seneca Lake between Watkins Glen and Ovid to the North. The thesis refers to the northwest, far updip toward the formation's outcrop, Trenton-Black River fields in the towns of Prattsburgh and Pulteney, and southwest of Watkins Glen where much of the good thermally developed oil and gas production is located. None of that production or formation characteristics are similar to the subject Salina salt beds discussed by Finger Lakes in its underground storage permit application. In addition, in the same southwest area at Avoca, drilling of several brine disposal wells were attempted, some as deep as 12,500 feet finding no faults, but formations that were similar to quartzite with no porosity or permeability.

Dr. John Fountain, one of the Thesis Committee members for Lugert's dissertation, did a surface soil gas study in the area of Bath/Savona in the late 1990s ago and found no propane or butane anywhere around the Bath Petroleum (now Inergy Midstream) salt cavern storage site, thus concluding there were no fracture pathways or faults which existed in the salt. In 1997, Dr. Robert Jacobi also examined well logs, driller's logs, seismic reflection profiles, and performed reconnaissance in the area surrounding the Bath/Savona site and found no structures that could be construed as faulting. See **Exhibit 1** attached to this memorandum.

Lugert notes that "[d]uring the Alleghanian Orogeny lateral compression caused the layers [of rock] overlying the Silurian salt to slip to the northwest along a decollement that formed within the salt, while the layers below remained fixed." (Lugert, 2005, p. 5). As noted in Finger Lakes' underground storage permit application, because the literature avers that the faulting below is not affecting the geologic framework of the Watkins Glen site, comments will be limited to the salt section and overlying formations. At the Finger Lakes site, Lugert shows in Figure 4.9 on page 112, from seismic, that the S1, S2, S3, and S4 faults are not affected below from basement faulting, or above the salt – simply along the decollement as is the case at Watkins Glen. Based on well drilling, detailed well logging and cross-sectional construction from sonar surveys, the faults are well known and even so, the brine field has been developed with several caverns being acceptable for safe, secure storage of natural gas and LPG over many years previously. DEC has insisted that numerous adjacent old wells be reentered and new casing inspection and cement bond logs be performed. The result is that the site is secure based on logging inspection and proper plugging and abandonment of older nearby wells.

Part of the dissertation comments on Fracture Intensification Domains or FID's and ENE striking lineaments (surface lines similar to a pipeline right of way) affecting the Trenton-Black River formation – none of those are near the Finger Lakes site. Lugert referenced FIDs as being defined by Jacobi and Fountain (1996) and are inferred to indicate areas with an increased likelihood of faulting. However, the dissertation refers to the Tully limestone west of Ithaca, out of the area for Finger Lakes permitting.

There is no question that there are surface lineations in abundance all over the world, and specifically in New York and the area of Watkins Glen and Seneca Lake. However, those that can be traced consistently for miles, or those that are absolute reflections of prevalent basement faulting that extend to the earth's surface, are few. Due to the fact

that no fracturing of the rocks in the area will be performed, this limits the validity of the public concern in comments on the DSEIS.

The rocks that are exposed in the study area are limited to Middle Devonian Tully to Upper Devonian Canadaway Group, not including those from the Onondaga through Salina Formation. Folding and topographic structures such as anticlines are prevalent in the area and run from southwest in Pennsylvania both north and south as well as northeast thru the Watkins Glen area. Some topographic features can be traced continuously for miles while others are not exposed. There are multiple fractures in both exposed and buried rocks throughout the area. There are three northeastward trending normal faults with small throws of between 8 and 30 meters, none of which affect the salt properties.

Lugert further notes that "[a]long the western shore of Seneca Lake is the Seneca Lake fault. Murphy (1981) described the Seneca Lake fault as a 355° trending, right lateral strike-slip fault, extending south from Himrod, New York to the Elmira Dome. Its location is outside the study area, but its significant length (>100km) and horizontal offset (approximately 390m) make it an important feature". (Lugert, 2005, pp. 18-19). However, based on our review, the trace on the surface is not continuous and it has had no effect on the US Salt operations of the brine field within the Salina Formation salt. There is no indication fault movement has occurred later than during Devonian basin development.

Researchers disagree as to whether fracture spacing increases or decreases near faults, improving or limiting fluid movements in those areas, respectively. Other researchers have emphasized occurrences of lineaments with faults, fractures and different formation contacts and formation thickness without concluding there is a direct relationship with future movement.

Lugert notes that there are primarily two groups of fractures in the study area: ENE-E trending strike parallel group and a NNW-N trending cross strike group. ENE striking fracture set is the second most common within the study group. The E striking set is the least common. The third most common is the N striking fracture set. The NNW trending fracture set is the most common at 120 sites – 58%. However, all are surface features and outcrops that are related to release of stress with the beds being close to the surface.

In discussing rock type controls on fracture spacing, Lugert states that ".....several authors suggest a linear relationship exists between bed thickness and fracture spacing (although others dispute their claim)." (Lugert, 2005, p. 82). In this discussion, the author presents "the results of the analysis designed to determine if the change in fracture spacing observed between the southern and northern portion of the study area in the ENE- and E-striking fracture sets can be attributed to lithologic changes." The dissertation talks about the frequency of fracture sets and their location and concludes that "the distribution of frequencies (fracture) within each lithology is consistent across the different lithologies." However, it notes that the primary frequency of fracturing was in the northern portion of the study area. Most importantly, for the

proposed project, none of this can be related to Watkins Glen since the formations studied were all surface outcrops above the Onondaga and Marcellus Shale.

As part of the author's evaluation of fracture potential, soil gas methodologies were reviewed. As noted above, this is the avenue of analysis that one of Lugert's thesis committee members, Dr. Fountain, performed in 1997 for the Bath/Savona area. See **Exhibit 2** attached to this memorandum. As Lugert explains (pp. 105-109), soil gas methodology is based on the concept that thermogenic gas will accumulate in soil above open bedrock fractures (Budney, 2002). In this scenario fractures in the bedrock provide a high permeability pathway which gas can exploit as it migrates from gas-bearing units below. Using the ratio of ethane to methane, researchers are able to distinguish whether the gas extracted from the soil is of thermogenic origin (Budney, 2002). Using soil gas composition to determine gas origin is based on the principle that the amount of ethane in biogenic gas (shallow sourced) is undetectable, therefore if ethane is detected in significant amounts the gas is considered thermogenic gas, which has a deep source (e.g. Jacobi and Fountain, 1993, 1996 and 2000; Budney).

The typical pattern of gas concentration along the traverse is valued near background, punctuated by clusters of higher values. Budney (2002) found that the number of samples containing ethane was elevated between the towns of Ovid and Valois and decreased south of Valois (in the direction of Watkins Glen). This pattern is similar to that of the elevated fracture frequencies for the ENE- and E- striking fracture sets in the same region and pattern was also observed in the same sets in the lineament data. Frequency graphics in the dissertation show the fewest lineaments and lowest soil gas responses in the area east, across the lake from the US Salt plant and the Finger Lakes Project.

Within the Lugert study area a seismic line parallel to the Lake on the east side of Seneca Lake was examined by Jacobi and Lowenstein. There is a significant amount of faulting in the deep sections (from just above the Trenton, to well within the basement), but only a small number of faults (3, 6 and 7) were identified above the Trenton Group by Jacobi and Lowenstein (2003). Several of the deeper faults terminate once they enter the Paleozoic section and are not recognized farther up into the section. Based on the age of the sections they intersect, three faults near Valois may have been active during Ordovician time, but not recently.

Faults S1-S5 shown in the Lugert study are in the Silurian Salt near Hector. They are the result of movement along the decollement and strictly within the salt section. Finger Lakes' studies show that the faults are sealing since the caverns that encountered the faults do not leak. In addition, field operational experience shows that breaks in the fault reseal, by salt recrystallization, and the salt becomes stronger in compressive strength. Ancient basement faulting has no affect on the brine and storage field decollement faults at Watkins Glen even though there is an indication that surface lineaments might be loosely related to the basement faulting.

In summary, this paper was written to explain the reasons for the prolific Trenton-Black River limestone hydrocarbon production and has nothing to do with the salt production and planned storage area near Watkins Glen, except for the fault sequence S1-S5,

discussed above. However, its focus is the area east of Seneca Lake. The Thesis only briefly refers to the salt section and we have used industry earthquake data and predictions, and empirical local data to assist in supporting permitting for the site.

Exhibit 1 to the January 19 Memorandum from Finger Lakes Containing Response to Public Comments Regarding Geology and Underground Storage Caverns

WELL LOG ANALYSES
AND
REVIEW OF MAGORIAN'S COMMENTS
AT
BATH PETROLEUM STORAGE

FINAL REPORT

7/18/97

Robert D. Jacobi, Ph.D.
Consulting Geologist
Box 52
Getzville, NY 14068

INTRODUCTION

I have been retained to examine the Bath Petroleum Storage, Inc. site ("Bath site") and the existing salt caverns using several scientifically accepted methods to determine whether any evidence of a geological fault exists at the Bath site which would lend support to a claim that the conversion of these caverns to gas storage would result in an environmental risk to the surrounding communities. I focused my attention on examination of electric logs produced by Schlumberger for wells 7-13 as well as certain driller logs maintained by the Bath Petroleum Storage, Inc. (BPSI) for the original six wells (1-6) at the Bath site. Additionally, I examined Thomas Magorian's affidavit and accompanying reprocessed seismic reflection profile of the area in light of the well log data. I concluded that Magorian's thesis was largely unfounded for the Bath site because the seismic data upon which he relied and to which he attached his affidavit was not scientifically verifiable, and there was no logical or scientific basis for his conclusions.

