Transaction Paper

A perspective of marine mining within De Beers

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Synopsis

Although the De Beers group has a long history of placer mining on land, the group only became actively involved in deep water marine diamond exploration and mining in 1983 with the formation of De Beers Marine. Full-scale commercial mining commenced around 1991. Since then, the group marine mining capability has grown into a formidable fleet of 8 large deep water (>70 m) mining vessels, as well as other special purpose geosurvey platforms. Marine diamond production by the group is expected to be just short of 1 million carats in 2006. De Beers operates across the entire value-chain spectrum from geology and geosurvey, through sampling to mining, and finally ore processing into high value concentrate. Supporting these operations involves significant service activities such as maintenance, security, logistics and environmental management. Specific challenges exist in terms of developing or acquiring appropriate technology for marine mining. These challenges have resulted in De Beers operating extensive in-house R&D and projects departments, as well as drawing extensively from technology partners. An array of computational and test facilities is also available to support R&D and projects activities. Hydrotransport in various guises is key to the current approaches to marine mining and ore processing. Use is made of airlift and centrifugal pumping for hydraulic hoisting of very coarse gravel, while splitters, launders, dewatering, elutriators, jet pumps, centrifugal pumps, dense medium circuits, pipeline systems, and instrumentation for coarse abrasive particles are used extensively in the ore processing plant.

History of Marine Diamond Corporation and De Beers Marine

Diamonds were first discovered along the west coast of Africa in 1908 near Luderitz, and by 1927, extensive deposits had been found in raised beaches both north and south of the Orange River. Production from onshore deposits increased and by the 1950s was in excess of 2 million carats per year along the whole stretch of coastline.

As a consequence, claims were registered along approximately 900 kilometres of the west coasts of South Africa and Namibia (then South West Africa), and several expeditions were mounted from Cape Town to search for diamonds along the coast and on the offshore islands. However, other than occasional rumours, there are no records of diamonds being recovered from the sea until 1961.

The honour of recovering the first official diamonds from the sea goes to Texan oilman and entrepreneur, Mr. Sam Collins, whose Marine Diamond Corporation (MDC) recovered their first diamonds on 15 November 1961, netting a total of 45 stones with a combined weight of 9 carats (ct = 0.2 g) from Wolf Bay near Luderitz.

While tendering for an oil-pipeline installation contract for the Consolidated Diamond Mines (CDM), Sam Collins's interest was sparked by the presence of the shore-based operations. His acquisition of a company, Suidwes Afrika Prospekteerders, gave MDC rights to a large concession stretching from the Orange River to Diaz Point at Luderitz.

Sampling operations continued across the large concessions, and by the end of March 1962, a further 44 diamonds weighing 12 carats had been recovered.

Sam Collins, an archetypal Texan entrepreneur, wasted no time in developing a bankable reserve, and by May 1962, oil pipe-laying *Barge 77* had been converted into a diamond mining platform, and produced 12 700 carats by December 1962.

However, during a storm event in June 1963, *Barge 77* broke her mooring and was driven ashore north of Chameis Bay without loss of life. A tank landing craft vessel was quickly converted into the diamond recovery vessel *Diamantku*s, and a new barge, *Barge 111* was constructed as a replacement for *Barge* 77.

In 1965, a further new barge, *Colpontoon* was built, and production peaked at 241 000 carats. MDC was also awarded further deep-water concessions in 1963, which extended approximately to the edge of the continental shelf.

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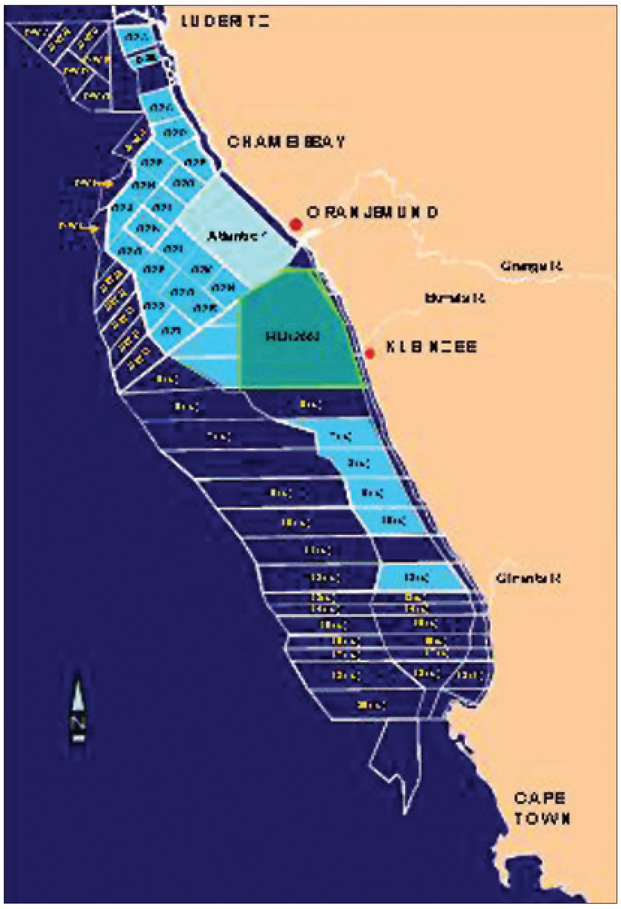

