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# Thickened and Paste Tailings Pumping Systems for Orapa Mine

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## Abstract

*Debswana is designing new slimes disposal systems for the current Number 2 plant and for the future Number 3 plant at Orapa mine in Botswana. In addition, Debswana is also considering replacing a similar size plant at Jwaneng during the same period. However, this paper will only be limited to the Orapa mine study. As part of the feasibility investigation into these systems, the following pump technologies were investigated: Phoenix pressure exchange system; Apex pressure exchange system; Piston diaphragm positive displacement pumps; Multi-stage centrifugal slurry pumps. This paper presents a review of these pump technologies and notes the technologies selected for the Debswana operations.*

*The selected pump technologies are evaluated for the future Orapa No 3 plant considering a range of slimes densities corresponding to different thickener selections, such as conventional and paste thickeners. The comparison basis is operational considerations and total cost of ownership over the life of the mine.*

## 1 Introduction

Orapa mine is situated in Botswana's arid central district where water is a scarce resource. Orapa is planning to replace one of its older plants, the No. 1 plant, and to upgrade the existing No. 2 plant with new waste disposal systems. The mine has investigated a number of options for future final residue dewatering and disposal. These include dewatering using conventional, high rate and paste thickeners with the associated disposal options. An integral part of this assessment is determining the pumping requirements for the systems considered and the equipment available to fulfil the requirements.

This paper presents the investigation into pumping options for the slimes disposal system and the comparison of suitable options from a financial and operational standpoint.

## 2 Pumping technology investigations

### 2.1 Background

A number of pumping options were investigated for Debswana for the disposal systems, including new and old pumping technologies, to determine their benefits for Debswana mines.

There are widely known technologies that are currently used in slurry pumping applications, such as centrifugal and piston diaphragm (PD) pumps. A review was also conducted for Debswana into alternate pump technologies that have been considered for slurry pumping applications over the last 30 years. A number of new technologies were also identified as having potential for applications at Debswana mines.

## 2.2 Previous pumping technologies

A number of slurry pumping systems have been developed over the years. These include the Mars pump shown in Figure 1 and the Hitachi pump shown in Figure 2.

