FROM HEAVY MINERALS MINING TO A WET DREDGE MINING OPERATION: A SUCCESFUL STORY IN BRAZIL

W. Herchenhorn[1] , H. van Muijen[2] , R. Ouwerkerk[3], M. Boor[4], C.J. Verkaik[5] and J.W. de Wit[6]

ABSTRACT

For a number of years Millennium Minerals in the Paraiba State of Brazil operated a dry mining - multi face “Heavy Minerals” mining operation successfully. The focus was on selective mining high grade areas of the deposit at relative low capacities. Depletion of these high grade parts, forced to other ways of feasible operation in the lower grade areas. After ample feasibility studies Millennium agreed to the concept that bulk mining by dredging is the most economic method. This method is applied elsewhere in the world. It was new for Brazil and this company to arrange for an artificial lake and floating processing plant.

Millennium selected after ample engineering studies an IHC wheel dredge. That type of mining equipment is not standard, but developed as a part of a floating process plant approach. In 2002 the IHC dredge was supplied with an initial capacity of 1500 t/hr. At this moment the dredge is producing 1650 t/hr with an operational efficiency of 92%. This paper will describe the operational particulars when changing from a dry to a wet mining operation and how equipment selection was effected. It will furthermore detail on this successful wet mining operation, evaluating typical operational aspects.

Keywords: Ilmenite, dune deposits, sand mining, wheel dredge, electric dredge

INTRODUCTION

Many “Heavy Minerals” deposits, consisting of minerals such as Rutile, Ilmenite, Zircon and Monazite are of placer origin, and are often found in either beach or in dune deposits.
Such deposits are located at the sea side at different locations in the world, including the Mozambique Coastline, north of Durban – South Africa, Madagascar, different sites near Perth and on the other side of Australia in Stratbrooke Island as well as in their Murray Basin, on the coast of the Indian states Kerala, Orissa and Tamul Nadu, Sierra Leone etc. In these areas mining is already done by dredging.

This paper describes a similar development in the Guaju mine near the city of Mataraca on the northern coast of the State of Paraiba. Near the utmost eastern point of Brasil, this mine operated by Millennium Inorganic Chemicals, a subsidiary of Lyondell Company, converted its mine from a shovel, truck and conveyor belt system operation successfully into a dredge operation.

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[1] Area Manager, IHC of Brasil, Av. Rio Branco 156-Salas 2206/7/8, 20040-004 Rio de Janeireo, R.J., Brasil, T: (00-55-21) 2262-1639, F: (00-55-21) 2220-8437, Email: ihcwh@terra.com.br
[2] General Manager, MTI Holland BV, Smitweg 6, 2961 AW Kinderdijk, The Netherlands,
T: (0031)-78-6910322, F: (0031)-78-6910331, Email: info@mtiholland.com
[3] Area Manager, IHC Holland Merwede BV, Molendijk 94, 3361 EP Sliedrecht, The Netherlands,
T: (0031)-184-411555, F: (0031)-184-411884, Email: info@ihcholland.com
[4] Manager Design Department, IHC Beavers, Molendijk 94, 3361 EP Sliedrecht, The Netherlands,
T: (0031)-184-411555, F: (0031)-184-411884, Email: info@ihcholland.com
[5] Manager Engineering, IHC Dredgers, Molendijk 94, 3361 EP Sliedrecht, The Netherlands,
T: (0031)-184-411555, F: (0031)-184-411884, Email: info@ihcholland.com
[6] Area Manager Mining, IHC Holland Merwede BV, Molendijk 94, 3361 EP Sliedrecht, The Netherlands,
T: (0031)-184-411555, F: (0031)-184-411884, Email: info@ihcholland.com

Figure 1. Map of Brazil with indicated mine location.

