A unique means of obtaining sea-water

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SYNOPSIS

Although the mining and treatment operations at The Consolidated Diamond Mines of South West Africa, Limited, are located within an average distance of 1 km from the Atlantic Ocean, the supply of clear sea-water in large and continuous quantities for use in treatment plants is made difficult by siltation of water-holes and the amount of sand in suspension in the sea itself. The need for sixty million litres of sea-water per day at the new No. 2 treatment plant necessitated the construction of a system that would ensure a continuous and reliable supply.

Several sea-water intake schemes were proposed. This paper outlines the need for an improved means of obtaining water and describes the construction of the scheme eventually chosen — a tunnel driven through bedrock for over 400 m beneath the Atlantic Ocean. At the end of the tunnel, two large chambers were excavated from which vertical holes were drilled to intersect the sea-bed.

SAMEVATTING

Alhoewel die myn- en behandelingsprosesse by die Consolidated Diamond Mines of South West Africa Limited, binne 'n gemiddelde afstand van 1 km vanaf die Atlantiese Oseaan geleë is, word die verskaffing van helder seewater, in groot en voortdurende hoeveelhede vir gebruik in diamant behandelingsinstallasies, bemoeilik as gevolg van versanding van watergate en die hoeveelheid drywende sand teenwoordig in die seewater. Die daaglikse gebruik van sestigmiljoen liters seewater by die nuwe no. 2 behandelingsinstallasie, het die konstruksie van 'n stelsel genoodsaak wat 'n voortdurende en betroubare watertoevoer sou verseker.

Verskeie skemas vir die opvang van seewater is voorgestel. Hierdie verhandeling skets die behoefte aan 'n verbeterde waterverskaffingsmetode en beskryf die konstruksie van die skema wat uiteindelik aanvaar is — 'n tonnel geboor deur 'n rotsbedding onder die Atlantiese Oseaan vir 'n afstand van meer as 400 meter. Aan die einde van die tonnel is twee groot kamers uitgedelf waarvandaan vertikale gate geboor is om tot die seebedding deur te dring.

INTRODUCTION

Far down the south-west coast of Africa, along a narrow stretch of land bounded on the one side by the Atlantic Ocean and on the other by desert or semi-desert, is the world's richest known deposit of gem diamonds. The deposit follows the coastline for 100 km north of Oranjemund, which is the headquarters of the Consolidated Diamond Mines of South West Africa, Limited (C.D.M.), a member of the De Beers Group. Here, in a mining operation that is unique, C.D.M. recovers over one and a half million carats of diamonds a year from ancient marine terraces on the land, beaches, and sea-bed.

The diamonds are recovered from gravels and conglomerates, and the mined material receives its first treatment at large treatment plants. The sequence is as follows:

1. Crushing — to break down large pieces of the conglomerate in which the diamonds are cemented.
2. Screening — to discard as much of the undersize (mostly sand) as possible.
3. Milling and scrubbing — to liberate smaller pieces of conglomerate ore and to wash off sand particles.
4. Heavy-medium separation — to remove the material of low specific gravity.

To minimize the transportation of barren material, the initial treatment is done at plants near the deposit. At present, there are two major plants and five field screening plants in operation.

A further two major plants are under construction. Of the material reporting to a plant, approximately 0,4 per cent remains for transportation to the Central Recovery Section for final separation of the diamonds. The sorting technique is based on the fluorescent properties of diamonds under X-ray, and is followed by hand sorting.

At a major plant, large quantities of sea-water are required for the screening, milling, scrubbing, and concentration processes. For example, the quantity of sea-water required at the No. 2 treatment plant is 60 million litres per 21-hour operating day. This paper describes the method used to obtain this volume of water.

CONVENTIONAL METHODS

As untenable as it sounds, the problem of obtaining sea-water for the major plants — all four are located within 1 km of the beach — is acute. Until recently there were only four methods.

1. *Waterholes*
   On the beach in the southern area of the mine, just north of the Orange River, the bedrock lies at an elevation of 10 to 20 m below mean sea-level. It is covered by varying depths of sediment in the form of marine gravels and wind-blown sands to a maximum depth of 20 m. Sea-water is obtained with relative ease under these conditions. A deep excavation, which collects water by seepage, is dug inland of the high water-mark.
2. *Wellpoints*
   In the area of low bedrock elevation, sea-water is also obtained by putting down wellpoints that suck the water out of the sand.
3. *Direct Suction from the Sea*
   Where the bedrock is at too high an elevation (relative to mean sea-level) for the waterhole method, water can be drawn from a suitable gully in the bedrock exposed on the foreshore at low tide. Such a gully must be open to the sea at all times so as to receive a continuous supply of water.
4. *Channelling the Sea to a Deep Sump*
   At the most northerly treatment plant, water is obtained from the sea via a canal to a deep sump cut into the bedrock some 70 m inland of the high water-mark. From this sump, the water is pumped to the plant.

*Consolidated Diamond Mines of South West Africa, Limited, Oranjemund.

THE PROBLEM OF SILTATION

With the exception of the waterhole method, all the systems are very vulnerable to siltation. The Orange River deposits large quantities of sand and silt into the Atlantic, and the fast, north-flowing Benguella current, together with the northerly long-shore drift, carries a high percentage of this material, mostly fine sand, north along the coast. In addition, the mine has for years, and to its advantage, been disposing sand from field screening plants and stripped overburden by dumping it on the beach. These sands are washed into the sea by the breakers and are redeposited by the currents into the gullies and canals from which water is being obtained. Apart from the danger of starving a plant of its water supply, the task of removing the sand from the gullies is frequent, difficult, and costly. Thus, in the design of the newest treatment plant, it was obvious that a new and more efficient means of ensuring a reliable water supply had to be developed. The critical factor in this instance was that the plant was to be sited in an area of high bedrock.

