UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

MAY 31 1984

MEMORANDUM

SUBJECT: Classification of experimental Nahcolite Solution mining Wells of Industrial Resources, Inc. in Region VIII
UIC Well Classification Advisory #1

FROM: Thomas E. Belk, Chief, Thomas E. Belk
Ground Water Protection Branch
Office of Drinking Water

TO: Patrick A. Crotty, Chief
Ground Water Section

We have received your request of March 6, 1984 for our concurrence on your classification of the two experimental wells which are proposed by Industrial Resources. We agree that the wells are properly classified as Class V since the technology is experimental (see GWPG #28). Therefore they may be authorized by rule for the two years they are operated as experimental. At the end of this period, or when it is determined that they are viable as a commercial operation, they would become Class III wells, and would be regulated as such.

ITEM III

Background Information

9 pages

Litigat DRAFT

AUG 13 1981

Claire Gesseman
EPA

Desalination of Brackish Groundwater

Reports of groundwater quality and availability show that in some areas high concentrations of dissolved solids are the norm (2,3,6,9). For example, in eastern Colorado much of the land is underlain by aquifers containing water with 3,000-10,000 mg/l total dissolved solids (TDS). Aquifers containing water with 1,000-3,000 mg/l TDS are prevalent in much of the rest of the state (9). In several subregions of Wyoming, the dissolved solids concentration in groundwater ranges from 200-9,000 mg/l (9). Other western states including New Mexico, Montana, Arizona, and Utah have areas of poor groundwater quality because of dissolved solids levels (9).

A 1979 U.S. Department of Interior report cited an earlier report by the American Water Works Association (AWWA) stating that more than 3,000,000 persons in the U.S. were served by systems supplying water with more than 1,000 mg/l of dissolved solids (3). Some of the sources contained over 3,000 mg/l TDS. Those persons were served by 1,066 utilities with raw water containing 1000-3000 mg/l TDS and 31 utilities with 3,000-10,000 mg/l TDS in their feed water. Only a few of these were being treated. According to a 1977 article in Desalination (5) which reported a 1973 AWWA study, 10% of the finished water supplies in the U.S. contained more than 500 mg/l TDS, and high TDS groundwater supplies are prevalent in the Northern Great Plains, the Southwest, Illinois, and Florida.

The areal extent of aquifers containing high TDS levels (8), population served by wells producing poor quality water, and present growth in arid areas suggest that increased use of water with high TDS may be required. It is necessary to ask whether this water can be treated to yield water of acceptable quality at a reasonable cost.

Research in treatment technology has produced major advances in the past few years, particularly in membrane technology (6). For example, low operational pressure membranes are being tested, offering savings in energy use, capital cost, and maintenance costs.

The first commercial electrodialysis (ED) plant was installed in 1915. Improvements such as development of synthetic membranes have resulted in large scale application of electrodialysis for reducing dissolved solids in water. The 40 ED plants in the U.S. produce 7 million gallons per day of potable water. (World-wide, 800 ED plants produce 60 MGD of treated water) (2). Source water for ED plants usually has 1000-10,000 mg/l TDS.

Reverse osmosis has been the subject of significant developmental work since 1953 (2). Most reverse osmosis (RO) plants operate with raw water sources containing 1000-45,000 mg/l TDS. As of January 1977 there were 518 RO plants with a total capacity of 167 MGD (4). Of those, 290 were in the U.S. (3).

Feasibility and cost projections were reported in 1977 for 15 communities served by high TDS groundwater (941-3236 mg/l) (6). The communities studied were located in Colorado, New Mexico, Texas, Arizona, Iowa, North Dakota, Montana, South Dakota, Kansas, and Hawaii and had populations ranging from 720 to 59,000. The treatment cost projections ranged from $0.37/1000 gallons to $1.57/1000 gallons. Technological improvements have led to lower costs than were projected in an earlier study based on 1970-73 technology ($0.42-$2.09/1000 gallons, in 1977 dollars). These technological improvements outweighed increased energy and other costs. The report concludes that in spite of higher costs, the ratio of benefits to costs is probably more favorable now for many communities that lack suitable low TDS water supplies.

The most recent inventory of desalting plants was completed by the Office of Water Research and Technology (U.S. Dept. of Interior) in 1977. Of the 481 desalting plants with capacity of at least 25,000 gallons per day listed in the U.S., 66 were for municipal water supplies (4). Listed plants were located in 15 states.

A three-volume report on commercial membrane desalination plants was published in 1980 by the Office of Water Research and Technology (2). It included detailed information about 24 desalination plants currently operating in the U.S. and in Caribbean nations. Ten of the plants have water sources containing more than 3,000 mg/l TDS. Seven of the ten are groundwater sources, four of which range fom 7,000-10,976 mg/l TDS.

- In Rotonda West, Florida, a 500,000 gallon/day (GPD) reverse osmosis plant has been in operation since 1973. It treats well water containing more than 6000 mg/l TDS at a cost of $1.88/1000 gallons.

- A one million gallon per day (MGD) reverse osmosis plant has been operating since June 1976 in Rock Harbor, Florida. The source water from the Floridan aquifer varies from 5000-9000 mg/l TDS. Treatment cost is $1.35/1000 gallons.

- The reverse osmosis plant in Ocean Reef, Florida treats 930,000 GPD at a cost of $1.26/1000 gallons. The original plant was installed in 1972, with additional capacity installed in 1973 and 1974. The feed water from five wells contains 5000-8000 mg/l TDS.

o A 300,000 GPD reverse osmosis plant was installed in 1974 in Card Sound, Florida. It treats water from five wells containing 5000-8000 mg/l TDS at a cost of $0.89/1000 gallons.

o Lake Killarney in the Bahamas is the source of 9000-18,000 mg/l TDS water that is treated in a reverse osmosis plant. This plant, in operation since March 1977, produces 600,000 GPD of treated water at a cost estimated at $2.75/1000 gallons.

Table 1 shows size, operating cost, and other data for those plants and others treating less highly mineralized water.

