MINNESOTA DEPARTMENT OF NATURAL RESOURCES

Minnesota
DEPARTMENT OF
NATURAL RESOURCES

OPERATIONS REPORT

January 1990

HILL
MINE
ANNEX
STATE PARK

Pursuant to 1988 Laws, Ch 686, Art 1
Sec 11(k) Vol 1 of 4 volumes

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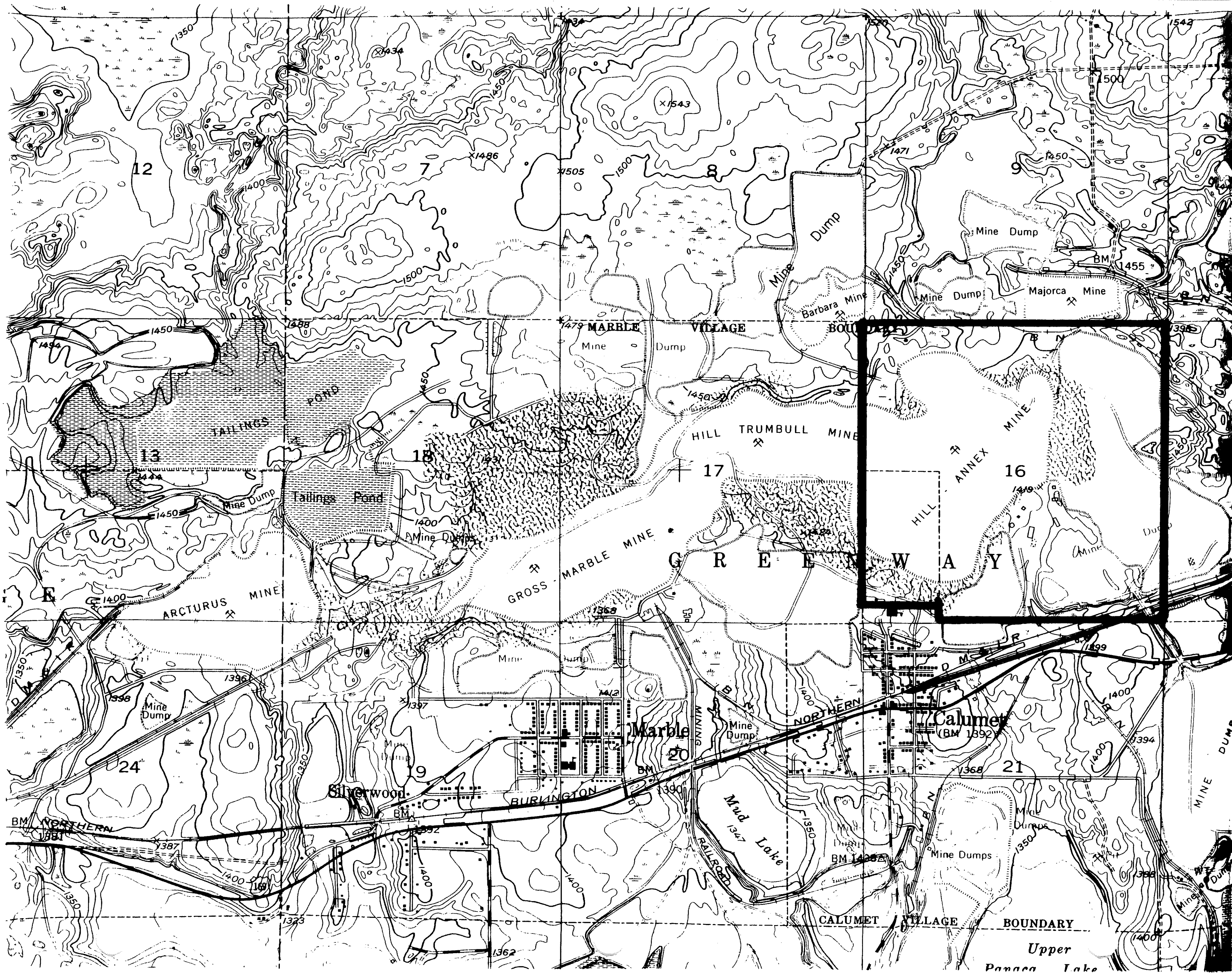
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I. INTRODUCTION

Hill Annex is not just another abandoned pit mine. It is a resource rich with the state's geologic, cultural and mining heritage. Of the more than 400 open pit iron mines that dotted the northern Minnesota landscape, only six are still in operation. Most or all of those that are abandoned will eventually fill with water. Hill Annex provides a rare opportunity for visitors to experience first-hand, Minnesota's open pit mining history. For this and the following reasons, Hill Annex merits status as a state park.

* *Settlements associated with the Hill Annex mine reflect a diverse mix of European cultures.*
* *The mine represents a 60 year evolution of mining technology.*
* *Hill Annex is the only abandoned open pit, natural ore mine with buildings intact.*
* *Hill Annex is on the National Register of Historic Places.*

A. HISTORY

The history of Hill Annex dates back almost a century. The mine lies on land held in trust by the State to be managed for the benefit of the public school system. The land was originally leased for mineral exploration in 1892. It was leased again in 1900 for a period of more than 50 years. Mining began in 1913 and continued until 1978.

More than 400 mines dotted the Minnesota Iron Range. These produced 85% of the nation's iron through the first half of this century. The Hill Annex mine produced 63 million tons of ore, and was the sixth largest producer in the state. This yielded more than $27 million in royalties for the State School Trust fund.

Over its sixty years of operation, mining technology at Hill Annex changed drastically. In 1913, horses provided the power. Eventually coal and then electrical power replaced the horse drawn equipment.

In 1978, with its high-grade ore finally played out, Jones and Laughlin Steel sold the Hill Annex mine with all its existing buildings and equipment to the Iron Range Resources and Rehabilitation Board (IRRRB) for $1. The IRRRB gave tours of the mine for ten years. In 1986, the mine was placed on the National Register of Historic Places; two years later the Minnesota legislature made Hill Annex a state park.

(Appendix A provides a history summary of Hill Annex.)

B. LEGISLATION

The Laws of Minnesota for 1988, Chapter 686, Article 1 is the enabling legislation which transferred the Hill Annex Mine from IRRRB to DNR.

M.L. 1988, Chapter 686, Article 1, Section 52 requires the Commissioner of Natural Resources to report to the legislature by January 1, 1990, regarding revenues, visitation, and operating costs for this new park. It also requests recommendations on continuing operational requirements. This is the basis for this report.

Appendix B details the complete legislation regarding the establishment of Hill Annex Mine as a State Park.

Appendix C is a Memo of Understanding outlining the transfer from IRRRB to DNR.

II VISITATION AND REVENUE

Revenues for Hill Annex mine have been climbing yearly while attendance is a bit less stable. The DNR believes that with proper marketing, attendance can be increased quickly from 13,000 (1988) to 25,000. Through more effective marketing and by charging for group bus tours, the DNR can more than double current revenues. The DNR believes that attendance can eventually equal the 50,000 visitors who annually stop at the Soudan Underground Mine State park

Year	Paid Attendance	Free Attendance	Miners Day Attendance**	Total Visitation/Year
1980	4,238	2,479	4,500	11,217
1981	4,346	2,081	3,500	9,927
1982	5,200	2,973	4,600	12,773
1983	5,784	4,214	4,000	13,998
1984	7,456	4,171	6,000	17,627
1985	10,659	5,065	4,300	20,024
1986	8,541	9,938	5,919	24,398
1987	15,081	6,320	5,665	27,066
*1988	13,672	8,064	6,014	27,750
1989	10,461	5,526	***2,312	15,987

Year	Admission	Merchandise	Total Revenue/Year
1980	$ 5,460.75	$1,036.37	$ 6,497.12
1981	$ 5,322.22	$2,103.91	$ 7,426.59
1982	$ 6,123.50	$2,008.09	$ 8,131.59
1983	$ 6,447.50	$2,080.16	$ 8,527.66
1984	$ 8,239.11	$3,365.11	$11,604.22
1985	$11,626.95	$5,241.39	$16,868.34
1986	$18,047.72	$8,377.42	$26,425.14
1987	$25,904.59	$6,151.30	$32,055.89
*1988	$22,973.74	$5,965.36	$28,939.10
1989	$26,542.80	$5,250.98	$31,793.46

*DNR began operations on August 1, 1988.
**Miners Day attendance was free up to 1989.
***This figure is part of the paid attendance figure.

III OPERATIONS

Although some operations are similar to other state parks, Hill Annex has unique features that require special attention.

A. PUMPING

Pumping water from the bottom of its mine distinguishes Hill Annex from other state parks. Mine tours of the park's unique cultural and mineral heritage are only possible if the pit is dewatered. In 1988, the legislature appropriated $298,000 for that purpose. (See appendix H.)

The challenge of dewatering the park has proven costly and complex. The original barge, pump and pipeline acquired with the park all needed repair. In addition, the pit had partially filled with 85 feet of water when pumping ceased in 1986. Since one pump was not equal to the challenge, the DNR purchased a second pump and barge.

The DNR needed a dewatering plan that would lay out the least expensive and most effective approach. The Abe Mathews Engineering Company studied the situation and issued its recommendations in January of 1989. The study indicated trade-offs between cost and time required to dewater the mine. The DNR selected an option that would dewater the park in less than two years at a cost of $73,000. The system was installed in Fall of 1989. Its two pumps are now capable of pumping 5,400 gallons/minute which equates to more than 2 billion gallons of water a year.

DEWATERING OPTIONS

System 1 would cost $28,800 and dewater the pit in 5.6 years.

System 2 would cost $35,800 and dewater the pit in 5.6 years.

System 3 would cost $73,300 and dewater the pit in 1.8 years.

System 4 would cost $167,000 and dewater the pit in 1.6 years.

System 5 would cost $257,000 and dewater the Hill Annex and Gross Marble pits.

System 6 would cost $532,000 and dewater the Hill Annex, Gross Marble, and Arcturus pits.

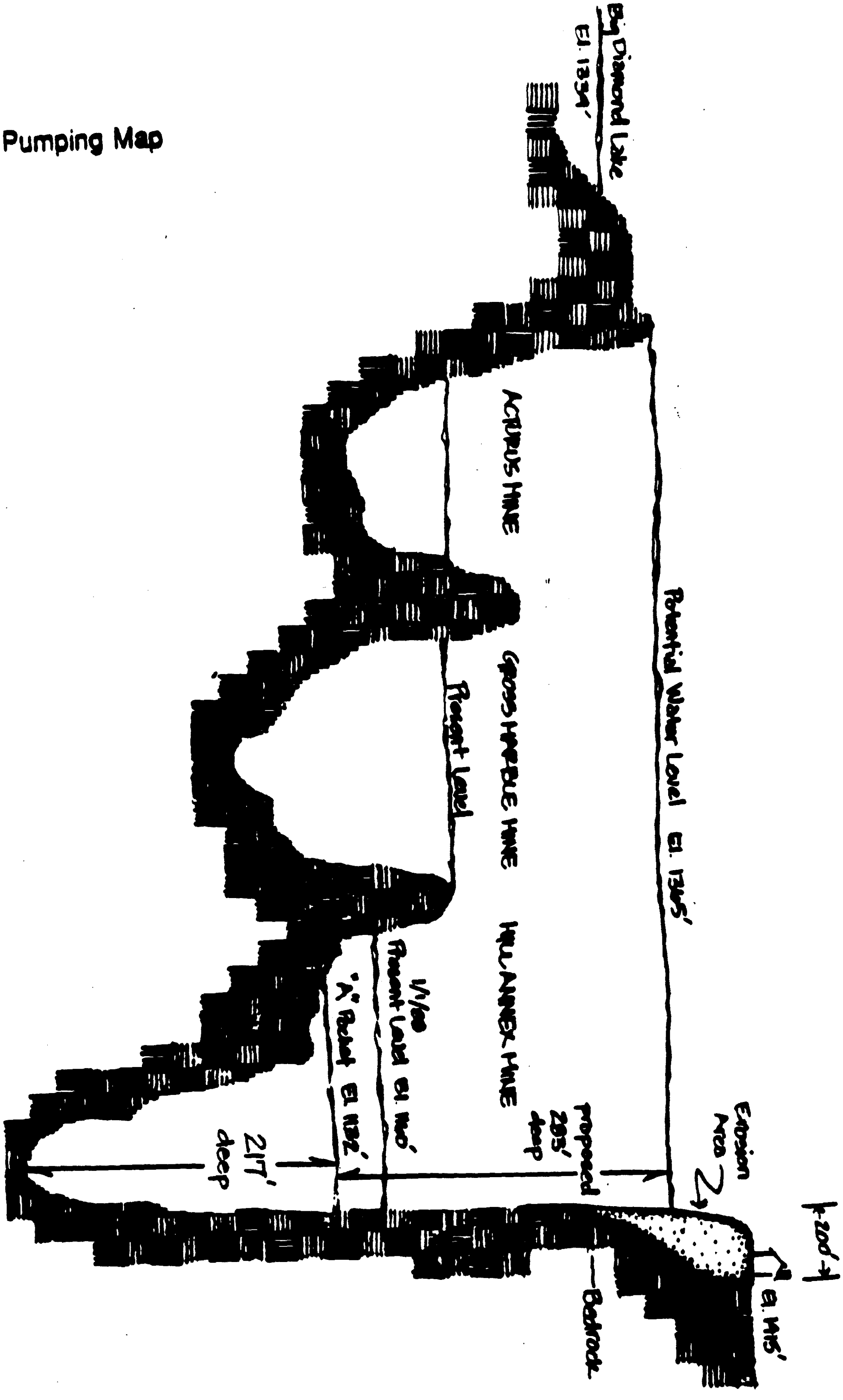
The DNR implemented a second recommendation to reduce electrical costs for pump operation. DNR purchased a generator capable of powering both pumps, thus becoming eligible for a reduced electrical rate from Minnesota Power Company. (See appendix D.)

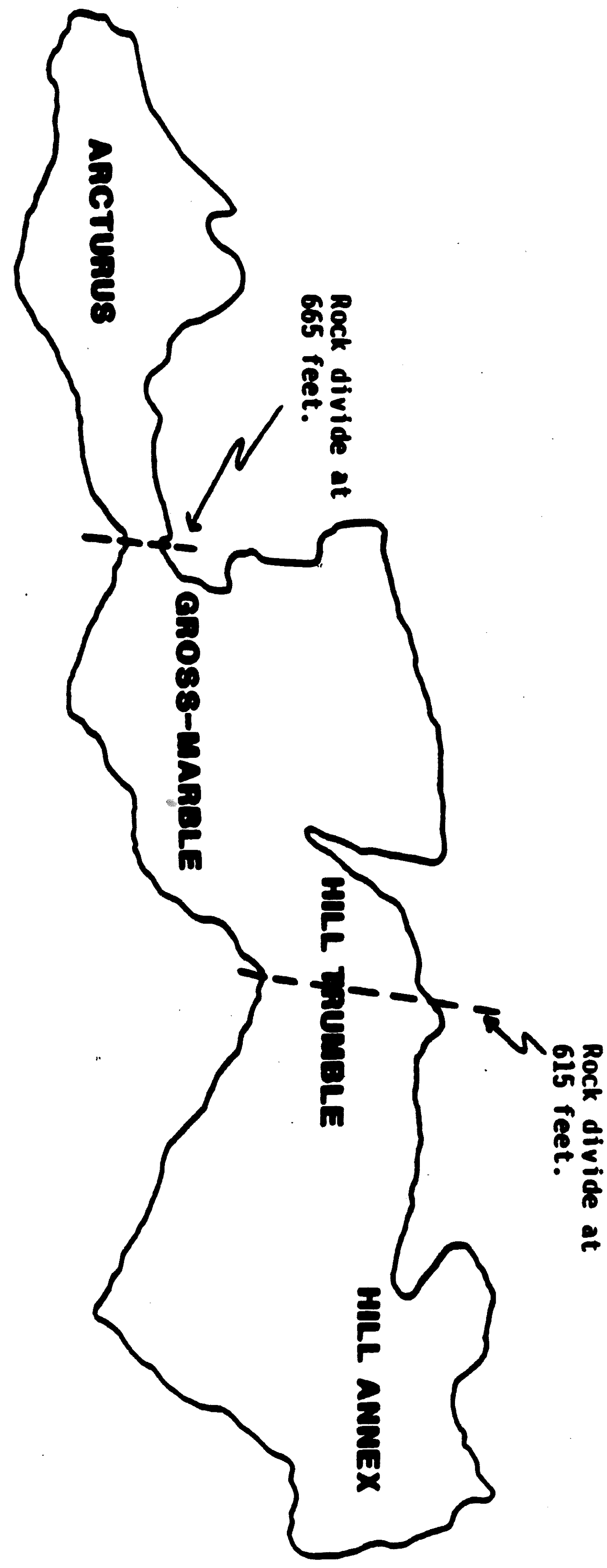
The new pumping equipment and lower rates have not totally resolved the water problems. Two adjacent privately-owned abandoned mines are rapidly filling with water. One of these, the Arcturus will soon overflow into the other, the Gross Marble mine, which already is overflowing 3.5 million gallons a day into the Hill Annex mine.

A 1987 study by Barr Engineering concluded that dewatering must be considered for the two private mines if the Hill Annex water level problems are to be managed. However, the DNR currently has neither the authority nor the funding to control the water flow from the private pits.

The Barr study also concluded that allowing the three mines to fill with water was not a feasible option. Such inaction would cause severe erosion which would damage Club House museum and possibly other buildings. Dewatering the Hill Annex mine to the A Pocket Level (See p.8) would facilitate continued interpretive tours and provides the best long term solution.

Pumping Map


Big Diamond Lake
El. 1339'
Potential Water Level El. 1365'
ACTURUS MINE
GROSS MARBLE MINE
HILL ANNEX MINE
Present Level
1/1/88
Present Level El. 1160'
"A" Pocket El. 1132'
proposed
285'
deep
217'
deep
Erosion
Area
El. 1415'
200'
Bedrock
1400
1300
1200
1100
1000
900


ARCTURUS
Rock divide at 665 feet.
GROSS-MARBLE
HILL TRUMBLE
Rock divide at 615 feet.
HILL ANNEX

B PHYSICAL PLANT

The physical plant of the Hill Annex mine is a major historical component of the park but requires significant maintenance efforts. The state inherited 48 buildings with Hill Annex mine. Each building played a distinct role in the mine operations.

The existence of these buildings was a major reason for the designation of the mine on the National Register. Many are included in the park tours and must be maintained in a safe condition. All are deteriorating, although the club house and office have been restored for public use.

In 1989, the DNR estimated that $357,500 would be needed to restore the most significant mine buildings that are part of the public tour. (See appendix E.)

C. STAFFING

DNR intends to provide the same level of service to the public at Hill Annex as at other state parks.

To provide this service, DNR has staffed Hill Annex as follows:

1 manager - full time

1 naturalist - full time

1 building and grounds worker - full time

1 Greenview worker - 50%

1 parks worker - seasonal (May - September)

3 student workers - seasonal (May - September)

4 seasonal guides - seasonal (May - September)

4 guides - on call

1 clerk - seasonal (May - September)

IRRRB staffed Hill Annex in the following manner:

3 building and grounds worker - full time

1 clerk - seasonal

10 non-tenured laborers - temporary

6 student workers - temporary

The Mineland Reclamation program provided management and clerical staff.