Figure 1—West coast map and consessions—Namibia and South Africa

Figure 2—*Barge 77*—MDC's first production system

Financial woes for the MDC, which had started with the loss of *Barge 77* continued, and Sam Collins invited De Beers to participate in the business. After some negotiation, De Beers secured an option to participate, subject to an independent survey of the concession area and a decision whether to participate. In 1965 De Beers exercised their option and became the majority shareholder in the MDC.

The MDC had up to this point been recovering diamonds from what is today referred to as the shallow-waters (<30 m), and most of the production had come from select high grade features in Chameis Bay and Bakers Bay. The MDC continued to report financial losses, and several vessels operated at losses relative to their direct operating costs. Mineral reserves were non-existent, and a form of hand to mouth sampling and mining was practised, relying on the instincts and luck of the production superintendents.

With the new majority shareholders now exercising their influence, opinions varied at this time (1965) as to the best course of action with the two options considered being: to halt production while the geosurvey and sampling activities continued until ore reserves had been established and the mining methods developed, or, to continue with operations in order to recoup the substantial investment made up to that point.

A compromise was arrived at, and the production fleet was selectively phased out while survey and sampling continued in a much more systematic way. Production dropped from 241 000 carats in 1966 to only 132 000 carats in 1967 as the *Diamantkus*, *Barge 111*, and *Colpontoon* were withdrawn, and a new barge *Pomona*, with a much enlarged capacity, was commissioned in July 1967.

Production from *Pomona* continued and, thanks to the discovery of a large new reserve feature in Hottentots Bay, production continued to 1971, with output peaking from this one barge at 239 898 carats in 1970. Due to exhaustion of reserves, and the anticipated expense of refitting the *Pomona* after 3 years at sea, mining operations closed at the end of March 1971.

The MDC, now under complete ownership by De Beers and unencumbered by operational pressures, focused it efforts on development of an understanding of the marine diamond resources. The operations were vested with CDM and came to be known as CDM marine.

Operations continued to focus on the shallow water areas, but during early 1971 when weather precluded the sampling vessel from continuing work inshore, a series of grab samples were collected along the coast about 20 km south and north of Chameis Bay out to approximately 100 m water depth, so as to determine the presence of any minerals of value. At this stage, marine geological models were almost non-existent, and the origin of the diamonds in the sea was still subject to debate. (It is also worth remembering that plate tectonics theory was universally only accepted in the 1960s.) These grab samples indicated the presence of significant sediments offshore containing concentrated heavy minerals. This was then the first indications of paleo-beaches beyond 35 m water depth.

The team remaining subsequent to the cessation of production in 1971 was given the brief to confirm the then considered absence of a potential for economic reserves of diamonds in the MDC concession areas covering 27 000 km^2 in water depths from 35 m to 200 m.

Geophysical surveys, supplemented by vibracore sampling were carried out up to 1974. The information thus generated suggested the presence of sediments extensive in area, but variable in thickness and mineral content.

The most promising results narrowed the area proposed as potential sampling sites to approximately 100 km^2, and in total, 3 297 samples were taken between 1974 and 1977 in 70 m to 90 m water depth areas. However, the whole resource was at that time estimated to contain no more than 0.5 million carats and was seen to be too small to support the development of the mining systems required to operate at these depths.

As a result, sampling operations moved further offshore in 1977. This exercise seemed to confirm the presence of a widespread low grade deposit in the 100 m to 120 m water depth.

There was no announcement of these results at the time because of political and business uncertainty, lack of knowledge of the size of the deposit, and the need to develop mining technology.

Sampling continued between 1977 and 1982 with a total of 9 228 samples taken in the reconnaissance area between the Orange River mouth and the Diaz Point at Luderitz in water depths of between 100 m and 135 m. As more detailed geophysical information became available, the area was seen to contain wide variations in topography with clear relationships between ridges, basins and valleys, and the concentration of diamonds. This was used in 1982 as the basis for interpolation between sampling results on the basis of topography, thereby enabling the isolation of two large targets known today as the Northern and Southern Target Areas.

