Hydrologic Effects of Sand Mining in Lake County, Florida

Prepared for:
E.R. Jahna Industries, Inc.

By Marc V. Hurst, P.G.
January 22, 2002

Independent Geological Services, Inc.

Table of Contents

List of Figures

Page

List of Tables

Page

Executive Summary

This study examines the effects of sand mining on the groundwater resources of Lake County, Florida, with emphasis on water levels and recharge to the Floridan Aquifer System. It includes introductory review of background information and theoretical analysis of the effects of sand mining based upon numerical simulations, measurements, and observations.

All of the currently active operations mine by a method described in this report as "closed-loop hydraulic dredging," a method that retains water on site and recycles it to minimize consumption of water and eliminate the need for off-site discharges. Closed-loop hydraulic dredging has replaced older, less environmentally-friendly methods that involved excessive removal of water.

Water use and consumption by sand mines was quantified and compared with other water users in Lake County. Water Management District and producer's records were reanalyzed to account for recycling versus consumption. Only the consumed portion (that which is removed from its source and not replaced) has any hydrologic or environmental significance.

Based on hydrologic considerations and geographic setting, the study groups the sand mines of Lake County into two general categories: Swamp-Type Mines and Ridge-Type Mines. Swamp-type mines typically occupy low relief upland areas that are mostly surrounded by and intermixed with large wetlands, such as the Green Swamp. Ridge-type mines are located in high ridge areas that are dominated by uplands, such as the Lake Wales Ridge. Generic swamp-type and ridge-type mines were simulated (modeled) under pre-development, active operation, and post-mining conditions to evaluate potential effects on groundwater levels and recharge.

Lake County requires periodic monitoring of groundwater levels at new mines. Vegetative monitoring has been required in some cases. Most of the existing monitoring data were collected from swamp-type sand mines, where no measurable impacts have been detected in water levels or vegetatation to date. The site-specific data confirm this study's conclusions concerning swamp-type mines. However, the existing site-specific data were not sufficient to confirm this study's theoretical predictions for ridge-type mines.

Several informative conclusions were derived from this study. They are summarized below.

- In 1997, the most recent year for which complete records were available, agriculture and public supply consumed the largest quantities of water in Lake County. Sand mining was the third-largest consumer. The 9 sand mines that were active in Lake County in 1997 were responsible for about 10 percent of Lake County's water consumption. Although sand mines pumped very large

quantities, the majority was recycled; just 14 percent was consumed (removed from its source).

- An average sand mine is responsible for about 1 percent of the water consumption in Lake County.

- Sand mining in a swamp-type setting may subtly reduce adjacent Surficial Aquifer System water levels. Simulations indicated mine-related reductions that were small (inches) in relation to natural seasonal variations (feet), therefore difficult to detect, and probably of little environmental significance.

- Setbacks offer little hydrologic protection for wetlands. In a swamp-type setting, simulations indicated that mine-related water table reductions were insignificantly small, with or without wetland setbacks.

- Sand mining in a ridge-type setting might measurably reduce adjacent Surficial Aquifer System water levels. Unconfirmed simulations indicated reductions approximately equal in magnitude to natural seasonal variations. However, the predicted water level reductions are expected to have little regulatory or environmental significance, because the Surficial Aquifer System is not an important water source in Lake County; and natural upland plants associated with the ridge-type environment are insensitive to water table variations, particularly in areas where the water table is extremely deep.

- Both swamp- and ridge-type mines might subtly reduce Floridan Aquifer System levels (potentials). Simulations predicted reductions that are small (inches) relative to natural seasonal variations (feet), and insignificant from regulatory or environmental perspectives. Although ridge-type sand mines typically require larger well withdrawals than swamp-type mines, reviewed data indicate that the Floridan Aquifer System is typically more transmissive in the ridge mining areas, and better able to accommodate larger withdrawals.

- Land use changes associated with mining, like conversion of uplands to lakes, can potentially reduce availability of water for recharge to the Floridan Aquifer System by increasing evaporation from the site. Reductions are partially offset by capture and storage of additional water in mine pits that otherwise would have run off from the site.

- A typical sand mine pit lake in Lake County consumes about the same amount of water as a residential development of the same size with a housing density of 2-3 units per acre.

- A typical sand mine pit lake in Lake County consumes only 50-75% as much water as a typical citrus grove of the same size.

Introduction

Sand is essential to our modern society, particularly in growth areas like Lake County and the Central Florida area. Roads, bridges, and buildings are basically just cleverly shaped piles of sand held together by cement. When a new building rises from the ground, somewhere else an excavation is made to supply the raw materials. Although few people visit sand mines as often as the grocery store, everyone uses large quantities of sand. The public pays for the sand that governments and contractors buy for them through taxes and mortgage payments.

Coarse-grained sand that meets specific size gradation and purity standards is required for production of strong and durable concrete. To ensure public safety, the Florida Department of Transportation (FDOT) has adopted the most stringent standards for concrete sand. To be certified as "FDOT sand," a sand product must contain specific proportions of a variety of particle sizes, and it must be free of impurities that can cause deterioration of concrete. FDOT sand is required for all public construction projects, including highways, bridges, and public buildings. Many private contractors require FDOT sand for their projects, too.

Thin layers of fine-grained sand are found almost everywhere in peninsular Florida. Unfortunately, very little is coarse or pure enough for commercial use. The commercial sand deposits of Peninsular Florida are generally related to two geologic units, the Cypresshead Formation and Quaternary sediments that were reworked from the Cypresshead and redeposited. These units occur in a long and relatively narrow zone, about the same width as Lake County, that follows a north-south trend along the middle of the Florida peninsula. Lake County straddles this trend almost perfectly. Figure 1 shows the locations of commercial sand mines in Florida. Lake County is one of very few counties in Florida with commercial-grade sand deposits suitable for mining and use in the construction industry. In places like South Florida, where local sources are not available, commercial-grade sand must be imported at great expense, or manufactured by expensive rock crushing and screening processes.

As of the date of this report, three of Lake County's commercial sand mines have recently closed due to depletion of reserves, leaving only seven active operations. Although Lake County has permitted several expansions of existing mines, only 2 new operations have been permitted in the past decade. One is scheduled to begin production soon. Figure 2 shows the locations of sand mines in Lake County.

Ironically, in Lake County, the same developments that fuel the demand for commercial sand have begun to compete with mines for the land that contains the sand deposits. Data from Lake County records indicate that as of late 1993, urban development had affected over 62,000 acres. About 2,200 acres had been affected by sand mining.

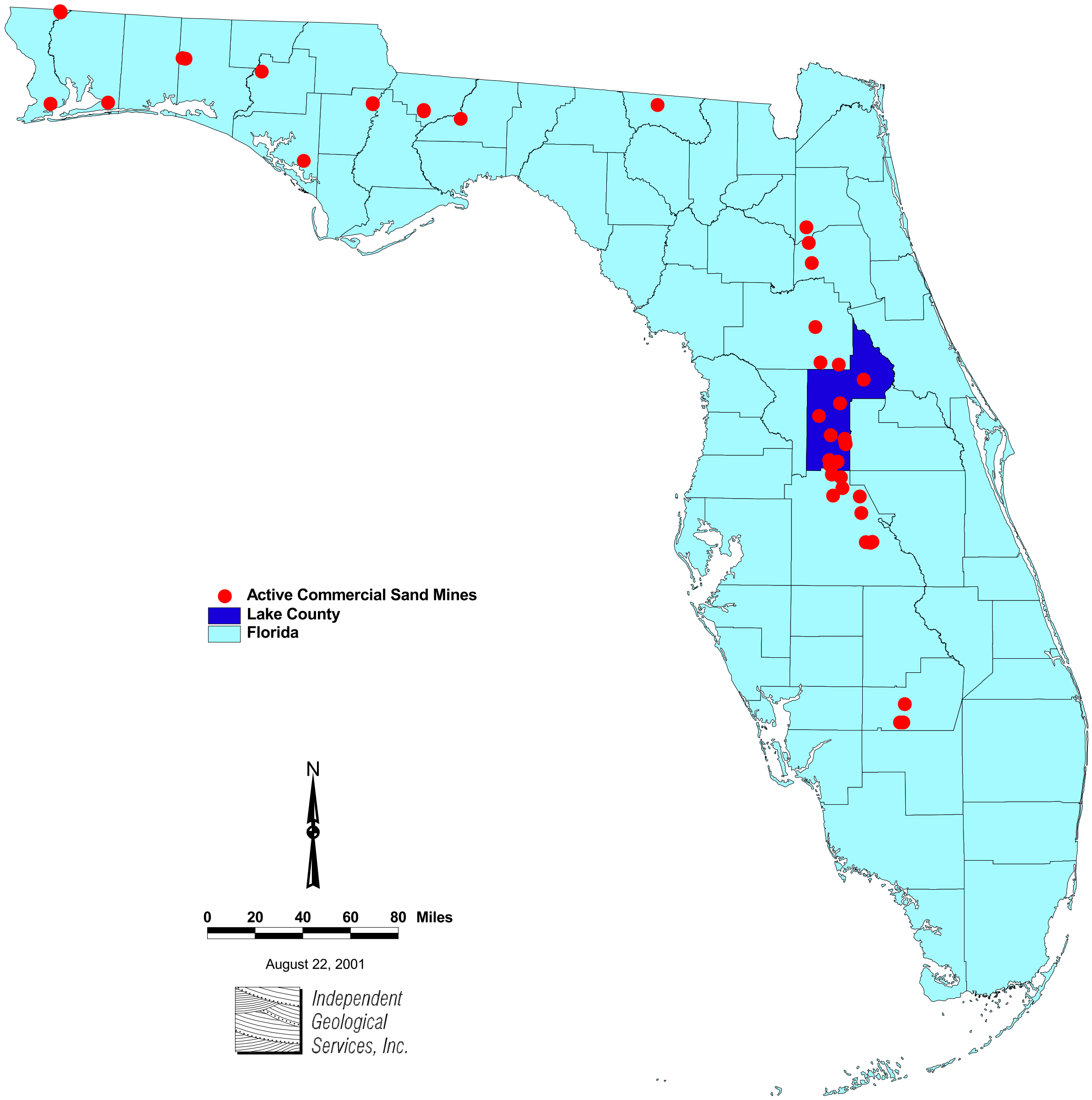


Figure 1. Locations of Commercial Sand Mines in Florida

Note: Sources of fill material, manufactured sand, and sand by-products were excluded.

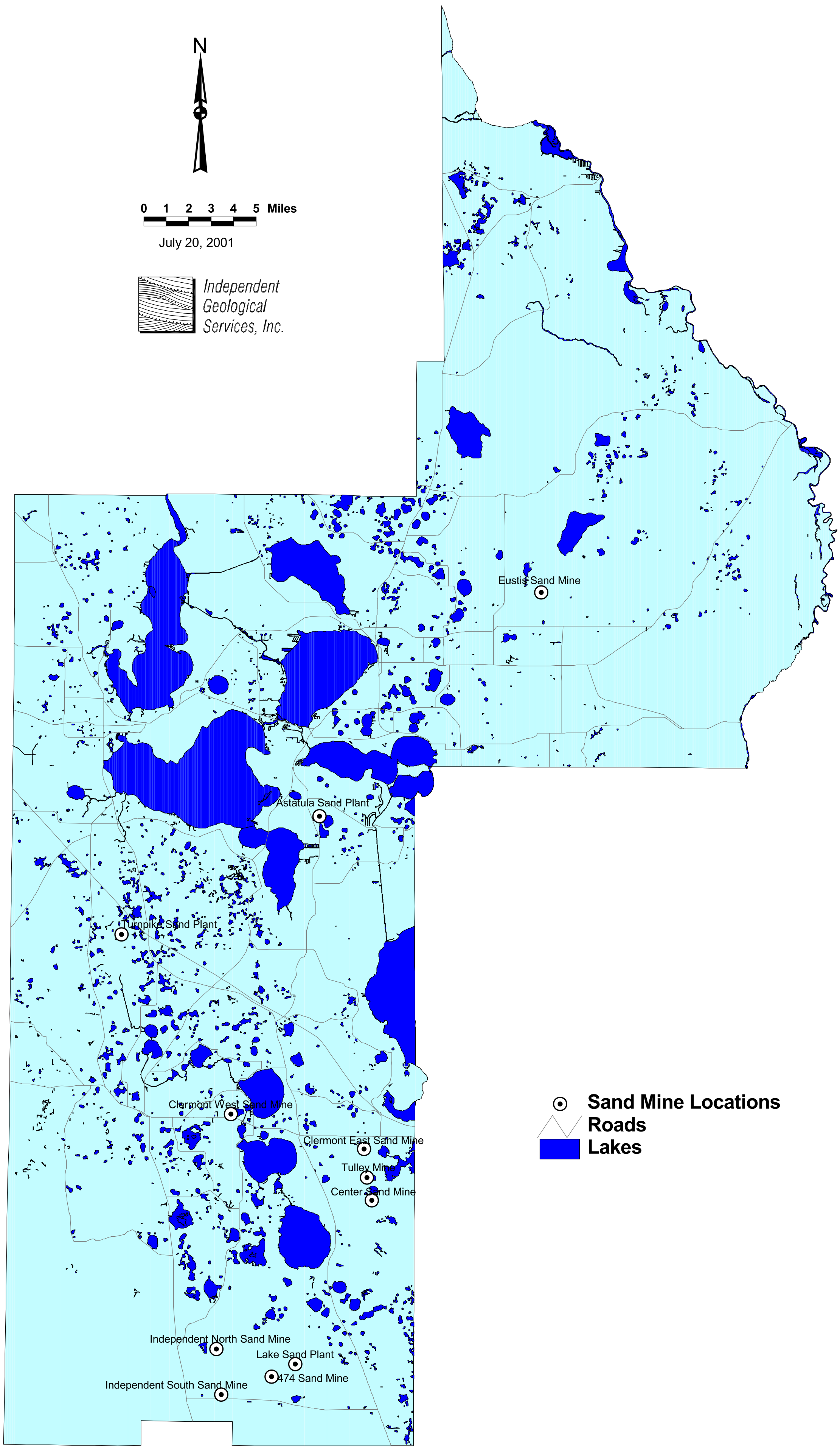


Figure 2. Locations of Sand Mines in Lake County

In response to rapid development, Lake County has adopted a comprehensive plan and a set of Land Development Regulations (LDR) to manage growth. Responsible growth management should include planning for sources of raw materials like commercial sand. Under the comprehensive plan and LDR's, sand mining is regulated like other forms of development; and a variety of concerns must be addressed before a new mine is started. Monitoring programs are required to assure compliance as mining operations progress. Some impacts, such as traffic and land use, are easily identified and measured. Others, like some hydrologic impacts, are more difficult to assess.

This study examines the potential effects of sand mining on the groundwater resources of Lake County, Florida, with emphasis on water consumption, and effects of land use changes on water levels and recharge to the Floridan Aquifer System. It includes introductory review of background information, theoretical analysis of the effects of mining based upon numerical simulations, measurements, and observations.

Geology of Sand Deposits of Lake County

Lake County has had a relatively short, but complicated geological history. The oldest known rocks in this area are volcanic and metamorphic rocks. They are buried thousands of feet below land surface. Only the deepest petroleum exploration wells have penetrated them. These "basement rocks" are remnants of an ancient continent. They predate Florida as we know it today.

The Florida we know began as coral reefs and related marine communities that developed in a shallow ocean on the much older basement rocks. Because Florida was not directly connected with the North American continent during its early development, the only sources of sediment were the skeletons of marine organisms, which became limestone deposits, and minute traces of dust that settled from the atmosphere. The shallow ocean basin gradually subsided under the increasing weight of the accumulated hard body parts of the flourishing marine life that progressively filled it. The result was a tremendous thickness of limestone strata. Geologist's call features like this "limestone platforms."

While the Florida platform was developing, Lake County resembled the contemporary Bahamas, or Florida Keys. Limestone was very common; but quartz sand was conspicuously absent. During this time, known as the Eocene Epoch, limestone formations known as the Ocala Group were deposited. Today, these limestones are found under all of Lake County, at relatively shallow depths.

By the Miocene Epoch, which began about 24 million years ago, a physical connection had been established between Florida and the land mass that today is known as Georgia. Florida was no longer an island. The Appalachian Mountains were much taller and steeper than today; and tremendous quantities of gravel, sand, and clay were eroded from them and washed into the adjacent ocean. Tidal processes and longshore currents began to transport quartz sand and clays south along the coastline, from Georgia to Florida. Sea levels fluctuated; but they were generally much higher than today.

Around the same time, phosphate deposits began to accumulate in central Florida as strong currents caused nutrient-rich deep-ocean water to upwell and bring unusual concentrations of phosphorus into the area.

When water moves sediments, the more fine grained fractions, like sand and clay, migrate more quickly and farther than the more coarse-grained materials, like gravel. During the Miocene, most of the sediments that reached Polk County from Georgia were relatively fine-grained and clay-rich. And due to the phosphorus-rich chemical environment, most of the sand that was deposited in Lake County during that time contained phosphate. These Miocene sediments are known as the Hawthorn Group. Sediments of the Hawthorn Group generally consist of clays with smaller amounts of quartz and phosphate sand. Most of the Hawthorn Group sediments that were deposited in Lake County were subsequently removed by erosion.

During the Pliocene Epoch, which began about 5 million years ago, sea levels were again very high. Tidal processes and longshore currents transported more coarse-grained sand into Lake County from the north. When sea levels were highest, Lake County was a shallow shoal area where sand bars accumulated. When sea levels were lower, Lake County was part of a narrow peninsula. Beaches, that developed along various shorelines, related to different sea levels, acted to further concentrate coarse sand. By this time, phosphate deposition had ended; so the Pliocene sand deposits of Lake County generally contain little or no phosphate. The Cypresshead Formation is the geologic unit that was deposited in Lake County during the Pliocene Epoch. The Cypresshead Formation contains many commercial sand deposits, generally related to old beach lines.

More recently, during the Quaternary Period, which began about 2 million years ago, sea levels rose high enough to flood Lake County several times. Figure 3 shows the approximate locations of several ancient shoreline terraces that formed at times when sea levels were high. During each high stand of sea level, sediments deposited during earlier times were partially eroded and redeposited along new beach lines, rivers, or tidal channels. Geologists call this process “reworking.” Frequently, when older sand-bearing deposits were reworked, high-quality sand deposits were formed. The Quaternary sediments that were reworked from the older Cypresshead Formation frequently contain commercial sand deposits. Although no formal names have been given to the Quaternary sediments of Lake County, several different units have been recognized. Recent geologic maps show their locations. Figure 4 is a geologic map of Lake County based upon work completed by the Florida Geological Survey (Scott, 1992).

The occurrence of commercial sand deposits in Lake County, and their high quality, is related to the numerous changes in sea level that occurred in the past. At times when sea levels were high, sediments were reworked; and, in some cases, coarse-grained sand was reconcentrated into more valuable sand deposits. During times when sea levels were low, and Lake County was above sea level, sand deposits were exposed to a different geochemical environment, and a process that geologists call “subaerial weathering” occurred. Atmospheric gases and rainwater percolated down through the sediments and chemically leached many impurities out the sand, further improving the quality of the deposits.