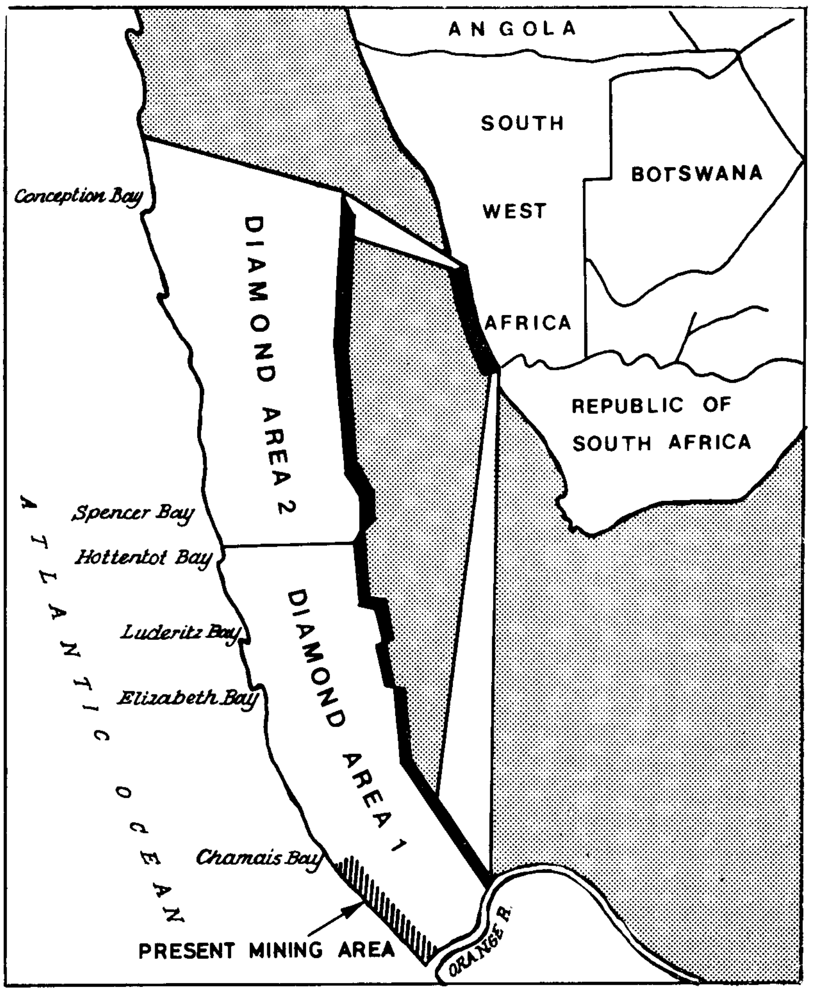


Fig. 1—Map showing the world's richest known deposit of gem diamonds

SURVEYING THE SEA-BED

Before a scheme could be considered, a detailed survey of the sea-bed was essential. As any structure in the sea would have to be anchored to bedrock, it was necessary to ascertain whether the bottom was exposed bedrock or sediment and, if the latter, its extent and thickness.

The area just to seaward of the proposed plant was surveyed by a seismic profiler early in 1973. Contour plans of sea-bottom elevations, bedrock elevations, and the thickness of sediments were subsequently produced with a contour interval of 0,5 m. Independent checks showed the survey to be accurate to within 0,5 m vertically over the area covered.