De Beers Marine formation

By 1983, CDM marine had delineated a deposit of world-class proportions although the total caratage was unknown, and operations in deep-water deposits moved to an evaluation and ore reserve generation phase. To mine the deposit would require substantial financial input, and the onshore operations at CDM would not be capable of carrying the investment. At the same time, South West African independence was being pursued by liberation movements within the country. In addition, the South African sea areas (SASA) concessions had been awarded, with De Beers receiving the 4c and 5c, while 1c was awarded to Alexkor, 2c was awarded to African Selection Trust Exploration (ASTE), and 3c was awarded to Sedswan.

To allow operations in both South and South West African waters without disruption of resources while protecting the technology that existed at the time as well as those still to be developed, De Beers Marine (DBM) was formed as a contracting company that would own proprietary technology, and would offer the services to clients by operating on the concession holders' behalf, and being remunerated for this service. At the time, exclusive contracts were signed with CDM and De Beers Consolidated Mines (DBCM) for De Beers Marine to undertake prospecting operations in their respective grant areas.

During this time, sampling in the SASAs yielded the first deep-water diamonds in these concessions in 1984.

The focus for sampling changed after 1983, moving towards gaining a more detailed knowledge of the geology of the existing resource rather than further exploration for extensions to the resource. In addition, after identifying the clear need for the development of technology for mining in deep water, De Beers Marine formed a Mining and Research Division within the company in 1984.

Various mining systems and equipment designs were conceptualized between 1985 and 1988, while geological work was being carried out simultaneously to support the thinking for mining tool design. Of primary importance was the assessment of seabed conditions; and using high resolution seismic surveys supported by visual calibration using remotely operated underwater vehicles, some assessment of the footwall was made. In addition, grab samples were taken in 1988 using a cactus grab capable of extracting boulders up to a metre in diameter from the seabed.

Prior to making any major financial commitment to acquiring the hardware for mining, security of tenure was sought and received after some negotiation.

The initial approach to mining was based on the sampling tool, and by enhancement and enlargement of this technology, the first mining tool was developed. To accommodate this equipment, a larger platform was required and in July 1986, the 77 m long *Pacific Installer* was purchased for conversion by December 1987. The vessel was renamed the *Louis G. Murray*, and included in the conversion was a large dense medium separation (DMS) section, a drier, and X-ray unit for the final concentration process. Concentrates were to be bagged and transported to CDM in milk urns.

The first mining device was then similar to the digging head on the earlier barges, but included the ability to traverse, and while traversing, operated using a bouncing motion within a frame, thereby enabling the depletion of a swath. This tool underwent modifications at various times but was used in essentially the same configuration until June 1989, by which time the recoveries had exceeded 42 000 carats from the device.

Figure 3—*Louis G. Murray*—first production vessel of modern De Beers operations

Concerns about the effectiveness of the suspended digging head and the controllability of the depletion resulted in the withdrawal of the *Louis G. Murray* from service in 1989 for the conversion to a crawler mining tool. This conversion to a crawler vessel heralded the start of the official production phase of De Beers Marine.

The conversion involved the fitting of an A-frame with a docking device to deploy the crawler. The crawler itself was unmanned, weighed approximately 40 tons, and was powered by supplying 1100 volts through an umbilical cable. The crawler was tethered by a 100 mm diameter nylon composite rope fed through a constant tension winch.

The business end of the crawler was a cutter wheel with a horizontal suction port supplied by Orenstein & Koppel (O&K). The loosened material was airlifted to the surface through twin 200 mm diameter flexible hoses. Diamond recoveries were of concern with this first front end device and, subsequent to numerous attempts to modify the cutter, a suction box design was decided on in preference to the cutter system, this primarily to eliminate the unfavourable recoveries experienced with the cutter wheel.

The alteration was a success and the vessel regularly mined in excess of 1 000 m^2 per day. These successes resulted in the declaration of 28 663 carats from production in the deep-water deposits in 1990. Subsequently, the crawler was modified and a triple box arrangement was commissioned, resulting in even higher rates of mining sometimes exceeding 1 500 m^2 per day.

The quest for a higher mining rate stems from the need to reduce the cost per square metre mined, as this is the primary factor determining the cut-off grade that can be mined economically. By reducing the cut-off grade, larger areas can be moved from resource into reserve, and the life of mine and the net present value of the resource optimized. To this end, numerous mining tools were conceptualized for the crawler, some of which were tested but returned less than desired results.