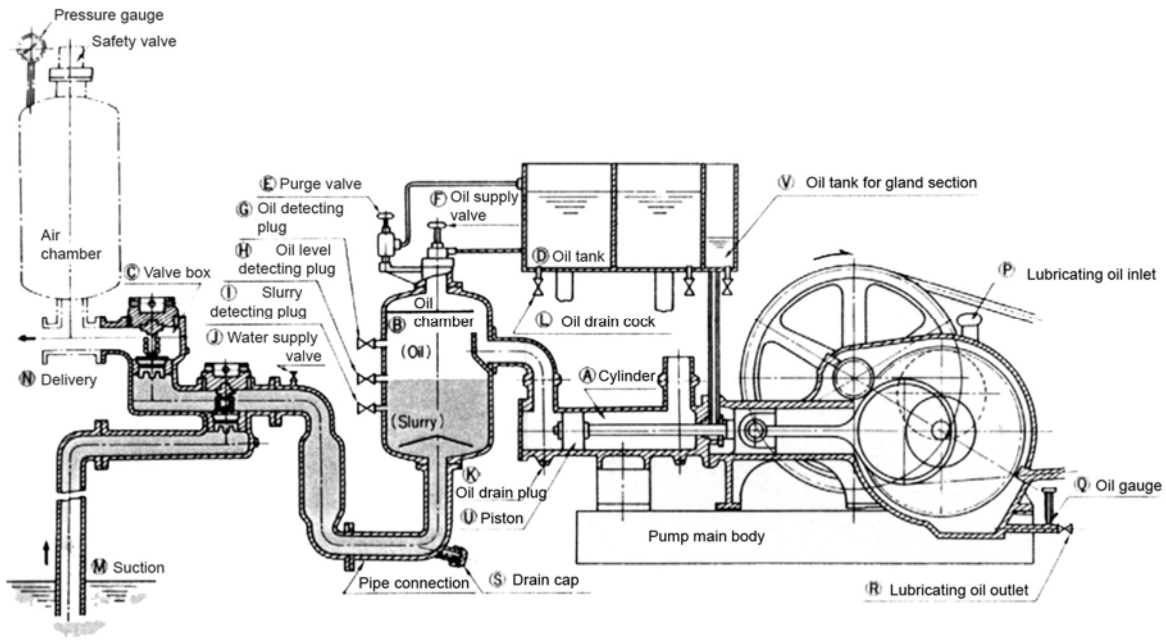


**Figure 1 Mars pump (Snoek and Gandhi, 1991)**

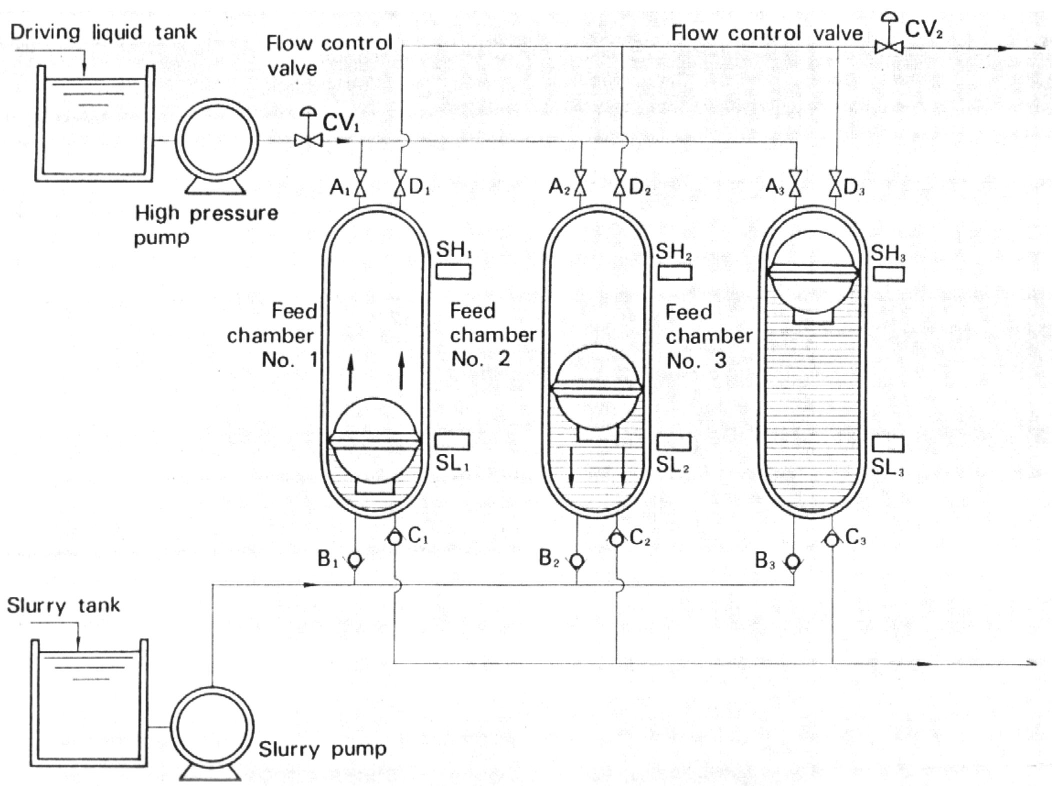


**Figure 2 Hitachi slurry pump (Sakamoto et al., 1979)**

Most of these technologies have been supplanted by piston diaphragm pumps. However, there is ongoing development on a number of these concepts, such as the water separation pump under development in China (Yu et al., 2007) and the hydrohoist system used in the Czech Republic for high pressure pumping systems (Kolarcík et al., 2007) which are both similar in concept to the Hitachi pump.