STUDY TO EXTEND LIFE

Millennium Inorganic Chemicals started the Guaju mine in 1983 as a dry mining operation. During 17 years the richer sections in the coastal dune type of ore body were mined with vibrating chutes buried in the dunes, fed by tractors that pushed the sand towards the vibrating chutes, forming fan-shaped trajectories. These chutes fed movable feeding conveyors that in turn fed fixed feeding conveyors, conducting the dry sand mining to the processing unit, called the "ilmenite wet process". This dry mining operation was performed at an average rate was 700 tons per hour. The dry mine approach with a dry separation and ore purification method resulted in a cost per ton that had the owners conclude that the mine was nearing the end of its economic life near the start of the new Millennium end of 1999.

Figure 2. Aerial picture of the dry mining operation showing the funnel shaped trajectory and conveying system to the process plant.

However, geological surveys had determined that the mine site still held a substantial amount of lower grade blocks.
Millennium Inorganic Chemicals focused on growing its world wide operating companies through value creation and technology based advancements. As second largest producer of titanium dioxide, the company uses its mineral concentrate production primarily as feed stock for its own white pigment production and the possibility of economically mining these lower grade blocks became the subject of different studies.

It was concluded that to continue to operate the mine at Guaju site, it was required to economically and safely produce 120,000 tons of quality ilmenite concentrate per year. If that target was met then they could extend the life of the mining pit with 17 years.

Two options were investigated and engineering company Mineral Deposits issued a specification for dredges of 800 and 1500 tph respectively. The 800 ton per hour capacity was slightly more that the dry method used and a 1500 ton per hour nearly doubled existing dry mine production. Based on economic considerations, Millennium Inorganic Chemicals was forced to select the larger capacity of 1500 tph.

Figure 3. Aerial picture of the mine with dry mining/rehabilitation site at left site and start of dredge mining operation at right.

MINE PLANNING

From that comparative study the conclusion was drawn that dredging followed by wet primary separation was the method to be selected and economically justified investing additional money onto the lower grade ore blocks.
A similar conclusion had been drawn in other areas of ore material handling earlier: for moving large ore volumes dredging with pipeline transport is one of the most economic, if not the most economic means of bulk transportation (van Muijen & Ouwerkerk).
The change from a multiple unit - low capacity dry mining operation to a single unit - high capacity dredge mining operation required a complete change of operational mindset.

A mining plan with a much longer vision than the dry mining method had to be developed as well as the separation methodology and equipment to be adapted. In the dry mining operation the geologists can inspect the mine face which gives them the opportunity to control mine grades on a daily basis and adapt mine planning accordingly. As a multiple unit operation with low capacity change of plans do not effect overall mine planning too much. In general this allows a very flexible operation.

The wet dredge mining operation on the other hand requires longer preparation and planning in advance. The one unit – high capacity operation does not allow a flexible planning. In stead of a daily adaptation a planning period of a number of months is required. The dredger and connected floating wet concentration plant require a pre-specified dredge path and it is not possible to change course at will.
Furthermore the geologists can not check the mine face as dredge mining is performed under water. A proper exploration planning advances the actual mining and determines the path to be taken.

THE LAKE

Dredge mining in the dunes requires the creation of an artificial lake. Creating a lake in beach sand sounds like carrying water to the sea and partially it is.
The lakes are often at only a few hundred meters from the sea but their water level can be substantially above sea level. In this case such an artificial lake can loose lots of the water pumped into the lake.
Although ground water levels are lower, permeability figures can restrict drainage. This is typical for a number of these sand dunes deposits with heavy minerals deposited together with sand matrix material in the 0.05 – 1 mm size range.
It will be clear that ground water levels, permeability and the specific geological characteristics need a thorough study to establish the possibility of a lake suitable for dredge mining.