Plans for an alternative approach to mining were formulated from 1988 when the opportunity to modify and combine the technology employed at that time in the offshore oil drilling and foundation industries became apparent. From this thinking evolved the concept of the large diameter drill (LDD) mining system with a drill bit tens of square metres in area coupled to a large diameter reverse circulation riser pipe feeding through a hole in the hull of the vessel, known as a moon pool, and via a compensation system into the plant on board the vessel. As a result, the *Glomar Coral Sea* was purchased in 1989 and converted in Cape Town.

Figure 4—*Coral Sea*—first large diameter drill (LDD) vessel

This vessel sailed in February 1991 as the *Coral Sea*, and after some commissioning modifications were done, she commenced mining in April of that year. The recoveries were considered excellent and on the strength of the initial results, a sister ship, the *Glomar Grand Banks* was purchased in the same year. The jump in production capacity resulted in diamond recoveries from the deep water concessions reaching 159 000 carats in 1991.

The *Grand Banks* was subsequently converted, with operational improvement incorporated in the design of the compensation system to enable operation of the vessel in move severe swell and wind conditions. With this improvement in the weather window came a better utilization of the capital asset with a commensurate increase in annual mining rate.

While the *Grand Banks* was being converted, a world-wide search was launched for further vessels that could be converted to the large diameter drill technology, and two further LDD vessels were sourced, both larger than the *Grand Banks* with an overall length of 138 metres.

Both of these vessels had the advantage of a larger moon pool, which facilitated the deployment of a 30% larger drill bit. The net effect of this was a 24% improvement in productivity for the design. The first vessel to be converted was the *Debmar Atlantic*, and she was commissioned in 1994, significantly contributing to the production capacity, and resulting in production of 405 000 carats in 1994, 453 000 carats in 1995, and 470 000 carats in 1996.

Approval for the conversion of the *Debmar Pacific* was given in the last quarter of 1995 and final commissioning was completed in March 1997, while at the same time, the *Coral Sea* was withdrawn from mining production to be converted into a dual-purpose sampling and mining vessel. This step was taken following a significant review of sampling methods and mineral reserves, which found that both were not of sufficient quality to justify the scale to which the operations had now grown, as well as to justify the significant capital risk of each of the expansion projects.

Further capacity expansion came in 1999, which saw the commissioning of the first *!Gariep* conversion into a crawler based mining system. The front end of this crawler was based on continuous miner coal cutting technology, but due to significant technical difficulties, the technology fell short of expectations. Subsequently, the *!Gariep* underwent a second conversion into an LDD mining vessel and was successfully commissioned in 2003.

Production capacity was further increased in 2003 with the acquisition of the production assets on the *Ya Toivo* mining vessel. This crawler vessel was previously operated by Namco, which following two episodes of receivership, was finally forced to sell all their production and material assets in 2003.

Figure 5—De Beers Marine Namibia fleet

Figure 6—De Beers Marine fleet

The demise of Namco, and the MDC before them, highlights the risks of miscalculated marine mining, and the critical necessity to have well-defined mineral reserves in place, as well as deep pockets to carry the exploration overhead and occasional operational mishaps.

The formation of De Beers Marine Namibia

As a result of political pressures during concession agreement renegotiations, De Beers formed a wholly Namibian company in 2001 to operate in the Namibian waters, and so De Beers Marine Namibia (DBMN) was born. De Beers Marine Namibia, as a fully independent company, now owns or operates a fleet of 5 production vessels in the Namibia concessions, while De Beers Marine continues to provide survey, sampling, and other select specialized technical services to Namibia.

In 2003, DBCM was granted a mining license in the SASA concessions following an extended period of low priority exploration and sampling where most of the focus was directed towards the Namibian concessions. In addition to the services provided to DBMN, DBM is currently in the process of converting the mining vessel *Peace in Africa* and developing the operational readiness plans for a dedicated mine in this SASA mining licence.

De Beers Marine currently owns or operates a fleet of 3 vessel: one destined for production in SASA, one dual purpose sampling and mining vessel, and one dedicated exploration sampling vessel; and in addition owns 2 survey class autonomous underwater vehicles (AUVs), and survey towfish equipment, which are typically operated from vessels of opportunity.

Marine production record

From the inception in 1990, carat production rose rapidly as additional capacity was added to the fleet. But this rise in production occurred against a backdrop of decreasing average grade, which by the late 1990s, had almost neutralized the impact of additional capacity, such as the addition of the *Debmar Pacific* in 1997. This resulted in a relatively flat growth curve prevailing into the early 2000s, as incremental improvements in production across the fleet were offset by ever decreasing average grades from the resource. The commissioning of the *!Gariep* and the *Ya Toivo* mining vessels in 2003 added greatly to the total production capacity. This, together with consistent and significant continuous improvements to the technology used on the LDD vessels and the *Ya Toivo* flowing from a concerted R&D campaign, reignited a strong positive growth trend which has continued to the present.