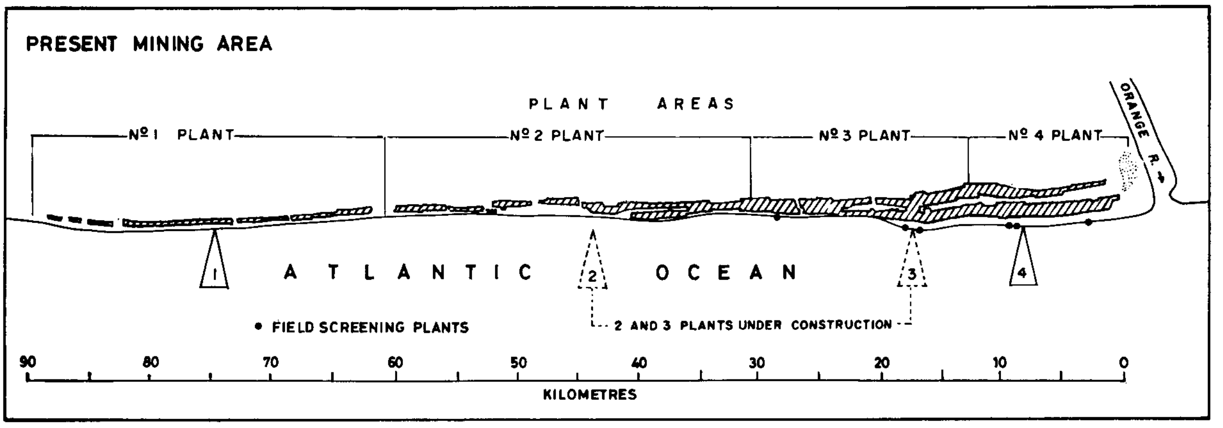


Fig. 2—Plants for the initial treatment

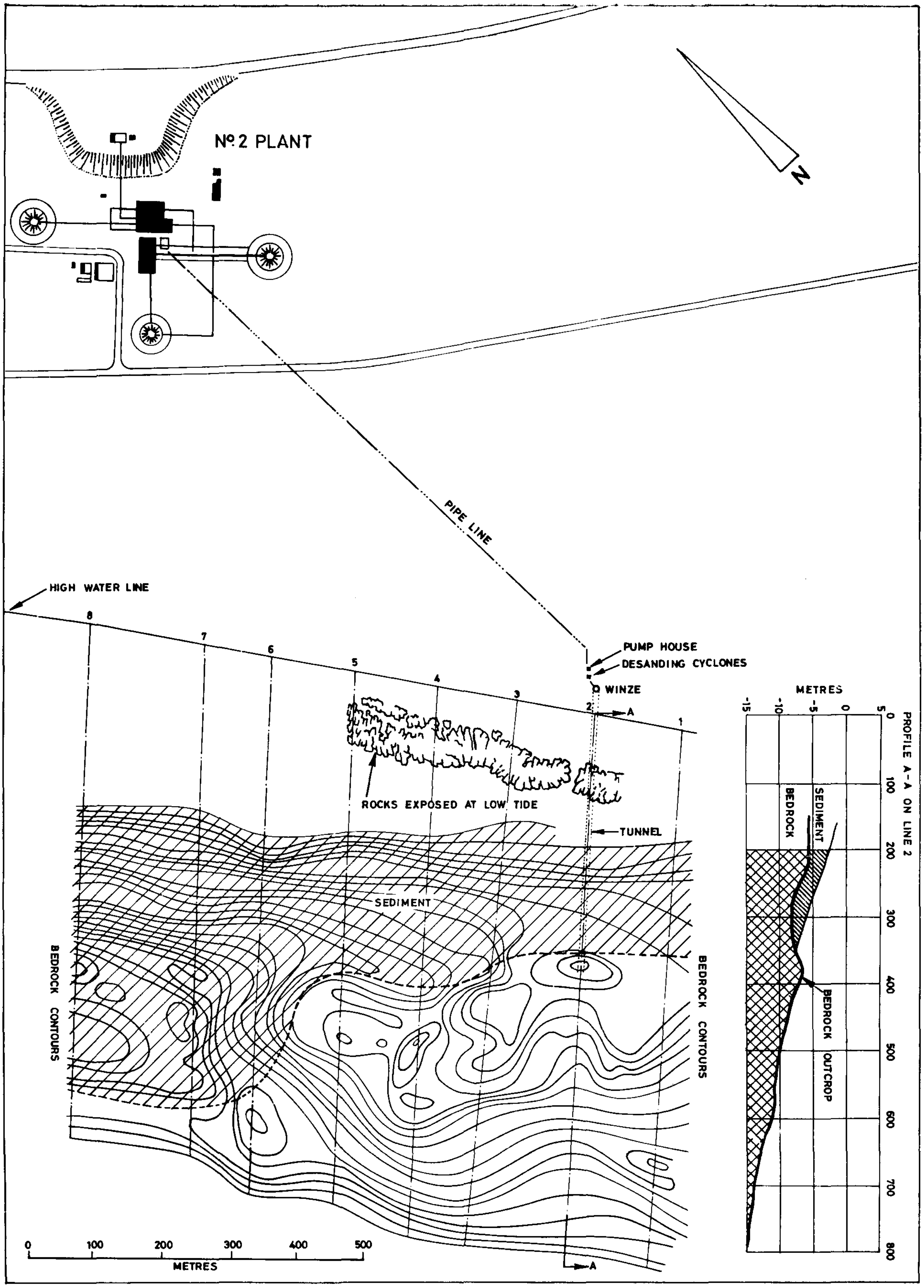
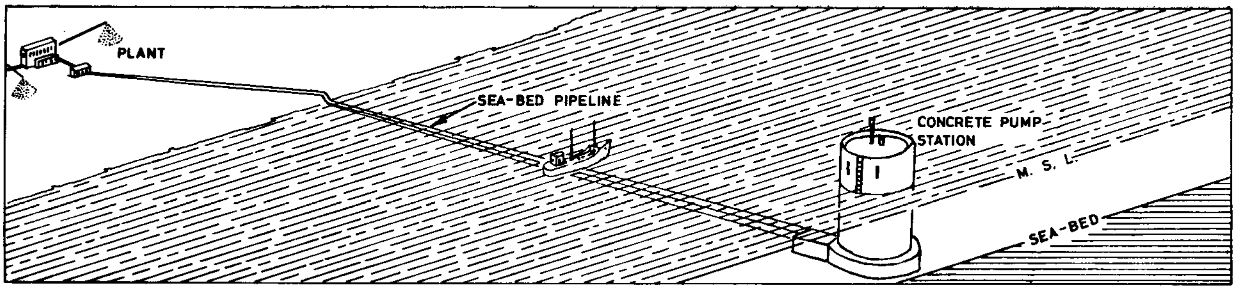
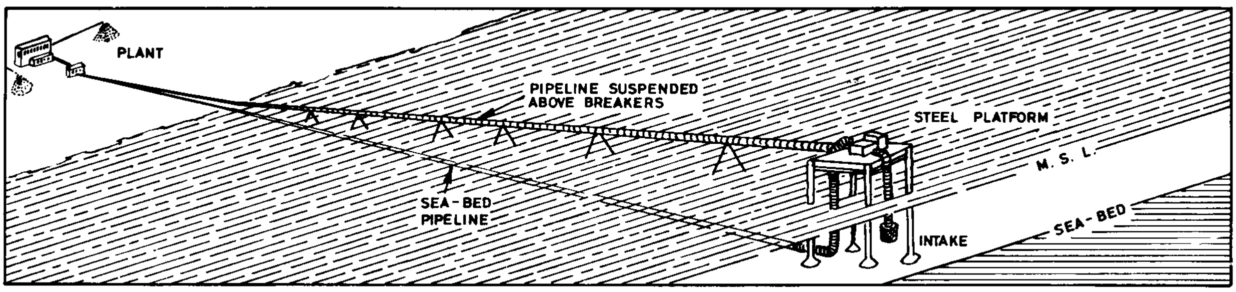