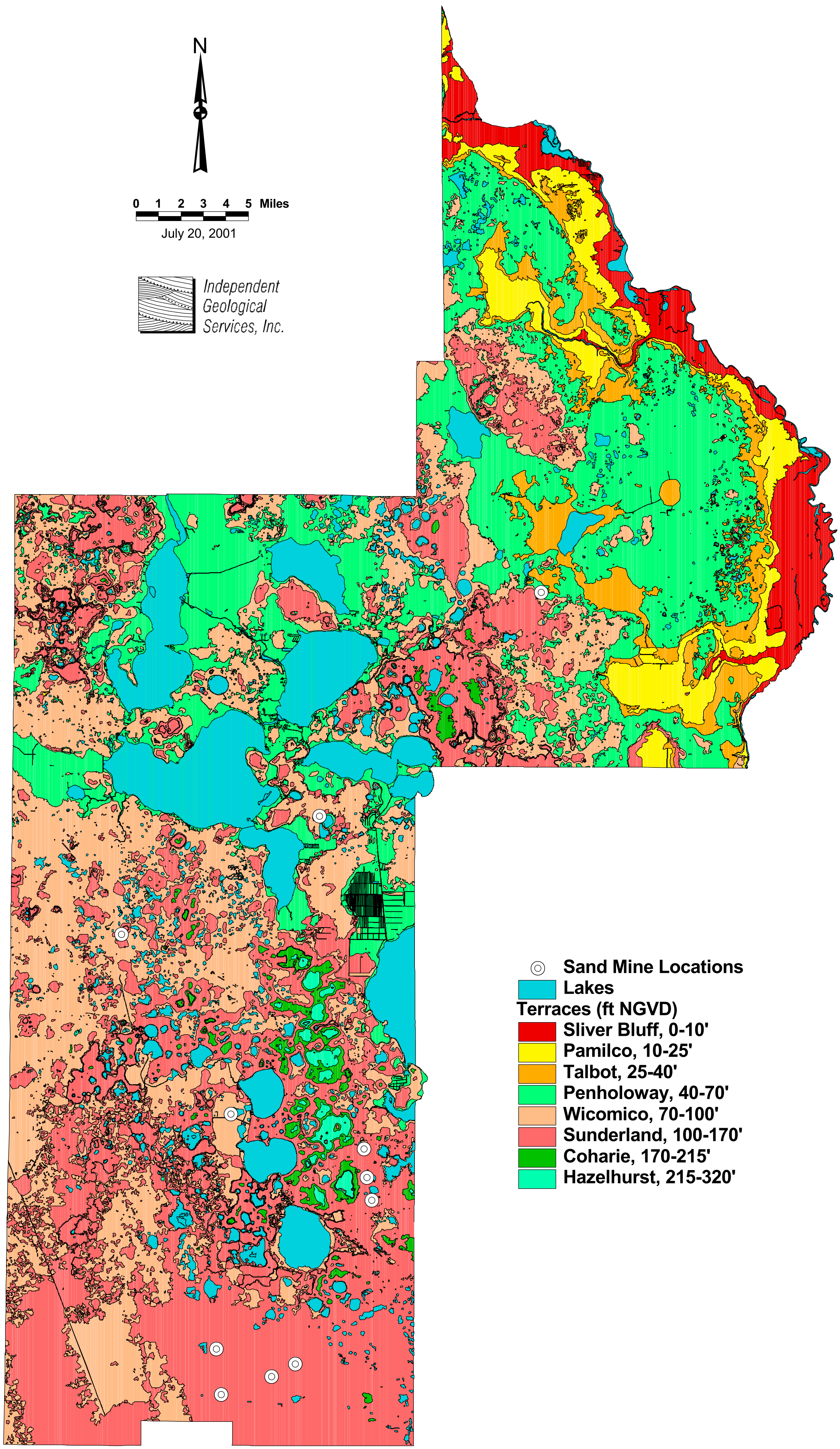


Figure 3. Ancient Shoreline Terraces in Lake County

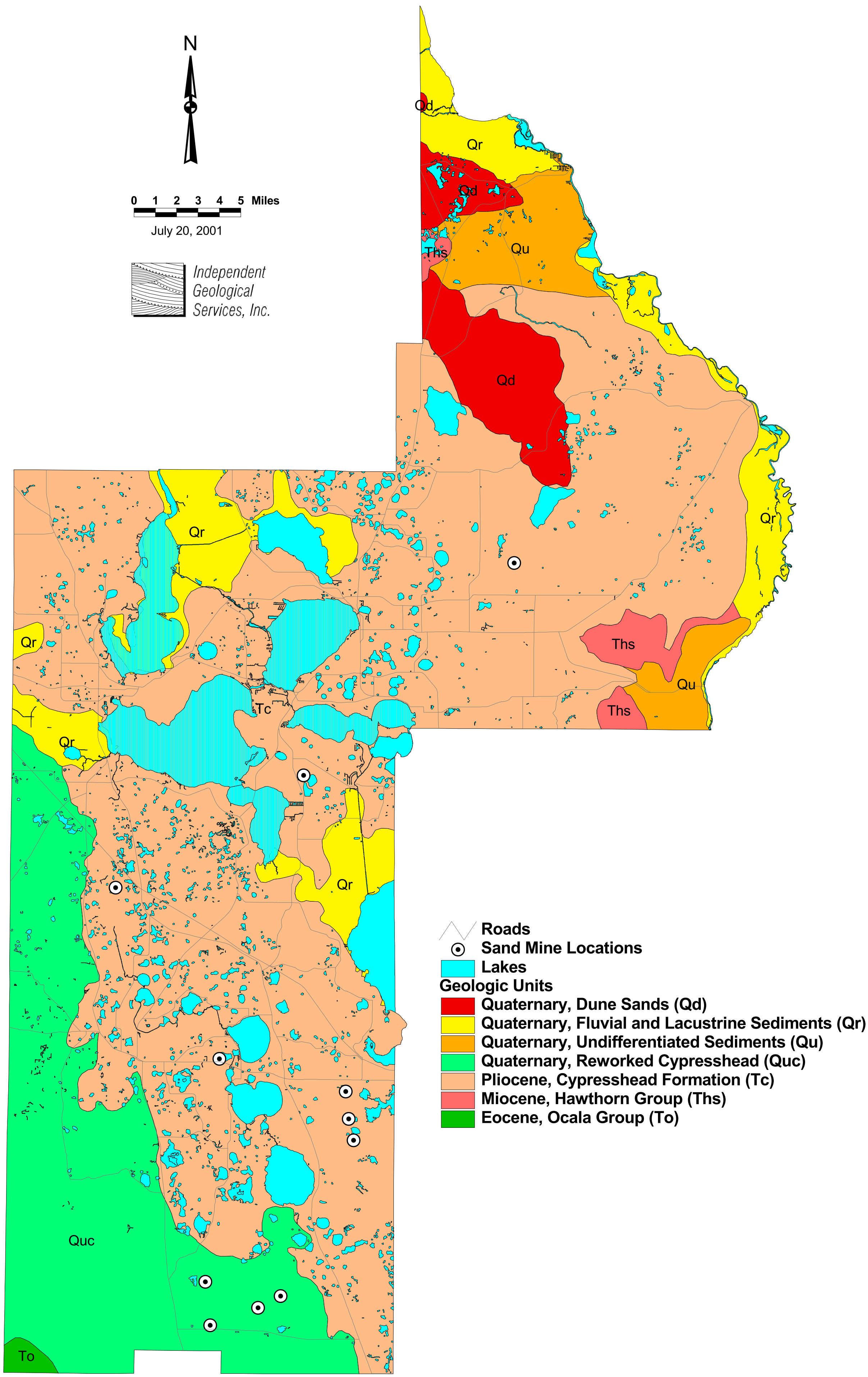


Figure 4. Geologic Map of Lake County

Sand Mining Methods

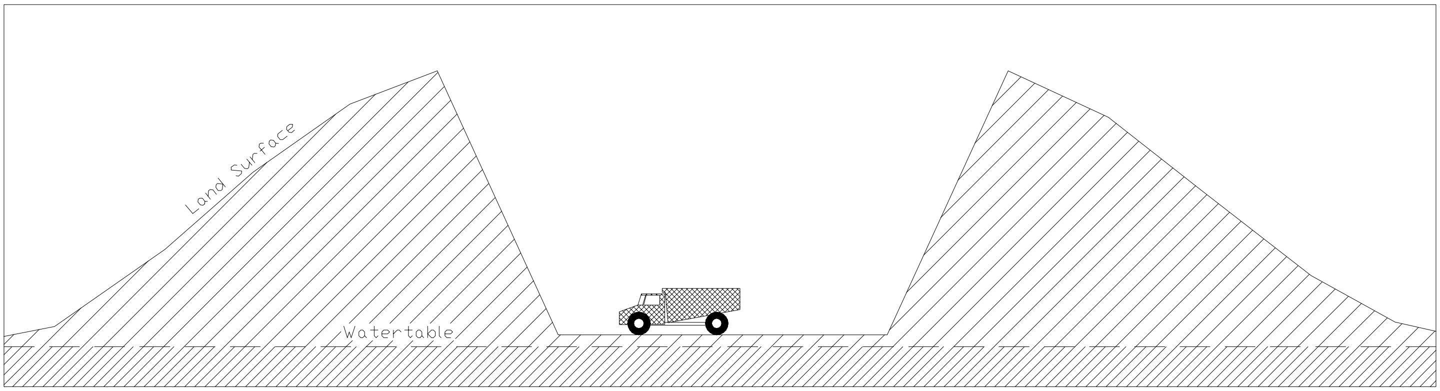
Sand can be mined or extracted by several methods. General descriptions of four methods are given below. Three of the methods are commonly used in Lake County. Factors including thickness and depth of the deposit, depth of the water table, and environmental factors must be considered to select the most practical method for mining a particular deposit.

The simplest method, excavation from dry open-pits, may be used to mine materials from high, well-drained ridges where water tables are deep. A generalized cross-section of this type of mine is shown in Figure 5A. In Lake County, borrow pit operators typically mine by this technique. It is seldom used by commercial sand miners. Trucks are driven into the dry pits and loaded directly with materials that are excavated by conventional wheel or track-mounted earth moving equipment, like pan excavators or loaders. Mining depths are limited by the depth of the water table. When conducted properly, with appropriate erosion controls, this method results in no significant hydrologic impacts, because no alteration of groundwater flow is required. If appropriate mining and reclamation plans are followed, reclaimed dry open-pit mines can be environmentally sound and aesthetically pleasing parcels of land. After vegetation becomes completely reestablished, they are frequently indistinguishable from adjacent properties. There are numerous active and inactive borrow pits in Lake County. Many were completed before sound reclamation was required.

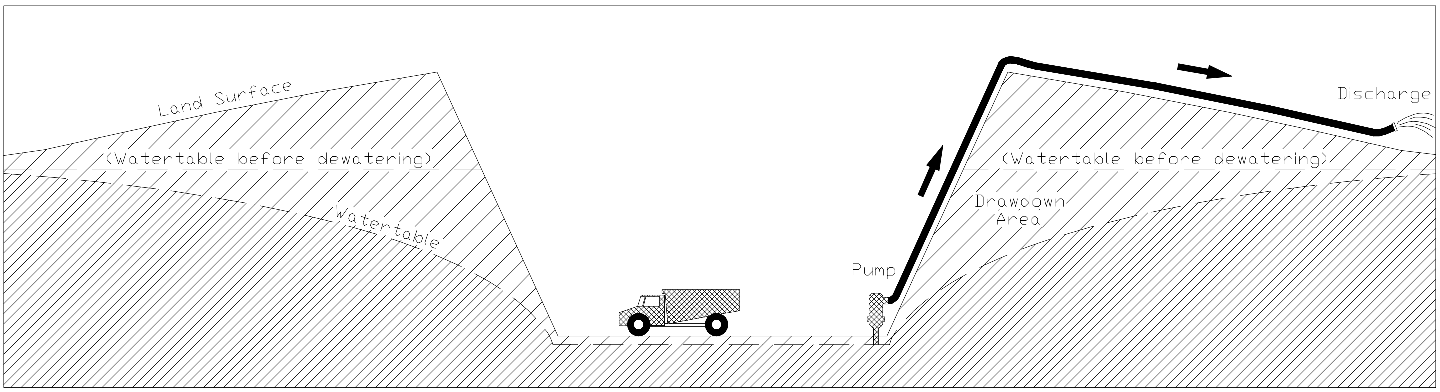
Dry open-pit methods are seldom practical for mining sand in Lake County. Most commercial sand deposits are too thick and deeply-buried to mine completely without penetrating the surficial water table. Many commercial sand deposits are located in areas like the Green Swamp, where the water table is very shallow.

When pits are excavated to depths below the water table, groundwater from the Surficial Aquifer System seeps in and floods them almost as quickly as they are excavated. To mine below the water table with conventional wheel or track-mounted earth-moving equipment, it is necessary to maintain a dry excavation by installing large pumps to remove water from the pit as it seeps in. This process is called dewatering. Figure 5B is a simplified cross-section of a dewatered open-pit mine. No sand miners use this method in Lake County today; however, it is commonly used for mining peat.

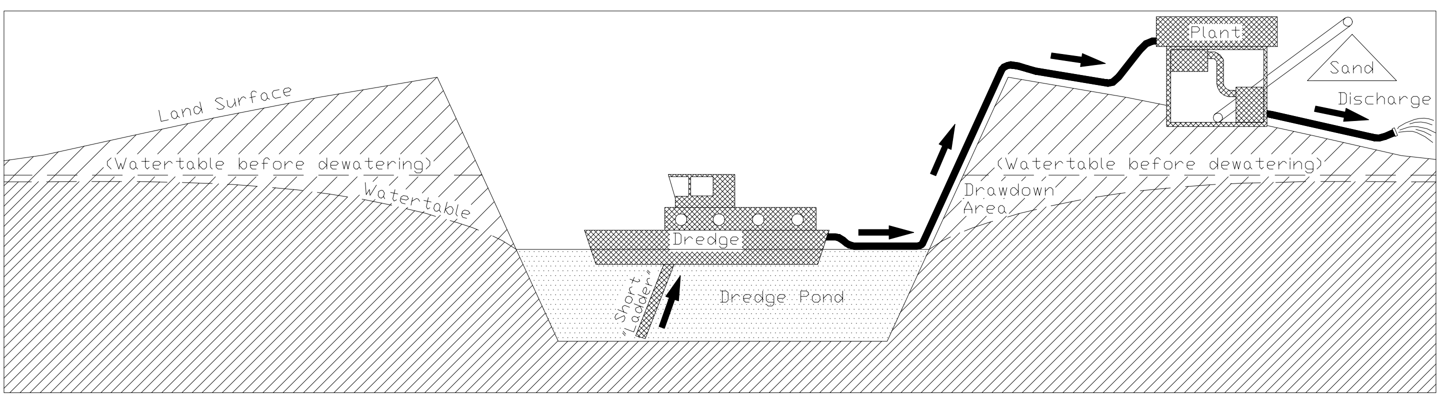
Pit dewatering may cause three environmental impacts that must be mitigated. First, dewatering tends to draw down (lower) water tables adjacent to the dewatered pits, which may distress vegetation. And second, the water that is removed from the pits must be stored on-site, or discharged elsewhere, where it may cause flooding problems. And third, unless proper treatment methods are used, water quality violations may result.



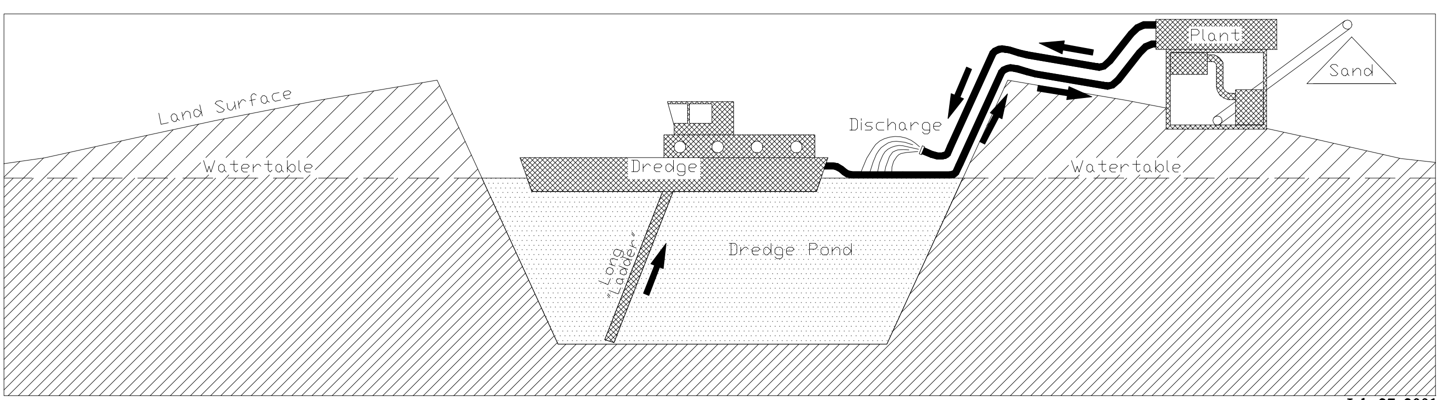
A. Dry Open-Pit Mine, No dewatering is required.
(Borrow Pit)



B. Dewatered Open-Pit Mine, Water is removed from pit and discharged elsewhere.



C. Open-Loop Dredge Mine, Some water is removed and discharged elsewhere.
(Not allowed in Lake County)



Independent
Geological
Services, Inc.

D. Closed-Loop Dredge Mine, Water is recycled through pond and plant.
(Commonly used in Lake Co.)

July 27, 2001
Not to Scale

Water Flow Direction

Figure 5. Simplified Cross-Sections of Various Mining Methods

For technical reasons, pit dewatering may be an absolute requirement in some types of operations, such as peat mines, or the phosphate mines in nearby Polk County. However, modern sand mines seldom dewater their excavations; there is generally no technical necessity to do so. And it is very expensive to dewater and mitigate the associated environmental impacts.

To avoid dewatering, and the associated environmental and economic costs, almost all sand miners use dredge mining techniques. A dredge is a floating excavation device that functions like an underwater vacuum cleaner. It pumps a mixture of sand and water from the bottom of a water-filled excavation, called a dredge pool (also referred to as a dredge pond or a mine lake). Because dredges are designed to float in ponds above the areas they mine, it is not necessary to remove water from the excavations. Generally, the sand and water mixture, called a slurry, is pumped through a pipeline to a processing plant where the sand products are separated and sized. Dredging can be a closed-loop or an open-loop process, depending on whether the water that is pumped by the dredge is returned to the dredge pond after processing, or discharged elsewhere.

In the past, open-loop dredge mining was used at some sand mines. Old-fashioned dredging equipment was limited in how deep it could mine. To lower water levels in the dredge ponds, so that the dredges would float lower, and sand could be mined from deeper in the deposit, miners would discharge some, or all, of the water that was pumped from the dredge ponds to other places, to partially dewater the ponds. Figure 5C is a simplified cross-section of a open-loop dredge mine, similar to past operations in Lake County. In addition to the environmental costs that resulted from dewatering, fuel costs to run the pumps for dewatering were very expensive. So over the years sand miners modified their dredges to mine deeper without dewatering. Modern sand mines seldom dewater their excavations. With modern dredging equipment, there is no technical necessity to do so.

Most modern sand mines, including all that are currently active in Lake County are closed-loop dredge mines. Please refer to Figure 5D. After the sand is separated from the water at the plant, virtually all of the water is returned to the pond and recycled. Very little water is removed from the system; and environmental problems associated with discharging water off-site are avoided. If the water is returned to the same pond that it was removed from, the water levels in the dredge ponds are almost identical to adjacent natural water tables, and areas adjacent the dredge ponds are not typically affected by the operation of the mine.

If a mine site does not contain an appropriate pond to begin mining in, then a “start-up” pit and a tailing disposal area must be excavated. And a large well must be installed to produce water to use for mining during the first few weeks or months of operation, until dredging has enlarged the pond to a self-sufficient size. This initial phase of operation is called the “start-up” phase. Water consumption and related impacts are significantly greater during the brief start-up phase than during the remainder of the mine life.

In some closed-loop sand mines, water used for processing flows through a series of hydraulically linked ponds as it returns to the dredge pond. The hydraulic resistance of the connections between ponds may result in a significant water level gradient. Ponds on the upstream end of the chain will be elevated above adjacent natural water tables; and ponds on the downstream end of the chain will be depressed below adjacent natural water tables. This effect can be minimized by designing interconnections between ponds with minimal hydraulic resistance, and eliminating water level control structures.

Sand mining does not physically penetrate, or disturb, the strata that comprise the Floridan Aquifer System. The sand-bearing layer is typically separated from underlying limestones by a clay layer. No economic sand is found in the clay or limestone found below the mine. Therefore, there is no reason for sand mines to penetrate into the Floridan Aquifer System.

Sand Processing

In Lake County, most sand deposits consist of mixtures of different sizes of sand grains, silt, and clay. Some products, like fill and some clay materials, require no processing; raw materials are dug from the ground and simply loaded onto trucks for delivery to customers. However, most commercial and industrial sand products, require processing of the raw materials to remove undesirable impurities and to extract specific sizes of sand grains. In Florida, the coarser (larger) sand grain sizes are very uncommon, and therefore the most valuable.

Most commercial sand mines have processing plants, called washers, on site. Raw sand and clear water from the dredge pond are fed into the plant; and various sand products and wastes, consisting of fine-grained sand and clay, come out. The sand products are stacked into piles, where any remaining water is allowed to drain out for reuse. Fine grained materials, called tailings, and waste water are directed to a treatment area, generally a mined-out part of the mine lake, where the solid particles settle out of the water. Then the clear water is returned to the system and used again.

Processing requirements differ depending upon the characteristics of each sand deposit. So, washer plants are generally custom designed. Many use proprietary processing methods. However, most sand washer plants are generally similar. Raw sand from the mine is mixed with clear water to make a “raw slurry” that is fed into the washer plant. The slurry is agitated to separate the sand particles and remove clay and/or organic coatings from the sand grains, and then passed through a very coarse screen to remove “oversized” wastes like roots, clay balls, and other large impurities. Then the slurry is passed through one or more devices to grade the sand. Grading is the process of separating the particles in the raw sand mixture into different grain sizes, called grades. The coarser grades of sand, and some of the other grades, are valuable as products. However, most of the fine-grained sand, silt, and clay found in the raw sand are not valuable. These waste materials are generally mixed with the waste water from the plant to make a “tailings slurry.”

The tailings slurry from washer plants usually is pumped through a pipeline to wastewater pond/disposal area, which is frequently a mined out part of the dredge pond. The natural water and soil materials found with the sand deposits are safe and clean. Consequently, the waste process water from washer plants typically has very good water quality, except for turbidity which is easily treated. Due to the mineral and chemical nature of the sand deposits in Lake County, tailings solids typically settle rapidly out of the waste water without the use of chemical additives. However, in some instances, small amounts of environmentally safe, FDEP-approved polymers are added to accelerate the settling process.

Washer plants use large quantities of water. However, almost all of it is reused over and over again. So, despite the fact that washer plants recirculate water very rapidly, very little is lost, or consumed. Traces of moisture that remain in the sand products after they are drained are called "entrained water". Entrained water, which may amount to approximately 5 percent of the total product weight (12 gallons of water per ton of sand product), is carried away from the site with the products. This is the only significant consumption (loss) of water used for processing.

Additional processing, consisting of chemical leaching, may be required to remove black stains from raw sand that was contaminated with natural organic matter. Because the leaching process is relatively expensive, it is generally more practical for operators to avoid parts of their deposits that are stained excessively with organic coatings. Only one facility in Lake County uses an additional organic removal process, the CSR Rinker 474 Mine.

Accessory manufacturing plants, for products that use sand as a raw material, may be located on sand mine sites for convenience. In Lake County, prominent examples of accessory manufacturing industries include the Dura-Rock facility located at the Tulley Mine, and the sand drying plant located at E.R. Jahna Industries' Clermont East Mine. However, accessory manufacturing industries are not directly related to sand mining or processing. Their potential impacts are related to industrial processes that must be evaluated on an individual basis, not to sand mining or processing in general. Consequently, they are not discussed further in this report.

Water Use Versus Consumption

Consumption occurs when water is removed from a source and not replaced. If water is consumed excessively, then impacts to other water users or the environment may occur. Excessive consumption may result in reduction of a source's water availability or water levels. In practice, water managers usually restrict the definition of consumption to withdrawals of liquid water. Evaporation is not typically accounted for.

Withdrawal of water from a source does not necessarily result in consumption of water. Water can be used without consuming it. If all of the water that is withdrawn from a source is returned to the same source, then it is completely recycled and none is consumed. Consumption is the difference between the amount withdrawn from a source and the amount returned to the same source.

All of the commercial sand mines in Lake County withdraw surface water from on-site mine lakes and use it for mining and processing. However, most of the water is returned to the same pit that it was withdrawn from. So very little of the water is consumed. Because consumption is typically more difficult to measure than recirculation, the Water Management Districts sometimes require monitoring of recirculation rates instead.

After being mined and processed, wet sand products are stockpiled and allowed to drain before they are loaded on trucks and shipped to customers. Small amounts of water that adhere to the sand grains do not drain out. This water is frequently called "product moisture," or "entrained water." It is shipped off-site with the sand. Since it is not returned to its source, it is consumed.

Water that is withdrawn through wells from the Floridan Aquifer System cannot be returned directly to its source. It is consumed. Although most new mines temporarily use significant quantities of well water for mining and processing when they first start up, they generally require much less well water after the first few months of operation. Ridge-Type Mines may continue to consume nominal quantities of well water after the startup phase. However, Swamp-Type Mines typically use very little water from the Floridan Aquifer System, or none at all, after the initial startup period.

Most published summaries of water use in Lake County do not account for the difference between withdrawal and consumption. It is easier to measure withdrawal than consumption. And for many types of water use the distinction is not important, because most of the water that is withdrawn also is consumed. However, sand mines withdraw and recycle large quantities of water that are not consumed. So, in sand mines, the difference is very significant. To accurately compare water use by sand mines to other uses, one must consider consumption, not withdrawal.

Consumption of water by sand mines in Lake County during 1997 is summarized in Table 1. Although the sand mines recycled water at a rate of about 56 million gallons per day (MGD), they consumed only about 9.5 MGD.

To accurately compare water use by sand mines to other users of water in Lake County, in this study the St. Johns River Water Management District's (SJRWMD) 1997 water use data were reworked to split sand mining into a separate category, and the figures were further split to account for consumption versus recirculation. The Southwest Florida Water Management District's (SWFWMD) 1997 water use data were added to account for the remainder of Lake County.

Water consumption in Lake County is summarized by category in Table 2. Based on our interpretation of water use data sand mines consume about one-tenth of the water consumed in Lake County. That amounts to about one-fifth the water consumed for agriculture, and less than one-third of the water consumed for public supply. A typical sand mine consumes less than 1 percent of the total water consumed in Lake County.

Tables 1 and 2 account for consumption of liquid water. Although most users of water consume significant quantities through losses of water vapor, site-specific estimates were not available for comparison.