Total diamond production from the De Beers' marine mining activities is expected to be close to 1 million carats in 2006, and 2005 already marked a historic milestone as marine production surpassed land production in Namibia for the first time ever.

The marine mining value chain

The value chain of any mining venture starts with exploration. Marine mining is no different in principle; it is made more complicated only by the spatially diverse and geologically complex nature of the deposit. Placer deposits are acknowledged to be difficult and expensive to evaluate due to the lack of homogeneity in the deposit. The value chain has evolved to the point were reserve is developed on a rolling basis, rather than full bankable reserve definition up front. Survey and sampling are conducted in parallel with mining operations to ensure that an adequate reserve is in place for future operations and capital expansion, as well as to replace the reserves that are depleted annually.

While most of the sampling activity is directed to resource and reserve generation (evaluation) from well-defined target locations within the deposit, a certain fraction is also directed towards exploration and identification of new target locations. This is essential to secure new areas that will be required in the future as production depletes known areas, as well as to evaluate the comparative economic value of potential targets and to seek out the highest net present value options.

Disparate target locations are additionally beneficial when operating a large production fleet, as each vessel requires a definite exclusion zone to ensure safe operating. As new capacity is introduced, this requirement becomes more pressing.

The typical value chain employed by De Beers in marine mining is illustrated in Figure 8.

The output of the mining activity is a high-value concentrate, which for security reasons is sealed on the

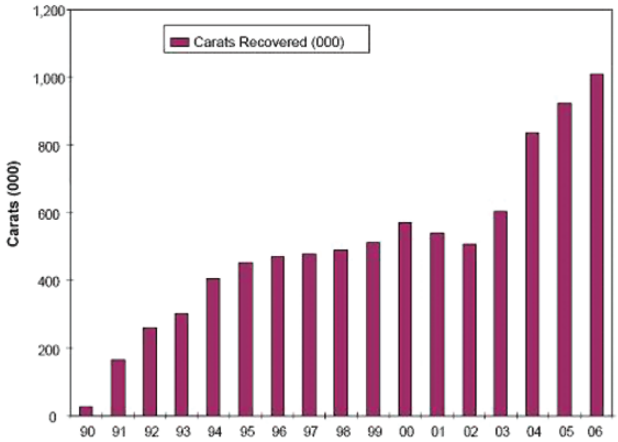

Figure 7—Marine diamond production from De Beers activities 1990–2005

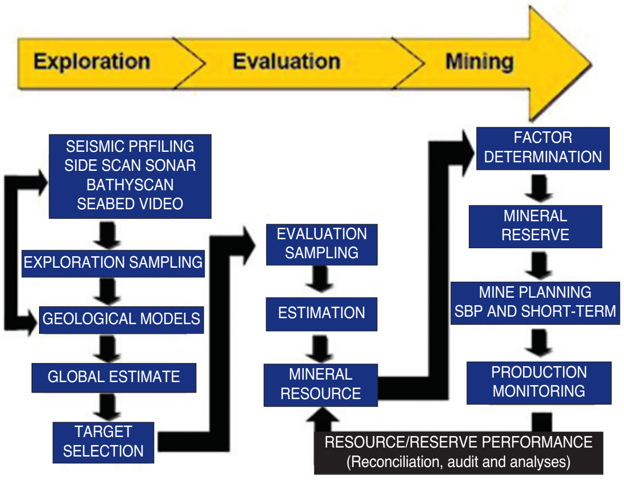

Figure 8—Marine diamond mining value chain

Figure 9—Refuelling at sea (RAS)

Figure 10—Helicopter operations for crew transfer

vessel in tin cans (known affectionately as Neptune cans) and dispatched via helicopter to the Namdeb sorthouse facilities.

A complex operation, of this scale, conducted along a remote and somewhat hostile coastline, requires a considerable support infrastructure. To this end, both companies have service departments focused on the main operation challenges from securing the product, to coordinating the movements of personnel to and from the vessels, to maintenance of the fleet, and ensuring that activities take place in a safe and environmentally responsible manner. Both companies', activities are ISO 14001 Environmental Management certified, and high safety standards and culture are vigorously promoted.

Vessels stay at sea in up to 3-year cycles between statutory inport maintenance, and are refuelled at sea.