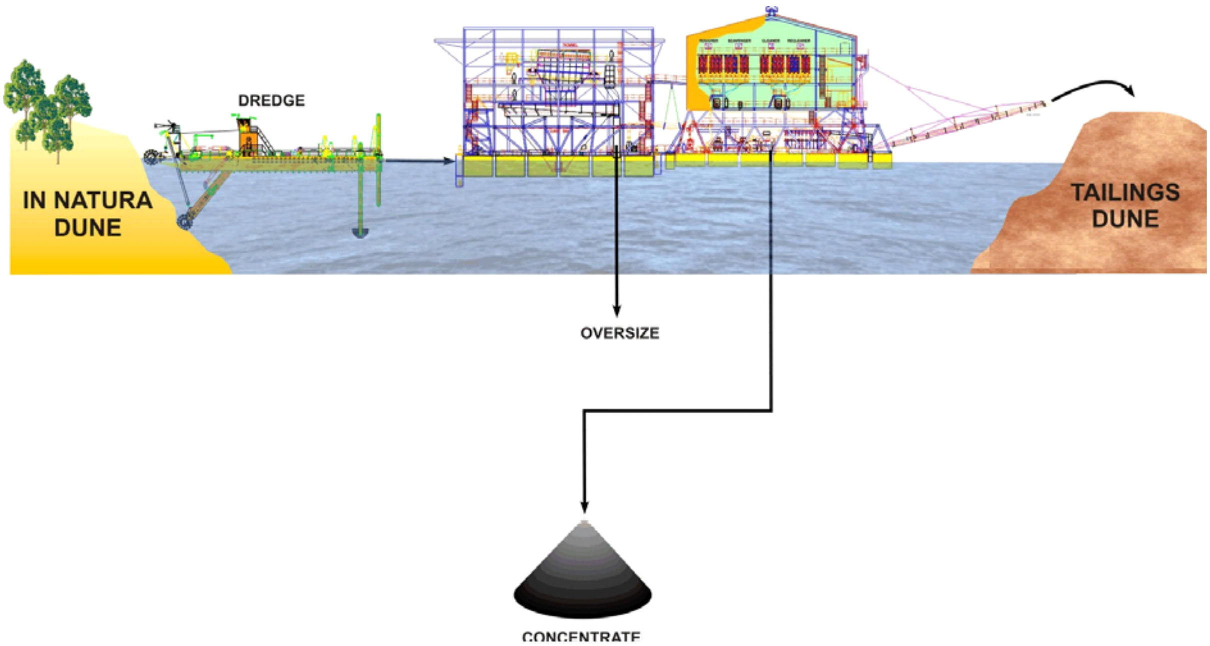

Figure 4. Schematic overview of a typical heavy minerals dredge mining operation.

The suitability is not only focusing on the possibility of maintaining the water level in an economic way, also slime studies have to be performed. The small particles that tend to seal the bottom surface of the pond and reduce the loss of water, can also be so abundant that they remain in suspension. Slimes differ significantly from turbidity, as turbidity trails will eventually settle as the oxygen eventually separates from the particles. The much smaller particles forming slimes can remain suspended for years. They have shown to be able to take percentages of the water volume, not only quickly reducing the cooling characteristics of water, but especially making the water not suitable for washing -animportant element in the separation technology.

This is not a theoretical fear – one of the largest heavy mineral mines in the world in Australia was abandoned in the mid-nineties because of the very high content of slimes generated in this mining process.
Millennium Inorganic Chemicals determined that 1100 m^3/hr (4800 gpm) water had to be brought in to maintain the lake. A pump station was generated near a close by river. Electric power provisions had to be provided, not only for the pump station, but also for the mining plant itself.

FEEDING THE SEPARATION PLANT

Millennium requested Mineral Deposits of Australia, a leading designer and supplier of separation plants to execute a feasibility study for the wet mining. The separation process, using a multitude of spiral concentrators, functions best with a continuous feeding capacity and quality.
A suction dredger does not produce a continuous flow, due to its way of operating. The dredge swings around its spud and at the end of the swing segment the dredge slows down , stops and then swings back. At that turning moment the production drops sharply. At larger intervals the dredge also needs to use its step-spud to move forward, sometimes combined with the need to re-set the swing anchors. Than the production drops to virtually nil.

As a buffer between the dredge's fluctuating delivery and the plant's demand for a continuous feed, a surge bin is placed at the front end of the separation plant, allowing the fluctuating dredge production to be evened out to a more continuous feed for the plant. Sizing of all elements is an intricate engineering effort and this balancing act is identified as the "game of capacities".