Dr. John Fountain performed an extensive soil gas study both of the vicinity surrounding the Bath site and within the Bath site itself. The conclusions reached by both studies supports a conclusion that there is no evidence of faulting at the Bath site in the upper 2,650 ft of bedrock, and no evidence that could be used to infer any faults above the salt horizon southeast of well #8.

METHODOLOGY

In order to determine whether a fault of the magnitude described by Magorian affects the rocks at the Bath site, I analyzed in detail the well logs and drillers logs of wells 1 -13 at the Bath site. The locations of the wells are shown in Figure 1, and the operations involved in the detailed analyses are summarized in Tables 1-5 and Appendices I and II. Conclusions from the well log data are discussed below.

I also performed reconnaissance field structural analyses to determine whether anomalous fractures occur at the surface in the Bath site area that could indicate localized faulting extending to the surface at, or near, the Bath site.

Finally, I examined Magorian's reprocessed seismic line in an attempt to determine its reliability at the scale of the structures proposed by Magorian. Those results are also reported below.

EXECUTIVE SUMMARY

I analyzed all the well logs and drillers logs available to me at the Bath site, and examined Magorian's reprocessed seismic reflection profile in light of the conclusions reached from the well log data. I also performed a reconnaissance fracture study in the area surrounding the Bath site. The following conclusions result from these studies.

1) Well log analyses demonstrate that both the Tully and the Onondaga formations are essentially flat in the region of the wells at the Bath site. They do not show any structure that could be construed to be related to faulting.

2) This flat nature, which is evidenced by incontrovertible well log data, is in direct contrast to the supposed "sag" as imaged on Magorian's reprocessed seismic reflection profile. This inconsistency between the seismic reflection profile and the well log data indicates that the seismic reflection profile does not accurately portray subsurface structure at the fine scale of structure in the region.

3) A monocline (wherein the beds dip in only one direction) for the top-of-salt horizon can be inferred from well log data of the northwestern wells at the Bath site. The dip of the bedding in the area of the monocline, as evidenced from the well log data, is consistent with the dip observed on the Schlumberger formation microscanner log.

4) The flat nature of the overlying Tully and Onondaga units at the Bath site demonstrates that the monocline does not affect these units at the the Bath site; thus, the chances are remote that localized effects of the monocline, such as fracturing, occur in the Bath site area in the upper 2650' of bedrock. Fountain's study confirms the lack of throughgoing, open fractures in this interval at the Bath site.

5) The flat nature of the top-of-salt horizon southeast of the monocline indicates that no faulting offsets this surface. The rocks immediately above the top-of-salt horizon in this area would thus not be expected to exhibit an anomalous (greater than usual) amount of fracturing. Additionally, based on most tectonic and salt movement/diapir models (e.g., Gwinn, 1964; Frey, 1973; and Magorian's), no significant brittle faults (i.e., those that have fractured the rock) subparallel to bedding at or above the top-of-salt horizon would be expected at the Bath site southeast of the monocline.

6) Fracture analyses in outcrops near the Bath site do not show anomalous fracture orientations or abundances that might be expected if the upper units at Bath site had been subjected to faulting. Thus, these outcrops support the

conclusions drawn from the well log analyses that no major fault affects the bedrock down to at least 2650' below the Bath site. Additionally, the core of well #8 was evaluated by International Gas Consulting. Their report states: "fractures [immediately over the salt] are filled with salt and calcite;...they are not continuous, [and] they are only sporadic". Because well #8 is located in the region of the monocline, well #8 would be the most likely to exhibit evidence of anomalous fracturing, including open fractures. That the core fails to exhibit substantial fractures, coupled with the observation that anomalous fractures are not observed in outcrop, and are not inferred from the soil gas studies of Fountain, supports the conclusion that there is no evidence for a significant fault above the top-of-salt horizon at the Bath site.

7) The lack of anomalous fractures in the core and at the ground surface, and the lack of open, continuous fractures above the salt section, as inferred from the soil gas study, strongly suggest that the bedrock layer forming the roof of the salt caverns is not anomalously highly fractured, and that gas flow through the fractures from the salt cavern to the ground surface is not indicated.

8) Detailed analyses of Magorian's reprocessed seismic line show inconsistencies, both within the seismic line itself, and also in comparison to the incontrovertible well log data, that indicate that the seismic line does not portray the actual conditions at depth at the Bath site. Thus, Magorian's proposed fault cannot be supported by the seismic line.

WELL LOG ANALYSES

1) Among the wells at the Bath site (Figure 2), the Tully Formation displays a total of 21 feet of structural relief, which is within the range of error of the elevations of the drilling sites (see Appendix 1 and Table 1). The total structural relief is so small that the slight apparent folding (Figure 3) may well be merely an artifact of the errors in data reduction.

2) The top of the Onondaga Formation shows even less structural relief than the Tully--13 feet, which is again well within the range of error to be expected at the Bath site (Figure 4). Thus, the top of the Onondaga Formation should be regarded as flat at the Bath site.

3) The top-of-salt horizon does display an apparent monocline with structural relief on the order of 120 feet at the Bath site near well #8 (Figures 5 and 6). The structure trends NE, and the structure at the top-of-salt appears to be asymmetrical. The southeastern limb is essentially flat and extends south across most of the Bath site. The northwestern limb has relatively steep dips, on the order of 40°, based on well logs at the northwestern boundary of the Bath site

property. A Schlumberger formation microscanner well log from well #8 confirms both the strike of the structure (NE) and the relatively steep dip in the salt.

4) A few of the wells penetrate a distinctive sequence of interbedded dolostone/shale beds with thin salt horizons (labeled S8, S8.1, and S9 on the cross-section, Figure 7), as determined from gamma ray log signatures. The subsurface elevations of these horizons (and several horizons above) show that the lower section of the drilled salt is relatively continuous from well to well, and is relatively flat, compared to the top of the upper salt (top-of-salt surface; see cross section, Figure 7). Thus, any asymmetric fold at the northwestern boundary of the Bath site is primarily located in the upper salt section (see cross section, Figure 7), and does not affect (to any great extent) the lower salts and interbedded units at the Bath site.

5) The monocline along the northwestern margin of the Bath site, and the thicker upper salt section southeast of the monocline could be the result of at least two different mechanisms. In the first scenario (a salt "dome" model), the salt "flowed" into a broad diapiric structure. In this case, any faulting would be a consequence of accommodating the space requirements of the rising salt diapir. In other areas these faults usually are high angle faults (i.e., they are steeply-dipping) that are most abundant above the margins of the diapir. We observed no offset in the Onondaga and Tully formations across the monocline and to the southeast at the Bath site; thus, there are no high-angle faults in units above the salt that would be consistent with a salt dome model.

In a second scenario, a northwest-directed thrust fault model essentially "doubled" the thickness of the salt. In other words, a low-angle fault broke the salt section, and transported the southeastern part of the salt layer (and higher units) over the northwestern part of the same salt layer, piggyback style. In this model, the steep dip (down to the northwest) of the top-of-salt horizon at the northwestern margin of the Bath site would mark the northwestern extent of the transported salt "block". Thus, southeast of the monocline, the thrust would not be expected to be at the top of the salt section; rather it should be lower in the salt section. Therefore, anomalously high abundances of fractures associated with the thrust fault would not be expected at and above the top-of-salt horizon southeast of the monocline, across most of the Bath site. The lack of anomalous abundances of fractures at the ground surface in this area (see "Reconnaissance Fracture Survey" section) supports this contention. In the units directly overlying the salt, most anomalous fracturing associated with the thrust would be expected at, and northwest of, the monocline, largely outside of the Bath site.

It is largely immaterial where the proposed thrust resides in the salt layers in terms

of fractures, because the salt usually is ductile (i.e., it deforms without breaking), and therefore is self healing. Thus, fractures are generally sparse in the salt layers.

One way to identify a thrust fault in well logs is to recognize a distinct gamma ray signature that is repeated upsection, implying that the same unit occurs twice in the sequence, separated by a thrust fault. There is no unequivocal evidence of thrust faulting in the salt section, based on gamma ray logs from the wells southeast of the monocline..

In summary, there is no evidence from well log data of high-angle faults cutting up through the Onondaga and Tully which would support the salt dome model. Nor is there unequivocal data that a thrust fault exits in the salt section which would support a thrust fault model. Even if there is a thrust fault in the salt layer below the Bath site, we would not expect anomalous fractures associated with a thrust fault in the units overlying the salt southeast of the monocline. Accordingly, whether a thrust fault exists in the salt layer at the Bath site is largely immaterial.

7) In either model, the salt "dome" flowage or thrust fault model, the units directly above the salt, especially in the vicinity of wells #10 and #11 could have fractured during the deformation in the region of the monocline. To document whether anomalous fractures reach ground surface in the vicinity of the "monocline", field work was performed (details are below); the results show no significant faulting and no anomalous fractures in outcrops near the Bath site. In addition, to determine whether the fractures are presently sufficiently open to allow gas to migrate through the fractures to the surface, a comprehensive soil gas survey was undertaken; the negative results are presented in a separate report by Fountain.. In the absence of a positive result from both studies, any fracturing in the region southeast of the monocline is judged to be insignificant.

