SECTION B

B. Additional information required for an application for a permit to drill and operate a disposal well or to convert a previously drilled well to such a well:

B.1 Form EQP 7200-14, Injection Well Data.

Injection Well Data is presented on form EQP 7200-14, which is attached at the end of this Section (B 1).

INJ. WELL
DATA
7200-14
7

DEQ MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY - OFFICE OF GEOLOGICAL SURVEY

INJECTION WELL DATA

Supplemental information for drilling or converting to an injection well

By authority of Part 615 or Part 625 of Act 451 PA 1994, as amended
Non-submission and/or falsification of this information may result in fines and/or imprisonment

Applicant
Beeland Group, LLC

Well name and number
Bay Harbor Disposal Well No. 1

INSTRUCTIONS: Complete all portions of form which apply to this well. **Attach supplemental documents as needed.**

1 File a separate plat which identifies the depth and location of this proposed well and all producing abandoned or drilling wells within 1320 feet of it. Also identify the permittee of each producing well within 1320 feet of this proposed well

2 Enclose a copy of the completion reports for all wells and the plugging records for all plugged wells shown on the plat. Identify what steps will be necessary to prevent injected fluids from migrating up or into inadequately plugged or completed wells.

3. If this is an existing well to be converted to an injection well, enclose this form with an Application To Change Well Status (form EQP 7200-6) Also enclose a copy of the completion report and geologic description and electric logs for this well.

4 Injection wells (except for gas storage) must receive a mechanical integrity test every 5 years pursuant to Rule 324 805

5. Type of fluids to be injected
☒ Brine ☐ Natural Gas (omit #7 & #12)
☐ Fresh Water (omit #12) ☒ Other Non hazardous remediation

6. Maximum expected injection rate 200 gpm

7. Specific gravity of injected fluid 1.01-1.05 (max calc. @ 1.10)

8. Maximum expected injection pressure 563 psig

9 Maximum bottom hole injection pressure 3426 psi
Show calculations 563+ 1 1*0 433*6010

10 Fracture pressure of confining formation 4207 psi at base
Show calculations 0 7*6010
also Eaton method, see B.12

11 Fracture pressure of injection formation >3426 psi
Show calculations 0 57*6010
also Eaton method, see B.12

12 Chemical analysis of representative samples of injected fluid
Specific conductance TBD

Cation (mg/l)		**Anions** (mg/l)	
Calcium	12.1	Chloride	1,730
Sodium	889	Sulfate	14,500
Magnesium	<0.5	Bicarbonate	1,620
Potassium	13,800		

What was the source of this representative sample? Injectate from Bay Harbor Michigan Remediation, source of injection, DW

13 Is this well to be completed in a potential or previous oil or gas producing formation? ☐ Yes ☒ No
If yes provide a list of all offset permittees and proof of service of notification of this application to all permittees by certified mail.

14 Attach proposed plugging and abandonment plan OR Briefly list depths, volumes and types of cement and mechanical plugs and depths where casing will be recovered

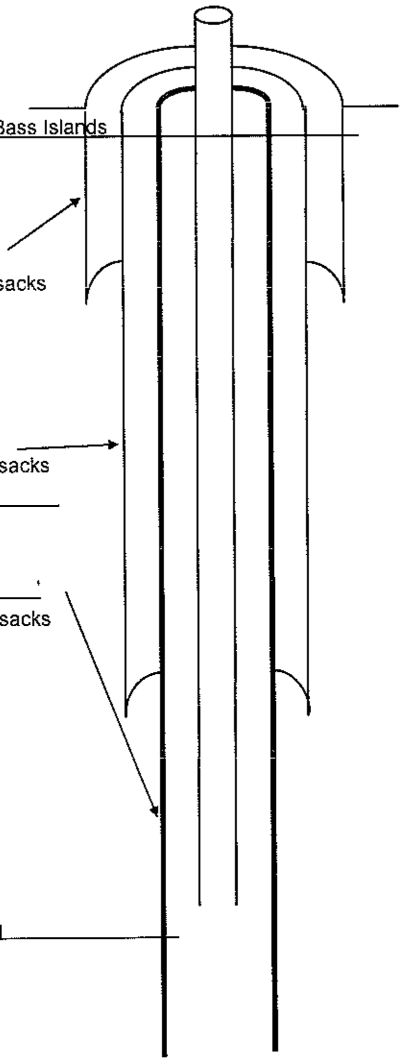
Attached plan and Figure Q-1 from October 2009 EPA permit application for this well

Schematic of wellbore construction

Complete bottom of diagram as needed to conform with proposed construction (e g show rat hole below casing open hole completion packer loc etc)

Fresh water fms name & depth
Traverse: 0 - 540' BGS
other formations to be tested

Base of freshwater name & depth
540' - Traverse; possible 2,000' Base of Bass Islands



Surface casing 13 3/8 "x 250 '
Amount of cement 177 sacks
T O C ground surface

Intermediate casing (if applicable)
9 5/8 "x 1750 - 2000 '
Amount of cement 552 @ 1750' sacks
T.O C ground surface

Long string casing 7 "x 6010 '
Amount of cement 797 sacks
T O C ground surface

Confining formation(s)
Depth to top 4434'
Depth to base 6010'

Injection formation(s) Mt. Simon/Munising
Depth to top 6010'
Depth to base 7500'

Tubing 4 1/2 x >6010 '
Packer Depth 6000'

Bottom TD or PBTD 7500 ft.

15 Application prepared by (print or type):
Kenneth Cooper, PE; Consultant/Petrotek Engineering Corporation

Date
6/2/2010

EQP 7200-14 (rev 8/2004) Enclose with *APPLICATION FOR PERMIT TO DRILL* or *APPLICATION TO CHANGE WELL STATUS*

B.2 A calculation of the area of review in the injection interval over the anticipated life of the well. "Area of review" means either of the following:

A. For a well disposing of non-hazardous waste, that area the radius of which is the greater of 1/4 mile or the lateral distance in which the pressures in the injection zone are sufficient to increase hydrostatic head in the injection zone above the base of the lowermost underground source of drinking water, but not more than 2 miles.

B. For a well disposing of hazardous waste that area the radius of which is the greater of 2 miles or the lateral distance in which the pressures in the injection zone are sufficient to increase hydrostatic head in the injection zone above the base of the lowermost underground source of drinking water.

The radius of investigation used in this permit request has been based on standard practices applied historically in Michigan The area of review (AOR) for this non-hazardous injection well has been defined as a fixed radius of ¼-mile for the evaluation of all non-fresh water penetrations In addition, a calculated 3-mile cone-of-influence has also been shown on maps regarding deep, non-fresh water penetrations, and data has been supplied for all such wells within this radius. A fixed radius of one-quarter mile for the circumscribing area around the disposal well has also been defined for the evaluation of fresh-water artificial penetrations. Area of review and cone-of-influence radii have been applied from the property boundaries for the well facility. Fresh water well data for penetrations located within the area around a ¼-mile radius have been identified from state files and submitted Maps generated from Michigan Department of Environmental Quality (MDEQ) data have been submitted to summarize these data. See Figure 4 at the end of Section A 4 for a summary of shallow fresh water penetrations and Figure 6 at the end of Section B 2 for a summary of all deep penetrations.

The cone-of-influence for injection is defined as that area around a well within which increased injection zone pressures caused by injection could be sufficient to drive fluids into an underground source of drinking water (USDW). The pathway for this theoretical fluid movement is assumed to be a hypothetical, open abandoned well which penetrates the confining zone for injection. Information used in the following calculations has been estimated from logs and available neighboring well information summarized in this document.

Critical Pressure Rise

To calculate the COI, a value must first be assigned for the pressure increase in the injection interval that would be sufficient to cause injection zone brine to rise in a hypothetical open pathway to the base of the lowermost USDW. This critical pressure rise, Pc, is assigned as indicated in Figure 7.

The pressure required at the top of the injection interval to support injection zone brine in the configuration indicated is, in psi units:

$$P = 0\ 433\ [y_B D_B + y_w(D_w - L)]$$

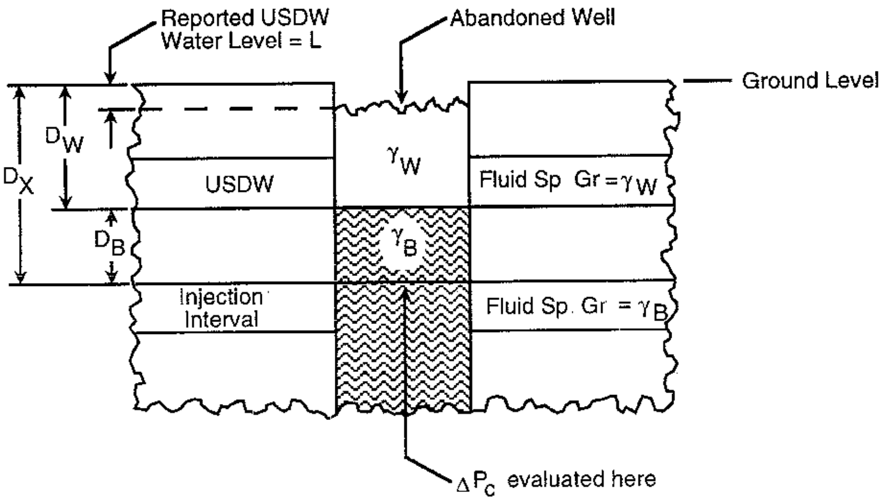
where: $D_B = D_x - D_w$

and the pressure rise is then:

$$Pc = 0\ 433\ [\ y_B D_B + y_w(D_w - L)] - Po$$

where Po is the original, pre-injection value for pressure at the top of the injection interval expressed in psi units

FIGURE 7 CRITICAL PRESSURE RISE



Original pressure in the Mt Simon has been estimated from typical fluid gradients found in northern Michigan for this formation For the estimated top of the injection interval of 6,010 feet, a gradient of 0.433 psi/ft yields a pressure of 2,602 psi at the top of the Injection Interval, the top of which is the Franconia. Note that it is assumed that while the Mt Simon is the injection zone, it is also assumed that the entire Cambrian column is in hydrostatic equilibrium, and the top of this column is the Franconia

In assigning the critical pressure rise and calculating the cone-of-influence at this site, the base of the lowermost USDW is assigned as 540 feet, as discussed in Response 2.D of this document. The lowest potentiometric surface of the water table within 1/2 miles of the Bay Harbor well is projected to be between 210-35 feet below ground surface, based on local water well data. Therefore, in these calculations, it is assumed that the water table is at approximately 210 feet below ground level, which is larger than anticipated drawdown, and is deeper that the total depth of many of the water wells in the area.

TABLE 2 CRITICAL PRESSURE CALCULATION PARAMETERS

Parameter	Value
Original pressure, Po	2,602 psi @ 6,010 feet
Depth to base of USDW, D_w	540 feet*
Depth to top of injection zone, D_X	6,010 feet
Depth to USDW fluid level, L	35-210 feet BGS (within ½ mile radius of site)
Specific Gravity of USDW fluids, γ_w	1.0
Density of injectate or injection zone brine, γ_B	1.16 (Briggs,1968)

*could be as deep as 2,000 ft; 540 ft assumes USDW is base of Traverse excluding Bell Shale

These values were used in the above equation to compute the critical pressure rise as follows:

$$Pc = 0\ 433[1\ 16(6{,}010-540) + 1\ 0(540-210)] - 2{,}602 \text{ psi}$$

or:

$$Pc = 288 \text{ psi}$$

Cone-of-Influence

Based on the calculated value for the critical pressure rise, the cone-of-influence can be calculated for the Bay Harbor well over a twenty-year period of injection. At the proposed Bay Harbor well, there is projected to be less than a 3-mile cone-of-influence for continuous injection at a conservatively overestimated rate of 200 gpm (6,857 bwpd) This value can be confirmed by examination of the following calculation (oilfield units) of pressure rise in the reservoir at a distance of five feet from the injection well:

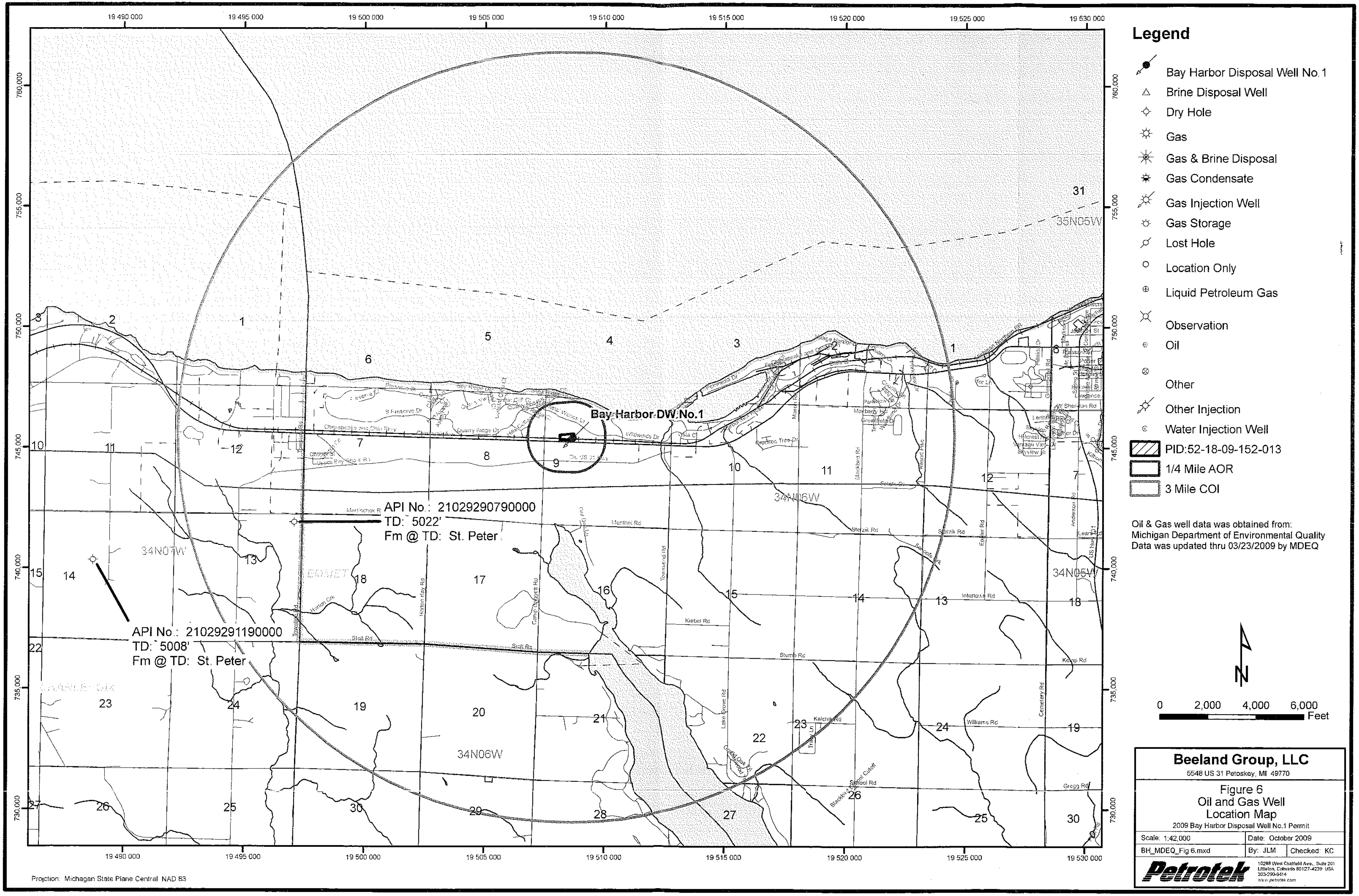
$$dP = -70\ 6\ Bq\mu /kh * \ln ([1{,}688\ \phi\mu c_t r^2/kt] -2s)$$

where the values listed in Table 2 have been assigned based on estimates for site-specific information.

The above calculation for pressure rise due to twenty years of injection at a rate of 200 gpm yields an increase of approximately 280 psi. This value is smaller than the conservatively calculated critical pressure, Pc, of 288 psi which would be necessary before there is potential for upward fluid movement to the base of a USDW if an open pathway were present Therefore, the cone-of-influence at this site is approximately 3 miles, even under a conservative scenario Due to the complete lack of potential pathways, significant depth, high-density natural brine, and relatively low original pressure of the Mt. Simon sandstone injection formation at this site, there exists no potential for contamination of USDW resources in the Radius area of review

TABLE 3 CONE-OF-INFLUENCE PARAMETERS

Parameter	Calculation	Value
Flow rate, q	200 gpm *1440 min/day* bbl/42 gal	6,857 bbl/d
Thickness, h	General estimate of 0>5%	300 feet (conservative estimate for entire Munising Group based on projected estimates, Milstein 1983, 1989)
Formation Volume Factor, B		1 015
Porosity, Φ		0.05 (from MIDCARB website)
Permeability, k		10 md
Viscosity, μ		0 6 centipoise @ 72 degrees F 0 013 degrees/ft gradient with td temp of 123, temperature at 30 ft BGS of 45 degrees, and depth of 6010 ft, values estimated form the Hand Well No.1
Total Compressibility, C_t	$3.2x10^{-6}$ psi^{-1} + $4.8x10^{-6}$ psi^{-1}	$8x10^{-6}$ psi^{-1}
Radius, r		15,840 feet
Time t	20 years x 365 25 days/yr * 24hr/day	175 320 hours



Legend
Bay Harbor Disposal Well No.1
Brine Disposal Well
Dry Hole
Gas
Gas & Brine Disposal
Gas Condensate
Gas Injection Well
Gas Storage
Lost Hole
Location Only
Liquid Petroleum Gas
Observation
Oil
Other
Other Injection
Water Injection Well
PID:52-18-09-152-013
1/4 Mile AOR
3 Mile COI
Oil & Gas well data was obtained from:
Michigan Department of Environmental Quality
Data was updated thru 03/23/2009 by MDEQ
Bay Harbor DW No.1
API No.: 21029290790000
TD: 5022'
Fm @ TD: St. Peter
API No.: 21029291190000
TD: 5008'
Fm @ TD: St. Peter
35N05W
34N06W
34N07W
34N05W
0 2,000 4,000 6,000 Feet
N
Projection: Michigan State Plane Central NAD 83
Beeland Group, LLC
5548 US 31 Petoskey, MI 49770
Figure 6
Oil and Gas Well
Location Map
2009 Bay Harbor Disposal Well No.1 Permit
Scale: 1:42,000
Date: October 2009
BH_MDEQ_Fig 6.mxd
By: JLM
Checked: KC
Petrotek

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY - OFFICE OF GEOLOGICAL SURVEY

DEQ

INJECTION WELL DATA

Supplemental information for drilling or converting to an injection well

By authority of Part 615 or Part 625 of Act 451 PA 1994, as amended
Non-submission and/or falsification of this information may result in fines and/or imprisonment.

Applicant
Beeland Group, LLC

Well name and number
Bay Harbor Disposal Well No. 1

INSTRUCTIONS: Complete all portions of form which apply to this well **Attach supplemental documents as needed.**

1 File a separate plat which identifies the depth and location of this proposed well and all producing, abandoned, or drilling wells within 1320 feet of it Also identify the permittee of each producing well within 1320 feet of this proposed well
2 Enclose a copy of the completion reports for all wells and the plugging records for all plugged wells shown on the plat Identify what steps will be necessary to prevent injected fluids from migrating up or into inadequately plugged or completed wells.
3 If this is an existing well to be converted to an injection well, enclose this form with an Application To Change Well Status (form EQP 7200-6). Also enclose a copy of the completion report and geologic description and electric logs for this well
4 Injection wells (except for gas storage) must receive a mechanical integrity test every 5 years pursuant to Rule 324 805

5. Type of fluids to be injected
☒ Brine ☐ Natural Gas (omit #7 & #12)
☐ Fresh Water (omit #12) ☒ Other Non hazardous remediation

6. Maximum expected injection rate 200 gpm

7. Specific gravity of injected fluid 1.01-1.05 (max calc. @ 1.10)

8. Maximum expected injection pressure 563 psig

9 Maximum bottom hole injection pressure 3426 psi
Show calculations 563+ 1 1*0 433*6010

10 Fracture pressure of confining formation 4207 psi at base
Show calculations 0 7*6010
also Eaton method, see B.12

11 Fracture pressure of injection formation >3426 psi
Show calculations 0 57*6010
also Eaton method, see B.12

12 Chemical analysis of representative samples of injected fluid
Specific conductance TBD

Cation (mg/l)	**Anions** (mg/l)
Calcium 12.1	Chloride 1,730
Sodium 889	Sulfate 14,500
Magnesium <0.5	Bicarbonate 1,620
Potassium 13,800	

What was the source of this representative sample? Injectate from Bay Harbor Michigan Remediation, source of injection, DW

13. Is this well to be completed in a potential or previous oil or gas producing formation? ☐ Yes ☒ No
If yes, provide a list of all offset permittees and proof of service of notification of this application to all permittees by certified mail.

14. Attach proposed plugging and abandonment plan OR
Briefly list depths volumes and types of cement and mechanical plugs and depths where casing will be recovered

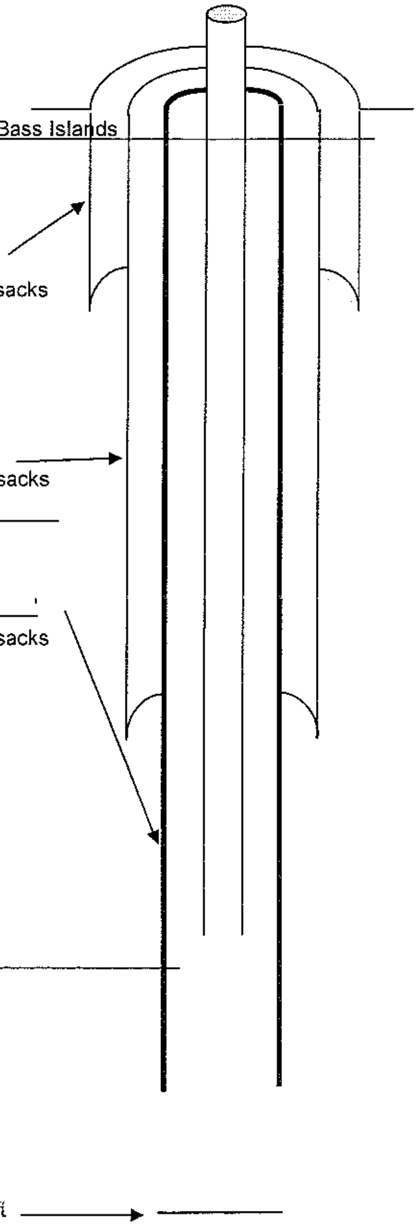
Attached plan and Figure Q-1 from October 2009 EPA permit application for this well

Schematic of wellbore construction

Complete bottom of diagram as needed to conform with proposed construction (e g show rat hole below casing, open hole completion packer loc etc)

Fresh water fms , name & depth
Traverse: 0 - 540' BGS
other formations to be tested

Base of freshwater, name & depth
540' - Traverse; possible 2,000' Base of Bass Islands



Surface casing 13 3/8 " x 250 '
Amount of cement 177 sacks
T O C ground surface

Intermediate casing (if applicable)
9 5/8 " x 540 - 2000 '
Amount of cement 646 sacks
T O C ground surface

Long string casing 7 x 6010 '
Amount of cement 856 sacks
T O C ground surface

Confining formation(s)
Depth to top 4434
Depth to base 6010'

Injection formation(s) Mt. Simon/Munising
Depth to top 6010'
Depth to base 7500'

Tubing 4 1/2 " x >6010 '
Packer Depth 6000'

Bottom TD or PBTD 7500 ft

15 Application prepared by (print or type):
Kenneth Cooper, PE: Consultant/Petrotek Engineering Corporation

Date
10/23/2009

B.3 A discussion of the affect of injection on the present and potential mineral resources in the area of review.

No mineral resources have been identified in or in proximity to the area of review of the cone-of-influence that may be affected by injection. While natural gas reservoirs can occur within the Antrim Shale and/or Traverse Limestone regionally, there is no local production from these formations. Additionally, although other zones such as the Niagaran, Dundee, and Prairie du Chien may produce hydrocarbons in the northern portion of the state; there is no data to suggest that these formations are productive within the AOR, or the county. Figure 8 at the end of this Section (B.3) presents the stratigraphic column in the area, and Figure 9 shows the location of nearest hydrocarbon production and producing formations. Figure 9 indicates that the closest mapped production occurs in the Antrim and Niagaran formations, with the closest producing well approximately 16 miles to the southeast of the Bay Harbor site. This well produces from the Antrim, and none of these distant producing wells are completed in the proposed injection zone.

STRATIGRAPHIC NOMENCLATURE FOR MICHIGAN

Michigan Dept. of Environmental Quality
Geological Survey Division
Harold Fitch, State Geologist
and
Michigan Basin Geological Society

Stratigraphic Nomenclature Project Committee:
Dr. Paul A. Catacosinos, Co-chairman
Mr. Mark S. Wollensak, Co-chairman

Principal Authors:
Dr. Paul A. Catacosinos
Dr. William B. Harrison III
Mr. Robert F. Reynolds
Dr. David B. Westjohn
Mr. Mark S. Wollensak

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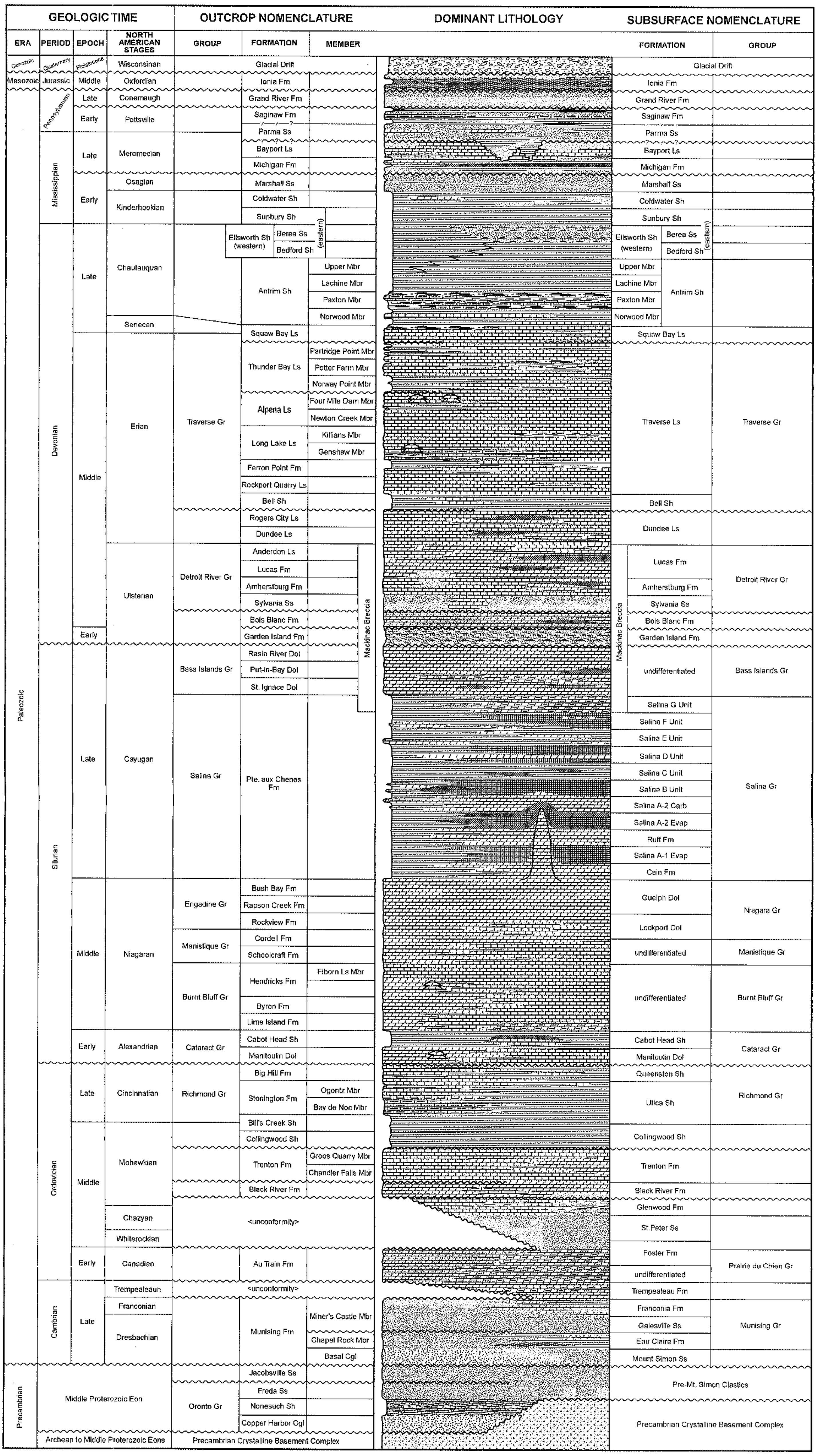


Acknowledgements

This work is the product of the combined efforts of the geological communities of Michigan and the surrounding states and provinces. Below are given just a representative few of the contributors:

Academia: Dr. Aureal T. Cross, Michigan State University; Dr. Robert H. Dott, Jr., University of Wisconsin; Mr. William D. Everham, Ph.D. Candidate, Michigan Technological University.

Government: Dr. Terry R. Carter, Ontario Ministry of Natural Resources; Mr. John M. Esch, Michigan Department of Environmental Quality; Dr. Brian D. Keith, Indiana Geological Survey; Mr. Lawrence H Wickstrom, Ohio Geological Survey.

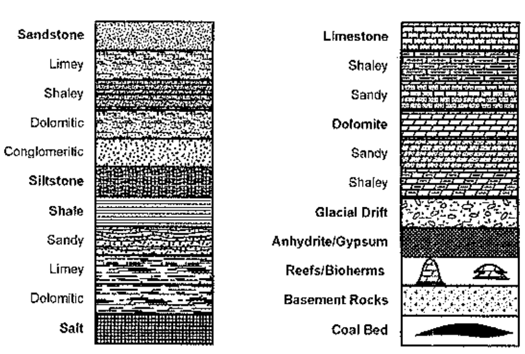
Industry: Mr. Donald J. Bailey, Consultant; Mr. Jimmy R. Myles, Scot Energy; Mr. Dan E. Pfeiffer, Pfeiffer Exploration Services.

A complete listing of all contributors will be found in the Stratigraphic Lexicon for Michigan, of which this column is an integral part.