D. BUDGETS

Enabling legislation transferring the Hill Annex to the DNR required the IRRRB to provide $200,000 a year for operations until July 1 of 1991. That sum is inadequate in view of the high cost of pumping water. The DNR estimates that $353,000 is required for Hill Annex operations on a fiscal year basis.

DNR's budgets for FY89 through FY92 are described below.

HILL ANNEX OPERATIONS BREAKDOWN

	FY89	FY90	FY91	FY92
Salaries				
Manager	0	(1)$22,000	(3) $33,600	(3) $35,280
Naturalist		(2) 6,859	(3) 28,807	(3) 30,247
Maintenance Worker	24,216	27,000	(3) 28,350	(3) 29,767
Seasonal (Clerical, guides, parks workers	44,000	57,286	(3) 60,150	(3) 63,157
Supplies and Expenses				
routine supplies	$ 76,187	41,500	45,500	45,500
electricity for pumping	56,312	114,000	149,000	149,000
Total Costs	$ 228,715	268,645	341,407	352,951
allotted	228,000	200,000	200,000	0
balance	-715	* -68,645	** -141,407	*** -352,951

(1) November 89 through June 90
(2) April 90 through June 90
(3) 5% wage increases - Union contract

*This is a projected deficit that DNR intends to pursue as a change level request. If a change level request is denied pumping will be reduced to stay within the existing budget.

**This is a projected deficit that DNR intends to pursue as a change level request. If a change level request is denied pumping will be reduced to stay within the existing budget.

***This is the projected budget that DNR will be seeking funding for during the 1991 legislative session.

E. SUMMARY OF BUDGET NEEDS

Short Term Needs

FY90 deficit	$ 68,645
FY91 deficit	$141,407
FY92 budget	$352,951
Building maintenance	$360,000

Long Term Needs

1. ***Land Acquisition:*** *In 1990, the DNR will initiate a land exchange to compensate the Permanent School Trust fund for use of the land. Until that exchange is complete, the DNR will pay a leasing fee to the School Trust Fund.*

2. ***Long-Term Building Maintenance:*** *The DNR will develop a long-term building maintenance plan based on anticipated costs to upkeep the 48 buildings in the inventory.*

3. ***Long-term Water Control Plan:*** *Details of a long term plan have not been developed. However, the Barr study indicated that pumping systems and dikes around the three mine pits would cost between $500,000 and $8,000,000. This range of costs depicts several water control systems which include pumps and pipelines, wells, and dikes and dams.*

4. ***Grants:*** *The new manager for the Hill Annex mine will explore availability of grants to address some of the critical long-term needs of the park.*

F. RECOMMENDATIONS

Residents in the area of the Hill Annex mine harbor strong feelings on its historical and recreational value. The DNR facilitated a meeting with local residents to develop recommendations on future management of the park. Residents of the City of Calumet, DNR staff, IRRRB representatives and members of the Northern Minnesota Citizen's League attended the meeting. They addressed the following issues:

1. *pumping requirements,*
2. *building inventory and maintenance,*
3. *operational budget,*
4. *actions to defray costs,*
5. *foundation grants.*

Attendees agreed unanimously to the following recommendations:

1. *The Hill Annex mine should continue to be a state park.*

2. *Pumping should be continued to maintain water below the A pocket level so that tours of the mine can continue.*

3. *The DNR should seek a $350,000 annual budget for the park.*

The DNR concurs with these recommendations.

APPENDICES

THE HILL ANNEX MINE
1900 - 1978

APPENDIX A

Exploration:	**1900** - 50 year lease awarded to Great Northern Iron Ore Properties by the State of Minnesota.
	1908 - Test drilling begins by Oliver Iron Mining Company.
Construction:	**1911** - First building constructed by Arthur Iron Mining Company (Great Northern Iron Ore Properties).
	1913 - Underground shaft started.
Mining Begins:	**1914** - First iron ore removed from shaft. Stripping for open pit begins.
	1917 - Large scale production from the open pit begins.
Plants:	**1918** - Washing plant constructed at Pinacie Lakes.
	1923 - Merchantable ore screening and crushing plant built.
	1953 - Present heavy media plant built.
	1957 - Tailings reclamation plant built.
	1961 - Tailings cretaceous ore plant built.
Ore Movement:	**1908 - 1930** - Steam power used.
	1930 - 1944 - Electrical haulage used.
	1944 - 1978 - Truck and conveyor system used.
Operations:	**1908 - 1914** - By Arthur Mining Company
	1914 - A. Guthrie & Company hired to operate the mine.
	1917 - Interstate Iron Co. (J & L) took over the lease.
	1930 - Guthrie contract terminated - Interstate Iron (J & L) took over operations.
Significant Dates:	**1930** - First mine electrified on the Mesabi Range
	1941 - Largest annual production; 3,646,000 tons.
	1948 - Last year of direct merchantable ore shipments.
	1950 - 25 year lease awarded to J & L Steel Corp.
	1978 - Pit operations shut-down.

Production	63,682,773 tons shipped
Available Ore:	1,859,367 tons remaining
Royalties Paid:	$27,000,000 to the State

The above information was taken from: A Teachers Guide to the Hill Annex Mine - IRRRB 1986

APPENDIX B

Laws of Minnesota for 1988, Chapter 686, Article 1

Sec. 50

Minnesota Statutes 1986, section 85.012, is amended by adding a subdivision to read:

Subd. 27a. Hill Annex Mine state park, Itasca county

Sec. 51. PARK BOUNDARIES

Hill Annex Mine state park consists of the surface interest in land within Itasca County described as Section 16, Township 56 North, Range 23 West, excluding an area containing 6.5 acres more or less which is described as follows:

> Starting at the corner common to Sections 17, 16, 20 and 21, Township 56 North, Range 23 West; thence due east on section line 155 feet to point of beginning; thence due east 916 feet; thence due north 330 feet; thence due west 916 feet; thence due south 330 feet to the point of beginning.

*Sec. 52. OPERATION

Hill Annex Mine state park must be funded by the iron range resources and rehabilitation board at the level of $200,000 per year until July 1, 1991. The commissioner of natural resources must report to the legislature by January 1, 1990, regarding the revenues, visitation, and operating costs for the park, and making recommendations on continuing operational requirements.

Sec. 53. ACQUISITION

The commissioner of natural resources shall acquire by condemnation or exchange sufficient ownership interest in the surface estate of the land described in section 51 to create a state park to interpret and provide the public with an opportunity to view and experience natural iron ore open pit mining operations as conducted on Minnesota's' historic iron ranges. The commissioner may not condemn the mineral estate in the described property and in the establishment of the park, shall recognize the possibility that mining may be conducted on the property in the future, and that use of portions of the surface estate may be necessary to these possible future mining operations. Subject to the above conditions, all lands acquired for the Hill Annex Mine state park must be administered in the same manner as provided for other state parks and must be perpetually dedicated for that use.

Sec. 54 EQUIPMENT

For establishing Hill Annex Mine state park, the iron range resources and rehabilitation board must transfer the existing vehicles, maintenance equipment, and office equipment at Hill Annex Mine, other than vehicles and equipment used primarily for mineland reclamation, to the commissioner of natural resources.

M.L. Law 1988, Chapter 686, Article 1, Section 11 (k) $298,000. $270,000 of this appropriation is for pumping costs, including the purchase and installation of pumps, pipelines, and associated facilities. The commissioner of natural resources may seek additional matching money from organizations having access to historical preservation money to complement this appropriation. The commissioner of natural resources shall prepare a financial report on the use of this appropriation for the chairs of the house appropriations and senate finance committees no later than January 1, 1990.

$28,000 of this appropriation is from the state parks maintenance and operations account in the special revenue fund. The approved complement of the department of natural resources is increased by two positions.

MEMO OF UNDERSTANDING

APPENDIX C

As of July 1, 1988 the IRRRB Hill Annex Mine became a DNR State Park.

Since the Mine is now a part of the MN State Park System, DNR is now responsible for all operations of the Hill Annex Mine.

DNR and IRRRB have agreed mutually to manage the mine jointly through July 31, 1988. On August 1, 1988, DNR will be solely responsible for the operation of Hill Annex Mine. Orlyn Olson through the IRRRB Commissioners Office will continue to supervise existing mine employees through July 31, 1988. Don Logan through the DNR Grand Rapids Park Office will work with Orlyn Olson in supervising the mine operations through July 31, 1988.

The enabling legislation for the transfer of the mine from IRRRB to DNR identified a transfer of $200,000 operational funding for IRRRB to DNR per fiscal year until July 1, 1991. The Department of Finance, Executive Budget Officer for DNR and IRRRB will work with the respective DNR and IRRRB business offices to coordinate and facilitate the transfer of this operational budget.

Any expenditures for the mine operation by IRRRB must be approved by DNR in advance during the month of July.

It is understood that IRRRB mine employees listed on the attached document will be transferred from IRRRB employment to DNR employment by means of an Executive Order.

The Mineland Reclamation operations will be transferred out of the Mine by August 1, 1988.

Both parties agree that IRRRB will continue to operate and staff the Mineland Reclamation Growth Chamber located at the mine through October 31, 1988. Any associated cost, i.e. electricity etc., will be paid for by IRRRB. Also, it is understood that IRRRB will salvage the growth chamber equipment (and electrical fixtures etc.) and leave the chamber room in a clean and safe state after salvage operations are completed.

DEPARTMENT OF NATURAL RESOURCES	IRON RANGE RESOURCES REHABILITATION BOARD
Deputy Commissioner	Deputy Commissioner

BP101/1

APPENDIX D

Electrical Rates

Rate Comparison - Hill Annex Mine State Park

Monthly Loads	General Service 251	Dual Fuel 261	Large Light & Power 751
225 KW @ 200,000 KWH	10,639.75	6,073.80	7,920.16
500 KW @ 400,000 KWH	21,275.79	12,137.00	15,702.52
20 KW @ 4,000 KWH	280.03	280.03	
225 KW @ 4,000 KWH			1,832.57
450 KW 4,000 KWH			3,406.67
450 KW @ 200,000 KWH			9,319.39
6 months - 1 pump only	63,838.50	38,122.98 (3)	47,520.96
6 months - no pumps	1,680.18	1,680.18 (4)	10,995.42
Yearly Total	65,518.68	39,803.16	58,516.38
6 months - 2 pumps	127,654.74	74,502.18 (3)	94,215.12
6 months - 1 pump	63,838.50	38,122.98 (3)	55,916.16
Yearly Total	191,493.24	112,625.16	150,131.28
4 months - 2 pumps	85,103.15	49,668.12 (3)	68,810.08
8 months - 1 pump	85,118.00	50,830.64 (3)	74,554.88
Yearly Total	170,221.16	100,498.16	143,364.96
12 months - 2 pumps	255,309.48	149,004.36 (3)	188,430.24
3 months - 2 pumps	63,827.37	37,251.09 (3)	47,107.56
3 months - 1 pump	31,919.25	19,061.49 (3)	27,958.08
6 months - no pumps	1,680.18	1,680.18 (4)	20,440.02
Yearly Total	97,426.80	57,992.76	95,505.66

Notes:
1) No fuel adjustment
2) 6% state sales tax included
3) 20 KWH @ 4,000 KWH firm added to dual fuel rate.
4) No duel fuel used.

APPENDIX E

DNR Building Inventory

Proposed Contract Projects With Estimated Cost

Park Office - 2-478

Conference Room Basement	
Smoke Alarms	$ 3,000
Outside Exit	$ 1,000
Replace Paneling	$ 3,000
Ceiling	$ 5,000
Cut doorway in cement wall	$ 3,000
Sprinkler System	$ 8,000
Top Floor	
Upgrade Heating System	$20,000
Electric Exit Signs	$ 2,000
First Floor	
Handicap Accessible	$15,000
Light Fixture Cover	$ 500
Outside	
New Siding	$ 5,000
Repair Stops	$ 5,000
New Storm Windows$5,000	
New Insulation	$10,000

Electrical House - 2-479

New Heating System	$20,000
New Siding	$10,000
New Wall - Winterize shop	$ 5,000
Storm Windows	$ 3,000

Engine House - 2-489

Repair Brick Walls	$10,000
Windows	$ 1,000
Electrical Work	$25,000

Hill Annex Proposed Contract Projects continued

Truck Storage Shed - 2-488		
	New Overhead Door	$10,000
	Refasten Steel Siding	$ 2,000
	Window Glass	$ 1,000
Warehouse Storage - 2-490		
	New Roof	$ 8,000
	Repair Brick Walls	$10,000
Water Tower - 2,482		
	Paint and Repair	$15,000
	Sump Pump	
Club House - 2-476		
	New Siding	$15,000
	New Insulation	$10,000
	New Storm Windows	$ 5,000
	Handicap Elevator	$15,000
	Fuel Oil Tank Dug Out	$ 5,000
	Broken Windows	$ 1,000
	(440,000BTU Natural Gas Furnace)	$20,000
Media Building - 2-491		
	Feasibility Study	$40,000
Dump Master Shed		$30,000
Pay Master Shed		
	New Siding	$ 500
	New Roof	$ 500
Building Project Total		$357,500

IRRRB Building Inventory

APPENDIX F

October 8, 1980

Number	Size	Type	Use
1. Heavy Media Plant	46'x210'x65'	Steel	Ore wash plant
2. "D" pocket (surface screener)			
3. Pit screen and conveyor			
4. Belt building on conveyor	18'x23'	Steel	Protect motors
5. Belt building on conveyor	28'x35'	Steel	Protect motors
6. Belt building on conveyor	26'x26	Steel	Protect motors
7. Belt building on conveyor	26'x26'	Steel	Protect motors
8. Belt building on conveyor	28'x30'		Store dynamite
9. Dynamite storage shack in pit	6'x6'		Store dynamite
10. Dynamite storage shack in pit	10'x17'	Steel	Store dynamite
11. Storage building in pit	14'x20'	Steel	Storage
12. Dry house (pocket in pit)	14 1/2'x20'	Steel	Dry House
13. Fire shack (pocket in pit)	6 1/2'x6 1/2'	Steel	Fire Equipment
14. Feeder control shack in pit	7'x8'	Steel	Control pocket
15. Pit service garage (quanset)	59'x80'	Steel	Service Trucks & conveyor
16. Pit Storage building	32'x75'	Wood	Storage
17. Reject stacker system			
18. Machine shop	80'x172'	Brick	Machine shop store
locomotives			
19. Truck garage & warehouse	71'x160'	Steel	Truck repair & storage
20. Oil house	24'x37'	Brick	Oil storage
21. Office Building	36'x62'	Wood	Office building
22. Electrical shop	53'x75'	Wood	Electrical storage & repair
23. Chem lab & ore dressing building (Clubhouse)	44'x50'	Wood	Office for mine tour
24. Tire Storage building (quanset)	42'x44'	Steel	Tire storage
25. Timekeepers shack (Loading pocket)	8'x18'	Wood	Timekeepers Building
26. Sampler & grinders shack (loading pocket)	12'x16'	Steel	Sampler grinding
27. Power & locker building (pit conveyor)	16'x25'	Steel	Locker & generator
28. Small sampler storage building "	4'x4'	Steel	Sampler storage
29. Red fire building (office building)	8 1/2'x10 1/2'	Steel	Fire equipment
30. Red fire building (office building)	7 1/2' x 8'	Wood	Fire equipment
31. Red fire building (office building)	7 1/2' x 8'	Wood	Fire equipment
32. Sub station (adjacent to HM plant)	42'x48'	Brick	Power station
33. Idler repair building (adjacent to HM plant)	20'x24'	Wood	Repair
34. Storage building (adjacent to HM plant)	14'x21'	Steel	Storage
35. Storage building (adjacent to shop)	24'x29'	Wood	Storage
36. Battery & Misc. storage (adjacent to shop)	24'x41'	Brick	Storage
37. Storage building (pit)	14'x20'	Steel	Storage
38. Dynamite shack (pit)	6'x6'	Wood	Dynamite storage
39. Dynamite shack (pit)	10'x17'	Wood	Dynamite storage
40. Ticket booth	6'x8'	Steel	Ticket booth
41. Minnesota weight building (office)	6 1/2'x13'	Wood	State weightmaster
42. Water tank building (office)	10'x13'	Steel	Protect watertank pump
43. Water tank (office)		Steel & Wood	Water storage
44. Storage shed (HM dump)	5'x8'	Steel	Storage
45. Storage shed (HM dump)	7'x13'	Wood	Storage
46. Blasting shack mounted on rubber tires (pit)	23' circumference	Steel	Blast protection
47. Blasting shack (tour building)	25' circumference	Steel	Blast protection
48. Mine view platform mounted on steel skids	9'x18'	Steel	Tour View platform

Park Comparison - Cost/Visitor 1989

PARK	NO.	REG.	TOTAL ATTENDANCE	BUDGET	REVENUE	NET COST PER VISITOR
HILL ANNEX	38	2	16,000	$228,000	$31,793	$12.26
SOUDAN MINE	97	2	53,761	$548,494	$125,237	$7.87
BIG STONE LAKE	66	4	10,420	$62,099	$7,032	$5.28
SCHOOLCRAFT	67	3	9,035	$45,850	$4,777	$4.55
KILEN WOODS	25	4	13,723	$65,337	$13,264	$3.79
MONSON LAKE	33	4	10,040	$31,710	$3,439	$2.82
O.L. KIPP	94	5	20,829	$68,957	$13,166	$2.68
OLD MILL	37	1	21,513	$74,303	$16,987	$2.66
G. CROSBY MANITOU	64	2	6,715	$23,194	$5,943	$2.57
UPPERSIOUX AGENCY	98	4	33,793	$76,167	$7,252	$2.04
ZIPPEL BAY	63	1	32,314	$79,949	$18,308	$1.91
MN VALLEY TRAIL	16	6	58,243	$121,250	$11,883	$1.88
LAKE LOUISE	90	5	25,876	$63,544	$15,125	$1.87
GLACIAL LAKES	88	1	22,305	$69,635	$29,116	$1.82
LAKE MARIA	91	3	27,696	$69,813	$22,747	$1.70
LAC QUI PARLE	26	4	36,095	$84,713	$27,700	$1.58
BUFFALO RIVER	7	1	46,620	$113,675	$40,234	$1.58
BEAVER CREEK VALLEY	3	5	37,300	$90,048	$32,859	$1.53
SAVANNA PORTAGE	68	2	66,992	$154,455	$51,997	$1.53
FORT RIDGELY	15	4	37,206	$120,137	$64,032	$1.51
BEAR HEAD LAKE	69	2	72,006	$156,001	$63,621	$1.28
CAMDEN	8	4	91,343	$189,544	$73,103	$1.27
SPLIT ROCK CREEK	45	4	45,404	$75,967	$21,179	$1.21
SCENIC	42	2	84,935	$171,033	$70,592	$1.18
CROW WING	65	3	53,125	$99,180	$37,349	$1.16
C. A. LINDBERGH	10	3	43,193	$71,262	$21,538	$1.15
MC CARTHY BEACH	31	2	106,663	$179,618	$57,744	$1.14
RICE LAKE	95	5	53,694	$87,618	$26,951	$1.13
ST. CROIX	41	3	227,791	$482,075	$232,718	$1.09
CARLEY	78	5	23,310	$34,319	$9,332	$1.07
BLUE MOUNDS	34	4	86,692	$152,109	$60,847	$1.05
BANNING	86	3	62,136	$101,439	$38,152	$1.02