FRACTURE SURVEY NEAR THE BATH SITE

A survey for major fracture sets at the surface was conducted near the Bath site. We found outcrops of interbedded sandstones and shales along NYS RT 415 and along Eagle Valley Rd. Both outcrops are located in the region of Magorian's proposed thrust, and both outcrops are relatively close to the axis of the monocline at the top-of-salt horizon inferred from the well logs. To the west in Allegany County, we have found that fractures oriented parallel to faults increase in abundance in the vicinity of the fault. Neither outcrop near the Bath site displays an anomalous number of northeast-trending fractures (i.e., those that are parallel to Magorian's proposed thrust fault) compared to the number we found outside Magorian's proposed thrust zone along Culver Creek, Magees Hill and in a stream northeast of Bath. Thus, the outcrops near the Bath site do not indicate

that a major NE-trending thrust reaches the surface at the Bath site, or that anomalous fractures related to a thrust reach the surface at the Bath site. Additionally, no outcrop near the Bath site displayed any faults.

REVIEW OF MAGORIAN'S STATEMENTS CONCERNING A SEISMIC LINE NEAR THE BATH PETROLEUM STORAGE

I found it difficult to reconcile several of Magorian's statements with either the publications to which he refers, or with the seismic line he discusses.

1) *In the fourth paragraph of Magorian's report, he states that the proposed fault is "apparently shown on the Southern Tier structure map (Beinkafner, 1983)* [and] *is one of the large set of regional faults also shown on the state structure map (figure 3) (Van Tyne et al., 1980)..."* First, Van Tyne's map does NOT show Magorian's proposed fault. Rather, his map displays a fault about 2 miles SE of the BPSI location. Second: The only places that Beinkafner analyzed primary seismic data in Steuben County were centered on an area about 19 miles west of Bath (at Almond) and a second area centered about 12 miles southeast of Bath (at Gang Mills). Thus, any fault she might display in the region of the Bath site is based on either extraordinary extrapolations and/or an application of her tectonic/structural model to other researcher's maps. Other researcher's maps (e.g., Murphy's, 1981, compilation and Van Tyne et al.'s, 1980 compilation) do not indicate any fault in the vicinity of Bath.

2) *In the fifth paragraph of Magorian's report, he indicates that the seismic line was "properly stacked and migrated".* It is not possible to evaluate the veracity of this statement or the verisimilitude of the seismic line since the seismic line in Magorian's Figure 2 does not indicate any of the processing information needed to do so, such as 1) how exact were the corrections for the different elevations of the road along which the data were procured, 2) what velocity structure was utilized, 3) whether the same velocity structure was used along the entire line, and 4) whether crooked-line processing applied.

Without these and other typical data, it largely impossible to evaluate the accuracy of the seismic line. However, seismic lines are notorious for presenting misleading information because of inadequate or improper processing and interpretation. Because the truly flat nature of the Onondaga and Tully units at the Bath site is NOT replicated on the seismic line, and because the 120 foot monocline at the Bath site is not imaged on the seismic line, it appears that Magorian's seismic line is neither adequately processed nor interpreted. Below I review some of the considerations that may have led to the incorrect processing and interpretation.

Variable thicknesses of glacial and more recent sediment along the vibration line will result in variable amounts of "pull-down" because the velocity of the unconsolidated sediment generally is so much slower than the underlying strata. Unconsolidated sediment has velocities on the order of 1,312 ft/s to ~11,000 ft/s, compared to 13,000 ft/s for the upper rock units in the seismic section (as processed originally by Western Geophysical). If the unconsolidated sediment were all the same thickness along the line, no distortion of the underlying reflectors would occur--all of the signals from the underlying reflectors would be delayed an equal amount. Obviously, however, if the thickness of the unconsolidated material varies, the returning reflections from below the unconsolidated sediment will experience variable time delays depending on the thickness variations of the slow velocity material. Thus, reflectors below the unconsolidated material will have apparent highs and lows (pull-down) that can be misinterpreted as structure.

There is no indication from Magorian's data whether the sedimentary cover was considered in processing the data. If not, then when considered with possible inaccurate input of road elevation changes, pulldown/pullup errors would be present in the seismic line. Thus, the structural "sag" associate with the proposed fault may be an artifact, as is shown by the well log analysis that shows the Tully and Onondaga are essentially flat between VP 1482 and VP ~1501, unlike the northwest dip displayed on the seismic line. The seismic line shows an apparent drop of .007s (~50 ft) on the Onondaga between these same vibration points.

Another indication that the seismic line does not accurately portray conditions at the Bath site is that the steep limb of the monocline inferred from the well logs on the northwestern boundary of the Bath site is in direct contrast to the broad sag, or syncline, displayed on Magorian's reprocessed seismic line. Furthermore, if the steep limb of the monocline is extrapolated to the seismic line (by extending the limb parallel to the strike of the structure, ~N55E), it is clear that the Cammillus/salt contact (as proposed by Magorian) on the seismic line shows no indication of the 120 ft structural relief at vibration point approximately 1502. The reflector is, in fact, flat in this section. Either the monocline does not extend to the seismic line, or has a trend different from that proposed, or the line was processed sufficiently improperly so that structures as large as 120 ft are not portrayed on the seismic line. In any case, the seismic line clearly does NOT reveal the monocline at the Bath site, implying that the seismic line cannot be relied upon. Moreover, the monocline indicated by well logs is not near where Magorian's alleged fault is supposedly located.

Only by using an unusually low velocity (compared to published velocity structures in the region) can I make the Tully reflector picked by Magorian agree in depth with the actual depth of the Tully, as determined from well logs. This is

a further indication of the inaccuracy of the seismic display and interpretation; combined with the other considerations discussed above, it strongly suggests that Magorian's reprocessed seismic line does not adequately represent the structure at the Bath site area and thus is unreliable.

3) *In the fifth paragraph of Magorian's report, he states that the seismic line "clearly shows up to 200 ft of throw on the Oriskany with 20 ms displacement of the strong Onondaga/Oriskany reflector".* First, how did he arrive at 200 ft throw for 20 ms two-way travel time? Using ~14,000 ft/s (which is a higher velocity than what he apparently used--see the point above concerning general velocity), we arrive at 140 ft offset, not 200 ft. Using his ~13,000 ft/s, we arrive at 130 ft, not 200. Second, where is the .02 s of displacement on the Onondaga? At most, assuming the entire sag is related to the fault, an offset of less than .01 s (70 ft) two-way travel time can be seen Magorian's Figure 2.

The offset of the reflectors across the fault, as depicted on Magorian's figure 2, cannot be reconciled with each other. The lower reflectors are proposed to show a thrust fault (the C Shale is translated to the west up over itself), but the upper reflectors (Onondaga/Oriskany) show the opposite sense of displacement--a normal fault (a normal fault is the exact opposite of a thrust fault; i.e. in this case, the east side moved down, not up over itself) This discrepancy over such a short distance and thickness interval casts severe doubt on the veracity of the fault as show on Fig. 2 of Magorian, since such structures are not observed in New York State.

CONCLUSIONS

Both well logs and reconnaissance structural geology near the Bath site strongly suggest that the units from the surface down to at least the Onondaga Formation at ~2650 below ground surface, are not cut by high angle faults at the Bath site. Neither faults nor anomalous joints are present in the immediate Bath site area in the Onondaga and higher units.

A monocline is inferred from well log data for the top-of-salt horizon at the northwestern boundary of the Bath site near wells #8, #10 and #11, but its effect is not observed in the Onondaga and higher units at the Bath site. Fracture analyses and Fountain's soil gas surveys at the surface in the area of the monocline show that no anomalous fractures occur, and none are open and throughgoing.

Reflectors observed on Magorian's reprocessed seismic line do not agree with the structure indicated by the incontrovertible well log data, suggesting that the seismic line does not accurately portray the subsurface structure at the scale of the

structures proposed by Magorian.

Moreover, the thrust fault proposed by Magorian and drawn on the seismic line makes little geological sense because the offset along upper part of the fault is consistent with a normal fault, not a thrust fault. A normal fault is the exact opposite of a thrust fault.

Finally, the studies cited herein, which are based upon scientifically accepted methodologies, confirm that no evidence exists from which a geological fault could be inferred above the salt layers at the Bath site southeast of the northwestern site boundary. Additionally, the results of the soil gas survey (see Fountain's report) confirm that there is no leakage through fractures on the site of those materials currently being stored in the caverns.

APPENDIX 1
BATH PETROLEUM STORAGE
ERRORS IN WELL LOG ANALYSIS

There are several possible sources of error in well log analyses. I document some of these errors below, and demonstrate the probable size of these errors for the data at Bath. Errors in the ground elevation of the drill site will affect any studies that involve comparison of the subsurface elevations of particular units at several wells.

DRILL SITE GROUND ELEVATION

Table 1 documents the amount of error inherent in estimating the topographic elevation of the drill sites. Column 5 ("Elevation, Drillrs rpt or log") displays the elevation of each drill site as shown on the drillers log (wells #1 to #6) and on the electric (e-) logs (wells #8 to #13). Column 6 ("Elevation, Topo Sheet") displays elevations of the well sites, estimated from the USGS topographic map. Comparison of these two columns shows that the driller's logs/e-logs elevations and the elevation estimated from the topographic map differ between -11 ft and +8 ft; the range of error is thus 19 ft. This error is to be expected in areas with low surface gradients and 20 ft contours.