RELATED TERM CORRELATION

STRATIGRAPHIC POSITION	RELATED TERMS
Ionia Fm	Jurassic Red Beds
Michigan Fm	Clare Dolomite, Brown Lime, Stray Dolomite, Stray Sandstone, Stray-Stray Sandstone, Stray-Stray-Stray Sandstone, Triple Gyp
Coldwater Sh	Coldwater Red Rock, Speckled Dolomite, Wier Sand
Antrim Sh	Charlton Black Shale Member, Ellrim, Chester Black Shale Member, Upper Black Shale, Light Antrim, Lower Black, Lower Antrim Middle Antrim, Middle Gray Antrim, Dark Antrim, Middle Gray Shale, Unit 1A, Unit 1B, Unit 1C, Crappo Creek Grey Shale Member
Dundee Ls	Reed City Member/Dolomite/Anhydrite
Lucas Fm	Freer Sandstone, Horner Member, Iutzi Member, Massive Salt/Anhydrite, Sour Zone, Big Anhydrite, Richfeld Zone/Member/Sandstone, Big Salt
Amherstburg Fm	Filer Sandstone, Meldrum Member, Black Lime
St. Ignace Dolomite	Salina H Unit
Salina B Unit	Big Salt, B Salt
Ruff Formation	Salina A-1 Carbonate, Rabbit Ears Anhydrite,
Cain Fm	Salina A-0 Carbonate
Guelph Dolomite	Brown Niagara, Niagaran Reef, Pinnacle Reef, Engadine Dolomite
Lockport Dolomite	Gray Niagara, White Niagara
Burnt Bluff Gr	Clinton Formation
Trenton Fm	Cap Dolomite
Black River Fm	Van Wert Zone, Sneaky Peak, Black River Shale
Glenwood Fm	Goodwell Unit, Zone of Unconformity
St. Peter Sandstone	Bruggers Sandstone, Jordan Sandstone, Knox Sandstone, Massive Sand
Prairie du Chien Gr	Foster Formation, New Richmond Sandstone, Lower Knox Carbonate, St. Lawrence Formation, T-PDC, Oneota Dolomite, Brazos Shale
Trempealeau Fm	Lodi Formation
Galesville Ss	Dresbach Sandstone
Pre-Mt. Simon Clastics	Precambrian "Red Beds"

LEGEND

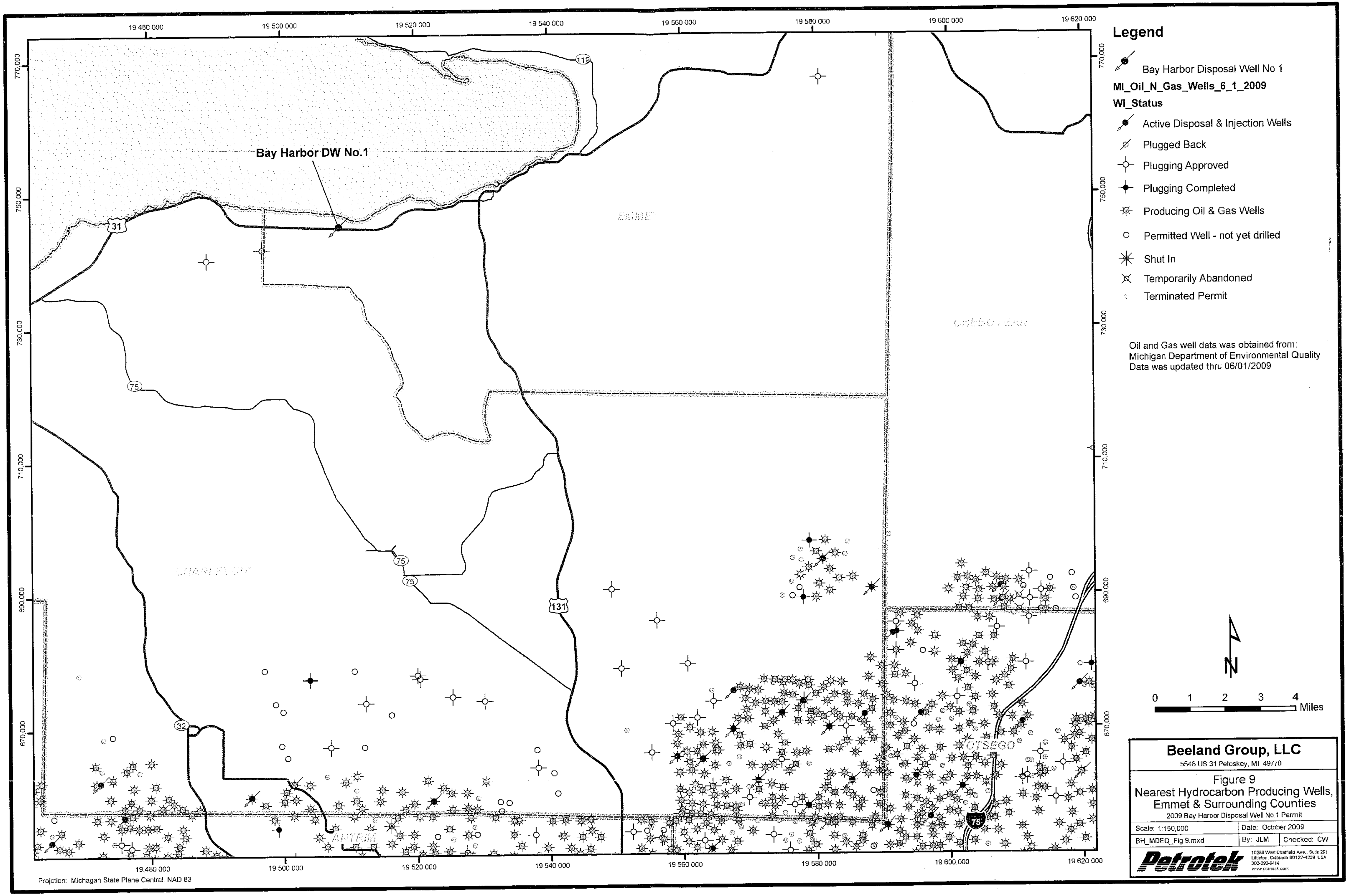


Beeland Group, LLC
5548 US 31 Petoskey, MI 49770

Figure 8
Stratigraphic Nomenclature for Michigan
2009 Bay Harbor Disposal Well No.1 Permit

Scale: NTS	Date: October 2009	
BH_MDEQ_Fig 8.ai	By: JLM	Checked: CW

Petrotek 10288 West Chatfield Ave., Suite 201 Littleton, Colorado 80127-4239 USA 303-290-9414 www.petrotek.com


Legend
Bay Harbor Disposal Well No 1
MI_Oil_N_Gas_Wells_6_1_2009
WI_Status
Active Disposal & Injection Wells
Plugged Back
Plugging Approved
Plugging Completed
Producing Oil & Gas Wells
Permitted Well - not yet drilled
Shut In
Temporarily Abandoned
Terminated Permit
Oil and Gas well data was obtained from:
Michigan Department of Environmental Quality
Data was updated thru 06/01/2009
Bay Harbor DW No.1
EMMET
CHEBOYGAN
CHARLEVOIX
OTSEGO
ANTRIM
31
119
75
131
32
75
0 1 2 3 4 Miles
N
19 480 000
19 500 000
19 520 000
19 540 000
19 560 000
19 580 000
19 600 000
19 620 000
770,000
750,000
730,000
710,000
690,000
670,000
Projection: Michigan State Plane Central. NAD 83
Beeland Group, LLC
5548 US 31 Petoskey, MI 49770
Figure 9
Nearest Hydrocarbon Producing Wells,
Emmet & Surrounding Counties
2009 Bay Harbor Disposal Well No.1 Permit
Scale: 1:150,000
Date: October 2009
BH_MDEQ_Fig 9.mxd
By: JLM
Checked: CW
Petrotek

B.4 A plat which shows the location and total depth of the proposed well, shows each abandoned, producing, or dry hole within the area of influence, and each operator of a mineral or oil and gas well within the area of influence.

Figures 4 and 6 show the location of water wells and oil and gas wells in the vicinity of the proposed Disposal Well. Data regarding these wells are presented in Sections A 4 and B.2 There are no wells being operated in the vicinity of the proposed location, so no operator data is available or required.

B.5 If a well is proposed to be converted to a disposal well, a copy of the completion report, together with the written geologic description log or record and borehole and stratum evaluation logs for the well.

Conversion of an existing well is not proposed. Upon installation of the new well, copies of the written geologic descriptions and all log data collected from the well will be submitted to MDEQ.

B.6 Plugging records of all abandoned wells and casing, sealing, and completion records of all other wells and artificial penetrations within the area of influence of the proposed well location and a map identifying all such artificial penetrations. An applicant shall also submit a plan reflecting the steps or modifications believed necessary to prevent proposed injected waste products from migrating up, into, or through inadequately plugged, sealed, or completed wells.

Topographic Map

A copy of the USGS Topographic map available from the area of review with the outline of the minimum ¼-mile radius area of review, the 3-mile cone-of-influence and an injection well symbol representing the facility superimposed on the map is included as Figure 3 (see Section A.4)

This topographic map extends in excess of 1 mile beyond the Bay Harbor COI in all directions. The Bay Harbor facility property encompasses an irregular trapezoidal area of approximately 3.2 acres in the northwest quarter of Section 9. In addition, the map shows the location of all known surface bodies of water, springs, mines, quarries, residencies and roads. Separate additional maps submitted in this Response present local water wells and deeper artificial penetrations. A listing of neighboring property owners within a ¼-mile radius has been also been developed and submitted with this application for the well permit, as well as a Figure showing the location of these properties (see Figure 10a at the end of this section) No RCRA permitted hazardous waste treatment storage or disposal facilities are present within the AOR based on available state of Michigan permit information. It is noted that a CMS Land groundwater remediation project treatment plant for injectate is located on the Bay Harbor Company property where the well is to be located.

Artificial Penetrations

As shown on Figure 6, there are no artificial penetrations identified in the area of review conducted for a ¼-mile radius surrounding the proposed Bay Harbor disposal well. The closest deep well is within the 3-mile COI and is located over 2 miles southwest of the Bay Harbor area. This is the only well located within the 3-mile COI. Table 4 presents information pertaining to this well This well, and the second well located approximately 4 miles to the west/southwest of the proposed well site do not penetrate into the proposed injection zone. Copies of pertinent MDEQ completion or plugging records for this well are presented at the end of this section

Figure 6 (Section B.2), is a map generated with the PETRA software program from data provided by the state of Michigan in October of 2009 This Map shows that there are no non-fresh water artificial penetrations in the state oil and gas well database that penetrates below the St Peter formation on this map The Proposed Bay Harbor Well No. 1 is designated as an injection well (also labeled with the well name), and is located in the southwest of the northwest quarter of Section 9. General geographic features and the outline of the required ¼ mile AOR and the 3-mile COI are also shown on the map. Index lines showing cross sections are also shown, with summaries of relevant formation tops from the MDEQ database The "legend" on this map contains pertinent information designating all other wells with the area of review.

Figure 4 (Section A.4), is a map modified from data generated by the state of Michigan in October of 2009, presents the location of local freshwater well penetrations within a ¼-mile radius of the proposed Bay Harbor well, as presented in the state water well database. Note that fresh water penetrations in the area of review range from approximately 113-425 feet deep, and all produce from the Traverse Formation. Copies of water well records for the three freshwater penetrations are submitted at the end of this section.

Due to the lack of any artificial penetrations in the AOR and COI, the proposed Bay Harbor Disposal well has no potential for causing endangerment to USDW resources in the vicinity

Corrective Action

A corrective action plan is not required for any of the artificial penetrations within the proposed Bay Harbor well COI because, based on calculations, there are no artificial penetrations that reach the depth of the injection zone that have the potential for allowing injection activities to have an impact on the USDW

If a corrective action plan for any neighboring well becomes necessary in the future, it will be developed according to appropriate regulatory standards and guidelines.

The corrective action plan which would be proposed by Beeland Group, LLC, should the potential for fluid migration to occur through the confining layer develop via any future well, it will include the following:

1 Bay Harbor Disposal Well No. 1 will be shut-in.
2. The USEPA, Region 5 UIC Section and the MDEQ will be notified
3. Following well shut-in, waste will be shipped to alternative permitted facilities for off-site treatment and/or disposal as necessary.
4. A contingency plan will be prepared as follows:
   a. Locate well and identify present operator or owner, if any.
   b. Identify mode of failure.
   c Prepare remedial plan outlining course of action.
   d The remedial plan will be submitted to the USEPA, Region 5 and MDEQ for approval.
   e. Upon authorization, the remediation plan will be implemented.

Area of Review Oil and Gas Well Data

Data regarding artificial penetrations collected for wells within the cone-of-influence (COI) have been categorized and are listed by well type, noting that a single well was identified within the area, and this well did not penetrate to the proposed injection zone (Cambrian section). Oil and gas industry (non-fresh water) well locations are shown on Figure 6. There are no oil and gas permitted wells drilled into or drilled deeper than the injection zone that have been either subsequently abandoned, still actively produce hydrocarbons, or were temporarily abandoned, or exhibit any other related well status. The single deep penetration near the Bay Harbor facility was not deep enough to encounter the injection interval, as it was drilled only to the St. Peter Sandstone (Figure 8). Information pertaining to this well is presented in Table 4. The well is labeled with the MDEQ permit number (29079). Figure 10b presents the wellbore configuration for this deep well. Copies of well records are presented at the end of this response for the closest non-freshwater penetration. Copies of records for this well are included in Attachment C.

TABLE 4 ARTIFICIAL PENETRATIONS: MDEQ OIL & GAS PERMITS WELLS PENETRATING TO INJECTION ZONE NEAR AOR

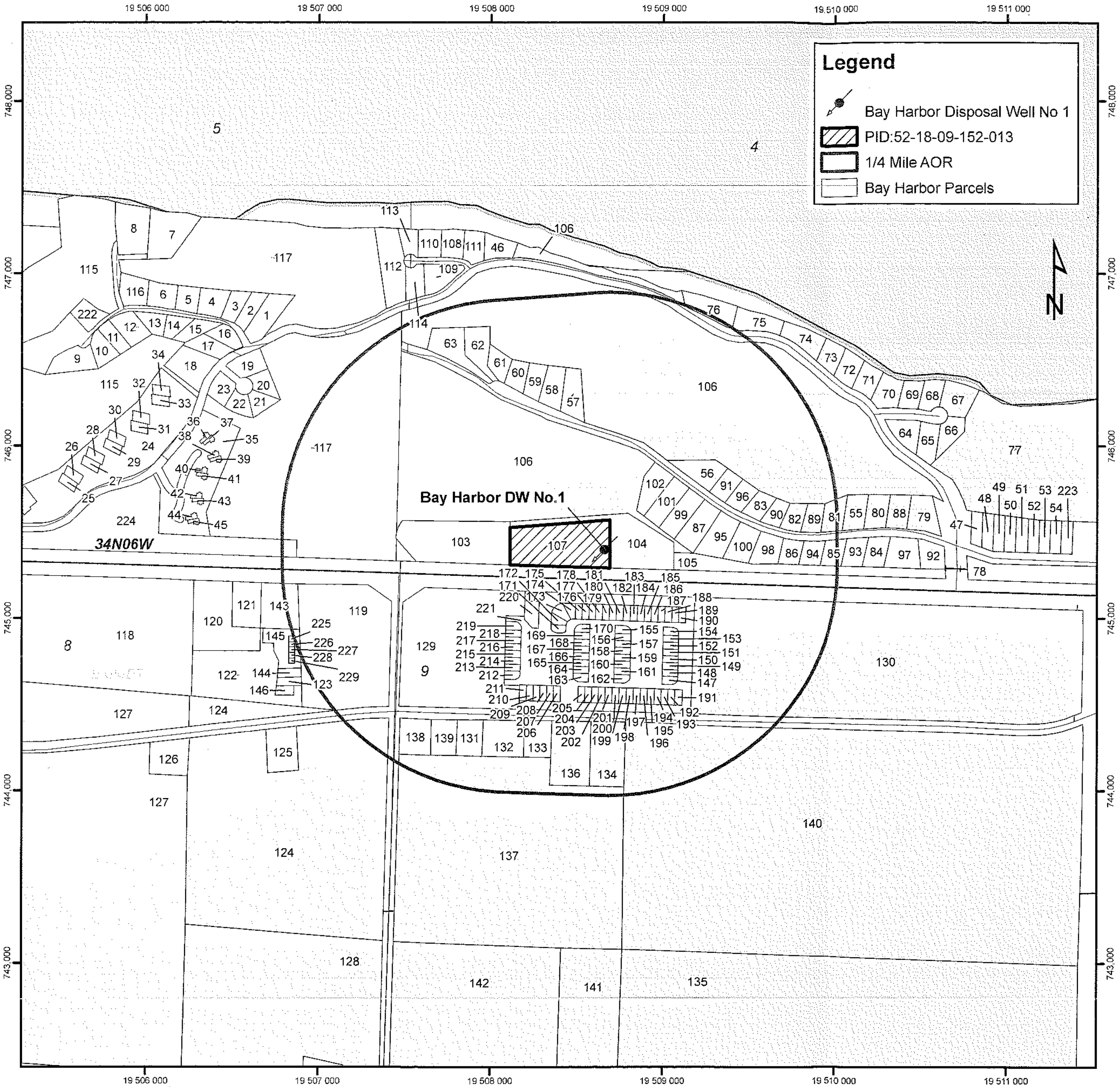
MDEQ Permit #	Location (T-R)	Section	Well Status	Formation at TD	Total Depth (ft. BGL)	Date of Completion or Plugging
29079	36N-7W	13	Dry Hole, Plugged	St. Peter	5,022	13-June-73

Water Wells Within ¼ Mile AOR

As shown on Figure 4, there is only one water well located inside the ¼ mile AOR radius in the available MDEQ databases, well 25000000643. A copy of data from freshwater wells in the vicinity of the proposed well, including the well in the AOR and two wells just outside the AOR (Figure 4) are presented as part of the characterization of the USDW in the vicinity of the proposed well included in Attachment C Table 5, below, presents summary information pertaining to these wells

TABLE 5 WATER WELLS WITHIN A ½ MILE RADIUS OF THE PROPOSED BAY HARBOR DISPOSAL WELL NO. 1 LOCATION

WELL ID	COUNTY	PERMIT #	TOWNSHIP	TOWNSHIP/ RANGE/ SECTION	OWNER NAME	WELL DEPTH (ft)	WELL TYPE	WELL STATUS	DEPTH TO WATER
24000000643 (AOR Well)	Emmet	W987004	Petoskey	34N 06W Sec 9	CITY OF PETOSKEY, Well #5	425	Type 1 Public Well	Assumed Active	35
24000001741 (Outside AOR)	Emmet	E02-545	Resort	34N 06W Sec 9	RAY LEDUC BAYVIEW ASSOCIATES	200	Household Well	Active	210
24000003134 (Outside AOR)	Emmet	E05-372	Petoskey	34N 06W Sec 9	PHILLIP MANTHEI	113	Type 3 Public Well	Active	38



Projection: Michigan State Plane Central NAD 83

Map ID = Parcel ID	Map ID = Parcel ID	Map ID = Parcel ID	Map ID = Parcel ID
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2 = 52-18-08-210-102	77 = 52-18-09-252-003	152 = 13-18-09-150-106	192 = 13-18-09-150-146
3 = 52-18-08-210-103	78 = 52-18-09-252-005	153 = 13-18-09-150-107	193 = 13-18-09-150-147
4 = 52-18-08-210-104	79 = 52-18-09-110-101	154 = 13-18-09-150-108	194 = 13-18-09-150-148
5 = 52-18-08-210-105	80 = 52-18-09-110-103	155 = 13-18-09-150-109	195 = 13-18-09-150-149
6 = 52-18-08-210-106	81 = 52-18-09-110-105	156 = 13-18-09-150-110	196 = 13-18-09-150-150
7 = 52-18-08-210-109	82 = 52-18-09-110-107	157 = 13-18-09-150-111	197 = 13-18-09-150-151
8 = 52-18-08-210-110	83 = 52-18-09-110-109	158 = 13-18-09-150-112	198 = 13-18-09-150-152
9 = 52-18-08-210-115	84 = 52-18-09-110-115	159 = 13-18-09-150-113	199 = 13-18-09-150-153
10 = 52-18-08-210-116	85 = 52-18-09-110-117	160 = 13-18-09-150-114	200 = 13-18-09-150-154
11 = 52-18-08-210-117	86 = 52-18-09-110-119	161 = 13-18-09-150-115	201 = 13-18-09-150-155
12 = 52-18-08-210-118	87 = 52-18-09-110-123	162 = 13-18-09-150-116	202 = 13-18-09-150-156
13 = 52-18-08-210-119	88 = 52-18-09-110-102	163 = 13-18-09-150-117	203 = 13-18-09-150-157
14 = 52-18-08-210-120	89 = 52-18-09-110-106	164 = 13-18-09-150-118	204 = 13-18-09-150-158
15 = 52-18-08-210-121	90 = 52-18-09-110-108	165 = 13-18-09-150-119	205 = 13-18-09-150-159
16 = 52-18-08-210-122	91 = 52-18-09-110-111	166 = 13-18-09-150-120	206 = 13-18-09-150-160
17 = 52-18-08-210-123	92 = 52-18-09-110-113	167 = 13-18-09-150-121	207 = 13-18-09-150-161
18 = 52-18-08-210-124	93 = 52-18-09-110-116	168 = 13-18-09-150-122	208 = 13-18-09-150-162
19 = 52-18-08-211-101	94 = 52-18-09-110-118	169 = 13-18-09-150-123	209 = 13-18-09-150-163
20 = 52-18-08-211-102	95 = 52-18-09-110-122	170 = 13-18-09-150-124	210 = 13-18-09-150-164
21 = 52-18-08-211-103	96 = 52-18-09-110-110	171 = 13-18-09-150-125	211 = 13-18-09-150-165
22 = 52-18-08-211-104	97 = 52-18-09-110-114	172 = 13-18-09-150-126	212 = 13-18-09-150-166
23 = 52-18-08-211-105	98 = 52-18-09-110-120	173 = 13-18-09-150-127	213 = 13-18-09-150-167
24 = 52-18-08-230-001	99 = 52-18-09-110-124	174 = 13-18-09-150-128	214 = 13-18-09-150-168
25 = 52-18-08-230-103	100 = 52-18-09-110-121	175 = 13-18-09-150-129	215 = 13-18-09-150-169
26 = 52-18-08-230-104	101 = 52-18-09-110-125	176 = 13-18-09-150-130	216 = 13-18-09-150-170
27 = 52-18-08-230-105	102 = 52-18-09-110-126	177 = 13-18-09-150-131	217 = 13-18-09-150-171
28 = 52-18-08-230-106	103 = 52-18-09-152-011	178 = 13-18-09-150-132	218 = 13-18-09-150-172
29 = 52-18-08-230-107	104 = 52-18-09-152-012	179 = 13-18-09-150-133	219 = 13-18-09-150-173
30 = 52-18-08-230-108	105 = 52-18-09-152-014	180 = 13-18-09-150-134	220 = 13-18-09-150-174
31 = 52-18-08-230-109	106 = 52-18-09-152-010	181 = 13-18-09-150-135	221 = 13-18-09-150-001
32 = 52-18-08-230-110	107 = 52-18-09-152-013	182 = 13-18-09-150-136	222 = 52-18-08-210-111
33 = 52-18-08-230-111	108 = 52-18-08-245-104	183 = 13-18-09-150-137	223 = 52-18-09-101-109
34 = 52-18-08-230-112	109 = 52-18-08-245-107	184 = 13-18-09-150-138	224 = 52-18-08-150-013
35 = 52-18-08-235-001	110 = 52-18-08-245-103	185 = 13-18-09-150-139	225 = 13-18-08-290-101
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51 = 52-18-09-101-105	126 = 13-18-08-400-007		
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56 = 52-18-09-110-112	131 = 13-18-09-300-003		
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59 = 52-18-09-110-129	134 = 13-18-09-300-007		
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61 = 52-18-09-110-131	136 = 13-18-09-300-011		
62 = 52-18-09-110-132	137 = 13-18-09-300-013		
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67 = 52-18-09-210-104	142 = 13-18-09-300-018		
68 = 52-18-09-210-105	143 = 13-18-08-200-009		
69 = 52-18-09-210-106	144 = 13-18-08-200-011		
70 = 52-18-09-210-107	145 = 13-18-08-290-001		
71 = 52-18-09-210-108	146 = 13-18-08-290-002		
72 = 52-18-09-210-109	147 = 13-18-09-150-101		
73 = 52-18-09-210-110	148 = 13-18-09-150-102		
74 = 52-18-09-210-111	149 = 13-18-09-150-103		
75 = 52-18-09-210-112	150 = 13-18-09-150-104		

Note:
See Table C-3 for Owner Information assoicated with Parcel ID number.

Emmet County Land Parcel data was obtained from:
Emmet County GIS Coordinator
Data was in the form of an ArcView Shape file
Data was current thru 09/22/2009

0 400 800 1,200 Feet

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Figure 10a
Surface Property Owners
within 1/4 Mile of Site Property
2009 Bay Harbor Disposal Well No.1 Permit

Scale: 1:7,500	Date: October 2009	
BH_MDEQ_Fig 10a.mxd	By: JLM	Checked: KC

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CEMENT VOLUMES FLUIDS and HOLE SIZE

TUBULARS and COMPONENTS

(A) Heavy Mud and Cuttings in Hole 0 - 1 818

(B) Heavy Mud and Cuttings in Hole Approx. 1,950 - 2,969'

(C) Heavy Mud and Cuttings in Hole Approx 3 100 - 4,891

[1] Mechanical Plug: 8 5/8 casing cutoff 3 below ground level, 10 sack cement plug bridged in top of 8 5/8" casing and a 1/2' steel plate welded on

[2] Surface Casing: 13 3/8" Set @ 243'

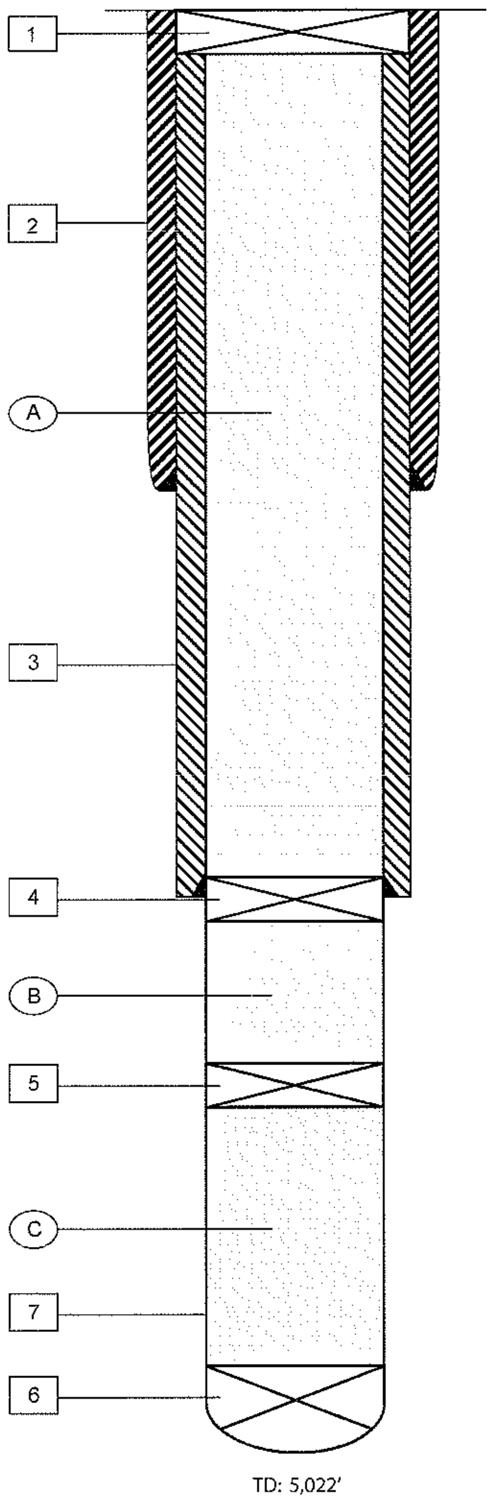
[3] Intermediate Casing: 8 5/8 , Set @ 1,902

[4] Mechanical Plug: Set @ 1 603 * - 1,950' with 75 sacks cement

[5] Mechanical Plug: Set @ 2 757 * - 3 100 with 75 sacks cement

[6] Mechanical Plug: Set @ 4 679 * - 5 022 with 75 sacks cement

[7] Hole Size: (assumed 7 7/8')



Notes:

* Plug thickness was estimated using assumption of "Class A Cement with Bentonite" slurry properties for cement yield The Calculation used was: 1 55 cu ft /sack.

Depths, RKB

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Figure 10b
AOR Schematic Well 29079

2009 Bay Harbor Disposal Well No.1 Permit

Scale: NTS	Date: October 2009	
BH_MDEQ_Fig 10b.ai	By: JLM	Checked: KC

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B.7 A map showing the vertical and areal extent of surface waters and subsurface aquifers containing water with less than 10,000-ppm total dissolved solids. A summary of the present and potential future use of the waters must accompany the map.

Figure 3 (Section A.4) is a topographic map of the disposal well area, and shows there to be several mappable surface water features in the Bay Harbor area. The location of surface water features was verified through survey (Attachment A).

The hydrogeology of Emmet County is described in Apple and Reeves, 2007, who indicate that "According to the February 2005 Wellogic database, approximately 75 percent of the wells in Emmet County are completed in the glacial deposits, and 11 percent in the bedrock units. There is insufficient information to make this distinction for 14 percent of the wells in the county. The bedrock wells primarily occur in the northernmost and southernmost portions of the county." Figure 4 shows the location of water wells within the ½-mile radii surrounding the proposed Bay Harbor site. According well records, there are three wells within this radius, all of which are completed in bedrock (Traverse Group).