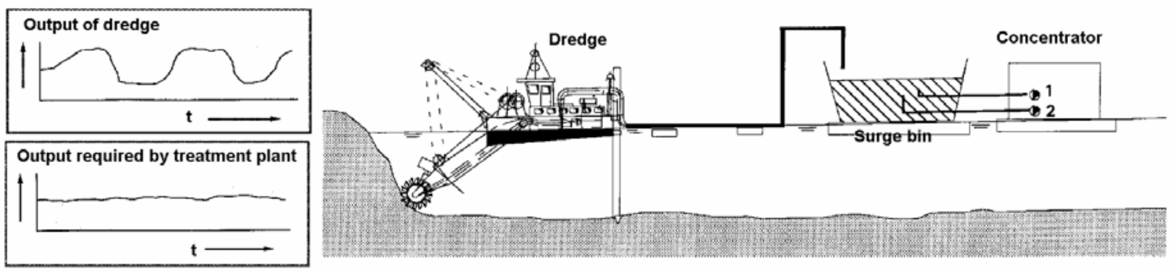

Figure 5. Dredge mining operation with surge bin to control the “game of capacities”.

Anchoring method and level of automation are of importance in this respect, but most important are material characteristics. Especially as beach sand matrix material deposited together with compact and hard clay basement material: sand with clay of 2-8%. In addition dunes with a 33% angle face could be encountered.
The harder materials evaluation required a special study of the cutting power. While the process of swinging action and spud stepping would take time that should be compensated by the surge bin, the use of the surge bin to compensate for reduced cutting performance, due to cutting limitations of the cutting tool in hard material, should be prevented.

The slimes effect as described above, can also impact the cutting process and a water monitor gun is included in many a mining dredge to break the built up resistance of the face, which goes together with the clayey character.
The dunes provide another challenge: the dredge cuts the deposit under water and the dune face will eventually be undercut creating an “avalanche” of dune face top down towards the dredge cut. Such a collapsing face rolling into a relatively shallow lake has the potential to burry the cutting tool and ladder. If the ladder of the dredge, and so the complete dredge, gets trapped into the face collapse, it had been experienced at other sites that the small “tsunami” created by the landslide, could seriously damage the dredge. Those experiences have lead to the decision to incorporate into the design of such dredges a feature to withdraw the dredge quickly from the cut, in case of a collapsing face.

For dredge mining nowadays hydraulic dredges with either a cutter or dredge wheel have to be the preferred cutting tool. A mechanical dredge such as the bucket chain ladder dredge is still for many miners a preferred mining tool as it may clean a mining site properly till bedrock. However a mechanical dredge only lifts the material to the surface and than an extra method of transportation is required.

A hydraulic dredge can transport the water-ore mixture directly into the plant. While in harder deposits an electrically driven cutter may be preferred, in the mining, and especially in the heavy minerals mining, the dredging wheel has become a preferred cutting tool.

The wheel in combination with a well selected dredge pump has proven to be able to provide a higher density, but also a better controllable flow. To have the surge bin properly served, the control of the dredge production has proven to be a major criteria.