Vessels are operated on a 24 hour per day, by 365 day per year basis, with crew, members working 12 hour shifts, and rotating 28 days onboard followed by 28 days ashore on leave. Crew are transferred to and from the vessels by helicopter.

Technology acquisition

Very special challenges exist in terms of developing or acquiring appropriate technology for marine mining.

- There are no off-the-shelf solutions for mining at 100 m water depth
- There are few competitors to learn with or from
- Failures on the scale of a marine mining vessel are not tolerated well by management
- The geology to be mined is under 100 m of water, making it difficult to visualize and quantify the challenge.

A strategy has evolved over time at De Beers that promotes the development of technologies offline from the project acquisition stage. In addition, the project acquisition stage is conducted using standard approaches and practices consistent with PMBOK[2].

While this approach is not always practical, it is very important for systems and technology for which the engineering sciences are not yet sufficiently developed to support verification of a solution by theoretical means. Alternatively, problems that require potentially excessive theoretical effort in a general case can often be solved for a specific case more easily using a physical model of the problem.

To this end, De Beers relies on an array of expertise, as well as computational and physical testing facilities both internally and externally within technology partner companies.

Because of the unique challenges of marine diamond mining, De Beers has invested heavily in facilities that support the development of technology of the mining tools.

Two large mining tool scale test facilities have been established in the Cape Town area, while a specialized scale tool testing and visualization facility has been established at the De Beers research laboratories in Johannesburg.

One facility is used primarily for LDD as well as similar related tool research and development, while the other is used primarily for crawler-based research and development. These facilities are used to both qualify as well as quantify the performance of scale models of mining tools.

Testing and technology development at technology partner facilities is also important to the successful introduction of new systems.

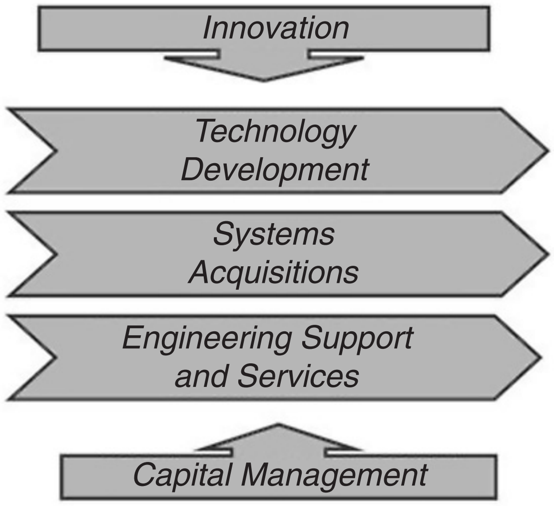

Figure 11—Technology acquisition and support value chain

Figure 12—Example of scale model test and full scale tool

Figure 13—Part of LDD tool research and development facility in Cape Town

[2]International Project Management Body of Knowledge

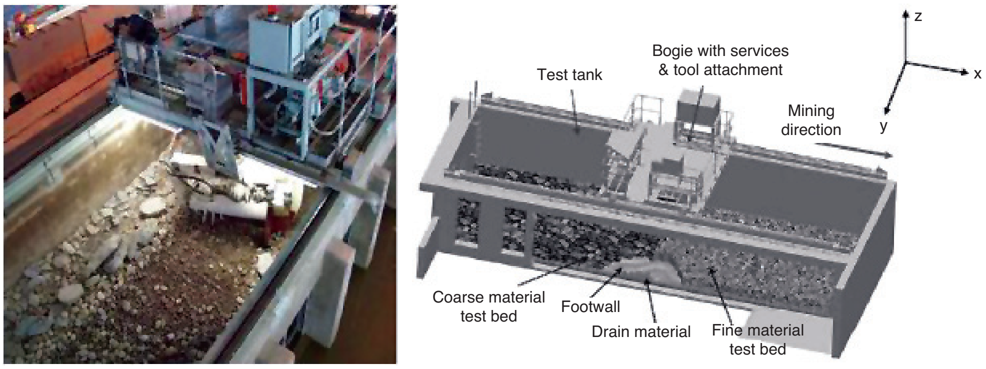

Figure 14—Part of crawler tool research and development facility in Stellenbosch

One example of this is the development of specialized milling technology for reduction of clays and shell present in the marine gravels. This development took place at KHI in Japan using specially prepared samples of actual marine gravels collected from concession areas. The collection of the samples, apart from the security challenges of removing potentially diamondiferous materials from a restricted area, were a significant challenge.