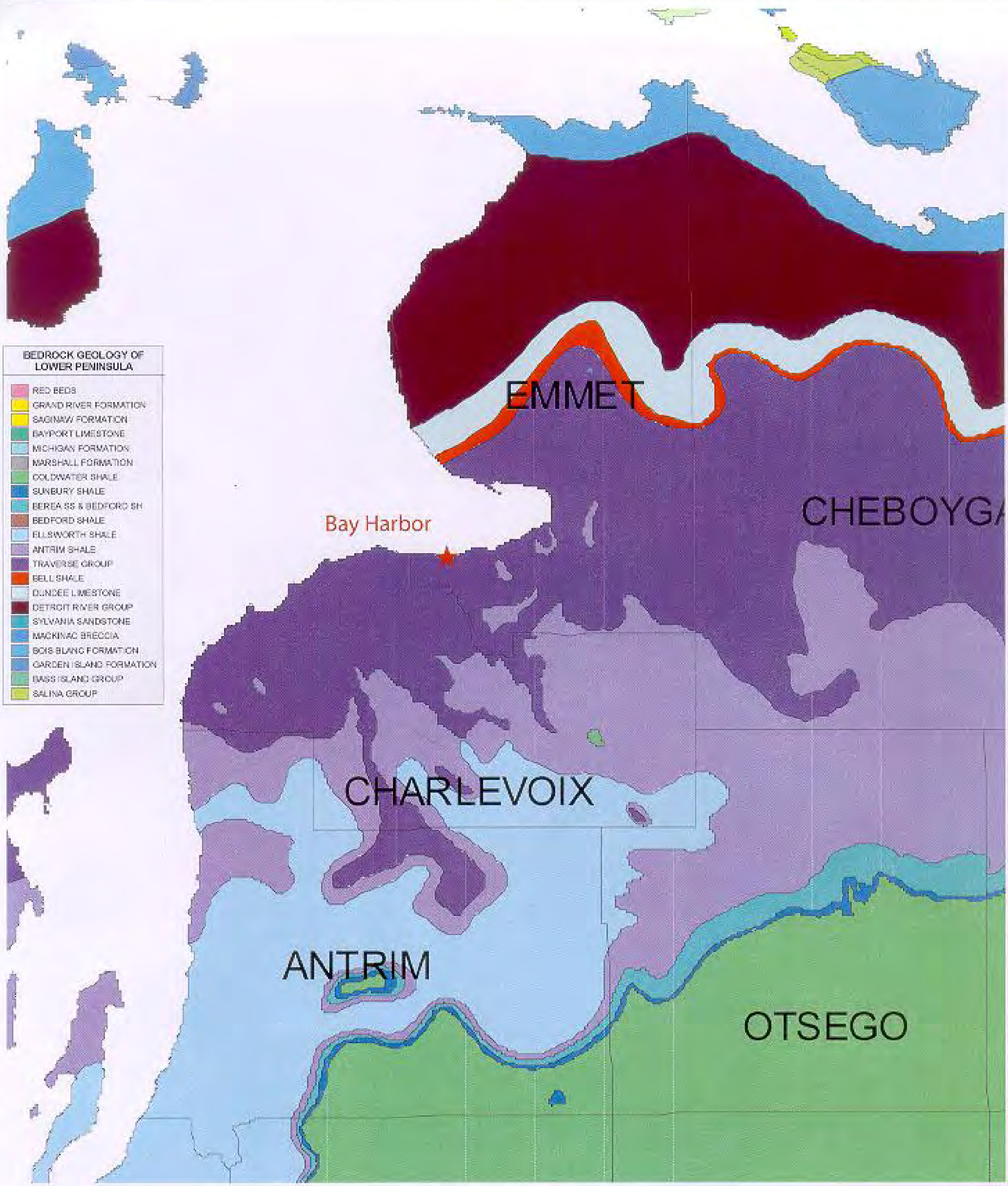
Apple and Reeves (2007) indicate that glacial lithologies do not regionally correlate due to the heterogeneity of these deposits in the area, but the majority of the deposits in Emmet County range from 201 to 800 feet thick. Bedrock surface below the glacial deposits in Emmet County varies from south to north, and are the Antrim Shale, Traverse Group, Dundee Limestone, Detroit River Group and Bois Blanc Formations. Figure 8 presents the stratigraphic nomenclature for Michigan. The Traverse Group subcrops below the Bay Harbor area and is composed primarily of fossiliferous limestone and shale. Apple and Reeves (2007) verify the presence of Traverse water wells in Emmet county, stating " In the southern portion of Emmet County, bedrock wells are located where the Traverse Group forms the bedrock surface."

The location of the lowest potential USDW is unknown, but extends to at least the base of the Traverse Group, if not deeper. Glacial Drift is present in the area, and also may serve as a USDW based on water quality, and ranges in thickness from less then 10 to over 100 feet thick in southwestern Emmet County. Locally, three water wells are completed within a ½-mile radius of the proposed well location (Figure 4); one is a City of Petoskey Public Water Supply Well No. 5 (Well ID 24000000643), while the other two are private wells (Well ID Nos. 24000003134 and 24000001741). Well No. 24000003134 is 113 feet deep, with shale and limestone occurring from about 11 feet BGS to TD. Well No. 24000001741 is 223 feet deep, with the clay/limestone sequence beginning about 78 feet below ground surface (BGS) sand and clay occur from 0-78 feet BGS. Well No. 24000000643 is 425 feet deep, with "blue shale and limestone" occurring at 29 feet BGS, and interbedded blue shales and limestones occurring from 29 feet BGS to TD. Records for these three wells are in Attachment C for wells within ½-mile of the proposed CMS well location. Examination of water well data in Townships 35N Ranges 5 and 6 West indicate that there are at least an additional 13 wells beyond those shown in Table 5 that are 500 or more feet deep. Well records for these penetrations indicate that they typically terminate in a shale interval, but descriptions do not indicate that the Bell Shale or underlying Dundee Formations were penetrated, implying that the wells were completed in the Traverse. No data examined indicated that any of the local wells were drilled deep enough to penetrate the Bell Shale

Potential USDWs are defined for the purpose of regulatory protection as aquifers that can yield more than 1 gpm of water with total dissolved solids (TDS) concentrations of less than 10,000 mg/l or ppm (parts per million). The base of the Traverse/top of the Bell Shale has been projected as the base of the USDW in this portion of Emmet County because none of the water wells in the area around the Bay Harbor well penetrate through the Bell Shale and all bedrock wells produce from the Traverse Formation limestone. However, there are no groundwater quality data available from the public record in the Bay Harbor area of Emmet County to indicate the base of the lowermost USDW below the Bell Shale. Therefore, the base of the USDW will need to be confirmed during the well installation process Beeland Group, LLC will drill through the Bell Shale, which is likely the Basal Formation of the USDW The Dundee will be tested for water quality and if it is a USDW, testing will continue to the top of the Bois Blanc or to the necessary depth until a 2,000 feet is reached or the 10,000 TDS threshold groundwater quality value is ascertained. Pipe will then be set to isolate the USDW. At a maximum, it is anticipated that the base of the USDW will likely be no greater than approximately 1,000 feet BGS, due to the presence of salt-rich beds of the Salina below this depth Figure 11 is a general isopach of the Glacial Till within Emmet County, and Figure 12 is a Bedrock Geology Map of the Emmet County area, showing the specific formations that subcrop below the surficial material and glacial till. Figure 13 is an isopach of the Traverse Formation and Figure 14 is a structure contour constructed at the top of the Traverse. Figure 14 presents the minimum vertical extension of the USDW in Emmet County, based on currently available data. These maps show that the Traverse Formation subcrops and occurs at or near ground surface in the Emmet County area. See Section B.8 for full discussion of the geologic column in the Bay Harbor area This discussion includes a structure contour map of the top of the Bell Shale (base of Traverse limestones), which also illustrates the horizontal extent of the Traverse

The USGS Produced Water Database (http://energy.cr.usgs.gov/prov/prodwat/data2.htm) was queried to identify wells within Emmet County and Charlevoix Counties for which there was water quality data This database shows that there are no wells within either county for which oilfield produced water quality data are available. Expanding this analysis to include the entire state, this data-base indicates that there are 202 wells completed in the Detroit River and Dundee for which water quality data were reported within the database (the number of wells in each formation far exceeds this value). For all but one well, reported water quality within the Dundee and Detroit River varied from 21,299- 398,470 ppm TDS. The single well with a reported TDS less than 10,000 mg/l, occurred in a well in T31N R7W Section 9, over 15 miles southwest of Petoskey. It should be pointed out that several Dundee injection wells are present in Charlevoix County in association with Antrim production. No local Mount Simon water quality data were reported in the database

In Michigan, the Glacial Till and/or unconsolidated material is also a source of fresh water for domestic, industrial, and agricultural purposes, Olcott (1992). However, the unit, when present, overlies the Traverse Formation, and water wells are typically completed in this limestone unit. The base of the USDW is likely the Traverse in the Bay Harbor area, but the vertical extent of the USDW will determined through formation testing during installation of the Bay Harbor well.



SOURCE

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
LAND AND MINERALS SERVICES DIVISION
RESOURCE MAPPING AND AERIAL PHOTOGRAPHY

Michigan Resource Information System
Part 609, Resource Inventory, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended

Automated from "Bedrock Geology of Michigan," 1987, 1:500,000 scale, which was compiled from a variety of sources by the Michigan Department of Environmental Quality, Geological Survey Division

Date: 11/12/99

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Figure 12
Bedrock Map of Emmet and Surrounding Counties
2009 Bay Harbor Disposal Well No.1 Permit

Scale: NTS	Date: October 2009	
BH_MDEQ_Fig 12.ai	By: JLM	Checked: CW

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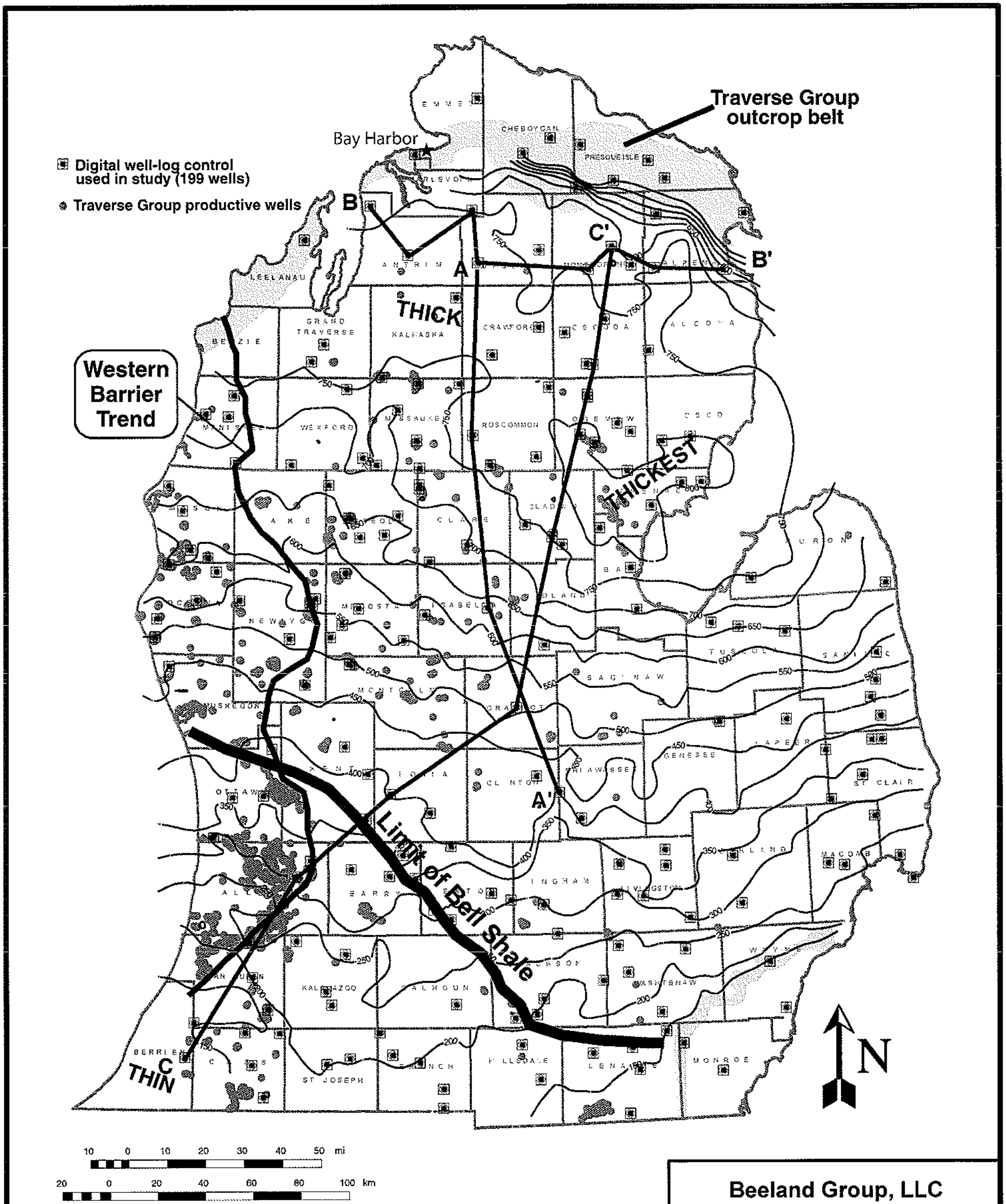

After: A. Wylie & J. Huntoon, 2003
(Cross Sections shown above are available in source document).

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Figure 13
Gross Isopach Map
of Traverse Group

2009 Bay Harbor Disposal Well No.1 Permit

Scale: See Bar Scale	Date: October 2009	
BH_MDEQ_Fig 13.ai	By: JLM	Checked: CW

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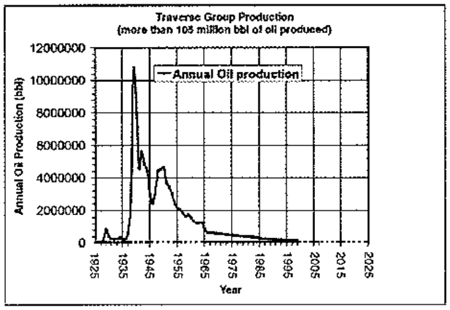

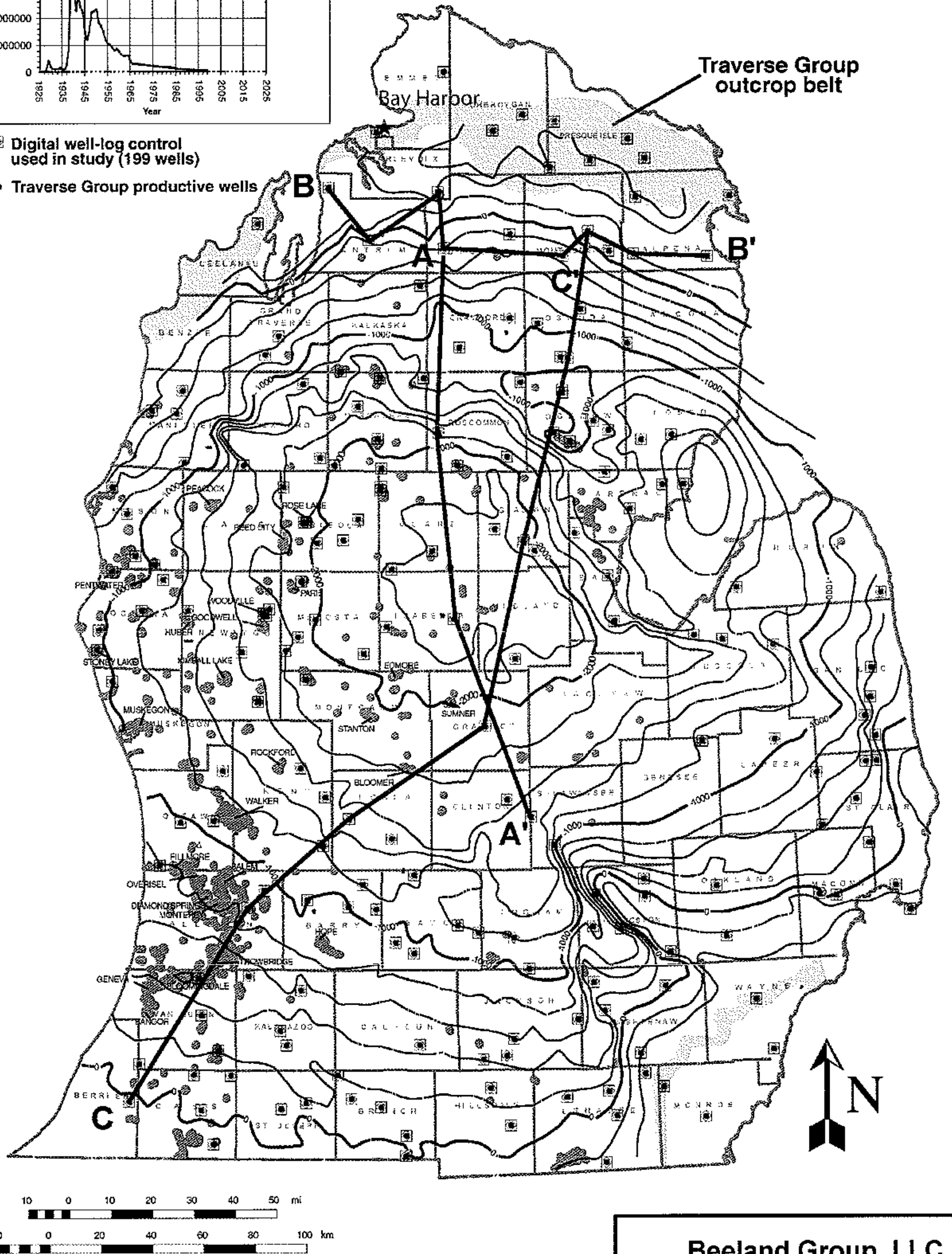

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Figure 14
Structure Contour Map,
Top of the Traverse Group
2009 Bay Harbor Disposal Well No.1 Permit

Scale: See Bar Scale	Date: October 2009	
BH_MDEQ_Fig 14.ai	By: JLM	Checked: CW

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After: A. Wylie & J. Huntoon, 2003
(Cross Sections shown above are available in source document).

B.8 Geologic maps and stratigraphic cross sections of the local and regional geology.

The proposed Bay Harbor DW No 1 is to be located in T34N R6W Section 9, in the southwestern portion of Emmet County on the northwestern edge of the Michigan Basin The immediate area has not been significantly explored for oil and gas, so subsurface geologic data specific to formations below the USDW are very sparse, and are available only on a regional basis

The Bay Harbor facility is located on the northwestern flank of the Michigan Basin as illustrated by the Regional Geological Map, Figure 15 The basin extends into northwest Ohio and northeast Indiana and covers all of Lower Peninsula of Michigan. To the southeast, is the structural axis of the Findlay Arch and to the southwest is the axis of the Kankakee Arch Regional dip in the vicinity of the site is to the northeast at 40 to 60 feet per mile A generalized East-West geologic cross section is included as Figure 16

Figure 6 presents deep borehole penetration locations within the Emmet and Charlevoix County areas, showing all non-water well (i.e. deep) penetrations Figure 17 presents the location of only deep wells within a larger area that includes the Emmet, Charlevoix, and Cheboygan Counties surrounding Bay Harbor Comparison of the two maps indicates that there are a few deeper wells in the Bay Harbor area (Figure 17), but none of these penetrate the Munising Group or the Mt. Simon A larger area around Bay Harbor must be presented (Figure 18) to show any well penetrations to deeper (Munising and below) formations As shown on Figure 18, there are six wells within a 30 mile radius of the Bay Harbor site that were drilled to or through the Cambrian, with five of these either penetrating into or through the Mt. Simon The closest boreholes drilled to the Mt. Simon are almost 20 miles to the southeast of the proposed Bay Harbor location. The North Michigan Land and Oil Corporation No 1-27 Well (Permit No. 34824) was drilled in T32N R4W Section 27, to the top of the Precambrian at 8,900 feet RKB The Mt Simon was encountered at 8,184 feet BGS, with Pre-Mt. Simon Jacobsville sandstone occurring from 8,696 feet BGs to the Precambrian The Mt Simon is about 512 feet thick in this area The Bradfield No.1 well is in T32N R4W Section 32, and was drilled to a total depth of about 8,030 feet through the Eau Claire Formation This borehole was not drilled deep enough to encounter the Mt. Simon. McClure Oil drilled the State Beaver Island #1 and #2 wells in 1961 on Beaver Island (T37N R10 W Section 6 and T38 N R10W Section 27, Permit Nos 23435 and 23478), and both encountered the Precambrian at about 4,700 feet below ground surface according to Milstein (1989) although the state database indicates that Well No. 23455 had a deeper total depth The Salling-Hansen Well No 1-11 was drilling in T34N R2W, Section 11 (Permit No.35060) This well was drilled to the Mt. Simon, which was encountered at about 5,886 feet RKB. The State Waverly 1-24 well (Permit No. 30682) was drilled in 1975 in T35N R01 W Section 24; this well is 30 miles from the proposed Bay Harbor location, and encountered the Precambrian about 5,600 feet BGS As this information shows, there is no Mt Simon well control within an approximately 20-mile radius of the proposed Bay Harbor disposal well.

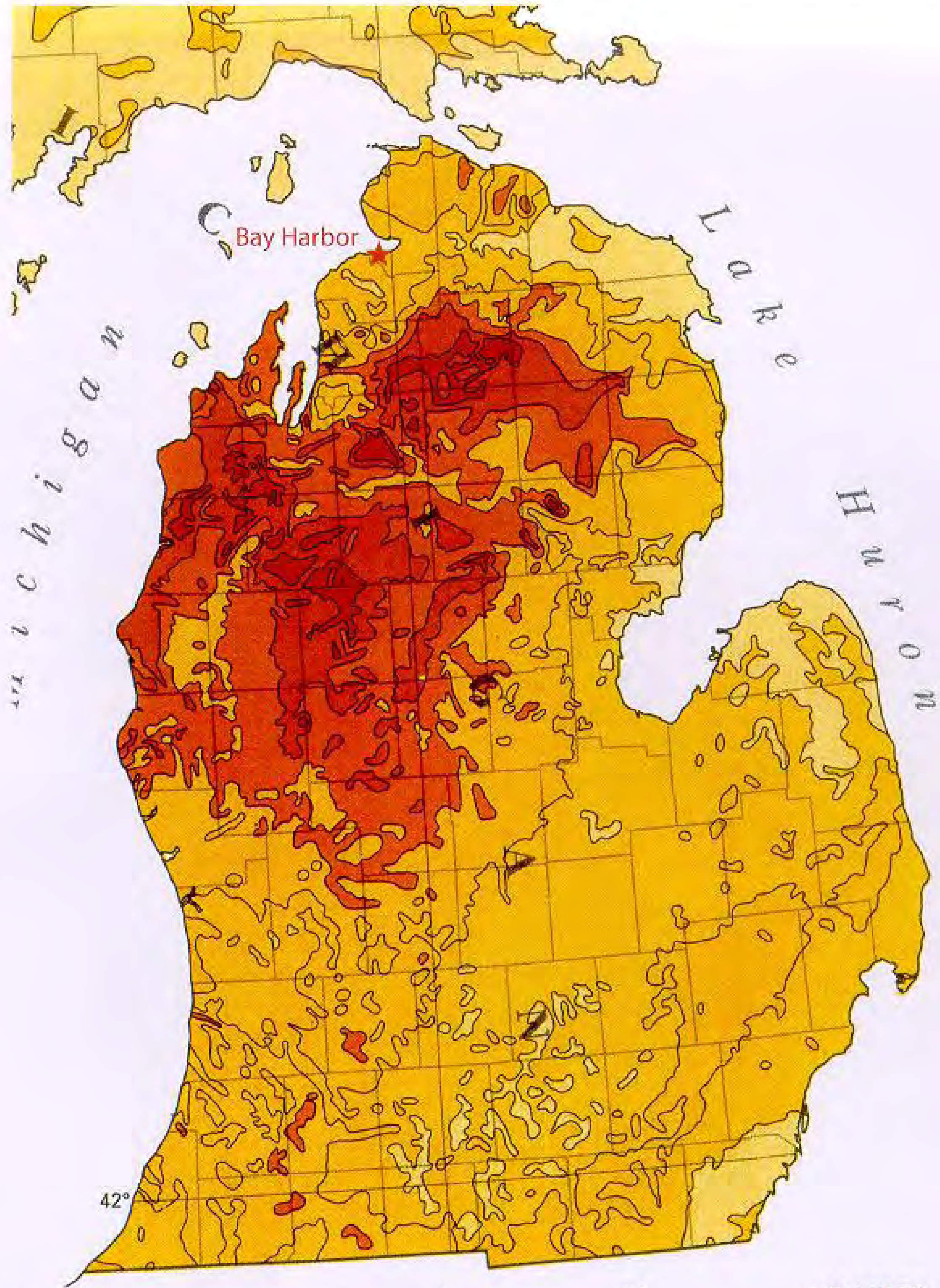
The closest deep (non-water) borehole to the proposed Bay Harbor well occurs about 12,000 feet to the southwest of the site and is located in Charlevoix County (Figure 17, API 21029290790000) This well, the Robert and Myra Hand #1, was drilled to the base of Glenwood Formation to a total well depth of 5,022 feet as logged by the driller. Data concerning thickness of the Mt Simon in the Bay Harbor area are extremely limited, but extrapolation based on the Hand #1 well (St. Peter test) and on regional structure contour and isopach maps [Milstein, 1983 and 1989, Western Michigan University (WMU) (1981) etc] suggest that there may be between 1,350 to over 1,625 feet of column between the base of the Glenwood and the top of the Mt. Simon in this area Because local data are lacking, literature was the only source of information for geologic data pertaining to the Mt. Simon in the Bay Harbor area. A variety of literature and public well data are available regarding the nature of the structure and stratigraphy in Emmet County

Stratigraphy and Lithology

The Northwestern Michigan Basin strata in the Bay Harbor region consists of more than 7,000 feet of sandstones, shales, limestones, conglomerates and clays. While several regional analyses have been performed with respect to the deep column in northeastern Michigan, well data specific to the northwestern Michigan/ Bay Harbor area are practically non-existent. Therefore, published literature and associated regional analyses were used to project the geologic strata in the area.

Figure 8 presents an MDEQ illustration of the stratigraphic column in Michigan. Table 6 presents a listing of projected depths (BGL) to top of major formations below the Bay Harbor site, based on a ground level of approximately 670 feet and using tops determined from the Robert & Myra Hand #1 Well (T34N R7W, Section 13), and extrapolated from regional isopach maps.

Note that formation tops have not been corrected to account for bed dip because there are no local data to use to adequately make these corrections. Therefore, depths below ground surface for formation tops may vary to some extent from those presented in Table 6 and will be evaluated during well installation and testing. Further, all depths are projections based on regional data, and may not represent site-specific conditions.



EXPLANATION

Thickness of glacial deposits, in feet

- Less than 50
- 50 to 200
- 200 to 400
- 400 to 600
- 600 to 800
- 800 to 1,000

Limit of Driftless Area—Dashed where approximately located

From unpublished maps by: D. Sollar, USGS (1992)

Beeland Group, LLC

5548 US 31 Petoskey, MI 49770

Figure 11
Isopach of Glacial Till Aquifer, Michigan Basin

2009 Bay Harbor Disposal Well No.1 Permit

Scale: See Bar Scale	Date: October 2009	
BH_MDEQ_Fig 11.ai	By: JLM	Checked: CW

Petrotek

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TABLE 6 PROPOSED BAY HARBOR DISPOSAL WELL NO. 1 PROJECTED FORMATION DEPTH SUMMARY

Unit	Depth of Top (ft) RKB Estimate Based on Robert and Myra Hand #1 Well (T34N R7W Sec 13)	Estimated Thickness at Bay Harbor (T34N R6W Sec 9)
Traverse	135	405
Bell Shale	540	100
Dundee	640	78
Detroit River	718	619
Bois Blanc	1,337	283
Bass Islands	1,620	265
Salina G	1,885	30
Salina F	1,915	585
Salina E	2,500	140
Salina D	2,640	25
Salina C	2,665	82
Salina B	2,747	233
Salina A	2,980	99
Brown Niagaran	3,079	21
Gray Niagaran	3,100	410
Clinton	3,510	410
Cabot Head	3,920	142
Manitoulin Dolomite	4,062	372
Utica	4,434	196
Trenton	4,630	172
Black River	4,802	148
Glenwood	4,950	35
St. Peter	4,985	150
Prairie du Chien*	5,135	500

Unit	Depth of Top (ft) RKB Estimate Based on Robert and Myra Hand #1 Well (T34N R7W Sec 13)	Estimated Thickness at Bay Harbor (T34N R6W Sec 9)
Trempealeau*	5,635	375-602
Franconia*	6,010-6,235	100-300
Galesville (Dresbach)*	6,135-6,360	0-375
Eau Claire*	6,258-6,510	25-475
Mt. Simon*	6,535-6,760	175-625
Pre Mt. Simon*	6,935-7,160	0-425
Precambrian Basement*	6,935-7,360	N/A

* Estimated depths based on approximate thickness ranges from regional maps in Milstein (1983) and 1989 and WMU (1981).

Figures 19 and 20 present the Structure Contour Maps for the Precambrian and Mt Simon surface Figures 21-27 present the isopach maps of the Mt. Simon, Eau Claire, Galesville, Franconia, Trempealeau, Prairie du Chien, Utica Formations. Figures 28 and 29 are regional cross-sections through northwestern Michigan that are available in published literature. Figures 30a through 30g present isopach and structure contour maps of major formations in the shallower geologic column, including the Traverse, Bell Shale, Dundee, Detroit River, Salina, and Niagaran. This information is presented to show the extent of regional control, and to demonstrate the general trends, thickness, and occurrence of units in the geologic column. Data are also presented to provide additional information regarding the regional geologic setting, and the injection and arrestment intervals. From the base of the injection zone upward, the following major intervals are anticipated to be penetrated at the proposed Bay Harbor Well No. 1 location

Precambrian and Cambrian Units (Lower Confining Zone and Injection Interval)

Precambrian

The Precambrian crystalline basement is described as primarily metasedimentary rocks formed by the metamorphism of shales, sandstones, carbonate and iron formations, creating quartzites, marbles, slates and other metamorphic rocks. Igneous intrusions may also occur within these units. The Precambrian basement is estimated to occur at about 6,935-7,360 or more feet below ground surface at the Bay Harbor site, and would serve as a lower confining zone (Figure 19).