## 2.3 Current pumping technologies

The two suitable pumping technologies which can be used at Orapa are centrifugal pumps, for lower yield stress material, and PD pumps. While PD pumps have higher capital costs they provide operational benefits such as higher pump efficiencies and no gland service water (GSW) requirements. Centrifugal pumps are limited by the pump pressure ratings and the yield stresses that can be pumped without significant efficiency losses, but have a lower capital cost.

## 2.4 New pumping technologies

Two new pumping systems were also identified as being suitable for use at Orapa, the Phoenix pump, developed by Nicro Engineering of South Africa, and the APEXS pump, developed by Combined Resource Engineering of Australia. Both are intended as alternatives to PD pumps with the capability to operate at high pressures and with higher efficiencies than centrifugal pumps.

The Phoenix pump was originally developed for water pumping applications. It has not been used for slurry applications and no water systems are currently operational. The design concept is similar to some previous pump designs, incorporating a diaphragm for separation between the pumped slurry and the motive fluid, water. What sets this pump apart from other similar systems is the large chamber size, resulting in slow cycling from one to the other and therefore theoretically substantially lower wear on the non return valves. Some design concerns were identified that needed to be resolved during pilot scale test work. A financial comparison of the system with equivalent PD pumps showed that there was incentive to pursue the development of the pumps. However, at the early stage of development for pumping slurry there is considerable risk attached. No further development test work was carried out on the project due to both the manufacturer’s unwillingness to commit additional development resources and Debswana’s reluctance to proceed with a prototype in its early stages.

