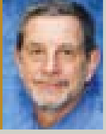
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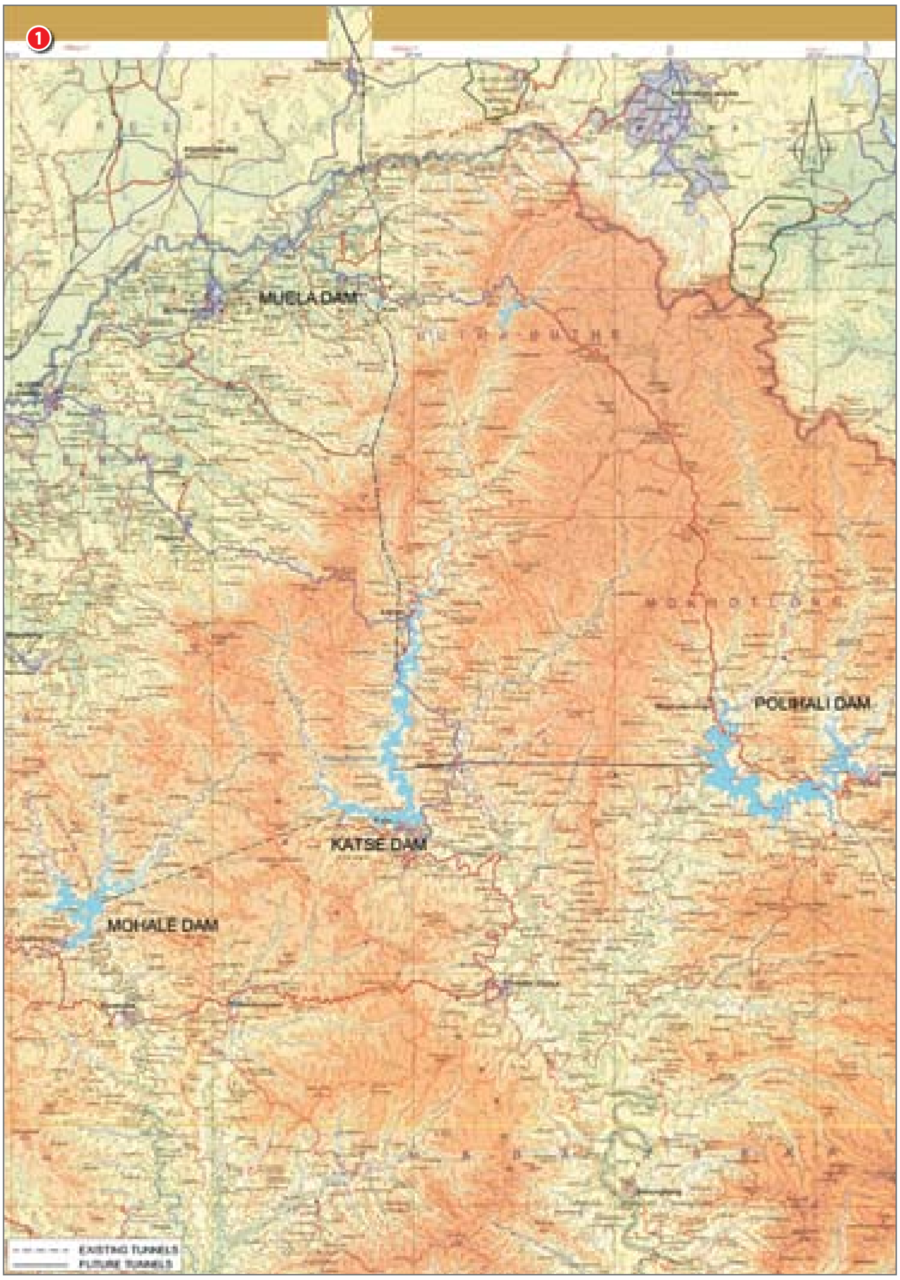
An overview of the engineering components
Lesotho Highlands Water Project:



BACKGROUND

The Lesotho Highlands Water Project (LHWP) Treaty, signed in October 1986, envisaged the development of the project in a number of phases to transfer up to a maximum of 70 m^3/s of water from the highlands of Lesotho to the Vaal River System in South Africa, and committed both parties to implement Phase I. Phase I has been implemented and commissioned.