Late Precambrian sediments may occur atop the crystalline basement, and are primarily identified through subcrop as present in the Northern Peninsula of Michigan, outside of the Michigan Basin. It is also possible that Precambrian sedimentary rocks may be present in areas of the Southern Peninsula (particularly northwestern portions of this area), but lack of well control (i.e. Precambrian penetrations) hinders identification of these units, particularly at the Bay Harbor area. In the Northern Peninsula, Precambrian sediments of the Oronto group include the Copper Harbor conglomerate, Nonesuch Shale, and Frieda Sandstone; these units may be overlain unconformably by the Jacobsville Sandstone. The Jacobsville and Frieda sandstones are collectively referred to as "Pre-Mt. Simon Clastics" (see Figure D-1) For completeness, these units are described below, but their presence below the Bay Harbor site is unknown at this time

The Copper Harbor Conglomerate is described as an extremely thick light brown to red cemented conglomerate described as "non porous" and consisting of arkosic material. Western Michigan University, WMU (1981) states that this unit pinches out "south of Township 55 North" implying it is not present below the Bay Harbor site. The Nonesuch Shale conformably underlies the Copper Harbor Conglomerate, and this shale is described as a grey siltstone that is sometimes copper-rich. The Freda Sandstone occurs above the Nonesuch, and consists of fine-grained arkosic sandstone and silty shale that is red and micaceous. The Jacobsville Sandstone is widely distributed in the Northern Peninsula, and WMU, 1981 states that Catacosinos (1973) identified this unit as being present in the Beaver Island wells (State No 1) WMU, 1981 states that this well penetrated through the Mt. Simon formation, into "813 feet of pale reddish-purple coarse-grained quartz, with much feldspar that is silica-cemented, abundant hematite staining, and some glauconite" Catacosinos suggested that this was an isolated occurrence of Pre-Mount Simon sediment, preserved at this location 20 miles northeast of Bay Harbor in a "down thrown fault block" Figure 18 shows the location of the Beaver Island Wells in relation to the Bay Harbor well

Cambrian System

The Cambrian is composed of the Mt. Simon Sandstone, Eau Claire Formation, Galesville (Dresbach) Sandstone, and the Franconia Formation. All of these units are described as being composed of sandstones of varying thickness and porosity. The proposed injection interval includes the entire Cambrian sequence, although the Mt Simon is the primary target injection zone. For this purpose of this application, units from the Franconia to the top of the Mt Simon comprise the Munising Group, noting that some authors include the Mt. Simon within the Munsing Group

Mt. Simon

The Mt. Simon lies unconformably above Pre-Mt. Simon Clastics or the Precambrian Crystalline Basement Complex and may occur about 6,500-7,000 ft below ground surface in the Bay Harbor area (Figure 20). WMU (1981) indicates that the Mt. Simon varies in thickness from 100 to over 1,000 feet thick in the Lower Peninsula of Michigan, (Figure 21), but is mapped as subcropping as part of the Munising Group in the Upper Peninsula. The Mt. Simon is described as a subrounded to rounded quartzitic sandstone that is generally coarse grained. It is pink to red, with a greater abundance of feldspar at the base of the unit. WMU, 1981 states that "glauconite, anhydrite, and green shale are present in minor amounts with local dolomite cement".

WMU (1981) states that with respect to the Mt. Simon as a whole, regionally "the permeable Cambrian quartz sandstone, siltstone, and arenaceous dolomite suitable for fluid injection comprise about 27% of the stratigraphic column" Porosity of 4-20% are present within the unit, and Briggs (1968) states that there is no discernable trend with depth although porosity decreases where sandstones grade laterally into carbonate facies. Due to lack of well control, there is no information regarding porosity development in the Mt. Simon below the Bay Harbor well site.

Barnes and Bacon (2008), as part of their carbon sequestration analysis, plotted measured permeability against formation depth for Mt. Simon wells in the Michigan basin. Their analysis showed that, at the estimated Mt Simon depth of 6,385 - 7,000 feet BGS at Bay Harbor, the estimated porosity would be approximately 5% at Bay Harbor. The authors did not identify the Bay Harbor area as ideal for CO_2 carbon sequestration in the Mt. Simon because of this low estimated porosity. It is unstated, but likely that lower porosities will generally be associated with relatively lower permeabilities.

Sources are highly variable with regard to projections of the Mt. Simon thickness in the Bay Harbor area. Catacosinos indicates (1973) that the Mt Simon may be only 100 feet thick below

Bay Harbor. However, WMU (1981) and Milstein (1983, 1989), indicate that the unit could be 300-400 feet thick. It must be pointed out that all authors have contoured the data based on very sparse well control, so the actual Mt Simon thickness is difficult to define with any accuracy. Data suggest that the Mt. Simon may be at least 100-200 feet thick below the Bay Harbor area.

Eau Claire

The Eau Claire formation occurs above the Mt. Simon in the Southern Peninsula, and consists of lower sandstone that may be included as part of the Mt. Simon formation The top of the unit is composed of thinly bedded siltstone WMU (1981), states that the Eau Claire ranges from 0-1,500 feet thick in the Michigan Basin, with the thickest deposits occurring in the central portion of the Basin. Milstein (1989) believes there to be about 800 feet of Eau Claire in the central portion of the basin It is described as appearing similar to the Mt. Simon sandstone, and may also include thinly bedded units of dolomite, and shale, Milstein (1989). Sandstones are well sorted and have dolomitic cement. The Eau Claire is mapped by Milstein (1989) as being about 200-250 feet thick near the Bay Harbor site (Figure 22).

Galesville (Dresbach) and Franconia

The Galesville is described as a medium grained silica-cemented sandstone that may have glauconite, with some siltstone and shaley units present locally. As with the Eau Claire, it is thickest in the central portion of the Michigan Basin. The Galesville is about 150 feet thick in the Bay Harbor area. The Franconia includes "a wide array of glauconitic dolomitic sandstone, shale, and sandy dolomite" that is sometimes indistinguishable from the underlying Galesville Sandstone. Milstein (1989) states that the Franconia is composed of a light pink to gray quartz sandstone that contains pyrite and abundant glauconite, but can be readily identified by gamma ray log. The Franconia has a maximum thickness of about 800 feet, and is about 125 feet thick in the Bay Harbor area (Figures 23 and 24).

Ordovician Units (Arrestment Interval and Confining Zones)

The sandstone-rich Cambrian section is unconformably overlain by carbonate and shale-rich sequences of the Ordovician. This interval includes the Trempealeau Formation, Prairie du Chien Group, Saint Peter Sandstone, Glenwood Formation, Black River/Trenton Formations, Collingswood Shale and Utica Shale The Trempealeau-Trenton interval is the arrestment interval, while the Utica Shale shall serve as the confining zone for the Bay Harbor well. All are discussed below. It should be noted that some authors include the Trempealeau within the upper Cambrian, but it is discussed within this section because of its similar geologic characteristics and for consistency with Milstein (1989)

Trempealeau Formation

The Trempealeau is a buff to light brown dolomite and can be sandy and cherty Literature suggests that the Formation is composed (top to bottom) of the St. Lawrence, Lodi, and Jordan members. The St. Lawrence member is a sandy dolomite with dolomitic shales, The Lodi is a sandy dolomite with interbedded stringers of shale and sandstone, while the Jordan sandstone is fine grained quartz sandstone to sandy dolomite. This Formation represents a transition between underlying sand-rich units and overlying carbonate rich intervals. The Trempealeau Formation is between 375-600 feet thick below the Bay Harbor site, depending on references cited (e.g Figure 25, from Milstein (1989)

Prairie du Chien Group

The Prairie du Chien Group includes the Foster Formation as well as other units identified by WMU (1981) as the Oneota Dolomite, New Richmond Sandstone, and Shakopee Dolomite.

WMU (1981) states that in the subsurface "the entire Prairie du Chien Group has characteristics similar to dolomite", and indicates that in some areas (near subcrops) the Prairie du Chien is porous. Milstein (1983) mapped the Prairie du Chien as about 500 feet thick (Figure 26). Prairie du Chien is a gas producer in the central portion of the Michigan Basin, with the deepest of these producing from depths more than 10,000 feet below ground surface. No production was identified in the Bay Harbor area from this formation

St Peter Sandstone/Glenwood Formation

The St. Peter Sandstone occurs above the Prairie du Chien, and occurs in northern portions of the Michigan Basin as mapped by Barnes et al, (1992) St. Peter/Glenwood can be a prolific oil producer as indicated by Drewiecki, et al (date):

> "The Middle Ordovician St. Peter Sandstone and Glenwood Formation (Ancell Group) represent a significant target for gas exploration at the base of the Tippecanoe sequence in the Michigan basin. Core and well log data show that the St. Peter-Glenwood interval contains numerous carbonate units that provide the basis for both regional correlation and subdivision of the section into at least 20 high-frequency sequences. The temporal resolution afforded by these sequences allows a detailed analysis of sediment partitioning as the basin evolved. The spatial distribution of the basal sequences illustrates the pronounced east-to-west onlap of the Wisconsin arch. An abrupt increase in sequence thickness upsection indicates that a major episode of basin-centered subsidence began during middle St. Peter deposition and continued through the deposition of the Glenwood Formation. The upper sequences show a significant beveling of the Glenwood Formation and the top of the St. Peter Sandstone in the north, south, and southeast areas of the basin prior to deposition of the overlying Black River carbonates. Although eustatic sea level changes were undoubtedly operating at several scales, the facies distribution of this mixed clastic/carbonate system also documents significant changes of local and regional tectonics."

The Glenwood Shale is a dolomitic and sandy shale that occurs in the western portion of the Michigan Basin. It thins to the east and is a greenish-grey shale in central Michigan. It is persistent and mappable throughout the Basin but typically is no greater than 20 feet thick. WMU (1981) suggests that this unit may serve as a confining zone, as it is "thought to be a barrier to the movement of hydrocarbons from the Black River Group into the underlying Prairie du Chien and Cambrian units".

Black River/ Trenton Groups

The Black River Group is composed of thick, undifferentiated dense brown/grey micritic limestones with cherty intervals and an altered volcanic ash called the Black River Shale. This shale is a thick, yet distinctive bed, of limited extent. Near outcrop, the Black River Group may produce water from solution joints/fractures, but is "quite impermeable except where it has been dolomitized" in areas away from subcrop, WMU (1981). The Black River is over 100 feet thick at Bay Harbor according to Wilson et al. (2001.

The Trenton Group consists of several hundred feet of light brown to brown limestone. It is 200-450 feet thick across the Michigan Basin. WMU (1981) states that "although the Trenton limestones are relatively impermeable, the possible presence of fractures and dolomitized zones could preclude its use as confining layer". The principle porosity zones are in areas of dolomitization. The Trenton Group is about 175 feet thick below Bay Harbor, Wilson et al. (2001)

Wilson, et. al. (2001) describe the Black River and Trenton Formations as follows:

> "The overlying section is another great sheet of Middle Ordovician carbonate, the Black River and Trenton formations. These strata [Black River and Trenton] host the largest single oil field in the state (Albion-Scipio). The lower part of the Middle Ordovician carbonates, the Black River Formation, consists of very micritic dense lime mudstone to wackestone with some brachiopods and possesses nodules of brown chert. Dark shale laminae in the Black River may indicate that source beds for petroleum occur within this carbonate sheet, in fact as high as the top of the Trenton Formation. Gamma-ray and neutron-porosity-density logs show that the Black River, like the Trenton, is thinner and more argillaceous in the northeast quadrant of the basin. "

Collingwood Shale (confining zone)

The Collingwood Shale occurs above the Trenton Formation, and is a 0-40 feet thick shale that occurs only in northern portions of the Michigan Basin. It is about 20 feet thick below the Bay Harbor site. Wilson et al (2001) states that The Collingwood Shale is a relatively thin organic-rich shale that has a hard ground at its top with phosphate pellets. Wilson et al (2001), also indicates that the unit appears to have some areas of non-deposition, further stating that "Churcher suggest[ed] that the hard ground surfaces are developed on the upthrown sides of fault blocks which result from the reticulate pattern of faulting proposed by Sanford (1985) from Silurian edgeline and isopach studies". Wilson et al. (2001) mapped a "zero line" for the Collingwood Shale, indicate that it is apparently ubiquitous and present throughout the Bay Harbor area. Wilson suggests that the Collingwood Shale may be a petroleum hydrocarbon source rock.

Utica Shale (confining zone)

WMU (1981) states "The top of the Trenton is a widely recognized and traceable stratigraphic boundary throughout the basin, well marked on both petrophysical and lithologic logs and also visible seismically. It is commonly used as a datum for structure contour maps and is assumed to be a chronostratigraphic surface." Note that various authors disagree whether the Trenton-Utica contact is conformable

The Utica Shale is upper Ordovician in age and records influx of argillaceous mud into the depositional system. As a result, the Utica, is a hard, dark gray to greenish black calcareous shale that is "homogenous throughout" the Michigan Basin, WMU (1981). Thickness varies from 400 to 150 feet thick (Figure 27), and it is about 190 feet thick below the Bay Harbor area. WMU (1981) states that this zone is "far too impermeable for use as an injection zone" and in fact "the very low permeability of this rather thick shale coupled with the fact that it forms the seal on known hydrocarbon traps indicates that it is an excellent confining layer".

Silurian Units

Between the Utica Shales and the top of the Bass Islands Groups is about 2,800 feet of sedimentary rock that is Silurian in age. The most prevalent units in this sequence are the Niagara, Salina, and Bass Islands Formations, which are described below.

Niagaran

Matzkanin, et al. (1977) summarizes the geology of the Niagaran as follows:

> "Niagara rocks in the subsurface are predominantly dolomites and limestones with scattered regional occurrences of cherty zones and thin shale beds. These rocks range in thickness from less than 100 feet in the basin interior to more than 1,000 feet at the basin margin... pinnacle reef complexes [occur] a few miles basinward from the thick

> carbonate bank. Reefs, reef associated sediments, and biostromes occur at various stratigraphic levels within the Salina-Niagara Group Reefs range in size from small isolated masses 10 feet in diameter to large complexes several hundred acres in extent and vary in height from a few feet to more than 500 feet Most reefs in the subsurface appear to be coral-algal-stromatoporoid mounds with occurrences of brecciation and a variety of fossil debris from shelly organisms. "Pay zone" porosity appears to be developed by preferential solution of coral skeletons and invertebrate remains from the fossiliferous rock by ground waters Dolomitization of limestone reefs frequently plays an important role in the development of porosity Occasionally evaporite infilling destroys potentially productive porosity."

WMU (1981) states that "in the subsurface of the Southern Peninsula of Michigan, rock of the Middle Silurian Niagara Group form gradation zones with distinctive rock characteristics In the central part of the basin the Niagara Group consists of a thin (50-120 feet) dense limestone (micrite) termed the "basinal facies" that grades outward into a dolomitic limestone ... then grades into a porous dolomite ... termed the "shelf facies". The Shelf facies [that is] about 120 to 300 feet [thick]. The shelf facies is characterized by the presence of locally thick areas in the form of "pinnacle" reefs. Outwash this facies grades into a thick (300 feet to 500 feet) zone ... called the "bank facies" This zone is composed of porous and permeable dolomite and extends southward into Indiana and Ohio and northward into the outcrop area".

Data presented in WMU (1981) indicate that the Bay Harbor DW #1 occurs in the "bank facies" area of the Niagara, where mapped thickness is approximately 400 feet (Figure 30a). The nearby Robert and Myra Hand #1 Well verifies this thickness, as the Niagara is about 430 feet thick near Bay Harbor based on log picks for the Brown Niagara and Clinton Formations at this well location While the Niagara is a prolific oil and gas producer in Michigan, no productive Niagara wells occur in Emmet or Charlevoix Counties.

Salina Group

Matzkanin et. al (1977) summarizes the Salina Group as follows:

> "The Salina Group contains evaporite, carbonate, and shale stratigraphic units. The A-1 Evaporite, A-1 Carbonate, A-2 Evaporite, and A-2 Carbonate units are of particular interest where Niagaran reefs are present While the A-1 Evaporite is a clean salt over most of the Michigan basin interior, the unit grades laterally into an anhydrite that thins and pinches out against the flanks of reef complexes. The A-1 Carbonate is essentially a dark colored limestone, dolomite, or both in non-reef locations. In the vicinity of reefs, the A-1 Carbonate may be completely or partially dolomitized and exhibits depositional thinning over the reef and margin reef complexes. The A-2 Evaporite is nearly a pure salt in the deeper parts of the basin, while near reefs the unit is generally represented entirely by anhydrite. Partial dolomitization and some depositional thinning occur in the A-2 Carbonate where it overlays reef complexes"

WMU (1981), states that the Salina Group is a "thick sequence of carbonate, anhydrite, salt and shale" that is restricted in areal extent to the approximate location of the Niagara Formation. The unit grades upward from the Basal "A" member (A-1 Evaporite, A-1 Carbonate, A-2 Evaporite and A-2 Carbonate) through F member, and is composed of interbedded shales, limestones and salts. It should be noted that the Salina may contain several hundred feet of bedded salt, in total. WMU, 1981 indicates that the A-1 Evaporite, A-1 Carbonate, A-2 Evaporite, are missing in the Bay Harbor area, but the rest of the Salina sequence is mapped to be present. Maps presented in WMU, 1981 indicate that the Salina Group is about 1,000 feet thick in the Bay Harbor area (derived by totaling the gross thickness of the A-2 through G sequence thicknesses). This is verified by the Robert and Myra Hand #1 well, wherein the gross Salina interval thickness is about 1,095 feet (Figure 30b). Note that others, Milstein (1983, etc., have mapped the Salina Bass Island interval as being much thinner.

Bass Islands

WMU (1981) states that the Bass Islands is described as a thick sequence of fine-grained dolomites that has floating anhydrite and celestite crystals, as well as some salt in central portions of the Michigan Basin. Regional data suggest the Bass Islands Group is about 250 feet thick in the Bay Harbor area, which is verified by the Robert and Myra Hand #1 well, wherein the Bass Islands is about 265 feet thick.

Devonian Units

Devonian-aged units present in the area include the Bois Blanc/ Detroit River Group, Dundee Formation, Bell Shale, and Traverse Group. In the Bay Harbor area, the Traverse Group subcrops and is the principal bedrock aquifer in the area. The USDW is previously described in Section 2.D of this application and will need to be confirmed by testing during well installation.

Detroit River Group

WMU (1981) states that the Detroit River Group (Figure 30c) includes the Garden Island, Bois Blanc, Sylvania, Amherstburg, and Lucas Formations. The Bois Blanc is composed of dolomite and cherty dolomites, with upper limestone-rich intervals. The Sylvania is a sandstone, composed of well-round and sorted fine to medium grained quartzitic sandstone with thick chert and dolomite rhombdehedrons in northwestern areas of deposition. In the Bay Harbor area, the Sylvania/Bois Blanc interval is about 250 feet thick. The Amherstburg is a dark brown to black carbonaceous limestone that is present most of the Michigan Basin. It is poorly bedded and dense, and is about 100 feet thick in the Bay Harbor area.

While the Detroit River includes the above formations, WMU (1981) indicates that it is "general practice" to only call that portion of the column between the top of the Amherstburg and Dundee the "Detroit River". This portion of the column includes the Richfield Member, which is a sequence of interbedded limestone, dolomite and anhydrite with minor amounts of sand, a massive anhydrite unit, and the Horner Evaporite composed of interbedded anhydrite, limestone, and salt. In total the Detroit River is mapped as being approximate 300 feet thick below Bay Harbor. This is verified by the Robert and Myra Hand #1 well, wherein the interval is about 619 feet thick, but this includes what is mapped as the Amherstburg and Sylvania, which may account for the additional 300 feet of section.

Dundee Limestone

The Devonian age Dundee is predominately a carbonate section ranging from dense, fine-grained, light colored limestones on the east side of the state to coarse-textured bioclastic limestone (with portions secondarily dolomitized) in the central part of the state. The top of the Dundee is easily picked on geophysical logs in the area of the proposed well because the Bell Shale is present. In the vicinity of the Bay Harbor well, the Dundee is about 78 feet thick. Figure 30d is a structure contour map of the Dundee in the Bay Harbor area, and Figure 30e is an isopach of the Dundee in the same area.

Bell Shale

The Devonian age Bell Shale is typically a soft, gray, gummy and silty shale containing scattered fossil fragments. In the Bay Harbor area, the Robert and Myra Hand #1 well indicates that the Bell Shale is about 100 feet thick (Figure 30f). Figure 30g is a structure contour map constructed at the top of the Bell Shale, which shows that this unit is ubiquitous in the Bay Harbor area.

Traverse Group

The Traverse Group occurs above the Bell Shale, and includes what is locally described as the Traverse Limestone and Traverse Formation. Both are described below. It should be pointed out that in the Bay Harbor area, the Traverse subcrops below overlying glacial till. Therefore, it is the uppermost bedrock unit in the area In total and based on the Robert and Myra Hand #1 well log, the Traverse is about 400 feet thick in the Bay Harbor area, with about 100 feet of overburden/glacial till above consolidated bedrock (Figures 13 and 14)

Traverse Limestone. In western Michigan, the Devonian-age Traverse Limestone is dominantly a gray to gray-brown limestone, with lesser gray shales. A few anhydrite stringers may also be present. To the east, the Traverse Limestone becomes increasingly shaley, and in southeastern Michigan the unit is composed almost entirely of shale. The Traverse Limestone is about 95 feet thick in the Bay harbor area, based on area logs.

Traverse Formation. Below the Traverse Limestone is the Traverse Formation, and in the Bay Harbor area this interval is comprised of a 235 feet thick interbedded limestone and shale zone that is described as gray-tan and calcareous. This unit is described locally interbedded tan-buff limestones that may be hard dense and fossiliferous.

Glacial Drift

Figure 11 is a generalized isopach of the Glacial Drift showing the drift is thin or absent near the Bay Harbor area. Well sample descriptions from the Robert and Myra Hand #1 well indicate that the drift is about 100 feet thick in this location, and is composed of unconsolidated sands and clays. Sands are quartzitic and are medium to coarse grained in size, and clays are grey to light grey

Structural Geology and Faulting

The Beeland Group, LLC Bay Harbor Disposal Well No 1 is to be located in the northwestern edge of the Michigan Basin (Figures 19 and 20). Figure 16 is a generalized cross section that shows the orientation of sediments within the Basin, as well as the subcropping units below Lake Michigan, which is adjacent to the Bay Harbor site. As shown in these figures, units dip to the south-southeast at about 100-150 feet/mile based on the structural orientation of the Mt. Simon surface as shown in Figure 20. The regional cross section shows that the Cambrian Rock Units, including the injection interval, arrestment interval, and confining zone do not subcrop below Lake Michigan anywhere in the proximity of Bay Harbor, and are isolated from the base of the lake, by several thousand feet of rock.

Published data concerning the geology of the Bay Harbor area present different interpretations of local structural geology with respect to the presence of faulting. For example, Figures 13-30 show no indication of any major faulting in the Bay Harbor area that are mappable to the extent of disrupting structural or stratigraphic units at the contour intervals presented. However, other documents imply the possible presence of faults in the area that extend at least through the Trenton Formation. Wood and Harrison (2002) included a map showing the presence of the Keweenawan Fault in the immediate vicinity of the Bay Harbor site (Figure 31), citing Buthman (1995) as the source for this fault map. The cited Buthman article deals with karst development elsewhere in the Basin, and cites an unreferenced Buthman (1986) document as the map source. Wood and Harrison (2002) also show the presence of linear features in the basement and through the Dundee in the Michigan Basin (Figure 32), and while none of the features are mapped to extend to the Bay Harbor area, one NW-SE lineament is "on trend" with the location. Further, Wood and Harrison show the presence of the Keweenawan Rift, which is an ancient Rift feature that extends through the central portion of the Michigan Basin basement (Figure 31). Catacosinos (1981) also mapped the presence of a mid-Michigan gravity anomaly that correlates to this rift with faults extending north to Beaver Island, essentially splitting the two Beaver Island Wells (1 and 2). Figure 33 also maps the occurrence of a north-trending fault that occurs between the two Beaver Island Wells, and extends southward to the west of the Bay Harbor area All of the faults mapped occur at least within basement, and may extend up to and through Cambrian units.

In summary, while regional isopach and structure contour maps suggest there are no major faults in the Bay Harbor area, other studies indicate there may be fault trends either below, Buthman (1986), or near, Catacosinos (1981), the Bay Harbor area. As discussed below, there are no data to suggest that the faults are active, based on seismic data

Seismic Activity

The Bay Harbor area of northwestern Michigan Basin has been designated as a relatively minor seismic risk area by the USGS(http://earthquake.usgs.gov/regional/states/michigan/hazards.php). The proposed area has a peak acceleration of 0-2 percent g, and no earthquakes have been identified in the Bay Harbor area over the past 100 years. A category VI earthquake occurred in southern Michigan in 1947, but USGS data do not suggest that this event was felt north of Cadillac, Michigan

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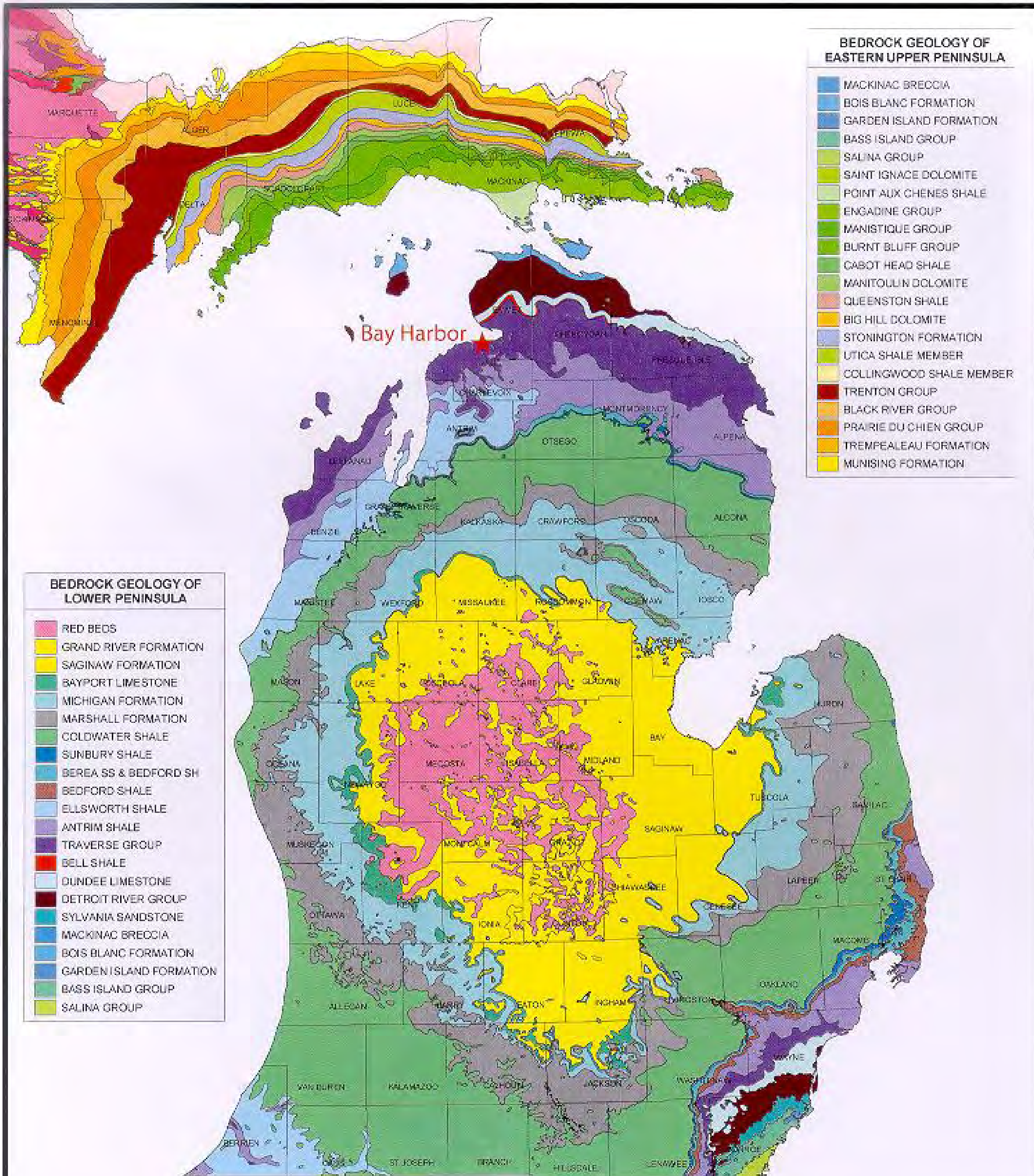

SOURCE

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
LAND AND MINERALS SERVICES DIVISION
RESOURCE MAPPING AND AERIAL PHOTOGRAPHY

Michigan Resource Information System
Part 609, Resource Inventory, of the Natural Resources and
Environmental Protection Act, 1994 PA 451, as amended.

Automated from "Bedrock Geology of Michigan," 1987, 1:500,000 scale,
which was compiled from a variety of sources by the Michigan Department
of Environmental Quality, Geological Survey Division.

Date: 11/12/99

0 20 40 Miles

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Figure 15
Regional Geologic Map
of Michigan Basin

2009 Bay Harbor Disposal Well No.1 Permit

Scale: See Bar Scale	Date: October 2009	
BH_MDEQ_Fig 15.ai	By: JLM	Checked: CW

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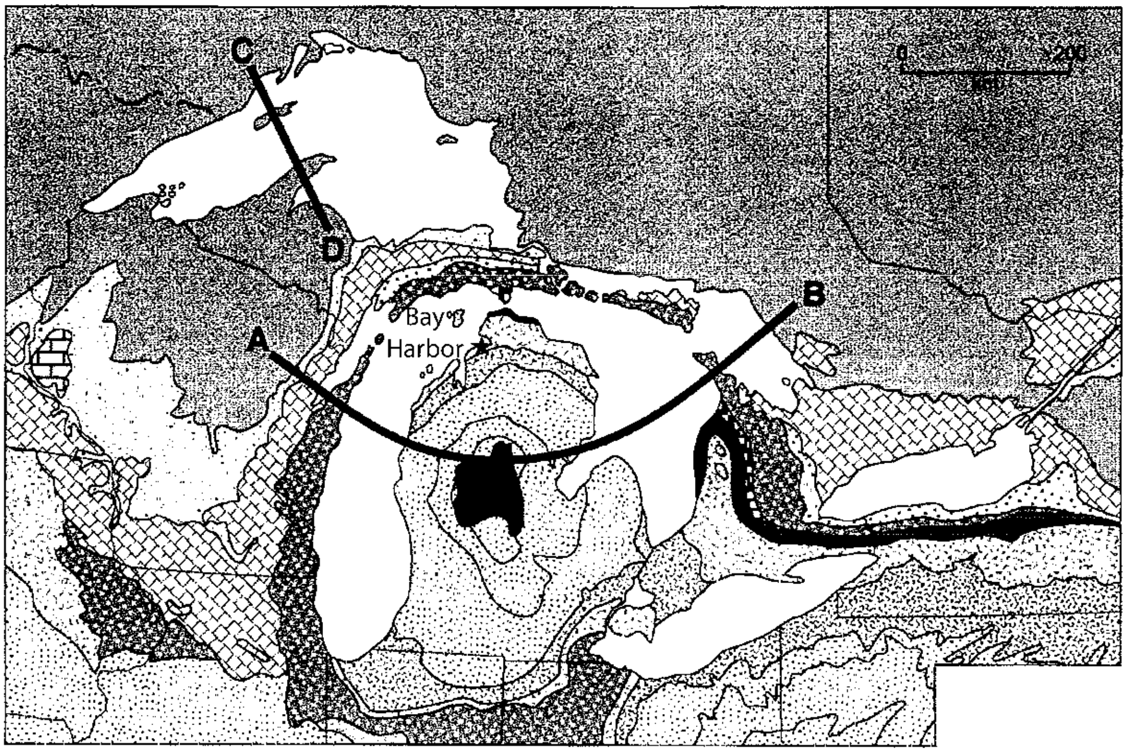
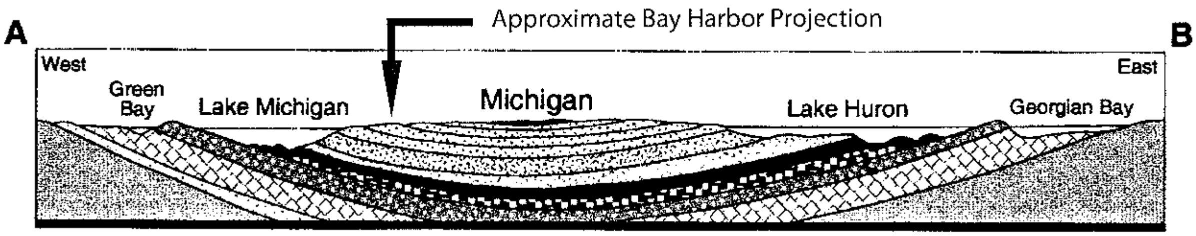


- Upper Jurassic rocks
- Pennsylvanian and Mississippian rocks undifferentiated.
- Upper Devonian rocks mainly shales: Antrim shale in Michigan
- Lower Devonian rocks, in United States: Devonian undifferentiated in Canada.
- Upper Silurian rocks, in Ontario and New York (mainly dolomite)
- Silurian Salina group rocks in Northern Michigan and Ontario (includes salt beds)
- Middle Silurian Niagaran series rocks in Northern Michigan, Ontario, and New York; Silurian rocks undifferentiated in Wisconsin, Iowa, Illinois, Indiana, and Ohio.
- Lower Silurian rocks in Northern Michigan, Ontario, and New York.
- Ordovician rocks, undifferentiated.
- Cambrian rocks, undifferentiated.
- Precambrian rocks, undifferentiated (mainly metamorphic and igneous rocks).