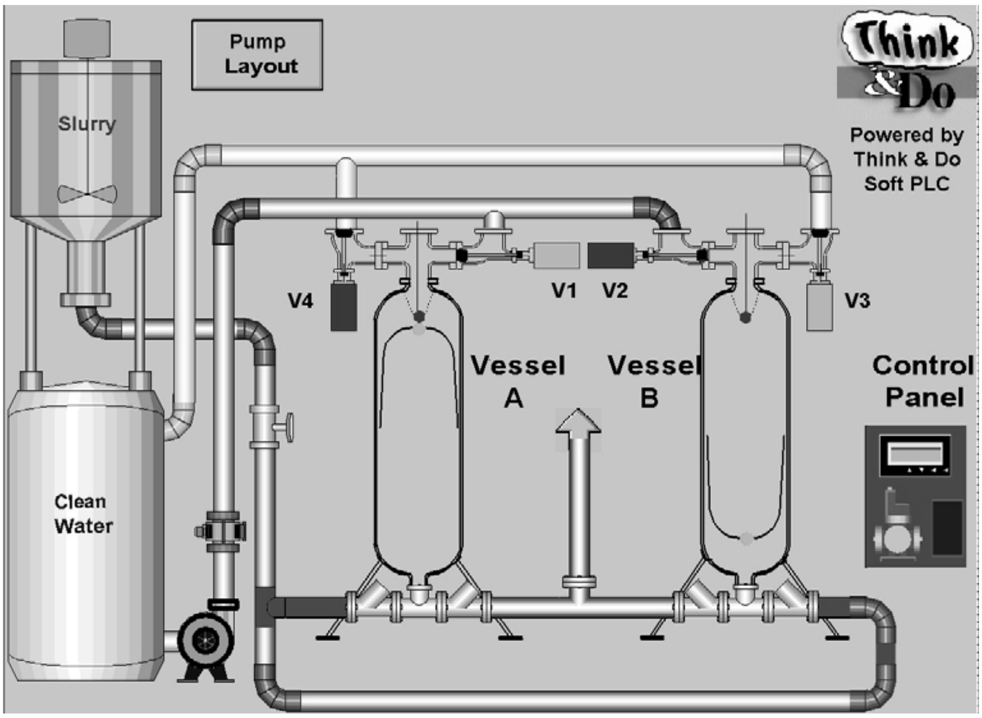


**Figure 3 Phoenix pump schematic**

APEXS pumps are operating at a number of installations in Australia as mine dewatering pumps. The pump is another variation on the diaphragm system, utilising hydraulic pumps for motive power. A technical and financial evaluation of the APEXS pump was carried out to compare with PD pumps. The operation of the APEXS pump was expected to be slightly affected by the material viscosity and yield stress that the pump would operate with at Orapa. To determine if there were any slurry related issues that had not been identified a pilot scale test unit was required before making a decision on a full scale unit. While the APEXS pump appeared to have the potential to operate successfully for the paste duty, the financial comparison of the APEXS pump system with a PD pump system showed that there was no apparent cost benefit. While the APEXS pump appeared to be a technically feasible alternative to PD pumps there was additional risk associated with the development of new technology. APEXS pumps are therefore no longer considered for the Orapa disposal systems.

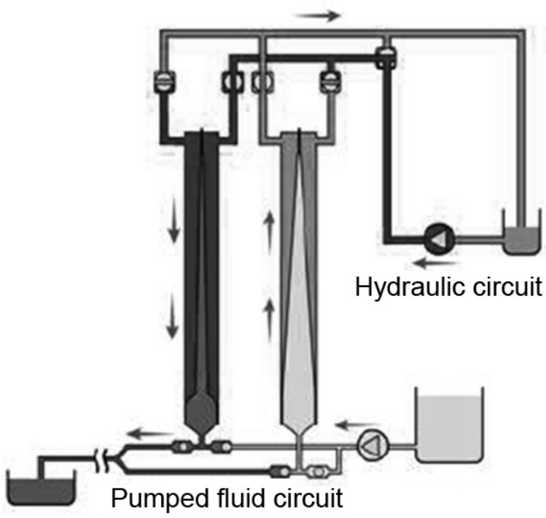


**Figure 4 APEXS pump schematic**

The new technologies considered did not offer significant operational or cost advantages over PD pumps, which are an established technology. The pumping options considered for the Orapa system are therefore centrifugal and PD pumps.

# 3 Pump operating comparison

While both centrifugal and PD pumps can achieve the system requirements, some aspects of the pump operation may lend themselves more towards the duty requirements than others. This section is an assessment of the pump suitability for the operation.

## 3.1 Pump range

The tonnage reporting to the slimes stream at Orapa varies with the ore treated, as does the achievable underflow density. The system must therefore be able to operate over a wide range of flow rates to accommodate this. The range of operating points is shown in Figure 5.

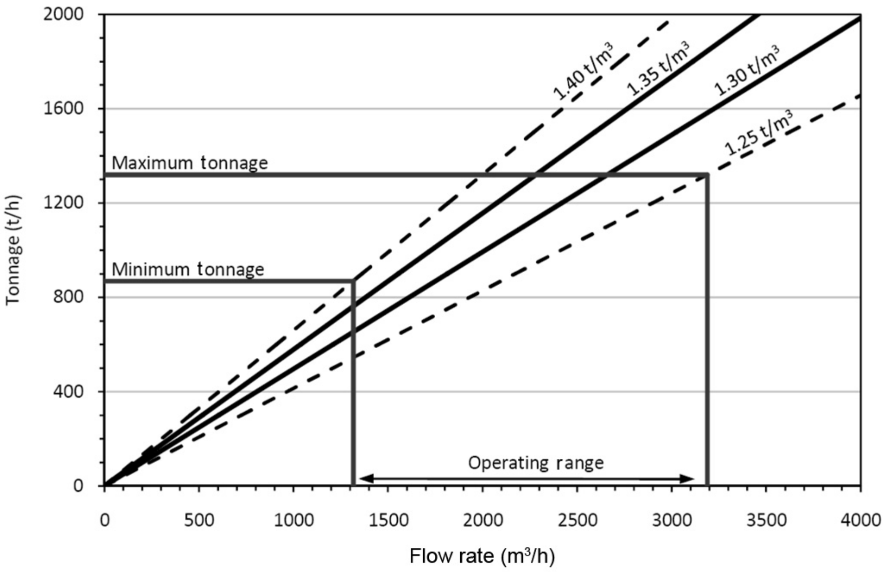


**Figure 5 Orapa operating range**

The selected pumping system should operate continuously over as much of the flow rate range as possible. The flow rate for a PD pump system is the combined discharge of a number of pumps operating in parallel, with each pump having a variable speed drive (VSD). The flow rate delivered by each pump is directly proportional to the pump speed.