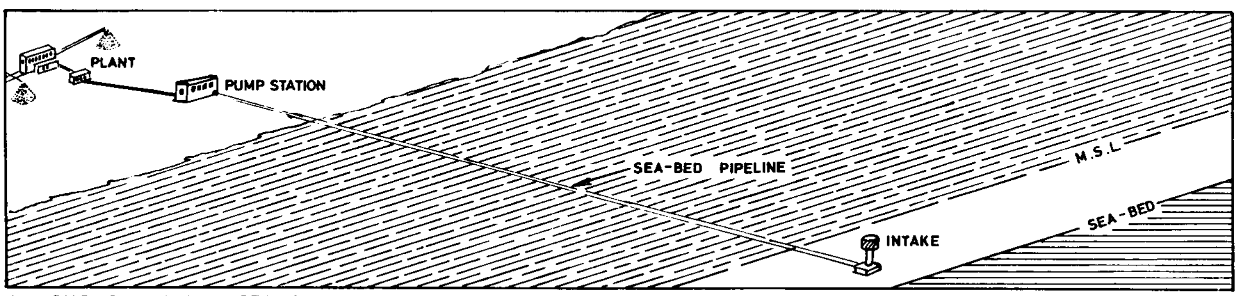
Fig. 3—A contour plan of the sea bottom



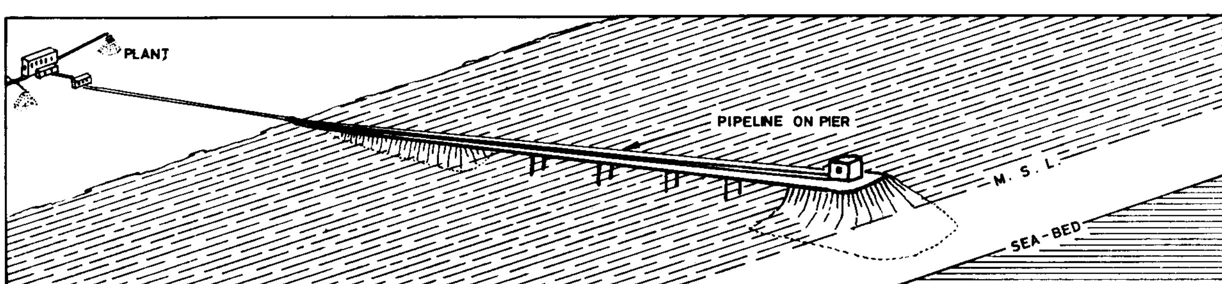
AN OFFSHORE CONCRETE PUMP STATION



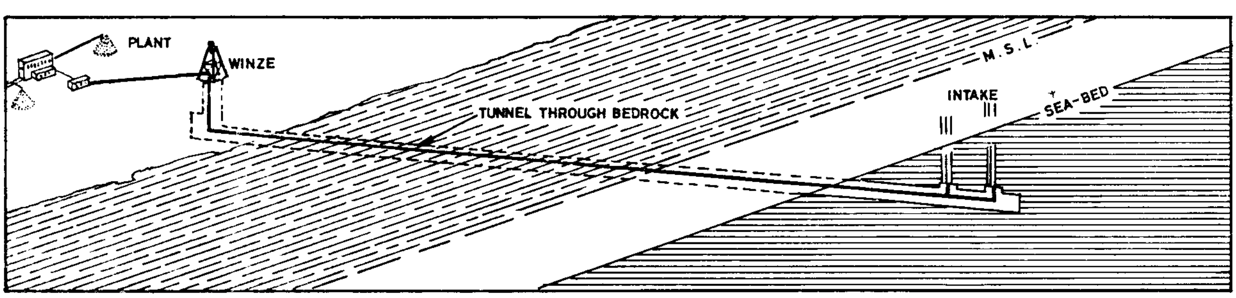
AN OFFSHORE STEEL PLATFORM



AN ONSHORE PUMP STATION



A PIER OR BREAKWATER



AN UNDERSEA TUNNEL

Fig. 4—Proposed methods for the intake of sea-water

METHODS PROPOSED

Several schemes were proposed for the intake of sea-water.

1. An off-shore concrete pump station to deliver water through a sea-bed pipeline.
2. An off-shore steel platform to deliver water via a pipeline on the sea-bed or suspended above the breakers.
3. An on-shore pump station to draw water through a sea-bed pipe from an intake pipe out at sea.
4. A pier or breakwater built into the sea to carry suction pipes.
5. An undersea tunnel through the bedrock to tap the sea-bed.

SELECTION OF THE TUNNEL METHOD

The tunnel method was chosen for the following reasons.

1. The inlet point of any intake system had to be positioned so as to remain clear of any expected siltation. The raised area of clear bedrock, found during the survey of the sea-bed (see Fig. 3), was favourable to the plan to tap off water through piped holes drilled up from the tunnel into the sea.
2. The tunnel system was less subject to possible total failure from storm damage.
3. As the system chosen had to function for a period of twenty years, reliability was essential.
4. Should sand build up at the inlet point, the tunnel could be easily extended into a clear zone.
5. The construction and maintenance of the tunnel method were considered to be simpler than those of the other systems proposed.
6. The construction of the tunnel was less vulnerable to delays from storms than that of a jetty or pipeline.
7. Time was an important factor — the tunnel method was able to meet the construction deadline.
8. Of all the schemes costed, that chosen was the least expensive at that time.

GEOLOGY OF THE SITE

The country rocks at the plant site are phyllites and schists. The phyllites are finely laminated, dip to the west with a local inclination of about 60°, and are characterized by foliation and cleavage planes coated with sericitic mica, which acts as a lubricant along the parting planes, and by zones of varying competence within the phyllite succession. The formation has been deformed, and the phyllites, which exhibit tight isoclinal folds, have been subsequently sheared.

The difference in competence, coupled with the shearing and micaceous parting planes, contributes to a rock mass that is difficult to mine because of its tremendous unpredictability.

The phyllite itself grades from a uniform green–grey through a darker grey variety, which is more calcareous, to a grey–green calcarenite variety. The whole mass is disrupted by a large number of segregated quartz stringers and veins, and dolerite occurs at several localities. These veins and stringers are frequently associated with shear zones and may often have a vug-like crystalline form, permitting the easy passage of water.

CONSTRUCTION OF THE SEA-WATER INTAKE

The system consists of three sections: a vertical winze at the bottom of which is the main pump station; a tunnel, driven far enough under the sea-bed to clear the overlying sediments; and two intake chambers from which vertical holes were drilled up through the bedrock to tap the water.