PARK	NO.	REG.	TOTAL ATTENDANCE	BUDGET	REVENUE	NET COST PER VISITOR
HAYES LAKE	99	1	49,777	$76,268	$25,667	$1.02
MINNEOPA	32	4	74,128	$117,193	$42,169	$1.01
SAKATAH LAKE	96	5	58,898	$110,640	$53,079	$0.98
LAKE SHETEK	30	4	111,873	$194,327	$87,376	$0.96
MOOSE LAKE	18	2	38,960	$50,526	$16,992	$0.86
NERSTRAND WOODS	35	5	53,727	$95,255	$51,543	$0.81
MAPLEWOOD	93	1	68,891	$128,726	$74,657	$0.78
WILD RIVER	24	3	158,659	$252,925	$135,698	$0.74
MILLE LACS KATHIO	60	3	123,918	$177,820	$91,042	$0.70
FRONTENAC	62	5	73,300	$119,115	$68,320	$0.69
LAKE BEMIDJI	27	1	120,144	$188,683	$108,263	$0.67
AFTON	89	6	129,181	$158,670	$78,843	$0.62
LAKE BRONSON	28	1	123,762	$147,251	$71,439	$0.61
JUDGE MAGNEY	71	2	64,923	$59,334	$22,516	$0.57
JAY COOKE	22	2	162,713	$238,770	$147,114	$0.56
TETTEGOUCHE	53	2	234,185	$215,777	$84,315	$0.56
WHITEWATER	48	5	185,255	$292,858	$193,168	$0.54
LAKE CARLOS	29	1	128,213	$206,151	$141,174	$0.51
HELMER MYRE	4	5	154,040	$164,971	$92,009	$0.47
CASCADE RIVER	61	2	150,014	$115,078	$53,391	$0.41
TEMPERANCE RIVER	59	2	154,760	$98,280	$52,205	$0.30
FLANDRAU	14	4	241,801	$179,795	$118,537	$0.25
WILLIAM O'BRIEN	49	6	248,660	$252,643	$196,867	$0.22
FATHER HENNEPIN	13	3	272,140	$156,421	$102,496	$0.20
FORESTVILLE	87	5	86,083	$130,265	$114,187	$0.19
INTERSTATE	20	3	401,772	$224,667	$157,792	$0.17
FORT SNELLING	77	6	559,279	$302,341	$211,275	$0.16
SIBLEY	43	4	517,393	$256,592	$173,245	$0.16
GOOSEBERRY FALLS	17	2	678,766	$290,193	$260,940	$0.04
SPLIT ROCK LIGHTHOUSE	83	2	223,650	$180,510	$179,216	$0.01
ITASCA	21	1	501,536	$1,283,678	$1,307,433	($0.05)
Division Totals			7,687,169	$10,457,218	$5,768,983	$0.61

ATTACHMENT

PUMPING FINANCIAL REPORT
HILL ANNEX MINE STATE PARK

This report is mandated by M.L. 1988, Chapter 686, Article 1, Section 11 (k) (see below).

An appropriation of $298,000 for Hill Annex Mine State Park was authorized by the above cited law. See Attachment A.

$270,000 of this appropriation was general fund money and was to be used for pumping costs as identified by the above cited law. The remaining $28,000 of this total appropriation was set up from the dedicated state parks maintenance and operations account (M & O account).

The $28,000 was used for operational needs at Hill Annex Mine State Park. The decision to use the $28,000 for operations was based on the fact this money came from the State Park dedicated M & O account and there was a need to supplement the operational budget for electrical use associated with pumping.

PUMPING LEGISLATION

Laws of Minnesota for 1988, Chapter 686, Article 1, Section 11, (k) Hill-Annex Mine State Park - $298,000

$270,000 of this appropriation is for pumping costs, including the purchase and installation of pumps, pipelines, and associated facilities. The commissioner of natural resources may seek additional matching money from organizations having access to historical preservation money to complement this appropriation. The commissioner of natural resources shall prepare a financial report on the use of this appropriation for the chairs of the house appropriations and senate finance committees no later than January 1, 1990.

$28,000 of this appropriation is from the state parks maintenance and operations account in the special revenue fund. The approved complement of the department of natural resources is increased by two positions.

DETAIL OF EXPENDITURES

Hill Annex Mine Appropriation
M.L. 1988 Chapter 686, Article 1, Section 11 (K)

Pumping Costs	$270,000

First contract - $54,115
This included repairing the existing pipeline, acquisition and placement of a used pump and barge and service road work.

Second contract - $88,816
This included pipeline section replacement, repair and refloat a second barge, fabricate and install walkway to barges, mount pump on barge.

Generator - $45,580
Lower dual fuel Minnesota Power Company - electrical rate.

Engineering Contracts - $25,473
ABE Matthews Mining Engineers, specifications for dewatering systems.

Equipment - $56,213
This included switchgear, MP generator hookup, transformers, switchhouse, shovel cable, service road stabilization, original pump repair.

M & O	$ 28,000

Supplement to the Operational budget directly associated with the electrical costs for dewatering the pit with electric pumps.

Total	$298,000

ADDITIONAL EXPENDITURES

In addition to the expenditure of the $298,000 DNR did meet with a few emergency needs during the construction of the pipeline. An additional $30,000 of operational funds were taken from the Division of Parks and Recreation budget to cover these emergency needs. This money was used to repair ruptured sections of pipe and to stablize pit slopes for safety considerations.

Another $24,000 of staff time was put into this project by using the expertise of park personnel from the Soudan Underground Mine State Park. These dollars are associated with over 1400 hours of labor put into the Hill Annex pumping project.

SAVINGS

Through the expertise of in-house DNR staff, a cost savings of over $253,000 was realized during the purchase of the hardware needs for the pumping project.

ITEM	COST NEW	DNR PAID	SAVINGS
Shovel Cable	$34,250	$16,500	$17,750
(2) Switch Houses	$25,000	$2,000	$23,000
Pump/Barge	$135,000	$10,000	$125,000
(10) Junction boxes	$2,650	$100	$2,550
10KVA Transformer	$450	$175	$275
(3) 330KVA Trans.	$10,500	$6,885	$3,615
(9) Cutouts	$360	$90	$270
(24) Joy plugs	$1,920	$0	$1,920
Generator	$120,000	$45,000	$75,000
Control Panel	$3,200	$0	$3,200
Low Voltage Cable	$900	$360	$540
TOTAL	$334,230	$ 81,110	$253,120

I RANGE RESOURCES AND REHABILITATION BOAF
MINELAND RECLAMATION DIVISION
CALUMET, MINNESOTA

ENERGY STUDY OF THE HILL ANNEX MINE
MARCH, 1984

ABE W. MATHEWS
ENGINEERING CO.
555 W. 27th STREET ■ HIBBING, MN. 55746 ■ 218/262-3465

Pursuant to 1988 Laws, Ch 686, Art 1
section 11(k) Volume 4 of 4 volumes

4. PIT PUMPING STUDY

A. General

The following report summarizes the results of a study conducted for the IRRRB. The object of the study is to explore ways to reduce the costs of maintaining an acceptable water level in the Hill Annex pit using either conventional or non-conventional pumping systems. Fifteen different pumping systems were studied.

Each of the fifteen systems are described in the report along with capital costs and operating costs of each. A recommended system was selected based on lowest capital and operation costs.

B. Pumping Requirements

The water level as of August, 1983 is about 540 feet above Lake Superior. **In order to have access to some points of interest in the pit and an access road to the west part of the pit, the water level should be no higher than 510 feet.** Due to seasonal fluctuations, it is possibly wise to try and maintain a somewhat lower water level to insure that the water level does not exceed 510 feet. It is estimated that 8.5 x 10^8 gallons plus inflow must be pumped to reach 510 feet. **It will take approximately one year, pumping continually at the present rate of 3500 gallons per minute to reach the 510 level.** Most of the pumping systems described herein are design only to maintain a water level and have only limited excess capacity to draw the water level down.

At the 510 foot level, the surface area of the remaining water is 3.13 x 10^6 square feet. That means that for every foot of water change, the amount of water in the pit is changed by 2.34 x 10^7 gallons.

The pumping records of Jones and Laughlin, during the years they mined the Hill Annex, gives an estimate of required pumping capacity. The following table is the record of gallons pumped per year.

Year	Gallons Pumped	Comments
1972	7.718 x 10^8	Pumped only part of year
1973	10.602 x 10^8	
1974	9.471 x 10^8	
1975	11.137 x 10^8	
1976	9.011 x 10^8	
1977	8.402 x 10^8	
1978	6.96 x 10^8	
1979	2.557 x 10^8	Pumped only part of year

The average for the full year pumping years (1973 through 1978) is 9.264×10^8 gallons with a standard deviation of 1.382×10^8 gallons. During these years J & L was pumping to keep the pit mineable at elevation 360 feet. Trying to maintain the water level at the higher elevation of 510 feet, a somewhat lower pumping rate can be expected. How much lower is impossible to determine before the fact. J & L's experience suggests that 95% of the years, pumping demands will be between the quantities of 6.5×10^8 gallons and 12.03×10^8 gallons. (average + 2 standard deviations). To put these numbers in perspective, a pump running continually all year would have to have a capacity of 1800 gallongs per minute to pump 9.3×10^8 gallons, the J & L average.

The pump discharge elevation is 795 feet. Therefore, a pump must pump against an elevation head of 285 feet (795-510) plus line losses. For the sake of this study, it will be assumed that the water level will be kept at an elevation of 500 feet to insure enough freeboard for seasonal fluctuations.

C. Results

The results of the study are summarized in the attached graph (page). The system numbers on the graph refer to the pumping systems described in this report. The system with the lowest combined operation and capital costs is a conventional electric motor driven pump, selected for best possible efficiency. Electric power for this system is to be supplied by MP&L. A new pipeline is required. This system could save $22,700.00 per year in electrical charges over the existing pumping system. The system would have a payback of 6.1 years.

The study also showed that energy savings could be realized if the power rate schedule for the Hill Annex was changed from the current rate schedule 35 to rate schedule 75. This change would save $5,200.00 per year for the existing pumping system. If the change to rate schedule 75 was made in combination with the installation of the lowest cost pumping system, the operator would save $31,800.00 per year over todays pumping costs.

D. Recommendations

Based on the results of this study, it is recommended that the Hill Annex remove the existing pumping system and replace it with **System No. 5,** a new, 2000 GPM pump selected for high efficiency, driven by a new, high efficiency electric motor and a new 18 inch diameter pipeline. It is also recommended that MP&L be requested to change the rate structure under which the Hill Annex is charged from schedule 35 to schedule 75.

If it is the Owner's desire to install a nonconventional pumping system powered by a source other than electric, then it is recommended that the existing pumping system be replaced by System No. 9, a two pump system driven by electric motors. The source of power for one of the motors would be a peat gasification powered, internal combustion engine and generator set.

E. Alternative Pumping Systems

Fifteen different pumping systems were studied. There are the following:

1. The present pump, electric motor and pipeline. Power supply by MP&L.

2. The present pump and electric motor with a larger diameter pipeline. Power supplied by MP&L.

3. A new pump and electric motor selected for highest possible efficiency with the present pipeline. Power supplied by MP&L.

4. An all new pump, electric motor and pipeline system. Pump capacity was 3000 GPM. Power supplied by MP&L.

5. An all new pump, electric motor and pipeline system. Pump capacity was 2000 GPM. Power supplied by MP&L.

6. A new 2000 GPM pump driven by an internal combustion engine running on gasified peat. Pipeline to be new.

7. A new 2000 GPM pump driven by an electric motor. Power for the motor supplied by an internal combustion motor and generator set fueled by gasified peat. Pipeline to be new.

8. A new electric motor powered, 1200 GPM pump plus a 2000 GPM pump driven by an internal combustion engine running on gasified peat. Pipeline to be new. Electric power from MP&L.

9. Two new electric motor powered pumps. One rated for 1200 GPM and one rated for 2000 GPM. Electric power for the smaller pump supplied by MP&L; power for the larger pump supplied by an internal combustion motor and generator set fueled by gasified peat. Pipeline to be new.

10. A new 2000 GPM pump, electric motor, and pipeline system. Same as 5 above but power supplied by wind generators.

11. A new 3000 GPM diesel driven pump and new pipeline.

12. A new 2000 GPM diesel driven pump and new pipeline.

13. A new 2000 GPM electric motor driven pump with new pipeline. Power supplied by a diesel powered generator.

14. A new 4000 GPM pump, electric motor and pipeline. Power supplied by MP&L. Pump to be run on off-peak hours only.

15. Three steam powered pumps rated for a total of 2000 GPM. The steam to be supplied from a peat fired boiler. Pipeline to be new.

Selections of the pumps, motors and pipe diameters are intended to establish order of magnitude performance and costs. Selections are based only on maximum efficiency that would meet the pumping conditions. Style of pump was not a prime selection criteria. Final selections may effect performance or costs slightly.

System No. 1: The current pumping system was evaluated in the current configuration (water level at elevation 540 feet) to establish the present pumping costs. The following is a summary of the current pumping system:

Pump: Ingersoll-Rand Model 8X23SF with 8SF34 impeller, 20.75 inch diameter. Direct drive.

Motor: Westinghouse, 450 HP, 4000 volt, 1775 RPM, frame 588-5-S, 1.15 service factor.

Pipeline: 12 inch diameter, spiral weld steel, 2800 feet long.

Performance: 3500 GPM, 350 feet TDH, 75% pump efficiency, 420 BHP, 93.3% motor efficiency, 336 KW power draw.

The current pump, motor and pipeline were also evaluated at the target water level elevation of 500 feet. When the water level is at 500 feet, the pumping system will be as follows:

Pump: Same as above.

Motor: Same as above.

Pipeline: Same as above.

Performance: 3200 GPM, 380 feet TDH, 77% pump efficiency, 400 BHP, 93.3% motor efficiency, 319 KW power draw, 4823 operating hours per year.

Calculations for the above evaluations were based on the Ingersoll-Rand pump curve, physical layout of the pipeline, and an assumed pipeline friction factor based on Cp=120. During the summer of 1983, the personnel at the Hill-Annex ran five flow measurement tests on the pipeline. The average of the results of these five tests showed that the flow rate is actually 2500 GPM. Based on the measured flow rate of 2500 GPM, the current pumping system was re-evaluated as System No. 1A.

System No. 1A:

Pump: Same as above.

Motor: Same as above.

Pipeline: Same as above.

Performance: 2500 GPM, 425 feet TDH, 78% pump efficiency, 344 BHP, 93% motor efficiency, 276 KW power draw, 6173 operating hours per year.

Discrepancies between the calculated performance of System No. 1 and the measured performance of System No. 1A could be accounted for in a number of ways.

1. The pump curve in this area of pump operation is relatively flat. So a little change in the head will have a large effect on pump output.

2. The assumed pipe roughness factor, Cp, could be too high. The Cp for the measured flow calculates out to 63.

3. It was observed that the pump intake allows air to enter the pump because the end of the suction pipe is not deep enough in the water. Air in the pipeline will reduce the capacity of the pump.

4. The method of measuring the flow is subject to error.

5. Or a combination of several of the above.

System No. 2: This system uses the existing pump and motor. The pipeline is replaced by one with a larger diameter in an effort to reduce the head. The change in head requires a change to a new size impeller. The results of the study are as follows:

Pump: Same as System No. 1 except 20.75 inch diameter impeller is replaced by a 19 inch diameter.

Motor: Same as System No. 1.

Pipeline: 18 inch diameter, polyethylene pipe.

Performance: 3000 GPM, 310 feet TDH, 76% pump efficiency, 309 BHP, 93.3% motor efficiency, 247 KW power draw, 5150 operating hours per year.

System No. 3: In this system the existing pipeline is used with a new pump and electric motor. The pump was selected for highest possible efficiency. The pump is a vertical turbine type. The results of this study are as follows:

Pump: Worthington Model 15H-277 with 4 stages of 10.59 inch diameter impellers. Direct drive. (Vertical turbine pump.)

Motor: 400 HP, 4000 volt, 1760 RPM.

Pipeline: Same as in System No. 1.

Performance: 3100 GPM, 373 feet TDH, 85.5% pump efficiency, 342 BHP, 93.3% motor efficiency, 273 KW power draw, 4980 operating hours per year.

System No. 4: This system was selected to have the same capacity as the existing pumping system but operated with the minimum amount of electricity. The pumps, motors, and pipeline are new. The results of this study are as follows:

Pumps: Worthington Model 8LR-13 with impeller A cut down to 13.63 inch diameter. Two direct drive pumps required in series. (Horizontal split case pump.)

Motors: 150 HP, 460 volt, 1770 RPM.

Pipeline: 18 inch diameter, polyethylene pipe.

Performance: 3000 GPM, 310 feet TDH, 88% pump efficiency, 268 BHP, 95.8% motor efficiency, 209 KW power draw, 5150 operating hours per year.

System No. 5: With this system, the effects on costs of reducing pump capacity to what would be considered minimum were studied. The pumps were selected to give highest efficiency at a capacity slightly over the average pumping requirement. The results of this study are as follows:

Pump: Worthington Model 15M-185, with 3 stages of 10.55 inch diameter impellers. Direct drive. (Vertical turbine pump.)

Motor: 200 HP, 460 volt, 1750 RPM.

Pipeline: 18 inch diameter, polyethylene pipe.

Performance: 2000 GPM, 303 feet TDH, 86% pump efficiency, 178 BHP, 95.8% motor efficiency, 138 KW power draw, 7720 operating hours per year.

System No. 6: In this system the pump was powered by an internal combustion motor. Fuel for the motor is supplied from gasified peat. The gasifier used in this study would produce 33.3 cubic feet of 150 BTU/cu. ft. conditioned gas per pound of dry peat pellets. The results of this study are as follows:

Pump: Worthington Model 15HH-340, with 9 stages of 9.94 inch diameter impellers. Right angle drive, ratio 1:1. (Vertical turbine pump.)

Motor: Caterpillar spark ignition motor Model G379, 240 HP at 1200 RPM.

Pipeline: 18 inch diameter, polyethylene pipe.

Performance: 2000 GPM, 303 feet TDH, 84% pump efficiency, 182 BHP, 23% motor efficiency, 2.018×10^6 BTU/hr. or 13,450 cu. ft./hr. gas consumption, 1560 tons/year peat pellet consumption, 7720 operating hours per year.