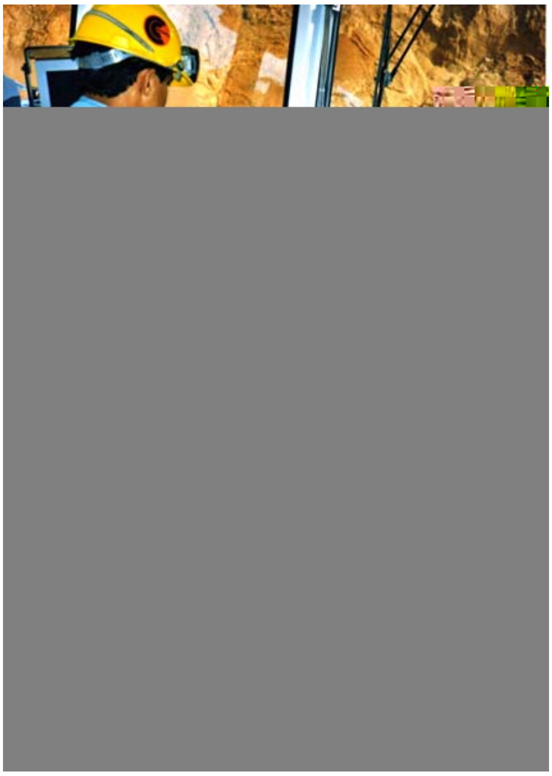

Figure 6. Dune deposit in front of dredge and view from control cabin.

Further the collapsing faces created by undercutting can roll past the cutter of the dredge. That material often includes a relatively high grade of minerals, and it is worth to be mined. In most mining plans clean-up sweeps are included. The dredge steps back out of the cut and re-do's the already mined area with a faster swinging pattern retrieving the loosely deposited spill.

Based on data collected it has been shown that the wheel renders a higher clean up production than the cutter. A wheeldredge has become an acceptable alternative for the bucket chain ladder dredge.

The wheel is been developed by IHC for both downward and upward cutting direction. Testing in an R&D type environment taught that neither direction could be preferred over the other, both directions had their application and there were a number of factors, not one a dominant one, that determine which rotation direction should be preferred.

MILLENNIUM's DREDGE SPECIFICATION

Millennium had done a thorough study on its side, and was supported by many data from its dry mining operation. The production requirements were determined through an extensive feasibility study and although the dredge was tendered in a competitive environment, these specifications were opened for discussion after the submittal of the bids and evaluated with the bidders based on technical considerations.

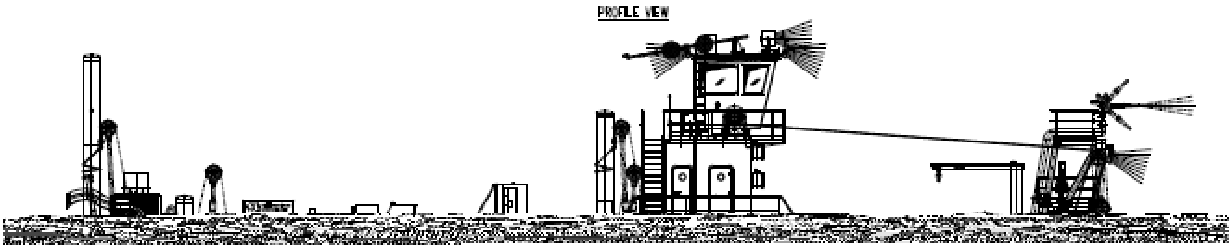

Figure 7. Profile view of the Millennium wheel dredger.

Based on the harder material evaluating with 2-8 % clay, the wheel power was adjusted in mutual cooperation, as well as the maximum dredge depth to be prepared for possible level variations.
While the nominal capacity was defined to be 1500 tons per hour, the maximum capacity had to be rated at 2100 tons per hour, a selection that became subject of lengthy discussions. In any case the dredge should be able to produce 11 million tons per year.
Collapsing faces in dunes had proven to be a catastrophe for other dredge mining operations and escape spuds in dune areas are a commonly accepted feature. However the dunes in the Guaja mine are not as high as in mines elsewhere in the world and the stroke of the escape spud was limited. Further, the dredge includes automation for the dredge process, but not as extensive as dredge in other advanced heavy minerals applications, as Millennium was set to have its operators contribute consciously to the production.

THE DREDGE.

The dredge is electrically powered with an independent power line supplied however via the material separation plant, rated at 1500 kVA. The dredge, measuring 41 m long, 7.90 wide and 2.44 m deep was delivered demountable for transportation purposes. Recesses were made for the ladder and the step spud carrier.