Before agreement could be reached on the development of further phases, certain key issues needed to be resolved between the parties and the main features of the further phases (after Phase I) had to be defined. The parties agreed to undertake jointly a two-stage feasibility study in order to acquire and collate the information necessary to make a decision on the further phases.

In Stage 1 of the feasibility study, all previous studies were reviewed and a reconnaissance study of possible layouts to meet the specified schedule of water deliveries to South Africa (the "Delivery Schedule") was carried out. Some 21 layouts of possible new dams and tunnels, with various phasings, were identified, designed and costed. Pump stations, hydropower plants and infrastructure were designed and costed, with running costs. Costing, economics, social and biophysical impact assessments, together with public participation and layout assessments, completed the Stage 1 investigations. A multi-criteria technical, environmental, social, cost and economic assessment of

1 Phase I layout and proposed Phase II

of the proposed Phase II of the
based on the feasibility study

Table 1 Agreed Delivery Schedule and proposed water transfers

Year	Desired annual water transfer	Proposed annual water transfer	Average flow rate	Cumulative shortfall assuming that proposed Polihali transfers are made
$m^3 \times 10^6$	$m^3 \times 10^6/a$	$m^3 \times 10^6$	m^3/s	$m^3 \times 10^6$
2015	21	0	0	0
2020	84	0	0	323
2025	150	183	5,8	24
2030	215	215	6,8	0
2035	280	280	8,9	0
2040	345	345	10,9	0
2045	410	410	13,0	0
2050	475	465	14,8	10

the layouts resulted in a recommendation of the layout for all future phases of the project to meet the Delivery Schedule. Thereafter the configuration of Phase II of the recommended layout was agreed.

The accepted Phase II consists of the Polihali Dam, which is a concrete-faced rockfill dam, 163,5 m high, on the Senqu River downstream of Mokhotlong, at a full supply level (FSL) of 2 075 m above sea level (masl), transferring water through a 38 km long gravity tunnel to the Katse Reservoir. The Phase II layout is shown in Figure 1.

The Stage 2 feasibility-level study consisted of dam and tunnel design, the assessment of hydropower-generation potential, and feasibility-level designs and costing for access roads, power supply, telecommunications and construction camp facilities. These designs were supported by surveys and mapping, geotechnical investigations, reservoir simulation modelling, water quality assessments, public participation, and social and environmental studies. Legal, institutional, procurement financing and implementation studies completed the Stage 2 study.

WATER RESOURCES

The Stage 2 study included an extensive catchment-specific hydrological modelling exercise for the catchment of the proposed Polihali Dam in order to improve the confidence in the Stage l inflow sequence to the dam and gave a natural mean annual inflow of 697 million m^3/a. However, the stream flow gauging in the vicinity of the Polihali Dam site is being improved.

In the yield determination the long-term average instream flow requirement was modelled at 130 million m^3/a, about 18,7% of the long-term average natural mean annual inflow of 697 million m^3/a.

From the stochastic yield analysis, the reservoir and system yields, for 98% assurance of supply to the Vaal River System (base case results), were:

- The incremental yield of Phase II of the LHWP will be 465 million m^3/a or 14,75 m^3/s.
- The total system yield for the LHWP (Phases I and II) will then be 1 271 million m^3/a or 40,30 m^3/s.

The addition of Polihali Dam to the Orange River System will give an overall increase in yield of the Orange River System of 182 million m^3/a

The agreed Delivery Schedule and proposed water transfers, based on the envisaged implementation programme, are summarised in Table 1.

THE PROPOSED POLIHALI DAM

The location of Polihali Dam and Reservoir are shown in Figure 2.

The key statistics of the Polihali Dam are given in Table 2. It is a concrete-faced rockfill dam with a concrete-lined side-channel spillway and a concrete-faced rockfill saddle dam 49,5 m high.