System No. 7: This system is similar to System 6. However, in this system, the gasified peat fueled internal combustion engine is used to power a generator. The electric power is used by an electric motor driven pump. This system has the advantage over System 6 in that during shutdowns of the gasifier, the pump can still be run on power from MP&L. Also effected is the pump selection. Selection of the pump for System 6 was limited to 1200 RPM pumps while this system can use a slightly more efficient and less costly 1800 RPM pump. The results of this study are as follows:

Pump: Worthington Model 15M-185, with 3 stages of 10.55 inch diameter impellers. Direct drive. (Vertical turbine pump.)

Motor: 200 HP, 460 volt, 1750 RPM.

Pipeline: 18 inch diameter, polyethylene pipe.

Performance: 2000 GPM, 303 feet TDH, 86% pump efficiency, 178 BHP, 95.8% motor efficiency, 138 KW power draw, 1560 tons/year peat pellet consumption, 7720 operating hours per year.

System No. 8: This system has two pumping systems operating in parallel. The first system is powered on electric motor. This pump would run year round to meet the pumping needs of a minimal pumping year. The second system has a larger pump powered by a gasified peat fueled motor. This system would supplement the first system during heavier demand periods. The results of this study are as follows:

Pump: Electric motor driven pump is a Worthington Model 12H-110 with 6 stages of 8.34 inch diameter impellers. Direct drive. (Vertical turbine pump.) Spark ignition motor was same as System No. 6 above.

Motor: Electric motor is a 125 HP, 460 volt, 1760 RPM. Spark ignition motor same as System No. 6.

Pipeline: 18 inch diameter, polyethylene pipe.

Performance: With electrical pump only. 1200 GPM, 298 feet TDH, 83% pump efficiency, 109 BHP, 95.4% motor efficiency, 85 KW power draw. With both pumps. Electric pump, 1160 GPM, 311 feet TDH, 83.5% pump efficiency, 109 BHP, 95.4% motor efficiency, 85 KW power draw. Spark ignition pump, 1890 GPM, 311 feet TDH, 83% pump efficiency, 179 BHP, 23% motor efficiency, 2.018 x 10^6 BTU/hr. gas consumption, 553 tons/year pellet consumption. Total pumping capacity of 3050 GPM. Operating time for one pump would be 5900 hours per year; for both pumps would be 2740 hours per year.

System No. 9: This system is similar to System 8. Two pumps operate in parallel. One pump to run year round to meet the minimal pumping demand and a second pump to supplement the first during high inflow periods. However, in this system, both pumps are driven by electric motors. Power for the first pump is supplied by MP&L and power to the second pump is supplied by a gasified peat fueled motor generator set. The advantage of the electric motor driven pumps, over the pump used in System 8, is that power for both pumps can be supplied by MP&L should it be required. The gasifier selected is not large enough to power both pumps. The results of this study are as follows:

Pumps: The minimal demand pump is Worthington Model 12H-110 with 6 stages of 8.34 inch diameter impellers. The supplemental pump is a Worthington Model 15HH-340, with 9 stages of 9.94 inch diameter impellers. (Both vertical turbine pumps.)

Motors: The motor for the minimal demand pump is a 125 HP, 460 volt, 1760 RPM. The motor for the supplemental pump is a 200 HP, 460 volt, 1160 RPM.

Pipeline: 18 inch diameter, polyethylene pipe.

Performance: With minimal demand pump only. 1200 GPM, 298 feet TDH, 83% pump efficiency, 109 BHP, 95.4% motor efficiency, 85 KW power draw. With both pumps. Minimal demand pump, 1160 GPM, 311 feet TDH, 83.5% pump efficiency, 109 BHP, 95.4% motor efficiency, 85 KW power draw. Supplemental pump, 1890 GPM, 311 feet TDH, 83% pump efficiency, 179 BHP, 95% motor efficiency, 140 KW power draw, 2.018 x 10^6 BTU/hr. gas consumption, 553 tons/year pellet consumption. Total pumping capacity of 3050 GPM. Operating time for one pump would be 5900 hours per year; for both pumps would be 2740 hours per year.

System No. 10: This system has the pump, motor and pipeline as System No. 5. Power for the pump motor is supplied by 57 wind generators with a rated output of 17.5 KW at 25 MPH (same model as is currently at the Hill Annex).

System No. 11: This system has a diesel powered pump. The diesel is fueled by No. 2 fuel oil. The results of this study are as follows:

Pump: Worthington Model 15HH-340, with 4 stages of 9.94 inch diameter impellers. Right angle drive, ratio 1:1. (Vertical turbine pump.)

Motor: Caterpillar Model 3406, 300 HP at 1800 RPM.

Pipeline: 18 inch diameter, polyethylene pipe.

Performance: 3000 GPM, 311 feet TDH, 84% pump efficiency, 280 BHP, 30% motor efficiency, 17 gal./hr. fuel consumption, 5150 operating hours per year.

System No. 12: This system also has a diesel powered pump. This system's capacity is sized to meet the average pit pumping needs. The results of this study are as follows:

Pump: Same as System No. 5.

Motor: Caterpillar Model 3306, 200 HP at 1800 RPM.

Pipeline: 18 inch diameter, polyethylene pipe.

Performance: 2000 GPM, 303 feet TDH, 86% pump efficiency, 178 BHP, 28% motor efficiency, 12 gal./hr. fuel consumption, 7720 operating hours per year.

System No. 13: This system uses the same pumping system as in System No. 12 above. However, instead of directly coupling the diesel to the pump, the diesel is coupled to an electric generator. The pump is driven by an electric motor. The results of this study are as follows:

Pump: Same as System No. 5.

Motor: Same as System No. 5.

Generator: Caterpillar Model 3406 diesel generator set with reduced voltage starter. 300 KW.

Performance: 2000 GPM, 303 feet TDH, 86% pump efficiency, 178 BHP, 95.8% motor efficiency, 138 KW power draw. 12 gal./hr. diesel fuel consumption, 7720 operating hours per year.

System No. 14: This system was sized to maintain a given water level for an average pumping year when the pump is run only during the off-peak electrical rate hours. MP&L does not currently offer an off-peak rate. The system is included in this report to show that this option was investigated.

System No. 15: This system has two steam driven, positive displacement pumps. The steam for these pumps will be generated by a peat fired boiler. The system is labor intensive because a boiler tender would be required at all times during operation. This system is sized to run three shifts per day, five days per week. The results of this study are as follows:

Pumps: Worthington Model PRL 18 x 12 x 24, two required.

Performance: 2000 GPM, 303 feet TDH, 7500 lb./hr. at 80 PSI steam consumption per pump, 13.5 M BTU/hr., 1800 lb./hr., 6950 tons/year fuel consumption, 7720 operating hours per year.

F. Economic Evaluation

Operating costs for all the systems listed above were determined. These operating costs fall into four categories. They are fuel costs, scheduled maintenance costs, operator costs, and capital costs. Fuel costs were calculated based on the following: Electric costs - MP&L's rate schedule 35; Fuel oil - $1.10 per gallon; Peat pellets - $55.00 per ton. Electrical costs were estimated assuming that the pumps would be run continually for the required number of hours per year

and not run on the basis of pumping part of each month. Rate schedule 35 bills demand charges based on the highest 15 minute load per billing period. Demand charges drop for billing periods that have no pumping. Power costs were calculated with the high voltage discount and fuel adjustments included in the rates. Scheduled maintenance costs were calculated based on the recommended service intervals and costs called for in the Caterpillar Handbook. Operator costs are based on a $12.00 per hour labor rate. Capital costs are based on amortizing the total estimated, installed equipment costs over a twenty year period at an interest rate of 10%. A summary of the study results is given in the attached spreadsheet and graph. All pumping systems were based on a barge mounted pump station. The barge price was based on 14' x 16' x 2' thick steel barge made of structural steel members covered top and bottom with 1/4 inch plate. The barge is protected from freezing by an air bubbler system. The air compressor for that system was sized for 75 cfm at 50 psi. The barge was priced without a pump enclosure. In the systems where a new pipeline is indicated, that pipeline runs to the rim of the pit and discharges in to a ditch. Details of the evaluation are given below.

System No. 1:

Fuel Costs:	Electric charges from MP&L		
	Demand charges	$ 6,730	
	Energy charges	66,890	
	Subtotal	$73,620	
	Air Compressor	2,060	
	Total		$75,680
Scheduled Maintenance:	None		0
Operator Costs:	None		0
Capital Costs:	Barge	$15,000	
	Air compressor	4,000	
	Total	$19,000	
	Amortized cost		$ 2,230
		Total	$77,910

System 1A:

Fuel Costs:	Electric charges from MP&L		
	Demand charges	$ 7,500	
	Energy charges	74,080	
	Subtotal	$81,580	
	Air Compressor	2,060	
	Total		$83,640
Scheduled Maintenance:	None		0
Operator Costs:	None		0
Capital Costs:	Barge	$15,000	
	Air compressor	4,000	
	Total	$19,000	
	Amortized cost		$ 2,230
		Total	$85,870

System No. 2:

Fuel Costs:	Energy charges from MP&L		
	Demand charges	$ 5,970	
	Energy charges	55,250	
	Subtotal	$61,220	
	Air compressor	2,060	
	Total		$63,280
Scheduled Maintenance:	None		0
Operator Costs:	None		0

Capital Costs:	Barge	$15,000	
	Air compressor	4,000	
	Pipeline	100,000	
	Total	$119,000	
	Amortized cost		$13,980
		Total	$77,260

System No. 3:

Fuel Costs:	Energy charges from MP&L		
	Demand charges	$ 5,770	
	Energy charges	59,100	
	Subtotal	$64,870	
	Air compressor	2,060	
	Total		$66,930
Scheduled Maintenance:	None		0
Operator Costs:	None		0
Capital Costs:	Barge	$15,000	
	Pumps	35,000	
	Air compressor	4,000	
	Total	$54,000	
	Amortized cost		$ 6,350
		Total	$73,280

System No. 4:

Fuel Costs:	Energy charges from MP&L		
	Demand charges	$ 5,040	
	Energy charges	46,800	
	Subtotal	$51,840	

	Air compressor	2,060	
	Total		$53,900
Scheduled Maintenance:	None		0
Operator Costs:	None		0
Capital Costs:	Barge	$15,000	
	Pumps	35,000	
	Pipeline	100,000	
	Air compressor	4,000	
	Total	$154,000	
	Amortized costs		$18,100
		Total	$72,000

System No. 5:

Fuel Costs:	Energy charges from MP&L		
	Demand charges	$ 4,580	
	Energy charges	46,320	
	Subtotal	$50,900	
	Air compressor	2,060	
	Total		$52,960
Scheduled Maintenance:	None		0
Operator Costs:	None		0
Capital Costs:	Barge	$15,000	
	Pumps	35,000	
	Pipeline	100,000	
	Air compressor	4,000	
	Total	$154,000	
	Amortized costs		$18,100
		Total	$71,600

System No. 6:

Fuel Costs:	Energy charges from MP&L		
	Demand charges	$ 660	
	Energy charges	6,710	
	Subtotal	$ 7,370	
	Air compressor	2,060	
	Subtotal	$ 9,430	
	Pellet costs for 1560 tons	$85,680	
	Total		$95,110
Scheduled Maintenance:			
	Lubrication	$ 2,320	
	Motor rebuild	3,320	
	Total		$ 5,640
Operator Costs:	1 man, 4 hr./day, 11 months/year		$11,440
Capital Costs:	Barge	$15,000	
	Pump	30,000	
	Motor	82,000	
	Pipeline	100,000	
	Gasifier	250,000	
	Air compressor	4,000	
	Total	$481,000	
	Amortized cost		$56,520
		Total	$168,710

System No. 7:

Fuel Costs:	Energy charges from MP&L		
	Demand charges	$ 5,240	
	Energy charges	9,030	
	Subtotal	$14,270	
	Air compressor	2,060	
	Subtotal	$16,330	
	Pellet costs for 1480 tons	$81,400	
	Total		$97,730
Scheduled Maintenance:			
	Lubrication	$ 2,320	
	Motor rebuild	3,320	
	Total		$ 5,640
Operator Costs:	1 man, 4 hr./day, 11 months/year		$11,440
Capital Costs:	Barge	$15,000	
	Pump	35,000	
	Pipeline	100,000	
	Gasifier	290,000	
	Air compressor	4,000	
	Total	$444,000	
	Amortized cost		$52,170
		Total	$166,980

System No. 8:

Fuel Costs:	Energy charges from MP&L		
	Demand charges	$ 3,320	

	Energy charges	34,310	
	Subtotal	$37,630	
	Air compressor	2,060	
	Subtotal	$39,690	
	Pellet costs for 553 tons	$30,420	
	Total		$70,110
Scheduled Maintenance:			
	Lubrication	$ 820	
	Motor rebuild	1,180	
	Total		$ 2,000
Operator Costs:	1 man, 4 hr./day, 4 months/year		$ 4,160
Capital Costs:	Barge	$15,000	
	Pump	50,000	
	Motor	82,000	
	Pipeline	100,000	
	Gasifier	250,000	
	Air compressor	4,000	
	Total	$501,000	
	Amortized cost		$58,870
		Total	$135,140

System No. 9:

Fuel Costs:	Energy charges from MP&L		
	Demand charges	$ 5,020	
	Energy charges	34,310	
	Subtotal	$39,330	
	Air compressor	2,060	
	Subtotal	$41,390	

	Pellet costs for 553 tons	$30,420	
	Total		$71,810
Scheduled Maintenance:			
	Lubrication	$ 820	
	Motor rebuild	1,180	
	Total		$ 2,000
Operator Costs:	1 man, 4 hr./day, 4 months/year		$ 4,160
Capital Costs:	Barge	$15,000	
	Pump	55,000	
	Pipeline	100,000	
	Gasifier	290,000	
	Air compressor	4,000	
	Total	$464,000	
	Amortized cost		$54,520
		Total	$132,490

System No. 10:

Fuel Costs:	Energy charges from MP&L		
	Demand charges	$ 4,580	
	Air compressors	2,060	
	Total		$ 6,640
Scheduled Maintenance:	None		0
Operator Costs:	None		0
Capital Costs:	Barge	$15,000	
	Pump	35,000	
	Pipeline	100,000	

	Generators	1,768,000	
	Air compressor	4,000	
	Total	$1,922,000	
	Amortized cost		225,840
		Total	$232,480
System No. 11:			
Fuel Costs:	Energy charges from MP&L		
	Air compressor	$ 2,060	
	Subtotal	$ 2,060	
	Fuel oil	96,300	
	Total		$98,360
Scheduled Maintenance:			
	Lubrication	$ 2,890	
	Motor rebuild	2,210	
	Total		$ 5,100
Operator Costs:	1 man, 1 hr./8 op. hrs., 5150 op. hrs./year		7,720
Capital Costs:	Barge	$15,000	
	Pump	30,000	
	Motor	32,000	
	Pipeline	100,000	
	Tank	10,000	
	Air compressor	4,000	
	Total	$191,000	
	Amortized cost		$22,440
		Total	$133,620

System No. 12:

Fuel Costs:	Energy charges from MP&L		
	Air compressor	$ 2,060	
	Subtotal	$ 2,060	
	Fuel oil	101,900	
	Total		$103,960
Scheduled Maintenance:			
	Lubrication	$ 2,890	
	Motor rebuild	2,210	
	Total		$ 5,100
Operator Costs:	1 man, 1 hr./8 op. hrs., 7720 op. hrs./year		11,580
Capital Costs:	Barge	$15,000	
	Pump	30,000	
	Motor	27,000	
	Pipeline	100,000	
	Tank	10,000	
	Air compressor	4,000	
	Total	$186,000	
	Amortized cost		$21,860
		Total	$143,040

System No. 13:

Fuel Costs:	Energy charges from MP&L		
	Air compressor	$ 2,060	
	Subtotal	$ 2,060	
	Fuel oil	101,900	
	Total		$103,960

Scheduled Maintenance:

	Lubrication	$ 2,890	
	Motor rebuild	2,210	
	Total		$ 5,100
Operator Costs:	1 man, 1 hr./op. hrs., 7720 op. hrs./year		11,580
Capital Costs:	Barge	$15,000	
	Pump	35,000	
	Motor/generator	38,000	
	Pipeline	100,000	
	Tank	10,000	
	Air compressor	4,000	
	Total	$202,000	
	Amortized cost		$23,740
		Total	$144,920

System No. 14:

System could not be priced because MP&L does not offer an off-peak power rate.

System No. 15:

Fuel Costs:	Energy charges from MP&L		
	Air compressor		$ 2,060
	Peat costs - 6950 tons/year		382,250
Scheduled Maintenance:	None		0
Operator Costs:	1 man/shift, 15 shifts/week, 52 weeks/year		74,880
Capital Costs:	Pump structure	$30,000	
	Pumps	300,000	

Boiler	8,000	
Pellet storage and handling	30,000	
Steam line	40,000	
Pipeline	100,000	
Total	$508,000	
Amortized cost		$59,690
	Total	$518,880

G. Alternate Rate Schedule

As mentioned, the operating costs of the above systems were estimated based on MP&L's rate schedule 35. This is the rate schedule MP&L currently uses to charge the Hill Annex for their power. The operating costs for System No. 1 and No. 5 were estimated using MP&L's rate schedule 75.

Rate schedules 35 and 75 differ in the following ways:

1. The demand charge rate is higher under schedule 75 than schedule 35.

2. The energy charge rate is lower under schedule 75 than schedule 35.

3. Demand charges under rate schedule 75 are based on the highest 15 minute use during the previous 11 months and are billed if power is used (i.e. pumps run) or not. Demand charges under rate schedule 35 are based on the highest 15 minute use during the billing period. Demand charges billed can drop dramatically when power usage for the billing period is low (i.e. pumps not run).

Minnesota Power's rate schedules 35 and 75 are attached.

The results of this study are as follows:

System No. 1:

Fuel Costs: Electric charges from MP&L (schedule 75)

Demand charges	$24,660
Energy charges	43,760
Subtotal	$68,420

Air compressor	1,230	
Total		$69,650
Other Costs (Unchanged):		$ 2,230
	Total	$71,880

Note that the difference between the costs under rate schedule 35 ($77,910) and rate schedule 75 ($71,880) is a savings of $6,030.