Table 1

Summary of commercial membrane desalination plants

Plant location	Size (1000 GPD)	Feedwater Quality TDS mg/1	Source (Surface, Ground)	Cost ($/1000 gal)	Type *	Operating Since	Ref
Lake Killarney, Bahamas	600	9000–18,000	Surface	$2.75	RO	3/77	2
Rock Harbor, FL	1,000	5000–9000	Ground	$1.35	RO	6/76	2
Ocean Reef, FL	930	5000–8000	Ground	$1.26	RO	1972	2
Card Sound, FL	300	5000–8000	Ground	$0.89	RO	1974	2
Rotonda West, FL	500	7000	Ground	$1.88	RO	1973	2
Minitonas, Manitoba	20 (imperial)	3500	Ground	$3.60 (imperial)	RO	1976	1
Dell City, TX	100	3159	Ground	$1.70	EDR	6/76	2
Sorrento Shores, FL	170	3034	Ground	$2.11	RO	10/75	2
Junius Ponds, NY	40	3000	Ground	$4.34	EDR	1974	2
Sorrento Shores, FL	70	2631	Ground	$1.76	EDR	1/74	2
Sanibel Island,FL	1,800	2620	Ground	$1.39	ED	11/73	2
Venice, FL	1,000	2400	Ground	$1.07	RO	10/75	2
Mohawk, AZ	12	2260	Ground	$5.43	EDR	6/70	2
Pine Island, FL	830	2200	Ground	$1.37	RO	3/75	2
Buckeye, AZ	650	2140	Ground	$1.13	ED	9/62	2
Foss Reservoir, AZ	3,000	1960	Surface	$1.33	ED	1974	2
Pattersonville, NY	20	1836	Ground	$4.33	EDR	4/75	2

* RO = Reverse Osmosis ED = Electrodialysis EDR = Electrodialysis with polarity reversal

References

1. Adams, H.J. and W.H. Brant. 1977. The reverse osmosis water-treatment plant at Minitonas, Manitoba. Jour. AWWA 69:352-355.

2. Data collection and analysis of commercial membrane desalination plants. 1980. DSS Engineers, Inc. for Office of Water Research & Technology (U.S. Dept. of Interior), Contract # 14-34-0001-8531. Vol. I (PB81-170573); Vol II (PB81-170581); Vol. III (PB81-170599).

3. Desalting handbook for planners. 1979. Office of Water Research & Technology (U.S. Dept. of Interior). OWRT TT/80 3.

4. Desalting plants inventory report no. 6. 1977. Office of Water Research and Technology (U.S. Dept. of Interior).

5. Hughes, M.V., Jr. 1977. Water requirements and desalting in the United States of America. Desalination 21:301-307.

6. Mattson, Melvin E. and Melvin Lew. 1981. Future trends in membrane desalination. presented at Ninth Annual Conf., Natl. Water Supply Improvement Assoc., Washington, D.C., May 31-June 4, 1981.

7. Miller, E.F. 1977. Demineralization of brackish municipal water supplies - comparative costs. Jour. AWWA 69: 348-351.

8. The National Atlas of the United States of America. 1970. U.S. Geological Survey (U.S. Dept. of Interior).

9. Westwide study report on critical water problems facing the eleven western states. 1975. Bureau of Reclamation (U.S. Dept. of Interior).

File 71 Litigation

Francoise M. Brasier

Report on the Borehole Slurry Mining of Phosphate Deposits

March 24, 1982

Hydraulic borehole slurry mining is at this time an experimental mining technique applicable to shallow ore bodies which can be slurried using a water jet. So far the technique has been successfully field tested under the aegis of the Bureau of Mines for the mining of coal, oil sands, uraniferous sandstones and phosphate. Further testing is planned for clay, bauxite, and foundry sands.

This paper will examine the technique in general, the Agrico operation in St. Johns County, Florida, and the potential for development of other phosphate slurry mining areas.

THE BOREHOLE SLURRY MINING TECHNIQUE

Description of Typical Operation

Typically a borehole approximately 18 inches in diameter is drilled to approximately 6 feet below a mineral bearing stratum. A casing is installed above the ore body to prevent cave-ins and inflows from the overburden. A cutting jet assembly is positioned in the hole at the end of a rigid service column containing the necessary conduits for injection of pressurized water and removal of slurry. The lower section of the cutting jet assembly contains the slurry pump which is positioned in the hole below the ore body. (Figure I)

The jet can rotate and move vertically. The operation starts with the jet in the lowest position, the jet rotates and cuts material through an arc of 200 to 300 degrees leaving enough unmined material to support the overlying strata. The material can be slurried to a radius of up to 75 feet depending on the properties of the ore and the design of the jet system. The slurried material is pumped to the surface and the jet is raised to reach the next level of ore. The duration of mining at a borehole is a function of the ore characteristics and the capacity of the jetting apparatus. It is estimated that a 45 to 75 foot borehole could be mined out in 1 to 3 days assuming an ore zone 30 feet thick.

Potential effect on aquifers

The specific effect of any given operation will depend upon the local geohydrology. In general however, the following possibilities should be considered when devising a ground-water protection program at a site.

- <u>Establishment of hydraulic communication between aquifers of different qualities.</u> The degree to which this will occur will depend upon 1) the degree of separation between the mined zone and the surrounding aquifers and the nature of intervening strata; 2) the hydrostatic pressure in the aquifers and in the mined zone during and after mining; 3) the thoroughness and adequacy of the backfilling operations. The severity of the problem will depend upon the quality of the water in the different aquifers. In very shallow operations hydraulic communication could be similarly established between the surface or the vadose zone and underlying aquifers.

- <u>Subsidence of the overburden.</u> This would be a major problem in cases where the overburden contains an aquifer used for drinking water purposes. The degree of subsidence is affected by the nature of the overburden, the geometry of the borehole and the backfill techniques.

- <u>Transport of mobilized constituents from the ore body into adjacent aquifers.</u> The degree to which this will occur will depend on 1) original permeabilities of surrounding strata; 2) the tendency of the slurried ore to clog the flow channels and thus reduce permeabilities; 3) the magnitude of the hydraulic gradients established during and after the mining operation; 4) the duration of the borehole operation. The nature of the mobilized constituents will depend upon the geochemical reactions occuring between the aqueous and solid phases.

It should be noted however, that these potential problems are not unique to in situ slurry practices. Extraction of the ore by any other technique but most particularly by open pit mining would result in greater environmental damage.

