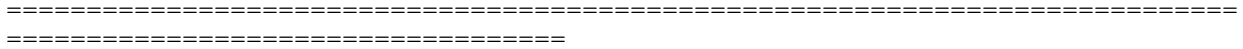


REVIEW OF THE
MINED LAND USE PLAN
CAYUGA MINE, CARGILL, INC.
Seneca and TompkIns Counties, New York

REPORT NO. 2499.4
FEBRUARY 2002

John T. Boyd Company
Mining and Geological Consultants



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Mining and Geological Consultants
February 7, 2002
File: 2499.4

New York State Department of Environmental Conservation
Division of Mineral Resources
625 Broadway – Third Floor
Albany, NY 12233-6500

Attention: Mr. C. Bruce McGranahan, Director Bureau of Resource
Management & Development

Subject: Review of the Mined Land Use Plan Cayuga Mine, Cargill, Inc.
Seneca and Tompkins Counties, New York

Gentlemen:

In accordance with the January 30, 2001, request of Mr. Steven M. Potter of the New York State Department of Environmental Conservation (NYSDEC), John T. Boyd Company (BOYD) has reviewed documents provided by Cargill, Inc. in support of their application to modify the existing Mined Land Reclamation Permit MLF #709-3-29-00S2 for the Cayuga Mine. The salt mine is located beneath Cayuga Lake in Seneca and Tompkins Counties as illustrated on Figure 1, following this text. Surface facilities for the mine are located on the eastern lakeshore near Lansing approximately 6 miles north of Ithaca.

Principal documents reviewed are the Mined Land Use Plan (MLUP) (Volume 1) and the Expanded Environmental Assessment (Volume 2). Other supporting documents are listed in the References section of this report (Appendix A).

Purpose of this review is to identify environmental risk issues as related to geotechnical conditions and mine design.

Conclusion

Based on available information provided by Cargill, it is BOYD's opinion the current design is adequate to provide stable mine

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conditions over the short- to medium-term (next 5 to 10 years) of operations. Areas requiring further investigation, study, or documentation in regard to long-term operations include:

- Disturbed salt zone near the western lakeshore scheduled for mining in the period 2016-2020. Earlier plans by Cargill reportedly avoided this area.
- Thinning solid bedrock strata above the mine level near the northern extent of the proposed mining area scheduled for mining after 2030.
- Design justification for the absence of main barrier pillars between main development entries and production panels.

Geologic Setting

Future mining proposed under the Mined Land Use Plan is a continuation and extension of present operations beneath Cayuga Lake within current and proposed mineral leases from the New York State Office of General Services. Lease boundaries coincide with lake boundaries so that all future mining is beneath the limits of the lake.

Depth of the lake over the planned extent of the mine varies from shoreline up to 700 ft at the proposed northern mineral lease boundary. Figure 2 illustrates the subsurface setting of the mine. Bedrock thickness above the mine onshore ranges up to about 2,850 ft and decreases to 800 ft beneath the lake at the proposed northern mineral boundary.

The study area is at the northern edge of the glacially eroded Appalachian Plateau characterized by a series of hills and valleys with average relief of around 850 ft. although relief up to 1,000 ft is common. The erosion resistant Onondaga Limestone that outcrops at the northern end of Cayuga Lake forms the Onondaga Escarpment, the division between the Appalachian Plateau and the flat plains of the Ontario Lowland.

The strata in the mine area dip gently southward at 0.5 to 1.0 degree, being controlled by the regional dip. The Firtree Point Anticline, a broad east-west trending fold whose axis passes just north of Portland Point, is associated with a small dome and faults located mostly above the level of the salt being mined.

Stratigraphy of the mine area is varied and requires some explanation of the site's geologic history to understand the relationship among the materials in and surrounding the mine.

The No. 6 Salt being produced at the Cayuga Mine is of Upper Silurian Age (slightly over 400 million years old). Figure 3 illustrates the stratigraphic framework of the study area. At the time of deposition, western and central New York and Pennsylvania were covered by the shallow Salina Sea that was separated from a shallow ocean to the west and south by the Niagaran Reefs and Banks. Salt was deposited in the Salina Sea when salty waters flowed in from the ocean. When the reef cut off the salt water inflow, finegrained clastic sediment was deposited (now mudstone) near the shore and carbonate mud (now dolomite) was deposited nearer the center of the sea.