The Winze

A collar of 4,0 m above mean sea-level was established and the winze centred east of the high water-mark. Precautionary measures were taken by the drilling of six 50 mm-diameter holes immediately outside the proposed excavation to a depth of 6 m below the lowest point of excavation. These holes were pressure grouted according to standard practice, and in addition pilot holes were drilled during sinking. For geological information, three cover holes were drilled from surface: one vertical hole at the winze centre, a second vertical hole east of the centre line to cover the area of the proposed pump chamber, and a third inclined hole ($22\frac{1}{2}$° from the vertical) drilled to the west to obtain some indication of the ground conditions along the line of the tunnel.

The winze, 3,65 m in diameter and concrete lined, was sunk to a depth of 39,0 m, allowing 3,0 m for a sump. Seepage during sinking was considerably reduced by the precementation process.

For the sinking, station cutting, and excavation of the pump chamber, a 50 000 kg crawler-mounted crane was used for hoisting. The winze was equipped with two compartments: one a travelling way with wooden ladders spaced at bunton intervals of 4,0 m, and the second a compartment to take the kibble and service facilities. Before tunnelling was started, a permanent A-frame headgear of special design was installed.

The Tunnel

The tunnel, 2,42 m in cross-sectional area, was driven a total distance of 407 m from the vertical winze at a gradient of +1 in 100.

Cover drilling was effected by the drilling of four 36,0 m-long holes in the corners of the advancing face. A 50,00 mm-diameter diamond drill hole provided a core sample for each length covered.

The maximum volume of water obtained from a cover hole was 2500 l/min.

The excavation was lined with steel arches at 1,5 m centres and, depending on the type of ground encountered, they were carried immediately behind the face or up to three lengths away.

The tunnel was finished with a 300 mm-thick concrete lining, poured from surface, and a concrete floor with drain and rails was carried on average 75 m behind the face.

Concurrent with the development, two intake chambers were broken away in the northern side of the tunnel with centres at 380 m and 400 m from the vertical winze. After adequate cover drilling had been completed, the chambers were excavated to a final size of 9,2 m long by 3,2 m wide by 6,1 m high. It was coincidental that in both cases the ground encountered was competent.

Both chambers were fully lined with a 300 mm-thick layer of con-

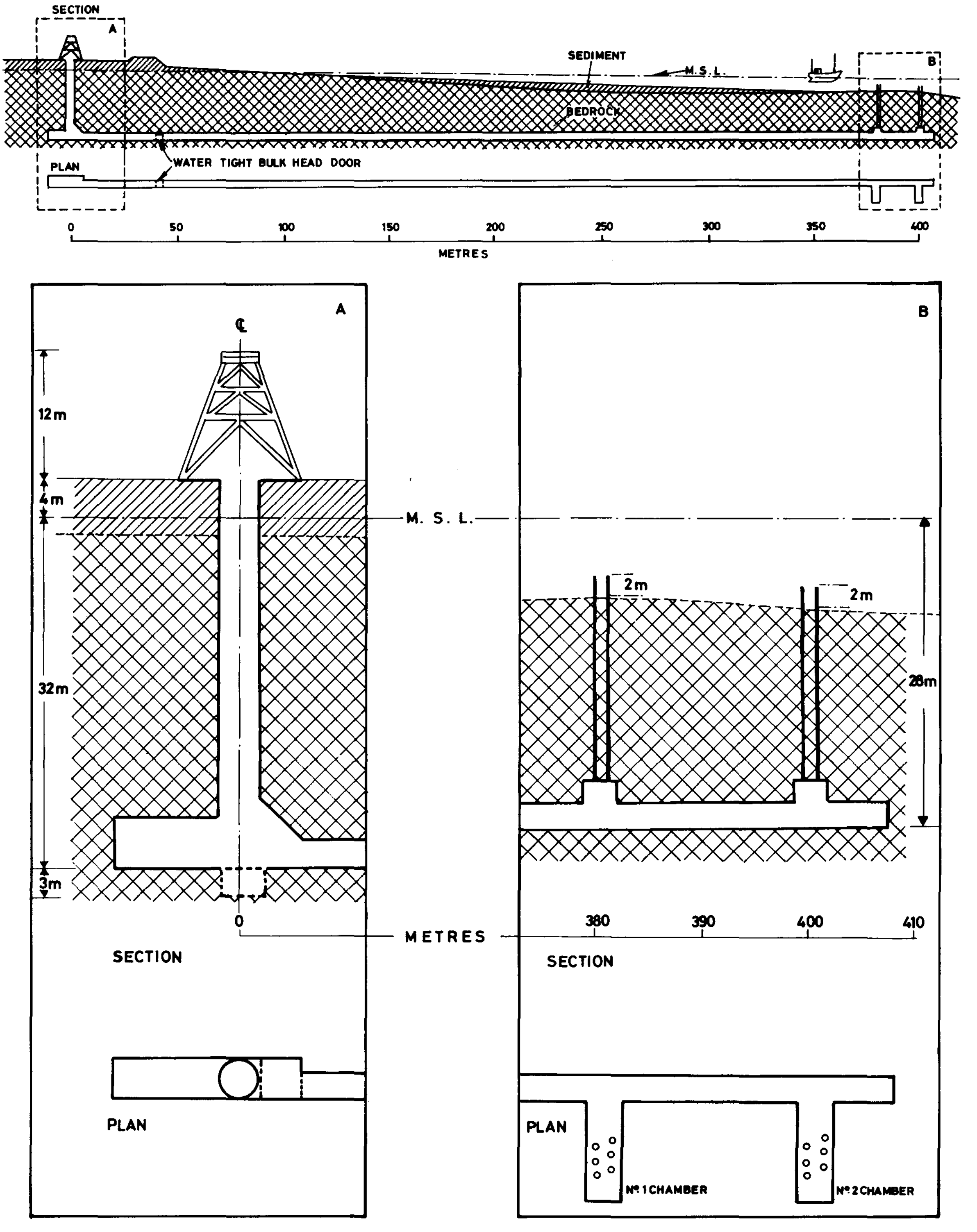
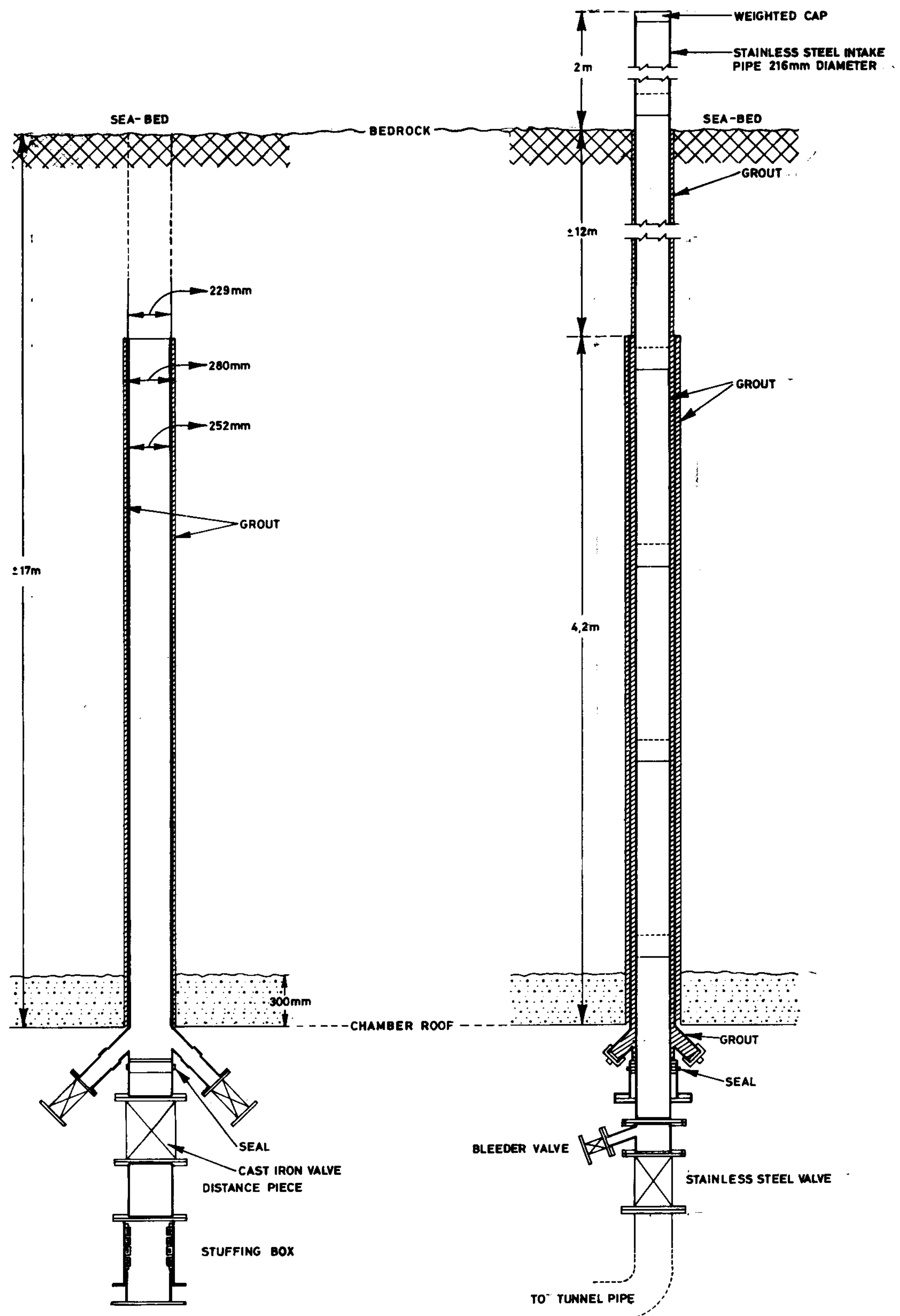