THE AGRICO OPERATION

In 1980 Agrico Mining Company conducted an experimental slurry mining of deep phosphatic materials in St. Johns County, Florida. The USGS conducted a study of this experiment in cooperation with the U.S. Bureau of Mines. The report on this study is not yet available but preliminary results have been furnished by George Savanick of the Bureau of Mines.

Hydrogeologic setting

The site is located in Northeastern Florida, approximately 10 miles northwest of St. Augustine and 5 miles from the Atlantic Ocean. It is situated on Marine Terraces of Pleistocene age which together with the underlying Pliocene deposits form the shallow clastic aquifer of East Florida. (Figure 2) This aquifer composed of sand, shell, sandy clays and marl is approximately 75 feet thick in the project area. The shallow nonartesian water is an important source of water in those areas where deeper aquifers contain water too highly mineralized for use. A part of the municipal water supply for St. Augustine and many rural domestic supplies are obtained from these deposits.

The Hawthorn Formation of Oligocene and Miocene age underlies these deposits. It generally consists of gray to green plastic, phosphatic sandy clay and marl interbedded with lenses of phosphorite pebbles, phosphatic sand and phosphatic sandy limestone. The phosphate deposit of interest to the Agrico operation consists of two beds of phosphatic sandy clay separated by a hard dolomitic limestone at a depth of about 225 feet below the land surface. (Figure 3) Thin discontinuous lenses of limestones, shell and sand within the Hawthorn formation form the secondary artesian aquifers. These aquifers are recharged from both overlying and underlying aquifers and yield moderate amounts of water to domestic wells in St. Johns County. However according to Mr. Savanick, the yields from the Hawthorn aquifers are very low in the vicinity of the site and to his knowledge they are not currently used as a water supply source.

The base of the Hawthorn formation is composed of hard dolomite limestone and clays which are 10 to 15 feet thick in the area of the Agrico site; these beds mark the unconformable contact with the eroded surface of the Ocala group of Eocene age. The Ocala group is a thick sequence of permeable marine limestones which act as a single hydrologic unit, the Floridan aquifer. The Floridan aquifer is the major source of water for irrigation, public supply and industry in the area. Part of the municipal ground-water supply for the city of St. Augustine is obtained from this aquifer. Near the coast the Floridan is subject to salt water intrusion.

Shallow Hydrogeologic Unit Map of Florida.

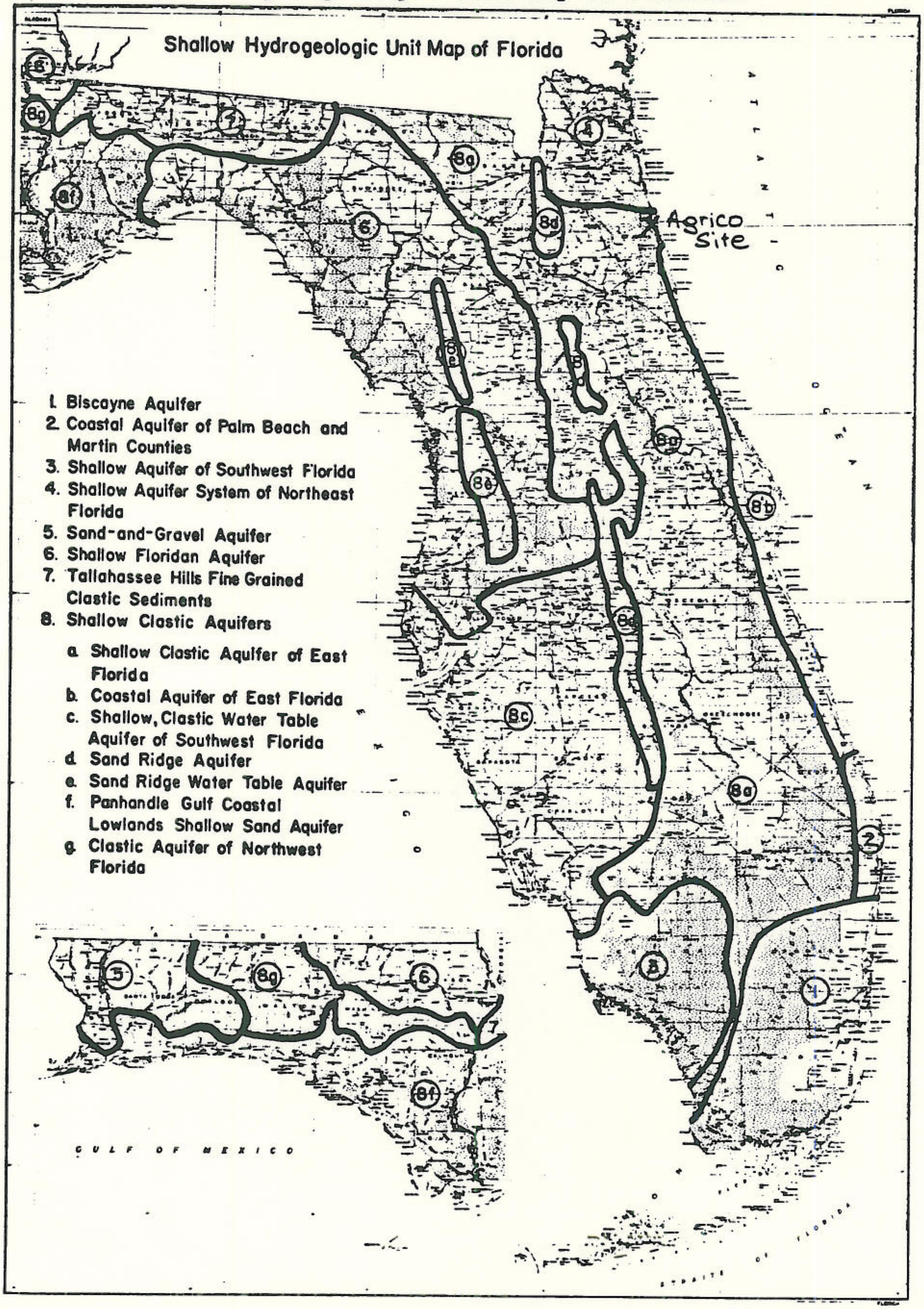
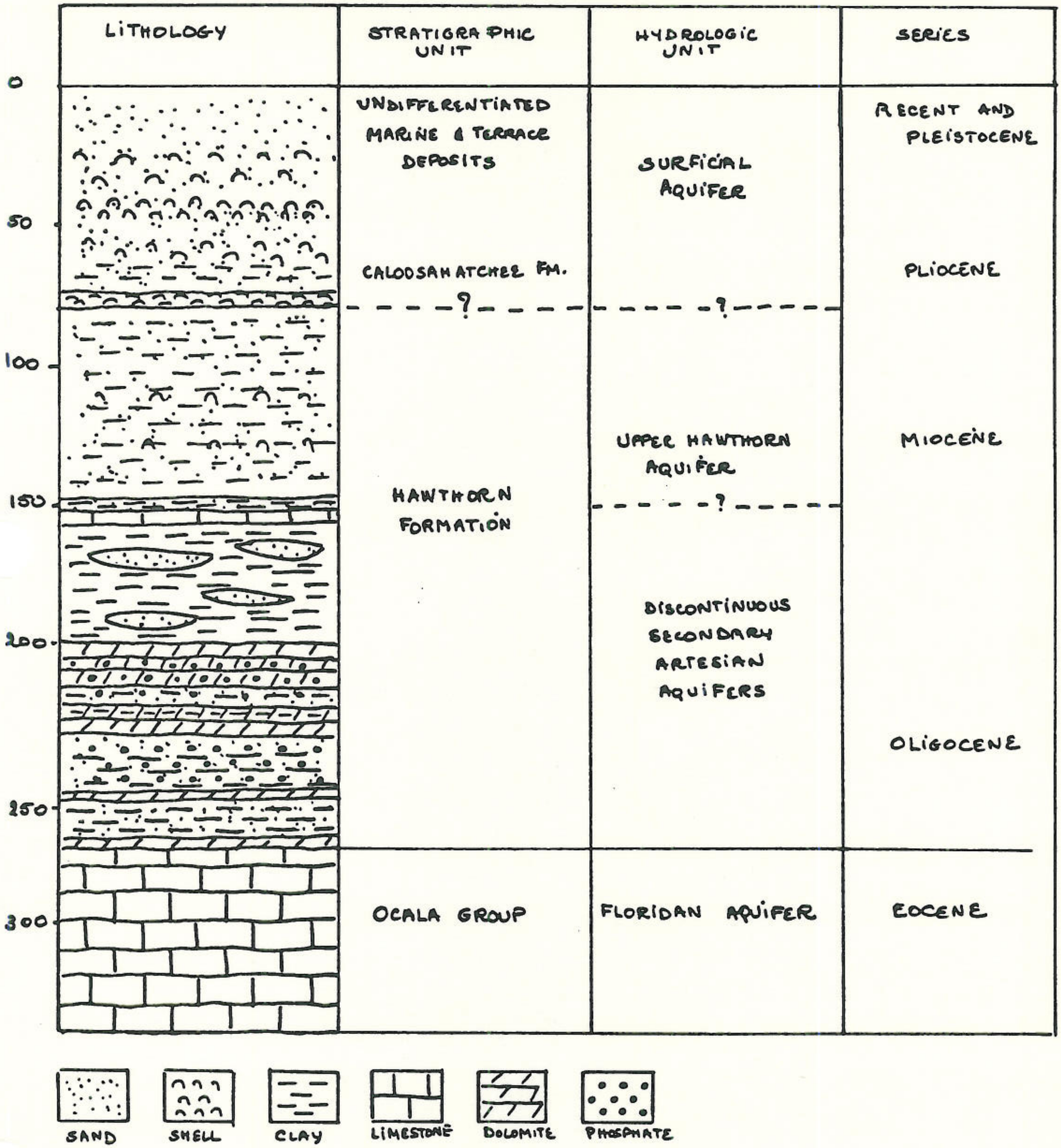