The dredge was developed with a ladder pump. Although the dredging depth did not limit the vacuum and for that reason an inboard pump could have been selected, the safety issue and the experience that submerged dredge pump and wheel

combined allow one of the best controls available on the production. The wheel, with a down turning cutting action has a diameter of 2.70 meter and is hydraulically driven by 150 kW drive, while the dredge pump is a single walled IHC high efficiency pump with an impeller diameter of 810 mm with a 500 kW electric drive, connected to a 450 mm suction and discharge line. On the ladder gantry a monitor gun is positioned to facilitate the cutting process. The dredge is equipped with the full scope of instrumentation, automated and fitted with a SCADA system.
The Human Machine Interface allows the operator to monitor the full process. The main process page shows all main process parameters. The level of the surge-bin and the production and other main parameters are shown in one page. The control desk allows the control via levers and pushbuttons. If a control problem occurs, the system is self diagnostic and analysis which condition is interfering with proper operation, using diagnostic and trending pages.
Each part of the dredge system, has its own process page, such as wheel, pump, ladder and spud carrier. Calibration of the measurements is performed by the system.

Figure 8. Millennium wheel dredger in the dredge pond at the mining site.

The surge bin is connected to the dredge control system. If the production exceeds the surge bin's need the production of the dredge is reduced.
The dredge was built in IHC's Beaver Dredges plant in Holland launched and submitted to a battery of tests powered by a generator pontoon. After the dredge was raised from the water, demounted and shipped with a Brazilian flag vessel.

THE INTEGRATION OF THE DREDGE OPERATION

The dredge was delivered in 2002. Previous to shipping it was submitted to an extensive dock test near IHC's yard.
The dredge was delivered ready to go at site.
It was transported in dismounted condition and re-assembled in a provisional dry-dock, prepared before the lake was flooded. The floor of the provisional dock was prepared at about 1 m below water level. After re-assembling, the dam protecting the dock was removed and the dock flooded , the dredge, after completion of the plant it was hooked up and

powered by which had just enough keel clearance to be towed out to the plant.

Although a stand-alone performance test was prescribed in the contract, the need to have the dredge break into the cut of the dune face and the endurance time of the test was understood – after the lakes was finished – to create such a displacement of material that the new lake would be substantially altered. It was decided to activate the dredge with the plant together.

Before starting the plant, Millennium organized thorough training courses for their personnel, in which the theory of dredge mining, the dredge design and maintenance procedures were relayed in both classroom as well as hands-on.

Figure 9. Wheel dredger in pond connected to the floating primary concentration plant.

The approach paid of. The dredge was quickly on line and operated well. During the start-up, hick-ups were encountered, but resolved with a systematic approach. IHC develops many components specifically for dredge applications. On imports to Brasil a high amount of duties, taxes etc. is levied. Therefore Millennium instructed that Brazilian availability of components had to be taken into consideration. Leaving the IHC products caused some start-up problems deducted but was dealt with by adapting the products for the purpose intended, such as the electric motor.

AN EXAMPLE OF SOCIAL COMMITMENT

The management of the 1260 hectare Guaju mine by Millennium, not only involves the mine operation, but also in all aspects of life around the mine. In this remote area the company is also involved in the community and education. The mine soon became an example, not only because of pursuing excellence in the operational area and safety performance and prevention programs, but also because of its involvement in the local social life and environment. An example thereof was the name giving of the dredge, which was done by popular vote among the personnel, resulting in the name APOENA (The mine itself is by the way ISO 9001-2000 and ISO 14001.2004 certified.)

The Paraiba site earned national recognition for its environmental program and natural forest rehabilitating.

From the consideration that dunes form the natural coastal defense line against the ocean, it is accepted as a must that in a mining site eventually the original dune land shape is restored in one way or another. At virtually every heavy minerals mine in the world one or other form of restoration is enforced. However Millennium's effort goes far beyond the minimum requirements and submitted itself to professional supervision of universities.