During construction, the works will be protected by upstream and downstream embankment cofferdams with diversion tunnels 7 and 9 m in diameter through the left flank. Material for the rockfill and concrete aggregate will be obtained from three quarries, primarily located below the full supply level (FSL).

WATERWAYS

After considering three alternative alignments for the gravity tunnel to transfer water from the proposed Polihali Reservoir to the existing Katse Reservoir, the southern alignment, via Matsoku to Katse, as shown in Figure 4, was selected.

The proposed tunnel is 38,2 km long and 5,2 m in diameter, sized to convey a maximum flow of about 35 m^3/s. The intake, with an invert level of 2 000 masl, is located approximately 5 km upstream of the Polihali Dam wall.

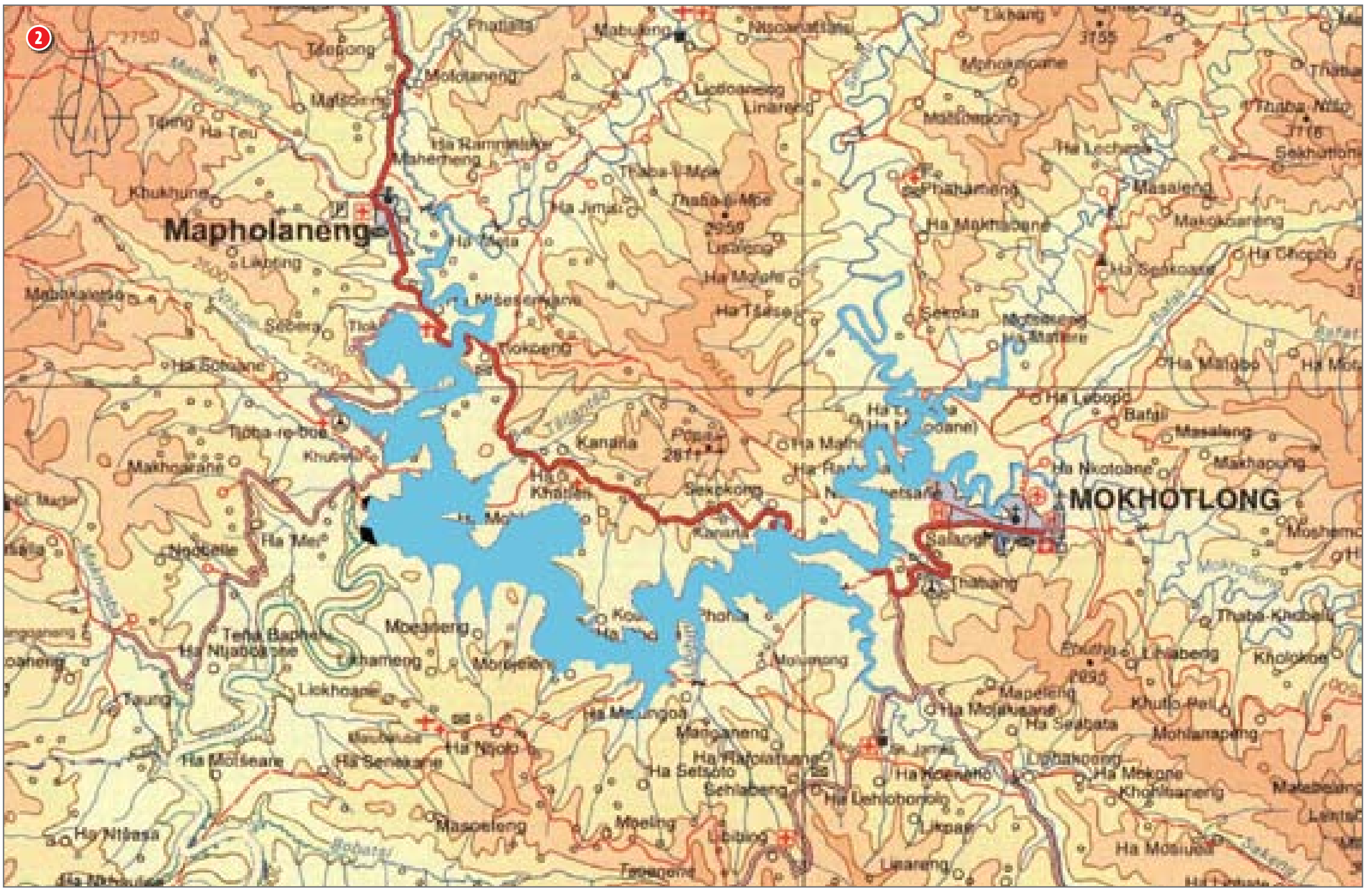
Details of the recommended southern alignment tunnel option are given below and shown on Figure 4. Altogether 29 km of the tunnel will be constructed using two tunnel-boring machines, and the 9 km from Matsoku to Katse will be done in three drill-and-blast drives.