Table 1. Water Consumption by Sand Mines in Lake County (MGD)[1]

Facility	Water Consumed (Removed) Floridan Aquifer[3]	Water Consumed (Removed) Surface Water[4]	Recirculated[2] (Recycled) Process Water
CSR Rinker - 474 Sand Mine	**0.02**	**0.01**	21.30
E.R. Jahna - Clermont East Mine	**0.96**	**0.02**	1.10
E.R. Jahna - Clermont West Mine	**0.00**	**1.51**	1.56
E.R. Jahna - Independent North Mine	**0.39**	**0.05**	6.12
E.R. Jahna - Independent South Mine	**0.00**	**0.03**	1.75
Eustis Sand Company	**0.27**	**0.01**	0.73
Florida Crushed Stone - Tulley Mine	Out of Production		
Florida Rock Industries - Astatula Sand	**0.50**	**0.03**	7.49
Florida Rock Industries - Lake Sand	**0.03**	**0.04**	7.71
Florida Rock Industries - Turnpike Sand[5]	**0.00**	**0.00**	0.00
Tarmac - Center Sand Mine	**5.53**	**0.05**	8.19
Subtotals	**7.70**	**1.75**	55.95

The sand mines in Lake County consume a total of **9.45 MGD**, or 14% of the water they withdraw. The remainder is recycled.

[1] Compiled from SJRWMD 1997 records, producer's records, and estimates.

[2] Sand mines withdraw and recirculate large quantities of surface water from their mine pits. However, little of the recirculated water is consumed, or removed from the site. The majority is returned directly to its source and recycled.

[3] All of the water withdrawn from the Floridan Aquifer is consumed. None is returned directly to its source.

[4] Small quantities of surface water are consumed when sand products are shipped. Sand products contain moisture that is removed from the site with them. In addition, dewatering at the Clermont West Mine consumed 1.49 MGD during 1997.

[5] The Turnpike Sand Plant was not in production in 1997.

Table 2. Water Consumption in Lake County by Category (MGD)[6]

Category	Ground Water	Surface Water	Total	Percent
Agriculture[7]	36.88	6.02	42.90	47.7
Public Supply	30.51	0.00	30.51	33.9
Sand Mining[8]	**7.70**	**1.75**	**9.45**	**10.5**
Commercial/Industrial[9]	2.50	0.00	2.50	2.8
Domestic Self-Supply	1.62	0.00	1.62	1.8
Recreational/Landscape	1.38	0.99	2.37	2.7
Uncapped Artesian Wells	0.52	0.00	0.52	0.6
Power Generation	0.00	0.00	0.00	0.0
Totals	**81.11**	**8.76**	**89.87**	**100.0**

Sand Mining is the third-largest consumer of water in Lake County, following Agriculture and Public Supply. Mines consume about 9.45 MGD, only one tenth of all the water consumed in Lake County. That is about one fifth as much as Agriculture consumes, or one third as much as Public Supply consumes.

6 Totals were estimated from SJRWMD’s 1997 data, except as noted.

7 Agriculture totals include SJRWMD’s 1996 data and SWFWMD’s 1997 permitted quantities.

8 Mining totals were derived from producer’s records and estimates.

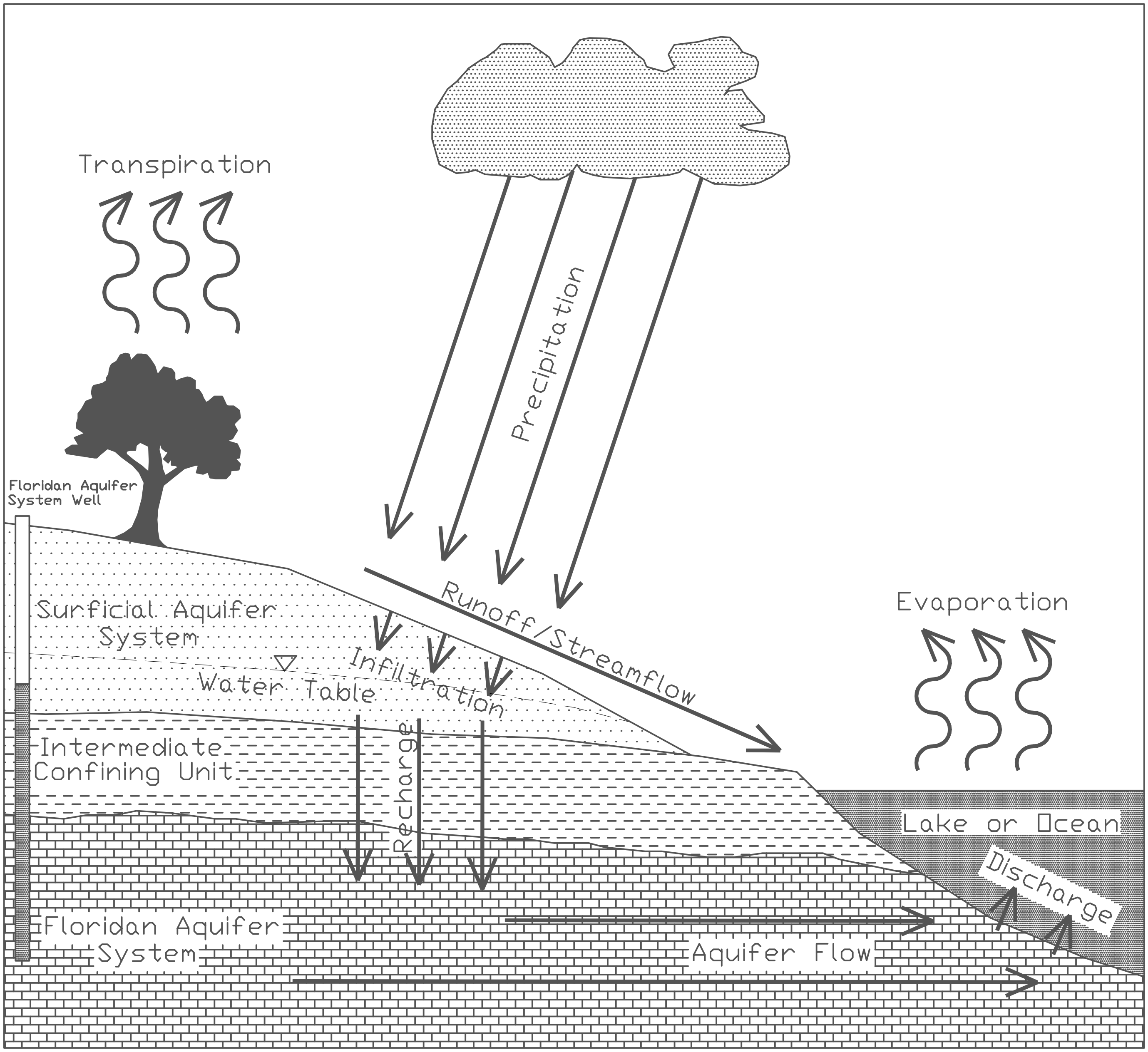
9 SJRWMD’s 1997 Commercial/Industrial totals were adjusted to separate Sand Mining.

Recharge to the Floridan Aquifer System

Recharge occurs when water percolates downward into an aquifer. A variety of factors control rates of recharge into the Floridan Aquifer System, the primary source of drinking water in Lake County. First, water must be available at, or near, the surface for recharging. When precipitation strikes the land surface, some of it drains away to lakes and streams before it can percolate into the soil. Some of the water may evaporate and return to the atmosphere before it enters the soil. Plants may remove some water from the soil through their roots and transpire it out through their leaves into the atmosphere. (In practice, the effects of evaporation and transpiration are typically combined into a single term called evapotranspiration, or "ET.") Only the remainder is available to recharge aquifers. Second, the hydraulic pressure of the water table must be greater than the pressure of the water in the Floridan Aquifer System, so that the water will flow down. Otherwise, ground water would flow up and discharge out of the aquifer instead. Third, the magnitude of the pressure difference, or "head," controls the rate of recharge; larger pressure differences make the water flow more quickly. And fourth, rates of recharge are controlled by the thickness and hydraulic characteristics of the soils and rocks that recharging water must percolate through. Soils that resist the downward flow of water are called "confining units". Sinkholes may act as drains that carry recharging water through confining units more rapidly. Please refer to Figure 6, entitled "Hydrologic Cycle" for an illustration of the preceding discussion.

Several workers have analyzed the factors discussed above and estimated recharge in areas that included Lake County. Stewart (1980) produced a statewide map of recharge to the Floridan Aquifer. McKenzie-Arenberg and Szell (1990) produced a recharge map that was later used by Lake County to produce Map 1-1i of the Future Land Use Element of the Comprehensive Plan. The Florida Geological Survey (1991) compiled recharge maps from various sources. Boniol, Williams, and Munch (1993) used a Geographic Information System (GIS) to map recharge to the Floridan Aquifer in the SJRWMD area. Their map was incorporated into the Lake County's official GIS system. Figure 7 is a compilation of recharge rates in Lake County, including estimates for the SJRWMD areas by Boniol, Williams, and Munch (1993), and estimates for the SWFWMD areas by Stewart (1980).

Boniol (1998) used the raw data from Boniol, Williams, and Munch (1993), and the National Resource Conservation Service's SSURGO soils data, to produce a map of "significant" groundwater recharge. The term "significant" was defined to satisfy requirements of the Florida Legislature's Bluebelt Act, which required the water management districts to advise county governments of areas with recharge rates that were sufficiently large to warrant tax breaks for preservation. He determined an area-weighted average recharge potential of about 13 inches per year for Lake County, and defined "significant" recharge areas as those with soil permeability rates greater than 60 in/hr and recharge potentials greater than 13 in/yr. These areas are subsets of



Not to Scale

Independent Geological Services, Inc.

Reserves Evaluation
Environmental Permitting
Mine Planning and Impact Analysis
Geological and Hydrogeological Services

121 Market Street
Davenport, FL 33837

Phone: 863-419-1239
Fax: 863-419-4968

Prepared For:

E.R. Jahna Industries, Inc.

Date: *July 27, 2001*

Figure 6. Hydrologic Cycle

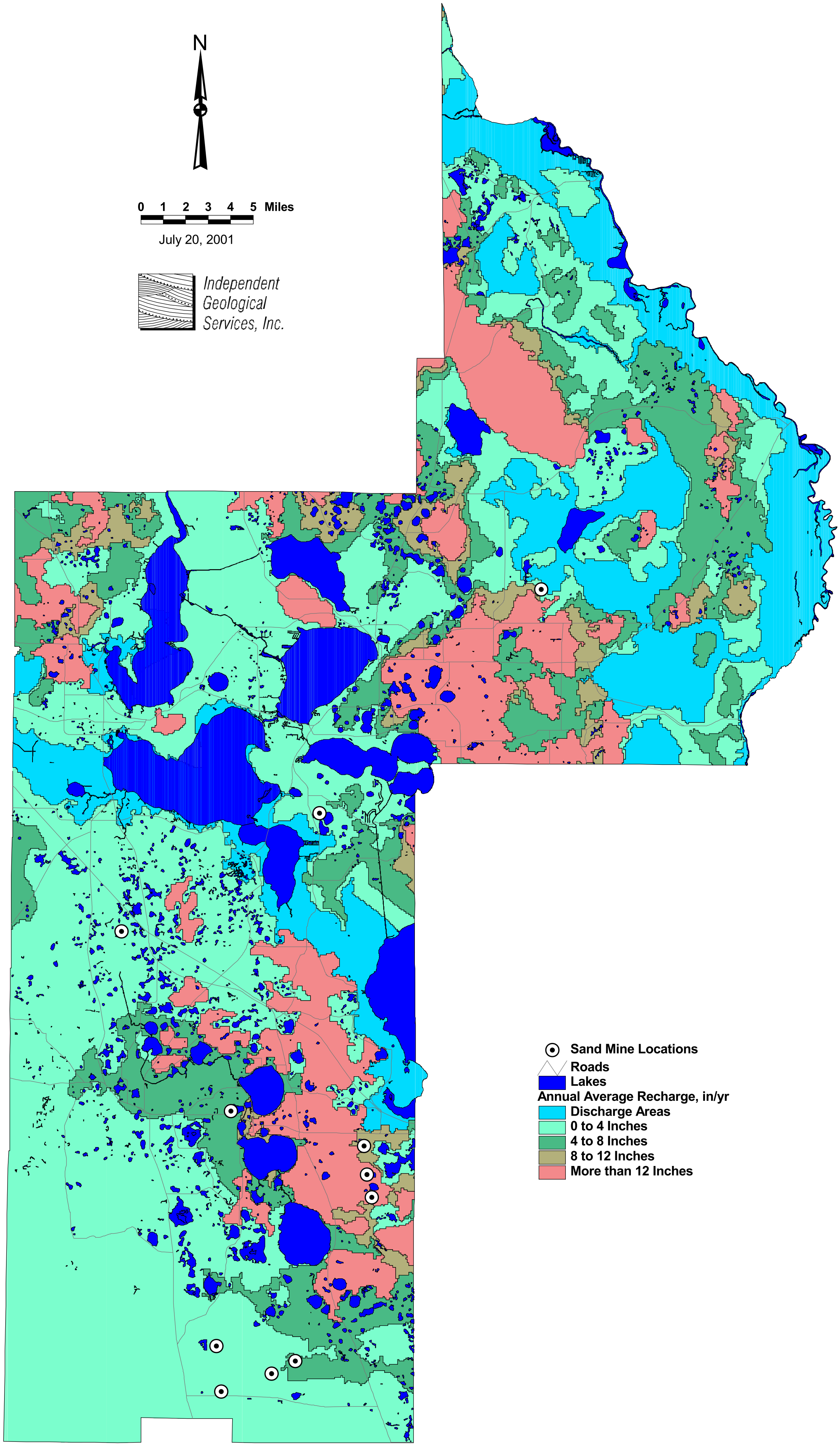


Figure 7. Recharge Rates in Lake County

the regions where “12 or more” inches of recharge were indicated in his earlier map. Mr. Boniol stated in a personal communication with the author that this map is not broadly applicable beyond its stated purpose.

The studies discussed above were all regional studies. They are useful for identifying approximate limits of broad general trends. In general the studies all agree that recharge rates are low in the Green Swamp area, and moderate to high in topographically high areas like the Lake Wales Ridge. However the maps are not extremely detailed. Site-specific study may be required for accurate determination of recharge potential at some sites.

Climatic Factors

Natural climatic factors generally have greater influence on hydrologic conditions in the vicinity of sand mines than day-to-day mine operations. Although large quantities of water are recirculated for mining and processing, very little is removed from the site; so recirculation does not typically affect hydrologic conditions adjacent to the mine. Well withdrawals from most mines are not significantly large, except in areas where water returns rapidly by recharge to the aquifer that it was pumped from; and, again, hydrologic effects of the sand mine are usually not significant adjacent to the mine.

Climatic factors are typically monitored by measuring precipitation and evaporation. Precipitation is a measure of how rapidly rain accumulates on the ground. Evaporation is a measure of how fast water evaporates from open water bodies. These factors are measured at numerous stations and recorded by agencies like the National Oceanographic and Atmospheric Administration. Both precipitation and pan evaporation have been measured for many years at the Lisbon Station in Lake County and at the Lake Alfred Experiment Station in northern Polk County. Table 3 summarizes precipitation and pan evaporation data on a monthly basis from 1988 through 1998 measured at the Lisbon Station. Similar data collected from 1983 through 1988 at the Lake Alfred Experiment Station are summarized in Table 4.

Long term averages of precipitation indicate good agreement between the two stations, about 53 inches of rain per year. Although precipitation does not follow a fixed pattern, the monthly averages indicate that more rain generally falls during a relatively short period in the late summer months than in the winter months.

Long term averages of pan evaporation rates from the two stations do not agree very well. According to experts, actual evaporation rates in Lake County are not drastically different from those in northern Polk County. The large differences between measurements at the two stations are attributed to different placements of the pans at each station, relative to trees and buildings, that sometimes block wind and/or sunshine. However, measurements from both stations show the same general trends. More water evaporates during the spring and summer, when solar intensity, air temperature, and wind velocities are stronger than at other times.

These data clearly indicate that the climatic factors that control rainfall and evaporation are extremely variable. Since groundwater levels are directly related to the same climatic factors, they too are extremely variable.

Groundwater monitoring reports submitted to Lake County by Florida Rock Industries for their Lake Sand Plant graphically demonstrate the influence of climatic variations on Surficial Aquifer

Table 3. Climatological Data, Lisbon Station, Lake County

Precipitation by Month (Inches)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1988	4.30	2.90	5.58	0.98	2.73	9.59	9.59	4.56	6.74	0.87	2.64	1.09
1989	3.40	0.50	2.84	2.25	5.27	5.05	5.37	6.50	7.60	2.48	1.89	4.35
1990	1.51	3.49	1.64	5.25	0.66	10.41	6.75	5.37	2.70	2.18	1.55	0.43
1991	6.07	1.76	10.46	9.36	8.20	8.95	6.08	6.93	3.90	1.68	0.77	0.91
1992	1.83	2.22	3.50	1.57	3.21	8.44	5.58	12.05	6.45	4.81	5.49	0.72
1993	4.63	3.71	6.85	1.53	2.07	2.22	3.55	6.64	5.76	4.32	1.36	1.67
1994	6.61	0.89	2.30	0.98	3.99	9.98	7.73	9.68	10.49	6.23	5.12	2.88
1995	2.98	1.22	1.76	5.92	3.44	7.10	5.93	11.29	4.37	5.20	1.09	1.82
1996	5.97	1.64	9.89	1.85	4.95	8.04	4.07	8.58	5.24	4.01	0.94	2.72
1997	1.95	1.12	2.74	3.51	1.77	5.24	4.09	6.69	7.84	4.56	6.53	10.02
1998	4.75	7.81	4.82	0.28	1.22	0.15	4.42	7.83	10.63	0.98	1.14	0.95
11-YR AVG	4.00	2.48	4.76	3.04	3.41	6.83	5.74	7.83	6.52	3.39	2.59	2.51
Std.	1.72	1.96	2.98	2.63	2.06	3.17	1.71	2.25	2.41	1.74	2.00	2.62
Max.	6.61	7.81	10.46	9.36	8.20	10.41	9.59	12.05	10.63	6.23	6.53	10.02
Min.	1.51	0.50	1.64	0.28	0.66	0.15	3.55	4.56	2.70	0.87	0.77	0.43
Cumul. AVG	4.00	6.48	11.24	14.28	17.69	24.53	30.27	38.10	44.62	48.01	50.60	**53.11**

Adjusted Pan Evaporation by Month (Inches)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1988	1.51	1.93	4.34	5.01	6.29	5.65	5.58	5.23	4.38	2.59	1.51	1.52
1989	1.76	2.11	3.85	5.26	6.33	5.66	6.92	5.83	4.41	2.81	1.65	1.54
1990	1.65	2.27	4.90	5.30	6.54	6.07	5.87	5.32	5.12	3.03	1.90	1.53
1991	2.43	2.25	4.25	5.82	6.02	5.84	5.13	5.55	5.07	2.46	1.37	1.00
1992	1.51	1.61	3.41	4.84	6.10	7.03	6.45	5.09	4.87	2.98	2.03	1.20
1993	1.44	1.79	3.01	5.24	6.00	6.43	5.62	5.37	4.56	2.72	2.10	0.87
1994	2.33	1.58	3.71	5.07	6.04	5.28	5.36	5.06	4.27	1.96	1.50	1.51
1995	1.49	1.44	3.32	4.71	6.15	4.95	5.79	5.20	4.16	2.42	2.00	1.47
1996	1.54	2.15	3.47	4.77	6.15	6.02	6.45	5.78	3.99	1.93	1.72	1.55
1997	1.11	1.51	3.29	4.66	5.26	5.11	5.64	4.74	3.95	1.86	5.16	1.33
1998	1.23	1.56	3.18	4.89	5.37	6.22	5.41	5.32	3.42	1.97	1.07	1.10
11-YR AVG	1.64	1.84	3.70	5.05	6.02	5.84	5.84	5.32	4.38	2.43	2.00	1.33
Std.	0.39	0.30	0.55	0.32	0.37	0.58	0.52	0.30	0.49	0.42	1.04	0.24
Max.	2.43	2.27	4.90	5.82	6.54	7.03	6.92	5.83	5.12	3.03	5.16	1.55
Min.	1.11	1.44	3.01	4.66	5.26	4.95	5.13	4.74	3.42	1.86	1.07	0.87
Cumul. AVG	1.64	3.47	7.17	12.23	18.25	24.09	29.93	35.25	39.63	42.06	44.06	**45.39**

Table 4. Climatological Data, Lake Alfred Experiment Station, Polk County

Precipitation by Month (Inches)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1983	1.60	8.63	7.67	2.76	2.45	10.64	3.17	10.47	5.86	4.05	2.28	5.23
1984	1.45	4.15	1.67	2.68	3.59	3.31	9.54	4.17	7.14	0.44	1.49	0.27
1985	1.22	1.05	3.28	1.39	1.82	6.41	8.75	8.23	7.09	1.96	0.51	2.86
1986	3.74	2.72	3.97	0.58	1.32	7.42	3.81	10.86	3.24	4.45	0.86	1.48
1987	2.92	2.08	9.57	0.90	1.69	4.18	9.24	4.86	6.92	4.06	7.83	0.33
1988	2.17	2.15	7.38	0.72	4.06	2.39	4.37	4.55	7.62	0.91	7.01	0.89
1989	2.84	0.05	1.99	2.38	4.31	4.02	9.63	5.36	7.03	0.66	1.36	5.61
1990	0.21	4.10	3.56	3.06	2.12	5.72	8.06	7.24	2.22	4.08	1.25	0.55
1991	1.95	0.59	4.25	4.92	9.21	10.99	13.01	3.02	2.63	4.98	0.16	0.21
1992	1.14	3.42	1.15	6.80	2.43	11.67	5.06	11.50	7.90	3.24	4.01	0.56
1993	4.72	1.44	4.47	3.80	2.85	1.66	9.27	6.00	9.09	3.85	0.19	1.27
1994	7.59	2.03	2.12	1.43	1.44	12.76	8.35	8.54	12.64	2.82	3.48	4.25
1995	1.87	1.34	2.23	2.32	2.26	8.95	10.64	13.26	4.85	8.14	1.76	0.38
1996	6.82	2.48	6.68	1.30	2.30	9.89	5.30	7.18	5.41	4.81	0.87	2.99
1997	1.71	1.90	2.87	5.10	2.16	9.23	7.25	6.52	4.64	2.72	6.61	13.19
1998	3.04	9.20	8.64	1.12	2.46	1.59	11.94	3.56	13.53	0.68	2.23	1.24
16-YR AVG	2.81	2.96	4.47	2.58	2.90	6.93	7.96	7.21	6.74	3.24	2.62	2.58
Std.	1.97	2.50	2.59	1.74	1.83	3.65	2.82	2.96	3.05	1.97	2.42	3.24
Max.	7.59	9.20	9.57	6.80	9.21	12.76	13.01	13.26	13.53	8.14	7.83	13.19
Min.	0.21	0.05	1.15	0.58	1.32	1.59	3.17	3.02	2.22	0.44	0.16	0.21
Cumul. AVG	2.81	5.77	10.24	12.82	15.72	22.65	30.61	37.82	44.56	47.80	50.42	**53.00**