FIGURE 2

Source: Florida Surface Impoundment Assessment.



CROSS-SECTION OF TEST SITE

FIGURE 3

Potential Ground-Water Problems

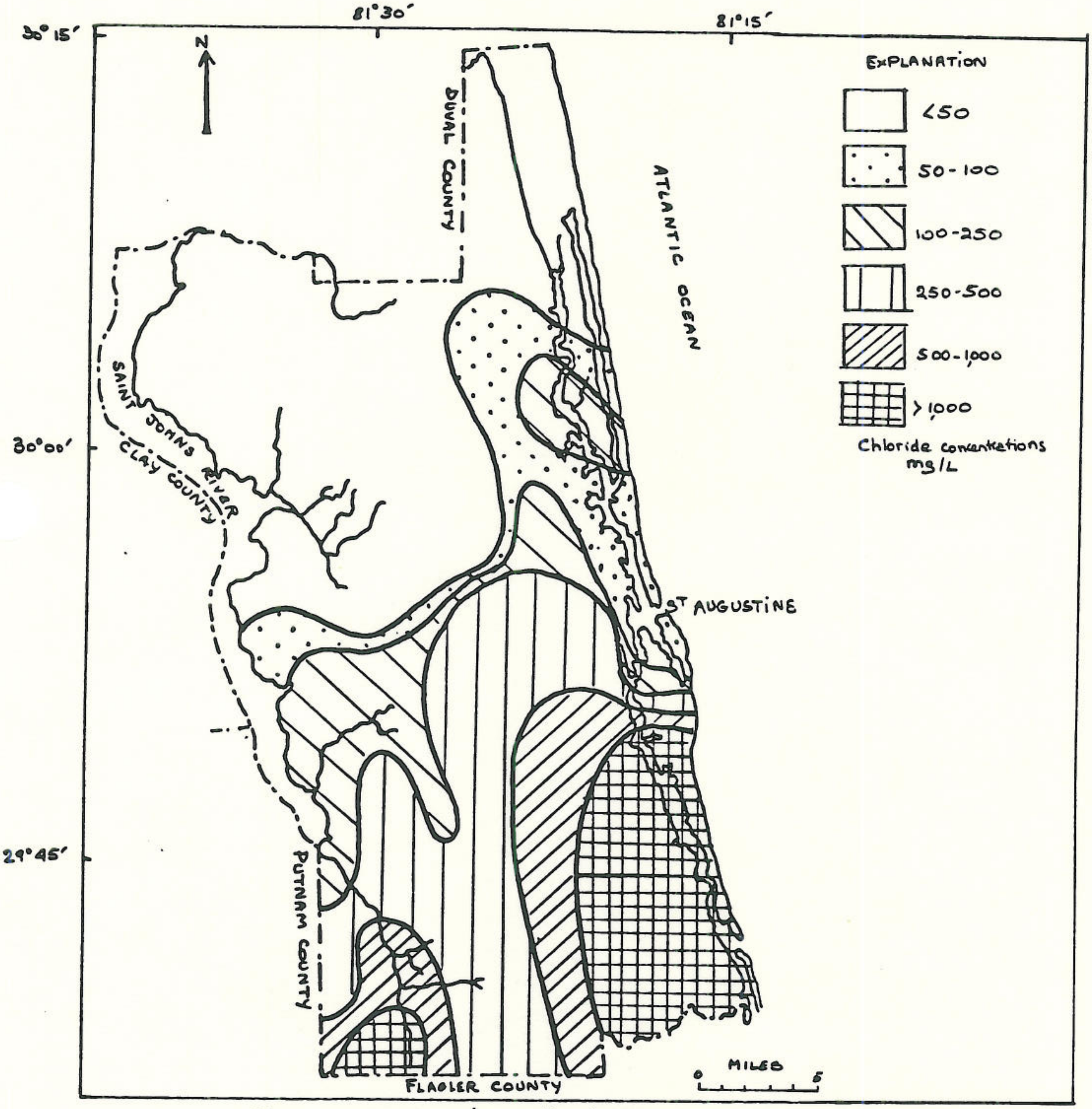
As noted above in the site area the Floridan aquifer lies only 10 to 15 feet below the lower phosphate bed. Should the relatively thin confining beds fail, water from the Floridan would leak upward entering the surficial aquifers or flowing at the surface. This could in turn lead to a decline in artesian pressure in the Floridan and an increased possibility of sea water intrusion. The aquifer already contains highly mineralized water in much of St. Johns County. (Figure 4)