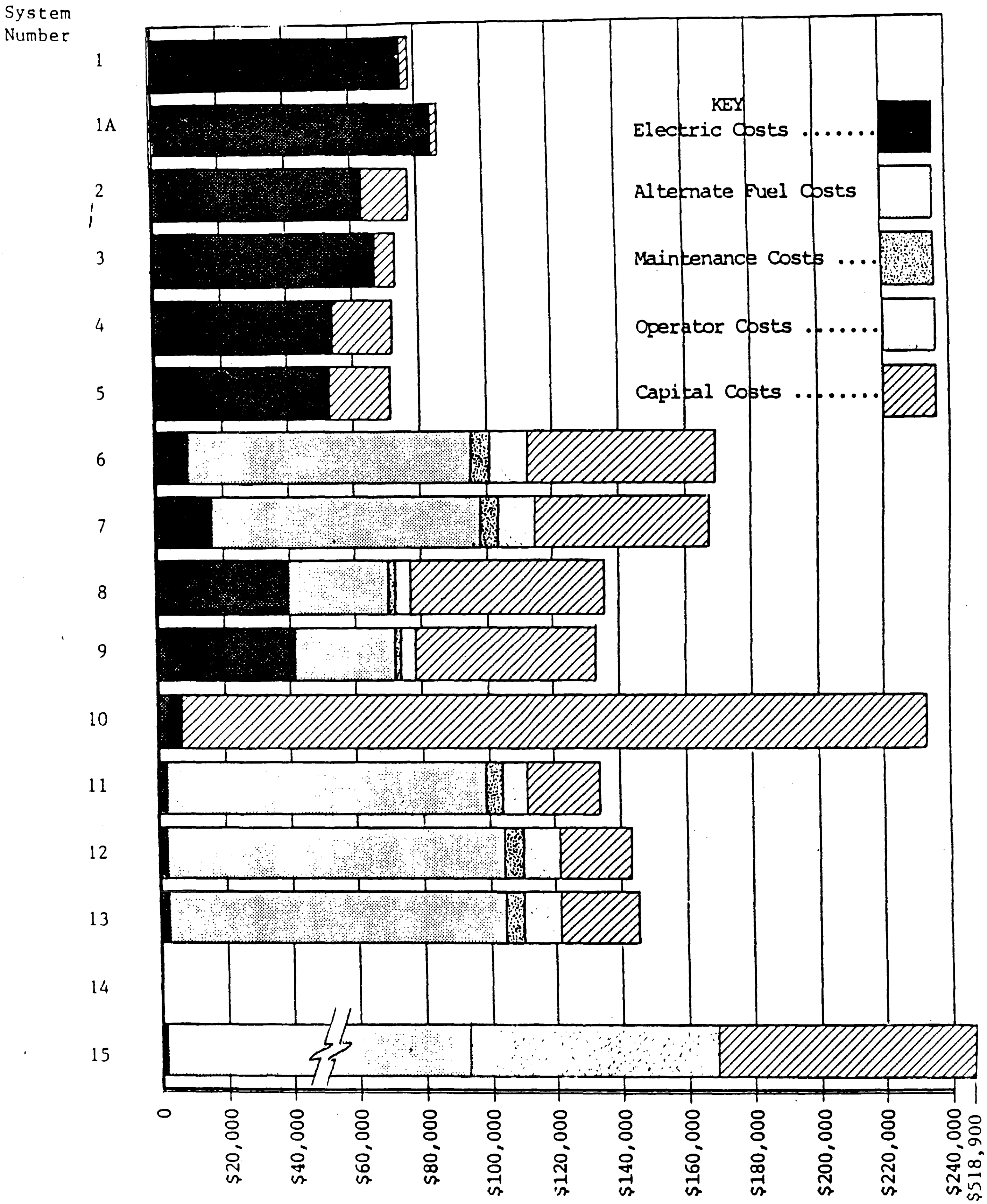
System No. 5:

Fuel Costs: Electric charges from MP&L (schedule 75)

Demand charges	$11,520	
Energy charges	30,300	
Subtotal	$41,820	
Air compressor	1,230	
Total		$43,050
Other Costs (Unchanged):		$18,100
	Total	$61,150

Note that the difference between the costs under rate schedule 35 ($71,600) and rate schedule 75 ($61,150) for this system is a savings of $10,450.

COSTS PER YEAR FOR THE 16 PUMPING SYSTEMS STUDIED



HYDROLOGY STUDY

HILL-ANNEX MINE

Prepared for
IRON RANGE RESOURCES AND REHABILITATION BOARD

MAY 1987

BARR ENGINEERING CO.
Minneapolis, Minnesota

HILL-ANNEX MINE
HYDROLOGY STUDY

TABLE OF CONTENTS

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

Philip B. Solseng

Date: 6/22/87 Reg. No. 12465

HYDROLOGY STUDY OF HILL-ANNEX MINE

FOR

IRRRB

CALUMET, MINNESOTA

INTRODUCTION

In accordance with our proposal we have performed a hydrologic investigation of the Hill-Annex Mine watershed for the purpose of minimizing the pumping costs. We also investigated the non-pumping option of allowing the water to rise in the mine and evaluated the damage caused by erosion from the rising water levels and the cost of providing erosion protection measures along the mine pit wall.

Background

Prior to 1979, the Hill-Annex Mine and the adjacent mines, Gross-Marble (includes Hill-Trumbull) and Arcturus Mines, as shown on Figure 1, were kept dewatered for mining purposes. By 1981 all mining operations had ceased operations and the open pit mines began filling with water. The IRRRB purchased the Hill-Annex Mine for recreational purposes and began regular pumping in 1983. The intent was to keep the water level in the Hill-Annex mine at a level that would allow tourists to view the open pit mine.

Between the period of 1983 to November of 1986 the water surface in the Hill-Annex Mine was kept between elevations 1130 and 1150 MSL by pumping during the non-winter months. The quantity of water pumped annually was slightly less than the annual inflow quantity so the water level slowly increased at a rate of approximately 5 feet per year. In the meantime the adjacent mines were not being pumped and their water levels increased substantially above the water level in the Hill-Annex Mine. The Arcturus Mine, Gross-Marble Mine and the Hill-Annex Mine are separated by rock ledges at the elevations shown on Figure 1 so that overland flow between the Mines did not occur until November, 1986. Therefore prior to November, 1986, the water being pumped from the Hill-Annex Mine was coming from the local watershed and groundwater primarily from the Gross-Marble Mine.

In November, 1986, the water in the Gross-Marble Mine had risen to an elevation such that it overflowed into the Hill-Annex mine. The quantity of water required to be pumped now includes water from the Gross-Marble Mine Watershed and groundwater from the Arcturus Mine. The water level in the Arcturus Mine is still below the overflow elevation. At some future period if not controlled, water will connect the mines and probably discharge into Big Diamond Lake located west of the Arcturus Mine shown on Figure 1.

SUMMARY

The current annual cost of pumping from the Hill-Annex Mine is approximately $80,000 per year to pump 1,700 acre-feet of water. Past pumping costs were on the order of $50,000 per year but not all the inflow was being pumped. The inflow of water will increase to approximately 3,400 acre-feet of water per year and the cost to keep the mine dewatered at Elevation 1132 MSL will be about $160,000 if the present system is used and nothing is done to prevent the inflow of water.

The option with the least capital cost is controlling the water levels in the Hill-Annex Mine, Gross-Marble Mine and the Arcturus Mine with a system of pumps and pipelines. This option is shown on Figure 2. The water level in each of the mines will be kept below their overflow elevations of 1267 MSL for the Arcturus and 1215 MSL for the Gross-Marble. The Hill-Annex Mine will be at Elevation 1132 MSL. Three (3) pumping systems will be required and will cost approximately $500,000. The annual pumping cost will be $100,000.

Alternatively, constructing a dike between the Gross-Marble and the Hill-Annex Mine will keep the annual inflow into the Hill-Annex Mine at about 1,700 acre-feet. This option involves constructing the dike to Elevation 1270 feet, MSL and pump water from the Hill-Annex Mine over the dike and into the Gross-Marble Mine. This option is shown on Figure 3. When the water in the Gross-Marble Mine is near Elevation 1267 MSL the Arcturus Mine will be connected by water to the Gross-Marble and a pumping system can then be installed in the Arcturus Mine to pump the water into Big Diamond Lake and the Swan River Watershed. The cost for the dike is estimated to be approximately $500,000 and each pumping system is expected to cost $150,000. The total capital cost is estimated to be $800,000. The annual pumping cost is estimated to be $90,000 per year.

Annual pumping costs can be reduced further if the inflow of water is intercepted before it flows into the mines. At the Hill-Annex Mine, the annual inflow can be reasonably reduced to about 75 percent of its current amount by constructing ponds, canals and pump stations along the crest and installing shallow groundwater wells at locations of concentrated seepage. This is shown on Figures 2 and 3. The cost of constructing the diversion structures and installing groundwater wells is estimated to be in the range of $50,000 to $100,000. The annual savings in pumping costs is approximately $9,000. Similar water control measures are presumably available for the Gross-Marble and the Arcturus Mines, as well.

If the water level is not controlled, the water is expected to reach approximately Elevation 1365± MSL and flow into Big Diamond Lake. Since the bedrock is below Elevation 1365 the water will be against the overburden material and severe erosion of the overburden is expected as shown on Figure 4. At the Hill-Annex Mine where the bedrock is about Elevation 1300, the property within 200 feet of the existing mine crest may be in jeopardy. The economic damage for the existing development along the Hill-Annex Mine is potential loss of the IRRRB offices and museum and approximately 40 acres of land. Another concern is the poorer water quality in the mines resulting from the erosion. The economic damage along the other mines was not evaluated.

Erosion can be prevented by using slope stabilization methods along the pit wall. The cost of reshaping just the south side of the Hill-Annex

Mine and providing erosion protection along the water line is estimated to be approximately $1,500,000.

TECHNICAL ANALYSIS

Methodology

Pumping costs are directly proportional to the quantity of water pumped and the pumping head (vertical distance of pumping plus friction losses). The pumping costs are reduced if the quantity of water to be pumped is reduced and if the pumping head is reduced. Therefore, the objective of the investigation is to evaluate methods to reduce the quantity of water to be pumped and to minimize the pumping head.

The quantity of water in the mine can be reduced by minimizing the flow of water into the mine from the surrounding watershed. A watershed yield analyses was made to determine how much water was coming from the surrounding watershed. Based on this, a determination of methods to control the inflow of water can be evaluated.

The pumping head is minimized at areas of lower elevation. Since the topography of the land slopes down from east to west, the lowest point for pumping is on the west end of the mine.

Watershed Yield Analysis

The watershed yield was determined by Meyer's Method transferred from calculations of a nearby watershed with similar characteristics. Yield is defined as the difference between precipitation which falls on the watershed and losses from the watershed to the atmosphere. It includes recharge of groundwater as storage and as groundwater flow quantity but does not predict when or where the water will appear.

The Hill-Annex watershed is shown on Figure 1. The watershed boundary was defined by using U.S.G.S. maps and visual inspection. The subwatersheds were identified by visual inspection as areas that appear to common discharge point as in areas 1 through 6 or are landlocked as 7 and 8. Areas 9 and 10 are within the mine pit boundary. A more detailed topographic map would allow a more accurate determination of the watershed boundary. The Hill-Annex Mine watershed yield does not include the surface water inflow from the Gross-Marble Mine which started to discharge overland into the Hill-Annex Mine on October 31, 1986 at an average rate of 1.5 cfs (November through February average).

The average annual yield from the watershed is shown on Table 1. Table 1 presents the subwatershed descriptions, their area in acres, the average annual precipitation in Grand Rapids, the estimated evaporation and transpiration and the yield in inches of runoff. The annual volume yield into the mine is calculated from the yield of runoff times the land area. The total volume into the mine represents the average annual pumping quantity that will have to be maintained in order to have the water level remain approximately stable.

The estimated yield from the Hill-Annex Mine watershed, assuming the groundwater watershed is the same as the surface water watershed, is 1,150 acre-feet per year. An additional 550 acre-feet of water is entering as groundwater from outside the surface water watershed.

For purposes of clarification the additional inflow in the amount of 550 acre-feet into the mine was estimated by comparing the measured inflow with the calculated inflow and attributing the difference to groundwater flow from outside the Hill-Annex Mine watershed. However, much less evaporation may also be contributing to the difference. For the period of November 1, 1983 through October 31, 1986 the yield using Meyer's Method averaged 1,385 acre-feet per year and the measured inflow quantity averaged 1,941 acre-feet per year. The difference is 556 acre-feet per year average additional inflow. The measured volume was made using Figures 5 and 6 which were derived from available data. Figure 5 shows the water stage and pumped volume since 1980. Figure 6 shows the stage volume curve for the Hill-Annex Mine. Evaporation from the lake and dumps within the mine was decreased from normal lake evaporation values by assuming a 50 percent decrease in wind velocity. Adjustments to the evaporation for la temperature differences was not made.

The Gross-Marble is currently discharging into the Hill-Annex Mine as of October 31, 1986 and eventually water from the Arcturus Mine will flow into the Hill-Annex Mine as well. The total yield from The Gross-Marble and Arcturus Mines is expected to be in the range of 1,700 acre-feet per year. This is based on annual pumping records from the mining companies as shown on Table 2 and multiplying the average pumping volume by 60 percent to account for evaporation and less head for groundwater flow.

The results shown on Table 1 mean that approximately 3,400 acre-feet or approximately 2,100 gpm is required to be pumped on an annual basis if flow from the Gross-Marble continues. Fluctuations will occur due to annual variations in precipitation and evaportranspiration.

Based on the hydrologic study, the following can be concluded:

1. Subwatershed areas 1 through 6 contribute approximately 290 acre-feet per year to inflow as surface water flow and groundwater flow. Approximately 100 acre-feet per year of the 290 acre-feet enters as overland flow so that elimination of all overland flow from the Hill-Annex Mine subwatershed areas 1 through 6 into the Hill-Annex Mine decreases the pumping requirements by approximately 100 acre-feet. Groundwater flow from subwatershed areas 1 through 6 is not concentrated and would be difficult to intercept.

2. Subwatershed areas 7 and 8 contribute approximately 280 acre-feet per year to inflow as groundwater flow only. Reducing seepage from the Hill-Annex Mine subwatershed areas 7 and 8 is only reasonable along the southeast corner in area 8 where flow is concentrated and yields approximately 260 acre-feet per year.

3. Subwatershed areas 9 and 10 are inside the mine pit boundary and the only water losses are by evaporation and transpiration.

Evaporation and transpiration rates are currently greatly reduced at the Hill-Annex Mine due to a decreased velocity in the wind, lower water temperatures and lack of vegetation. Increasing the evaporation inside the mine boundary would reduce the pumping requirements, but is probably not feasible.

4. The groundwater inflow from other watersheds is approximately 550 acre-feet per year, and most of it is believed to be from the Gross-Marble Mine. Minimizing seepage from the Gross-Marble Mine will decrease the pumping requirements however, effective seepage cutoffs may be difficult to construct.

5. Stopping overland flow from the Gross-Marble Mine into the Hill-Annex Mine will eliminate future pumping requirements. Based on short-term measurements, the current flow is estimated to be approximately 1,100 acre-feet per year. However, eventually this rate is expected to be approximately 1,700 acre-feet per year when the Arcturus Mine fills with water. A detailed study of the Gross-Marble and Arcturus Mines is needed to verify the quantity of flow.

Water Control Options

Water control options involve methods to reduce the pumping requirements assuming the mine is dewatered to its desired elevation of 1132 MSL which is approximately elevation 530 Lake Superior datum. Pumping requirements can be reduced by using methods to reduce the quantity of water pumped or reduce the pumping head. The cost of pumping is determined from the equation:

pumping cost = (0.275) (Q)(H)

where: Q is the quantity of water pumped in gallons per minute and
H is the head pumped in feet.

The methods identified to reduce the pumping requirements and the cost reductions are as follows:

1. Control Overland Flow From Hill-Annex Mine Watershed: - Overland flow into the mine occurs only as a result of storm events and snowmelt. The estimated surface water inflow is about 100 acre-feet per year and can be controlled by the following methods.

   a. Storage ponds along the crest of the mine with intermittent pumping of the water to areas outside the watershed. The pumping head is reduced by approximately 240 feet. The capital costs include installing a new pump and pipelines, constructing storage basins and performing grading for drainage.

   b. Dikes and canals diverting water to another watershed. The capital costs include constructing the dikes and canals and performing the necessary grading to ensure proper drainage.

   The reduced pumping head of 240 feet for 100 acre-feet of water per year will reduce the current pumping cost by approximately $4,000 per year. The capital costs involved with constructing these control methods are estimated to be in the range of $10,000 to $50,000.

2. Control Groundwater From Hill-Annex Mine Watershed: - Groundwater inflow from the watershed into the mine occurs as general non-point seepage which is difficult to intercept except along the southeast corner where a dip in the bedrock collects groundwater before it discharges into the mine. The estimated flow from this area is 260 acre-feet per year. Shallow wells in this area will reduce the pumping head from approximately 260 feet to 150 feet. The capital costs include installing wells, pumps and pipeline. Implementing groundwater flow control methods will reduce the pumping head by 110 feet for 260 acre-feet per year and the pumping cost will be reduced by approximately $5,000 per year.

3. <u>Control Flow From Gross-Marble</u>: - Controlling the flow from the Gross-Marble can be accomplished by either pumping from the Gross-Marble to keep it below the overflow elevation or constructing a dike between the Hill-Annex Mine and the Gross-Marble Mine to stop the flow. The two methods are discussed as follows:

   a. Pumping the Gross-Marble Mine also implies eventually pumping from the Arcturus, since this will eventually overflow the Gross-Marble Mine. The outflow water levels in the Hill-Annex Mine, Gross-Marble Mine and Arcturus Mine are 1132 MSL, 1215 MSL and 1267 MSL, respectively. The estimated total quantity of water required to be pumped is 3,400 acre-feet per year to Elevation 1365 MSL. Instead of pumping all 3,400 acre-feet of water at the Hill-Annex Mine, under a head of 233 feet, 1,700 acre-feet is assumed to be pumped 233 feet, 1,300 acre-feet is pumped 150 feet and 400 acre-feet is pumped 98 feet on an annual basis. This method is shown on Figure 2.

   Controlling the water levels in the Gross-Marble and Arcturus Mines and pumping from the Arcturus Mine will reduce the pumping cost by approximately $60,000 per year due to the reduced pumping head. A 10-foot deep canal on the west end of the Arcturus Mine reduces the pumping cost an additional $5,000 per year but capital costs are necessary to construct the canal. A canal deeper than 10 feet is not be reasonable since Big Diamond Lake may drain into the mine if the canal is deeper.

   b. Constructing a dike between the Hill-Annex and the Gross-Marble Mines may require a dike to the elevation of the stabilized water level. Based on groundwater elevations from the Hydrologic Atlas the surrounding groundwater elevation are approximately 1400 MSL. The water elevation reported in the wells during mining operations in the year 1924 was approximately 1300 MSL. The water level is expected to stabilize at Elevation 1365 MSL, which is the low elevation on the Arcturus Mine. This is about 25 feet higher than the lakes located south of the Hill-Annex Mine and 50 to 75 feet above the bedrock. A top of dike elevation of 1365 MSL requires the dike to be 150 feet high and 2,300 feet long. The estimated quantity of fill is 4.4 million yards.

The cost of placing 4.4 million yards of fill is over $10 million and is not considered feasible. However, it may be feasible is construct a lower dike and controlling the water level in the Gross-Marble and Arcturus Mine at a higher level. This also reduces the pumping head. A dike approximately 50 feet high between the Gross-Marble and the Hill-Annex Mines allows the Gross-Marble and Arcturus Mines to be connected with water, as shown on Figure 3. A 50-foot high dike is estimated to require 150,000 cubic yards of material and cost less that $500,000. The pumping costs will be reduced by $70,000 due to the reduced pumping heads.