From: Larson and Schaetzl, 2001

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Figure 16
Regional Cross Section,
Michigan Basin

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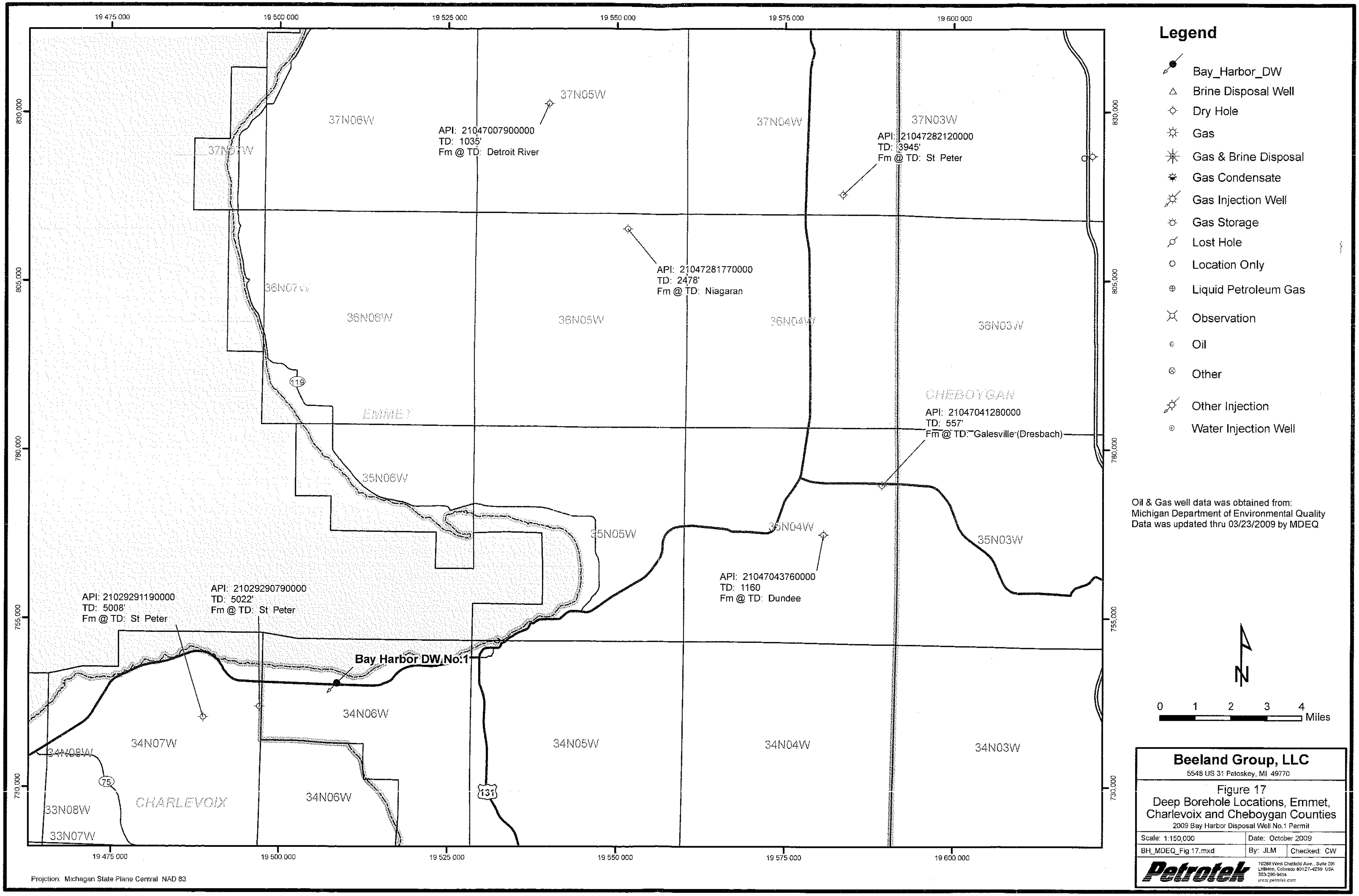

Figure 17
Deep Borehole Locations, Emmet, Charlevoix and Cheboygan Counties
2009 Bay Harbor Disposal Well No.1 Permit

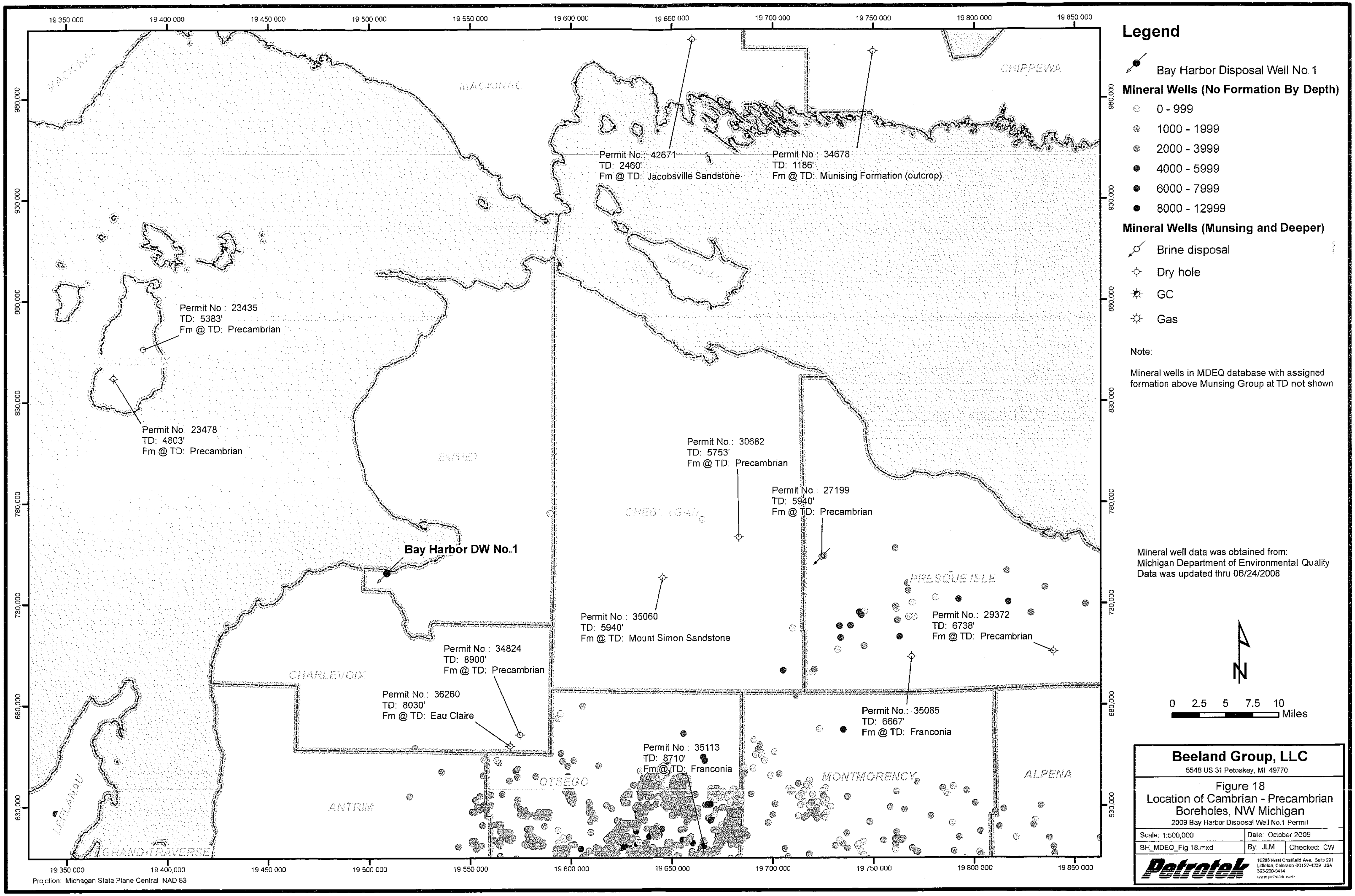

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Figure 18
Location of Cambrian - Precambrian Boreholes, NW Michigan
2009 Bay Harbor Disposal Well No.1 Permit

Scale: 1:500,000	Date: October 2009	
BH_MDEQ_Fig 18.mxd	By: JLM	Checked: CW

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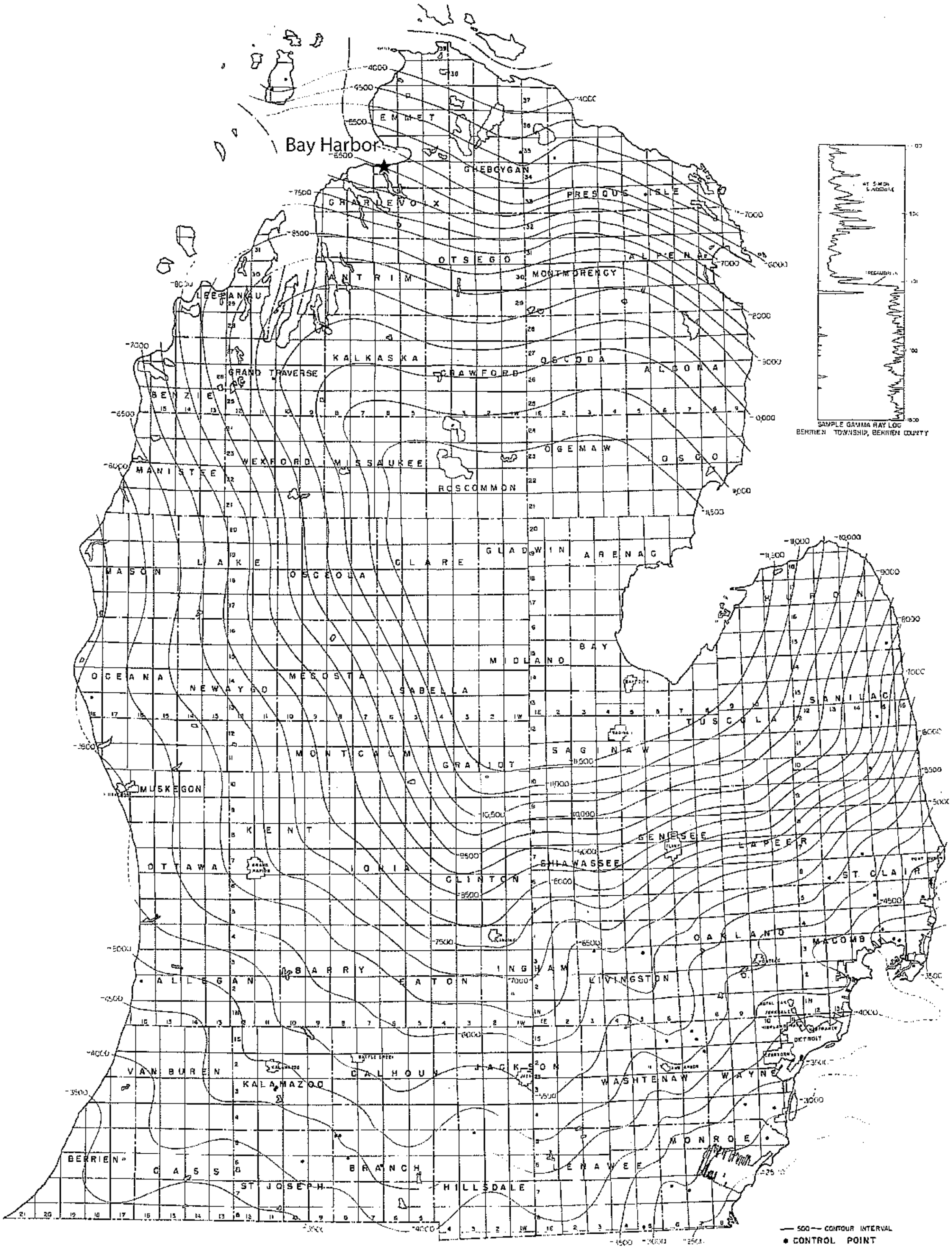

After: R. Milstein, 1988

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Figure 19
Precambrian Structure
Contour Map, Michigan Basin
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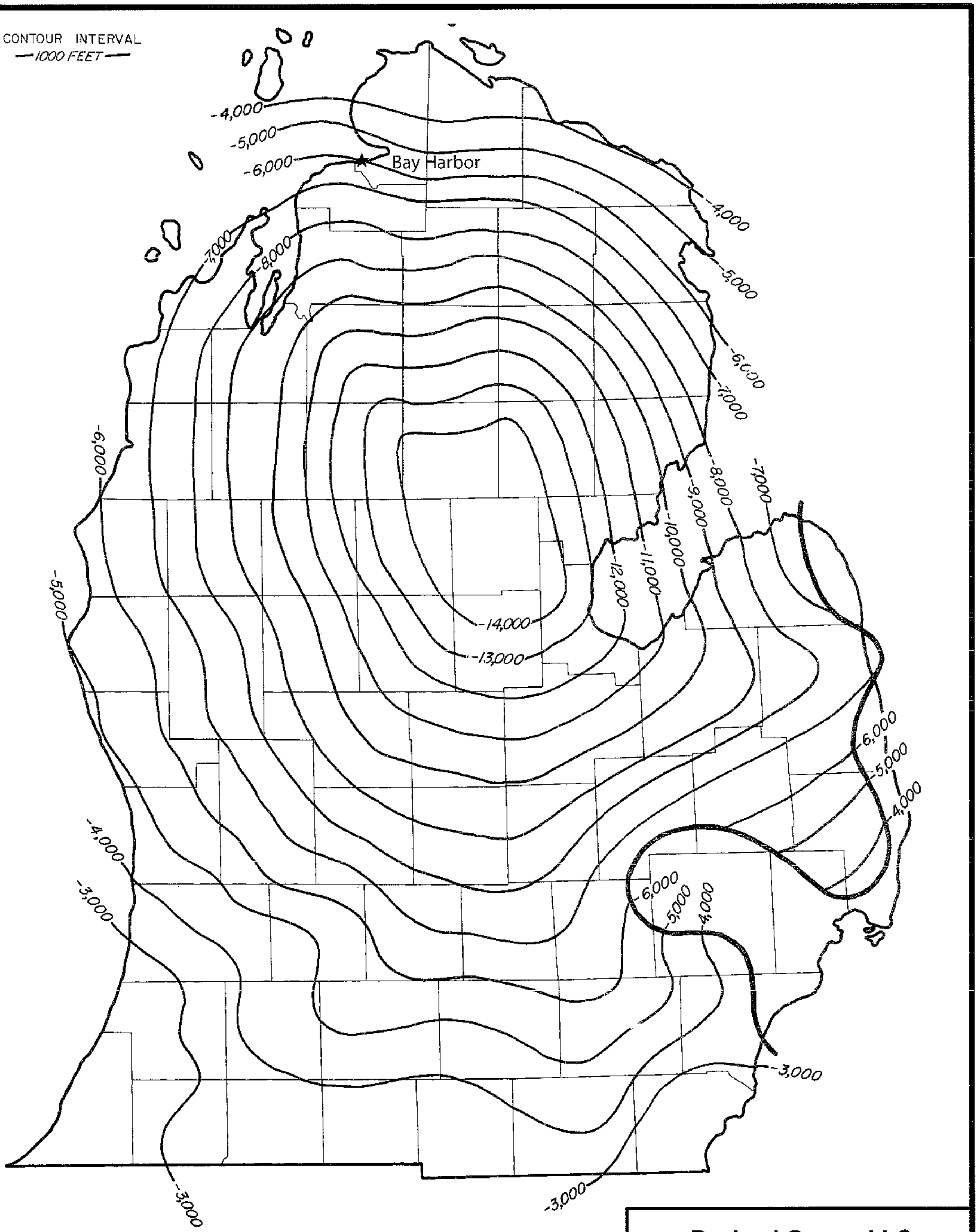

After: R. Milstein, 1983

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Figure 20
Mount Simon Structure
Contour Map, Michigan Basin

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Scale: NTS	Date: October 2009
BH_MDEQ_Fig 20.ai	By: JLM / Checked: CW

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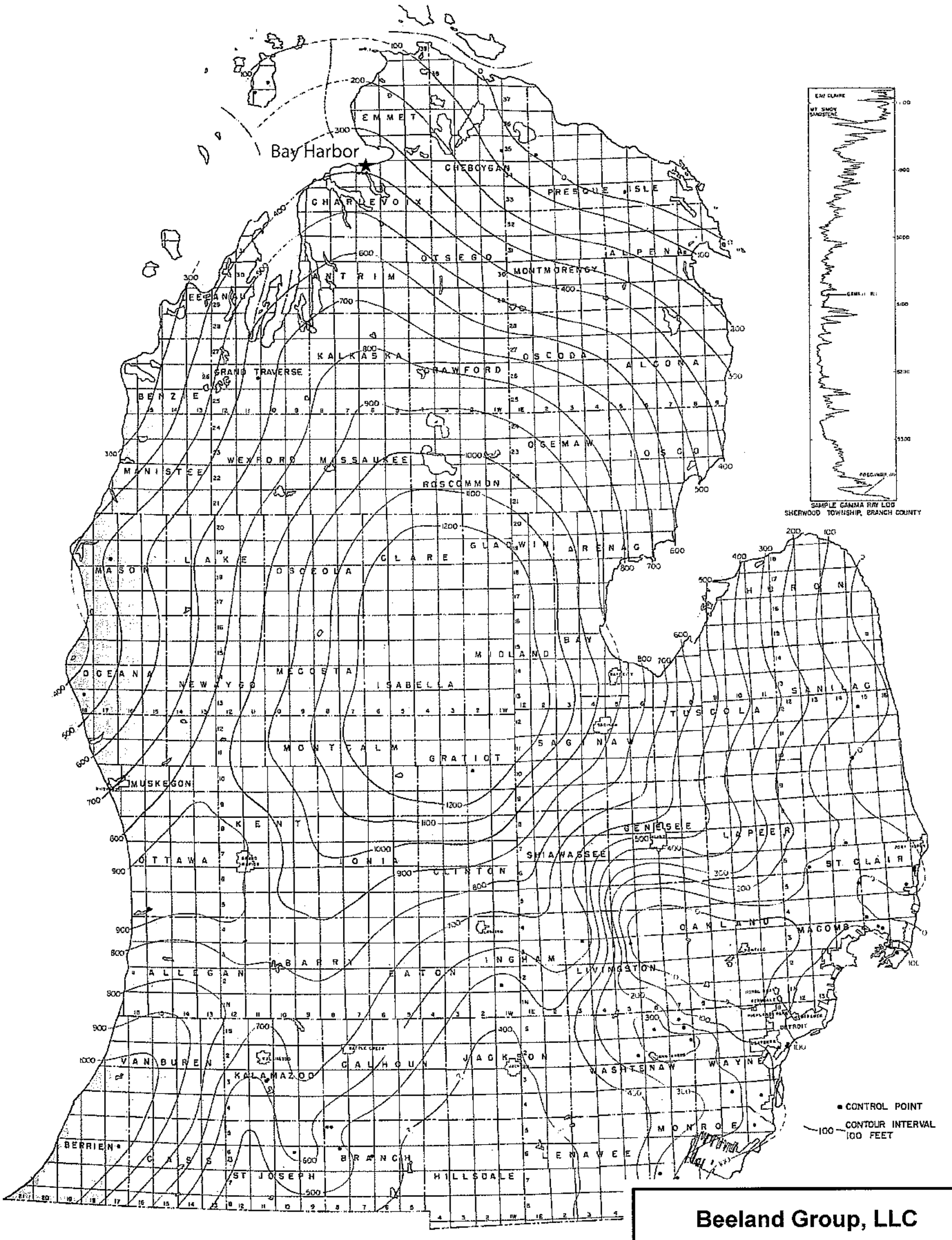

After: R Milstein, 1988

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Figure 21
Mount Simon Formation
Isopach Map, Michigan Basin

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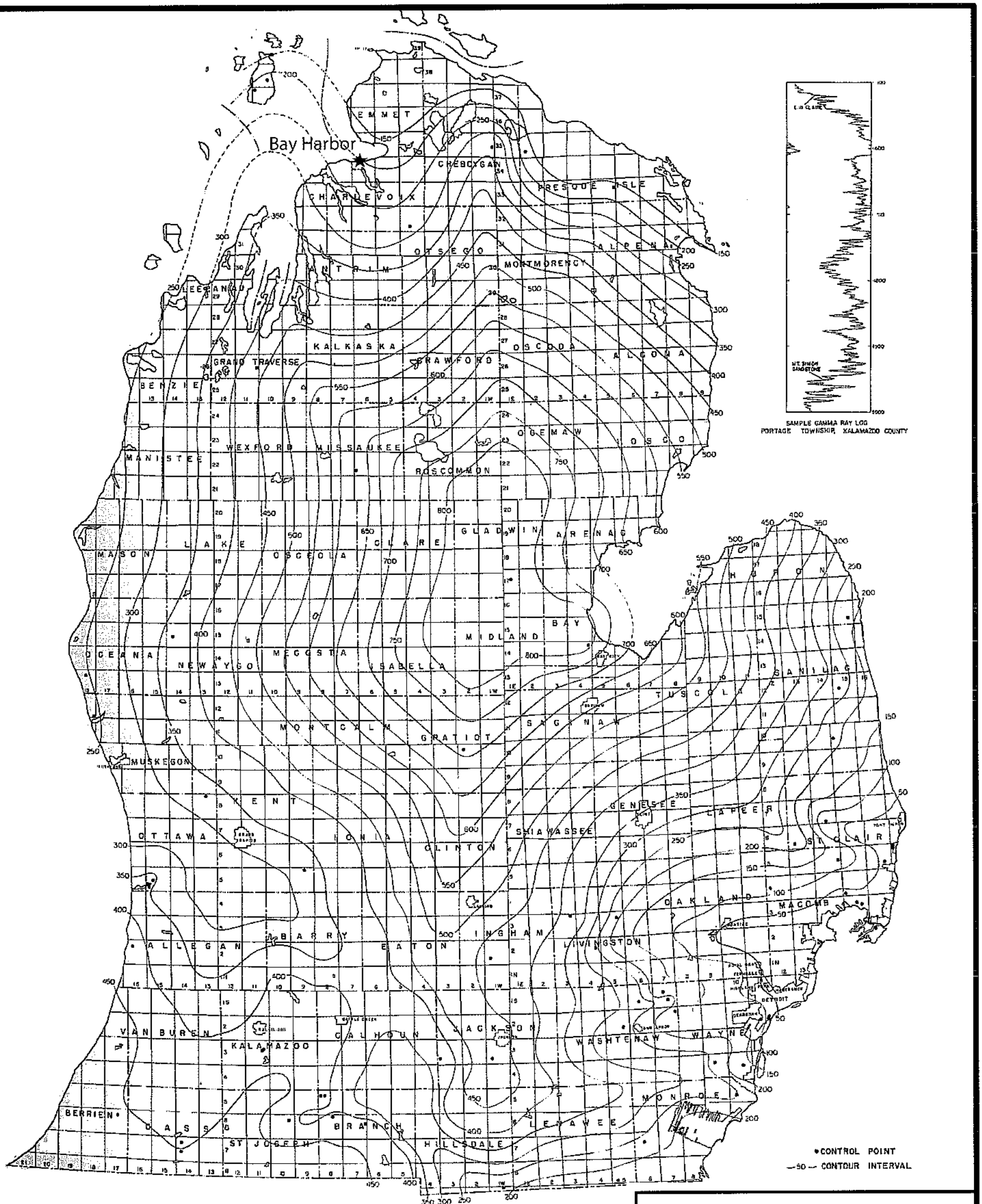

After: R. Milstein, 1988

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Figure 22
Eau Claire Formation
Isopach Map, Michigan Basin

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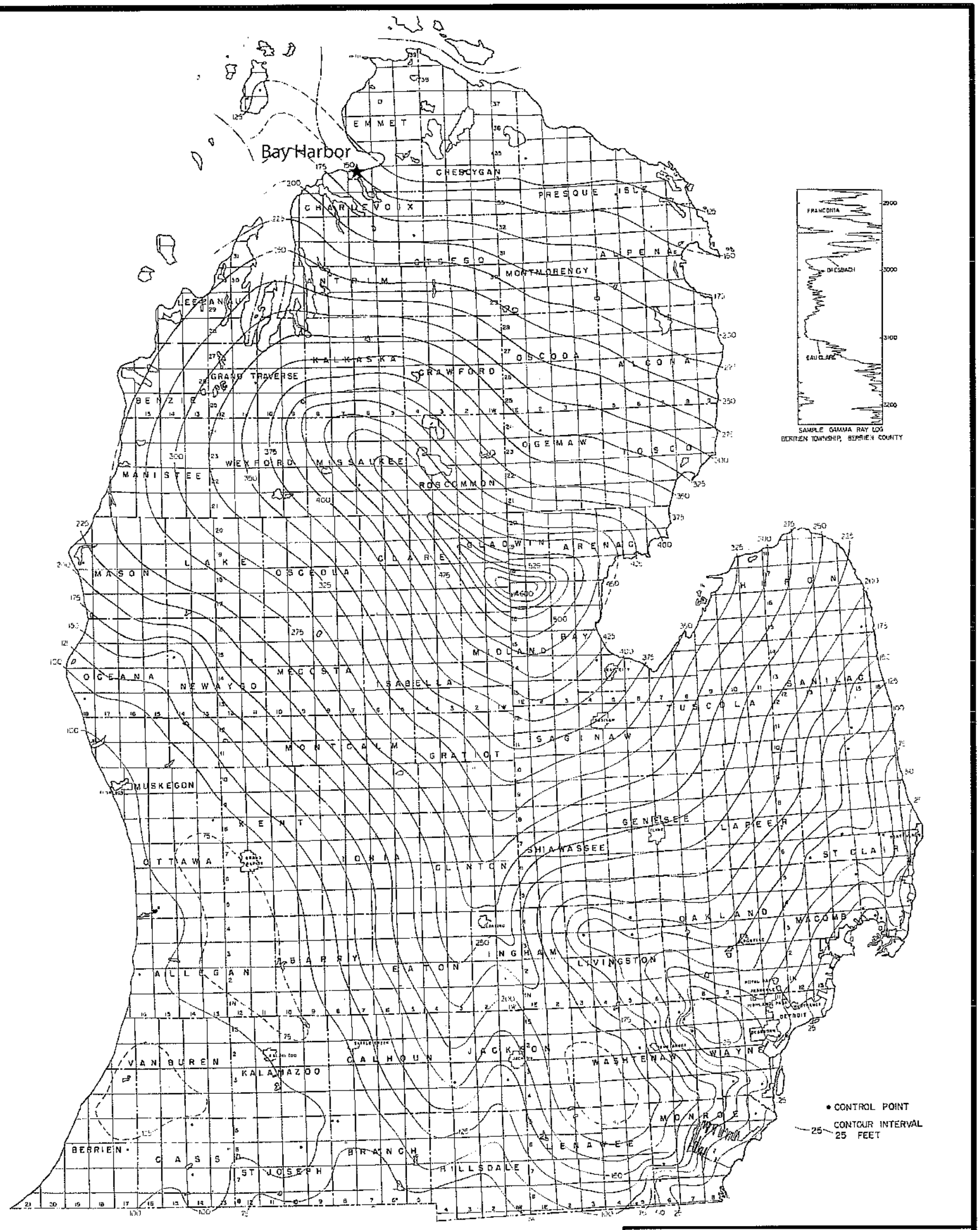

After: R Milstein, 1988

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Figure 23
Galesville (Dresbach) Sandstone Isopach Map, Michigan Basin