The normal operating range for a single pump is from 50 to 100% speed (50 to 100% of the pump's design capacity). The number of operating pumps can be varied to give a wide variation in system pumping rate. The minimum pumping rate is theoretically one pump operating at 50% of its design capacity.

The permissible flow rate range for centrifugal pumps is dictated primarily by the pump volute discharge velocity and the operating point on the pump curve. Limits set on these parameters are determined by the slurry properties (slurry density and particle size) according to the guidelines provided by the Hydraulic Institute (2005) for cost effective pump performance and wear life. These are summarised in Table 1.

Based on particle size distribution and expected nominal slimes density, the Orapa slimes stream is at the border between a Class 2 and Class 3 slurry. The design guidelines for Class 3 service duty have been applied to the design to ensure reasonable pump wear component life.

**Table 1 Pump operating range limits**

| Service Duty | Impeller Tip Speed Limit | Pump Discharge Velocity Limit | Flow Rate Range Limit (% of BEP(1) Flow Rate) |
|---|---|---|---|
| Class 3 | 33 m/s | 8 m/s | 50 to 110% |

(1) Flow rate at best efficiency point for a given pump speed being considered.

### *3.1.1 Results*

The operating ranges of a number of suitable pump sizes are shown in Figure 6. To provide pumping capacity over the full duty range either PD pumps or two trains of centrifugal pumps are required.

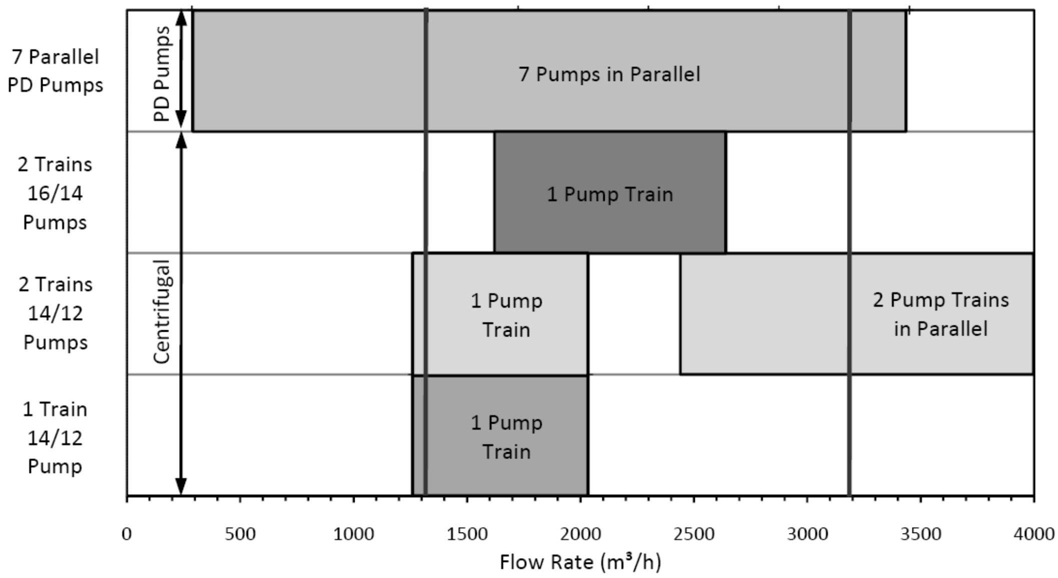


**Figure 6 Pump operating ranges**

## 3.2 Pump operation

A number of other aspects relating to pump operability have been identified and are presented in Table 2.