Over time, the area of central and eastern New York and Pennsylvania sank further below sea level, ending the salt deposition sequence.

Much of the folding in the mine area occurred with the Appalachian Orogeny some 250 to 290 million years ago during the Permian Age. This folding likely led to the formation of rolls found in the southern part of the Cayuga Mine that have in the past limited mine development in that direction. These rolls are associated with the Firtree Point dome and faults noted above.

Some of the resulting horizontal movement during this mountain-forming event is believed to have occurred within the salt layers of the Salina Group. At times this horizontal movement would sag the rock overlying or underlying the salt beds. It is such an event that is believed to have caused the rolls in the roof and floor of the Cayuga Mine. These rolls have caused some production and minor roof instability problems in the northern areas of the mine.

During the Mesozoic Era (250 to 100 million years ago), the continents of North America, Europe, and Africa diverged allowing for the formation of the Atlantic Ocean. The separation pulled lava to the surface producing volcanoes fed by the kimberlite dikes. The Cayuga Mine encountered these Cretaceous kimberlite dikes in the onshore workings, and it is anticipated that these dikes will again be intercepted as the mine progresses southward. It has been shown that a kimberlite sill had formed at the top of the Syracuse Formation (see Figure 3), and it is likely that other sills may have radiated from these kimberlite dikes. Although these dikes will represent a production problem for the Cayuga Mine, they likely will not affect overall mine stability.

Cayuga Lake was later carved out of the surrounding rock by several glaciers that started moving southward across New York some 1.8 million years ago and continued through the Pleistocene Epoch. As the final Laurentide (late Wisconsinian) Glacier receded some 14,000 years ago, at the end of the Pleistocene, sediment from that glacier was deposited in Cayuga Lake. The first sediments to enter the lake were gravel and sand (see Figure 3), and as the glacier receded further north away from the lake,

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finer-grained silts and clays were deposited. Finally, lake sediments were deposited and these lake depositions continue today. Unconsolidated lake sediments range from 0 ft to 700 ft above the bedrock in the existing and proposed mining area.

Mine Characteristics

The No. 6 Salt being produced varies in thickness from 12 ft in the existing mining area to 19 ft near the proposed northern boundary. The extraction thickness varies with the bed thickness but is modified by the existence of rolls and equipment limitations. Extraction height at the mine has varied from under 8 ft to over 14 ft, but extraction in recent years has been between 10 and 12 ft.

According to the MLUP, the mine will develop production panels 488 ft wide. Panel barrier pillars 300 ft wide (excluding the notch length) separate these panels from each other. Eight rows of 15 ft x 13 ft yield pillars are placed across the panel separated by nine entries 32 ft wide. Each set of yield pillars is separated by rooms 30 ft wide. To aid in transitioning from the yield pillars to the ridged barriers, a notch is cut into the barrier the width of the room and 48 ft deep.

Because of its location beneath the lake, the mine does not have what would be considered a typical level of drilling investigation conducted from the surface in advance of mining. This lack of drilling information would normally lead to a somewhat lower confidence level in projecting continuity of mining conditions. To obtain information useful in mine planning, Cargill instead relies upon lake-based seismic reflection surveys conducted by researchers under grant and by contractors on their behalf.

To review the relationship of the existing and proposed mine to the lake bathymetry, bedrock thickness, and unconsolidated sediments beneath the lake, BOYD prepared a three-dimensional model of these units using AutoCAD drawings supplied by Spectra Environmental Group, Inc. and employed VULCAN software of Maptek Pty Ltd to develop the model.

Overburden Thickness and Yield Pillars

The use of yield pillars in soft rock (coal, trona, salt, etc.) is a proven technique to aid in ground control. Under conditions such as those at the Cayuga Mine, the adaptation has resulted in better working conditions, increased production, and conservation of resources. As pillars in the panel yield, loads once carried by them are transferred to the adjacent panel barrier pillars. To accomplish this task the strata overlying the panel must form a rock arch to span the panel and carry the load once carried by the yield pillars to

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the barrier pillars. Increasing panel width requires a corresponding increase in rock arch height and width. Experience has shown that stable arches can be achieved with height to width ratios from 0.5 to 2.5. In general, stable arches form at a ratio of 0.5 in strong rock overburden comprised mostly of sandstones and limestones with very little dead load (glacial till, soil, lake sediments, and water). The opposite is true for the stable arch ratios near 2.5 which can form in weaker rock and support additional dead load.