Water from Phase II will flow under gravity into the Katse Reservoir, from where

Table 2 Key statistics: Polihali Dam

Item	Description
Dam type	Concrete-faced rockfill dam
Full supply level	2 075,0 masl
Gross reservoir storage	2 085,5 m^3
Reservoir surface area at FSL	50,4 km^2
Top of rockfill	2 081,5 masl
Riverbed level	1 919 masl
Live storage	1 892 million m^3
Upstream slope	1V: 1,4 H
Downstream slope	1V: 1,25 H, with 4,5 m access road berms at various levels
Main embankment	
Embankment height	163,5 m to top of rockfill
Crest width	10 m
Crest length	915 m
Embankment volume	12 311 210 m^3
Saddle embankment	
Embankment height	49,5 m
Embankment volume	664 380 m^3
Spillway	Reinforced concrete side-channel with chute and flip bucket
PMF outflow	4 024 m^3/s
Outlet works	Free-standing tower, 70 m high and 8,0 m in diameter, with intakes at five levels

2 Polihali Dam and Reservoir: locality map



it will flow through the existing transfer tunnel to the Muela power station, into the Muela Reservoir and through the delivery tunnel to the Ash River outfall. The Ash River already has extensive energy-dissipation and erosion-control measures and it is not anticipated that significant further work, other than some limited additional protection, will be required.

The existing delivery tunnel has sufficient capacity to transfer the water required, until at least 2048. The Muela Dam will not require any modification, but raising the dam and upgrading the delivery tunnel are future options that will increase the hydraulic capacity of the delivery tunnel if required.