**Table 2 Pump operating comparison**

| | Centrifugal System | PD Pump System |
|---|---|---|
| Pros | Technology currently in use at the mine.<br>Multiple pump stations could all have the same layout, reducing design and construction costs. | A single pump station is required, even for high yield stress slimes.<br>The system can be controlled at high pressures and low flow rates to clear blockages.<br>The system has fewer components and therefore control is simplified.<br>The system has lower power consumption due to higher pump efficiencies.<br>Continuous operating range for system duty. |
| Cons | Gland service systems (GSW) result in dilution, are difficult to set up and have proved to be problem areas at Orapa.<br>Intermittent operation over some of the duty range.<br>There is the potential for de-rating problem if the system is operated at low flow rates and high yield stresses.<br>Booster pump stations will require additional control and maintenance personnel.<br>Power lines and additional services such as water and communication are required to the booster pump station locations. | Only one pilot PD pump is currently installed at the mine.<br>PD pumps have a long lead time (currently 18 months).<br>PD pumps are more susceptible to currency fluctuations than locally supplied equipment. |

# 4 Pump financial comparison

## 4.1 Financial comparison scenario

Debswana has initiated a number of studies to determine the cost of slimes disposal pumping systems at Orapa mine. Previous studies compared the use of centrifugal pumps for high density slimes systems with the use of piston diaphragm (PD) pumps for paste systems. These studies showed a large cost difference between centrifugal and PD pumps, but this was largely due to differences in system duties with the PD pump systems operating at much higher pressures than the centrifugal pump systems. Direct comparisons between the cost of a centrifugal pump system and a PD pump system could therefore not be drawn.

Here the PD and centrifugal pump options are compared for the future No. 3 plant at Orapa mine for the same duty. The pumping requirements will be determined by the disposal method selected for the mine. The pumping systems have therefore been compared for the disposal options selected: conventional, high density and paste systems, referred to as Case 1, 2 and 3 respectively. The yield stress values and the resulting pumping requirements are shown in Table 3 for the analysis cases.

**Table 3 Comparison scenario details**

| | Case 1 | Case 2 | Case 3 |
|---|---|---|---|
| Yield stress | 25 Pa | 45 Pa | 100 Pa |
| Pumping pressure | 2.5 MPa | 4.5 MPa | 11 MPa |

### *4.1.1 Centrifugal pumps*

For a single centrifugal pump station the maximum discharge pressure is limited to approximately 5 MPa by the pump casing pressure rating. Based on this limitation one pump station is required for Case 1 and Case 2, but Case 3 requires three pump stations.

### *4.1.2 PD pumps*

PD pumps do not have these pressure rating limitations. The pressure output capacity of PD pumps can be up to 25 MPa for some models. One pump station can therefore be used for all the cases analysed, but different pump models are required.

## 4.2 Cost estimate summary

The cost estimate results are presented in Botswana Pula (The exchange rate used is BWP 6.50 to US$ 1(February 2008)) in Table 4 and in Figures 7 to 9.

**Table 4 Case cost estimate comparison**

| | Case 1 | | Case 2 | | Case 3 | |
|---|---|---|---|---|---|---|
| | **CF pumps** | **PD pumps** | **CF pumps** | **PD pumps** | **CF pumps** | **PD pumps** |
| Capital cost | P 76.7 M | P 127.0 M | P 86.1 M | P 145.2 M | P 136.2 M | P 192.7 M |
| Annual operating cost | P 7.7 M | P 6.6 M | P 12.6 M | P 8.0 M | P 23.9 M | P 12.4 M |
| Net present cost (Assessed over 20 year project life) | P 176.3 M | P 212.3 M | P 248.8 M | P 249.3 M | P 446.1 M | P 353.9 M |