Fig. 5—The sea-water intake system



SECTION CASING PIPE & STUFFING BOX DURING RAISE BORING OF HOLE
TEMPORARY ARRANGEMENT

SECTION THROUGH SEA WATER INTAKE PIPE
PERMANENT ARRANGEMENT

Fig. 6—The method of drilling

crete, the floors being reinforced with steel beams.

The Intake Holes

Through the roof of each chamber, six 229 mm-diameter holes were drilled vertically to intersect the sea-bed. The machine used was a ROBBINS IID electro-hydraulic mini-borer. Although the machine was new on the market and had not been used previously for this type of work, it proved to be highly successful in this application.

The sequence and method of drilling for each intake hole were as follows.

1. The exact position of the hole was surveyed in the chamber.
2. Conventional cover drilling — a 50 mm-diameter vertical hole drilled and cementated at interval lengths of 4 m — probed the ground to be traversed between the chamber roof and the sea-bed and also established the actual length of piping required per hole. The average thickness of bedrock between the chamber roof and the sea was 17,0 m.
3. A hole of 280 mm-diameter was drilled a distance of 4,2 m by the mini-borer. A stainless-steel casing pipe of 252 mm outside diameter and 240 mm internal diameter was then inserted and grouted in position.
4. A valve and stuffing box were fitted to the end of the casing pipe.
5. Through the casing pipe, the mini-borer then drilled the remainder of the hole at a diameter of 229 mm to intersect the sea, the rod line being pushed well up into the sea after intersection to ensure that a full holing had been achieved. It was then withdrawn through the valve, which was closed before drawing the bit through the stuffing box.
6. Using the mini-borer, specially fabricated stainless-steel pipes of 216 mm outside diameter and 196 mm internal diameter were then inserted. The 1,1 m-long pipes were screwed together and pushed up the hole by the machine, far enough to protrude 2 m above the bedrock. The top pipe was equipped with a weighted cap to prevent the ingress of water during this part of the operation.
7. The installed column was grouted between the initial casing pipe and the rest of the drill hole. A seal at the position indicated in Fig. 6 prevented the grout from entering the cast-iron valve of the casing pipe. This valve was then removed and a stainless-steel manifold fitted to the end of the stainless steel intake pipe.
8. The cap was then blown off, using a 100 mm-diameter compressed-air column connected to the bleeder valve.