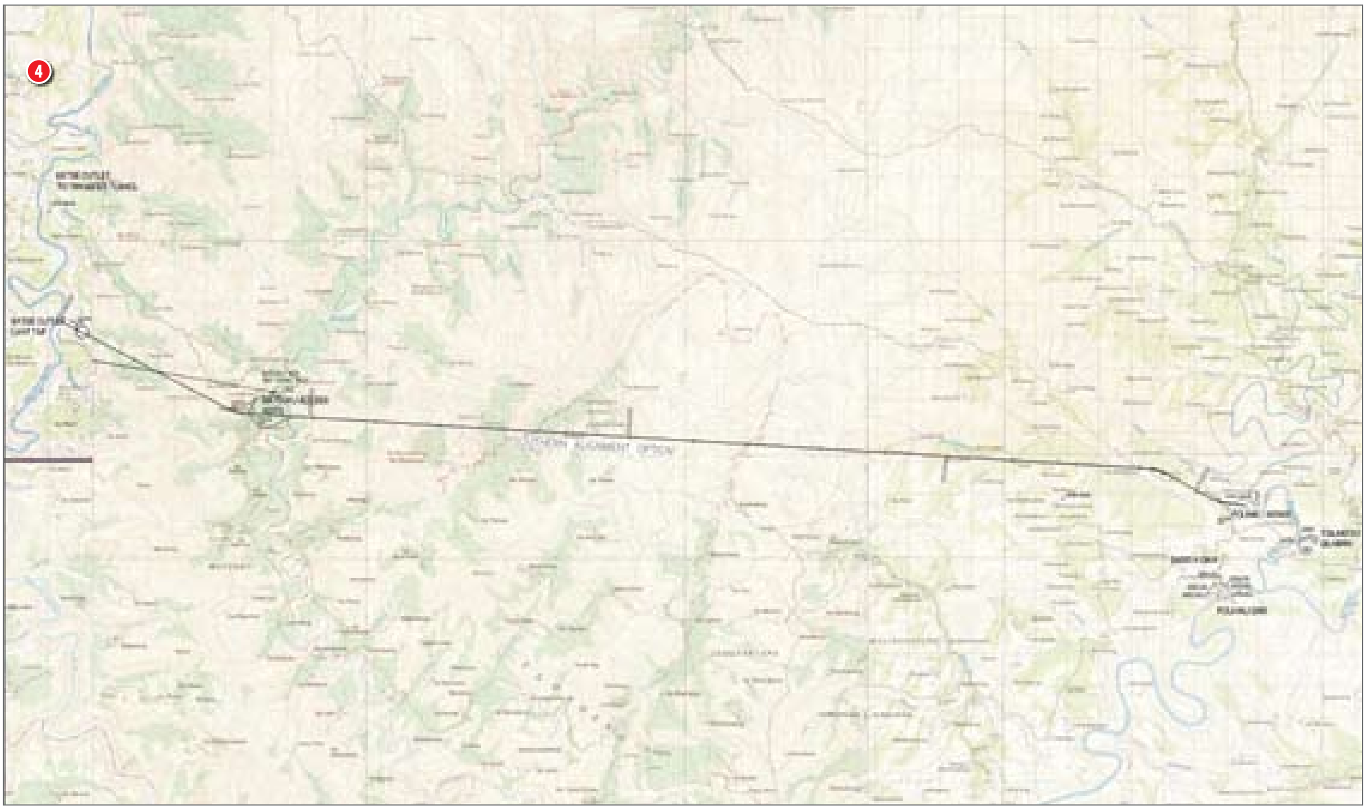
HYDROPOWER

The Phase II development will have the following implications for hydropower:

- Transferring Polihali flows to Katse will reduce the status of the existing Muela hydropower station from being a load-following power station to being a base load plant, generating about 80 MW for 100% of the time. Further potential exists to expand the hydropower generated over and above the 72 MW currently being generated.
- Harnessing the instream flow requirement (IFR) releases from the dams, assumed to equal about 19% of the mean annual runoff, will produce about 4 MW at the toe of the dam and seems to be a cost-effective course of action.

3

4



INFRASTRUCTURE

Two alternative main access routes were investigated:

- The Butha Buthe-Oxbow-Mokhotlong route, with a length of about 80 km, would involve upgrading the width and grades of the existing surfaced road from St Peters via Moteng Pass and Oxbow. From the junction with the surfaced road, the existing gravel road would be upgraded to a surfaced road and extended to the construction sites at Polihali.
- The alternative route from Ha Seshote to Polihali Dam, approximately 60 km long, would, for most of its length, require new construction, crossing three major rivers and several minor streams. It is mainly above the snow line and its design would have to cater for freeze-thaw conditions.

Either of the two routes could be implemented since the capital costs are relatively similar and the final selection of the road access route should be done

Table 3 Summary of costs M refers to Maloti (Lesotho currency) with 1 M = 1 Rand

Cost centre	Activity	Total project cost (incl VAT)
		M x 1 000
Polihali Dam	Construction contract	2 301 604
	Environmental management	70 680
Polihali/Katse Tunnel	Construction contract	1 948 786
	Environmental management	42 180
Access roads and bridges	Construction contract	414 203
	Environmental management	3 420
Feeder roads, road bridges and footbridges	Construction contract	289 726
	Environmental management	2 280
Power supply and telecoms	Construction contract	200 463
	Environmental management	5 700
Camps	Construction contract	206 167
	Environmental management	5 700
	Total construction costs	**5 360 949**
	Total environmental management costs	**129 960**
Engineering	Polihali Dam	420 692
	Polihali/Katse Tunnel	463 928
	Access roads	35 462
	Feeder roads and bridges	94 549
	Power supply	15 389
	Camps	20 073
	Total engineering costs	**1 050 093**
Administration	**Total cost of implementing agent**	**324 292**
Environmental costs	Biophysical monitoring	11 400
Short term	IFR baseline study	11 400
	Environmental mitigation	296 400
	Environmental management (included above)	
	ESIA for advanced infrastructure	5 472
	ESIA for dams and tunnels	5 700
Long term	Environmental monitoring	22 800
	Total environmental costs	**353 172**
Social costs	SIA implementation and monitoring	1 254
Short term	Resettlement and compensation	67 335
	Social mitigation: livelihoods and income restoration	97 802
Long term	Resettlement and compensation	184 560
	Total social costs	**350 951**
	GRAND TOTAL	**7 569 417**