Column 7 displays the average elevation between the driller's log and the topographic map estimate. This average elevation is first compared to surveyed elevations available for some wells (columns 9 and 10, entitled "Elevation, Town of Bath, MSES Cons.-8/95", and "Ave Elevatn-MSES Survey"). The range of error between the average elevation and the surveved elevations is from -13 ft to + 4 ft. for a total of 17 ft (Column 10).

Column 11 displays the drill site elevation from a table provided to me by the client. Column 12 compares these elevations to the surveyed elevations where possible (column 10) or to the average elevations, where survey data is not available (column 6). The error range is again from a -19 ft to + 0.15 ft.

In summary, each comparison between different methods of obtaining the drill site elevations shows that there is as much as 19 ft discrepancy between methods. Thus, apparent structural relief of 19 ft or less, as determined from the e-logs, is within the error range, and therefore may not reflect true structure, but merely problems with unsurveyed elevations. For this project, I used the most defensible elevations: the surveyed elevations where possible, and the average elevation (average of the annotation on the well logs and the estimated elevation from topographic maps) elsewhere.

IDENTIFICATION OF ROCK UNITS BASED ON WELL LOGS AND DRILLERS LOGS

For most of the "picks", i.e., the identification of the formation from characteristics of the well logs, I used those picks of Van Tyne and Foster (1979). As a backup, I consulted the picks of Beinkafner (1983). As long as I identify the same well log characteristics in each well, for structural purposes, it does not matter what I call the pick in terms of a formation name. However, the correct identification of the formation from the well logs becomes critical in areas where integration of drillers logs with the well log data is desirable. In those areas, the same unit obviously must be applied to both the well log characteristics and the drillers logs, or else a large apparent structure (fault) in subsurface elevations may occur between data sets. Fortunately, the Tully Formation and the top of the salt section are easily recognized both drillers logs and in the gamma ray well logs. Thus, neither the Tully subsurface elevations nor the top-of-salt subsurface elevations display significant differences between closely spaced wells with the two different types of logs (e-logs vs driller's logs). In fact, both the Tully and the Onondaga subsurface elevations across the Bath site are within the range of error of the assumed elevations of the well sites.

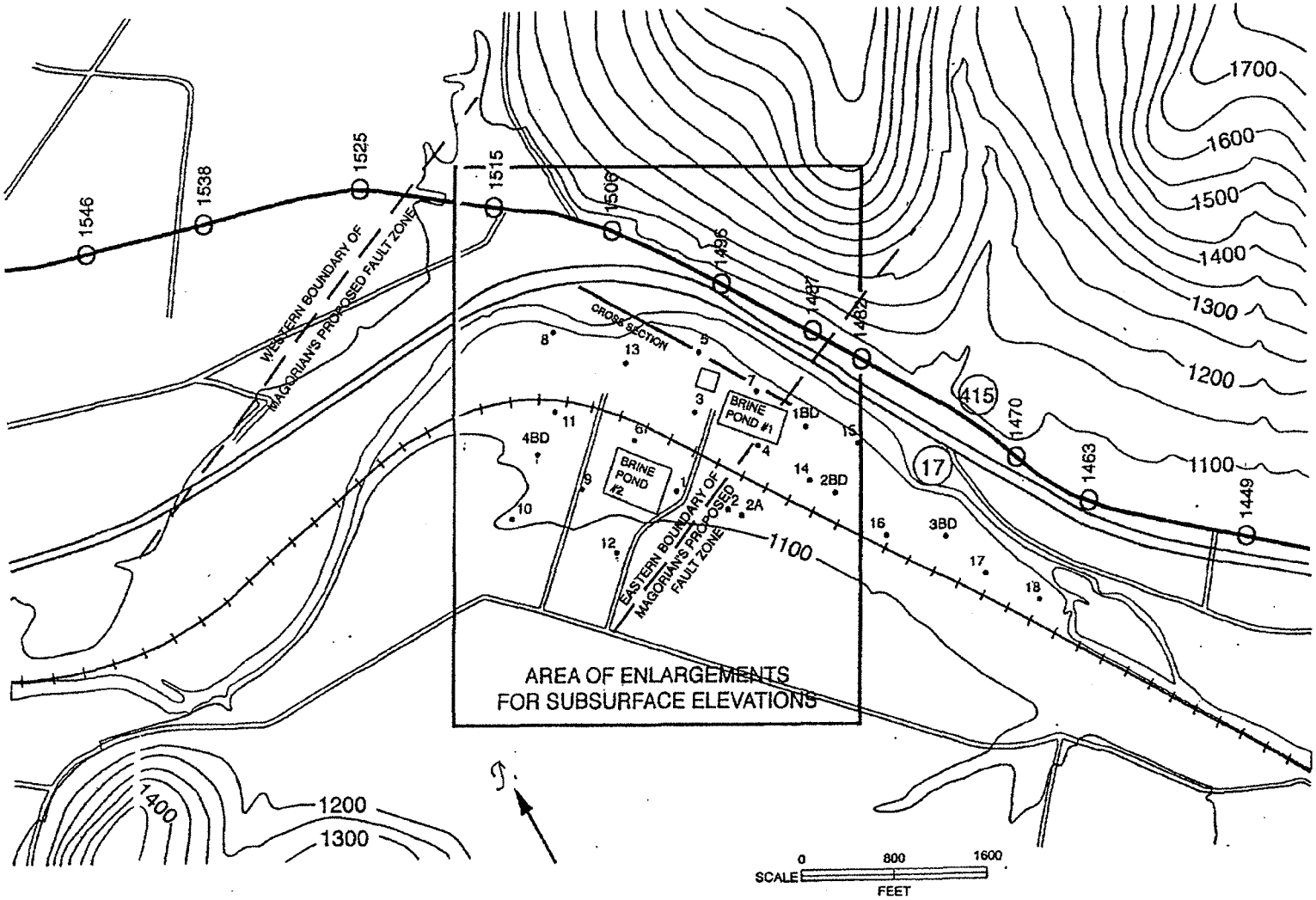
1546
1538
1525
1515
1506
1496
1487
1482
1470
1463
1449
415
17
1700
1600
1500
1400
1300
1200
1100
WESTERN BOUNDARY OF MAGORIAN'S PROPOSED FAULT ZONE
CROSS SECTION
BRINE POND #1
BRINE POND #2
EASTERN BOUNDARY OF MAGORIAN'S PROPOSED FAULT ZONE
AREA OF ENLARGEMENTS FOR SUBSURFACE ELEVATIONS
SCALE
0
800
1600
FEET

FIGURE 1

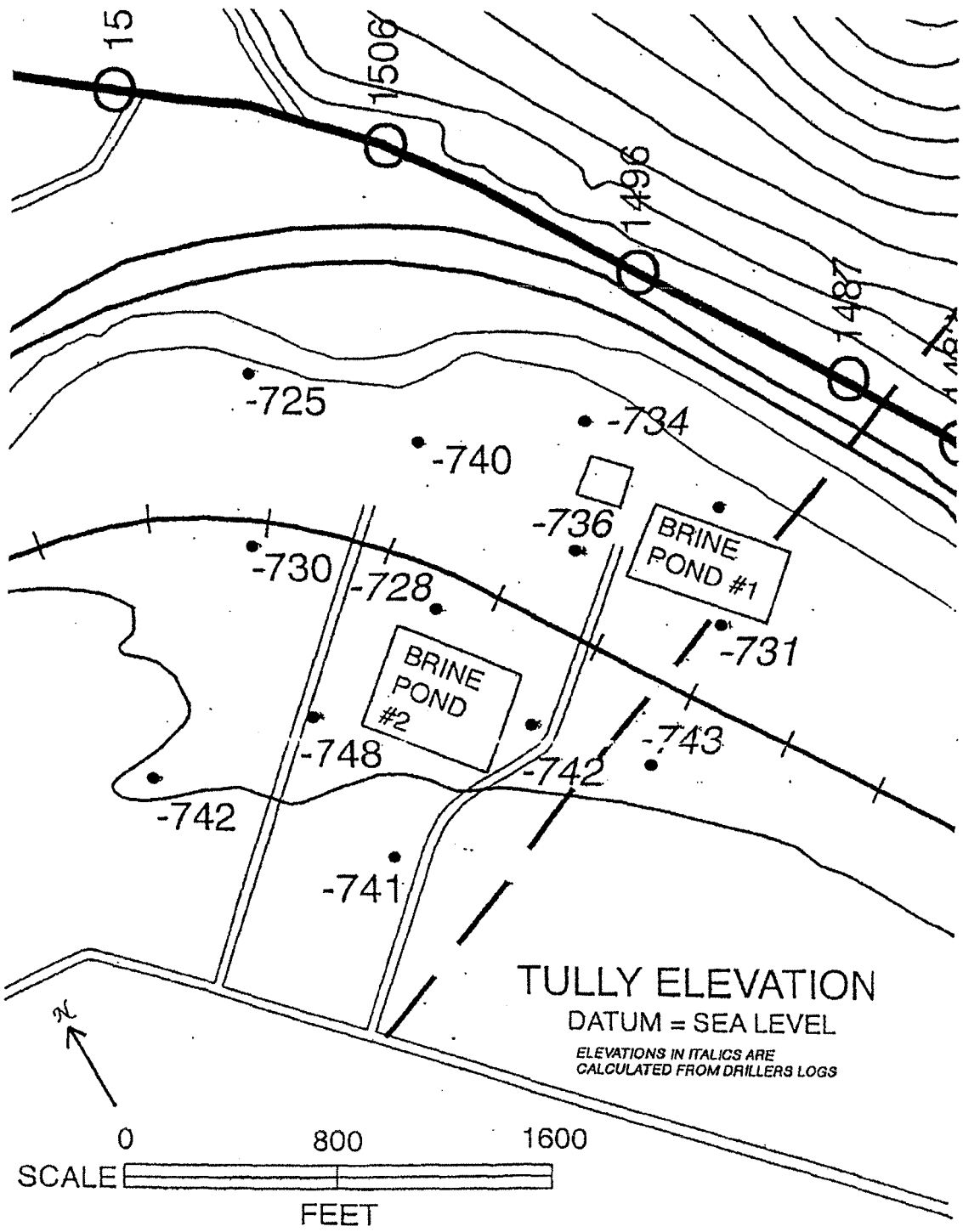
15
1506
1496
1487
-725
-734
-740
-736
BRINE POND #1
-730
-728
-731
BRINE POND #2
-748
-743
-742
-742
-741
TULLY ELEVATION
DATUM = SEA LEVEL
ELEVATIONS IN ITALICS ARE CALCULATED FROM DRILLERS LOGS
N
0
800
1600
SCALE
FEET