Results of the 1980 Test

An initial experimental program of borehole slurry mining was conducted by Agrico in 1980. Permits for Slurry Well No. 1 were issued by St. Johns County and the Florida Department of Environmental Regulation during January 1980. Drilling of the well to a depth of 251 feet was completed in early April 1980.

Experimental mining was initiated in mid April and continued intermittently for approximately ten days. The mining test was conducted under flooded conditions with both the well and cavity completely filled with water. Test results were good with a total of +800 tons of matrix extracted from a 15-foot-radius cavity at an average rate of 37 tons per hour. No roof failure or other major problems were encountered. Following the completion of this test, the cavity water level was pumped down to conduct an air mining experiment. At this point the roof caprock failed, allowing overlying clay and water into the cavity. Inflow was too large for the mining equipment, making it necessary to terminate the test and abandon the well.

A permit application for Slurry Well No. 2 was submitted. This permit was issued on May 28, and the drilling of Slurry No. 2 was completed in early July. The primary objective of this experiment was to determine the efffective range of the water jet and the strength and competency of the roof caprock in an air environment. In this test mining was restricted to the top five feet of the phosphate bed within a 30-degree arc segment. Mining had progressed to about 20 feet when the roof caprock suddenly failed, allowing overlying clay and water into the cavity. Again the flow was too great for the mining equipment, making it necessary to terminate the experiment and abandon the well. From this test it was concluded that the roof caprock did not have sufficient strength to permit mining in an air environment.



CHLORIDE CONCENTRATION OF WATER FROM THE UPPER PART OF THE FLORIDAN AQUIFER

After USGS.

FIGURE 4

In order to reconfirm the results obtained in Well No. 1 and to field-test a laboratory-developed concept that an air shield around the mining jet would increase its effective range, a request for Slurry Well No. 3 was submitted. This permit was approved and the drilling completed on August 26th. In this experiment initial mining was conducted under flooded conditions using only the water jet (same as the test in Well No. 1) until a total of 430 tons of matrix had been extracted and the solids content of the slurry stream had dropped to less than 5 percent. At this point the air shield was activated and an additional 180 tons of matrix were mined at a rate of 20 tons per hour. The radius of the mined cavity was estimated to be about 20 feet with no roof failure or other major problems.

The main conclusions developed from this test program were:

(1) The roof caprock does not have sufficient competency to permit air mining, and future mining must be conducted under flooded conditions.

(2) The air shield substantially increases matrix production.

(3) The eductor pump performs well under flooded conditions with no serious plugging problems at the eductor ports.

(4) The underlying artesian aquifer remained stable and was unaffected by the mining activity.

The last conclusion was borne out by the results of a ground-water monitoring survey conducted by the Bureau of Mines. A total of 6 wells, one in the Floridan aquifer, three in the Hawthorn formation (one in each phosphatic bed and one in the upper Hawthorn) and two in the surficial aquifer were sampled repeatedly before, during and after the test.

The results of chemical analysis of the samples (Table 1) show that the mining operation did not affect the quality of water in the monitored aquifers. They also indicate little communication between the various aquifers in the Hawthorn formation as evidenced by the noticeable differences in the level of certain parameters particularly chlorides and sulfates. The only monitor well showing any change was the one completed in the Upper Hawthorn. In that well the water became much softer and levels of silica and potassium dropped appreciably. There is no explanation for these changes.

DRAFT

TABLE 1

Owner	Depth of well (ft)	Date of collection	Cal-cium (Ca)	Magne-sium (Mg)	Sodium (Na)	Potas-sium (K)	Bicar-bonate (HCO_3)	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)	Ni-trate (NO_3)	Dis-solved solids (sum)	Total hardness as $CaCO_3$	Spec. Cond. (mmhos at 25°C)	pH	Silica (Si)	Alkalinity as $CaCO_3$	U Diss. µg/L	Ra 226 pCi/L
A 1 Ocala Fm Floridan Aaq.	351	2-2-80	75	31	55	3.0		160	110	0.9			320			27	150	0.02	0.46
		5-2-80	76	35	62	3.0		160	110	1.0			330			28	150		
		5-12-80	71	32	61	2.5		170	—	0.9			310			26			
		5-30-80	70	32	61	2.7		160	110	1.0			310			26			
		6-11-80	72	33	63	2.9		160	110	0.9			320			27			
		6-27-80	75	34	64	2.9		150	120	0.9			330			27			
		7-11-80	71	34	67	3.1		170	110	0.9			320			27			
		7-27-80	75	34	64	2.9		150	120	0.9			330			27			
		11-10-80	69	32	61	3.0		160	110	1.0			310			27		0.05	0.58
C 1 Hawthorne Lower Phosphate Bed ±50 ft from test wells	251	2-2-80	64	27	54	6.8		150	38	1.2			250			48	180	1.2	2.2
		5-12-80	56	29	53	6.4		170	54	1.3			260			45			
		5-30-80	60	30	50	6.3		160	55	1.3			270			44			
		6-11-80	60	31	52	6.5		170	54	1.2			280			43			
		6-27-80	61	32	53	6.3		170	71	1.3			280			34			
		7-11-80	61	31	47	6.2		160	55	1.2			280			43			
		7-27-80	61	32	53	6.3		160	71	1.3			280			44			
		11-10-80	50	26	61	6.5		150	39	1.3			230			49		0.3	3.1*