In this manner, all twelve intake pipes were successfully positioned in the sea and between them give a theoretical yield of 110 000 l/min.

PUMPING CONFIGURATION

From each set of intake pipes, a 500 mm-diameter manifold carries the water via a strainer box into two pipelines running along the side-wall of the tunnel to the pump chamber at the bottom of the winze. The tunnel pipes are supported on concrete cradles spaced at 6 m intervals.

At the pump chamber, a common manifold receives the two tunnel pipes and feeds the water to two main pumps, with one standby pump. These pumps have open impellers of special design, having been fabricated from stainless steel to resist the tremendous rate of abrasion. The pumps have been made highly efficient, there being a very close tolerance between the pump body and the impeller. The pumps deliver through three 400 mm-diameter pipes up the winze and out to a set of cyclones and desanding reservoirs in a building adjacent to the bank of the winze. The cyclones have been designed to remove approximately 2 tonnes of sand per hour from the water before it is sent by three booster pumps to the treatment plant about one kilometre away.

EMERGENCY SYSTEMS

As serious flooding of the intake tunnel could starve No. 2 Plant of its water supply, much emphasis was placed on safety provisions. There are three separate systems: a watertight bulkhead and door, float switches in the spillage sump for warning and control, and a source detection system that employs weirs in the drain.

The water-tight bulkhead and door

At a position approximately 40 m from the winze bottom is a concrete bulkhead, 10 m long, 5 m wide, and 5 m high, allowing access to the intake end and through which pass the intake pipes and drain, ventilation and air columns, and electric cables. A water-tight door is bolted on the intake end of the bulkhead.

Should there ever be an inrush of water between the intake end and the bulkhead, the door will protect the pump chamber and can allow a continued supply of water to the plant.

The spillage sump

The pumps that handle normal tunnel seepage are operated by the level of water in this sump. Should this level rise above a fixed height, a float switch triggers off the alarm system at the plant's central control room and simultaneously causes hydraulic valves, located on the winze side of the bulkhead, to shut off the pipes and drain-water. The pumps of the main chamber are also isolated by the alarm system. Manual opening of the drain valve allows the flow of water to the sump to be controlled to the capacity of its pumps. The danger of flooding the main pumps having been removed, they can now continue pumping to the plant.

Weirs in the drain

Weirs have been installed at four strategic points in the drain: one opposite each intake chamber and two along the tunnel. Under normal conditions, seepage water flows under each weir. However, any excessive water flows over the weir and, in doing so, activates a switch. A panel of lights in the control room then indicates what section of the tunnel is affected.

In the unlikely event of a major accumulation of water behind the door, the intake pipes would be capped by divers and the tunnel pumped dry through the drain valve. Failing the capping of the pipes, the tunnel and shaft would