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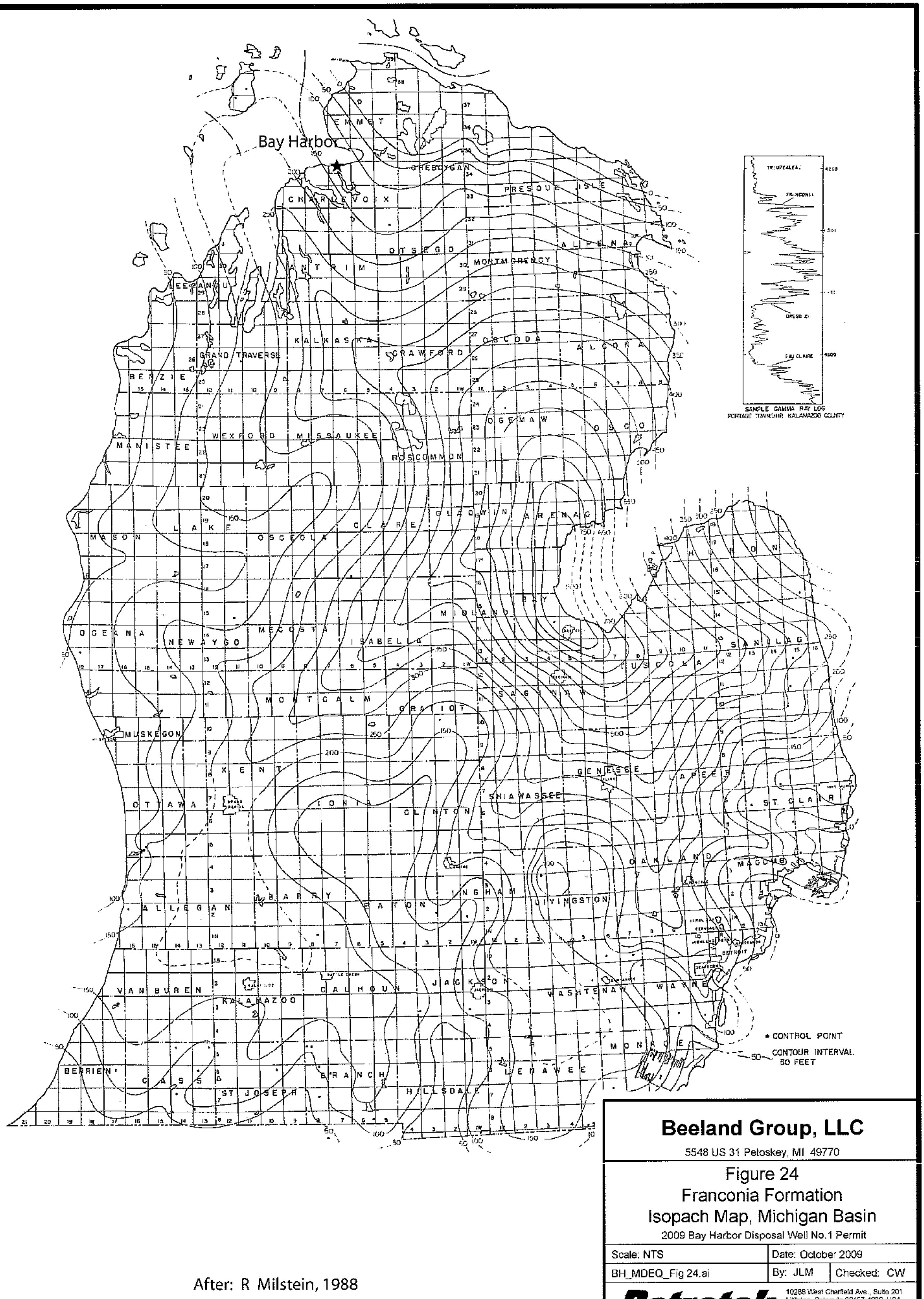

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Figure 24
Franconia Formation
Isopach Map, Michigan Basin

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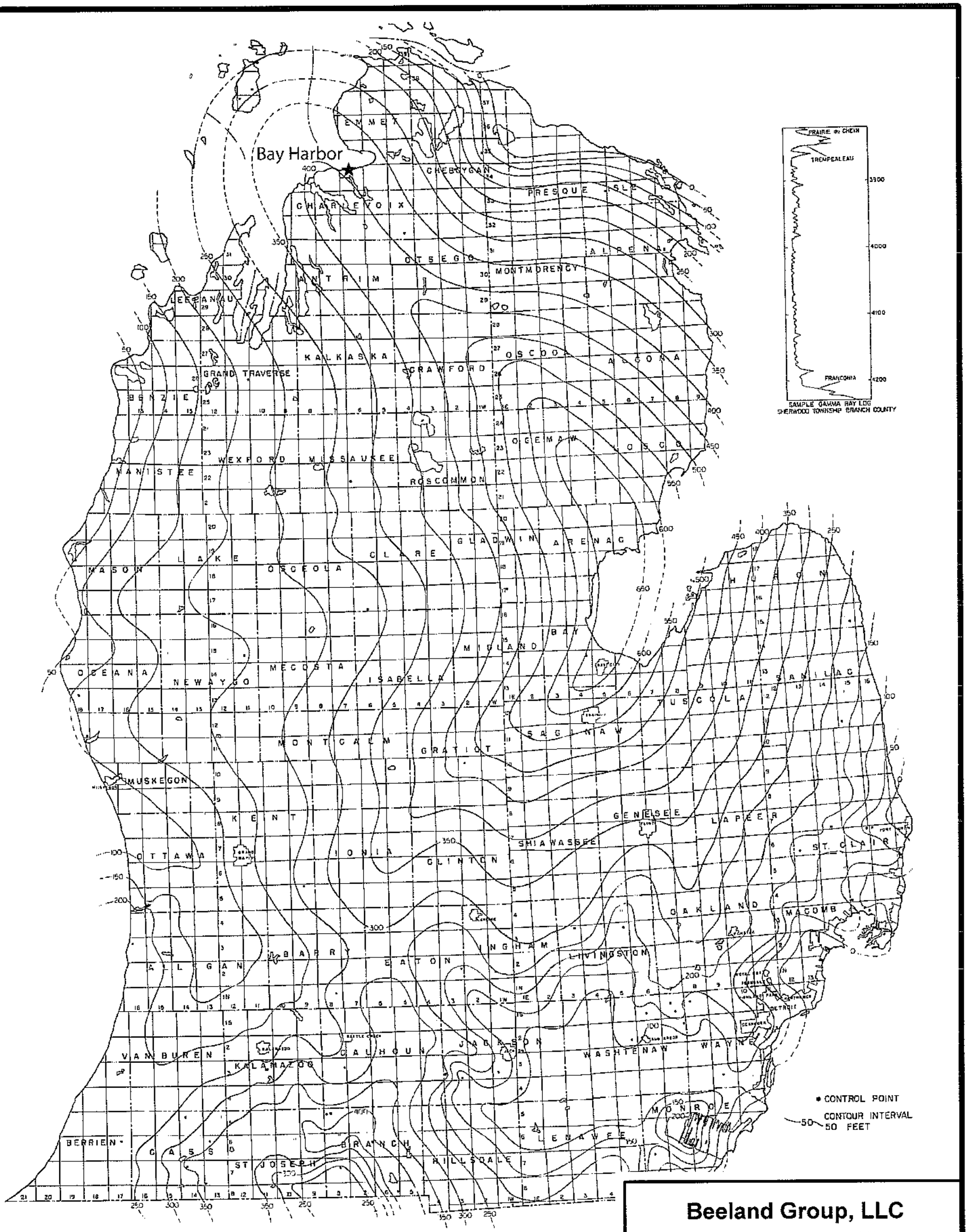

After: R. Milstein, 1988

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Figure 25
Trempealeau Formation
Isopach Map, Michigan Basin

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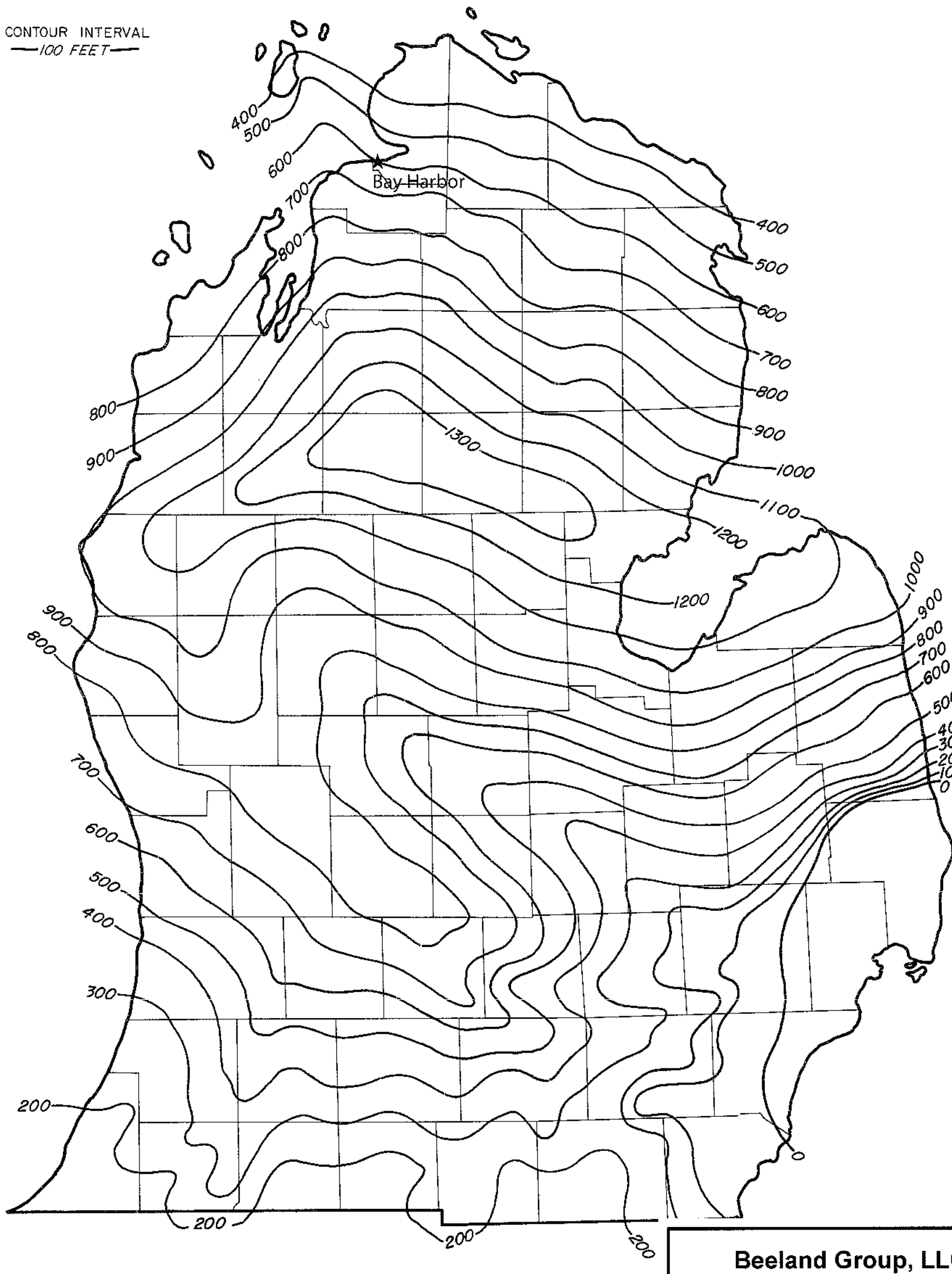

After: R. Milstein, 1983

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Figure 26
Prairie du Chien Group
Isopach Map, Michigan Basin

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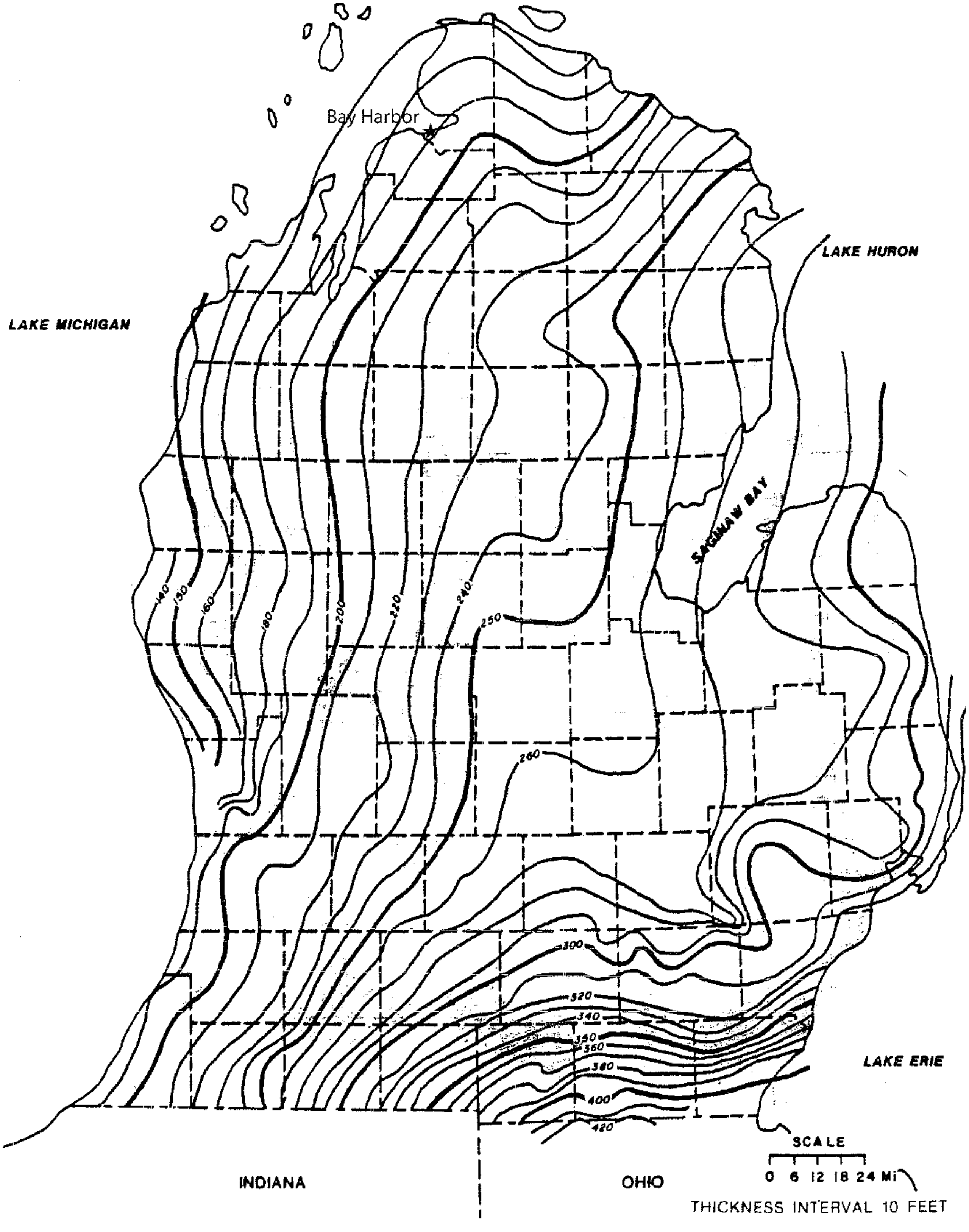

After: Nurmi, 1972 as presented in WMU, 1981

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Figure 27
Utica Shale Isopach Map, Michigan Basin

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Scale: See Bar Scale	Date: October 2009	
BH_MDEQ_Fig 27.ai	By: JLM	Checked: CW

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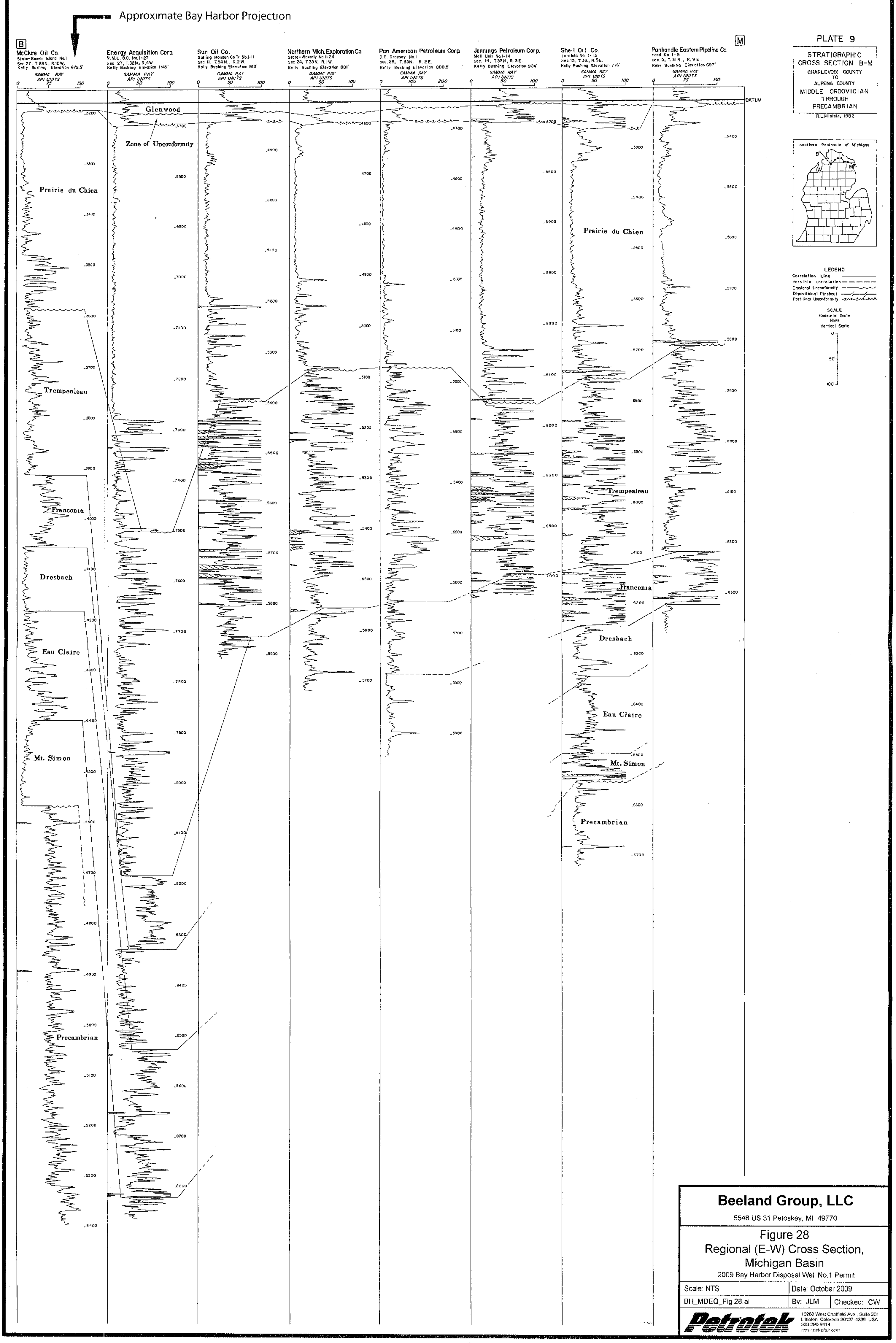

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Figure 28

Regional (E-W) Cross Section, Michigan Basin

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Scale: NTS	Date: October 2009	
BH_MDEQ_Fig 28.ai	By: JLM	Checked: CW

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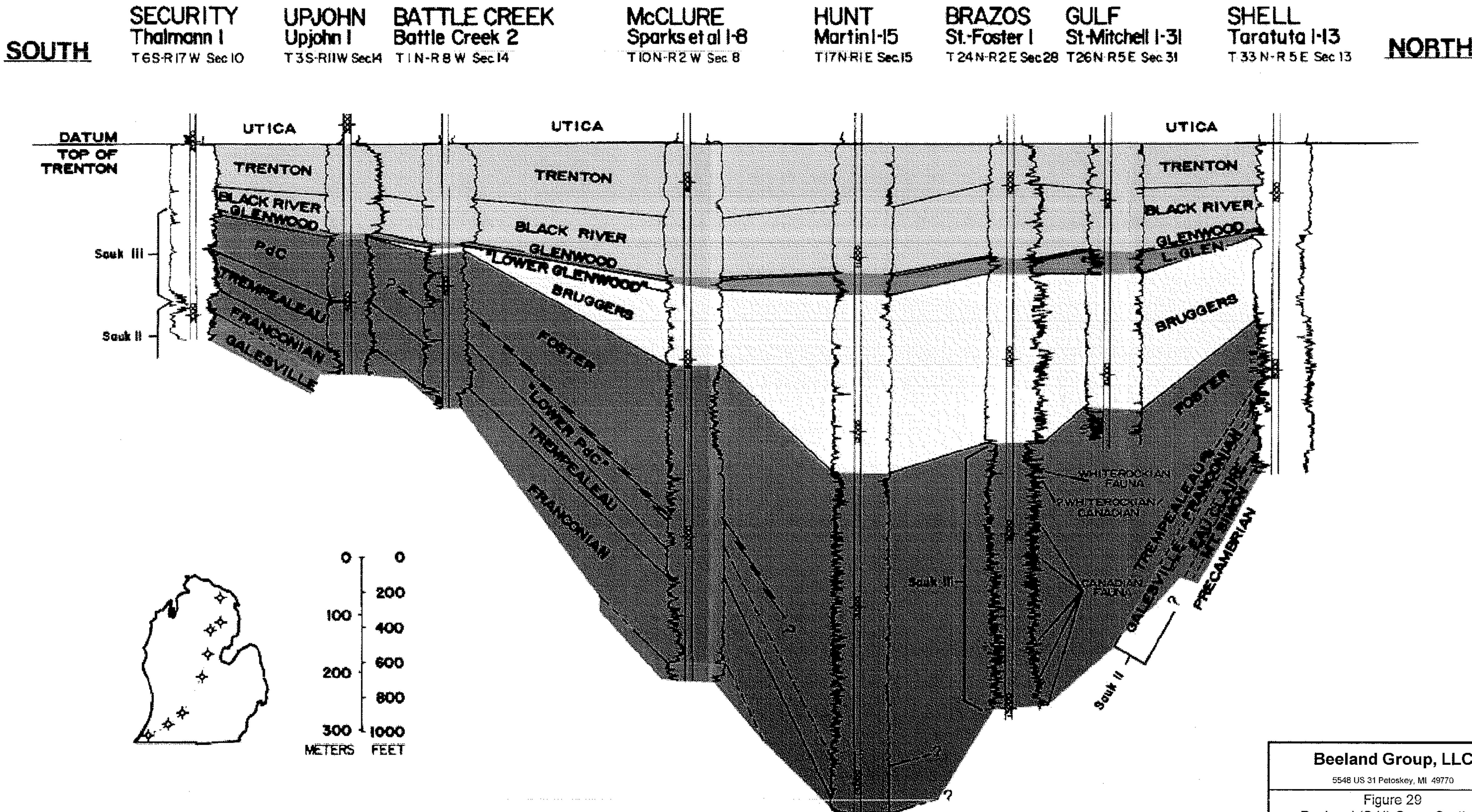

After: Fisher and Barratt, 1985

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Figure 29

Regional (S-N) Cross Section, Michigan Basin

2009 Bay Harbor Disposal Well No.1 Permit

Scale: See Bar Scale	Date: October 2009
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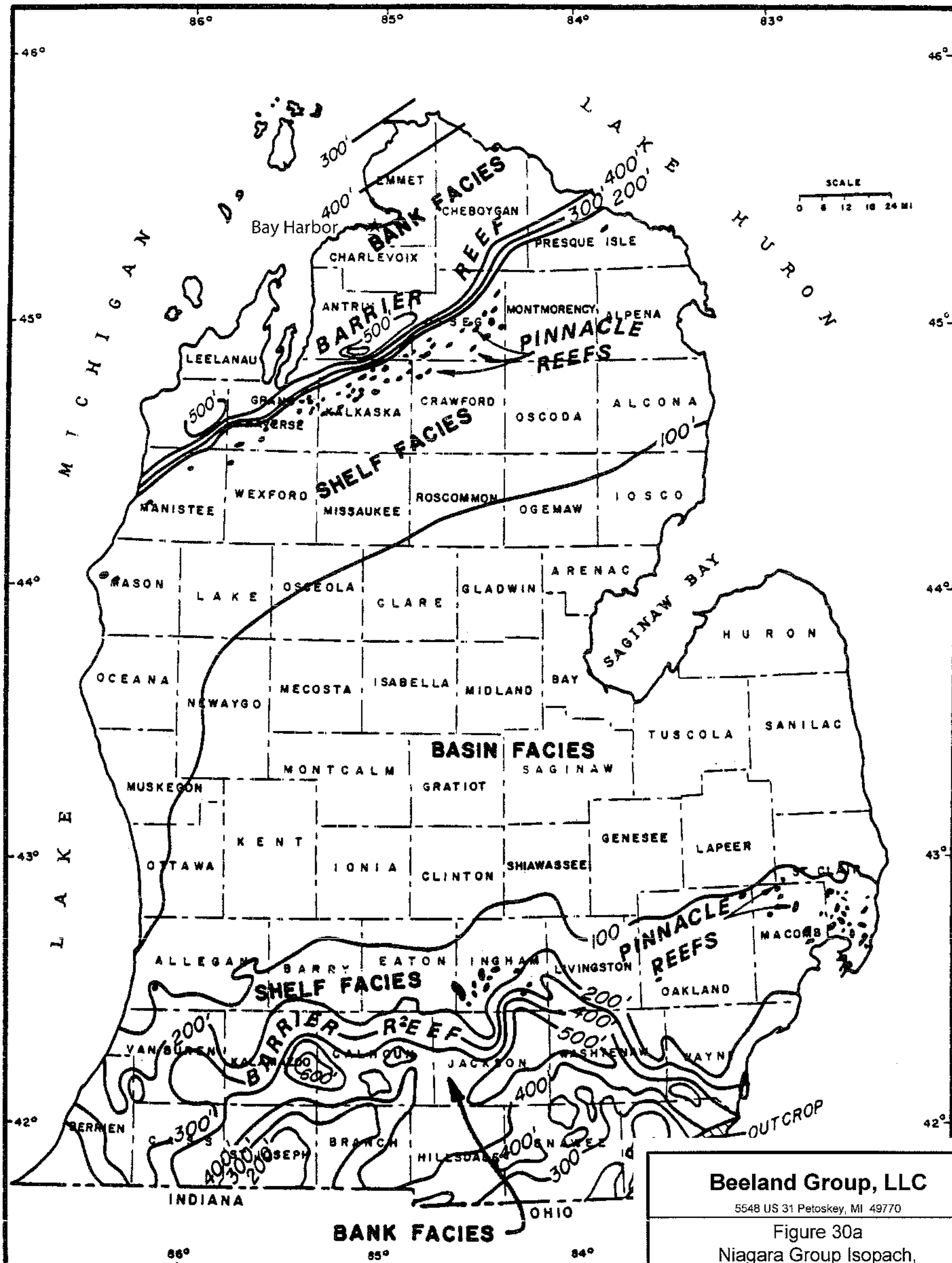

After: Mesolella, 1974, as presented in WMU, 1981

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Figure 30a
Niagara Group Isopach,
Michigan Basin

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Scale: See Bar Scale	Date: October 2009
BH_MDEQ_Fig 30a.ai	By: JLM / Checked: CW

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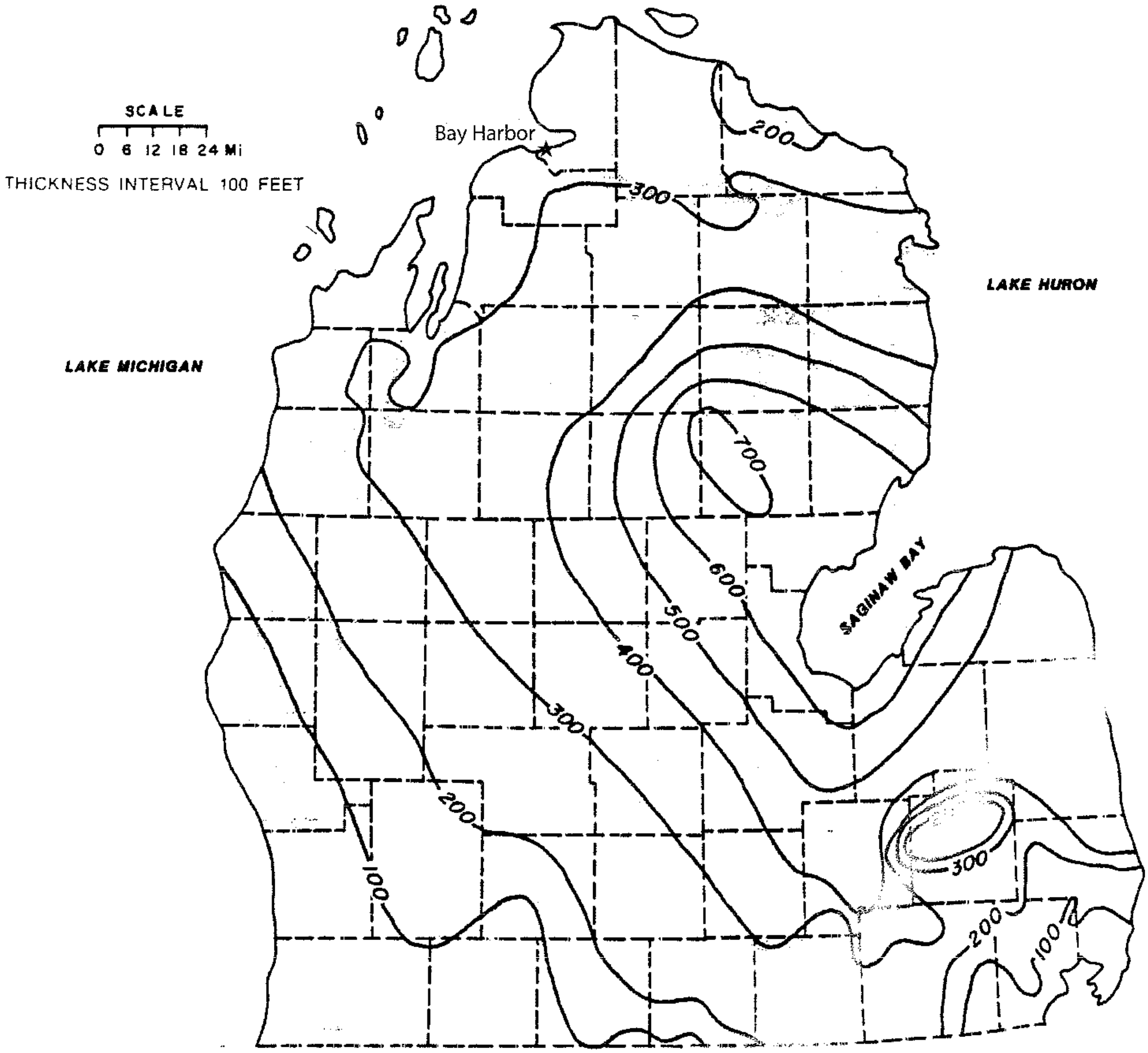

After: Dali, 1975, as presented in WMU, 1981

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Figure 30b
Salina / Bass Islands Group Isopach, Michigan Basin

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Scale: See Bar Scale	Date: October 2009	
BH_MDEQ_Fig 30b.ai	By: JLM	Checked: CW