Adjusted Pan Evaporation by Month (Inches)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1983	2.15	3.36	4.98	5.97	7.07	6.30	6.67	6.00	4.79	4.50	3.30	2.39
1984	2.41	3.92	4.90	6.02	6.54	6.26	6.68	6.32	6.71	5.55	3.65	3.03
1985	3.39	3.96	6.62	6.05	8.02	7.74	6.63	5.69	5.76	5.02	3.69	3.30
1986	3.20	3.89	5.37	7.22	8.17	6.14	6.24	6.61	5.47	5.32	3.39	2.67
1987	2.82	3.11	5.32	6.71	7.04	7.36	6.40	6.12	5.68	4.78	3.12	2.85
1988	2.46	3.55	5.54	6.49	7.24	6.64	6.31	5.81	5.51	5.02	3.40	2.78
1989	3.25	3.96	5.05	6.25	8.01	6.60	6.85	6.63	5.47	4.62	3.53	2.73
1990	3.32	4.17	5.89	6.24	7.36	6.86	5.93	6.58	5.83	4.78	3.53	2.89
1991	2.97	3.79	5.05	5.72	6.67	6.56	5.83	6.41	5.75	4.21	3.09	2.89
1992	2.78	3.39	4.90	5.80	6.86	6.50	6.92	5.05	4.84	4.36	3.28	2.50
1993	2.73	2.91	4.17	6.03	6.50	6.50	6.69	6.49	5.02	4.06	2.72	2.66
1994	3.16	3.29	5.59	6.11	6.36	6.01	5.65	6.00	4.31	3.75	3.13	2.68
1995	2.49	3.52	4.84	5.28	7.41	6.09	6.24	5.05	5.54	4.63	3.97	2.60
1996	3.15	3.71	5.01	5.33	6.20	5.84	6.37	5.74	5.83	4.36	3.64	2.82
1997	3.45	3.56	5.36	5.89	6.54	7.40	7.03	6.90	5.32	5.27	3.13	3.33
1998	2.74	4.13	4.68	6.01	7.04	8.63	7.07	6.72	4.69	4.97	2.96	2.71
16-YR AVG	2.90	3.64	5.20	6.07	7.06	6.71	6.47	6.13	5.41	4.70	3.34	2.80
Std.	0.38	0.35	0.54	0.46	0.59	0.71	0.41	0.54	0.56	0.47	0.31	0.25
Max.	3.45	4.17	6.62	7.22	8.17	8.63	7.07	6.90	6.71	5.55	3.97	3.33
Min.	2.15	2.91	4.17	5.28	6.20	5.84	5.65	5.05	4.31	3.75	2.72	2.39
Cumul. AVG	2.90	6.54	11.75	17.82	24.88	31.59	38.06	44.20	49.60	54.30	57.65	**60.45**

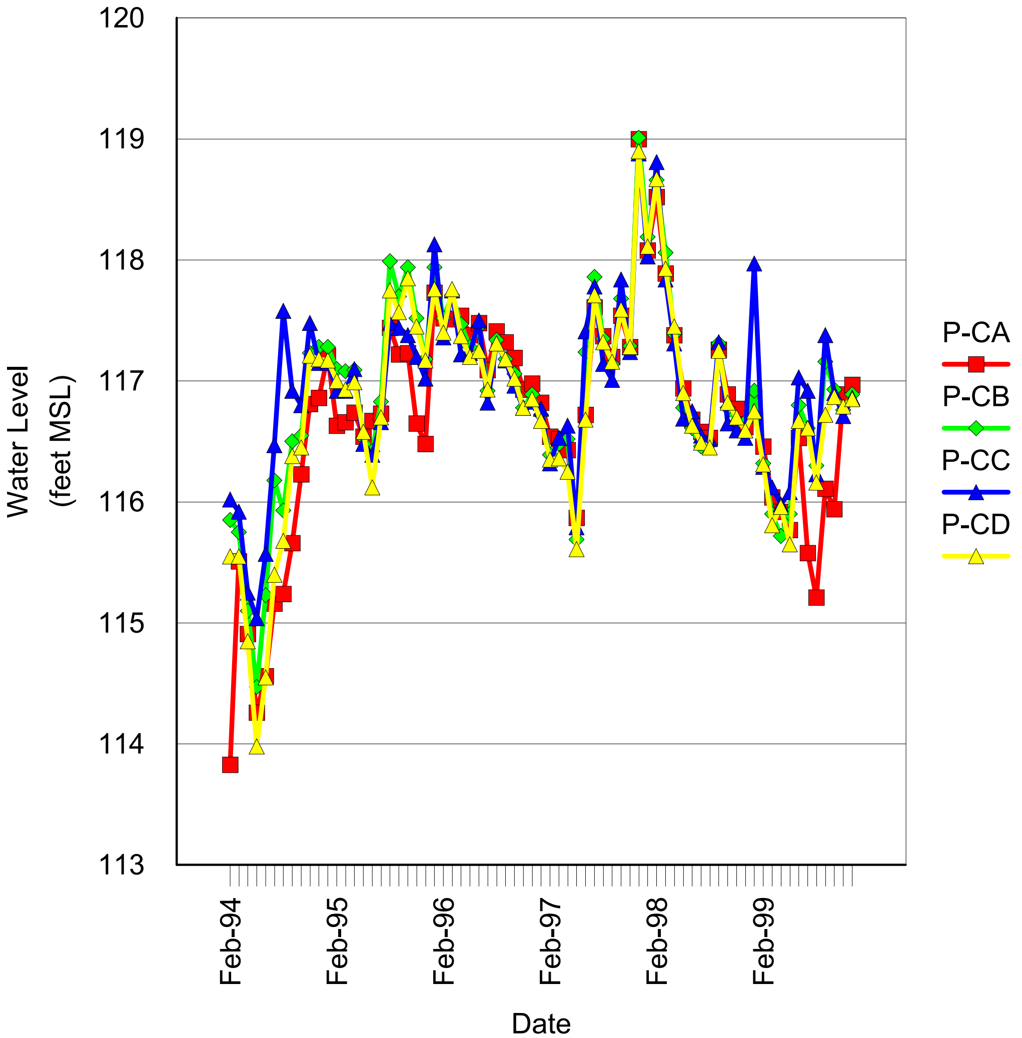
System water levels. Figure 8 shows the variations of levels in 4 “control piezometers” that were installed to monitor background water levels for comparison with data from piezometers installed closer to the mine. The variations recorded in these wells result entirely from natural climatic factors. Each piezometer indicated a slightly different water level; but they all show the same general climate-related trends, and approximately the same range, about 5 feet.

Water levels in Floridan Aquifer System wells also vary with climatic conditions. Figure 9 shows water levels measured by the U.S. Geological Survey in the “City Well at Clermont.” Note that the water level variations in this well show the same general climate-related trends, and the approximately the same range, about 5 feet, that were evident several miles away, and in a different aquifer system, at the Lake Sand Plant.

Water level variations in wells installed to monitor the effects of sand mining are typically influenced more by climatic variations than by sand mining. Groundwater levels rise dramatically in response to rainfall and they drop in response to droughts. Although the range of natural climatic variations in groundwater levels may differ from place to place depending on site-specific conditions, natural variations of several feet are typical in Lake County.

Figure 8. Seasonal Variability of the Surficial Aquifer System

Control Piezometers at FRI's Lake Sand Plant



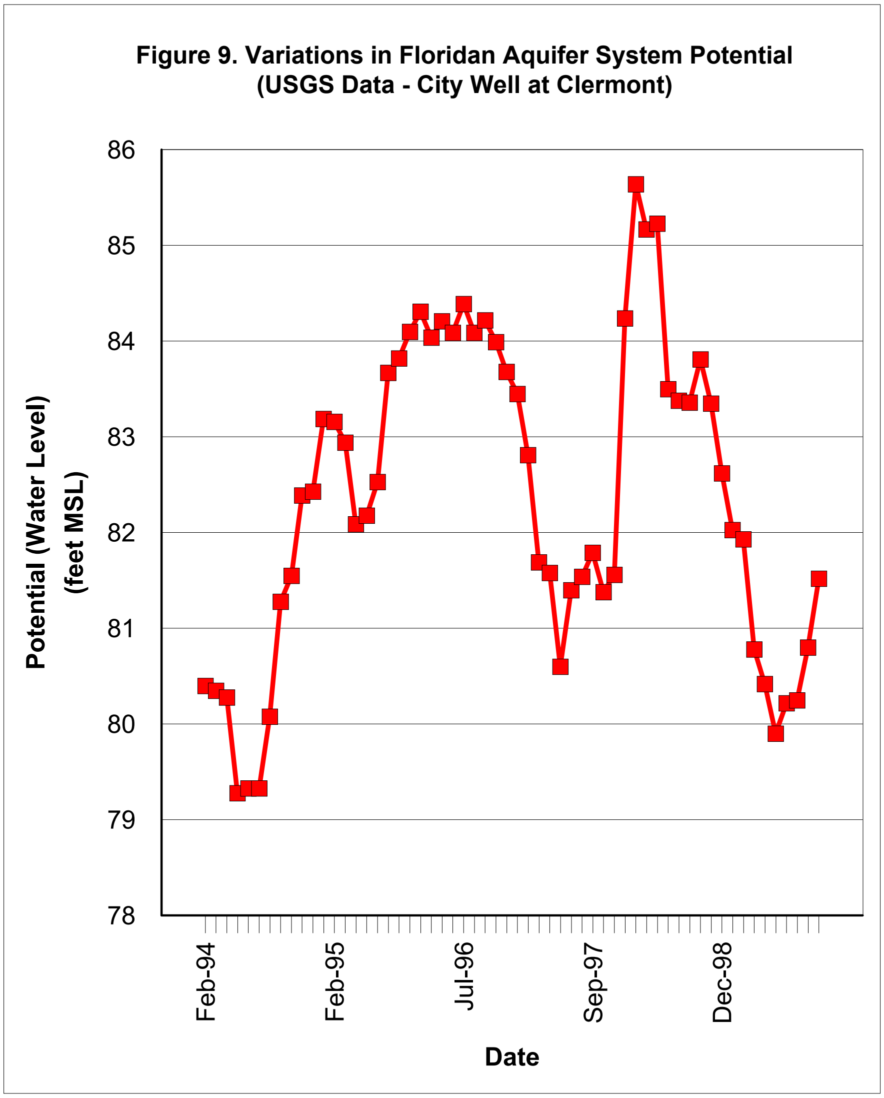


Figure 9. Variations in Floridan Aquifer System Potential
(USGS Data - City Well at Clermont)
86
85
84
83
82
81
80
79
78
Potential (Water Level)
(feet MSL)
Feb-94
Feb-95
Jul-96
Sep-97
Dec-98
Date

Hydrologic Effects of Land Use

Land use changes can affect groundwater levels. For example, impervious surfaces, like pavement and buildings, prevent rain water from infiltrating the ground and recharging aquifers, by causing it to runoff to other places. Other more subtle land use factors also can affect groundwater levels.

Plants uptake water from the ground through their roots and evaporate it into the atmosphere by a process called evapotranspiration. Some types of vegetation can remove water from the ground more rapidly than others do. And evaporation rates from open water bodies, like lakes and swamps, are known to be somewhat greater than from most land areas. So changing the vegetative cover of a site, or altering its land use, can change groundwater levels in the vicinity.

Evapotranspiration (ET) rates of agricultural crops have been studied and known for many decades. And a few earlier workers, like Pride et al. (1966), made estimates of natural evapotranspiration rates based upon water budget models. However, direct measurements of evapotranspiration rates of lakes and natural plant communities were not made until recently. A summary of published estimates of evapotranspiration rates is included in Appendix A.

Review of the published data indicate that ET rates are quite variable, depending upon land cover, depth of water table, and climatic factors, including solar intensity, air temperature, relative humidity, and wind velocity. However, the data indicate that ET rates are smallest in upland areas, greater in pine flatwoods, even greater in wetlands, and greatest from lakes.

Sand mining typically results in two hydrologically significant land use changes. First, excavation of mine pits contains and stores runoff that would have drained from the site before mining, increasing the amount of water on the site that is available for recharging aquifers. And second, sand mining converts upland mining areas into lakes, which increases the site’s ET rate, and generally decreases the amount of water on the site that is available for recharging aquifers. Clearly the two factors offset each other to some degree in the overall water balance of a sand mine site. Typically, these factors are omitted from water use/consumption accounting due to the difficulty of accurately measuring them.

Settings of Commercial Sand Mines in Lake County

Based upon geomorphologic and hydrologic considerations, Lake County's sand mines were classified by this study into two general settings: Swamp-Type Mines and Ridge-Type Mines. The two settings differ in proximity to wetlands, depth of water table, well withdrawals, and local recharge potential.

Swamp-Type Mines usually occupy flat uplands or low profile ridges that are almost completely surrounded by and intermixed with wetlands. Water tables are generally shallow; and the bottoms of the deposits being mined are much deeper than the water table. Water withdrawals from wells are generally small because water tables are shallow and the mine lakes contain ample water for mining and processing. Most of these mines are located in or near the Green Swamp, an area where rates of recharge to the Floridan Aquifer System are typically small. Figure 10 shows the location of the Green Swamp and the limits of the Green Swamp Area of Critical State Concern in Lake County.

Ridge-Type Mines are located on high ridge areas, generally far from large interconnected wetland systems. Water tables are relatively deep. Mine pit bottom elevations are typically shallow in relation to water tables. Well withdrawals may be required to augment water levels in mine lakes during mining. Most of the ridge-type mines are located along the Lake Wales or Mount Dora Ridges, shown in Figure 11, Geomorphology of Lake County. In these areas, rates of recharge to the Floridan Aquifer System may be regionally significant.

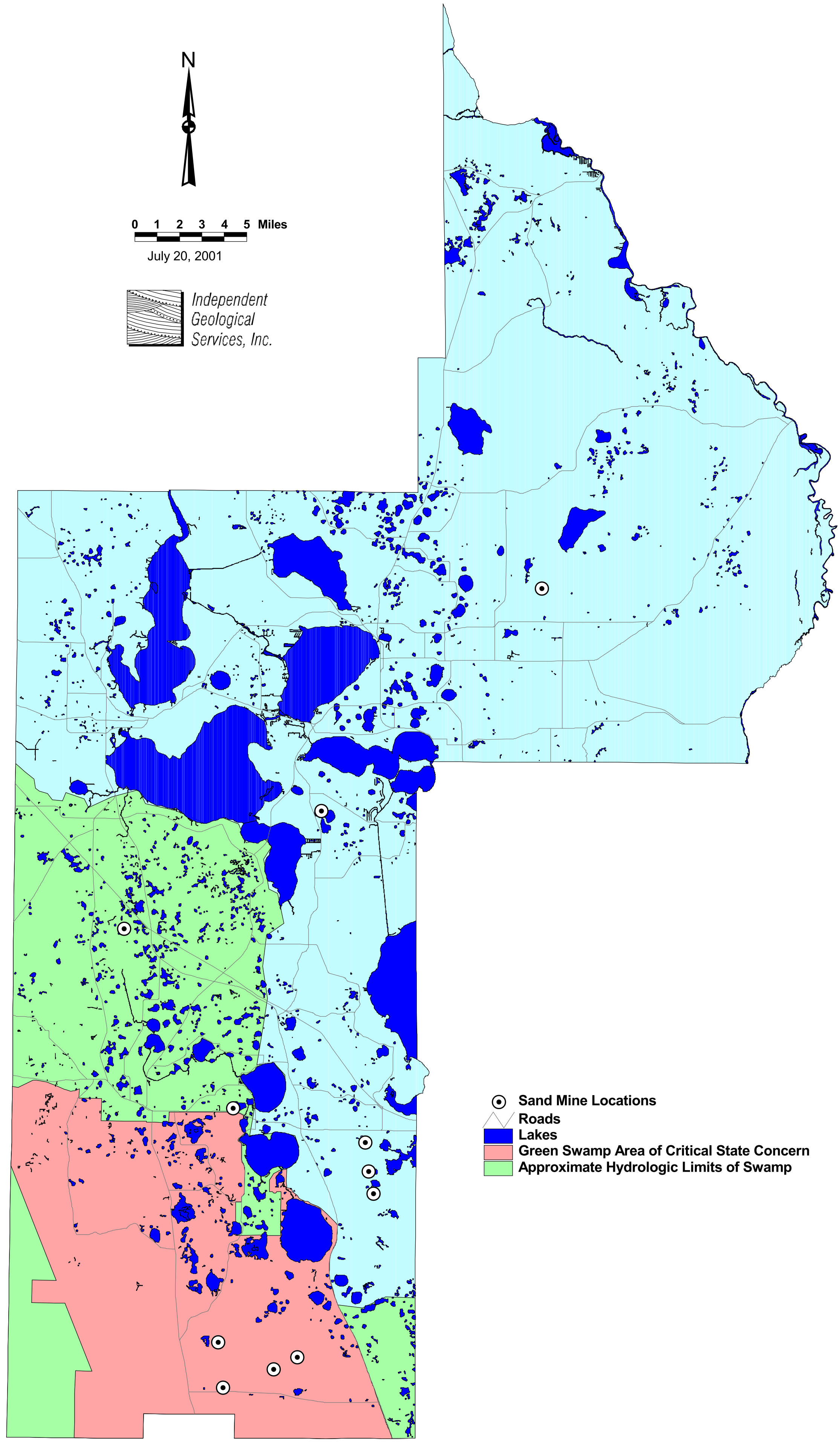


Figure 10. Green Swamp in Lake County

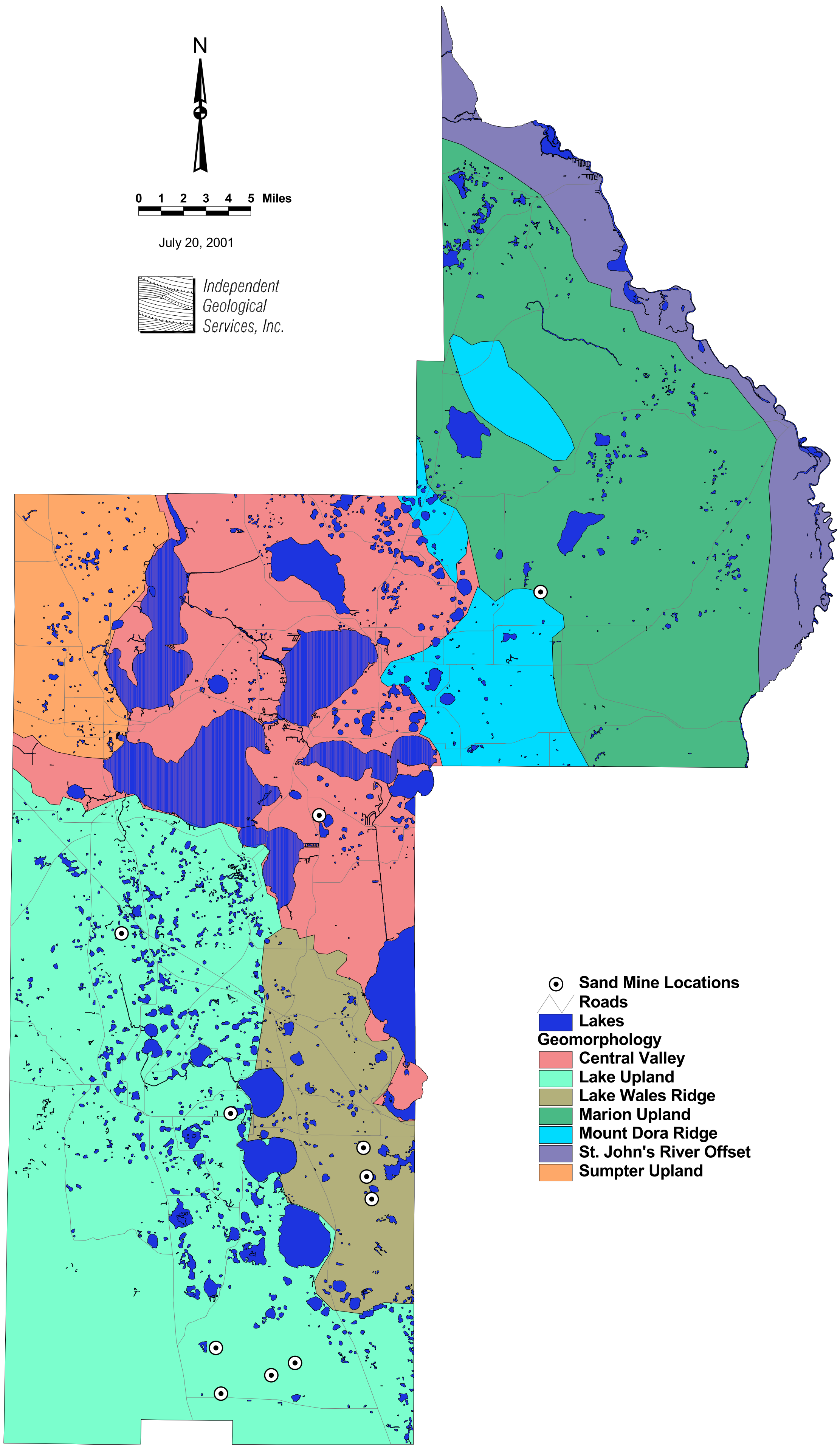


Figure 11. Geomorphology of Lake County

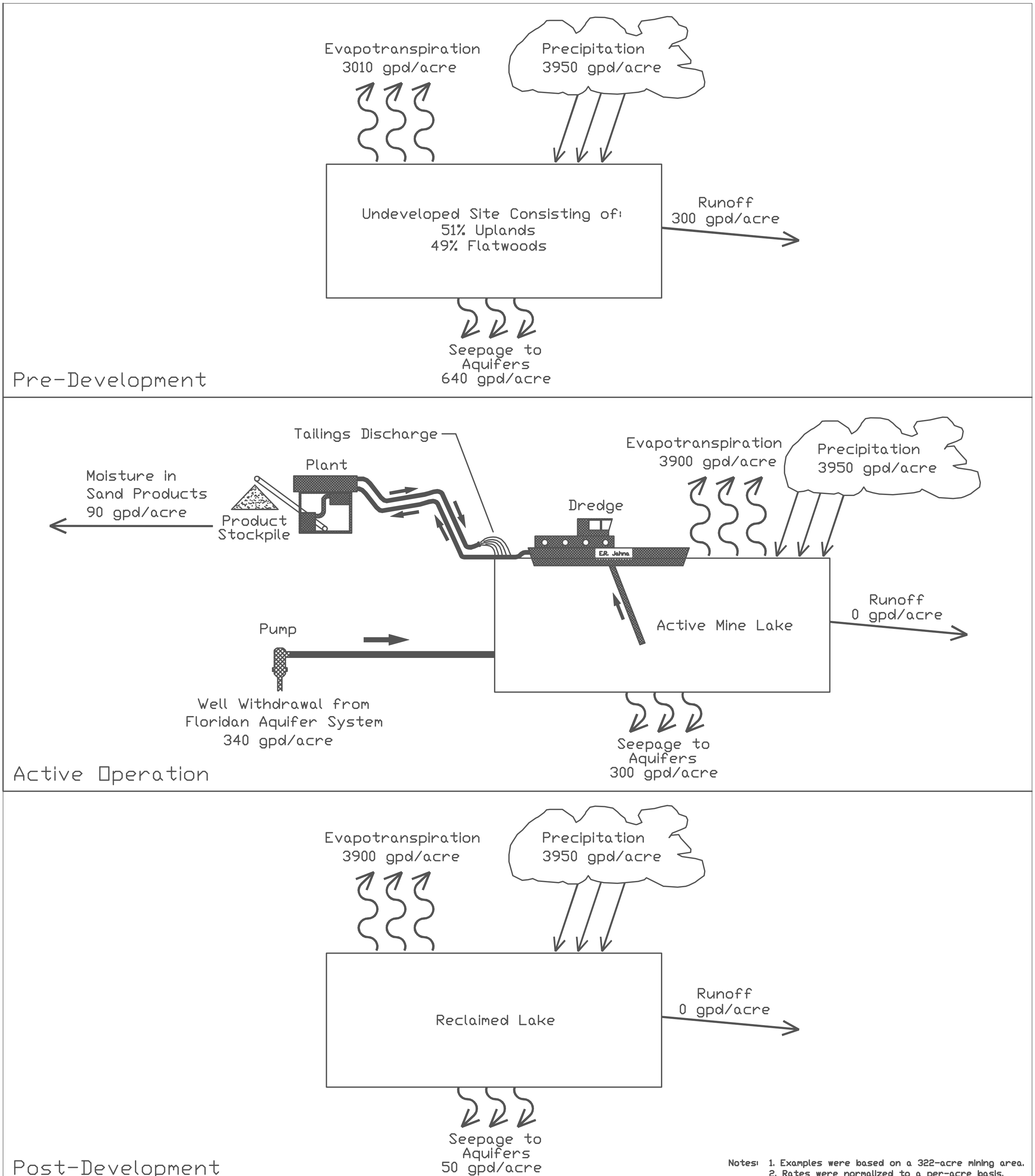
Simulation of a Swamp-Type Sand Mine

Basic numeric simulations were prepared to evaluate the effects of land use changes resulting from a swamp-type sand mine upon the Surficial Aquifer System and the Floridan Aquifer System. Models were made to simulate pre-development conditions, active operation, and two post-mining scenarios. Reliable site-specific data were available for setting most model parameters. The model geometry was designed to be simple and generic so that results would be generally applicable to all sand mines, but not directly applicable to any particular one.