Transferring Polihali flows to Katse will reduce the status of the existing Muela hydropower station from being a load-following power station to being a base load plant, generating about 80 MW for 100% of the time. Further potential exists to expand the hydropower generated over and above the 72 MW currently being generated

3 Polihali Dam – general arrangement
4 Polihali-Katse Tunnel – southern alignment

The implementation programme is based on the Memorandum of Understanding between South Africa and Lesotho, which is being concluded in 2009 and which will allow for the studies to be reviewed and approved, as well as for the parties to agree on the principles for implementation

in conjunction with the selection of the route for the powerline to Polihali.

The reservoir will impede the community's access across the river and inundate some local roads which will have to be relocated above full supply level. Two vehicle bridges, 85 and 135 m high, two footbridges up to 110 m high, as well as additional all-weather access roads have been proposed to provide access across and around the reservoir.

Power supply for construction needs to be provided at the Polihali Dam site, the tunnel intake, the tunnel construction adits and the tunnel outlet works. Communication during construction and operation is vital and provision has been made for appropriate telecommunications infrastructure for the construction camp, the routing of fibre optic cables to all camps, and a tower at Polihali for a wireless code-division multiple-access (CDMA) network.

COSTING

The approach to costing differed for the various components of Phase II. The most detailed estimates were undertaken for the dam and the tunnel. Construction costs were estimated using resource-base costing methods in the same way as a contractor would price a tender. The cost of infrastructure works was estimated using current industry unit rates, adjusted for Lesotho conditions and applied to the relevant items in a Bill of Quantities.

Engineering, administration, and operating and maintenance costs were built up from first principles by estimating person hours and disbursements, and then applying appropriate staff rates and direct costs.

Resettlement and compensation costs were arrived at using assumptions regarding the number of people and the assets that would be affected, then applying current costs or current Lesotho Highlands Development Authority rates, adjusted where applicable. The cost of the environmental management activities, including livelihood and income restoration, and social and biophysical surveys, were assessed from first principles and compared with experience from other projects.

Physical operating and maintenance costs were estimated at M 20 million per annum for the life of the project.