* A different well closer to the mined site was tested on Nov 10.

WATER QUALITY ANALYSES OF MONITORING WELLS, 1980 AGRICO TEST, ST. JOHNS COUNTY, FLORIDA

(Except as oterwise noted all data are expressed in mg/1)

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TABLE 1 (CONTINUED)

Owner	Depth of well (ft)	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (sum)	Total hardness as $CaCO_3$	Spec. Cond. (mmhos at 25°C)	pH	Silica (Si)	Alkalinity as $CaCO_3$	U Diss µg/L	Ra 226 pCi/L
A3 Hawthorne Upper Phosphate bed	200	5-2-80	32	20	50	7.0		51	25	1.8			160			63		0.4	4.8
		5-12-80	32	20	49	6.8		54	26	1.7			160			62			
		5-30-80	33	21	51	–		58	23	1.8			170			63			
		6-11-80	33	22	56	7.5		54	24	1.7			170			64			
		6-27-80	35	22	56	7.2		59	32	1.8			180			65			
		7-11-80	33	21	49	7.3		62	24	1.7			170			63			
		7-27-80	35	22	56	7.2		59	32	1.8			180			65			
		11-10-80	30	19	50	7.1		61	33	1.8			180			63		0.03	4.3
A4 Upper Hawthorne	151	2-12-80	34	16	21	15		5.0	1.8	0.8			150			28	200	0.01	0.39
		4-28-80	30	16	24	14		5.8	–	0.9			140				170		
		5-12-80	31	17	26	15		4.8	2.0	0.9			150						
		6-11-80	29	16	27	14		4.6	2.7	0.8			140			12			
		6-27-80	31	17	26	–		4.9	–	0.9			150						
		7-11-80	37	16	24	14		1.0	0.7	0.8			130						
		7-27-80	31	17	26	24		4.9	0.6	0.9			150			6.4			
		11-10-80	14	11	24	5		1.4		0.8			73			6.9	93	0.03	0.11
A5 Shallow Aq.	73	2-12-80	60	9.6	11	14		3.0	0.4	0.4			190			–		0.02	0.36
		4-28-80	54	9.7	12	13		3.0	0.0	0.4			170			12	190		
		5-19-80	55	10	13	14		2.7	–	0.4			180			29			
		6-11-80	53	10	14	13		2.9	–	0.4			170			22			
		6-27-80	57	10	13	20		3.1	0.3	0.4			180			15			
		7-11-80	57	10	12	14		3.2	1.1	0.4			180			12			
		7-27-80	57	10	13	14		3.1	–	0.3			180			–			
		11-10-80	55	9.8	11	16		3.1	1.6	0.4			180			–	210	0.05	0.25
A6 Shallow Aq.	45	2-12-80	83	2.7	13	22		0.7	0.4	0.1			220			25	230	0.26	0.19
		5-2-80	82	2.9	14	22		0.6	0.8	0.2			220			25			
		6-11-80	82	3.0	15	22		0.4	0.1	0.2			220			25			
		Well destroyed																	
Reinjected Water		5-2-80	63	33	58	6.6		160	93	1.8			290			35			

Samples from these wells were also analysed for radioactivity before and after the test mining. The results indicate no significant changes in the wells completed in the Floridan or the surficial aquifers. Levels of radium 226 are naturally higher in the phosphate beds than in the other aquifers.

Proposed Agrico Program for 1982

The proposed slurry mining program for 1981-82 will consist of mining six slurry wells, desliming the matrix, storing the clay and feed, and backfilling the mined-out cavities with a reconstituted mixture of clay and feed. A scanning sonar unit will be used to measure size, shape and configuration of the excavated cavities.

The lower phosphate bed near the Hawthorn formation will be mined. Slurry well casing will be set in the dolomitic unit overlying the phosphate bed and stabilized at the surface with a retention collar. With the outer annulus between hole wall and casing filled with heavy drilling mud, the casing will remain in place during mining and backfilling, eliminating the need for cement or downhole packers.

Mined-out cavities will be backfilled with a mixture of clay and feed. This will simulate a clay-tails mixture which would be used for cavity backfilling in a full-scale pilot or production operation. The sonar unit will be used to determine backfill conditions including direction and rate of flow, compaction and fill-water interface. After cavity backfilling is completed, the drill hole will be backfilled at the same time that the casing is extracted. Casing will be stored for reuse in the next hole.

The USGS and the Bureau of Mines are planning an intensive monitoring program for this proposed program.

APPLICABILITY OF THE TECHNIQUE TO OTHER AREAS

If the slurry mining method used at the Agrico site proves to be economically and environmentally sound, thousands of acres in St. Johns and neighboring Duval counties could be opened to phosphate mining using this technique.