The results should be regarded as the worst case for three reasons. First, real mining areas typically include some wetlands, as well as uplands and flatwoods; so the difference between pre-development and active operation or post-development evapotranspiration (ET) rates is not typically as great as simulated. Second, the post-development simulation assumes that 100 percent of the simulated pit was reclaimed as a lake. Real sand mine pits are typically reclaimed partly as uplands, partly as wetlands, and partly as lakes; so the difference between pre-development and post-development ET rates is not typically as great as simulated. And third, ET compensation effects were ignored; in real wetland systems ET rates slow down as water tables decrease.

Water balances corresponding with the swamp-type sand mine simulations were presented in Figure 12. The examples were based upon a 322-acre mining area. Rates were normalized to a per-acre basis. Land use changes resulting from mining have two hydrologic effects: Mine lakes capture all of the precipitation that falls on them, eliminating runoff from the site; and conversion of land to lakes increases evaporation rates. In addition, active operation of a sand mine typically involves pumping from a well into the mine lake, and removal of water from the site as moisture in sand products. All of these factors balance to determine rates of seepage from the mine area into aquifers.

Cross sections comparing simulations of active mine operation with pre-development conditions were presented in Figure 13. The results suggest that a 320-acre mine pit could reduce Surficial Aquifer System water levels by a maximum of about 0.24 feet at the wetland edge, on an annual average basis. Reductions in Floridan Aquifer System potentials of about 0.46 feet and 0.23 feet were predicted at the production well location and the wetland edge, respectively. Please note that the simulation of active operation represents an ideally-designed sand mine. If water recirculation is significantly impeded by restrictive flow paths or control structures, significantly greater local effects on the Surficial Aquifer System would result; however, effects on the Floridan Aquifer System are not expected to be significantly different. Dynamic effects of this nature could vary significantly from mine to mine depending upon very specific design



Independent Geological Services, Inc.

Reserves Evaluation
Environmental Permitting
Mine Planning and Impact Analysis
Geological and Hydrogeological Services

121 Market Street
Davenport, FL 33837

Phone: 863-419-1239
Fax: 863-419-4968

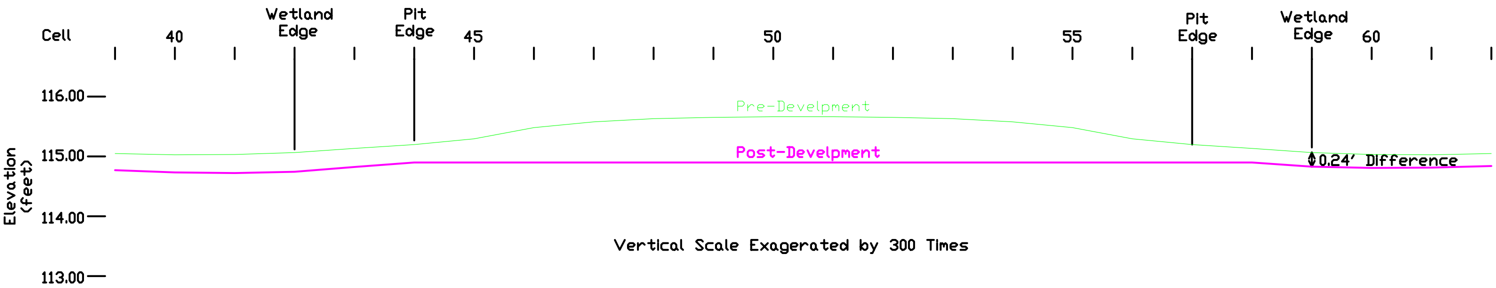
Prepared For:

E.R. Jahna Industries, Inc.

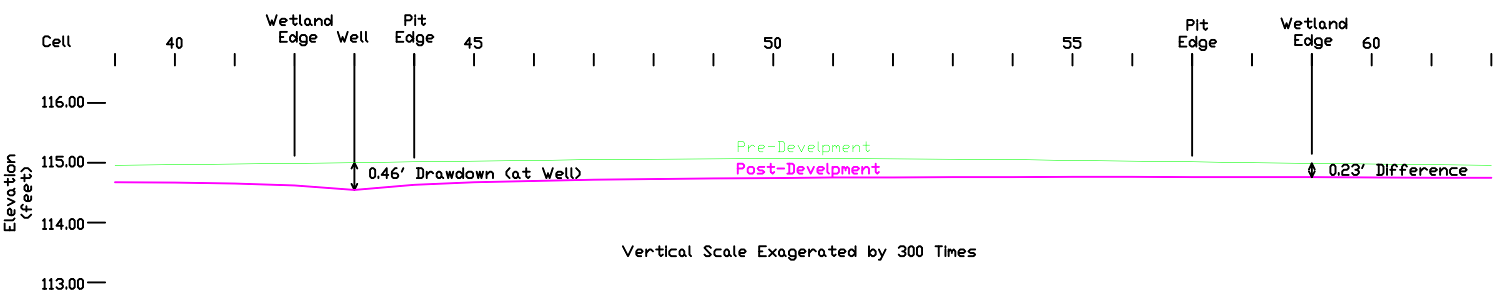
Date: *July 27, 2001*

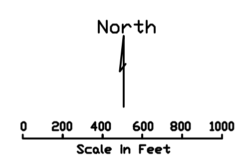
Figure 12. Normalized Water Balance of a Sand Mine in a Swamp-Type Setting

Surficial Aquifer Potentiometric Surface



Floridan Aquifer Potentiometric Surface





Based on Swamp-Type Model V.7

Independent Geological Services, Inc.

Reserves Evaluation
Environmental Permitting
Mine Planning and Impact Analysis
Geological and Hydrogeological Services

121 Market Street
Davenport, FL 33837

Phone: 863-419-1239
Fax: 863-419-4968

Prepared For:

E.R. Jahna Industries, Inc.

Date: *July 27, 2001*

Figure 13. Cross Sections of Simulated Swamp-Type Mine in Active Operation

considerations. Detailed site-specific analysis would be required to accurately quantify these dynamic flow effects, and would not be generally applicable to all sand mines.

Cross sections comparing simulations of a post-mining scenario that included a 300-foot setback from adjacent wetlands, with pre-development conditions were presented in Figure 14. The results indicate that a 320-acre mine lake could reduce Surficial Aquifer System water levels by about 0.25 feet at the wetland edge, on an annual average basis. A reduction in Floridan Aquifer System potential of about 0.23 feet is predicted at the wetland edge, on an annual average basis.

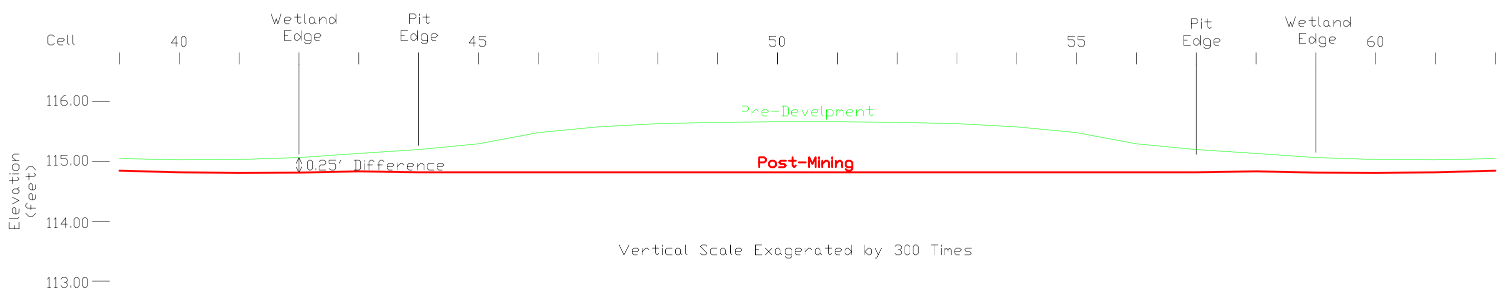
Figure 15 shows cross sections comparing simulations of another post-mining scenario that included no wetland setback, with the pre-development conditions. The results suggest that a 415-acre mine lake could reduce Surficial Aquifer System water levels by about 0.29 feet at the wetland edge, and reduce Floridan Aquifer System potentials at the wetland edge by about 0.25 feet, on an annual average basis.

Two useful conclusions can be drawn from these cross sections. First, land use changes resulting from sand mining in a swamp-type setting might cause subtle reductions of Surficial and Floridan Aquifer System potentials. However, the magnitudes of the reductions are expected to be very small in relation to natural seasonal variations, and, therefore very difficult to measure or detect in the field. Second, wetland setbacks have no significant benefit in protecting wetland systems adjacent to sand mines; the predicted drawdowns are very small in either case.

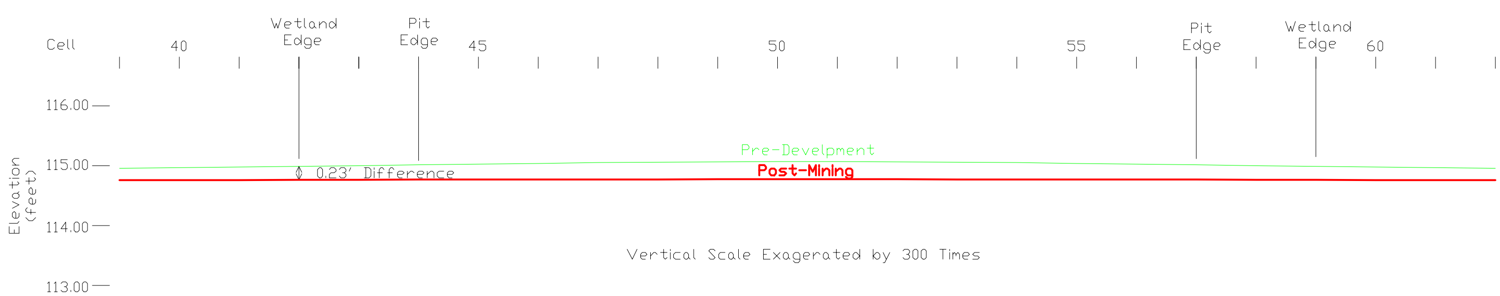
Changes in recharge to the Surficial and Floridan Aquifer Systems resulting from the land use changes associated with a generic swamp-type mine were evaluated. The simulations indicate a worst case reduction in recharge approximately equal to the difference in evapotranspiration caused by converting an upland area to an open water body.

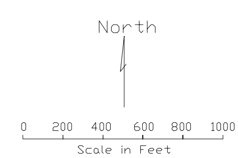
Please refer to the Appendix for a detailed description of the model design and parameter selection.

Surficial Aquifer Potentiometric Surface



Floridan Aquifer Potentiometric Surface





Based on Swamp-Type Model V.7

Independent Geological Services, Inc.

Reserves Evaluation
Environmental Permitting
Mine Planning and Impact Analysis
Geological and Hydrogeological Services

121 Market Street
Davenport, FL 33837

Phone: 863-419-1239
Fax: 863-419-4968

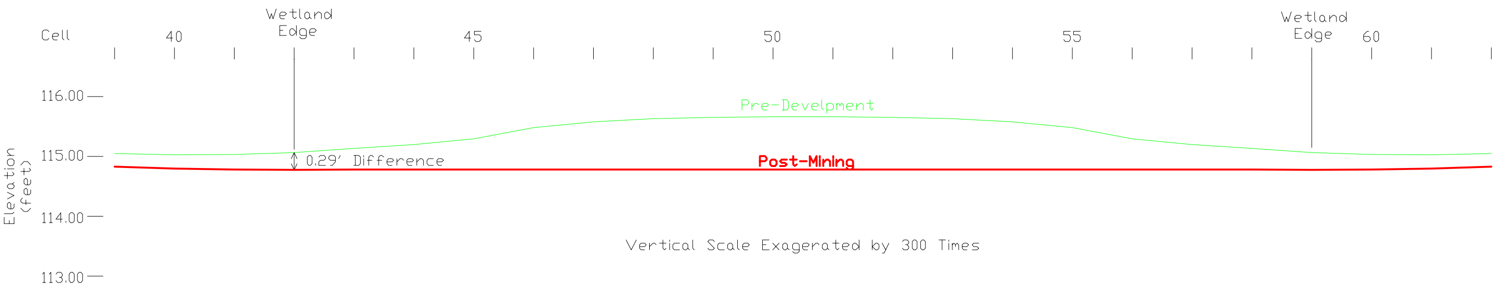
Prepared For:

E.R. Jahna Industries, Inc.

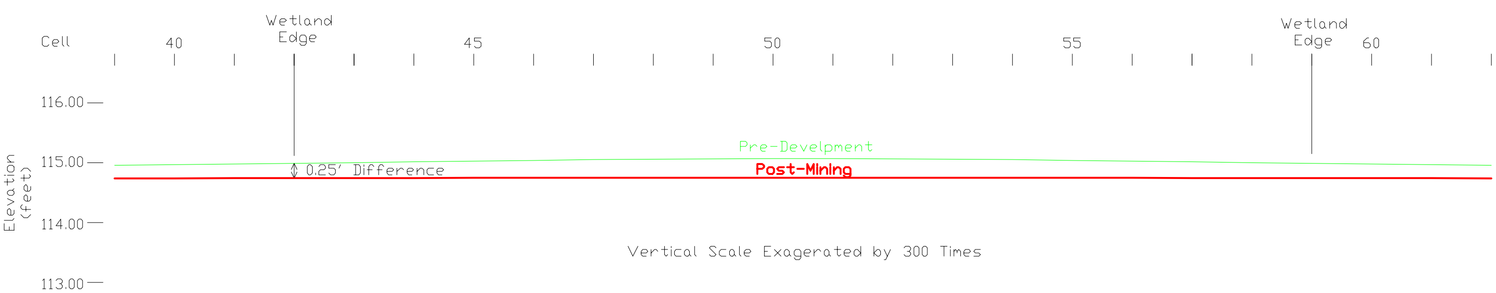
Date: July 27, 2001

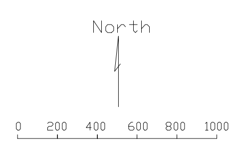
Figure 14. Cross Sections of Simulated Swamp-Type Mine with 300-Foot Wetland Setback

Surficial Aquifer Potentiometric Surface



Floridan Aquifer Potentiometric Surface





Based on Swamp-Type Model V.7

Independent Geological Services, Inc.

Reserves Evaluation
Environmental Permitting
Mine Planning and Impact Analysis
Geological and Hydrogeological Services

121 Market Street
Davenport, FL 33837

Phone: 863-419-1239
Fax: 863-419-4968

Prepared For:

E.R. Jahna Industries, Inc.

Date: *July 27, 2001*

Figure 15. Cross Sections of Simulated Swamp-Type Mine with No Wetland Setback

Simulation of a Ridge-Type Sand Mine

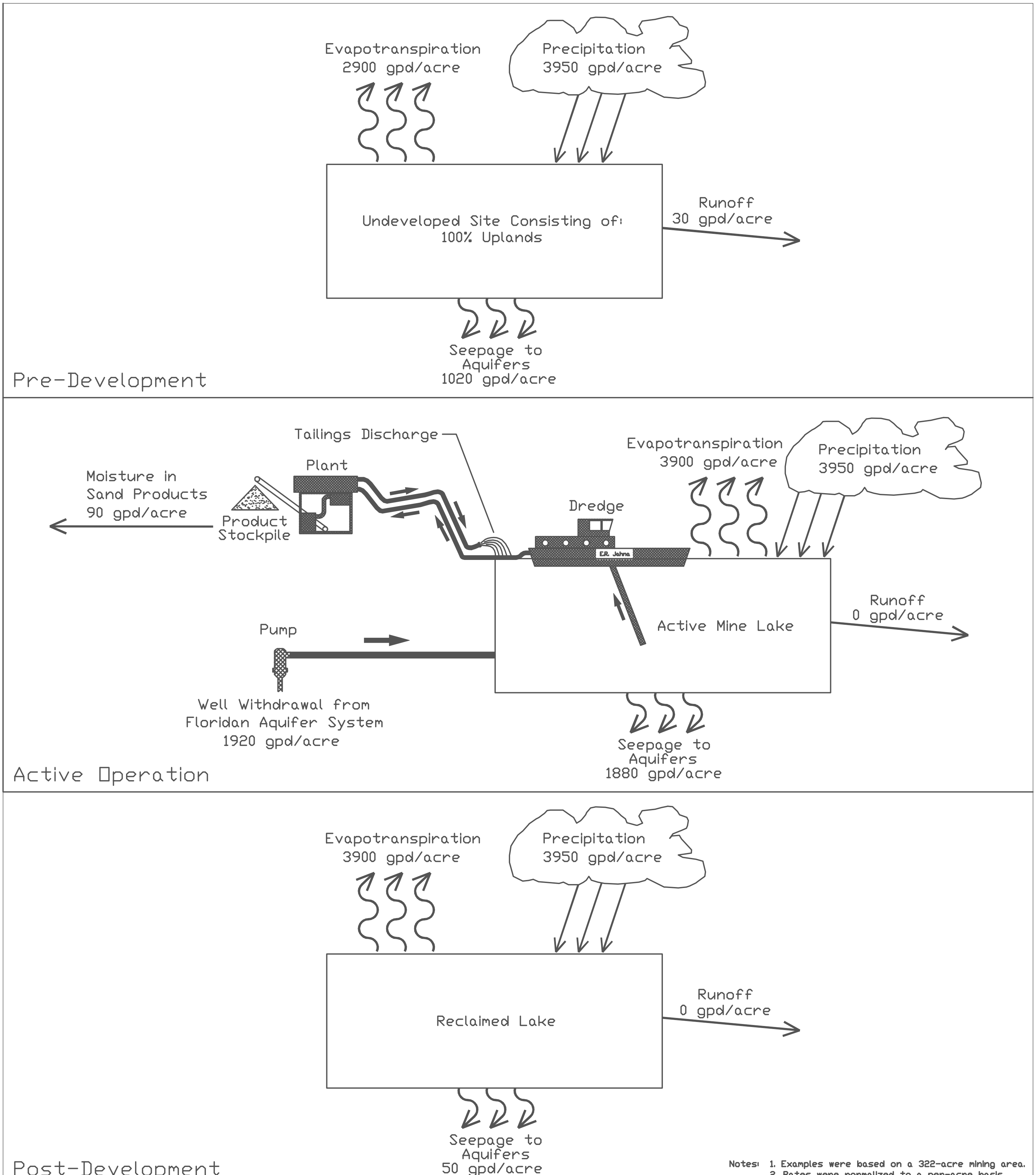
Simulations of a generic ridge-type mine were prepared for comparison with the simulations of swamp-type mines. Models simulate pre-development conditions, active operation, and post-mining conditions to evaluate the effects of land use changes resulting from sand mining. Because few site-specific data were available for the ridge areas, many parameters were selected from regional studies and calibrated regional models. Please refer to the Appendix for detailed descriptions of the models.

The results should be regarded as the worst case for three reasons. First, real ridge-type sand mines, and the areas adjacent to them, typically contain some flatwoods and wetlands, as well as uplands; so the difference between pre-development and active operation or post-development evapotranspiration (ET) rates is not typically as great as simulated. Second, the post-development simulation assumes that 100 percent of the simulated pit was reclaimed as a lake. Real sand mine pits are typically reclaimed partly as uplands, partly as wetlands, and partly as lakes; so the difference between pre-development and post-development ET rates is not typically as great as simulated. And third, ET compensation effects were ignored; in real wetland systems ET rates slow down as water tables decrease.

Water balances corresponding with the ridge-type sand mine simulations were presented in Figure 16. The examples were based upon a 322-acre mining area. Rates were normalized to a per-acre basis. Land use changes resulting from mining have two hydrologic effects: Mine lakes capture all of the precipitation that falls on them, eliminating runoff from the site; and conversion of land to lakes increases evaporation rates. In addition, active operation of a ridge-type sand mine involves removal of water from the site as moisture in sand products, and there is significantly more pumping from a well into the mine lake than in a swamp-type setting. All of these factors balance to determine rates of seepage from the mine area into aquifers.

Cross sections comparing simulations of active operations with the pre-development conditions are presented in Figure 17. Operation of the mine might depress Floridan Aquifer System potentials by about 0.22 feet at the pit edge, except in the vicinity of the production well where a maximum drawdown of about 1.47 feet was predicted. The simulation indicates that the pit water level would be augmented by the addition of well water to an elevation about 2.76 feet above pre-development conditions. In reality, miners would regulate the well pumping rate to maintain a pit water level approximately equal to pre-development conditions. Less pumping may be required. Impacts to the Floridan Aquifer System may be less than the simulation indicates.

Please note that the simulation of an active operation represents an ideally-designed sand mine. If water recirculation was significantly impeded by restrictive flow paths or control structures,



Independent
Geological
Services, Inc.