FIGURE 2

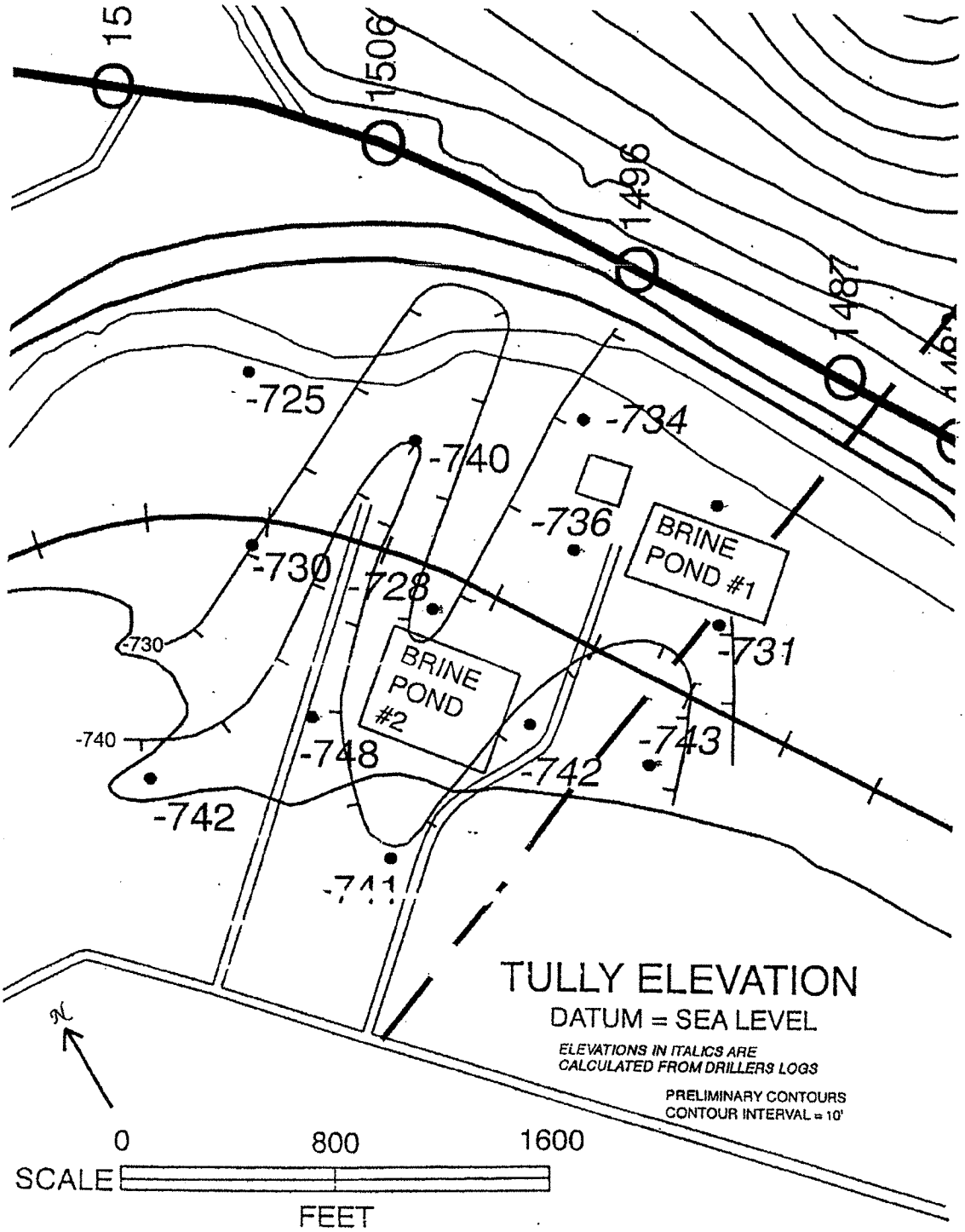
15
1506
1496
1487
-725
-740
-734
-736
BRINE POND #1
-730
-728
-731
-730
BRINE POND #2
-740
-748
-743
-742
-742
-741
TULLY ELEVATION
DATUM = SEA LEVEL
ELEVATIONS IN ITALICS ARE CALCULATED FROM DRILLERS LOGS
PRELIMINARY CONTOURS
CONTOUR INTERVAL = 10'
N
0
800
1600
SCALE
FEET

FIGURE 3

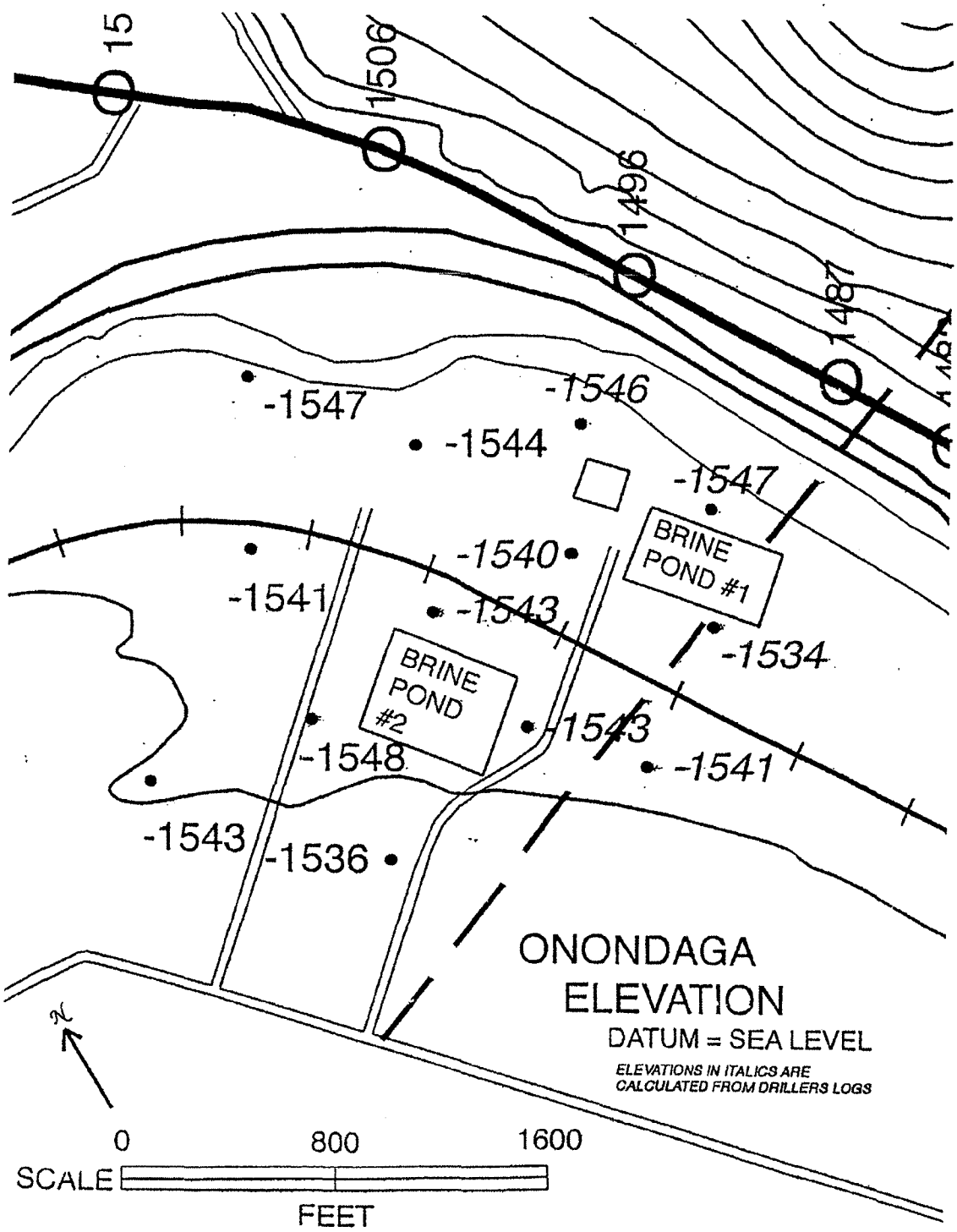
15
1506
1496
1487
-1547
-1546
-1544
-1547
-1540
-1541
-1543
BRINE POND #1
-1534
BRINE POND #2
-1548
-1543
-1541
-1543
-1536
ONONDAGA
ELEVATION
DATUM = SEA LEVEL
ELEVATIONS IN ITALICS ARE CALCULATED FROM DRILLERS LOGS
N
0
800
1600
SCALE
FEET