As the Cayuga Mine progresses northward, the solid rock overburden in which the arch will form becomes thinner as illustrated on Figure 2, following this text. This is occurring at the same time the glacial till and lake sediment thickens and lake depth increases. The rock thickness reduces to 800 ft at

the northern limit of the proposed mineral lease. Assuming the panel width will be maintained at 488 ft. the arch ratio will be approximately 1.6 which, in BOYD's opinion, should be stable. However, this condition must be more thoroughly analyzed for stability by Cargill and reviewed by NYSDEC before mining enters this area (currently scheduled after 2030).

Comparison to Retsof Mine

In light of the Retsof Mine flooding, BOYD was aware in this review to note any similarities in physical conditions that may exist between the Cayuga Mine and collapsed areas of the Retsof Mine. Since BOYD believes that Retsof Mine flooding was due to the collapse of the pressure arch above a yield pillar panel, and the yield pillars at the Cayuga Mine were designed using the pressure arch concept, we considered a comparison of conditions contributing to the dimensions and loading of the pressure arch to be warranted.

The following table presents a comparison of conditions of the collapsed area of the Retsof Mine to those projected for the Cayuga Mine at the northern boundary of the proposed mining area where overlying bedrock is thinnest.

		Cayuga Mine	Retsof Mine
Total Depth	(ft)	1,850	1,100
Lake Depth	(ft)	400	0
Sediment and Glacial Till Thicknes	(ft)	650	500
Bedrock Thickness	(ft)	800 (min)	600
Panel Width	(ft)	488	670
Pressure Arch Height to Width Ratio		1.6	
0.9			
Pressure at Top of Arch (dead load)	(psi)	850	520

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As previously shown, the height to width ratio of the arch that can form above the Cayuga Mine is substantially greater than the arch in the collapsed areas of the Retsof Mine. In BOYD's opinion, the arch that could form at the Cayuga Mine under these conditions is adequate to support the additional dead load.

For the Retsof Mine the thickness of bedrock and unconsolidated material was determined by drilling while most of the thickness information for the Cayuga Mine was determined by subbottom seismic reflection. The subbottom seismic reflection method may be less accurate; however, it appears that mine workings in the thin rock overburden area of the Cayuga Mine will be structurally more sound than those of the Retsof Mine prior to the collapse.

Disturbed Salt Area

A disturbed salt zone, identified by seismic survey and shown on No. 6 Salt structure contours (top of salt), may exist near the west shore of the lake in the northern extended mineral lease area. As reported to NYSDEC in our letter of January 5, 1998, Cargill previously stated that the mine would

avoid the disturbed salt zone near the western lakeshore. However, mine projections show that present plans are to extract this area some time between 2016 to 2920. The MLUP reports this disturbed area is possibly "a graben-like structure" and "appears to contain at least one deeply penetrating, near vertical fault that affects the salt interval." It appears to vertically displace the salt 100 ft downward from the surrounding areas. Further investigation of this disturbance needs to be completed before mining proceeds in this area.

Main Barrier Pillars

Previous reports by BOYD to NYSDEC pointed out the absence of main barrier pillars between the main development entries and production panels. Documents provided for this review do not address BOYD's previous comments regarding the appropriateness of such barrier pillars. While not necessary as an integral design component to produce a stable underground structure, it is BOYD's opinion such barriers are appropriate as a matter of good practice to limit unplanned overburden collapse in the production panel from overriding the development entries.

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Summary

The proposed mine design presented in the MLUP appears to be adequate to provide stable conditions throughout the permit term. Further study of areas to be accessed post-2020 is required to:

- Investigate and report on the adequacy of the thin rock overburden at the northern extent of the proposed mine and mineral leases in regard to mine stability.

- Investigate and report on the disturbed salt zone near the western lakeshore as to its characteristics and mineability.

As a matter of good engineering practice, BOYD encourages the use of main barrier pillars between the main development entries and production panels.

Please contact us if you require additional comment or if we may be of further service in this matter.

Following this page are:

Figures

- 1: General Location Map,
- 2: Plan and Profile View
- 3: Stratigraphic Section

Appendix A: List of References

Respectfully submitted,

JOHN T. BOYD COMPANY

By:

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Vice President

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APPENDIX A

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