Reserves Evaluation
Environmental Permitting
Mine Planning and Impact Analysis
Geological and Hydrogeological Services

121 Market Street
Davenport, FL 33837

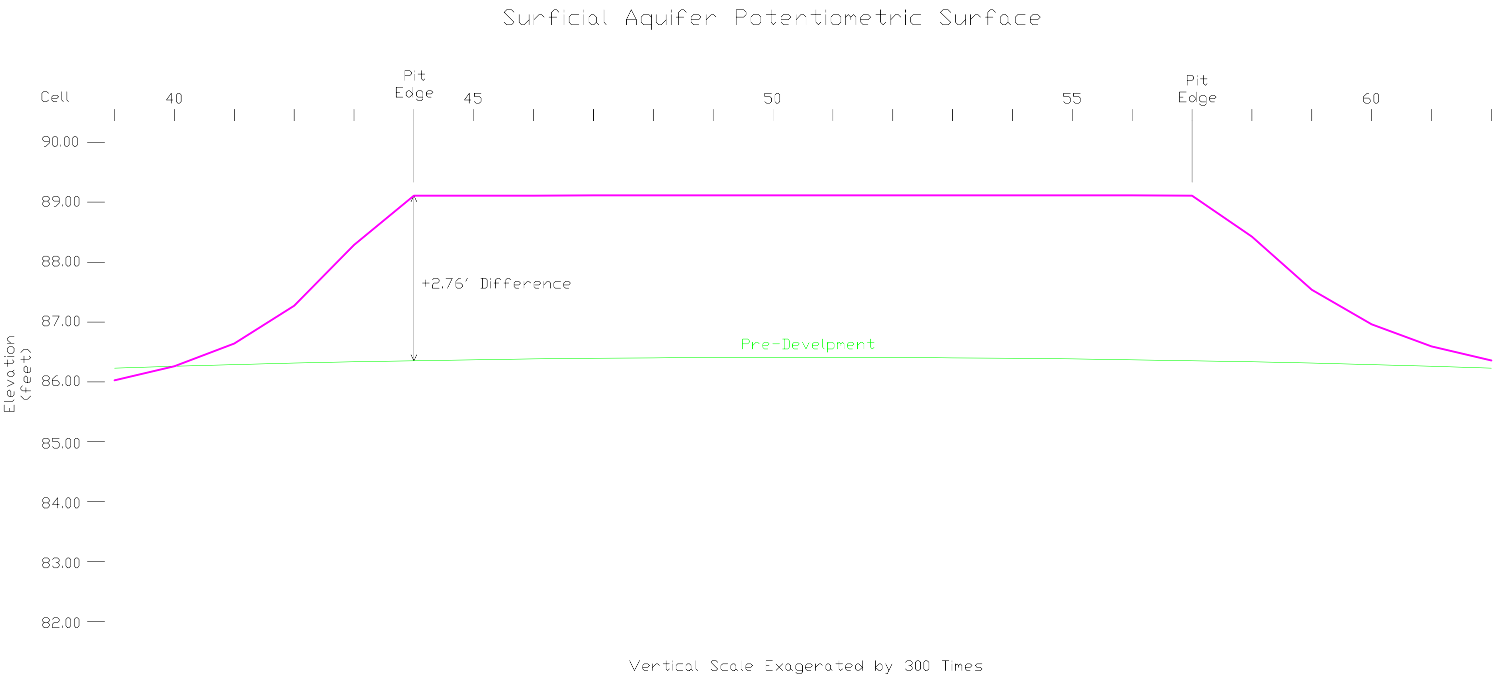
Phone: 863-419-1239
Fax: 863-419-4968

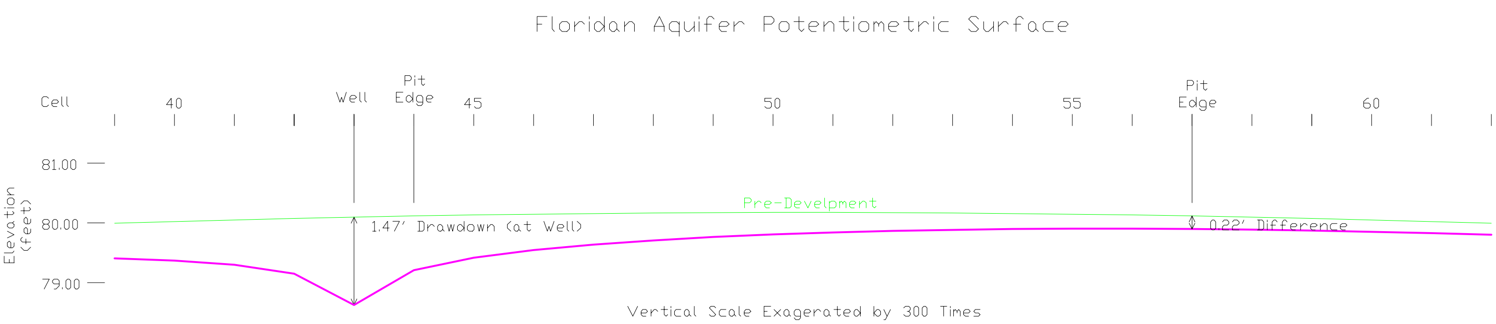
Prepared For:

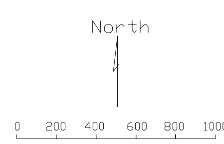
E.R. Jahna Industries, Inc.

Date: July 27, 2001

Figure 16. Normalized Water Balance of a Sand Mine in a Ridge-Type Setting







Based on Ridge-Type Model V.7a

Independent Geological Services, Inc.

Reserves Evaluation
Environmental Permitting
Mine Planning and Impact Analysis
Geological and Hydrogeological Services

121 Market Street
Davenport, FL 33837

Phone: 863-419-1239
Fax: 863-419-4968

Prepared For:

E.R. Jahna Industries, Inc.

Date: July 27, 2001

Figure 17. Cross Sections of Simulated Ridge-Type Mine in Active Operation

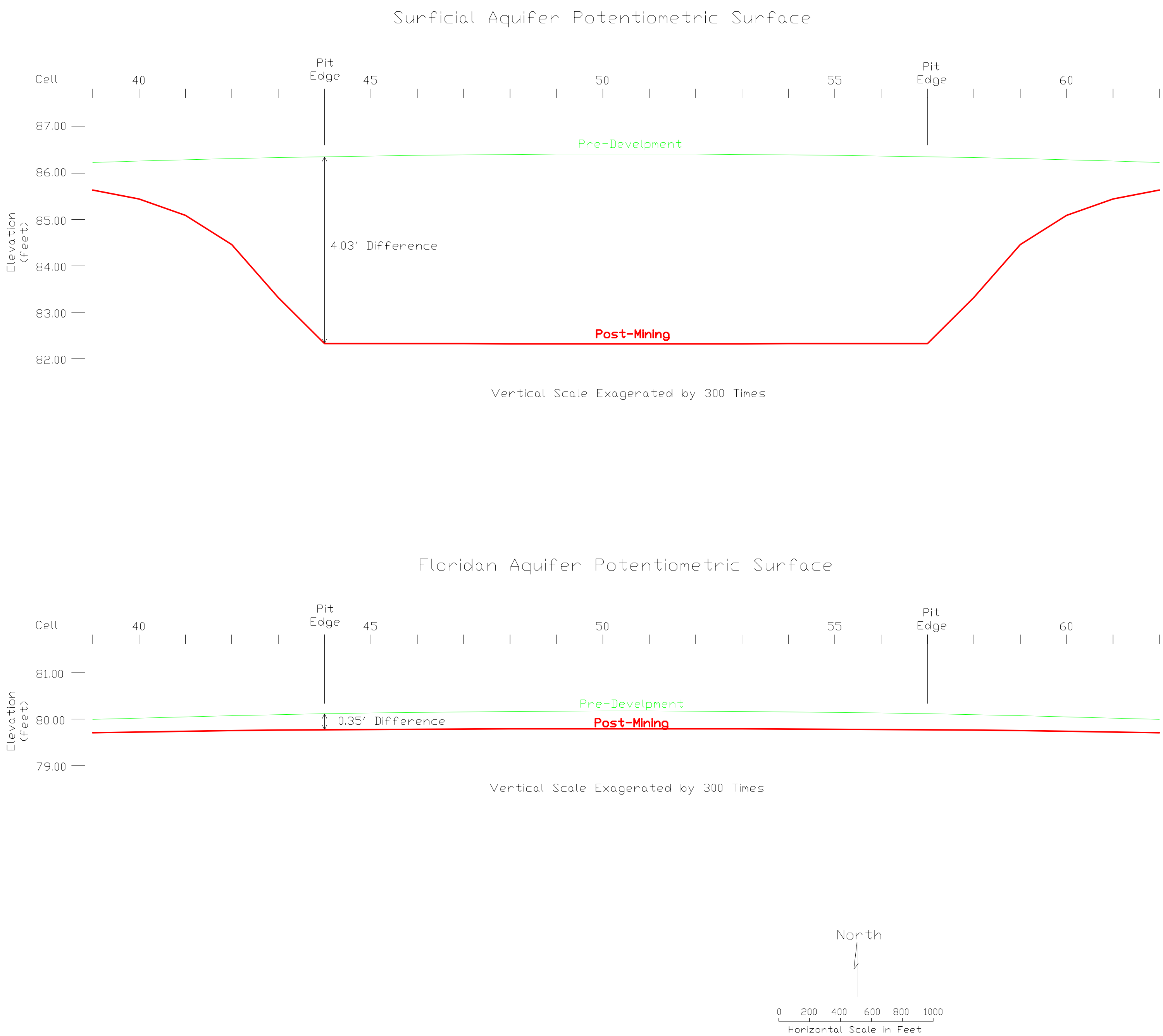
significantly greater local effects on the Surficial Aquifer System would result. Dynamic effects of this nature could vary significantly from mine to mine depending upon very specific design considerations. Detailed site-specific analysis that would be required to accurately quantify these dynamic flow effects, and would not be generally applicable to all sand mines.

Cross sections comparing simulations of post-mining and pre-development simulations were presented in Figure 18. These worst case results indicate that a 320-acre mine pit could reduce Surficial Aquifer System water levels by about 4 feet, and reduce Floridan Aquifer System potentials by about 0.35 feet, at the pit edge, on an annual average basis.

The relatively large difference between pre- and post-mining Surficial Aquifer System potentials results from the large contrast between evapotranspiration rates in the simulated mine lake and adjacent uplands. In the swamp-type setting, where mine pits are typically bordered by wetlands with evapotranspiration rates that are not drastically different from those of the mine pits, pre- and post-mining differences are much more subtle.

Generic simulations of this sort cannot precisely predict the effects of every ridge-type mine. The wide range of water use by ridge-type mines reflects the variability of hydrogeologic conditions in the ridge areas. However, widely-applicable general conclusions can be drawn from the generic modeling. Ridge-type mines are not likely to significantly impact Floridan Aquifer System potentials. Because the transmissivity of the Surficial Aquifer System is very small relative to the Floridan Aquifer System transmissivity, pumping of production wells at closed-loop recirculating sand mines is expected to have larger effects on pit water levels than on Floridan Aquifer System potentials. Further, rates of seepage loss from the mine pit to the Surficial Aquifer System are very small relative to rates of recharge from the pit to the Floridan Aquifer System. In other words, most of the water that ridge-type mines pump from the Floridan Aquifer System returns by recharge to the aquifer that it was pumped from. No significant impacts to Floridan Aquifer System potentials are expected to result from operation of typical ridge-type mines in Lake County.

The effects of a generic ridge-type mine on rates of recharge to the Surficial and Floridan Aquifer Systems were evaluated numerically. The results indicate that, in the worst case, mining might reduce recharge by an amount approximately equal to the difference in evapotranspiration between pre- and post-mining conditions.



Based on Ridge-Type Model V.7a

Independent Geological Services, Inc.

Reserves Evaluation
Environmental Permitting
Mine Planning and Impact Analysis
Geological and Hydrogeological Services

121 Market Street
Davenport, FL 33837

Phone: 863-419-1239
Fax: 863-419-4968

Prepared For:

E.R. Jahna Industries, Inc.

Date: July 27, 2001

Figure 18. Cross Sections of Simulated Ridge-Type Mine

Comparison of Swamp- and Ridge-Type Mine Simulations

The simulations presented in this report suggest that ridge-type sand mines drawdown the Surficial Aquifer System significantly more than swamp-type mines. However, the same land use changes result from mining in either setting: upland areas are replaced with mine pit lakes. And rates of evaporation from the mine pit lakes are about the same in either setting. The only significant differences between the two settings are the hydrologic properties of unmined areas adjacent to the mine pit lakes. Evaporation from lakes contrasts hydrologically with evapotranspiration rates of adjacent unmined areas to a much greater extent in a ridge-type setting than in a swamp-type setting, making drawdown effects more apparent.

The water table underlying a ridge-type mine site consists of a relatively flat plain before mining. A ridge-type mine produces a valley in the water table by making a lake that evaporates water faster than the adjacent uplands. After mining, the water level in the mine pit lake contrasts distinctly with adjacent upland-associated water tables.

Prior to mining, the water table underlying a swamp-type mine site consists of a relatively flat plain, punctuated by small peaks that correspond with upland islands, where more water reaches the water table because ET rates are lower. Mining an upland island in the swamp-type setting has the effect of removing a peak in the water table. After mining, the water level in the mine pit lake contrasts less with adjacent wetland-associated water tables than the upland-associated water table did before mining.

Comparisons with Other Types of Development

Almost all types of development reduce the supply of ground water to some degree. Withdrawing water, altering land use, or changing the potential for recharge between aquifers may affect local water supplies. For perspective, the following discussion compares estimates of water consumption by active sand mines with residential development and citrus production, the two largest consumers of water in Lake County.

Residential developments reduce supplies of ground water. Residents use water for drinking, sanitary uses, and lawn irrigation. Exact measurements of residential water consumption in Lake County are not available. However, reasonable estimates can be made. The Lake County Comprehensive Plan includes a minimum Level-of-Service for residential water service of 350 gallons per day (gpd) per Equivalent Residential Unit (ERU). An ERU is the equivalent of a typical single family, 3-bedroom, 2-bath house. Estimates based upon this Level-of-Service should be regarded as minimum, because 350 gpd/ERU does not account for typical lawn irrigation requirements in Central Florida. The St. Johns River Water Management District allocates up to 150 gpd/person for residential use, which equates to 450 to 600 gpd/ERU. These estimates do not account for losses of water through evaporation. Table 5 summarizes minimum estimates of water consumption by urban residential developments.

Sand mines potentially reduce the supply of ground water by direct consumption from wells, and through evaporative losses resulting from conversion of land to lakes. In Table 6, the reduction of groundwater supply by typical active sand mines, based upon the estimates presented in Figures 12 and 16 of this report, was compared with residential development. In a swamp-type setting, each acre of a mine pit lake is equivalent to an acre of residential development with about 2 houses. In a ridge-type setting, each acre of a mine pit lake is equivalent to an acre of residential development with about 3 houses.

The irrigation requirements of a typical citrus grove in Lake County are about 16 to 22 inches per year (Parsons, 2001). That amounts to about 1413 gpd per acre. Table 7 compares water consumption of typical swamp-type and ridge-type sand mines with typical grove irrigation requirements. In the swamp-type setting, each acre of mine pit lake consumes about half as much water as an acre of typical citrus grove. In the ridge-type setting, each acre of mine pit lake consumes about three-quarters as much water as an acre of typical citrus grove.

Table 5. Estimates of Water Consumed by Urban Residential Developments

Future Land Use	Maximum Units/Acre	Minimum Water Consumption (gpd/acre)
Urban (UR)	7	2450
Urban Expansion (UE)	4	1400
Suburban (SU)	3	1050

Assume: Water Consumption of 350 gpd/Equivalent Residential Unit
(per Lake County Comprehensive Plan concurrency requirements)

Table 6. Comparison of Active Sand Mines to Residential Development

	Reduction of Groundwater Supply (gpd/acre)
Residential, 7 Units/Acre (UR)	2450
Residential, 4 Units/Acre (UE)	1400
Residential, 3 Units/Acre (SU)	1050
Sand Mine, Ridge-Type Setting	1150
Sand Mine, Swamp-Type Setting	770

Table 7. Comparison of Active Sand Mines to Typical Citrus Grove

	Reduction of Groundwater Supply (gpd/acre)
Citrus Grove	1413
Sand Mine, Ridge-Type Setting	1150
Sand Mine, Swamp-Type Setting	770

Conclusions

Under the current regulatory scheme, wetland areas are protected to a much greater extent than uplands. Sand miners avoid mining wetlands to the greatest practical extent to avoid the cost of mitigation. The direct impacts of mining are concentrated in the upland parts of mine sites, except for small isolated wetlands that might be more difficult to avoid than to mine and mitigate. These direct impacts are obvious and very easy to quantify.

Indirect impacts, such as reductions of aquifer water levels or recharge rates, are typically less obvious. Most hydrologic impacts can be reliably detected by well-designed water level monitoring programs, which are being implemented as conditions of newer development permits issued under the Lake County Land Development Regulations. However, subtle changes in water levels, particularly those that are much smaller than the range of natural seasonal variations are more difficult to detect and quantify.

This study estimated the consumption of water by sand mines and compared it with other water uses in Lake County, and examined the hydrologic effects of land use changes resulting from sand mining in Lake County. Basic numerical simulations were prepared to evaluate theoretical factors that may be difficult to quantify through empirical water level measurements. Several informative conclusions were reached.

- In 1997, the most recent year for which complete records were available, agriculture and public supply consumed the largest quantities of water in Lake County. Sand mining was the third-largest consumer. The nine sand mines that were active in Lake County in 1997 were responsible for about 10 percent of Lake County's water consumption. Although sand mines pumped very large quantities, the majority was recycled; only 14 percent was consumed (removed from its source).

- Land use changes resulting from sand mining in a swamp-type setting could subtly reduce adjacent Surficial Aquifer System water levels. Comparisons of numerical simulations of a generic swamp-type mine under pre-, active-, and post-mining conditions suggest that Surficial Aquifer System water levels might be reduced by as much as a couple of inches adjacent to an average size mine lake, on an annual average basis. Water table differences of this magnitude are consistent with site-specific monitoring data collected at swamp-type mines and reported to Lake County. Reductions of this scale are very small in relation to the range of natural seasonal variations (several feet), therefore very difficult to empirically detect, and probably of no environmental significance. Vegetative monitoring, in addition to hydrologic monitoring, was conducted at Florida Rock Industries' Lake Sand Plant to evaluate any hydrologic impact that mining might have on adjacent wetlands. Results of the monitoring program were summarized in the "FOURTH ANNUAL MONITORING REPORT" prepared by The Land Planning Group, dated November 1997. Four years of monitoring indicated no mining-related impacts.

- Wetland setbacks offer no significant hydrologic protection for wetlands. Numerical simulations of a generic swamp-type mine indicate that a mine lake with no wetland setback would reduce Surficial Aquifer System water levels only 0.01 feet more than a mine lake with a wetland setback of 300 feet. In a swamp-type setting, simulations predict mine-related water table reductions that are very small, with or without wetland setbacks.

- Land use changes resulting from sand mining in a ridge-type setting might measurably reduce adjacent Surficial Aquifer System water levels after active operations cease. Although water levels adjacent to ridge-type mines are typically maintained during active operation by augmentation the water levels of mine lakes, comparisons of numerical simulations of a generic ridge-type mine under pre- and post-mining conditions suggest that Surficial Aquifer System water levels might be reduced by as much as a few feet adjacent to an average size mine lake, on an annual average basis. However, the predicted water level reductions are probably of no regulatory or environmental significance. The Surficial Aquifer System is generally not an important water source in Lake County. And natural upland plants associated with the ridge-type environment are well adapted to dry conditions (Menges, 1994) and apparently insensitive to water table variations (Menges and Gallo, 1991).

- Land use changes resulting from both swamp- and ridge-type mines might subtly reduce Floridan Aquifer System potentials (head). Numerical simulations suggest reductions of a couple of inches, during and after mining, except in the immediate vicinity of production wells where drawdowns would be greater. Reductions of this magnitude are expected to be insignificant from regulatory or environmental perspectives. Although larger well withdrawals are generally required for operation of ridge-type mines, reviewed data suggest that the Floridan Aquifer System is typically more transmissive in the ridge mining areas, and better able to accommodate larger withdrawals.

- Land use changes associated with mining, like conversion of uplands to lakes, theoretically can reduce rates of recharge to the Floridan Aquifer System. Numerical simulations predict reductions approximately equal to differences between pre- and post-development ET rates, which may vary significantly with site-specific factors.

- Each acre of typical sand mine pit lake consumes about the same amount of water as an acre of residential development with a density of about 2 to 3 units per acre.

- Each acre of typical sand mine pit lake consumes only about 50-75% as much water as an acre of typical citrus grove.

Acknowledgments

The author gratefully acknowledges valuable contributions from Kirk Davis, Charles W. Drake, Doug Hearn, Mark Schwartz, Mark Stephens, Cornelis Winkler III, and Walter Wood.

Professional Certification

This document was prepared for E.R. Jahna Industries to satisfy conditions of an agreement with Lake County. It contains an assessment of potential hydrologic impacts based on analysis the best available regional and site-specific data, and reasonable assumptions drawn from my professional experiences.

Marc V. Hurst, PG, President
Independent Geological Services, Inc.
Florida Registration No. 243

Bibliography

Bidlake, W.R., Woodham, W.M., and Lopez, M.A., 1996, Evapotranspiration from Areas of Native Vegetation in West-Central Florida: Reston, U.S. Geological Survey, Water Supply Paper 2430, 35 p.

Bidlake, W.R., and Boetcher, P.F., 1997, Simulation of the Soil Water Balance of an Undeveloped Prairie in West-Central Florida: Denver, U.S. Geological Survey, Water Supply Paper 2472, 57 p.

Boniol, Don, 1998, Designation of Significant Groundwater Recharge Areas (Draft): Palatka, St. Johns River Water Management District, 1 p.

Boniol, Don, Williams, Marvin, and Munch, Douglas, 1993, Mapping Recharge to the Floridan Aquifer Using a Geographic Information System: Palatka, St. Johns River Water Management District, Technical Publication SJ93-5, 41 p.

Ewel, K.C., and Smith, J.E., 1992, Evapotranspiration from Florida Pondcypress Swamps: Water Resources Bulletin, Volume 28, No. 2, p. 299-304.

Florence, B.L., and Moore, C., 1997, Annual Water Use Survey:1995: Palatka, St. Johns River Water Management District, Technical Publication SJ97-4.

Florida Geological Survey, 1991, Florida's Ground Water Quality Monitoring Program Hydrogeological Framework: Tallahassee, Florida Geological Survey, Special Publication No. 32, 97 p.

German, Edward R., 1999, Regional Evaluation of Evapotranspiration in the Everglades: Salt Lake City, paper presented at 3rd International Symposium on Ecohydraulics, 14p.

Harbaugh, Arlen W., and McDonald, Michael G., 1996, User's Documentation for MODFLOW-96, an update to the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model: Reston, U.S. Geological Survey, Open-File Report 96-485, 56 p.

Healy, Henry G., 1975, Terraces and Shorelines of Florida: Tallahassee, Florida Geological Survey, Map Series No. 71.

Jones, J.W., et al., 1984, Estimated and Measured Evapotranspiration for Florida Climate, Crops, and Soils: Gainesville, University of Florida Institute for Food and Agricultural Sciences, Bulletin 840.

Knowles, Leel, Jr., 1996, Estimation of Evapotranspiration in the Rainbow Springs and Silver Springs Basins in North-Central Florida: Tallahassee, U.S. Geological Survey, Water-Resources Investigations Report 96-4024, 37 p.

Lee, T.M., and Swancar, A., 1997, Influence of Evaporation, Ground Water, and Uncertainty in the Hydrologic Budget of Lake Lucerne, a Seepage Lake in Polk County, Florida: Reston, U.S. Geological Survey, Water Supply Paper 2439, 61 p.

McKenzie-Arenberg, Margaret, and Szell, George, 1990, Middle St. Johns Ground Water Basin Resource Availability Inventory: Palatka, St. Johns River Water Management District, Technical Publication SJ 90-11, 56 p.

Marella, R.L., 1995, Water-Use Data by Category, County, and Water Management District in Florida, 1950-90: Tallahassee, U.S. Geological Survey, Open-File Report 94-521, 114 p.

Marella, R.L., 1999, Water Withdrawals, Use, Discharge, and Trends in Florida, 1995: Tallahassee, U.S. Geological Survey, Water-Resources Investigations Report 99-4002, 90 p.