4. <u>Control Groundwater Flow From Gross-Marble Mine</u>: - Groundwater from the Gross-Marble Mine may be partially controlled by seepage cutoffs or wells.

   a. A seepage cutoff entails a grout curtain or slurry wall to bedrock.

   b. Shallow wells could be installed to intercept the water before it reaches the Hill-Annex Mine. However, it may be just as practical to pump the seepage water directly from the Hill-Annex Mine.

Groundwater flow from the Gross-Marble Mine cannot be totally eliminated and is only applicable if the overland flow is controlled. If the total additional flow from outside of the Hill-Annex Mine Watershed is 550 acre-feet and all of it is from the Gross-Marble, and if it were successfully cut-off, the savings in pumping cost would be approximately $25,000 per year. However, a more reasonable estimate is that 50 percent is cutoff and the saving in pumping cost would be reduced to approximately $12,500 per year.

Summary of Water Control Options

Table 3 is a summary of the water control options. It lists the options, the annual savings in pumping costs and the estimated pumping cost assuming 3,400 acre-feet of water is needed to be pumped. Table 3 also shows a range of capital costs for implementing the water control option. The capital costs include the pump and pipelines necessary to keep the Hill-Annex Mine dewatered.

A previous study by the Abe Mathews Engineering Co. dated March, 1984 lists the capital costs for a pumping system at $154,000. Pumping System No. 5 was used in the capital cost computations on Table 3 which lists the costs as follows:

Barge	$15,000
Pumps	35,000
Pipeline	100,000
Air Compressor	4,000
	$154,000

The cost of the pumps and the pipeline are highly variable and depend upon, among other things, the period of time when pumping occurs. For cost estimating purposes, the figures provided in the Abe Mathews study was assumed to apply for each pumping system in the alternatives shown on Figures 2 and 3.

The economic feasibility of the options are highly dependent upon the life of the project, the interest return on the money and the increased revenue if the pit remains dewatered.

Slope Stabilization Alternative

Stabilizing the pit walls along the Hill-Annex Mine involves providing erosion protection along the water level and reshaping the slope. The south side of the mine is the most developed and presumably would derive the most benefit from the stabilization method. The south side is also the most unstable because of its steepness. The cost for stabilizing the entire south side of the Hill-Annex Mine is estimated to be in the range of $1.5 to $2 million. This is based on the reclamation costs for similar projects.

Do Nothing Alternative

If the water is allowed to rise in the mine without control and if the mine walls are not stabilized, it can be expected that severe erosion will occur and result in loss of property, utilities, land and perhaps poor water quality in the mine, especially during storm events and snowmelt. The damage cost is difficult to assess and depends upon the value one puts on this property and land. However, if the pit were stabilized or the water level controlled, the value of the property may increase. If the pit were not stabilized the value of the property is expected to decrease.

The quantity of land along the south side within 200 feet of the mine crest may be in jeopardy and amounts to approximately 40 acres. The closest property to the mine are the IRRRB offices and museum which would be in a marginal area for safety. The damage value is estimated to be less than $1,000,000 for the property and land. Future losses may be incurred due to the unsuitability of the site for industrial development or residential homes. The assessment of this is beyond the scope of this study.

Conclusion

The purpose of this study was to provide basic information to assess the cost of keeping the Hill-Annex Mine dewatered. The flow into the Hill-Annex Mine is approximately 1,700 acre-feet per year and will increase to approximately 3,400 acre-feet per year when the adjacent mines are filled with water. The water in the mines will rise to approximately Elevation 1365 and then overflow into Big Diamond Lake if not controlled. The mine walls will erode and result in unstable mine pit walls if nothing is done to stabilize the walls or control the water.

Options to control the immediate inflow consist of diversion structures and groundwater pumping systems on the crest which will decrease the inflow from 1,700 acre-feet per year to approximately 1,300 acre-feet per year. The cost for the diversion structures and groundwater pumping systems is between $50,000 to $100,000 and pumping costs are reduced by $10,000 per year.

Options to control the water levels from the adjacent mines all involve pumping systems to control the water level in all the mines. The cost for three separate pumping systems in each of the mines is approximately $500,000. The pumping costs are reduced by $60,000 per year by pumping from the Arcturus Mine versus the Hill-Annex Mine. One pumping system can be eliminated if a dike is constructed between the Hill-Annex Mine and the Gross-Marble Mine. The cost for the dike is $500,000 and the two pumping systems cost $300,000 for a total capital cost of $800,000. The pumping costs are reduced by $70,000 per year by pumping from the Arcturus Mine with a water level at Elevation 1267 MSL versus pumping from the Hill-Annex Mine at water Elevation 1132 MSL.

If the water levels are not controlled in the mines, the water level is expected to reach Elevation 1365 and overflow into Big Diamond Lake on the west end. The mine walls will erode and result in unstable pit walls.

The cost to stabilize the mine pit walls on the south side of just the Hill-Annex Mine is estimated to be $1.5 to $2 million.

Utilization of the mine water is a consideration when evaluating the options. Methods to use the pumped water or maintain the water quality are important issues. The cost of pumping to control the water levels or the cost of reclaiming the pit walls may be off-set by better utilization of the water. The utilization of the water is beyond the scope of this study, but should be addressed when reviewing the options.

ACKNOWLEDGEMENTS

Much data was collected and analyses made during this study which are not included in this report. Data collected consists of maps, water level readings, pumping records, geology and field observations of the mine pit. Mr. William Betzler provided valuable information about sources of information. Pumping records were obtained from the IRRRB and the DNR Division of Waters. Maps were collected from the IRRRB, U.S. Diversified Group, the DNR, and the Great Northern Iron Ore Properties. Aerial photos of the site during different time periods are available. Also, IRRRB personnel have been very helpful in furnishing water levels and flow measurements during the year. The assistance of all those involved with providing information is appreciated.

TABLE 1

AVERAGE ANNUAL YIELD INTO HILL-ANNEX MINE

A. Subwatershed Description	Area (acres)	Prec. (in)	Evap. (in)	Transp. (in)	Yield (inches)	Volume Yield Per Year (ac-ft)
1. Dumps & Roads	31	26.76	9.14	--	17.62	50
2. Dumps & Roads	74	26.76	9.14	--	17.62	110
3. Upland	28	26.76	9.82	6.71	10.23	20
4. Upland	57	26.76	9.82	6.71	10.23	50
5. Upland	28	26.76	9.82	6.71	10.23	20
6. Upland	49	26.76	9.87	6.81	10.23	40
7. Upland	28	26.76	9.82	6.71	10.23	20
8. Dumps	178	26.76	9.14	--	17.62	260
9. Dumps	295	26.76	7.00	--	19.76	490
10. Lake	125	26.76	18.00	--	8.76	90
TOTAL	893				Subtotal	1,150

B. Groundwater flow from other watersheds		550
	TOTAL	1,700 Ac-Ft
C. Overland flow from Gross-Marble and Arcturus		1,700
		3,400 Ac-Ft

TB1HA/334,0

TABLE 2

ANNUAL PUMPING RECORDS

Year	Hill Annex (ac-ft)	Gross Marble (ac-ft)	Arcturus (ac-ft)	Total (ac-ft)
73	3,255	2,627	0	5,882
74	3,327	3,183	0	6,510
75	3,417	2,567	0	5,984
76	2,767	2,112	342	5,221
77	2,580	2,245	899	5,724
78	2,136	2,334	743	5,213
79	785	72	1,321	2,178
80	0	306	1,143	1,449
81	401	311	1,259	1,971
82	0	0	0	0
83	1,404	0	0	1,404
84	1,631	0	0	1,631
85	1,051	0	0	1,053
86	1,126	0	0	1,126

TABLE 3

WATER CONTROL OPTIONS

Option	Annual Savings in Pumping Costs	Estimated Pumping Costs	Estimated Capital Costs *1
1. Pumping from Hill-Annex assuming 3,373 acre-feet per year	0	$160,000	0
2. Controlling overland flow from Hill-Annex Mine watershed	$ 4,000	156,000	$10,000-50,000
3. Controlling groundwater flow from S.E. corner of Hill-Annex Mine with wells	5,000	155,000	$25,000-75,000
4. Controlling water levels in the Hill-Annex, Gross-Marble and Arcturus Mines with pumping			
a. with a canal for outflow	65,000	95,000	$530,000
b. without a canal	60,000	100,000	500,000
5. Controlling overland flow from Gross-Marble Mine with dike			
a. dike elevation at ultimate water level elevation 1375 MSL	80,000	80,000	$8 to 15 million
b. dike elevation at overflow elevation of Arcturus Mine elevation 1267 MSL	70,000	90,000	$800,000
6. Controlling groundwater from Gross-Marble Mine	25,000	*2	*2

*1 Estimated capital costs include pumps and pipleines necessary to keep the Hill-Annex Mine dewatered. A previous study indicates that the capital cost for a new Barge, pumps, pipeline and air compressor is approximately $154,000 assuming 2000 gpm is pumped from the Hill-Annex mine with a TDH of 303 feet.

*2 This option is probably only feasible if overland flow from the Gross-Marble is controlled.

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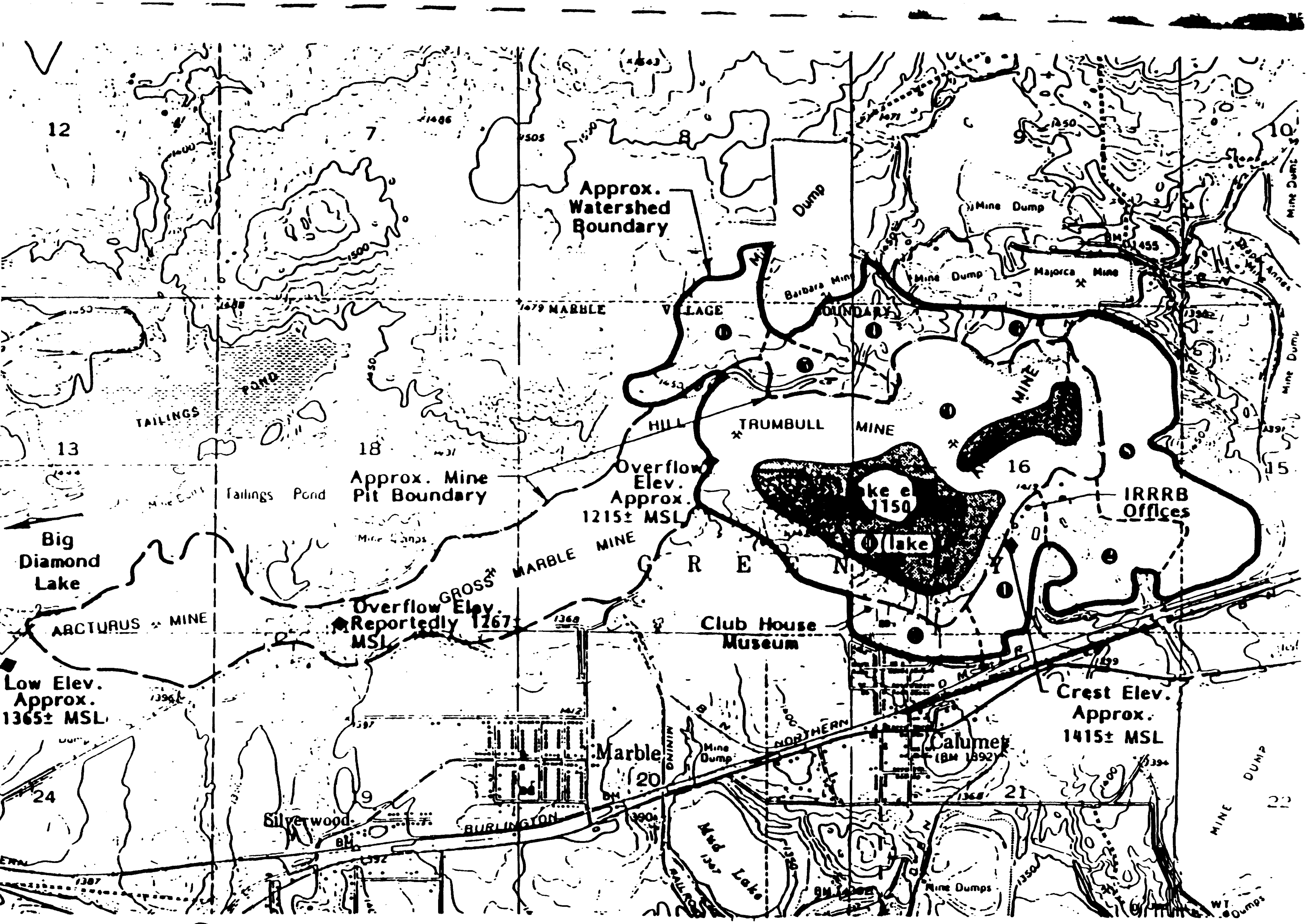

0 2000 4000

Scale in Feet

➊ Subwatershed Designation

Figure 1

LOCATION MAP
HILL-ANNEX MI.