FIGURE 4

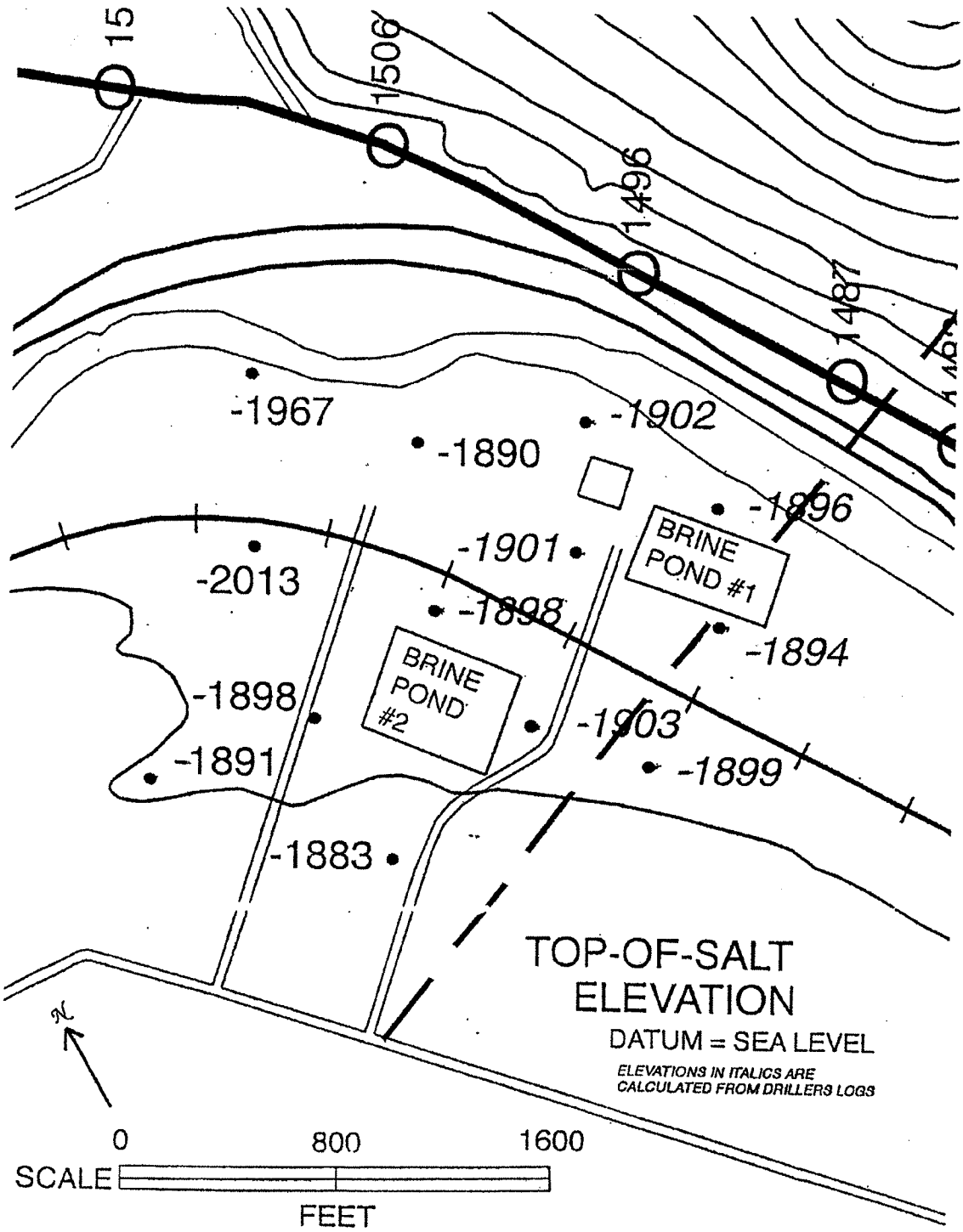
15
1506
1496
1487
-1967
-1902
-1890
-1896
-1901
-2013
-1898
BRINE POND #1
-1894
BRINE POND #2
-1898
-1903
-1891
-1899
-1883
TOP-OF-SALT ELEVATION
DATUM = SEA LEVEL
ELEVATIONS IN ITALICS ARE CALCULATED FROM DRILLERS LOGS
N
0
800
1600
SCALE
FEET

FIGURE 5

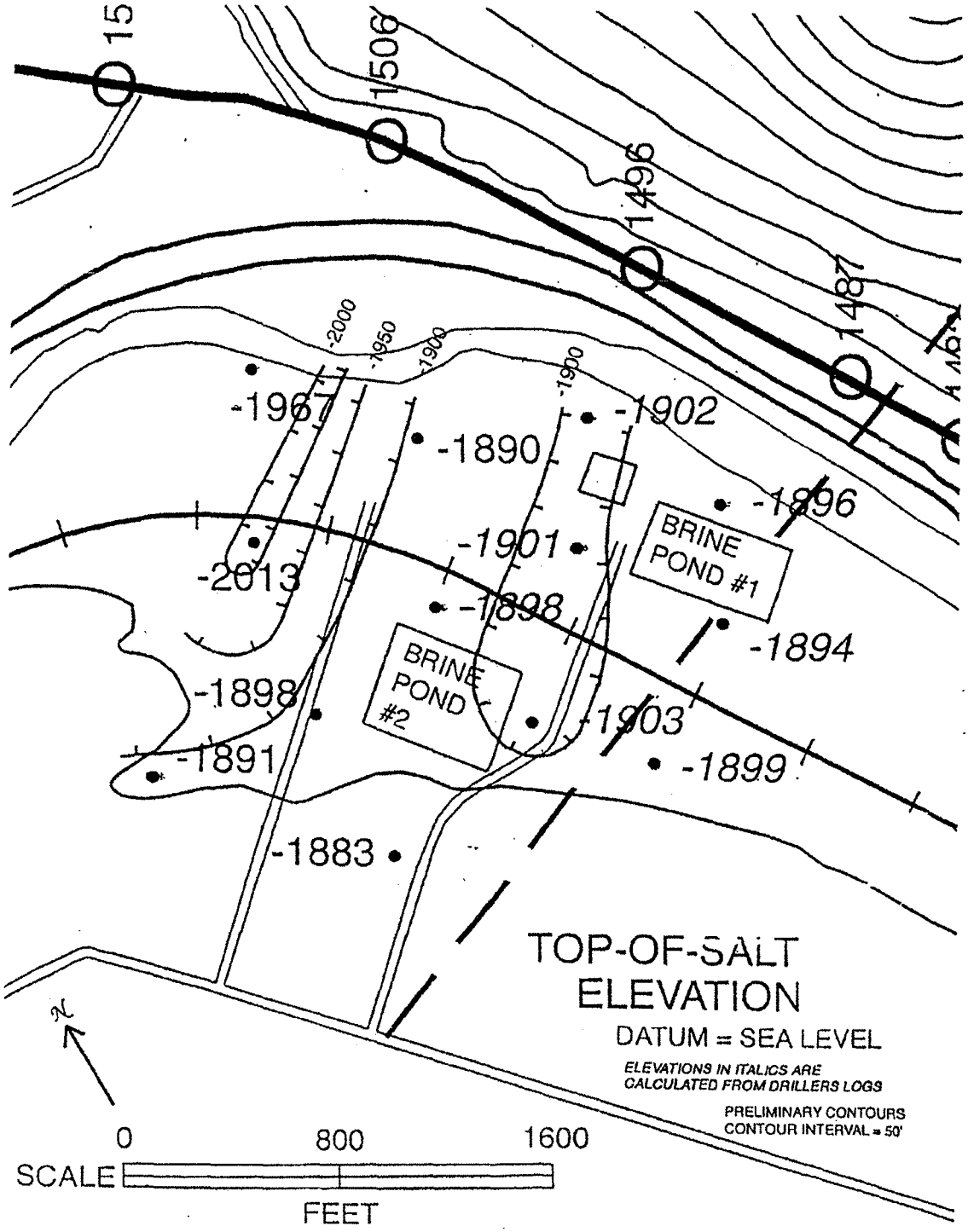
15
1506
1496
1487
-2000
-1950
-1900
-1950
-1967
-1902
-1890
-1896
-1901
-2013
-1898
BRINE POND #1
-1894
BRINE POND #2
-1898
-1903
-1891
-1899
-1883
TOP-OF-SALT ELEVATION
DATUM = SEA LEVEL
ELEVATIONS IN ITALICS ARE CALCULATED FROM DRILLERS LOGS
PRELIMINARY CONTOURS
CONTOUR INTERVAL = 50'
N
0
800
1600
SCALE
FEET