Menges, Eric S., and Gallo, Noreen P., 1991, Water Relations of Scrub Oaks on the Lake Wales Ridge, Florida: Florida Scientist, Vol. 54, No. 2, p. 69-79.

Menges, Eric S., 1994, Fog Temporarily Increases Water Potential in Florida Scrub Oaks: Florida Scientist, Vol. 57, No. 3, p. 65-74.

Murray, L.C., Jr., and Halford, Keith J., 1996, Hydrogeologic Conditions and Simulation of Ground-Water Flow in the Greater Orlando Metropolitan Area, East-Central Florida: Tallahassee, U.S. Geological Survey, Water-Resources Investigations Report 96-4181, 100 p.

O'Reilly, Andrew M., 1998, Hydrogeology and Simulation of the Effects of Reclaimed-Water Application in West Orange and Southeast Lake Counties, Florida: Tallahassee, U.S. Geological Survey, Water-Resources Investigations Report 97-4199, 91 p.

Parsons, Larry, 2001, Verbal Communication with Author.

Pride, R.W., Meyer, F.W., and Sherry, R.N., 1966, Hydrology of Green Swamp Area in Central Florida: Tallahassee, Florida Geological Survey, Report of Investigations No. 42, 137 p.

Quan, C.K., Water Use in the Domestic Nonfuel Minerals Industry: U.S. Bureau of Mines, Information Circular 9196.

Sachs, L.A., Lee, T.M., and Radell, M.J., 1994, Comparison of energy-budget evaporation losses from two morphologically different Florida seepage lakes: Journal of Hydrology 156, p. 311-334.

St. Johns River Water Management District, 2000, Water 2020 Work Group I: East-Central Florida Conceptual Water Supply Plan: Palatka, St. Johns River Water Management District, 137 p.

Scott, Tom, 1988, The Lithostratigraphy of the Hawthorn Group (Miocene) of Florida: Tallahassee, Florida Geological Survey, Bulletin No. 59, 148 p.

Scott, Tom, 1992, Geologic Map of Lake County: Tallahassee, Florida Geological Survey, Open File Map Series 9.

Southwest Florida Water Management District, 1987, Aquifer Characteristics Within the Southwest Florida Water Management District, Brooksville, 30 p.

Spencer, S.M., 1999, The Industrial Minerals Directory of Florida: Tallahassee, Florida Geological Survey, Information Circular No. 112, 6 p.

Stewart, J.W., 1980, Areas of Natural Recharge to the Floridan Aquifer in Florida: Tallahassee, Florida Geological Survey, Map Series 98.

Sumner, D.M., 1996, Evapotranspiration from Successional Vegetation in a Deforested Area of the Lake Wales Ridge, Florida: Tallahassee, U.S. Geological Survey, Water-Resources Investigations Report 96-4244, 38 p.

Swancar, Amy, Lee, T.M., and O'Hare, T.M., 2000, Hydrogeologic Setting, Water Budget, and Preliminary Analysis of Ground-Water Exchange at Lake Starr, a Seepage Lake in Polk County, Florida: Tallahassee, U.S. Geological Survey, Water-Resources Investigations Report 00-4030, 66 p.

Szell, George P., Aquifer Characteristics in the St. Johns River Water Management District, Florida: Palatka, St. Johns River Water Management District, Technical Publication SJ93-1, 495 p.

Vergera, B.M., Water Supply Assessment 1998 St. Johns River Water Management District: Palatka, St. Johns River Water Management District, Technical Publication SJ98-2, 154 p.

Vergera, B.M., District Water Supply Plan: Palatka, St. Johns River Water Management District, Technical Publication SJ2000-SP1, 170 p.

Visher, F.N., and Hughs, G.H., 1969, The Difference Between Rainfall and Potential Evaporation in Florida: Tallahassee, Florida Geological Survey, Map Series No. 32, 1 p.

Appendix A

Summary of Published Evapotranspiration Rates

Summary of Published Evapotranspiration Estimates

1. Lake Evaporation

Amount	Study Location	Reference
57.9	Lake Lucerne, Polk County	Lee and Swancar (1997)
	(Authors noted unusually dry conditions, only 40.9" rain in study year)	
59.45	North-Central Fl	Sachs, Lee, and Radell (1994)
50.39	Panhandle Fl	Sachs, Lee, and Radell (1994)
47.1	Rainbow & Silver Spr. Bas.	Knowles (1996)
	(Author noted a range of 18"/yr in Jan 1994 to 72"/yr in May 1994)	
53.1	Lake Helene, Polk County	Pride et al. (1966)
	(Authors noted a dry year in 1962; so the estimate may be large.)	
67.2	Lakeland, Polk County	Jones et al. (1984)
53.22-55.54	Everglades	German (1999)
50.68-54.04	Lake Starr, Polk County	Swancar, Lee, and O'Hare (2000)

2. Dry Prairie

Amount	Study Location	Reference
39.76	Sarasota County	Bidlake, Woodham,and Lopez(1996)

3. Deforested upland on Lake Wales Ridge

Amount	Study Location	Reference
27	Orange County	Sumner (1996)

4. Marsh

Amount	Study Location	Reference
38.97	Sarasota County	Bidlake, Woodham,and Lopez(1996)
42.78-43.44	Everglades	German (1999)
	(Areas where water level was below land surface several weeks per year)	
45.68-50.05	Everglades	German (1999)
	(Areas where water level was nearly always above land surface)	

5. Pine Flatwoods

Amount	Study Location	Reference
41.73	Sarasota County	Bidlake, Woodham,and Lopez(1996)

6. Cypress Swamp

Amount	Study Location	Reference
38.18	Sarasota County	Bidlake, Woodham,and Lopez(1996)
31.5-36.6	Central Florida	Ewel and Smith(1992)
	(Pondcypress swamp, corrected by author to account for interception)	

7. Regional Averages

Amount	Study Location	Reference	
37.9	Rainbow & Silver Spr. Bas.	Knowles (1996)	(Average over a 30-year period)
37.6	Silver Spr. Basin	Knowles (1996)	(Average over a 30-year period)
38.5	Rainbow Spr. Basin	Knowles (1996)	(Average over a 30-year period)
38.3	Eastern Bas.of Green Swamp	Pride et al. (1966)	(Average over 3-year period)
41.8	Western Bas.of Green S.	Pride et al. (1966)	(Average over 3-year period)

Appendix B

Design and Parameter Selection for Swamp-Type Mine Simulations
Design and Parameter Selection for Ridge-Type Mine Simulations

Design and Parameter Selection for Swamp-Type Mine Simulations

The Harbaugh and McDonald (96) MODFLOW-96 groundwater flow model was used to simulate a generic Swamp-Type Mine to evaluate subtle hydrologic effects of land use changes resulting from sand mining. Models were made to simulate pre-development conditions, active operation, and post-mining conditions. An additional simulation, of a new mine “start up” scenario was considered, but omitted from this study. Startup configurations of new mines are quite variable; so a single generic “start up” model does not accurately represent most mines. The startup phases of most mines are very brief and generally not very significant in relation to the remaining mine life.

The models were configured to use one layer for the Surficial Aquifer System and one layer for the Floridan Aquifer System, under steady state conditions. A model parameter associated with the first layer accounts for vertical flow through the Intermediate Confining Unit. To avoid shape-related effects that might be specific to some mine sites, but not others, the areal geometry of the models was designed to be as simple and generic as possible. Complications related to regional flow gradients were avoided by assuming that the centers of each model correspond with potentiometric highs of both simulated aquifer systems.

Each simulation was a square area, consisting of 100 rows and 100 columns, representing an area with sides measuring approximately 12 miles. Interior cells represent areas measuring 300 feet by 300 feet. Cell grid spacings were expanded progressively near the edges of the modeled area to 450, 675, 1012, 2277, 3415, and 5123 feet.

Because lateral flow out of the modeled area through the perimeter of Layer 1, which simulates the Surficial Aquifer System, was insignificantly small in relation to vertical flow down into Layer 2, the perimeter of Layer 1 was set as a “no flow” boundary. The perimeter of Layer 2, which simulates the Floridan Aquifer System, was set as a “constant head” boundary to allow lateral flow out of the modeled area through the perimeter of Layer 2. To summarize, water enters the model only through vertical recharge to Layer 1. As it flows laterally, in a radial pattern, toward the boundaries of Layer 1, it leaks downward into Layer 2. Then it flows laterally, in a radial pattern, through Layer 2, and exits the modeled area through the boundaries of Layer 2.

Model recharge parameters were based on long-term averages of precipitation, evapotranspiration estimates from various sources, and annualized stormwater runoff estimates. Please refer to Table B1 for details of the derivation of model recharge parameters. Precipitation was estimated from data collected at NOAA’s Lisbon and Lake Alfred Stations. No appropriate measurements of evapotranspiration from natural upland areas were available. An estimate was

07/20/2001
Independent Geological Services, Inc.
Table B1. Derivation of Model Recharge Parameters

Green Swamp Soil Associations, Aerial Percentages, and E.T. Estimates:

Soil Assoc.	% Acreage	E.T. (in/yr)	E.T. (ft/day)	Reference
Uplands	20	39	0.00890	Estimate
Flatwoods	30	42	0.00959	Bidlake, Woodham, and Lopez (96)
Wetlands	50	45	0.01027	German (99)
Totals	100	42.9	0.00979	Calculated

Notes: Soil Associations and percentages were estimated from Lake County GIS.
Uplands are "A" soils.
Wetlands are hydric soils and open water.
Remainers are flatwoods.

Open Water E.T. Estimate:

	E.T. (in/yr)	E.T. (ft/day)	Reference
Open Water	52.36	0.01195	Swancar, Lee, and O'Hare (2000)

Rainfall Estimates:

Station	Rain (in/yr)	Rain (ft/day)	Comments
Lisbon	53.11	0.01213	11-yr average of NOAA data
Lake Alfred	53.00	0.01210	11-yr average of NOAA data
Average	53.06	0.01211	

Runoff Estimates, Annual Average Basis:

Soil Assoc.	Avg. CN	Comments
Uplands	50	Pasture, fair
Flatwoods	80	Woods-grass combination, poor
Wetlands	80	Woods, fair
Totals		

Upland Areas, Rainfall and Runoff Weighted by Annual Distribution
Assume Rainfall (in/yr)= 53.06
Assume CN = 50

Days/Year	Per 24-Hr. Rain (in.)	Per 24-Hr. Runoff(in.)	Total Runoff(in./yr)
315.36	<0.50	0.00	0.0000
27.68	0.50	0.00	0.0000
10.86	1.00	0.00	0.0000
5.32	1.50	0.00	0.0000
3.18	2.00	0.00	0.0000
0.91	2.50	0.02	0.0182
0.82	3.00	0.09	0.0736
0.45	3.50	0.20	0.0909
0.23	4.00	0.33	0.0750
0.09	4.50	0.50	0.0455
0.09	5.00	0.69	0.0627
365.00			0.3659

Flatwoods Areas, Rainfall and Runoff Weighted by Annual Distribution
Assume Rainfall (in/yr)= 53.06
Assume CN = 80

Days/Year	Per 24-Hr. Rain (in.)	Per 24-Hr. Runoff(in.)	Total Runoff(in./yr)
315.36	<0.50	0.00	0.0000
27.68	0.50	0.00	0.0000
10.86	1.00	0.08	0.8691
5.32	1.50	0.29	1.5423
3.18	2.00	0.56	1.7818
0.91	2.50	0.89	0.8091
0.82	3.00	1.25	1.0227
0.45	3.50	1.64	0.7455
0.23	4.00	2.04	0.4636
0.09	4.50	2.46	0.2236
0.09	5.00	2.89	0.2627
365.00			7.7205

Wetlands Areas, Rainfall and Runoff Weighted by Annual Distribution
Assume Rainfall (in/yr)= 53.06
Assume CN = 80

Days/Year	Per 24-Hr. Rain (in.)	Per 24-Hr. Runoff(in.)	Total Runoff(in./yr)
315.36	<0.50	0.00	0.0000
27.68	0.50	0.00	0.0000
10.86	1.00	0.08	0.8691
5.32	1.50	0.29	1.5423
3.18	2.00	0.56	1.7818
0.91	2.50	0.89	0.8091
0.82	3.00	1.25	1.0227
0.45	3.50	1.64	0.7455
0.23	4.00	2.04	0.4636
0.09	4.50	2.46	0.2236
0.09	5.00	2.89	0.2627
365.00			7.7205

Calculated Runoff:

Soil Assoc.	Acre %	Runoff (in/yr	Runoff(ft/day	Ac%*in./yr
Uplands	20	0.37	0.00008	7.32
Flatwoods	30	7.72	0.00176	231.61
Wetlands	50	7.72	0.00176	386.02
Totals	100	15.81		624.95
Wt. Avg.		6.25	0.00143	

Basic Model Recharge Parameters for Swamp-Type Mine Simulations:

Cell Type	Rain	E.T.	Runoff	Recharge ft/day)	Recharge (in/yr)
Uplands	0.01211	0.00890	0.00008	0.00313	13.689
Flatwoods	0.01211	0.00959	0.00176	0.00076	3.335
Wetlands	0.01211	0.01027	0.00176	0.00008	0.335
Average	0.01211	0.00979	0.00143	0.00089	3.905
Pit (Inactive)	0.01211	0.01195	0.00000	0.00016	0.695

used. Bidlake, Woodham, and Lopez's (1996) estimate was selected to represent the flatwoods association. And a wetland evapotranspiration rate was calculated from the average of values given by German (99).

Soils data, obtained from Lake County's Geographic Information System, were used to estimate areal percentages of upland, flatwoods, and wetland soil associations within the Green Swamp. Areas near the center of the modeled area were designed to represent specific soil associations. Peripheral areas were designed to represent weighted average conditions.

Stormwater runoff was estimated from upland, flatwoods, and wetland areas using the SCS TR-55 methods and annualized by summing events in a long-term average annual rainfall distribution. A weighted average of the calculated upland, flatwoods, and wetland runoff rates were compared with Pride, Meyer, and Cherry's (1966) stream flow data, and found to be approximately equal.

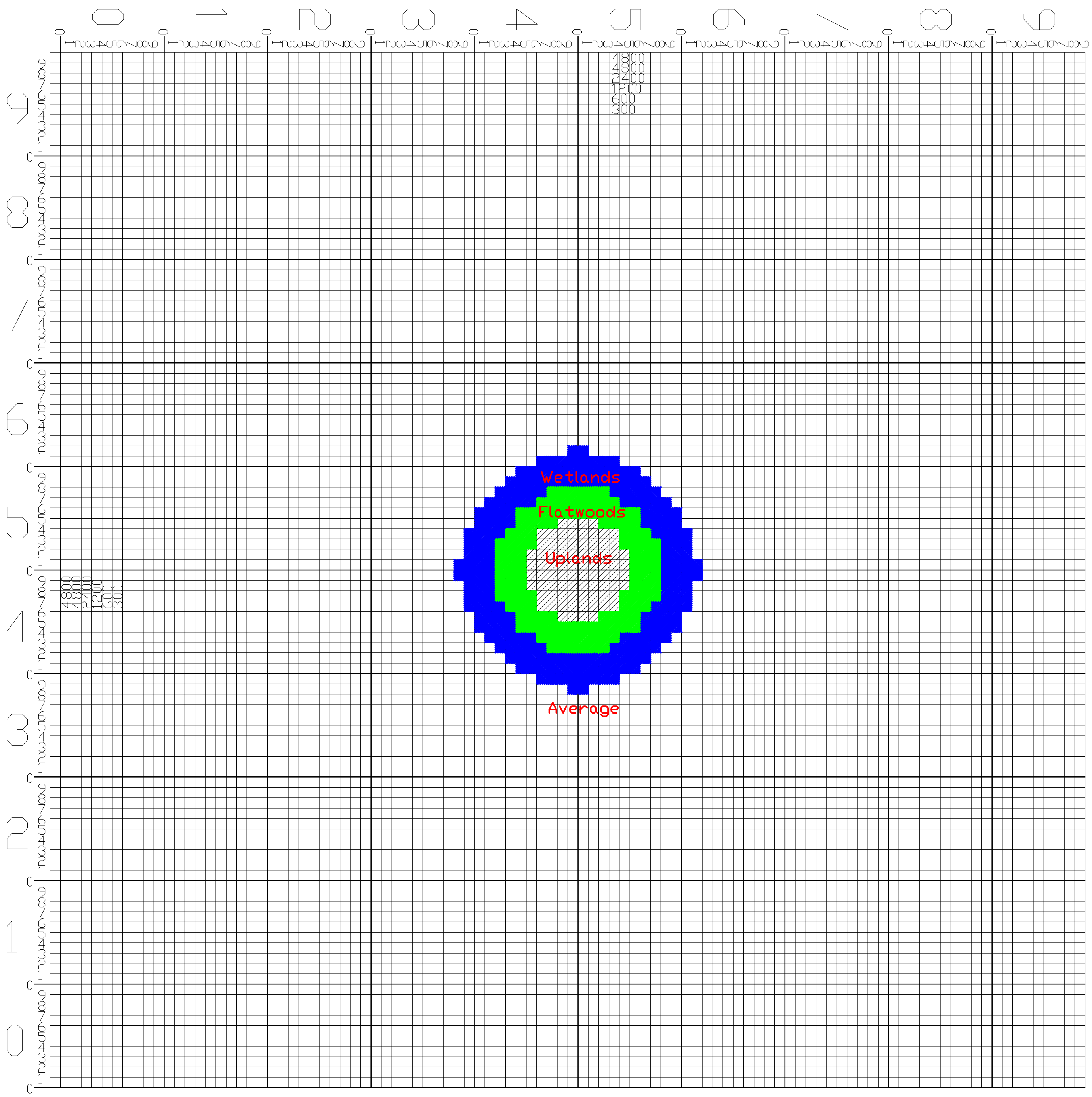
Layer 1 of the pre-development simulation represents an unconfined aquifer, the Surficial Aquifer System. In plan view, the center of Layer 1 consists of a circular area of model cells representing an upland area. It is surrounded in turn by concentric rings of model cells representing areas of flatwoods and wetlands, respectively. The remainder of the Layer 1 cells, between the simulated wetlands and the perimeter of the modeled area represent overall average conditions. Figure B1 is a cell map for Layer 1 of the pre-development simulation of a swamp-type mine.

A single hydraulic conductivity (a factor that describes how readily water flows through the ground) parameter was applied to all of the cells of Layer 1 of the pre-development simulation. It was calculated by averaging the larger of site-specific determinations reported in consultants hydrogeologic reports for sand mines in Lake County, summarized in Table B2.

A single parameter representing the bottom elevation of the Surficial Aquifer System was applied to all of the modeled area. It was calculated by averaging site-specific values reported in hydrogeological reports prepared by consultants for sand mines in Lake County, summarized in Table B2.

A single parameter representing the vertical leakance (a factor that describes how readily water leaks through a confining unit) between the Surficial and Floridan Aquifer Systems was applied to all of the modeled area. It was calculated by averaging results of several aquifer performance tests conducted in the Green Swamp area and one site-specific test conducted at Florida Rock Industries' Turnpike Sand Plant, summarized in Table B2. The measured leakance values clustered near the average value.

Layer 2 of the pre-development simulation represents a confined aquifer, the Floridan Aquifer System. A single transmissivity (a factor that describes water flow through a confined aquifer) factor was applied to all of Layer 2. It was calculated by averaging results of several aquifer performance tests conducted in the Green Swamp area and one site-specific test conducted at Florida Rock Industries' Turnpike Sand Plant, summarized in Table B2.



Not to Scale.

Independent Geological Services, Inc.

Reserves Evaluation
Environmental Permitting
Mine Planning and Impact Analysis
Geological and Hydrogeological Services

121 Market Street
Davenport, FL 33837

Phone: 863-419-1239
Fax: 863-419-4968

Prepared For:

E.R. Jahna Industries, Inc.

Date: July 20, 2001

Figure B1. Cell Map, Swamp-Type Mine Pre-Development

07/20/2001
Independent Geological Services, Inc.
Table B2. Site-Specific Hydrologic Data for Swamp-Type Setting

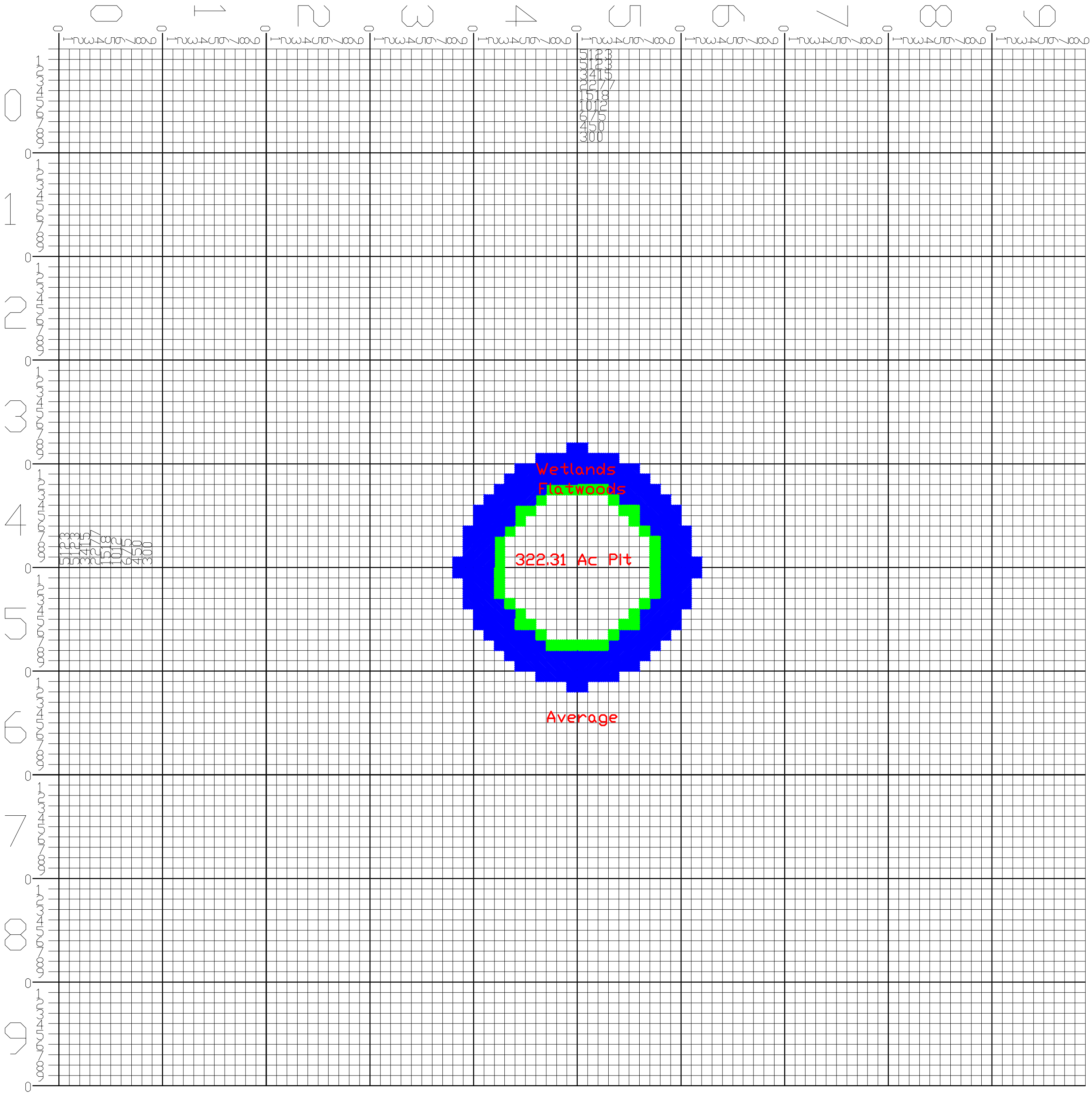
	Pre-Mining	Pre-Mining	Pond	Surficial Aquifer Characteristics				Hawthorn			Ocala Group		Floridan				
Mine	Runoff (in)	Rech. (in)	Potential	Sp. Yield	V.Cond.(ft/d)	H.Cond.(ft/d)	Avg.Sat.Thick.	Thick.	Elev. of Top	V.Cond.(ft/d)	Thick.	V.Cond.(ft/d)	Potential	H.Cond.(ft/d)	Trans.(sq.ft/d)	Leak.(1/d)	Storage
Site-Specific Hydro Reports:																	
474 Mine	6.6(e)	1.97(e)	115.5	15.6 - 32.7(e)	0.1-61.5(e)	2.8 - 12.2(e)	45.5	19	70				113.5				
Indep. North			114			13.6	59 - 44	20	70-55				108				
Astatula		1 - 5	66	14.6 - 32.7(e)	70.8 - 160(e)	18.6	26		40 (e)	0.025 - 0.26			64				
Lake Sand			115.5	5 - 10(e)		0.21 - 8.92	70.5	55	45								
Turnpike Sand			82				12	15	70				90 (e)		69380	0.004	0.00095
SWFWMD Floridan Aquifer Test Data:																	
S21,T23,R24															39169	0.0048	0.013
S21,T24,R24															13131	0.02	0.00025
S26,T25,R27															16042		0.011
S12,T26,R26															90903	0.0056	0.0018
SWFWMD Surficial Aquifer Test Data:																	
815-134-12				0.22		5.5	3										
810-144-2				0.22		7	3										
Parameters Selected for Swamp-Type Model						12			60						45000	0.005	

Only one model parameter was changed to adjust the pre-development simulation. The elevation of the constant-head boundary surrounding Layer 2 was empirically adjusted to make modeled Surficial Aquifer System potentials approximately 115 feet near the center of the modeled area.