A further example of technology partner enabled development, is the development of splitter launders use on the LDD vessels. Material is delivered in the form of an airlift slurry with components of water, air, and solids. After a vertical deceleration and partial de-aeration chamber, the slurry must be bridged from the mining system into the treatment plant, and be equally split and presented onto two vibrating screens. This was to be accomplished using a sloping chute (known as a launder), and included a 90° turn forced by design layout constraints. Scale model testing by Paterson & Cooke Consulting Engineers (PCCE) in collaboration with the launder designers resulted in a satisfactory configuration being identified.

Independent of the test activity, a computational fluid dynamics (CFD) study was also conducted on the flow in the launder to validate the applicability of this numerical tool to this type of problem. Because of the limitations of coarse particle flow within CFD analysis, the scale testing was still essential to confirm the split of soils in addition to the water split. Comparison of the CFD with the water flow was good, and this showed the potential of analytical techniques.

DBM is currently involved in a research study to evaluate the applicability and practicality of coupling CFD with discrete element modelling (DEM), which would then allow for general solution of fluid and solids coupled problems.

The final step in technology acquisition is usually embodied in a conversion or major upgrade project. A recent example involved the upgrading of the *Debmar Pacific* in 2005, which prior to upgrading was essentially as originally converted dating back to 1997. The upgrade involved a complete new treatment plant and control system, a major upgrade to the mining system, and replacement engines and alternators, while the vessel also required statutory marine maintenance as a condition of class. These type of upgrades involve an unusually intense period of work in the dry dock and alongside as every effort is made to minimize the downtime impact to the vessel.

Hydrotransport as key competency and technologies

Problems of fine and coarse particle flow in 2- and 3-phase flows are particular examples of the complex flows that are encountered routinely in marine mining. As a consequence, hydrotransport can be considered a key competency essential for the professional design and application of engineering solutions in the marine diamond mining industry.

Hydrotransport is embodied in a large number of unit processes used by De Beers in general. Marine mining adds to these with specific applications of hydrohoisting and pumping of particularly coarse slurries. The resulting important hydrotransport technologies for marine mining are as follows:

- Hydraulic entrainment and fluidization at the mining tool
- Gravel pumping and hydrohoisting, including
  - Centrifugal gravel pumping
  - Airlift pumping
- De-aeration of airlift slurry
- Coarse slurry splitting

Figure 15—Visualization laboratory facility at De Beers Campus, Johannesburg

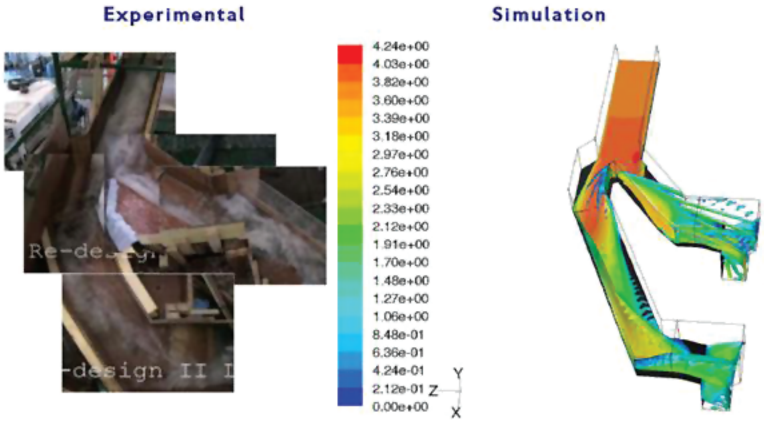

Figure 16—Launder splitting scale model tests and CFD simulation

- Dewatering and sizing of solids
- Elutriators and overflowing of excess water
- Jet pumping
- General centrifugal pumping
- Fluidizing and eductor extraction out of hoppers and bins
- Dense medium separation using hydrocyclones
- Ferro-silicon dense medium mixing and pumping; and correct medium maintenance
- Pipeline systems and networks, particularly for process water
- Instrumentation, particularly for coarse and abrasive solids
- Wear management, particularly for coarse and abrasive solids.

While many of the hydrotransport challenges are fairly conventional, the addition of coarse gravel to the situation leads to interesting and challenging new angles. It is in the up-front processes such as pumping and splitting that these challenges are greatest.

Both airlift and centrifugal pumping are used for hydrohoisting of mined material from the sea floor. Airlifts, although somewhat inefficient, are very robust and allow passage of very large particles. Modern centrifugal gravel pumps are very efficient, but carry a very large overhead with them. At the required depths of operation, centrifugal pumps have to be placed well below sea level to ensure sufficient net positive suction head (NPSH) at the suction, and the electrical challenges that accompany underwater deployment are considerable.