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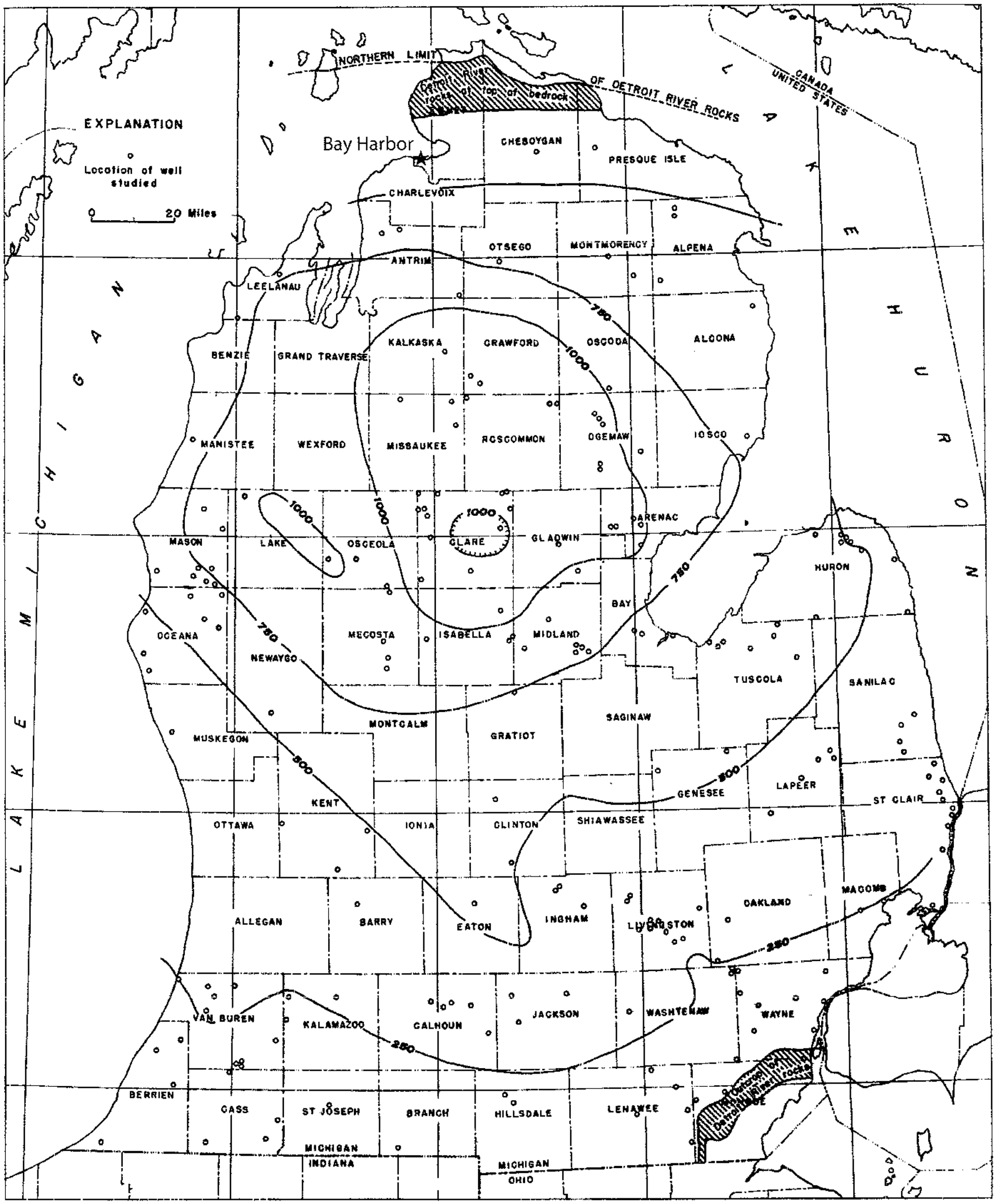

After: Landers, 1951

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Figure 30c

Detroit River Group Lucas Member Isopach, Michigan Basin

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Scale: NTS	Date: October 2009	
BH_MDEQ_Fig 30c.ai	By: JLM	Checked: CW

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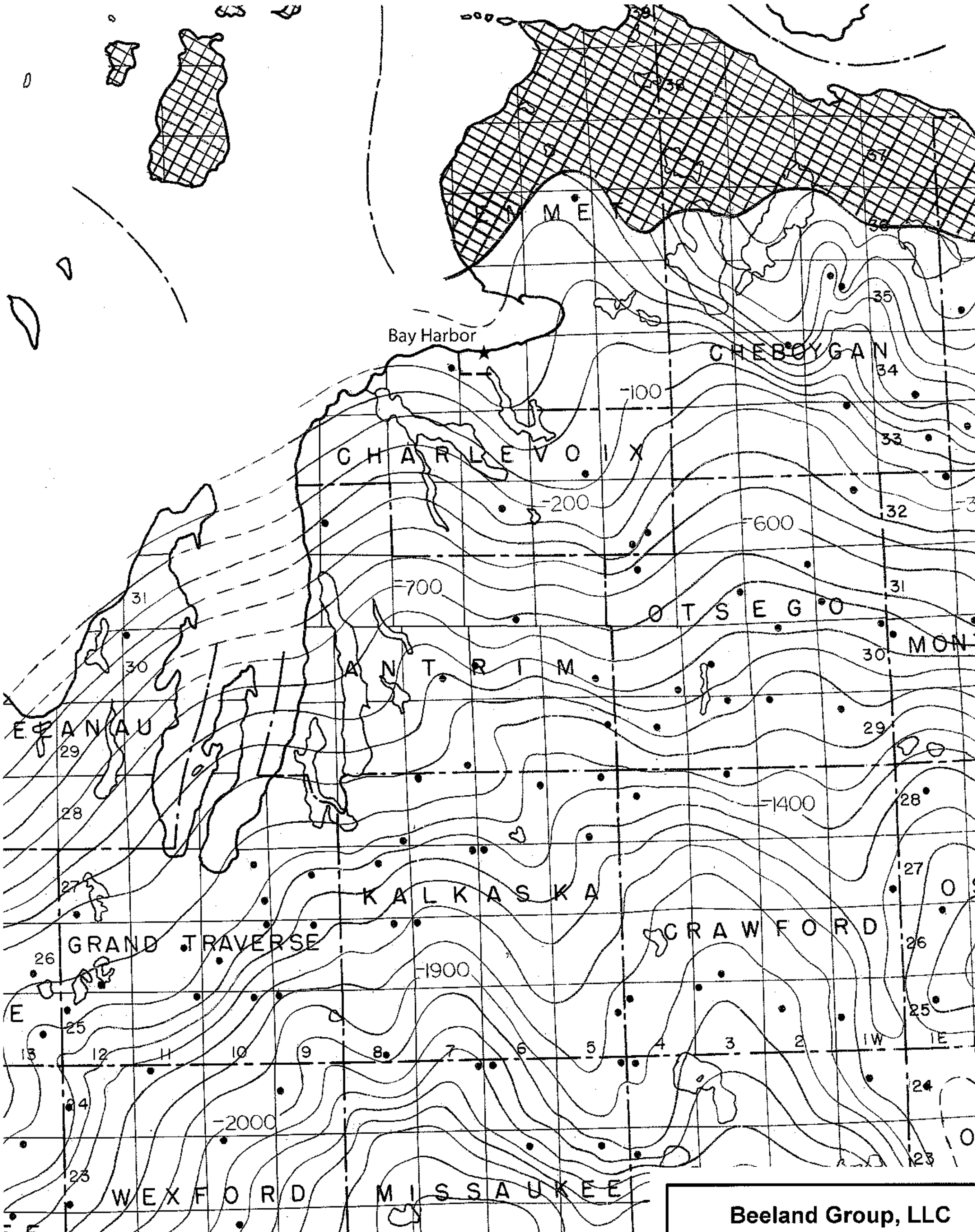

● CONTROL POINT

100 CONTOUR INTERVAL 100 FEET (sea level data)

DUNDEE FORMATION ABSENT

After: R. Milstein, 1985

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Figure 30d
Dundee Limestone
Structure Contour

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Scale: NTS	Date: October 2009	
BH_MDEQ_Fig 30d.ai	By: JLM	Checked: CW

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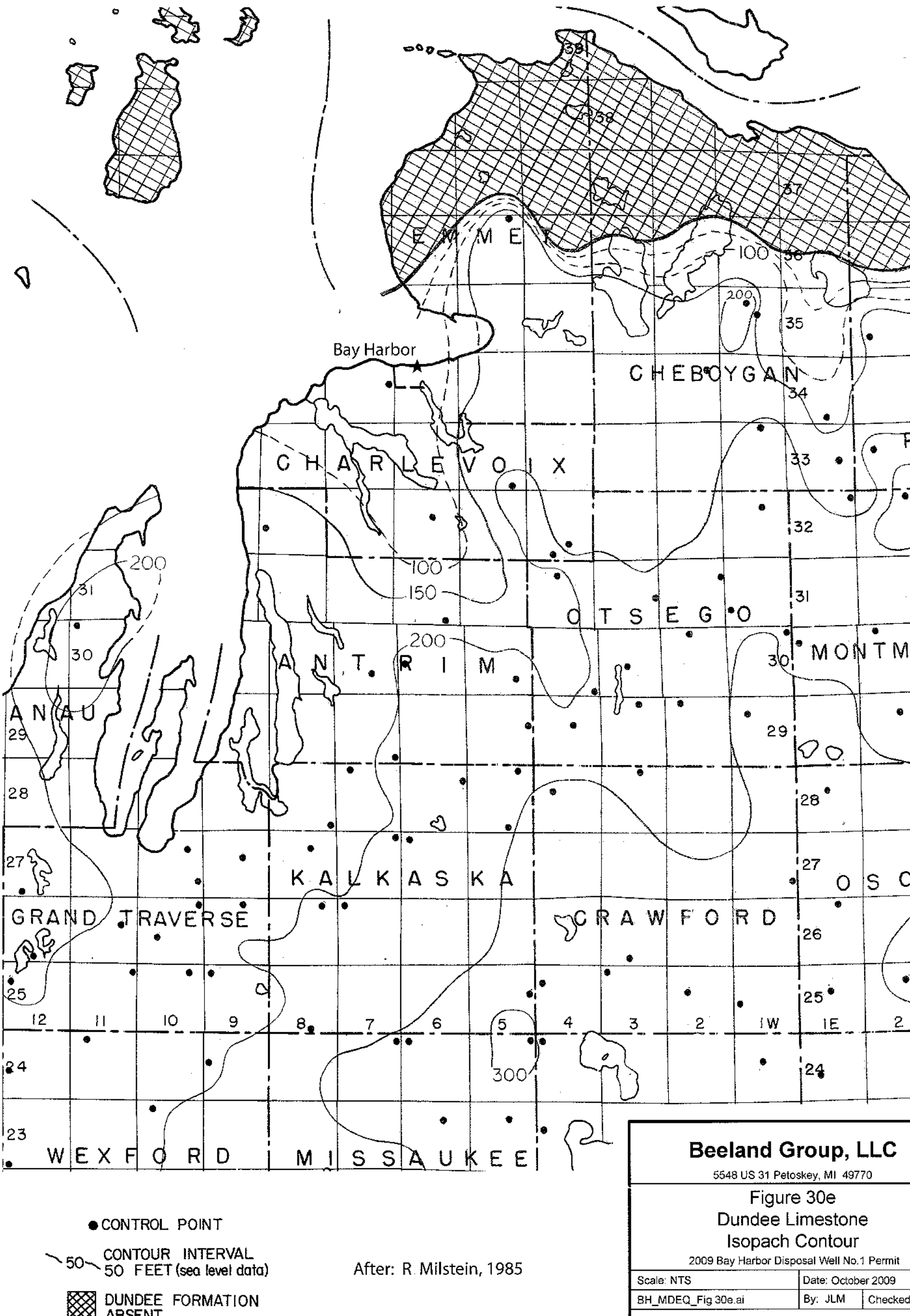

After: R. Milstein, 1985

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Figure 30e
Dundee Limestone
Isopach Contour

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Scale: NTS	Date: October 2009	
BH_MDEQ_Fig 30e.ai	By: JLM	Checked: CW

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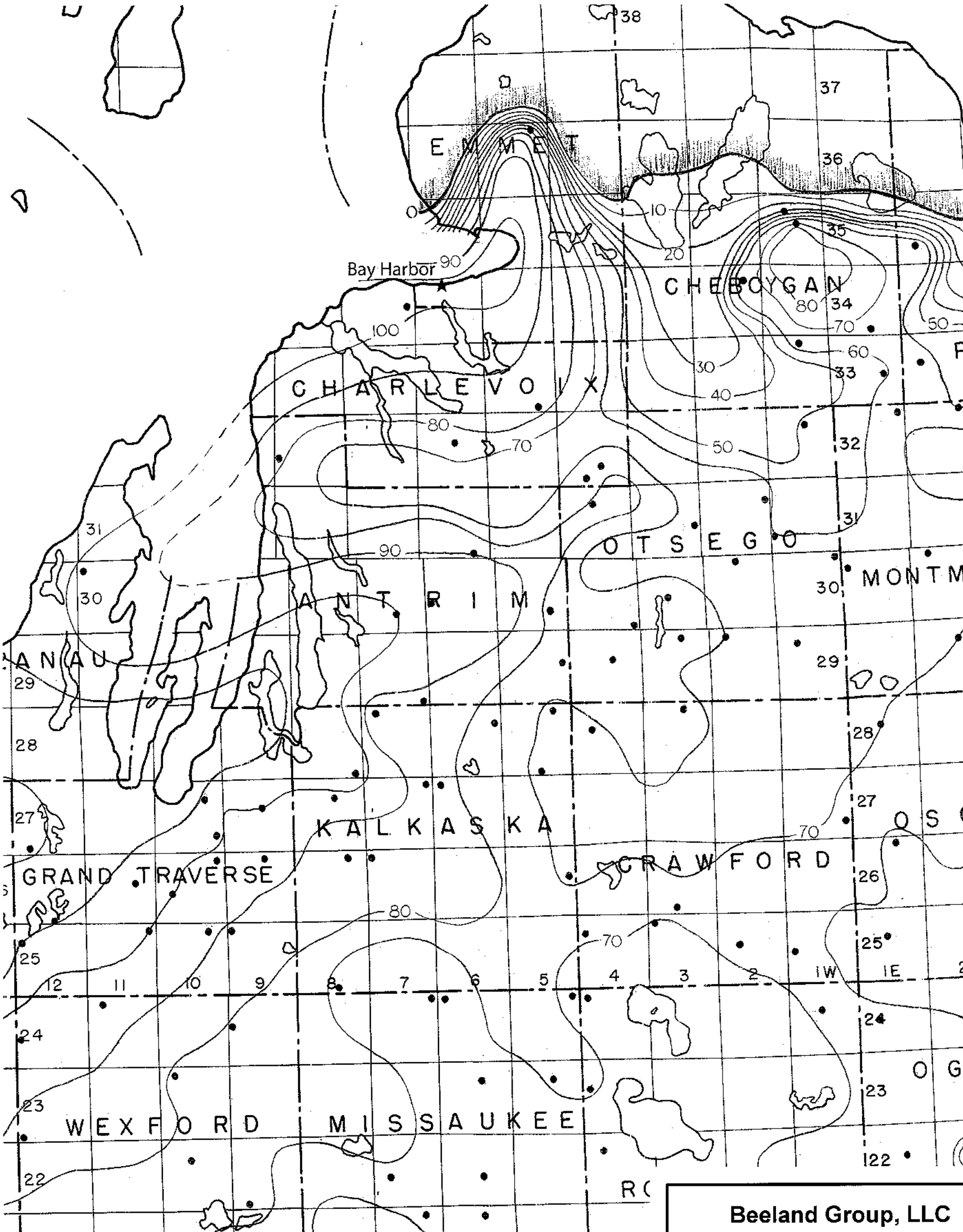

After: R. Milstein, 1985

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Figure 30f
Bell Shale
Isopach Contour

2009 Bay Harbor Disposal Well No.1 Permit

Scale: NTS	Date: October 2009	
BH_MDEQ_Fig 30f.ai	By: JLM	Checked: CW

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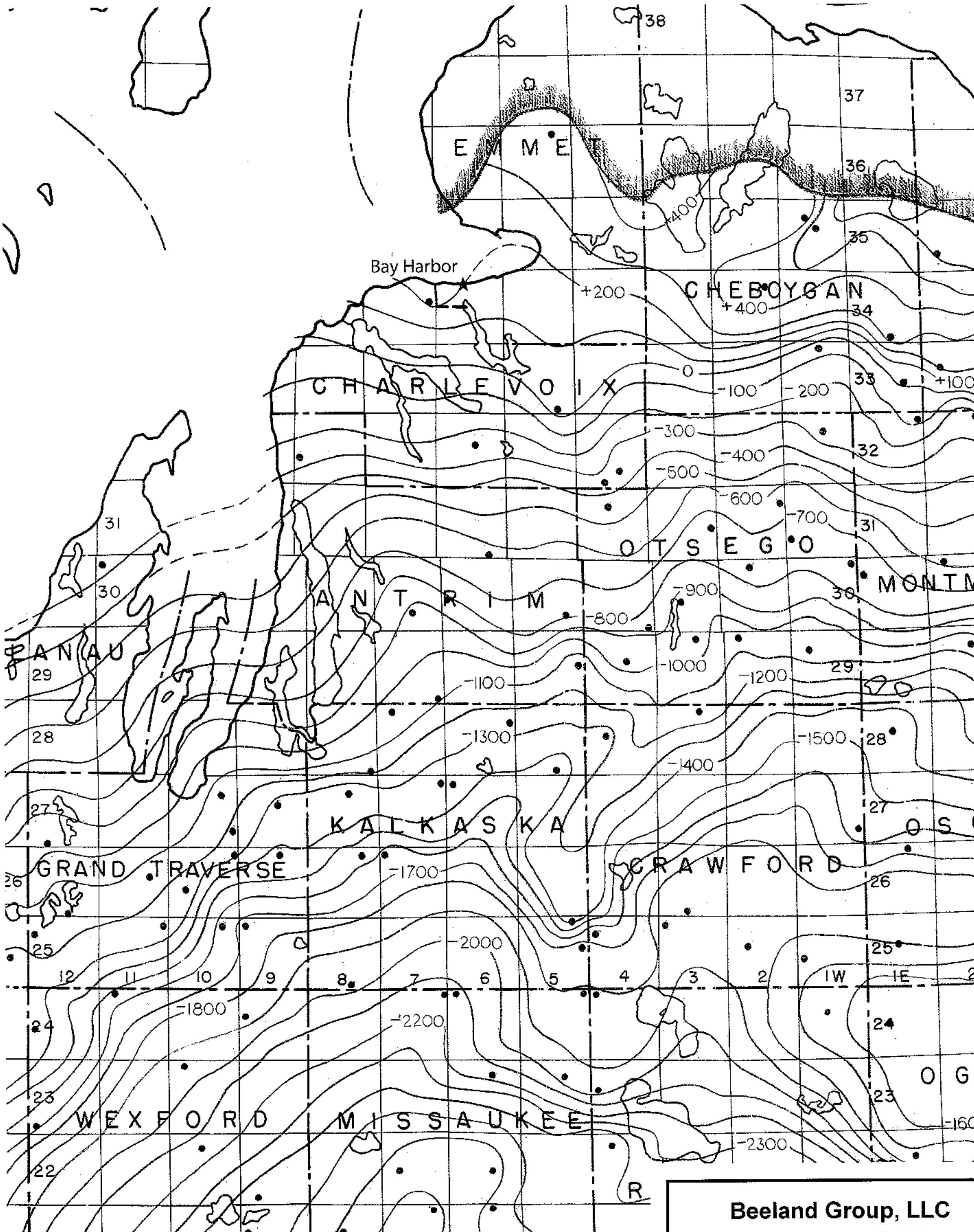

● CONTROL POINT

~100~ CONTOUR INTERVAL 100 FEET (sea level data)

BELL SHALE FORMATION ABSENT

After: R Milstein, 1985

Beeland Group, LLC

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Figure 30g
Bell Shale
Structure Contour

2009 Bay Harbor Disposal Well No.1 Permit

Scale: NTS	Date: October 2009	
BH_MDEQ_Fig 30g.ai	By: JLM	Checked: CW

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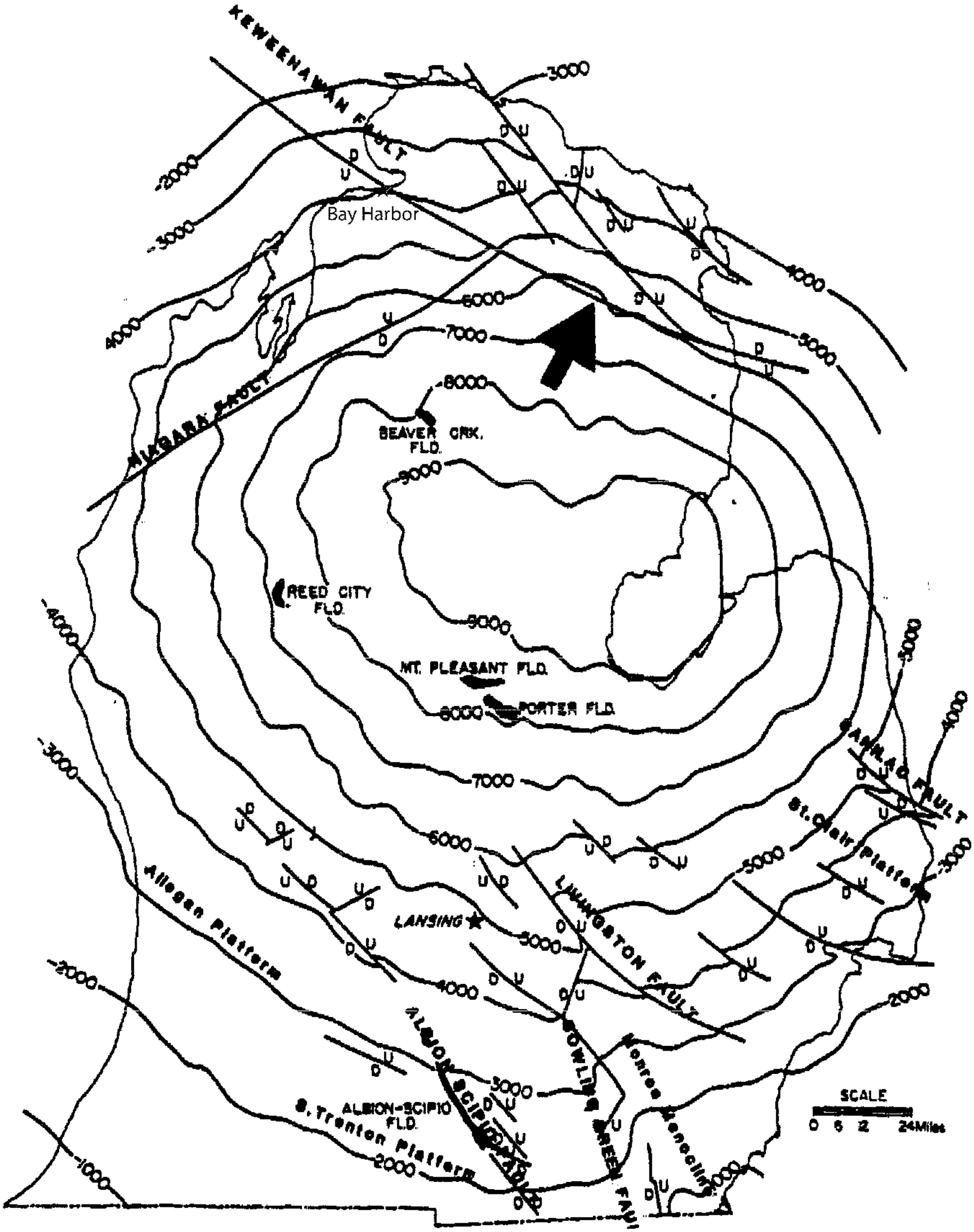

C.I. = 1,000′

After: D. Buthman, 1986, as presented in Wood and Harrison, 2002

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Figure 31
Basement Structural Features
in Northwestern Michigan

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Scale: See Bar Scale	Date: October 2009	
BH_MDEQ_Fig 31.ai	By: JLM	Checked: CW

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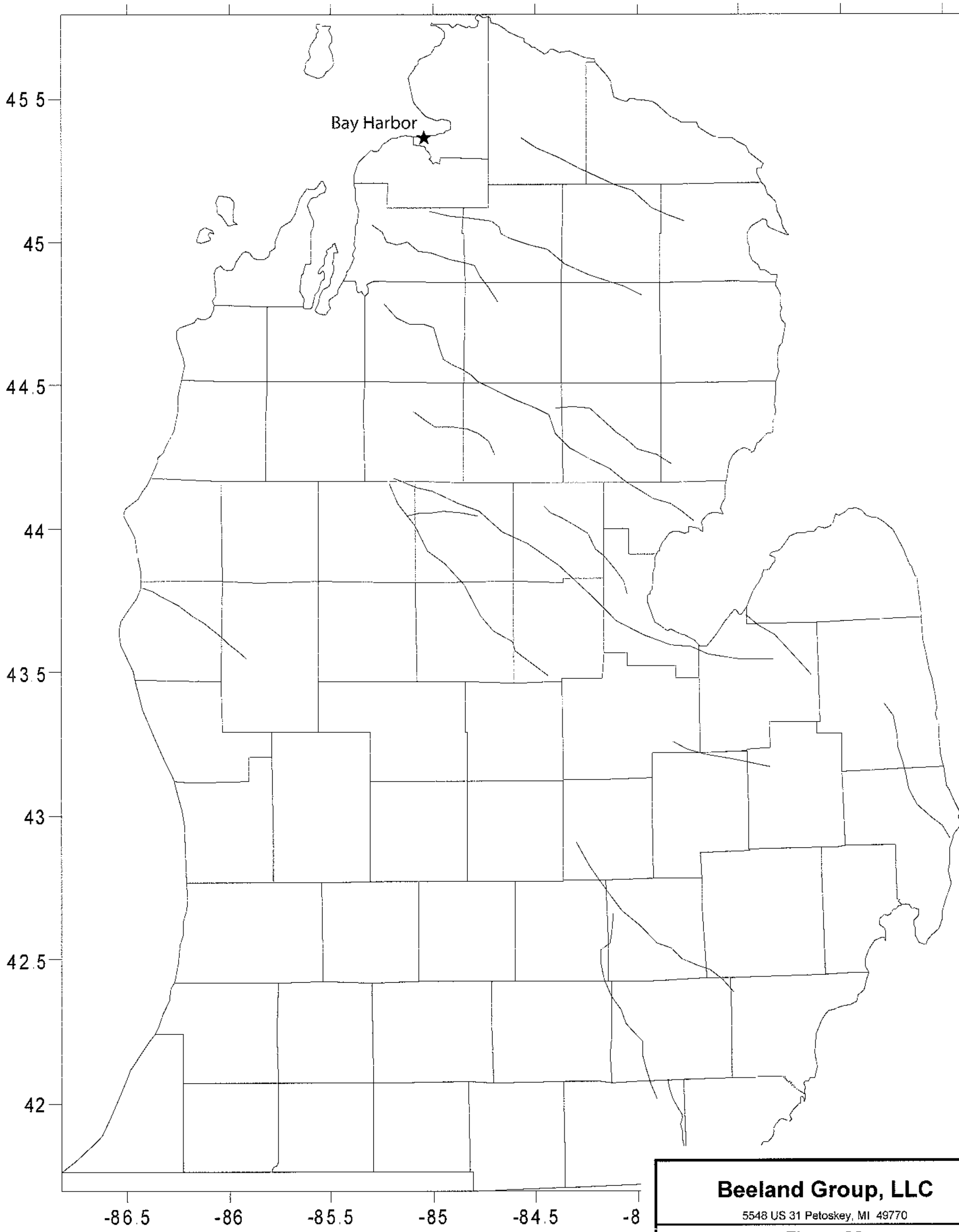

From: Wood and Harrison, 2002

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Figure 32
Dundee Lineaments,
Michigan Basin

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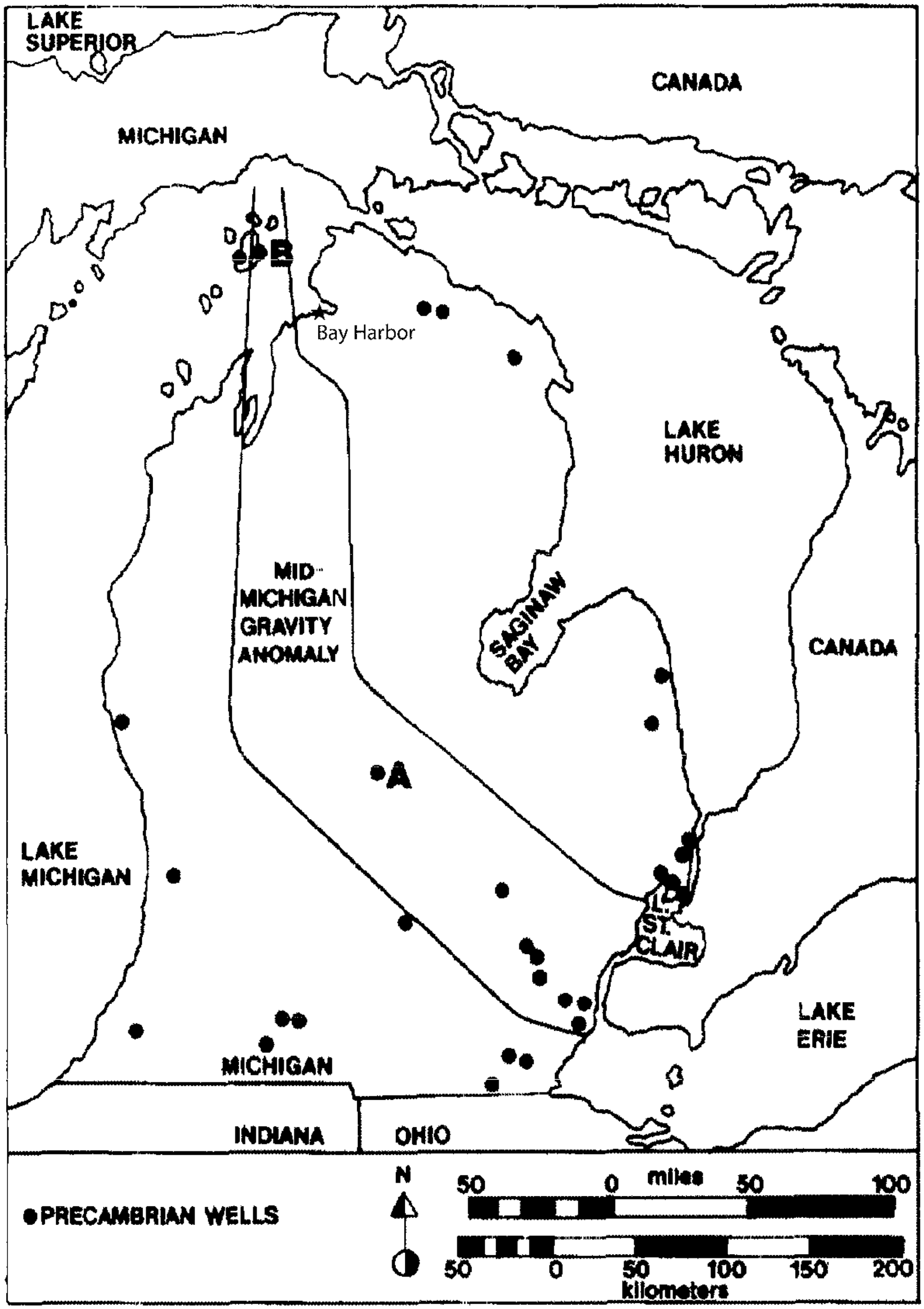

From: Catacosinos, 1981

Beeland Group, LLC

5548 US 31 Petoskey, MI 49770

Figure 33
Keweenanwan Rift and Related Basement Faults, Michigan Basin

2009 Bay Harbor Disposal Well No.1 Permit

Scale: See Bar Scale	Date: October 2009	
BH_MDEQ_Fig 33.ai	By: JLM	Checked: CW

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B.9 Chemical, physical and bacteriological characterizations of the waste stream before and after treatment and/or filtration. Include a characterization of the compatibility of the injectate with the injection zone and the fluid in the injection zone along with a characterization of the potential for multiple waste streams to react in the well bore or in the injection zone.