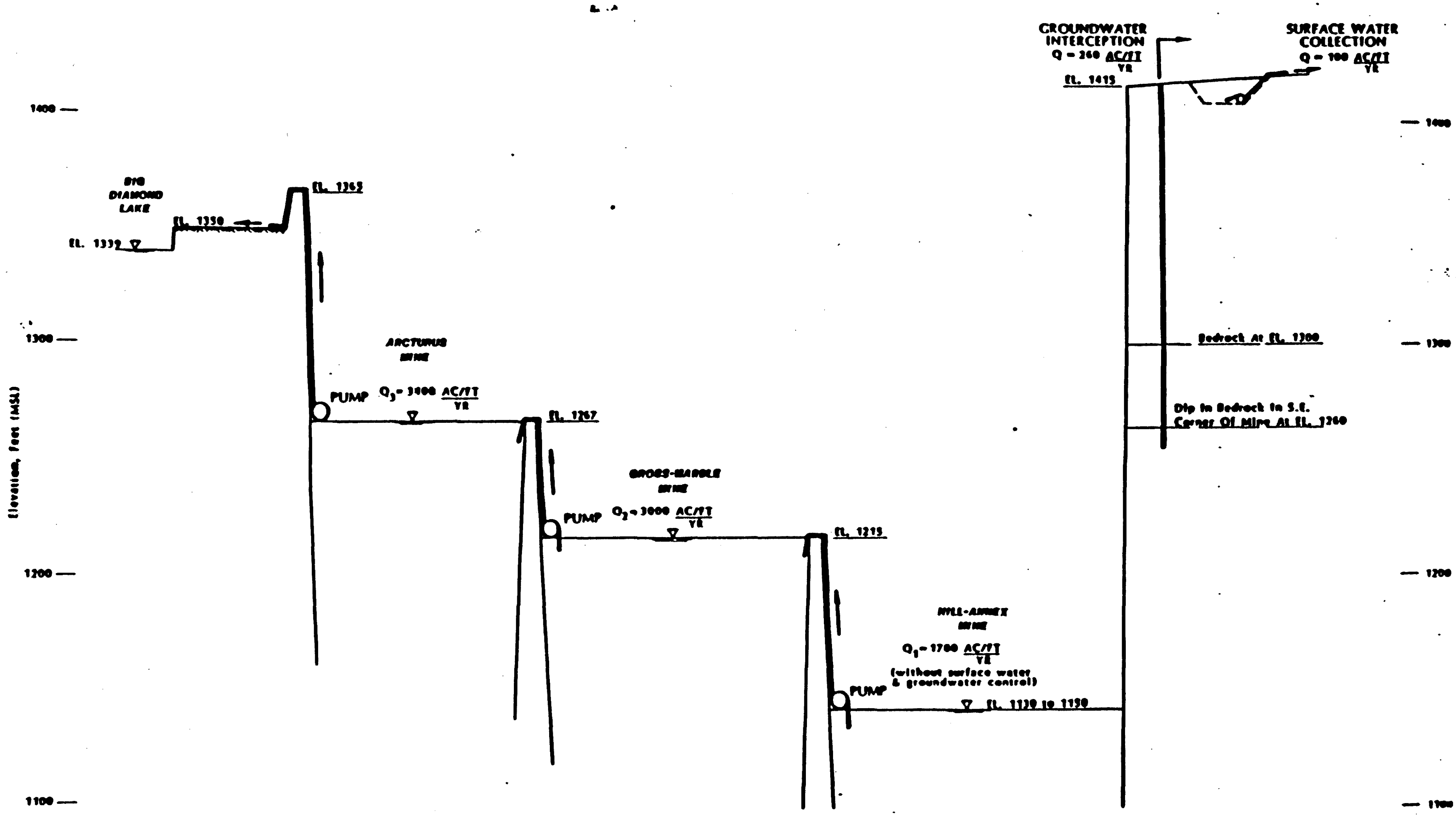

Figure 2
OPTION A - PUMPING SYSTEM

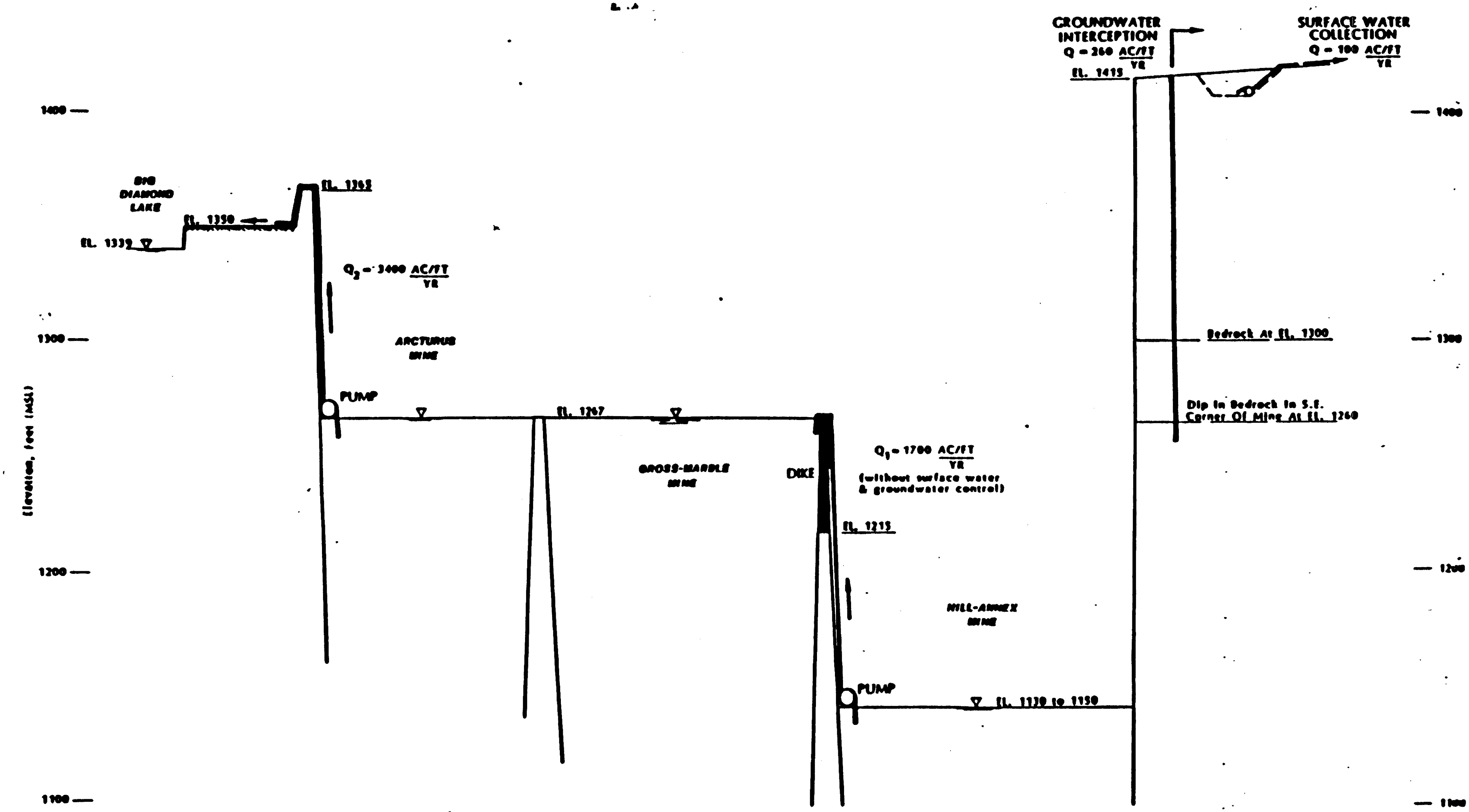

Figure 3
OPTION B - PUMP & DIKE SYSTEM

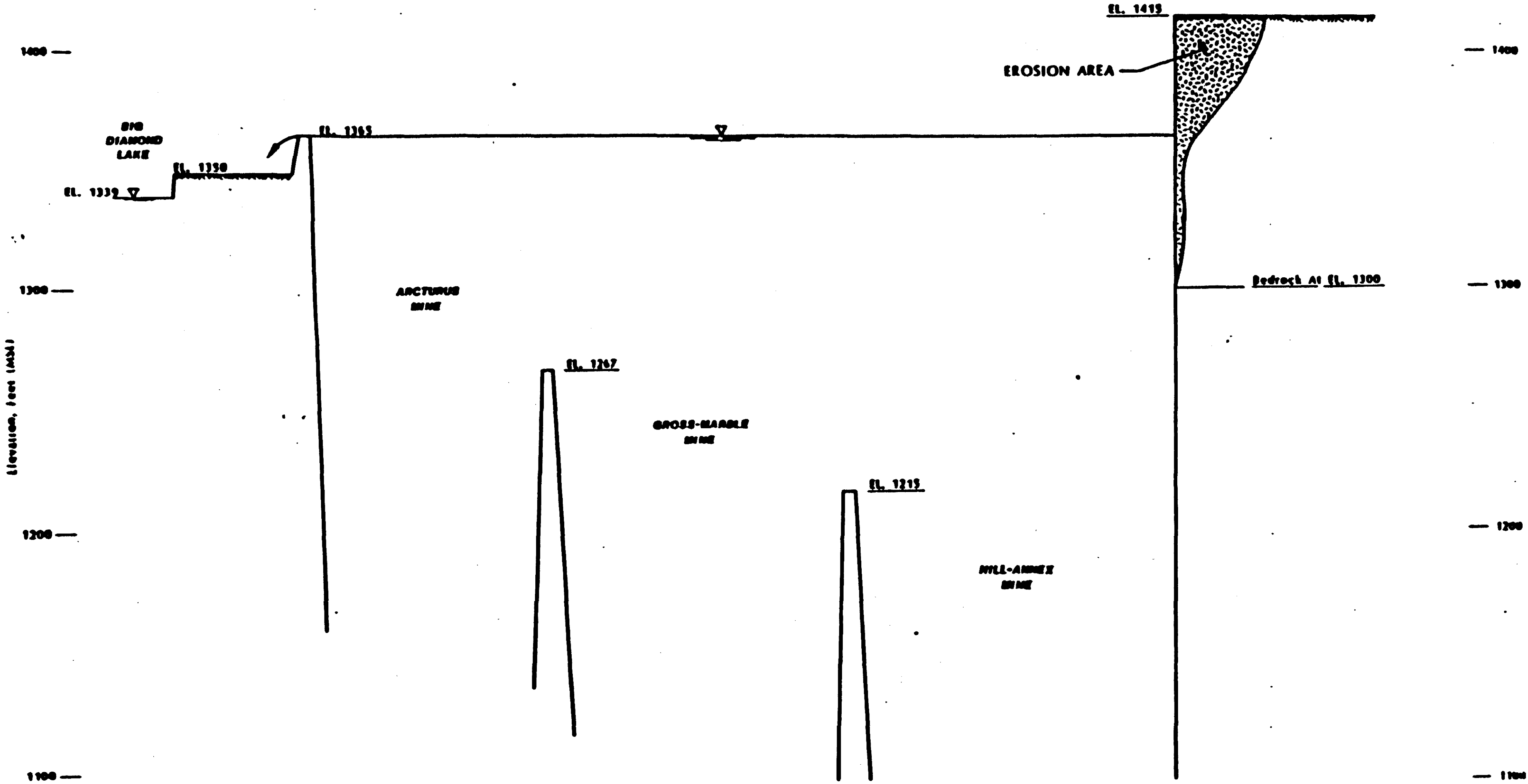

Figure 8

OPTION C - WATER LEVEL WITHOUT PUMPING

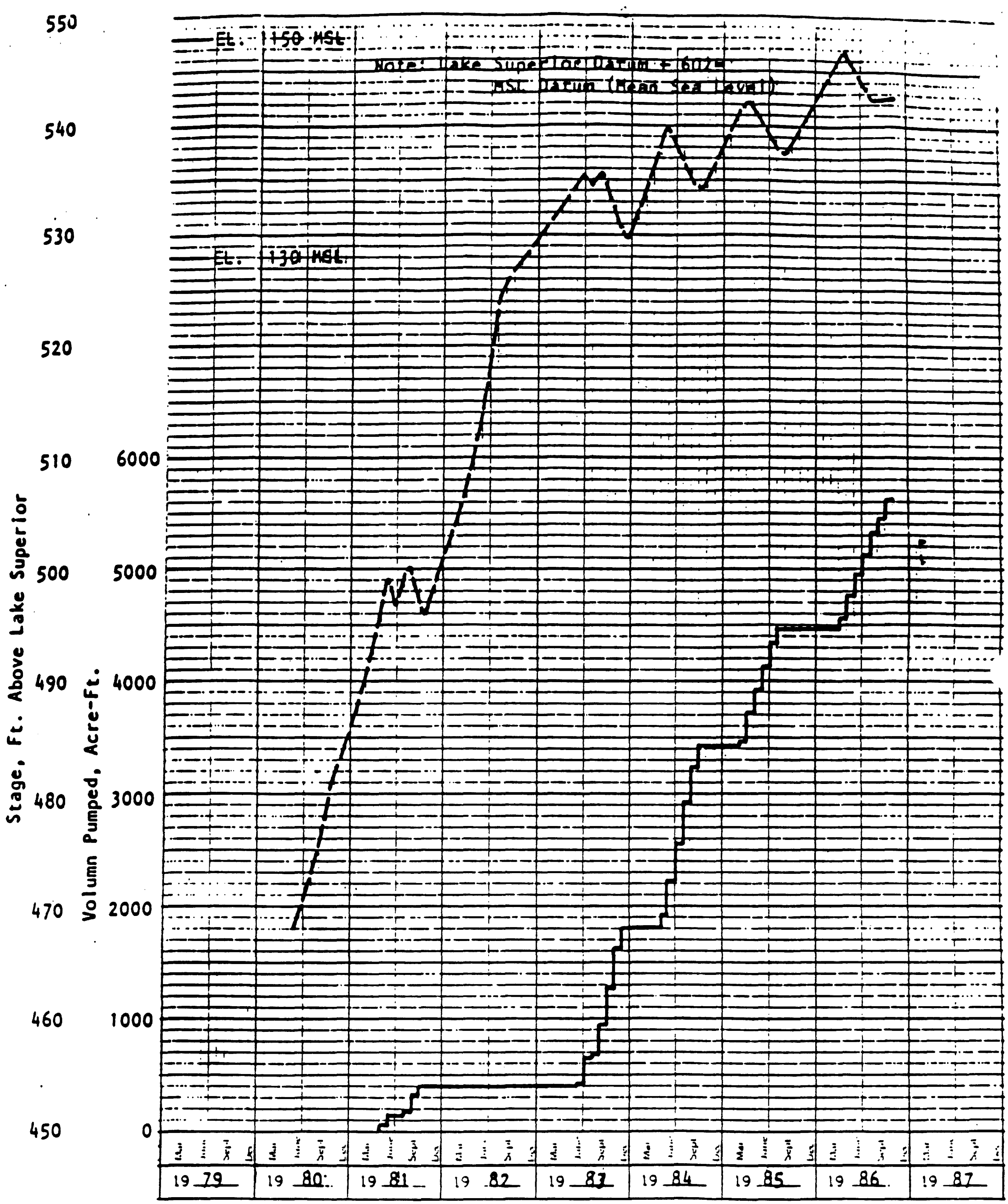

Figure 5

STAGE AND PUMPED VOLUME vs. TIME CURVES
Hill-Annex Mine

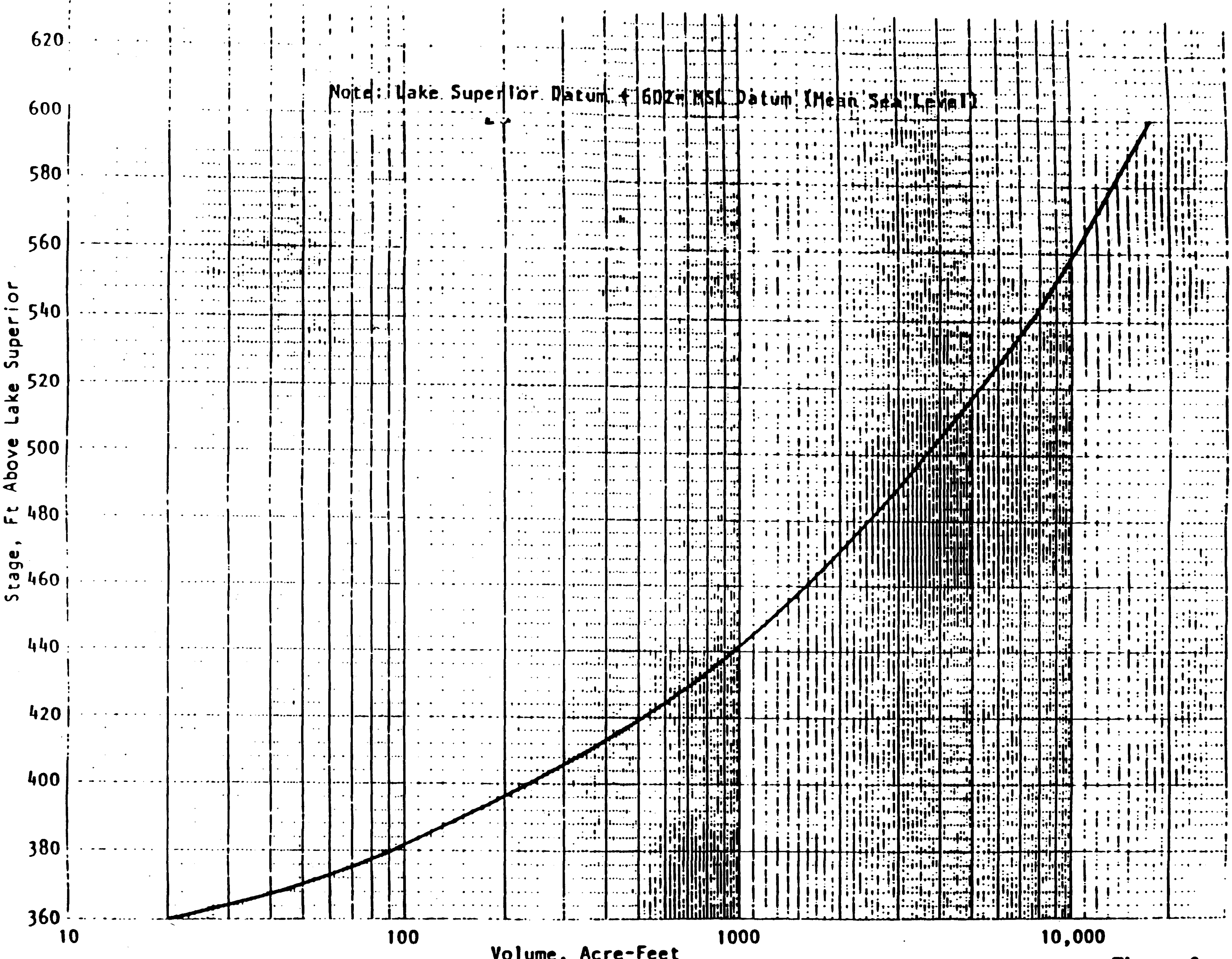

Figure 6

STAGE - VOLUME CURVE
Hill-Annex Mine

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Pursuant to 1988 Laws, Ch 686, Art 1
Sec 11(k) Vol 2 of 4 volumes

Minnesota Department of Natural Resources
Hill Annex Mine State Park
Calumet, Minnesota

Mine Dewatering Study
AWM Project No. M-147
January, 1989

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

Date 1-31-89 Registration No. 9241

A. W. Mathews Engineering Company
555 West 27th Street
Hibbing, Minnesota 55746

INDEX

1. PURPOSE OF STUDY

The following report summarizes the results of a study to investigate the least costly means of maintaining an acceptable water level in the Hill Annex pit using conventional pumping systems.

Each of the systems investigated are described in the report along with the capital costs and operating cost of each. A recommended system was selected based on lowest capital and operating costs. A time requirement for dewatering the pit to the desired level was not a design criteria for this study.

2. SUMMARY

Since pumping ceased in 1986, the level of water in the Hill Annex pit has risen an estimated 85 feet, and the number of gallons contained in this volume of water is estimated to be 3.03×10^9 gallons.

During the fall of 1988, a barge mounted turbine pump and pipeline were installed to minimize any further rise in water level. At the present time this pump is maintaining the present water level. However, measurements taken during pump operation indicate the pump is not operating on its original curve, probably due to wear. If this pump is to be used to maintain the final desired level in the pit, it should be rebuilt. The original Hill Annex pit pump has been recently rebuilt and the motor serviced and is ready for operation. The original barge will have to be repaired if it is to be used for pit dewatering. The pumping systems considered utilized these pumps along with a standby electrical generator in order to qualify for "dual fuel" power rates.

3. RECOMMENDATIONS

Based on the results of this study, it is recommended that the existing pumping system be upgraded by placing into service a new higher efficiency pumping system (System No. 2).

The existing Ingersoll-Rand pump should remain in service to serve as a backup.

It is recommended that MP&L be requested to change the rate structure under which Hill Annex is charged from Schedule 35 to Schedule 16, 26, 36 (Dual Fuel). Although an alternate energy standby system is required to be eligible for Schedule 16, 26, 36, electrical operating costs would be approximately one-half of the current costs under Schedule 35.

4. <u>PUMPING SYSTEMS</u>

Six different pumping systems were studied.

1. Pump all inflow from the Hill Annex with existing (Peerless turbine) pump at the present location utilizing existing pipeline.

2. Pump all inflow from the Hill Annex with a new higher efficiency pump mounted on the existing barge at the present location.

3. Pump all inflow from the Hill Annex utilizing both the original (Ingersoll-Rand) and the existing (Peerless turbine) pumps and pump through existing pipeline.

4. Utilize existing turbine pump and install a new pipeline similar to existing configuration. Leave existing pipeline as a standby system and for initial dewatering.

5. Pump the Hill Annex inflow with existing pump at the present location, and pump the Arcturus/Gross Marble inflow to either Mud or Diamond Lakes.

4. Pump Hill Annex into the Cross Marble, the Gross Marble into the Arcturus pit, and Arcturus into Diamond Lake.

All pumping systems were evaluated at the expected normal operating conditions, that is, with the Hill Annex water level at the desired 1130 elevation, and the Gross Marble and Arcturus pits at near overflow levels.

<u>System No. 1</u>:

Use existing pump and pump through existing 12" line in the existing configuration. Add approximately 400' of new pipe to replace old pipeline under road and to allow for barge settlement.

Pump:	Peerless Model 16MC, 5 stage vertical turbine.
Motor:	400 HP, 4000 volt, 1775 RPM.
Pipeline:	12" diameter, spiral weld steel, 3000 feet long.
Performance:	3000 GPM, 380' TDH, 80% pump efficiency, 360 BHP, 292 KW power draw, 6555 operating hours per year. Estimated time to dewater pit if run year round = 5.6 years.

System No. 2:

Install a new higher efficiency turbine pump on existing barge and pump through existing pipeline at existing location. Add approximately 400' of new pipe to replace old pipeline under roadway and to allow for barge settlement.

Pump:	Peerless Model 16HXB, 5 stage vertical turbine.
Motor:	400 HP, 4000 volt, 1775 RPM (reuse existing).
Pipeline:	12" diameter, spiral weld steel, 3000 feet long.
Performance:	3000 GPM, 380' TDH, 84% pump efficiency, 343 BHP, 275 KW power draw, 6555 operating hours per year. Estimated time to dewater pit if run year round = 5.6 years.

System No. 3:

Use original pump and existing turbine pump to pump through existing 12" line in the existing configuration. Add approximately 400' of new pipe as above and provide separate power circuit for turbine pump.

Pumps:	Ingersoll- Rand Model 8X23SF and Peerless Model 16-MC vertical turbine.
Motors:	450 HP and 400 HP, 4160 volts, 1760 RPM.
Performance:	Ingersoll-Rand - 2000 GPM at 450' TDH, Peerless turbine - 2500 GPM at 450' TDH for a total of 4500 GPM, 4370 operating hours per year. Estimated time to dewater pit if run year round = 1.8 years.

System No. 4:

Use original pump and install new pipeline similar to the original configuration. The original pump has been rebuilt and would be the main pump. To provide standby service and to help with the initial pit dewatering, the existing turbine pump/barge and pipeline would remain.

Pump:	Ingersoll-Rand Model 8X23SF with 83F3A impellor, 21" diameter.
Motor:	Westinghouse 450 HP, 4000 volt, 1775 RPM, Frame 588-5-S, 1.15 service factor.

Pipeline: 12" diameter, spiral weld steel, 2600 feet long.

Performance: 3200 GPM, 385' TDH, 76% pump efficiency, 404 BHP, 324 KW power draw, 6555 operating hours per year. Estimated time to dewater pit if run year round = 3.5 years, 1.6 years if both pumps are run year round.

System No. 5:

Use original pump/barge to pump approximately half the inflow from Hill Annex, and use the existing pump/barge to pump, under less head, the remaining inflow from the Gross Marble into Mud or Diamond Lakes.

Pump: Hill Annex - Ingersoll-Rand Model 8X23SF with 83F3A impellor, 21" diameter.

Gross Marble - Peerless, Model 16-MC, 5 stage vertical turbine.

Motor: Hill Annex - Westinghouse 450 HP, 4000 volt, 1775 RPM, Frame 588-5-S, 1.15 service factor.