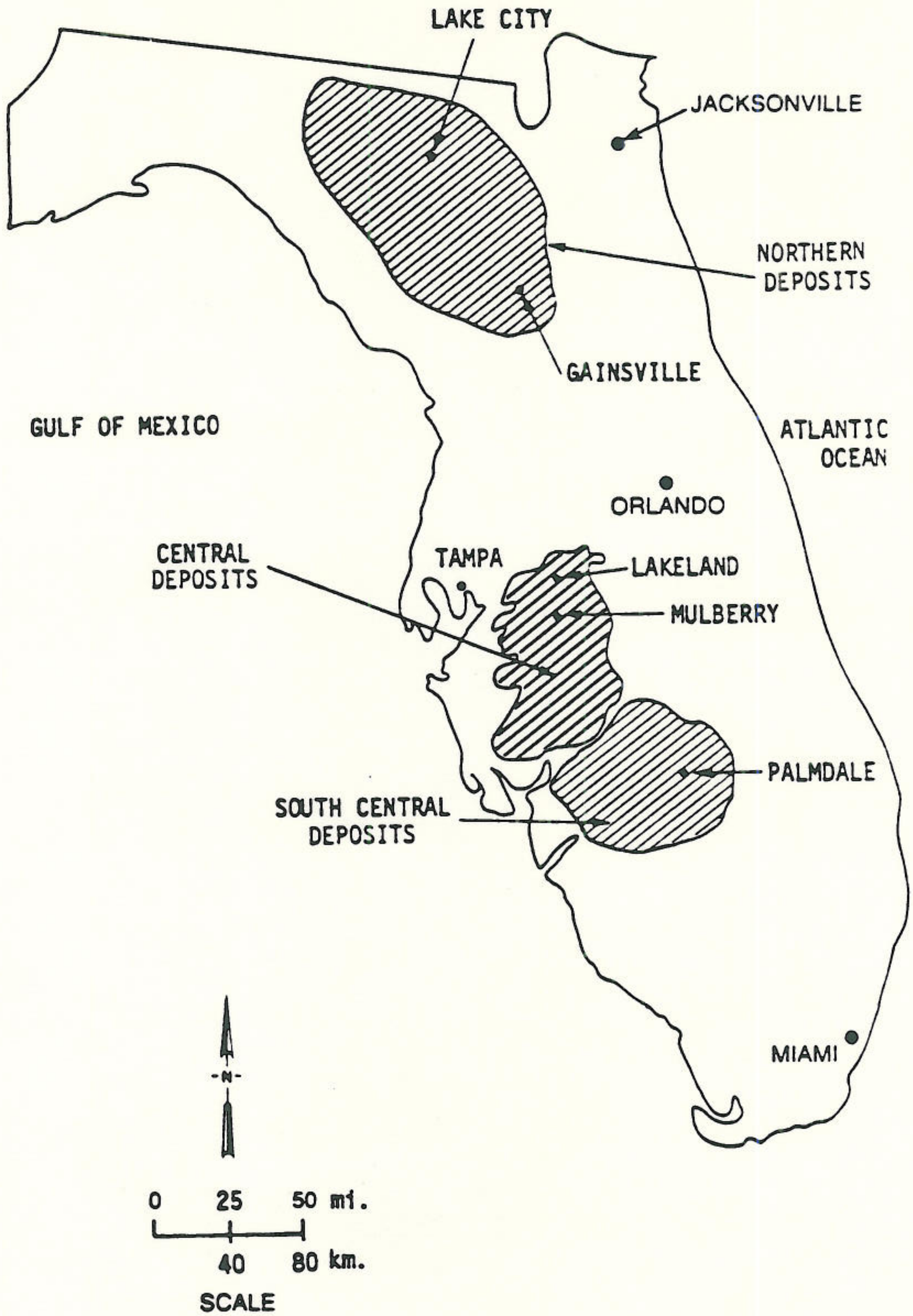
An environmental assessment prepared for the U.S. Bureau of Mines by PRC Toups and Mountain State Research and

Development also indicates current or near future in situ potential for the pebble phosphate deposits of Central Florida (Figure 5). These deposits are currently produced from near surface deposits by conventional stripping and open pit mining methods; however, long term exploitation of deeper strata might employ the in situ technique of borehole slurry mining.

The deposits are contained in the sandy clays of the Bone Valley Formation. They are overlain by clayey sands of the upper Bone Valley and Pleistocene surficial sands, and underlain by the fine grained clastics, sandy limestones and calcareous clay of the Lower Bone Valley. The overburden is a water table aquifer capable of yielding water to domestic wells. Underlying these deposits are the Miocene Age Hawthorn Formation and the Tampa Limestone which form the discontinuous secondary artesian aquifers and the upper unit of the Floridan Aquifer, used primarily for domestic and small scale irrigation purposes. A sand and clay unit at the base of the Tampa Limestone averaging 42 feet in thickness separates the upper unit of the Floridan Aquifer from the lower unit which consists of the limestone and dolomite beds of the Suwanee Limestone, Ocala group, and Avon Park Limestone. This is the major source of water supply in the area.