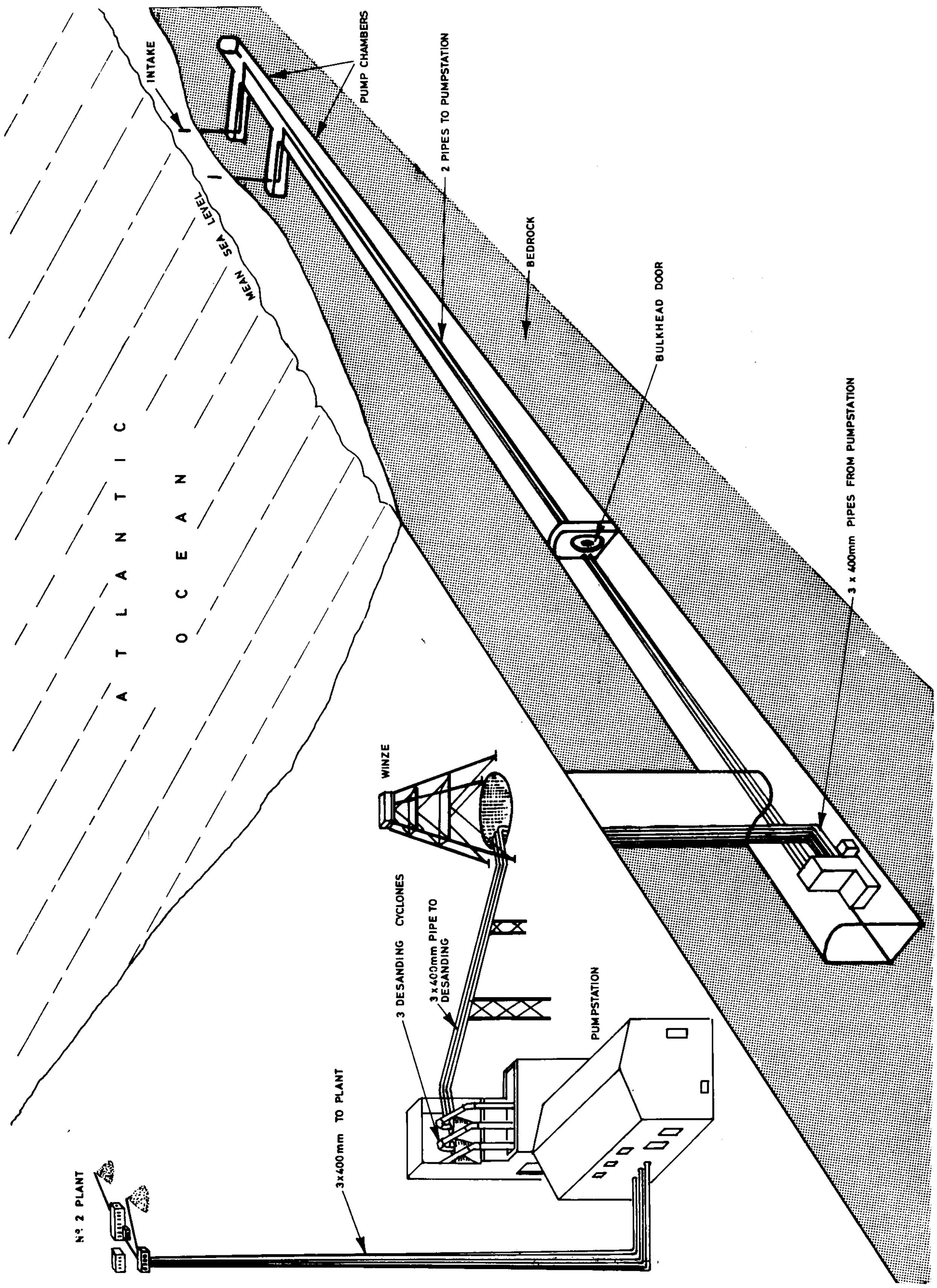


Fig. 7—The pumping configuration

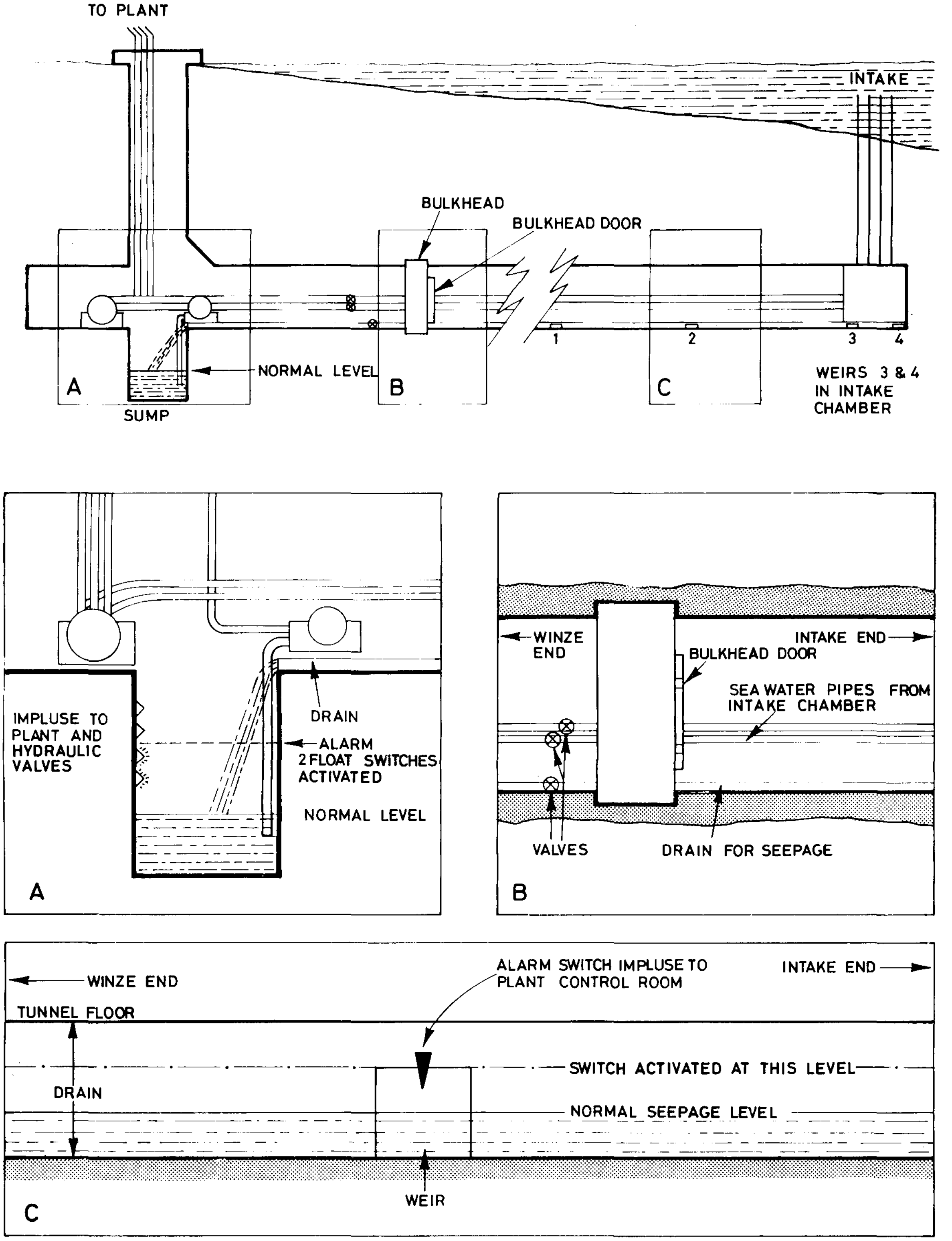


Fig. 8—The emergency systems

be deliberately flooded to relieve the pressure difference across the door. The divers could then gain access through the door to the intake chambers, where the pipe valves could be closed.

Closed-circuit television has been installed in the tunnel, with cameras at the intake chambers and behind the water-tight door. Their main purpose is to provide a regular check on the intake valves and on the area on the intake side of the door.

GENERAL INFORMATION

1. Time —With two 12-hour shifts 7 days per week, the projects took a total time of fifteen months.
2. Safety —Only one lost-time accident occurred.
3. Labour —The work was contracted out to Goldfields Cementation and Mining Co. Ltd, who used a crew of 62 Basutos. A gang of 25 Ovambos was supplied by the mine for surface duties. The White strength throughout the project averaged 10.
4. Cost —The total expenditure was 1,1 million rands.

ACKNOWLEDGEMENTS

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REFERENCE

O'Brien, J. J. K. Surveying the sea-bed. *J. Inst. Min. Surveyors S. Afr.*, Jun. 1974.

Company Affiliates

The following members have been admitted to the Institute as Company Affiliates.

AE & CI Limited.
Afrox/Dowson and Dobson Limited.
Amalgamated Collieries of S.A. Limited.
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Tvl Cons. Land & Exploration Co.
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