Gross Marble - 400 HP, 4160 volt, 1750 RPM.

Pipeline: Hill Annex - 12" diameter, spiral weld steel, 2600 ft. long.

Gross Marble - 12" diameter, spiral weld steel, 2600 ft. long.

Performance: Hill Annex - 3200 GPM, 385' TDH, 76% pump efficiency, 404 BHP, 324 KW power draw, 3550 operating hours per year.

Gross Marble - 2600 GPM, 223' TDH, 76% pump efficiency, 193 BHP, 155 KW power draw, 3551 operating hours per year.

System No. 6:

Use existing turbine pump and install two new pumps so each mine pit has a pump/barge. Also install new pipelines from pit to pit so water is pumped relay fashion to Mud or Diamond Lakes.

Pumps: Hill Annex - Centrifugal double suction.

	Gross Marble - Existing Peerless turbine. Arcturus - Centrifugal double suction.
Motors:	Hill Annex - 150 HP, 4160 volt, 1760 RPM
	Gross Marble - 400 HP, 4160 volt, 1760 RPM.
	Arcturus - 250 HP, 4160 volt, 1760 RPM.
Pipeline:	Hill Annex - 12" diameter, spiral weld steel, 3000 ft. long.
	Gross Marble - 12" diameter, spiral weld steel, 2600 ft. long.
	Arcturus - 16" diameter, spiral weld steel, 2600 feet long.
Performance:	Hill Annex - 2400 GPM, 148' TDH, 4361 hrs./yr.
	Gross Marble - 3200 GPM, 157' TDH, 5469 hrs./yr.
	Arcturus - 4500 GPM, 152' TDH, 4370 hrs./yr.

5. ECONOMIC EVALUATION

Operating costs for all the systems listed above were determined. These operating costs are fuel costs, scheduled maintenance costs, and capital costs. Fuel costs were calculated based on the following: Electric costs - MP&L's rate schedules 35, 16, 26, 36; and diesel fuel - $1.10 per gallon. Electrical costs were estimated assuming that the pumps would be run continually for the required number of hours per year and not run on the basis of pumping part of each month. Rate schedule 35 demand charges are based on the highest 15 minute load per billing period. Demand charges drop for billing periods that have no pumping. Power costs were calculated with the high voltage discount included in the rates. Scheduled maintenance costs for diesel driven equipment were calculated based on the recommended service intervals and costs called for in the Caterpillar Handbook. Capital costs are based on amortizing the total estimated, contractor installed equipment costs over a twenty year period at an interest rate of 10%. Total yearly costs assume Schedule 16, 26, 36 power rate is charged. All pumping systems were based on a barge mounted pump station. The new barge price was based on 24' x 16' x 4' steel barge made of structural steel members covered with 1/4 inch plate. The new barge is protected from freezing by an air bubbler system. The air compressor for that system was sized for 75 cfm at 50 psi.

The barge was priced without a pump enclosure. In the systems where a new pipeline is indicated, that pipeline runs beyond the rim of the pit and discharges into a ditch. Details of the evaluation are given below.

System No. 1:

Fuel Costs:

Electric Charges (MPL) -	Schedule 35	Schedule 16, 26, 36
Demand Charges	$10,730.00	0
Energy Charges	$88,640.00	
Subtotal	$99,370.00	$47,580.00

Capital Costs:

Turbine Pump (Rebuild & install existing)	$14,000.00	
Pipeline - Add 400' 12"	$14,800.00	
Subtotal	$28,800.00	
Amortizing Cost - Pumping Station		$3,380.00
Amortizing Cost - Gen Set		$14,560.00
Total Yearly Costs		$65,520.00

Repairing the original barge and installing the original (Ingersoll-Rand) pump was more costly than rebuilding and installing the existing turbine pump. This fact, plus the higher operating efficiency of the turbine pump, is why the turbine pump was included in the capital costs.

System No. 2:

Fuel Costs:

Electric Charges (MPL) -	Schedule 35	Schedule 16, 26, 36
Demand Charges	$10,000.00	0
Energy Charges	$83,480.00	$44,830.00
Subtotal	$93,580.00	$44,830.00

Capital Costs:

Turbine Pump (less motor)	$10,000.00	
Install on existing barge	$11,000.00	
Pipeline - Add 400' 12" Steel	$14,800.00	
Subtotal	$35,800.00	
Amortizing Cost - Pumping Station		$4,210.00
Amortizing Cost - Gen Set		$14,560.00
Total Yearly Costs		$63,600.00

New turbine pump was included in capital costs because of favorable payback.

Install cost of new higher efficiency (84%) turbine pump installed on existing barge.	$21,000.00
Install cost to rebuild and install existing 80% efficient turbine pump on barge.	$14,000.00
	$7,000.00

Energy savings with higher efficiency pump:

$47,580.00 (System No. 1)
$44,830.00 (System No. 2)
$2,750.00 Savings

Simple Payback = $\frac{\$7,000.00}{\$2,750.00}$ = 2.5 yrs.

System No. 3:

Fuel Costs:

Electric Charges (MPL) -	Schedule 35	Schedule 16, 26, 36
Demand Charges	$19,440.00	0
Energy Charges	$107,460.00	$57,670.00
Subtotal	$126,900.00	$57,670.00

Capital Costs:

Barge (Repair exist.)	$10,000.00	
Turbine Pump Repair	$4,000.00	
Install Pumps	$8,000.00	
Pipeline - Add 400' 12" Steel	$14,800.00	
Cable & Disconnect	$36,500.00	
Subtotal	$73,300.00	
Amortizing Cost - Pumping Station		$8,610.00
Amortizing Cost - Gen Set		$14,560.00
Total Yearly Costs		$80,840.00

System No. 4:

Fuel Costs:

Electric Charges (MPL) -	Schedule 35	Schedule 16, 26, 36
Demand Charges	$11,500.00	0
Energy Charges	$83,840.00	$45,020.00
Subtotal	$95,340.00	$45,020.00

Capital Costs:

Barge (Repair exist.)	$10,000.00	
Turbine Pump Repair	$4,000.00	
Install Pumps	$8,000.00	
Pipeline, New 12" Plastic	$108,500.00	
Cable & Disconnect	$36,500.00	
Subtotal	$167,000.00	
Amortizing Cost - Pumping Station		$19,620.00
Amortizing Cost - Gen Set		$14,560.00
Total Yearly Costs		$79,200.00

System No. 5:

Fuel Costs:

Electric Charges (MPL) -	Schedule 35	Schedule 16, 26, 36
Demand Charges	$16,700.00	0
Energy Charges	$74,120.00	$39,930.00
Subtotal	$90,820.00	$39,930.00

Capital Costs:

Barge (Repair exist.)	$10,000.00	
Install Pump	$4,500.00	
Pipeline, New 12" Plastic	$96,000.00	
Cable & Disconnect	$36,500.00	
Pole Line	$110,000.00	
Subtotal	$257,000.00	
Amortizing Cost - Pumping Station		$30,200.00
Amortizing Cost - Gen Set		$14,560.00
Total Yearly Costs		$84,690.00

System No. 6:

Fuel Costs:

Electric Charges (MPL) -	Schedule 35	Schedule 16, 26, 36
Demand Charges	$12,850.00	0
Energy Charges	$70,850.00	$37,960.00
Subtotal	$83,700.00	$37,960.00

Capital Costs:

Barge, New	$30,000.00	
Barge, Remodel	$10,000.00	
Pipeline (3)	$270,000.00	
Cable & Disconnect (2)	$73,000.00	
Pole Line	$110,000.00	
Pumps & Motors (2 new)	$35,000.00	
Air Compressor	$4,000.00	
Subtotal	$532,500.00	
Amortizing Cost - Pumping Station		$62,510.00
Amortizing Cost - Gen Set		$14,560.00
Total Yearly Costs		$115,030.00

Standby Energy System:

In order to qualify for the Schedule 16, 26, 36 (Dual Fuel) rate, MP&L requires an alternate energy means of providing power should regular service be interrupted. Details of estimated costs are as follows:

Fuel Costs:

Diesel fuel at $1.10/gal. (100 hrs operation)		$2,750.00
Lubricants, Misc.		$120.00
	Subtotal	$2,870.00

Capital Costs:

800 KVA Diesel Gen Set (New with weatherproof enclosure)	$80,000.00	
Set-up Transformer	$14,000.00	
Transfer Switch	$4,000.00	
Fuel Tank, 1000 Gal.	$1,500.00	
Subtotal	$99,500.00	
Amortized Cost		$11,690.00
Total Yearly Costs		$14,560.00

It is desirable to qualify for the Schedule 16, 26, 36 (Dual Fuel) rate because of the electrical power savings possible. For example, the simple payback for System 1 would be as follows:

Electric charges Schedule 35 =	$99,370.00
Electric charges Schedule 16, 26, 36 =	$45,580.00
Savings/year	$51,790.00

$$\text{Simple Payback} = \frac{\$99,500.00}{\$51,790.00} = 1.9 \text{ yrs.}$$

APPENDIX A - ELECTRICAL RATE DATA

Following this page are MP&L rate schedules 35 and 16, 26, 36.

SCHEDULE 35
GENERAL SERVICE (Continued)

HIGH VOLTAGE SERVICE

Where customer contracts for service delivered and metered at (or compensated to) the available high voltage of 13,000 volts or higher, the monthly bill, before Adjustments, will be subject to a discount of $0.50 per kW of Billing Demand.

ADJUSTMENTS

1. There shall be added to or deducted from the monthly bill, as computed above, a fuel adjustment determined in accordance with Fuel Clause No. 14, stated in Rider for Fuel Adjustment.

2. Plus the applicable proportionate part of any taxes and assessments imposed by any governmental authority which are assessed on the basis of meters or customers, or the price of or revenues from electric energy or service sold, or the volume of energy generated, transmitted or purchased for sale or sold.

DETERMINATION OF THE BILLING DEMAND

A demand meter will be installed when customer's use exceeds 2500 kWh for three consecutive months or where the connected load indicates customer's demand may be greater than 10 kW.

The Billing Demand will then be the kW measured during the 15-minute period of customer's greatest use during the month, as adjusted for power factor, but not less than the minimum demand specified in customer's contract.

Demand will be adjusted by multiplying by 85% and dividing by the average monthly power factor in percent when the average monthly power factor is less than 85% lagging.

PAYMENT

Bills are due and payable at any office of Minnesota Power & Light Company 15 days following the date the bill is rendered or such later date as may be specified on the bill.

SCHEDULE 35
GENERAL SERVICE

TERRITORY

Applicable in Rate Area III.

APPLICATION

To any customer's electric service requirements when the total electric requirements are supplied through one meter. Service shall be delivered at one point from existing facilities of adequate type and capacity and metered at (or compensated to) the voltage of delivery. Service hereunder is limited to Customers with total power requirements of less than 10,000 kW and is subject to Company's Electric Service Regulations and any applicable Riders.

Applicable to multiple metered service only in conjunction with the respective Rider for such service.

TYPE OF SERVICE

Single phase, three phase or single and three phase, 60 hertz, at one standard low voltage of 120/240 to 4160 volts.

RATE (Monthly)

CUSTOMERS WITHOUT A DEMAND METER

$4.65 Service Charge

Energy Charge

6.401¢ per kWh for all kWh

CUSTOMERS WITH A DEMAND METER

$4.65 Service Charge

Demand Charge

$4.10 per kW for all kW

Energy Charge

4.631¢ per kWh for all kWh

Plus any applicable Adjustments.

MINIMUM CHARGE (Monthly)

$4.65 plus any applicable Adjustments, however, in no event will the Minimum Charge (Monthly) for three phase service be less than $12.00

SCHEDULES 16, 26, 36

COMMERCIAL/INDUSTRIAL DUAL FUEL INTERRUPTIBLE ELECTRIC SERVICE

TERRITORY

Applicable to all Rate Areas.

APPLICATION

To the interruptible electric service requirements of Commercial/Industrial Customers where a non-electric source of energy is available to satisfy these requirements during periods of interruption. Service shall be delivered at one point from facilities of adequate type and capacity and shall be metered at (or compensated to) the voltage of delivery. Service is subject to Company's Electric Service Regulations and any applicable Riders.

TYPE OF SERVICE

Single phase, three phase or single and three phase, 60 hertz, at one standard low voltage of 120/240 to 4160 volts; except that within the Low Voltage Network Area service shall be three phase, four wire, 60 hertz, 265/460 volts.

RATE (Monthly)

	Secondary Service	Primary Service
Service Charge	$10.00	$10.00
Energy Charge		
All kWh (per kWh)	2.86¢	2.48¢

Plus any applicable Adjustments.

The Primary Service Rate is applicable where service is delivered and metered at (or compensated to) the available primary voltage.

MINIMUM CHARGE (Monthly)

The Minimum Charge shall be the Service Charge plus any applicable Adjustments.

ADJUSTMENTS

1. There shall be added to or deducted from the monthly bill, as computed above, a fuel adjustment determined in accordance with Fuel Clause No. 14, stated in Rider for Fuel Adjustment.

2. Plus the applicable proportionate part of any taxes and assessments imposed by any governmental authority which are assessed on the basis of meters or customers, or the price of or revenues from electric energy or service sold.

3. Bills for service within the corporate limits of the City of Duluth shall include an upward adjustment as specified in the Rider for City of Duluth Franchise Fee.

SCHEDULES 16, 26, 36 (Cont'd.)

COMMERCIAL/INDUSTRIAL DUAL FUEL INTERRUPTIBLE ELECTRIC SERVICE (Cont'd.)

PAYMENT

Bills are due and payable at any office of Minnesota Power & Light Company 15 days following the date the bill is rendered or such later date as may be specified on the bill.

CONTRACT PERIOD

Not less than thirty days or such longer period as may be required under an extension agreement.

SERVICE CONDITIONS

1. The primary energy source for the Company approved Dual Fuel installation must be electric. An approved Dual Fuel installation requires that the secondary or back-up energy source be capable of continuous operation. Under no circumstances will firm electric service qualify as the secondary or back-up energy source.

2. The interruptible load of the approved Dual Fuel installation shall be separately served and metered and shall at no time be connected to facilities serving customer's firm load.

3. The duration and frequency of interruptions shall be at the discretion of Company. Interruption will normally occur at such times:
   (a) when Company is required to use oil-fired generation equipment or to purchase power that results in equivalent production cost,
   (b) when Company expects to incur a new system peak, or
   (c) at such other times when in Company's opinion the reliability of the system is endangered.

4. Company shall not be liable for any loss or damage caused by or resulting from any interruption of service except in the case of gross negligence on the part of the Company.

5. Customer must be prepared to supply all of the interruptible load from an alternative energy source for up to 30% of customer's Dual Fuel requirements during any annual period.

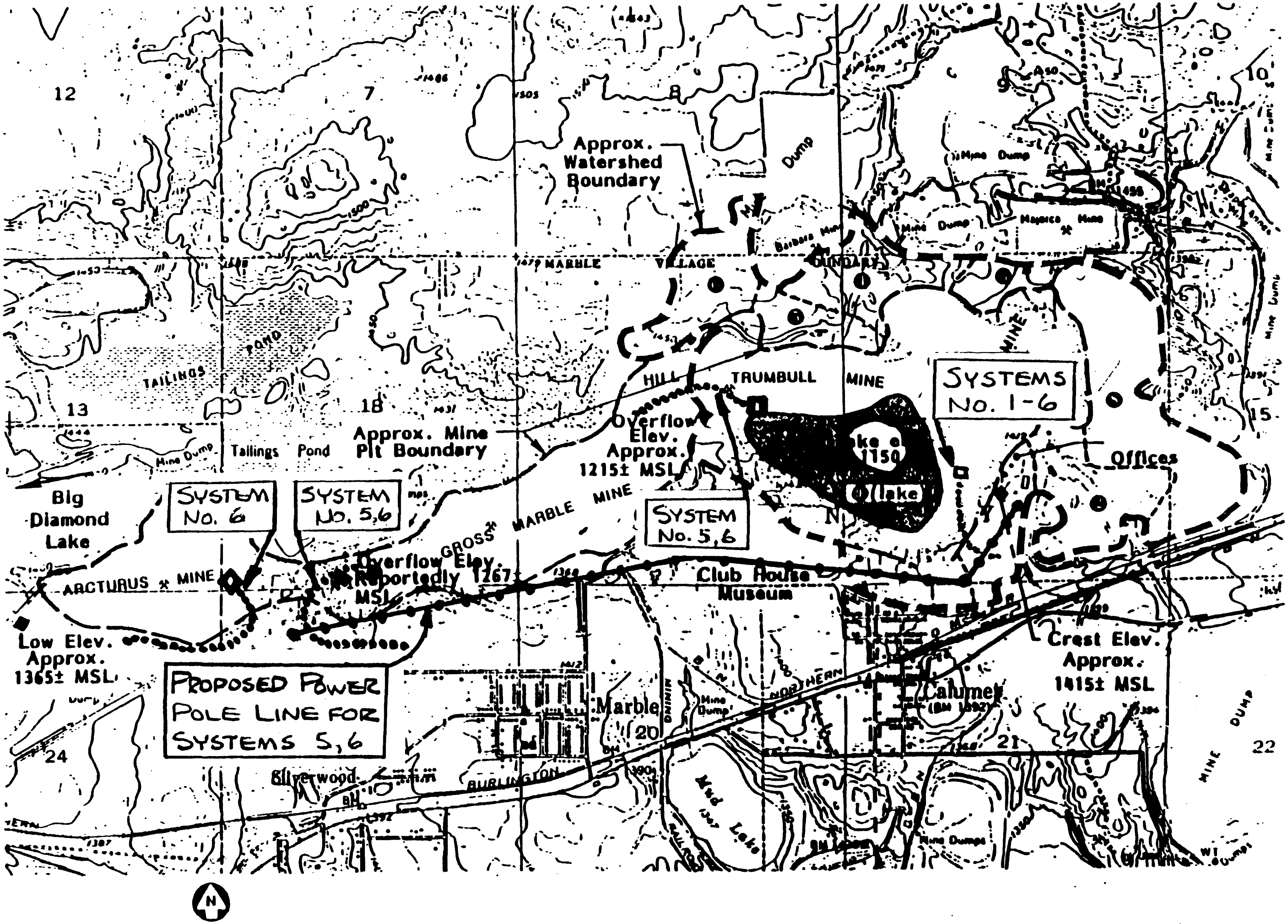
6. If required by Company, Company will provide, at customer's expense, and customer will install, as directed by Company, a load-break switch or circuit breaker. Customer must provide a continuous 120 volt AC power source at Company's control point for operation of Company's remote control equipment.

7. The rate contemplates that this service will utilize existing facilities with no additional major expenditures. Customer shall pay Company the installed cost of any additional facilities required which are not supported by this rate.

Approved [signature] Title President & Chief Operating Officer
Issued by authority of the Minnesota Department of Public Service
Submitted April 24, 1987 Order No. E015/M-87-238 Dated July 15, 1987
Effective July 15, 1987

APPENDIX B - LOCATION MAP

Following this page is a location map of the proposed pumping systems.



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❶ Subwatershed Designation

LOCATION MAP