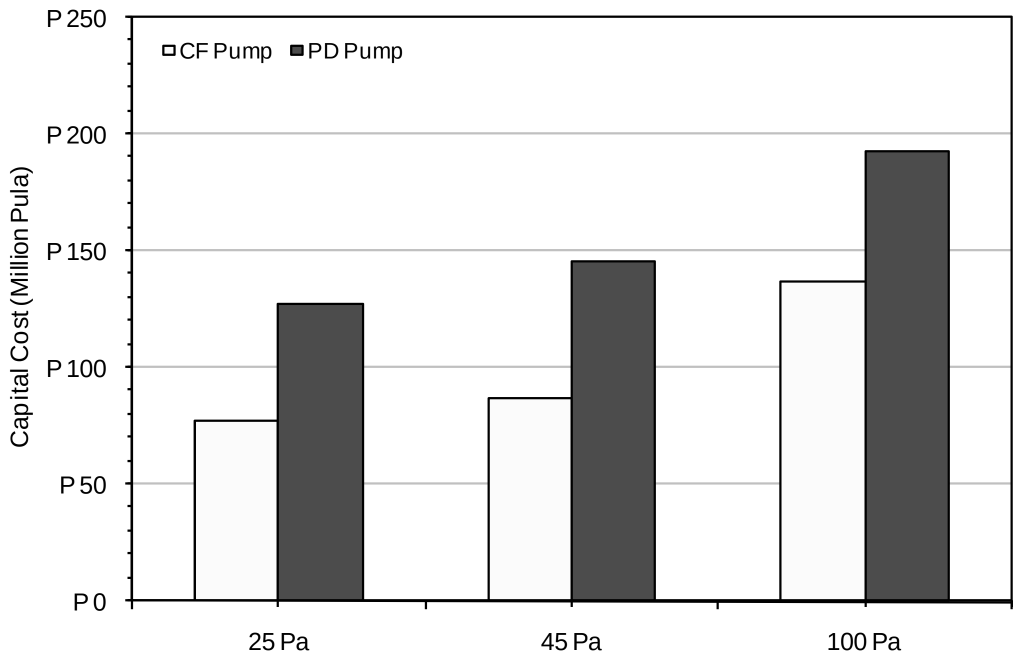


**Figure 7 Pump capital cost comparison**

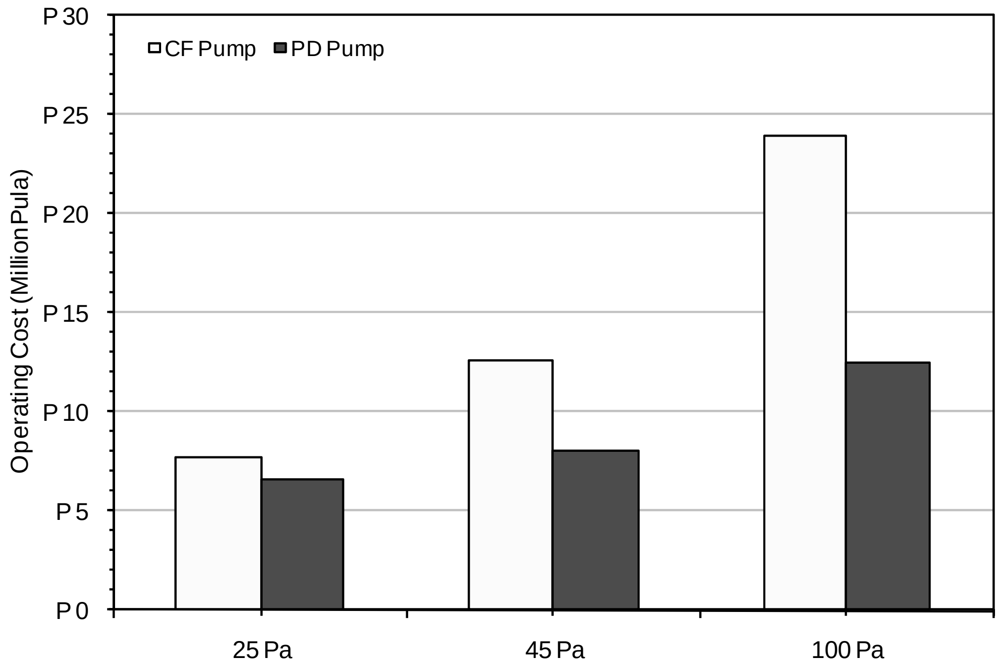


**Figure 8 Pump operating cost comparison**

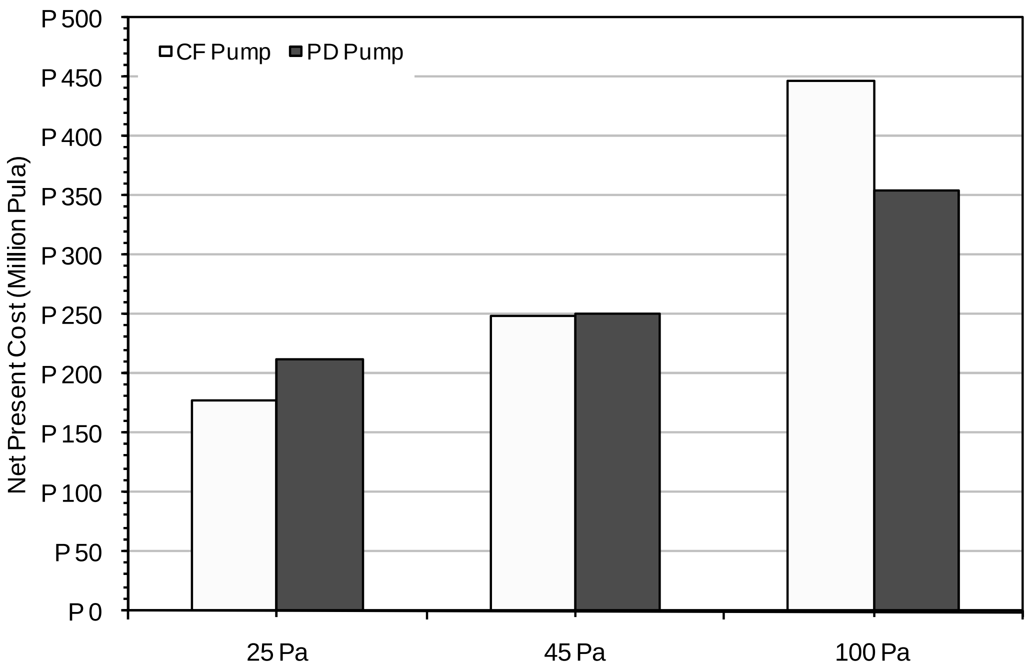


**Figure 9 Net present cost comparison**

### 4.3 System comparison

In all cases the centrifugal pump systems have a lower capital cost than the PD pump systems, due to the cost of the PD pumps themselves, but a higher operating cost, due mainly to the lower centrifugal pump efficiency.

For Case 1 the net present cost over the life investigated shows that the centrifugal system has a lower life cycle cost. This is expected as the PD pumps are not designed for high throughputs at low pressures.

For Case 2 the net present costs are almost equal. This intermediate duty is on the limit of a single centrifugal pump station, but the pressures are sufficiently high that it is reasonable to consider using PD pumps. PD pumps have operational benefits, such as lower maintenance requirements and no need for GSW water.

For Case 3 the net present cost is strongly in favour of the PD pumps. In addition to the higher cost of multiple centrifugal pump stations, the system would also be much more complicated and require additional manpower.

## 5 Conclusions

To determine the appropriate pumping solution a number of factors must be considered for an operation. In additional to the financial case, the operational range required and the ability to maintain effective control over the envelope must be evaluated. The control complexity and the maintenance requirements of the options must also be considered.

For the Orapa system, using PD pumps provides a cost effective solution for pumping applications at the limit of one centrifugal pump station or requiring multiple centrifugal pump stations. In addition, PD pumps provide operational benefits, such as a wide range of continuous operation and the exclusion of the gland service water requirements for centrifugal pump trains.

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