Injectate Characteristics

The proposed injectate is non-hazardous waste from a groundwater remediation project that is being generated near the proposed Bay Harbor disposal well site. Fluid from the remediation project will be sampled on a quarterly basis as specified in the attached Waste Analysis Plan (see Attachment B). Typical injectate composition for the remediation project fluids with regard to chemical and physical characteristics is presented in Tables 7A and 7B. Historically, fluids from this remediation project have been managed as non-hazardous via both injection into an offsite non-hazardous disposal well and via surface discharge through a POTW after treatment. Fluids typically contain various levels of total dissolved solids that is expected to range from 2,500 mg/l to 25,000 mg/l TDS. As noted in the following tables, only limited suspended solids have historically been encountered. Specific gravity is expected to range from 1.00 to 1.05, and pH is typically expected to range from approximately 7.0 to 10.0.

TABLE 7A EXAMPLE ANALYSIS OF INJECTATE FROM BAY HARBOR, MICHIGAN REMEDIATION, 2004

Parameter	Units	Results	Method	Date
Oxidation Reduction Potential	MV	296	Field	9/28/2004
PH	s.u.	7.42	Field	9/28/2004
Temperature	°C	19.1	Field	9/28/2004
Alkalinity-Phenolphthalein	mg/L	0	310.1	9/30/2004
Alkalinity-Total	mg/L	1,620	310.1	9/30/2004
Carbonate Alkalinity	mg/L	0	Calc.	9/30/2004
Bicarbonate Alkalinity	mg/L	1,620	Calc.	9/30/2004
Hydroxide Alkalinity	mg/L	0	Calc.	9/30/2004
Total Organic Carbon	mg/L	260	415.1	10/5/2004
Total Inorganic Carbon	mg/L	88	415.1	10/5/2004
Total Dissolved Solids	mg/L	32,800	160.1	9/29/2004
Total Suspended Solids	mg/L	123	160.2	9/29/2004
Biochemical Oxygen Demand	mg/L	*	405.1	10/8/2004
Chemical Oxygen Demand	mg/L	992	410.1	9/30/2004
Total Phosphorus	mg/L	1.4	365.2	9/30/2004
Phosphate, Orhto	mg/L	< 1	300	9/29/2004

Parameter	Units	Results	Method	Date
Nitrate-Nitrogen	mg/L	0.97	300	9/29/2004
Nitrite-Nitrogen	mg/L	0.74	300	9/29/2004
Ammonia-Nitrogen	mg/L	8.5	350.1	10/1/2004
Total Kjeldahl Nitrogen	mg/L	29	351.2	10/1/2004
Aluminum	mg/L	19.8	6020	10/3/2004
Antimony	mg/L	< 0.05	6020	10/3/2004
Arsenic	mg/L	0.237	6020	10/3/2004
Barium	mg/L	0.017	6020	10/3/2004
Beryllium	mg/L	< 0.005	6020	10/3/2004
Cadmium	mg/L	< 0.001	6020	10/3/2004
Chromium, Total	mg/L	0.029	6020	10/3/2004
Cobalt	mg/L	< 0.015	6020	10/3/2004
Copper	mg/L	0.024	6020	10/3/2004
Iron	mg/L	1.42	6020	10/3/2004
Lead	mg/L	< 0.001	6020	10/3/2004
Mercury	mg/L	0.0008	245.1	10/20/2004
Manganese	mg/L	0.088	6020	10/3/2004
Nickel	mg/L	0.223	6020	10/3/2004
Selenium	mg/L	0.063	6020	10/3/2004
Silver	mg/L	0.0005	6020	10/3/2004
Strontium	mg/L	0.034	6020	10/3/2004
Zinc	mg/L	0.019	6020	10/3/2004
Silica, Reactive as SiO2	mg/L	16.8	370.1	10/4/2004
Total Silicon as SiO2	mg/L	66.3	6020	10/2/2004
Calcium	mg/L	12.1	6020	10/3/2004
Magnesium	mg/L	< 0.5	6020	10/3/2004
Potassium	mg/L	13,800	6020	10/3/2004
Sodium	mg/L	889	6020	10/3/2004
Bromide	mg/L	15.2	300	9/29/2004
Chloride	mg/L	1,730	300	9/29/2004
Fluoride	mg/L	18.1	300	9/29/2004
Sulfide	mg/L	1.29	376.2	10/5/2004
Sulfate	mg/L	14,500	300	9/29/2004

TABLE 7B. EXAMPLE ANALYSES OF INJECTATE FROM BAY HARBOR, MICHIGAN REMEDIATION, 2006

Location	FRAC TANK	FRAC TANK	FRAC TANK	FRAC TANK	FRAC TANK
Date	4/26/2006	5/25/2006	6/2/2006	6/9/2006	6/15/2006
General Parameters (ug/L unless noted)					
Alkalinity, total	350000	310000	380000	380000	340000
Chloride	350000	310000	330000	320000	350000
Hardness, total	150000	110000	130000	92000	120000
Nitrogen Nitrate	560	410	390	59 *	190
Nitrogen total kjeldahl	4600	3900	4300	3900	4600
Nitrogen, ammonia as N	1100	960	1100	1000	1200
Phosphate, Ortho	48.0	<40.0 *	84.0 *	38	60
Phosphorus total	203	164	240	168	200
Solids, total dissolved	5710000	4800000	5220000	5120000	5540000
Solids, total suspended	6000	10000	17000	12000	11000
Sulfate	2300000	1900000	2200000	2100000	2300000
pH (standard units)	7.7 *	7.5 *	8.2 *	8.0 *	7.5 *
Specific Conductance (umhos@ 25oC)	7512	6569	6910	6990	7526
Carbon, total organic	35000	25000	28000	25000	27000
Carbon, total organic, unpreserved	54000	46000	46000	43000	48000
Metals (ug/L)					
Aluminum	2700	1400	6300	1500	1700
Antimony	<2.0	<2.0	8.4	<2.0	<2.0
Arsenic	27	21	30	20	21
Barium	<100	<100	<100	<100	<100
Beryllium	<1.0 *	<1.0	<1.0	<1.0	<1.0
Cadmium	<1.0	<1.0	<1.0 *	<1.0	<1.0
Calcium	44000	23000	27000	21000	23000
Chromium	12	<10	32	<10	<10
Copper	18	19	37	16	16
Iron	2300	1500	8500	1400	1600
Lead	<3.0 *	<3.0	5.5	<3.0	<3.0
Magnesium	12000	8100	11000	8500	8500
Manganese	<50	<50	94	<50	<50
Mercury	0.0726	0.0580	0.0963	0.062	0.0584
Nickel	54	41	54	39	39
Potassium	2200000 *	1800000	1900000	2100000	2200000
Selenium	8.4 *	8.4 *	17	14	9.3 *
Silicon	9200 *	8000	14000	9100	8000
Silver	0.21	<0.20	0.31	<0.20	<0.20
Sodium	190000 *	140000	150000	160000	170000
Strontium	<1000	<1000	<1000	<1000	<1000
Thallium	<2.0 *	<2.0	<2.0	<2.0	<2.0
Vanadium	38	36	51	35	34
Zinc	<50 *	<50	52	<50	<50

Operation as a dedicated industrial disposal well for fluids generated from the Bay Harbor remediation project will initially result in similar waste fluids being mixed in the disposal reservoir with fresh water testing and buffer fluids, then with the native Mt. Simon brines. As the operation continues, contact between most recently injected fluids and native brines will decrease as the mixing zone expands Since the Bay Harbor well will be dedicated to a single waste source (Bay Harbor remediation project fluids), incompatibilities between multiple waste streams will not be a concern. Successful Class I waste injection into the Mt. Simon has taken place in various locations in Michigan.

If compatibility issues are encountered due to injection of the Bay Harbor remediation fluids, they would be expected to primarily be associated with the injection or generation of particulate matter that could lead to decreases in flow capacity. Bacterial issues do not appear to be overly problematic, but due to the composition of the waste stream periodic biocide treatments may be instituted to prevent the establishment of bacterial plugging issues Such solids, compatibility or bacterial issues, if they do occur, would be an operations issue that could be managed, in part, via additional pretreatment. To sustain rates if reduced capacity is experienced, periodic stimulations may be required. At this time, only neutralized, relatively low suspended solids wastes from the Bay Harbor facility will be accepted for injection If additional solid loading becomes an issue, further filtration will be installed to minimize the potential for wellbore plugging.

B.10 Information to characterize the proposed injection zone, including:

- **A. The geological name of the stratum or strata making up the injection zone and the top and bottom depths of the injection zone.**
- **B. An isopach map showing thickness and areal extent of the injection zone**
- **C. Lithology, grain mineralogy and matrix cementing of the injection zone.**
- **D. Effective porosity of the injection zone including the method of determination.**
- **E. Vertical and horizontal permeability of the injection zone and the method used to determine permeability. Horizontal and vertical variations in permeability expected within the area of influence.**
- **F. The occurrence and extent of natural fractures and/or solution features within the area of influence.**
- **G. Chemical and physical characteristics of the fluids contained in the injection zone and fluid saturations.**
- **H. The anticipated bottom hole temperature and pressure of the injection zone and whether these quantities have been affected by past fluid injection or withdrawal.**
- **I. Formation fracture pressure, the method used to determine fracture pressure and the expected direction of fracture propagation.**
- **J. The vertical distance between the top of the injection zone from the base of the lowest fresh water strata.**
- **K. Other information the applicant believes will characterize the injection zone.**

Items A-C is addressed in Section B.7, above. Items D-K will be verified during the drilling and testing of the injector. Literature data available to characterize the formations has been cited in previous sections

As indicated in Section B.7 above, the injection zone is to be defined as the Cambrian sequence wherein the Munising/Mt. Simon are the injection interval and the Prairie du Chien-Trenton sequence is the arrestment interval. It is noted that the Mt. Simon is the primary injection target, but it is possible that other Cambrian units may accept fluid, so the entire Cambrian section has been identified as the injection interval. The middle-late Ordovician Collingswood and Utica Shales are the lowermost confining zones. The Cambrian occurs about 6,010 feet BGL and the Mt. Simon is about 100 to over 400 feet thick at the Bay Harbor Disposal Well No.1 location. This thickness will be confirmed during well installation and testing. An isopach map of the Mt. Simon, showing areal extent is presented as Figure 21 (Section B.8) Cambrian units as a whole, including the Mt. Simon, are described as being composed of sandstones of varying thickness and porosity and it should again be noted that the while the proposed injection interval includes the entire Cambrian sequence, although the Mt. Simon is the primary target injection zone. The Mt. Simon is described as a subrounded to rounded quartizitic sandstone that can be generally coarse grained, and is pin/red in color. The Mt. Simon exhibits porosities that vary from 4-20% on a regional scale, and online MIDCARB data indicate that the Bay Harbor area occurs in a location with relatively low Mt. Simon porosity (5% or less), which is based on mapped relationships between depth and porosity development in this formation. Horizontal permeability of the injection interval is unknown, but is conservatively estimated to be approximately 10 md. The occurrence and extent of fracturing specific to the disposal well location will be assessed through wireline logging of the well. Likewise, formation fluid information will be obtained through sampling and analysis at the time of drilling, although the unit is expected to exhibit a TDS that is significatnly greater than 10,000 ppm based on other distant Mt. Simon well samples from Michigan. The anticipated downhole temperature is estimated as approximately 142.5° F based on a temperature of 45°F below the seasonal effect and a temperature gradient of 0.013° / ft of depth and a total depth of 7,500 feet; downhole temperature will be verified after drilling. Formation fracture pressure is estimated as a minimum of 2,404 psi at 6,010 feet BGL (top of the potential Injection Zone) See Section B.11 for additional information The top of the injection zone is over 5,000 feet below the base of the lowest fresh water aquifer; the top of the Mt Simon is projected to occur at about 7,000 ft BGS, while the base of the lowermost aquifer is projected to occur about 540 to 2,000 feet BGS (Traverse Formation Aquifer).

B.11 Information to characterize the proposed confining zone, including:

- **A. The geological name of the stratum or strata making up the confining zone and the top and bottom depths of the confining zone.**
- **B. An isopach map showing thickness and areal extent of the confining zone**
- **C. Lithology, grain mineralogy and matrix cementing of the confining zone.**
- **D. Effective porosity of the confining zone including the method of determination.**
- **E. Vertical and horizontal permeability of the confining zone and the method used to determine permeability. Horizontal and vertical variations in permeability expected within the area of influence.**
- **F. The occurrence and extent of natural fractures and/or solution features within the area of influence.**
- **G. Chemical and physical characteristics of the fluids contained in the confining zone and fluid saturations.**
- **H. Formation fracture pressure, the method used to determine fracture pressure and the expected direction of fracture propagation.**
- **I. The vertical distance between the top of the confining zone from the base of the lowest fresh water strata.**
- **J. Other information the applicant believes will characterize the confining zone.**

Items A-C are addressed in Section B.7, above. Items D-J will be verified through the drilling and testing plan previously presented in this application. The confining zone includes all rock units from the base of the Collingswood Shale, along with the Utica Shale, up section through the Niagaran and Salina Groups, noting that the base of the USDW will be determined during well installation. Isopach maps of intervals above the Cambrian are presented in Figures 30a-30g, and Figures 13 and 14. The Collingswood Shale is projected to be a 20 feet thick shale at the Bay Harbor area and is organic and phosphate rich. The Utica Shale is about 190 feet thick below the Bay Harbor area according to regional maps (Figure 27). WMU (1981) states that the Utica is "far too impermeable for use as an injection zone" and that "the very low permeability of this rather thick shale coupled with the fact that it forms the seal on known hydrocarbon traps indicates that it is an excellent confining layer".

Effective porosities of these zones are estimated as between 2 and 20% based on general literature values for shales and carbonates. The vertical and horizontal permeability of the shale-rich portions of the confining zone (e.g. Utica Shale) are estimated as being substantially less than 0.1 md. Formations included as part of the confining zone are mapped as being laterally continuous in the Disposal Well No. 1 area, and are not expected to exhibit variations in effective permeability within the area of influence that are of concern for siting the injection well. The occurrence and extent of natural fractures and/or solution features within the area of influence will be assessed through wireline logging during drilling, as will the local porosity and permeability characteristics of the confining zone.

B.12 Information demonstrating injection of liquids into the proposed zone will not exceed the fracture pressure gradient and information showing injection into the proposed geological strata will not initiate fractures through the confining zone. Information showing the anticipated dispersion, diffusion and/or displacement of injected fluids and behavior of transient pressure gradients in the injection zone during and following injection.

Maximum Injection Pressure

The well has been designed for operation under positive pressure to be supplied by using an injection pump. Although no site-specific data are available, Region 5 USEPA Guidance #7 includes a default value of 0.57 psi/ft for the fracture gradient of the Mt. Simon. If injection fluid is assumed to be comprised of brine with a conservatively estimated maximum specific gravity of 1.10 that fills the tubing from the surface to a depth of 6,010 feet, a maximum wellhead injection pressure of 563 psi is calculated based on this Region 5 assigned gradient. No allowances for tubing friction are included in this calculation Note that the average specific gravity is expected to be in the 1.01 to 1.05 range

Estimates of general conditions have been used with Eaton's formula to prepare a worst-case estimate of fracture pressure. This formula is widely referenced and discussion can be found regarding the formulation on page 291 of "Applied Drilling Engineering," Bourgoyne, A.T et al, SPE, 1991. The pressure (P_{ff}) necessary to initiate a fracture is given as:

$$P_{ff} = P_r + \sigma_{min}$$

where: P_r is reservoir pore pressure (2,404 psi at 6,010 feet BGL assuming a 0.4 psi/ft original reservoir pressure gradient) and σ_{min} is horizontal matrix stress defined as:

$$\sigma_{min} = \upsilon/(1-\upsilon)\ (+\sigma_{ob} - P_r)$$

where: υ = Poisson's ratio estimated as 0.4 for a variable sandstone/shale system in-situ and σ_{ob} estimated as depth times a minimum overburden gradient of 0.9 psi/ft. Historically, an overburden gradient of 1.0 psi/ft has been applied for oil and gas reservoirs on land (Bourgoyne, et al, 1991). Based on this overburden gradient, at 6,010 feet BGL (approximate top of the Injection Interval at the Beeland Well), the calculated overburden pressure would be 5,409 psi

Substituting 0.4 for Poisson's ratio and estimated original reservoir pressure of 2,404 psi, $P_{ff} = P_r + \sigma_{min}$ or $P_{ff} = 2404 + 2003 = 4{,}407$ psi. The maximum pressure exerted by injectate at the base of the casing (6,010 feet BGL) is not likely to exceed 2,863 psi, and when adding the requested wellhead injection pressure of 563 psi yields a value of 3,426 psi. This pressure is still well below the calculated P_{ff} of 4,407 psi with friction losses neglected, thus offering a significant safety margin. An injection pressure of 1,544 psi would be acceptable (with a specific gravity injectate of 1.1) based on these calculations. A maximum pressure of 563 psi has been requested.

If necessary, subsequent testing may be conducted in the future to justify the use of pressures above 563 psi at the wellhead during future disposal operations.

Average Rates, Volumes and Pressures

The range of injection rates and pressures is expected to fluctuate depending on the demands of the groundwater remediation project along with variables related to the well and the reservoir conditions. Injection rates are projected to average between 50 and 200 gpm based on continuous operations. However, injection may occur in a periodic or "batch mode" depending on demand.

Average injection pressures during active operations are expected to range from approximately 450 to 550 psi depending on the history of recent well capacity demands and the condition of the well and the injection reservoir

Annulus Pressure

Annulus pressure will be maintained at a minimum of 100 psi above injection pressure, even during shutdown, except during the course of workovers and/or maintenance operations.

Nature of Annulus Fluid

In the proposed Bay Harbor Well, the annulus space between the injection tubing and the well protection casing will be sealed and filled with fresh water containing a corrosion inhibitor, an oxygen scavenger and a biocide. Annulus fluids will include Baker Petrolite CRW0037F or Unichem Technihib 366W corrosion inhibitors and bactericides, CRW 132 oxygen scavenger A-303 corrosion inhibitor, Knockout 50 oxygen scavenger, and Bacban 3 Biocides or suitable equivalents. No permit condition regarding specific brands or fluid additives are requested at this time.

Monitoring the pressure changes in the sealed annulus space is a means of verifying the continued mechanical integrity of the well. It must be non-corrosive, not subject to biologic degradation, and preferably non-freezing at winter temperatures. At this time, methanol, diesel, heat tracing, and/or a wellhouse heater may be used at the wellhead and in the annulus tank system to manage any potential for weather related problems.

The well is to be operated, and operating data reported, according to the following requirements:

TABLE 8 OPERATING, MONITORING AND REPORTING REQUIREMENTS BEELAND GROUP, LLC BAY HARBOR DISPOSAL WELL NO. 1

Characteristic	Value	Minimum Monitoring Frequency	Minimum Reporting Frequency
Average Injection Rate	6,857 bpd max.	Continuous	Monthly
Instantaneous Injection Rate	5 bpm max.	Continuous	Monthly
Cumulative Volume	6,857 bpd max.	Continuous	Monthly
Max. Injection Pressure	563 psig	Continuous	Monthly
Ave. Injection Pressure	500 psig	Continuous	Monthly
Annulus Pressure	100 psig min.	Continuous	Monthly
Annulus/Tubing Pressure Differential	100 psig min.	Continuous	Monthly
Sight Glass Level	Visible	daily when operated	Monthly
Annulus Fluid Addition Or Removal	-	Daily	Monthly
Chemical Composition of Injected Fluids [1]	-	Quarterly	within 30 days of sampling
Physical Characteristics of Injected Fluids [1]	-	Quarterly	within 30 days of sampling

1 As specified in the Waste Analysis Plan, Attachment B.

Impact of Injection

Information showing the anticipated dispersion, diffusion and/or displacement of injected fluids and behavior of transient pressure gradients in the injection zone during and following injection.

There are no deep disposal wells of any type in the vicinity of Bay Harbor, so there are no historical operating data from surrounding injection wells in Emmet County that verify the Mt Simon has sufficient capacity to facilitate the proposed disposal operations. However, permeability and porosity is anticipated, and will be tested to verify capacity upon well installation. Until data are obtained from installation of the well, conservative estimates of formation properties have been assigned based on regional data and projected operational parameters, to generate an estimate of the fluid front for the Bay Harbor well. Standard equations for the volume of a porous cylinder can be used with the following parameters to generate an estimate for a simplistic piston-like displacement fluid front radius: 300-foot net thickness, 5 percent effective porosity, and 2,103,840,000 gallons of injectate estimated based on twenty years of continuous injection at a rate of 200 gpm. As an estimate for illustrative purposes, this calculation yields a 100 percent injected fluid front radial distance of approximately 2,443 feet from the well. It is noted that "continuous" injection rates are more likely to be less than 125 gpm based on historical operation of the groundwater remediation project. Although dispersion will play a role in spreading this plume over a slightly larger area, even a relatively large dispersivity combined with a low concentration of interest would likely yield a plume that reaches a radial distance of less than one mile from the well This is substantially smaller than the three-mile con-of-influence calculated for this site, and for which well locations were identified and evaluated. Additional evaluation of dispersion, diffusion and/or displacement of injected fluids and behavior of transient pressure gradients in the injection zone during and following injection will be conducted upon site-specific information becoming available from testing the well.

B.13 Proposed operating data including all of the following data:

A. The anticipated daily injection rates and pressures.
B. The types of fluids to be injected.
C. A plan for conducting mechanical integrity tests.

See Responses B 8 and B 11 for information pertaining to daily injection rates/pressure and the types of fluids to be injected Based on available data that will be revised when well-specific data becomes available, average injection rates of 125 gpm with injection pressures of 450 psi to 550 psi are anticipated Groundwater and related fluids from the Bay Harbor remediation project are characterized previously in this document, as are various well tests proposed for initial completion

In addition to continuous annulus pressure monitoring, periodic mechanical integrity demonstration for the well will be accomplished via approved test method(s) such as a temperature log, or radioactive tracer survey, or noise log, or oxygen activation log. Beeland Group, LLC will provide the MDEQ with a notice of Part II testing to allow the agency to witness data collection activities Although Beeland may utilize any acceptable method per MDEQ procedure approval, at this time it is proposed that temperature logging be utilized for future mechanical integrity testing. Temperature logging to be conducted as follows:

1 Conduct Differential Temperature Log.
   A. Shut-in well for stabilization (minimum of 24 hours) prior to running base temperature log.
   B. Rig-up temperature log and run base log from surface to total depth. Pull tool to surface and shut-in master valve.
   C. Rig down equipment and return the well to normal operations.

B.14 For a proposed disposal well to dispose of waste products into a zone that would likely constitute a producing oil or gas pool or natural brine pool, a list of all offset operators and certification that the person making application for a well has notified all offset operators of the person's intention by certified mail. If within 21 days after the mailing date an offset operator files a substantive objection with the supervisor, then the application shall not be granted without a hearing pursuant to part 12 of these rules. A hearing may also be scheduled by the supervisor to determine the need or desirability of granting permission for the proposed well.

Production from the Mt. Simon and the Munising Formation has not been identified in the counties surrounding the proposed well site. The closest Mt. Simon exploratory well is approximately 20 miles southeast of Bay Harbor Since the proposed injection zone is not a producing oil or gas pool or natural brine pool, a list of offset operators is not required

B.15 A proposed plugging and abandonment plan

The following is the proposed plan for plugging and abandonment of the proposed Beeland Group, LLC non-hazardous Bay Harbor Disposal Well No 1

1 Install a test gauge on the annulus to perform a static pressure test. Ensure that the annulus is fluid filled and that the well has been shut-in for a minimum of 24 hours Pressurize annulus to approximately 500 psig and isolate from the annulus system. Monitor annular pressure for one hour The test will be successful if the pressure change is less than 3 percent of the starting pressure.

2. Prepare well and location for plugging. Remove wellhouse, well monitoring equipment and wellhead injection piping

3. Move in and rig-up workover rig, mud pump, circulating pit and pipe racks as necessary. Flush well with approximately 200 bbl of brine.

4. Remove wellhead and release slips.

5 Release injection packer Displace annular fluid from well into injection formation by flushing with approximately 100 bbl of brine.

6 Pull and lay down the injection tubing and packer.

7. Run cement retainer to approximately 6,000 feet.

8. Pump approximately 247 sacks of Michigan equivalent Class A cement with 4 percent bentonite (14.1 ppg, 1.55 cf/sx yield and 20% excess) below cement retainer and into 6 ¼-inch openhole

9. Tag cement on top of retainer at approximately 6,000 feet.

10. Stage cement remainder of casing to surface in approximately 500 foot stages using the balanced plug method Pump approximately 832 sacks of Michigan equivalent Class A cement with 4 percent bentonite (14.1 ppg, 1.55 cf/sx yield)

11. Cut off wellhead approximately 3 feet BGL and weld cap with permanent marker on casing.

12 Rig down and move out pulling unit and equipment.

13. Submit required plugging records to USEPA and MDEQ.

Post-Closure Care Requirements

Beeland will provide notification of closure to USEPA, Region 5, the MDEQ and the local zoning authorities as required. Included with the notification will be information regarding the nature of the injected waste stream, identification of the depths of the injection and confining zones, well schematics and plugging records. Beeland will retain, for a period of three years following the well closure, records reflecting the nature, composition and volume of all injected fluids. At the discretion of the MDEQ and the director of USEPA, Region 5, Beeland will then deliver the records to the regulators at the conclusion of the retention period, or dispose of such records upon written approval

B.16 Identify the source or sources of proposed injected fluids. Identify if injected fluids will be considered hazardous or non-hazardous as defined by Part 111, Hazardous Waste Management, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA)

The Beeland Group, LLC is a privately owned Michigan LLC that is wholly owned by CMS Energy. The Beeland Group was organized to pursue the installation and operation of a well to manage non-hazardous groundwater remediation wastewater (including groundwater, surface water, and storm water) from the CMS Land Company Bay Harbor project The remediate project manages seepage created from rain, snow melt, irrigation water and groundwater that comes into contact with buried kiln dust that originated from Bay Harbor and East Park mining operations and cement manufacturing from approximately 1917 through 1980. The fluid is being intercepted to mitigate impacts on Lake Michigan water quality. Approval is being requested to install this well to inject non-hazardous fluids generated from the remediation of groundwater and surface water at the Bay Harbor, Michigan facility.

Historically, fluids from this remediation project have been managed as non-hazardous via both injection via Class I (Mineral Well) disposal facilities and surface discharge after treatment via a POTW Fluids typically have contained various levels of total dissolved solids and are expected to range from approximately 2,500 mg/l to 25,000 mg/l Specific gravity is expected to range from 1 00 to 1 05, and pH is typically expected to range from 7.0 to 10.0.

B.17 Whether the well is to be a multisource commercial hazardous waste disposal well.

The well will be operated as a single source well, not as a multisource commercial hazardous waste disposal well.

B.18 Additional information required for an application for a permit to drill and operate a storage well or to convert a previously drilled well to such a well:

For an application to drill storage well or to convert a previously drilled well to a storage well, also submit the following information in addition to that submitted in the previous section for a disposal well. In the previous sections instructions, replace the term 'disposal' with 'storage' and 'waste' with 'stored product.'

1. **The name and chemical formula of the product to be stored, and a characterization of the physical, chemical, and hazardous or toxic properties of the product.**
2. **The anticipated vertical and horizontal dimensions and volume of the completed underground storage cavity.**
3. **The anticipated operating life of the underground storage cavity.**
4. **The method to be used to create the underground storage cavity.**
5. **The name of the geological stratum in which the underground storage cavity will be created.**
6. **A schematic diagram of the well bore showing the proposed arrangement and specifications of the down hole well equipment.**
7. **If the underground storage cavity is to be formed by solution mining bedded salt, then all of the following information shall be included:**
8. **The plan for disposal of brine produced during solution mining of the underground storage cavity and for the operating life of the underground storage cavity.**
9. **The expected starting and ending dates of the solution mining.**
10. **The range of anticipated operating pressures of the underground storage cavity.**
11. **The anticipated range of operating injection pressure.**
12. **The proposed method of displacing stored product.**
13. **A plan for testing the mechanical integrity of the underground storage cavity as provided in R 299.2392 and R 299.2393.**

N/A. This application is not being submitted for a permit to drill and operate a storage well or to convert a previously drilled well to such a well.

B.19 Additional information required for an application for a permit to drill and operate a well for the production of artificial brine or to convert a previously drilled well to such a well:

For an application to drill and operate a brine well for production of artificial brine or to convert a previously drilled well to a well for production of artificial brine, submit in addition to the information in the first section, all of the following proposed information:

1. **If the well will be drilled into an existing cavern, the number of wells in the cavern, the present extent of the cavern, and the purpose of the proposed well.**
2. **The name of the geological stratum or strata to be mined, the top and bottom depths of the mined zone, the gross and net mineable thickness, and the mineral or minerals to be recovered by solution mining.**
3. **An isopach map showing thickness and areal extent of the strata to be mined.**
4. **A sketch showing the extent of the planned mine area.**
5. **The geological strata to be left in place for roof support.**
6. **A diagram showing the well bore with the proposed casing program and its relationship to the stratum or strata to be mined.**
7. **A plan for conducting subsidence monitoring as required in R 299.2407 or a rationale for not conducting subsidence monitoring.**

N/A This application is not being submitted for a permit to drill and operate a well for the production of artificial brine or to convert a previously drilled well to such a well.

A public hearing may be scheduled by the Supervisor of Mineral Wells to take public comment on the proposed well. If such a hearing is scheduled, the applicant will be responsible for the scheduling and preparation and publication of the notice.

Please collate the above documents into a set and mail the original and two copies of the application (total of 3 sets) plus 3 additional copies of form EQP 7200-1 to:

Department of Environmental Quality
Office of Geological Survey
P.O. Box 30256
Lansing, Michigan 48909

The above documents have been collated and appropriate numbers of document and form copies have been sent to the above address.