Active operation of a generic swamp-type sand mine was simulated, too. The “active operation” model was prepared by modifying the pre-development model. Hydraulic conductivities and recharge rates of parts of Layer 1 were modified to simulate a roughly-circular 320-acre mine lake located at the center of the modeled area, shown in Figure B2. It was assumed that the mine lake replaced the entire thickness of the Surficial Aquifer System. Model cells representing the mine lake area were assigned a large hydraulic conductivity, to simulate open water, and recharge parameters that reflect zero runoff and Swancar, Lee, and O’Hare’s (2000) estimate of lake evaporation. In addition, water consumption from the Surficial Aquifer System and from the Floridan Aquifer System were simulated, based upon the averages of rates for swamp-type mines compiled in the section of this report entitled “Water Use and Consumption”. No other model parameters were changed. Please refer to Table B3.

Two post-mining models were prepared by modifying the pre-development model. Like the active operation model, parts of Layer 1 were modified to simulate roughly-circular mine lakes located at the centers of the modeled areas. In the first post-mining simulation, a mine pit replaced all of the uplands and most of the surrounding flatwoods fringe, simulating a 320-acre pit set back 300 feet from the wetlands that surrounded it on all sides. Please refer to Figure B2 and Table B3.

In the second post-mining simulation, a mine pit replaced all of the uplands and all of the surrounding flatwoods fringe, simulating a 415-acre mine pit with no setback from surrounding wetlands. No other pre-development model parameters were changed. Please refer to Figure B3 and Table B3.



Not to Scale.

Independent Geological Services, Inc.
Reserves Evaluation
Environmental Permitting
Mine Planning and Impact Analysis
Geological and Hydrogeological Services
121 Market Street
Davenport, FL 33837
Phone: 863-419-1239
Fax: 863-419-4968

Prepared For:

E.R. Jahna Industries, Inc.

Date: July 20, 2001

Figure B2. Cell Map, Swamp-Type Mine
Active Operation and Post-Development

07/20/2001
Independent Geological Services, Inc.
Table B3. Summary of Swamp-Type Model Parameters

Consumption from Pit (Product Moisture) = 0.03 MGD

Cell Type	Rain	E.T.	Total Runoff	Pit Withdrawal	Well Disch. Into Pit	Recharge ft/day)	Recharge (in/yr)	Well Withdrawal (cu.ft/day)	Pit Size(Ac)	
Uplands	0.01211	0.00890	0.00008	0.00000		0.00313	13.689			
Flatwoods	0.01211	0.00959	0.00176	0.00000		0.00076	3.335			
Wetlands	0.01211	0.01027	0.00176	0.00000		0.00008	0.335			
Average	0.01211	0.00979	0.00143	0.00000		0.00089	3.905			
Pit (Inactive)	0.01211	0.01195	0.00000	0.00000	0.00000	0.00016	0.695	0	322.31	
Pit (Active)	0.01211	0.01195	0.00000	0.00029	0.00105	0.00092	4.031	14705	322.31	(0.11 MGD)

Notes: Pit Withdrawal = Pit Consumption / Pit Area
Well Discharge into Pit = Discharge / Pit Area
For start-up, assume all of well water offsets seepage from SA (no pit augmentation).

Swamp-Type Mine Setting
Pre-Development

	Layer 1(Surficial Aquifer System)			Layer 2 (Floridan)	
Cell Type	Recharge ft/day)	HY (ft/day)	BOT (ft)	VCONT (1/day)	TRANS (sq.ft/day)
Uplands	0.00313	12	60	0.005	45000
Flatwoods	0.00076	12	60	0.005	45000
Wetlands	0.00008	12	60	0.005	45000
Average	0.00089	12	60	0.005	45000

Swamp-Type Mine Setting
Active Operation

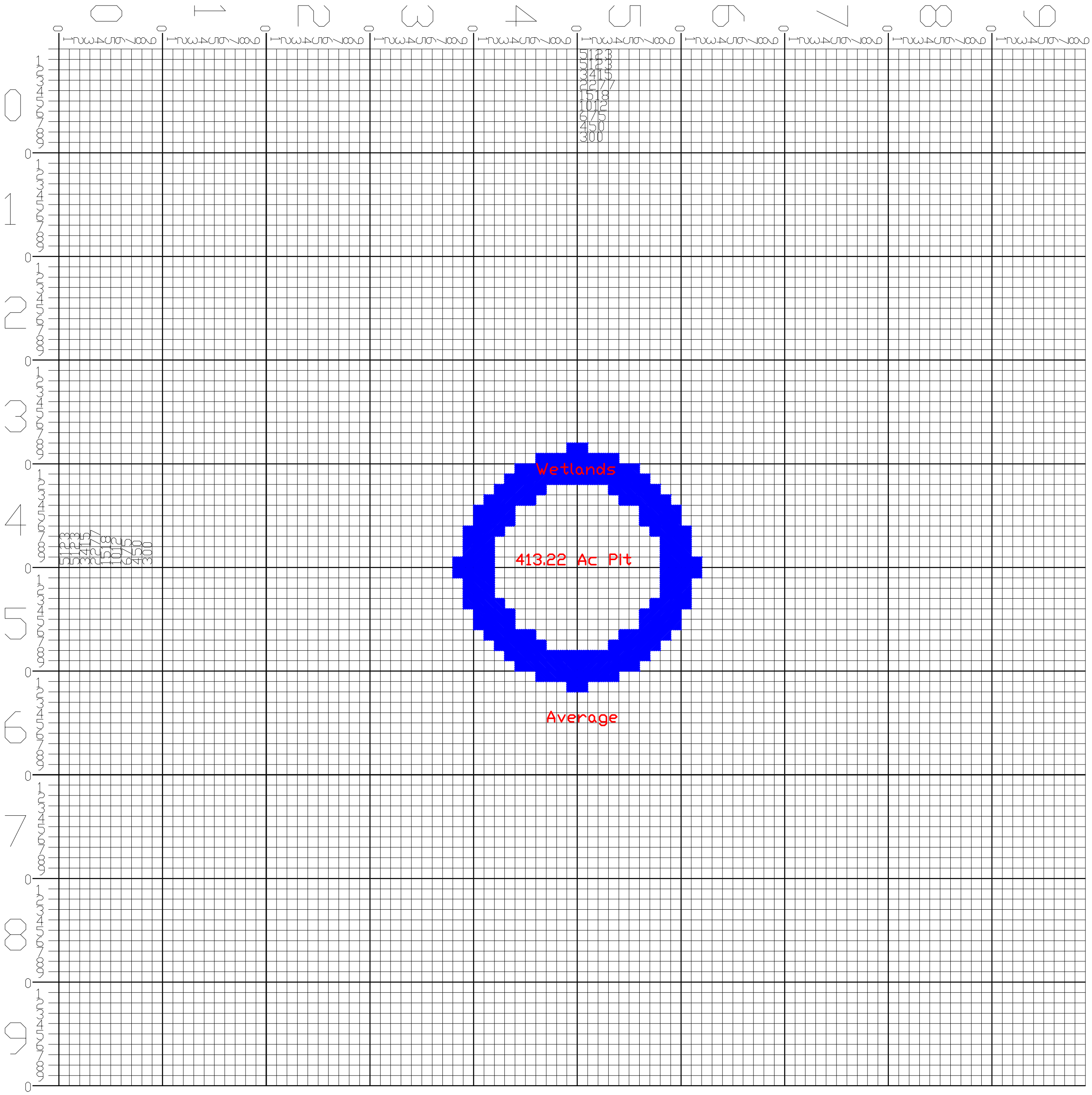
	Layer 1(Surficial Aquifer System)			Layer 2 (Floridan)	
Cell Type	Recharge ft/day)	HY (ft/day)	BOT (ft)	VCONT (1/day)	TRANS (sq.ft/day)
Uplands	0.00313	12	60	0.005	45000
Flatwoods	0.00076	12	60	0.005	45000
Wetlands	0.00008	12	60	0.005	45000
Average	0.00089	12	60	0.005	45000
Pit (Active)	0.00092	12000	60	0.005	45000

Well	Q (cu.ft/day)	
1	14705	(0.11 MGD)

Swamp-Type Mine Setting
Post-Development

	Layer 1(Surficial Aquifer System)			Layer 2 (Floridan)	
Cell Type	Recharge ft/day)	HY (ft/day)	BOT (ft)	VCONT (1/day)	TRANS (sq.ft/day)
Uplands	0.00313	12	60	0.005	45000
Flatwoods	0.00076	12	60	0.005	45000
Wetlands	0.00008	12	60	0.005	45000
Average	0.00089	12	60	0.005	45000
Pit (Inactive)	0.00016	12000	60	0.005	45000

Well	Q (cu.ft/day)
1	0



Not to Scale.

Independent Geological Services, Inc.

Reserves Evaluation
Environmental Permitting
Mine Planning and Impact Analysis
Geological and Hydrogeological Services

121 Market Street
Davenport, FL 33837

Phone: 863-419-1239
Fax: 863-419-4968

Prepared For:

E.R. Jahna Industries, Inc.

Date: July 20, 2001

Figure B3. Cell Map, Swamp-Type Mine
Post-Development, No Setback

Design and Parameter Selection for Ridge-Type Mine Simulations

The basic structure of the ridge-type mine simulations was the same as the swamp-type mine simulations that were discussed previously in this report. Each model was configured to use one layer to simulate the Surficial Aquifer System and one layer to simulate the Floridan Aquifer System. A model parameter associated with the first layer accounts for vertical flow through the Intermediate Confining Unit. To avoid shape-related effects, the areal geometry of the models was designed to be as simple and generic as possible. Complications related to regional flow gradients were avoided by assuming that the centers of each modeled area correspond with potentiometric highs of both simulated aquifer systems.

Cell numbers and dimensions were set identically to the previously discussed swamp-type simulations. The modeled area was a square, with sides measuring approximately 12 miles. Because lateral flow out of the modeled area through the perimeter of Layer 1, which simulates the Surficial Aquifer System, was insignificantly small in relation to vertical flow down into Layer 2, the perimeter of Layer 1 was set as a "no flow" boundary. The perimeter of Layer 2, which simulates the Floridan Aquifer System, was set as a "constant head" boundary to allow lateral flow out of the modeled area through the perimeter of Layer 2. To summarize, water enters the modeled area only through vertical recharge to Layer 1. As it flows laterally, in a radial pattern, toward the boundaries of Layer 1, it leaks downward into Layer 2. Then it flows laterally, in a radial pattern, through Layer 2, and exits the modeled area through the boundaries of Layer 2.

Layer 1 of the pre-development simulation represents an unconfined aquifer, the Surficial Aquifer System. All of the cells in Layer 1 represent uplands. The model recharge parameter was assigned a value based on long-term averages of precipitation, an evapotranspiration estimate, and an annualized stormwater runoff estimate. Precipitation was estimated from data collected at NOAA's Lisbon and Lake Alfred Stations. Stormwater runoff was estimated using the SCS TR-55 methods and annualized by summing events in a long-term average annual rainfall distribution. Please refer to Table B1 for the derivation of the upland model recharge parameter.

A single hydraulic conductivity (a factor that describes how readily water flows through the ground) parameter was applied to all of the cells of Layer 1 of the pre-development simulation. It was calculated by averaging the larger of site-specific determinations reported in consultants hydrogeologic reports for sand mines in Lake County, summarized in Table B4.

A single parameter representing the bottom elevation of the Surficial Aquifer System was applied to all of the modeled area. It was derived from published sources and site-specific values reported

07/20/2001
Independent Geological Services, Inc.
Table B4. Hydrologic Data for Ridge-Type Setting

Mine	Pre-Mining Runoff (in)	Pre-Mining Rech. (in)	Pond Potential	Surficial Aquifer Characteristics Sp. Yield	V.Cond.(ft/d)	H.Cond.(ft/d)	Avg.Sat.Thick.	Hawthorn Thick.	Elev. of Top	V.Cond.(ft/d)	Ocala Group Thick.	V.Cond.(ft/d)	Floridan Potential	H.Cond.(ft/d)	Trans.(sq.ft/d)	Leak.(1/d)	Storage
Site-Specific Hydro Reports:																	
Center Sand			98(aug),85				23(aug), 10	15	70								
SWFWMD Floridan Aquifer Test Data:																	
S12,T26,R26															90903	0.0056	0.0018
SJRWMD Floridan Aquifer Test Data:																	
LK-5															19584	0.0022	
LK-6															42708	0.0033	
Regional Model Data (in vicinity of the ridge-type sand mines):																	
O'Reilly (98)															500000	0.0003	
Murray & Halford (96)															300000	0.0006	
SJRWMD															456700	0.00009	
Parameters Selected for Ridge-Type Model:						12			70						51000	0.0005	

in hydrogeological reports prepared by consultants for sand mines in Lake County, summarized in Table B4.

A single parameter representing the vertical leakance (a factor that describes how readily water leaks through a confining unit) between the Surficial and Floridan Aquifer Systems was applied to all of the modeled area. Since no site-specific data were available, it was selected by averaging parameters used in calibrated regional models including those of O'Reilly (98), Murray and Halford (96), and SJRWMD, and empirically adjusted to simulate a head difference of about 5 feet between the aquifers. Please refer to Table B4.

Layer 2 of the pre-development simulation represents a confined aquifer, the Floridan Aquifer System. A single transmissivity (a factor that describes water flow through a confined aquifer) factor was applied to all of Layer 2. It was calculated by averaging parameters from calibrated regional models, summarized in Table B4, including those of O'Reilly (98), Murray and Halford (96), and SJRWMD.

In addition to the vertical leakance factor, discussed above, one other model parameter was changed to adjust the pre-development simulation. The elevation of the constant-head boundary surrounding Layer 2 was empirically adjusted to make modeled Surficial Aquifer System potentials approximately 85 feet near the center of the modeled area.

Active operation of a generic ridge-type sand mine was simulated with a model prepared by modifying the pre-development model. Hydraulic conductivities and recharge rates of parts of Layer 1 were modified to simulate a roughly-circular 320-acre mine lake located at the center of the modeled area, as shown in Figure B4. It was assumed that the mine lake replaced the entire thickness of the Surficial Aquifer System. Model cells representing the mine lake area were assigned a large hydraulic conductivity, to simulate open water, and recharge parameters that reflect zero runoff and Swancar, Lee, and O'Hare's (2000) estimate of lake evaporation. In addition, water consumption from the Surficial Aquifer System and from the Floridan Aquifer System were simulated, based upon the averages of rates for 2 of the 3 ridge-type mines compiled in the section of this report entitled "Water Use and Consumption". No other model parameters were changed. Please refer to Table B5.

A post-mining model was prepared by modifying the pre-development model. Parts of Layer 1 were modified to simulate a roughly-circular 320-acre mine lake located at the center of the modeled area, the same as the active operation model. No other pre-development model parameters were changed. Please refer to Figure B4 and Table B5.

Table B5. Summary of Ridge-Type Model Parameters

Consumption from Pit (Product Moisture) = 0.03 MGD

Cell Type	Rain	E.T.	Runoff	Pit Withdrawal	Well Disch. Into Pit	Recharge ft/day)	Recharge (in/yr)	Well Withdrawal (cu.ft/day)	Pit Size(Ac)	
Uplands	0.01211	0.00890	0.00008	0.00000		0.00313	13.689			
Pit (Inactive)	0.01211	0.01195	0.00000	0.00000	0.00000	0.00016	0.695	0	322.31	
Pit (Active)	0.01211	0.01195	0.00000	0.00029	0.00590	0.00578	25.301	82882	322.31	(0.62 MGD)

Notes: Pit Withdrawal = Pit Consumption / Pit Area
Well Discharge into Pit = Discharge / Pit Area
For start-up, assume all of well water offsets seepage from SA (no pit augmentation).

Ridge-Type Mine Setting
Pre-Development

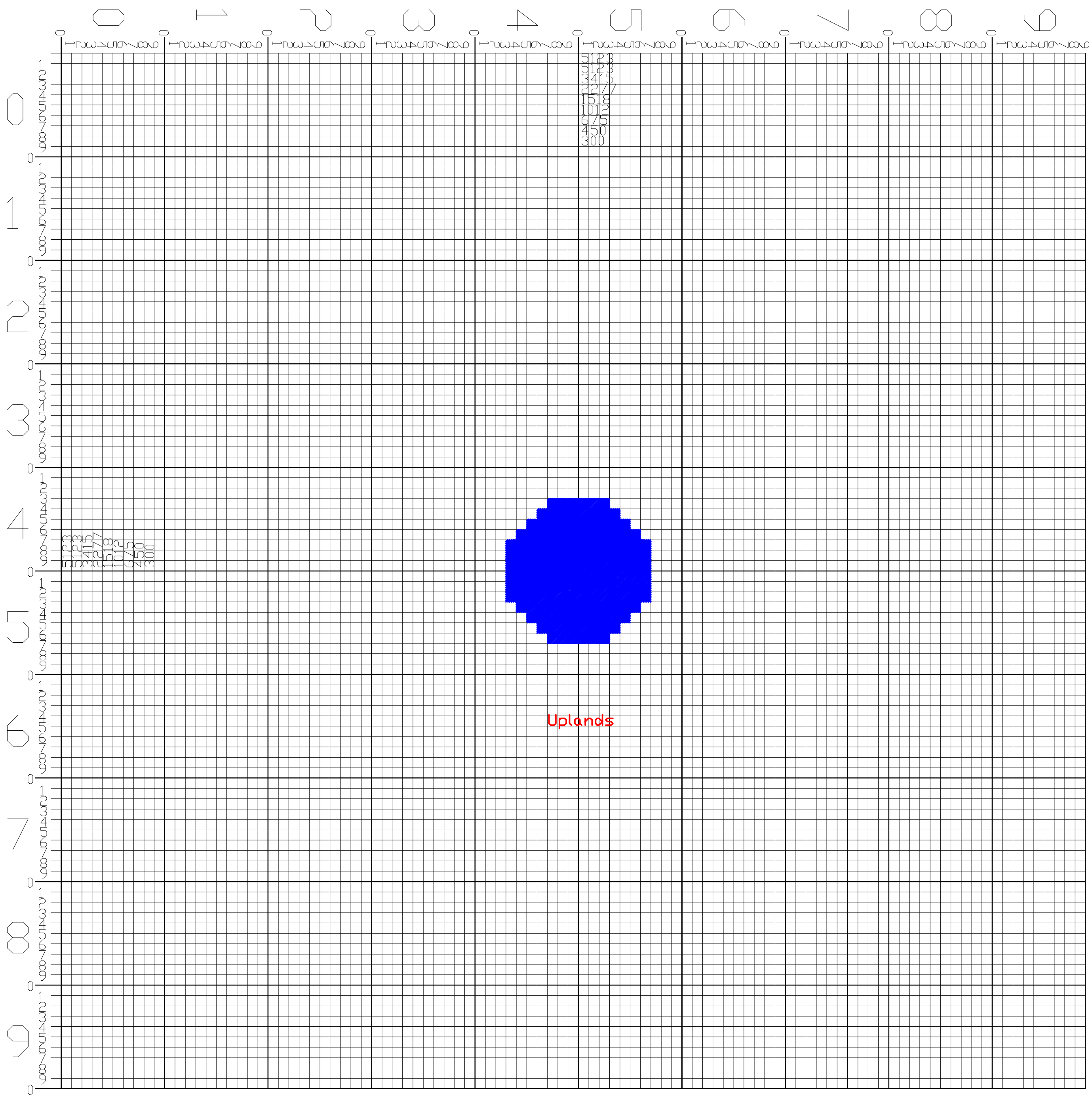
	Layer 1(Surficial Aquifer System)			Layer 2 (Floridan)	
Cell Type	Recharge ft/day)	HY (ft/day)	BOT (ft)	VCONT (1/day)	TRANS (sq.ft/day)
Uplands	0.00313	12	70	0.0005	51000

Ridge-Type Mine Setting
Active Operation

	Layer 1(Surficial Aquifer System)			Layer 2 (Floridan)				
Cell Type	Recharge ft/day)	HY (ft/day)	BOT (ft)	VCONT (1/day)	TRANS (sq.ft/day)	Well	Q (cu.ft/day)	
Uplands	0.00313	12	70	0.0005	51000	1	82882	(0.62 MGD)
Pit (Active)	0.00578	12000	70	0.0005	51000			

Ridge-Type Mine Setting
Post-Development

	Layer 1(Surficial Aquifer System)			Layer 2 (Floridan)			
Cell Type	Recharge ft/day)	HY (ft/day)	BOT (ft)	VCONT (1/day)	TRANS (sq.ft/day)	Well	Q (cu.ft/day)
Uplands	0.00313	12	70	0.0005	51000	1	0
Pit (Inactive)	0.00016	12000	70	0.0005	51000		



Not to Scale.

Independent Geological Services, Inc.

Reserves Evaluation
Environmental Permitting
Mine Planning and Impact Analysis
Geological and Hydrogeological Services

121 Market Street
Davenport, FL 33837

Phone: 863-419-1239
Fax: 863-419-4968

Prepared For:

E.R. Jahna Industries, Inc.

Date: July 20, 2001

Figure B4. Cell Map, Ridge-Type
Active Operation and Post-Development