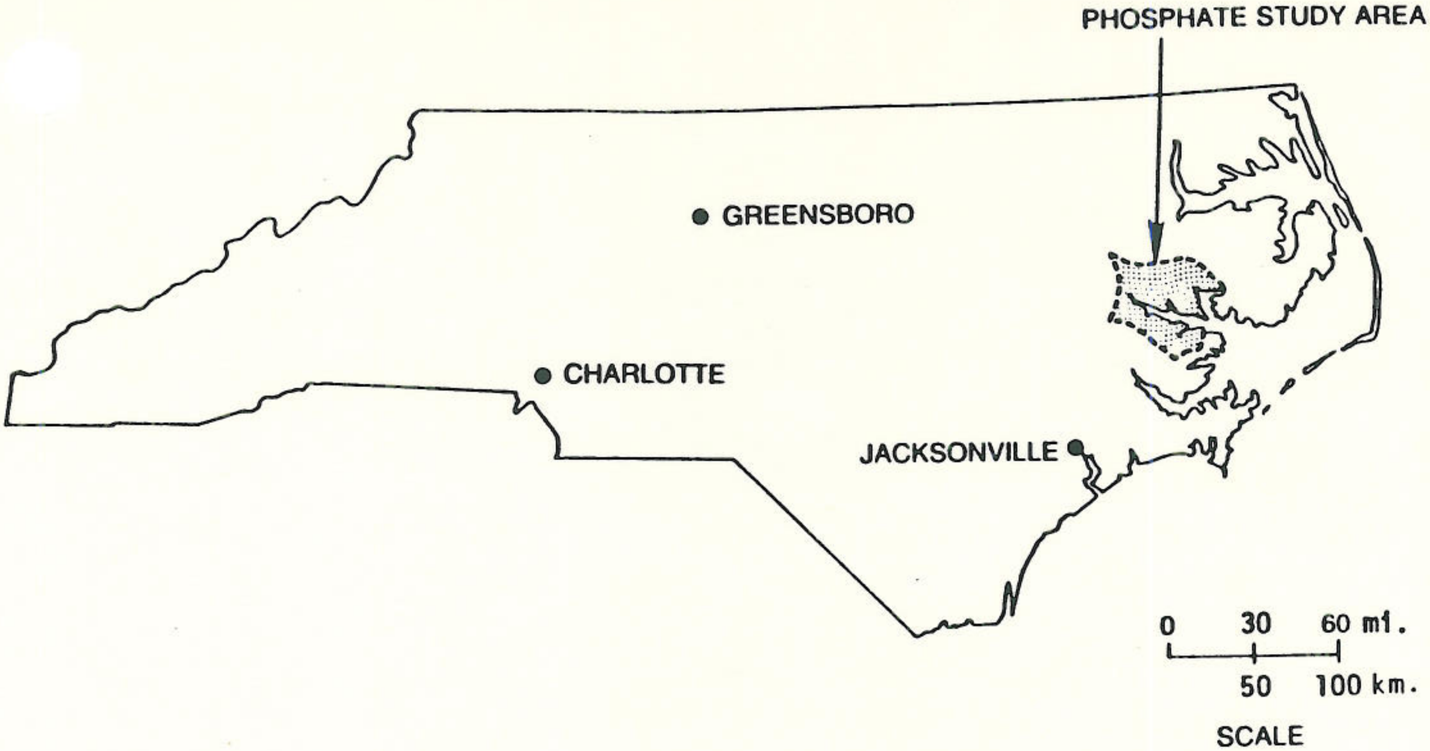
Another potential area for in situ mining of phosphate is located in North Carolina, in the Kidd Creek area. (Figure 6). These deposits occur in Tertiary environments, the phosphate deposits range from 3 to 90 feet thick and are overlain by strata that range between 45 and 250 feet in thickness. The overburden consists of undifferentiated surficial sand, and of the clay deposits with lenticular shell beds, marl, and sand, of the Yorktown Formation. This formation is capable of yielding significant quantities of water and is used as a water supply for municipal and industrial purposes.

Underlying the phosphate deposits which consist of phosphatic sands and alternate layers of calcitic and dolomitic limestones, is the Eocene Castle Hayne formation, which is the major artesian aquifer in the area and the most productive in the State. (Figure 7).



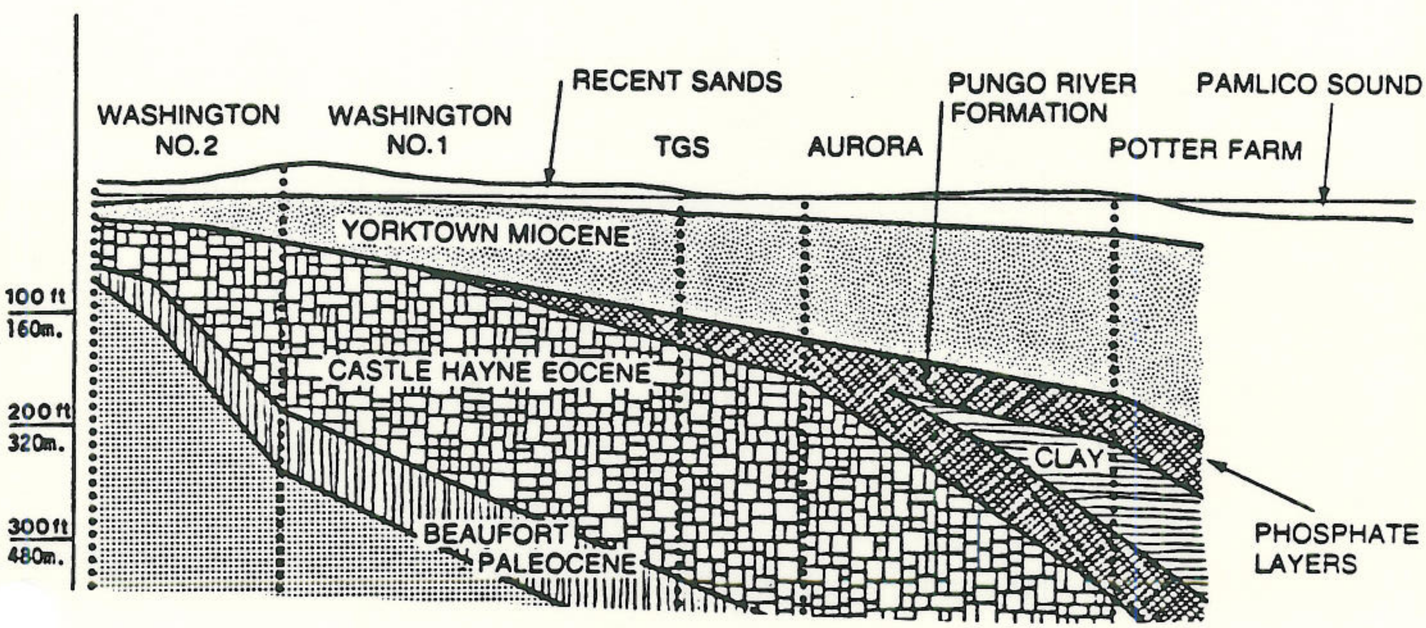
MAJOR PHOSPHATE DEPOSITS IN FLORIDA

FIGURE 5



KIDD CREEK PHOSPHATE DEPOSITS NORTH CAROLINA

FIGURE 6



CROSS SECTION OF THE KIDD CREEK PHOSPHATE DEPOSITS

FIGURE 7

CONCLUSIONS

The slurry borehole technique seems to be environmentally preferable to strip mining for mining phosphate deposits since it would result in less surface disturbance.

However, all of the potential sites are in water rich environments and aquifer protection should be the prime consideration in any regulatory environmental protection program. From the results of the Agrico test one can conclude that during the mining phase the primary concern should be to prevent the collapse of the overburden, and to avoid creating communication with underlying aquifers. As soon as the mining phase is over the cavity needs to be backfilled to prevent any communication between aquifers. The next phase of the Agrico testing program and the accompanying USGS monitoring program should provide valuable information which can be used in setting more specific requirements for this practice.

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