FIGURE 6

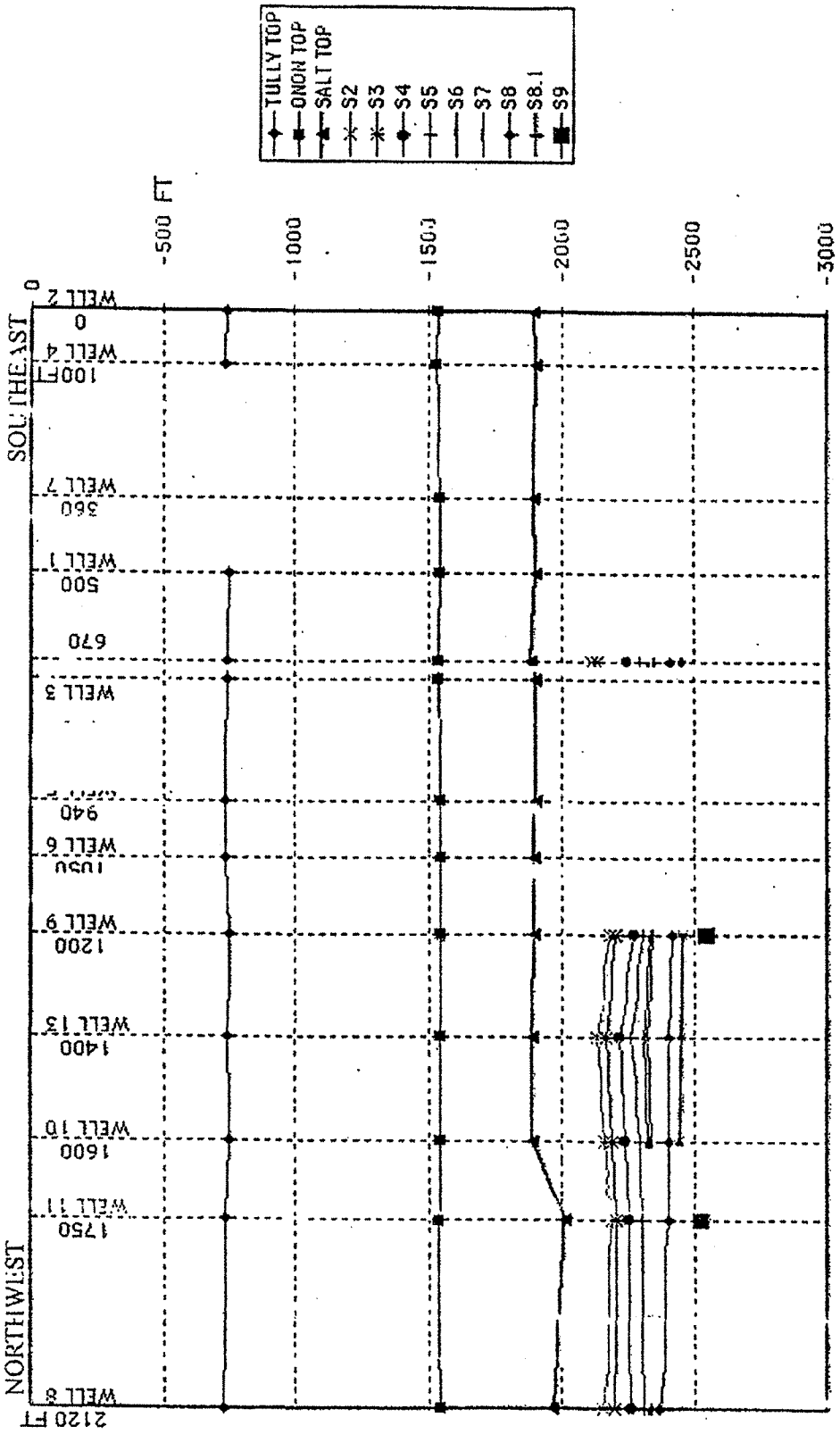
TULLY TOP
ONON TOP
SALT TOP
S2
S3
S4
S5
S6
S7
S8
S8.1
S9
-500 FT
-1000
-1500
-2000
-2500
-3000
SOUTHEAST
NORTHWEST
0
100FT
360
500
670
940
1050
1200
1400
1600
1750
2120 FT
WELL 2
WELL 4
WELL 7
WELL 1
WELL 3
WELL 6
WELL 9
WELL 13
WELL 10
WELL 11
WELL 8

FIGURE 7

TABLE 1: GROUND ELEVATION FOR DRILL SITES

1	2	3	4	5	6	7	8	9	10	11	12
LOCATION	WELL #	TYPE	DEPTH LGGD	ELEVATION	ELEVATION	ELEVATN DIF	ELEVATION	ELEVATION	AVE ELEVATN-	BPSI	SURVD OR AVE EL-
			(FT)	(DRILLRS RPT OR LOG)	(TOPO SHEET)	(LOG-TOPO)	AVERAGE	(TOWN OF BATH)	MSES SURVEY	Table	BPSI Table
BATH	1			1069	1077	-8	1073	(MSES Cons.-8/95)		1084	-11
	2			1067	1078	-11	1072.5			1081	-8.5
	3			1070	1068	2	1069			1088	-19
	4			1068	1071	-3	1069.5			1083	-13.5
	5			1067	1060	7	1063.5			1082	-18.5
	6			1075	1080	-5	1077.5	1090.47	-12.97	1090	0.47
	7	(gamma, density)	2850-3332		1066		1066			1085	-19
				(LOG ELVTN)							
	8	formation microscanner	2720-3092	1068	1060	8	1064	1077.15	-13.15	1077	0.15
	8	compenstd neutron density	2700-5000	1068	1060	8	1064	1077.15	-13.15	1077	0.15
	8	rx mechanics(Mecpro)	1380-3500	1068	1060	8	1064	1077.15	-13.15	1077	0.15
	8	mechanical properties	3380-5200	1068	1060	8	1064	1077.15	-13.15	1077	0.15
	8	gamma, density	0-3537	1068	1060	8	1064	1077.15	-13.15	1077	0.15
	9	gamma, density	0-3766	1090	1093	-3	1091.5			1100	-8.5
	10	gamma, density	0-3596	1090	1098	-8	1094	1105.6	-11.6	1106	-0.4
	11	gamma, density	0-3777	1082	1082	0	1082	1085.63	-3.63	1086	-0.37
	12	gamma, density	0-3602	1122	1122	0	1122	1118.13	3.87	1118	0.13
	13	gamma, density	0-3613	1065	1062	3	1063.5			1080	-16.5

Exhibit 2 to the January 19 Memorandum from Finger Lakes Containing Response to Public Comments Regarding Geology and Underground Storage Caverns

Results of a Soil Gas Study In the Vicinity of the Bath Petroleum Storage Facility Final Report

Submitted By: Dr. John C. Fountain
315 Brantwood Rd.
Amherst, NY 14226

July 21, 1997

Introduction

Samples of gas were collected from soil at over 900 sites in and around the Bath Petroleum Storage Facility, Steuben County, near Bath, New York to aid in determining if fracture pathways for gas seepage exist from the petroleum storage caverns at the facility to the surface. The location of the facility, and of the soil gas samples, are shown on Figure 1.

Soil gas analyses provide information on gas seepage along fractures (or faults) because gas will rise along open fractures and can accumulate in overlying soil. Bedrock in most units in Western New York contains natural gas (Jenden et al., 1993), providing a source for the gas. Although most rock units in Western New York contain natural gas, flow from these units is so minute that normally the gas content in overlying soils is not detectably enriched. Only when fractures or faults provide a pathway to the surface will thermogenic gas (natural gas) accumulate in the soil (Fountain and Jacobi, 1997; Jacobi and Fountain, 1993; Jones and Drozd, 1983). Gas may also accumulate from biogenic decay of organic matter. Gas produced by biogenic processes is characterized by a composition of almost pure methane and no significant amounts of heavier hydrocarbons such as ethane occur (Whiticar et al., 1986). In contrast, thermogenic (natural) gas of Western New York has ethane contents in the range of a few percent to over 15% of the methane content plus lesser amounts of propane and heavier hydrocarbons (Jenden et al., 1993).

Data from well logs and seismic data have been cited by Tom Magorian to suggest a structure, possibly a fault, exists in the area of petroleum storage facility near well no. 7. If a fault is present, and provides a pathway for gas migration to the surface, anomalously high contents of propane or butane, the principal gasses stored in the facility, should occur. This study was undertaken to determine if such an accumulation occurred.

Results

No butane was detected in analysis of over 900 samples of soil gas in the vicinity of the Bath Petroleum Storage Facility. Additionally no propane in excess of that expected from local thermogenic natural gas was found. Most importantly, the study uncovered no evidence in support of any structural pathways, including faults and fractures, between the petroleum storage caverns and the surface on the site of the Bath Petroleum Storage facility. Nor was evidence of a fault oriented as suggested by Magorian found.