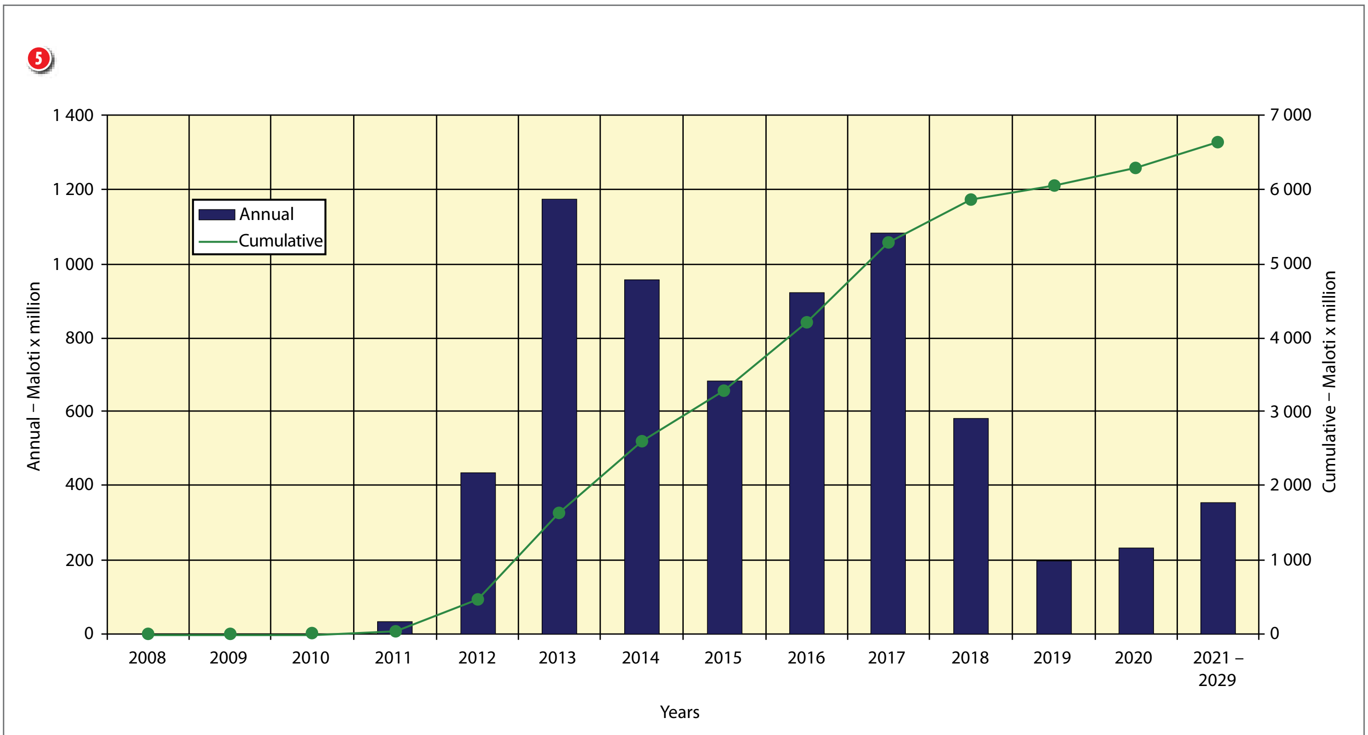
The capital expenditure cash flow is presented in Figure 5.

IMPLEMENTATION PROGRAMME

The implementation programme is based on the Memorandum of Understanding between South Africa and Lesotho, which is being concluded in 2009 and which will allow for the studies to be reviewed and approved, as well as for the parties to agree on the principles for implementation.

The programme indicates that it will take about 10 years from when the parties sign the Memorandum of Understanding, allowing project implementation to

5 Projected cash flow



commence, until the first delivery of water from the Polihali Dam can be made.

The various agreements, studies, resettlement and compensation, design and tendering processes will take approximately four years. The construction activities, some of which will run concurrently with the later design activities, will begin with the infrastructure contracts and take a total of seven years. Two-and-a-half years have been allowed for the dam to fill to minimum operating level and four months for commissioning the works.

According to the accepted Delivery Schedule, the Vaal River System will require limited further augmentation from 2013. As described above the first delivery from Polihali cannot be expected before 2019, so there will be a shortfall for six years. However, this shortfall can be made up by implementing water demand management measures and by reusing mining effluent and wastewater. Continued implementation of the latter course of action could mean that the next augmentation of the Vaal River System, after LHWP Phase II, may only be required in about 2050.

Allowance of 30 months has been made for impoundment to reach the minimum operating level, at which time commissioning can commence. The construction of the tunnel should not affect or be affected by impounding.

CONCLUSION

The feasibility study has defined the main features of Phase II and further phases, thus providing the information required to enable the Lesotho and South African governments to resolve key issues and decide to proceed with Phase II of the project.

ACKNOWLEDGEMENTS

The feasibility study was carried out for the Lesotho Highlands Water Commission by the C4 SEED Joint Venture which consisted of SEED (Senqu Engineering, Environment and Development Consultants) and Consult 4 (Goba (Pty) Ltd, Ninham Shand (Pty) Ltd, SRK (Pty) Ltd and Vela VKE (Pty) Ltd), consulting groups. □

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Source: http://www.saice.org.za/downloads/monthly_publications/2009/2009-Civil%20June/#/0