Although the vegetation in the sandy dunes is not a very heavy and dense, those plants shrubberies and trees are removed before the ore bearing sands are mined. Millennium cultivates in a nursery thousands of native plants, which are re-planted during the restoration activities in specific patterns, also creating living walls for more delicate plants, which are planted later in the protected environment. Not only plants, also the animals that live in the dunes, are captured, haled and cared for and re-introduced after completion of the restoration, in order to re-populate the area with the original habitat.

Figure 10. On site training practice.

CONCLUSION

Millennium worked up the plant and continued to improve. Today the dredge with plant is up to 1650 tph's well above the 1500 tph's design target. The extra production allows Millennium not only to provide all supplies for their own feed stock but also leave room for export. The conscious choice, well developed plan and dedicated fine tuning resulted indeed to what confident was announced in the first page of the engineering document. "This job will be completed with a handshake and a big Brazilian smile."

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www.lyondell.com; www.millenniumchem.com

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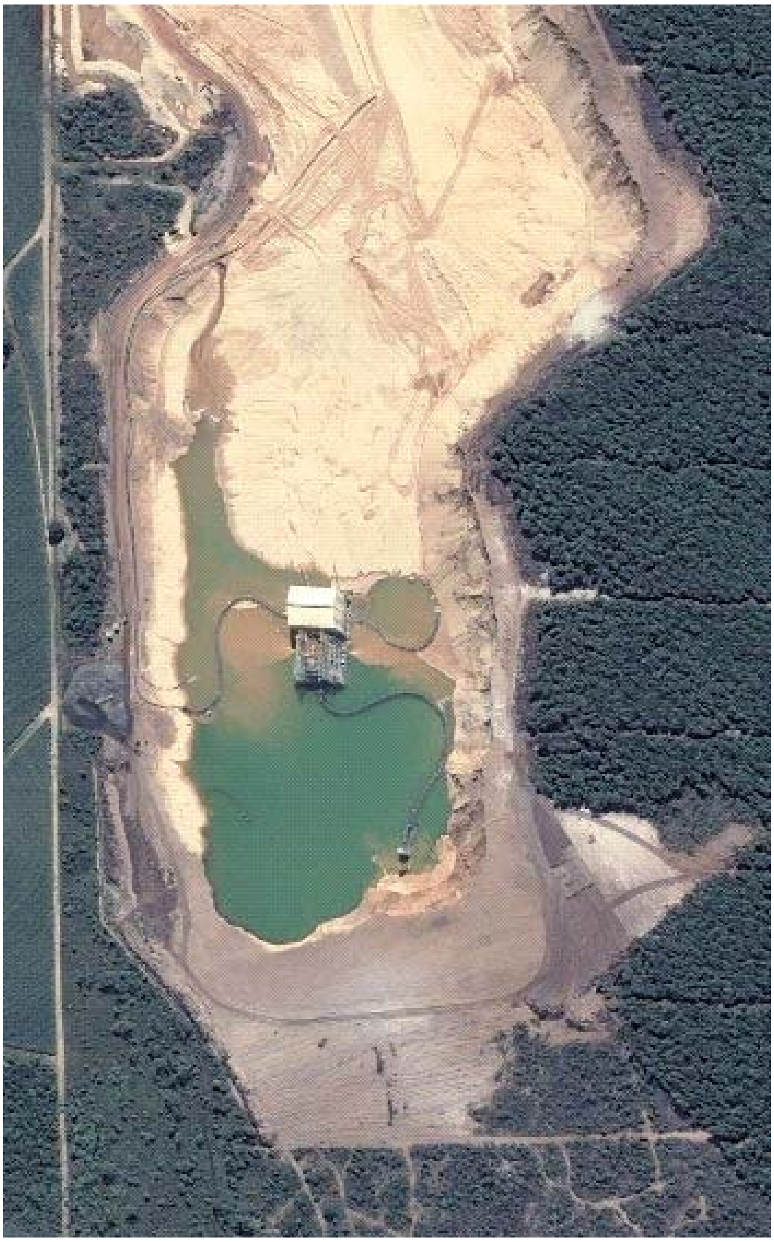

Figure 11. Aerial picture of the dredge mining operation.