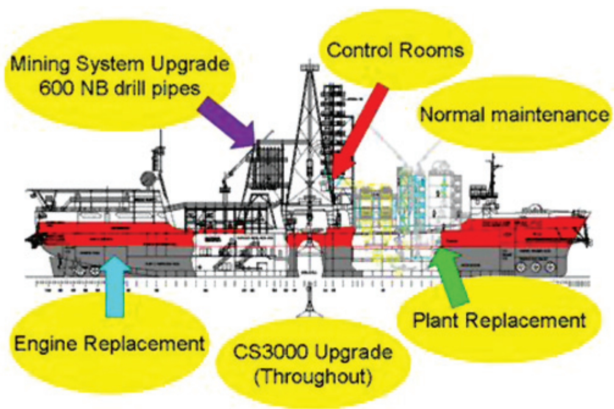

Figure 17—*Debmar Pacific* upgrade projects summary scope

Figure 18—Boulder hydrohoisted by airlift (approximately 450 mm max dimension)

Figure 19—IHC underwater pump and eMotor for crawler application

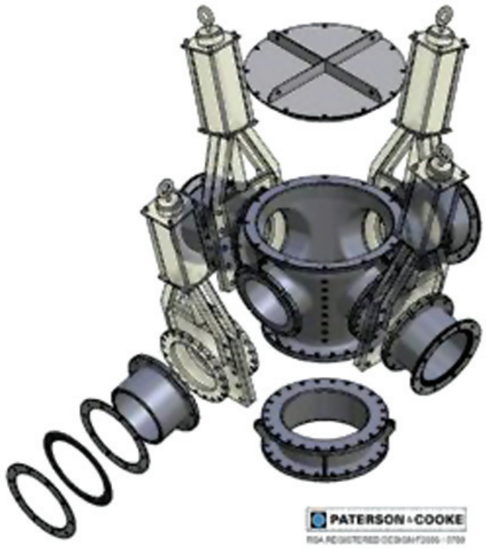

Figure 20—PCCE balanced head feed splitter

Currently airlift and centrifugal pump sizes up to 600 mm in diameter are used to depths of 150 m, and the installed pump power on the *Ya Toivo* is 1 800 kW. The envisaged installed pump power on the *Peace in Africa* is 2 400 kW and the diameter increases to 650 mm. These pumping systems are capable of delivering up to 2 500 tph of solids, and over 9 000 m^3/h of slurry.

Depending on the pumping system and the downstream process, this slurry may have to be decelerated and de-aerated prior to processing. For the airlift systems used on the LDD vessels, large de-aeration bins are an integral part of the vessel motion compensation system in addition to fulfilling this function.

Splitting of the head feed flow into equal fractions for dewatering and sizing is a particular challenge in marine mining. As the head feed flow rate increases, the flow has to be diverted to an increasing number of sizing processes. Balancing of these flows is important for downstream performance; however, the designs also need to allow for individual streams to be shut off for maintenance purposes, without significant disruption to the flow split to the remaining streams. PCCE have purpose designed such a splitting device, using rigorous scale testing, for the *Peace in Africa* vessel, which should be commissioned by mid 2007.

Dewatering and sizing has traditionally been accomplished simultaneously on vibrating screens.

However, the demands of increasing slurry flow rates are resulting in new ways of dewatering becoming the norm. Increasing reliance on static dewatering panels and overflowing weirs and hoppers is becoming essential. Obviously overflowing must be accomplished in such a way that ensures minimal risk of diamond loss.

The move to overflowing hoppers, in turn, creates additional requirements for refluidization of the material so that it can be further processed. This must be achieved despite the presence of large, as well as sticky clay materials.

Figure 21—Vibrating sizing screen with example oversize material

Thus new and challenging technologies must be developed and matured, preferably with minimal impact to operational assets, that can then be brought to bear in new and upgraded marine mining systems.

Closing remarks

The west coast of Africa has been endowed with a unique treasure of placer diamonds located on land and at relatively shallow water depths. This setting created the conditions for progressive exploration and mining of these marine deposits.

Sam Collins's MDC pioneered the exploitation of sea diamonds. De Beers added a long-term sustainability and professional impetus to marine diamond mining.

Marine diamond mining is starting to replace land-based mining of these placer resources as the land resources become depleted, and the technology and know-how for economic marine mining matures.

Marine diamond mining perhaps precedes many other commodities, which may one day be economically mined from the oceans, and hydrotransport will remain one of the key technologies for all of these future marine mining endeavours.

While marine diamond mining has highlighted some of the challenges of marine mining in general, many new challenges lurk out there in the deep.

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