If either faulting or folding occurred in the study area, and the related fracturing extended to the surface, the fractures would be concentrated along the structure and hence gas leakage would be expected. Some anomalously high concentrations of hydrocarbon gas were found, most of which had significant ethane concentrations indicating a thermogenic (as opposed to a biogenic) origin. These occurred primarily away from the

Bath Petroleum Storage facility property, along the valley walls near bedrock outcrops. The trend of the anomalies suggested leakage from fractures parallel to the main valley walls, with higher concentrations at the intersections with fractures forming the side valleys. The composition of the gas (methane and ethane) indicates an origin from the shallow bedrock.

Study Design

Several sets of fractures occur in bedrock throughout Western New York, although the trend of the dominant fracture set is different at different locations. Most of the major fracture sets were formed during the multiple orogenies that produced the Appalachian Mountain chain (Zhao and Jacobi, 1997) and hence are several hundred million years old. Old fractures typically are sealed and thus do not provide pathways for gas migration, as evidenced by the retention of natural gas for many millions of years throughout the region. Uplift and erosion during the recent glaciations has also caused extensive fracturing near the bedrock surface in many units, thus the presence of open fractures near the surface may not be indicative of open fractures at depth.

The study consisted of a number of soil gas traverses, each traverse consisting of a line of soil gas samples collected every 30 feet, typically along the sides of roads. Traverses were conducted on both the north and south sides of the valley as well as within the storage facility itself (Figure 1). On each traverse samples were collected every 30 feet from a depth of approximately 2 feet with stainless steel probes. Samples were collected with gas tight syringes and were immediately analyzed on-site with a portable organic vapor analyzer (Century OVA 128 GC) equipped with a flame ionization detector and a gas chromatograph column to separate hydrocarbon gasses. The instrument was calibrated daily with a calibration gas of known methane content. Methane, ethane and butane elution times were also verified with calibration gasses. Duplicate samples were taken periodically, and duplicate samples were taken whenever large spikes (anomalously high hydrocarbon contents) were found. Samples with high organic vapor content were injected in Gas Chromatograph (GC) mode to determine relative methane/ethane/propane and butane abundances.

933 samples were analyzed over 26,220 feet of traverse. The location of the individual traverses are shown on Figures 1 and 3. Data for each traverse is shown on plots in Appendix I, and tabulated in Appendix II. In this section the data are discussed in terms of local geology.

Discussion

Local Fracture Sets:

Fractures typically occur in sets, groups of fractures that have a similar trend over a relatively large area. Fracture sets from the local area thus provide a context for interpretation of soil gas anomalies. Study of outcrops adjacent to traverses on both the north and south sides of the valley, and in several creeks outside the area, determined that there are three prominent fracture sets in the area. A very strong fracture trends roughly northeast; this fracture is related to the prominent NE trending side valleys in the area (but not at the facility, which is not on trend with a side valley). A second strong fracture trends about northwest, parallel to the main valley through which highway 17 runs in this area. The prominent steep sided valley is strongly suggestive of a fracture controlled valley. Finally, a weakly developed fracture system trends almost due north. This fracture system has less topographic expression that the other two sets, perhaps the most prominent is the large valley running north from Bath.

Soil Gas Anomalies, General Characteristics:

Although fractures occur in all bedrocks in Western New York, most do not result in soil gas anomalies. Anomalies occur only where the fractures are open, presumably due to reactivation of a portion of the fracture zone providing a pathway for gas migration. Typically this results in anomalously high gas content over only a narrow zone of a fracture set, typically a zone ranging from 50 to several hundred feet (based on over 10,000 analyses in Western New York). A traverse running perpendicular to a fracture set usually yields a number of anomalously high abundances, with the samples with maximum magnitudes near the center of the anomalously high group. In contrast a traverse running nearly parallel to an open fracture set would have an extensive number of spikes, not showing a regular pattern.

Valley Wall Traverses:

A series of traverses were run along the walls of the valley, both the northern wall and the southern wall. The traverse along the northern wall followed route 415 (Figure 1). We believe that the steep-sided straight-edged valley wall reflects erosion along a fracture set that trends parallel to the valley itself. Thus we would expect some gas to be emitted from the fractures that are parallel to these traverses. The northern traverse begins approximately 0.8 miles north of the Petroleum Storage Facility, in an ENE trending side valley, continues along the bedrock on the valley wall, and ends south of the Petroleum Storage Facility (Figure 1). The traverse can be divided into three segments based on the soil gas analyses (Figure 2) . In the northern-most segment north of the side-valley wall, soil gas contents are fairly low, with no significant spikes. In the central section, which runs from 2000 feet north of the bridge to 1000 feet south of Irish Hill Road, there is a nearly continuous occurrence of anomalies of 10 ppm or more. These anomalies are consistent with a trend along a fracture, the pattern is of continual anomalies of similar size, not increasing in size towards the center of the anomaly cluster as expected for traverses that cross a fracture set. The southern end of the section, south of Irish Hill

Road, again has low abundances. This corresponds to an area without bedrock outcrop and of much lower relief. Gas chromatography determined that the spikes all along this traverse contained methane and ethane, but no butane or anomalously high propane (propane is present at abundances less than ethane in all natural gas, if propane was from propane storage, its abundance would be higher than expected ratio to ethane and methane). The ethane indicates the gas is from thermogenic natural gas in the shallow bedrock.

The principal spikes on this traverse, and on the southern traverse described in the next section, are shown on Figure 1. At each location that one or more samples yielded a value of 10 ppm or more (the maximum reading for the scale used) an "x" is marked on the Figure. Where several anomalies occur together, only 1 "x" is shown.

The traverse along the southern wall of the valley is quite different. It begins on Wagner Road, crossing a side valley, and continues down Eagle Valley Road past the Storage Facility (Figure 1). The northern end of the traverse, along Wagner Road and continuing to the bridge has many spikes of about 12 ppm (Figure 2). The central section past the Bath Petroleum Storage facility has few spikes, then a cluster of spikes is found approximately 0.4 miles south of the facility. Since the side valley cut by Wagner Road is also linear and aligned with the NE regional fracture set, it is presumably also a fracture controlled valley. The northern cluster of spikes, along Wagner Road and the remainder of the traverse in the side valley, is located at the intersection of the NE and the NW set that controls the main valley. Large concentrations of anomalies at fracture intersections are expected. This interpretation is supported by the smaller gas concentrations found along Eagle Valley Road. These spikes presumably arise from the valley wall parallel fractures in a similar manner to the spikes on the north side of the valley. The southern cluster of spikes on this traverse may represent another intersection of the NE fracture set and the NW fracture set. As with the northern traverse, no butane or anomalously high propane was found on the southern traverse.

Traverses on the Bath Petroleum Storage Property:

Traverses were run on Bath Petroleum Storage Facility property parallel to highway 17 and perpendicular to it (Figure 3). A circle of analyses was also made around well 8. A traverse was also run along the river, approximately centered on well 7 since an alleged fault postulated by Magorian was located in this area These traverses were close to a number of active and proposed storage wells. As shown on Figure 3, samples were also taken near wells 13, 11, 6, 9 and 5.

There was no correlation between distance to the wells and gas content. No anomalies were found close to any of the wells indicating that no detectable leakage occurs near the wells. No butane and no propane was found in of these any analyses indicating that no detectable leak from the depth of the storage reservoir was present. A number of spikes were found along the road that leads to the old barn (the road that runs past well 9 and 12). These spikes contained methane and ethane, but no butane; they were from shallow bedrock not from the depth of the storage caverns. No spikes were found along two

traverses run perpendicular to this road, except right along the road (Figure 3). A circle of samples taken around well 8 yielded no spikes (Appendix I). The traverse parallel to the river yielded one isolated spike, not close to any of the wells. The conclusions from this data are that no detectable butane or propane leakage occurs, that no systematic open fractures were detected anywhere except parallel to the access road and that these fractures are not concentrated near well 8 nor along the traverse centered on well 7.

The data suggest that there is no fracturing that reaches the surface associated with the monocline postulated by Jacobi based on well log analyses. This conclusion is consistent with Jacobi's observations that the Onondaga and overlying units are flat lying and that local outcrops do not display faulting or increased fracturing in this area. Traverse 97-7 (Figure 3) crosses the axis of the monocline, but no spikes were found along the portion of the travese near where the axis crosses the traverse. If open fractures were associated with the monocline and did reach the surface, spikes would be expected along the traverse. Analyses near well 9, which is located on the edge of the monocline, did not detect any butane, although the well is used for butane storage. If open fractures to the surface were associated with this structure, butane anomalies would be expected from samples near well 9.

Other Data:
A short traverse was run perpendicular to highway 415 approximately 1 mile south of the Bath Petroleum Storage facility (Figure 1). This segment passes under overpasses for highway 17. Several spikes were found along this traverse. Due to the extensive excavations and filling for the overpasses, it is not clear if the data on this traverse are reliable. No butane nor anomalous propane was found in any samples.

Conclusion

The intensive soil gas study conducted at this site is far beyond those characteristically done at conventional storage facilities. It provides perhaps the most comprehensive documentation of the integrity of any facility of which I am aware. There have been no published soil gas studies of this detail on other gas storage facilities. Based upon my personal experience, the Bath Petroleum Facility evidences less likelihood of the existence of faulting which would affect the structural integrity of the storage facility than any I have tested. There is no evidence of any leakage in the existing caverns which would cause concern regarding the storage of natural gas.

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