NVE - Water Resources Directorate

HYDROELECTRIC POWER IN LESOTHO

V - PUBLICATION Nº 3

NORWEGIAN
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ENERGY ADMINISTRATION

V- PUBLICATION

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ABSTRACT:

This V-publication describes different hydro power projects in Lesotho including Lesotho Highland Water Project, which is to export large amounts of water to the Republic of South-Africa.

SAMMENDRAG:

Rapporten gir en oversikt over prosjekterte vannkraftprosjekter i Lesotho, samt et stort vannforsynings/irregasjonsprosjekt som skal forsyne Johannesburg-området i Sør-Afrika med vann.

SUBJECT TERMS

Hydro Power Resources Studies

EMNEORD:

Ressursstudier

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FOREWORD

This report is prepared for The Norwegian Agency for International Development (NORAD), and is based on visits to Lesotho in 1985 and 86 and information kindly given by Ministry of Water, Energy and Mining (WEMMIN) which is charged with the responsibility for planning and implementation of water resources projects in Lesotho.

It gives a short description of hydrology, dams, waterways, mechanical equipment etc. on planned schemes which might be useful for those who want to learn about hydro power options in Lesotho.

Torodd Jensen

CONTENTS PAGE

HYDROELECTRIC POWER IN LESOTHO

1. GENERAL

1.1 The Resource

The Kingdom of Lesotho is endowed with an abundant supply of water, particularly in the Highlands which receives an annual rainfall of 1000 mm.

The water, or "White Gold" of Lesotho drains away to the Republic of South-Africa (RSA) before discharging into the Atlantic Ocean.

So far there are few or none investments in irrigation, hydro power, water supply and other water resources projects. The basic challenge, therefore, remains how to utilize such a natural resource, and convent it to a source of income for the Kingdom of Lesotho.

1.2 Large Hydro Options

Lesothos technically exploitable hydroelectricity potential is estimated at about 2000 GWh (450 MW). However, the cost of harnessing this potential is high because of the lack of natural heads and erratic seasonal flow patterns. The potential will take many years to develop and will depend on assurance from The Republic of South Africa (RSA) to buy energy from these projects.

Today there are plans for several large hydro power schemes which can utilize approximately 35% of the estimated potential.

1.3 Mini Hydro Options

The Government recognizes the potential role of mini/micro hydropower plants in reducing the dependence on diesel generators in areas remote from the transmission/distribution network of Lesotho Electricity Corporation (LEC). Mini/micro hydro schemes are usually of the run-of-the-river design.

Mini-hydro projects in the Highlands and the Lowlands have been studied by several companies and some 20-30 different sites have been investigated. The investmentcost of the schemes varies from NOK 5-20 kr/kWh.

1.4 Hydro Power Schemes mentioned in the report

Today there is not a single hydro power plant in operation in Lesotho. Two small hydro power plants are under construction and will be commisoned in 1987, and the construction of two other small plants will start early in 1987. Several pre-feasibility and feasibility studies on small and large hydro power schemes have been carried out the last years by different consultants.

This report gives information on the schemes under construction and 9 other small schemes. Information is also given on large schemes of which Lesotho Highland Water Projects are the most important.

2. LARGE HYDRO

2.1 Lesotho Highlands Water Projects (LHWP)

LHWP has been planned from the early 1950's and includes export of large amounts of water to the RSA. Implementation of the LHWP would give a hydro powerstation with a total output of approximately 275 MW, and mean annual energy production ca 870 GWh. In addition there will be pumping stations with installed capacity 55-60 MW and mean annual energy consumption approx. 150 GWh. Over the years the plans have changed and today they include Malibamatso, Segu and Sengunyane rivers. (Sengunyane had earlier been included in a multipupose scheme called The Jordane scheme diverting water from Sengunyane to the western lowlands. 150 GWh/40 MW/NOK 1 200 x 10^6 1984).

The LHWP consist of three phases. Phase I is planned in two steps. Step IA includes the implementation of Katse reservoir, a transfer tunnel to Sentelina pond, the Sentelina pond which is headwater for Thlaka hydro power station with planned output 74 MW, Tlaka pond (tailwater for the power station) and a transfer tunnel to Ask river in the RSA.

Step IB includes the construction of Mohale reservoir in Senguniane river, a transfer tunnel from Mohale to the Katse reservoir and a third turbine of max output 37 MW in the Tlaka hydro power station (appendix 1).

Phase II is the implementation of Mashai reservoir, a pumping station and transfer tunnel between Mashai and the Katse reservoir and the possibility for implementation of Matsohu reservoir and a transfer tunnel between Matsohu and the Katse reservoir.

Phase III includes the implementation of Tsoelike reservoir, a pumping station and transfer tunnel between the Tsoelike and Mashai Reservoirs.

The map in appendix 1 gives an overall view of the total project. Appendix 2 gives basic data for each phase including cost and time schedule.

2.2 Oxbow Project

Oxbow hydropower project diverts the water in Tsehlanyane river to the planned Tlhaka pond in phase 1A in the LHWP. Tsehlanyane flows naturally into the Katze pond which will be built in phase 1A in the LHWP. Hence phase 1A in the LHWP will utilize the water in Tsehlanyane in the Tlhaka Hydropower station before it flows into the Tlhaka pond. From Tlhaka pond the water will be diverted to Ask river in the RSA.

The development of the LHWP phase 1A will utilize the water in Tsehlanyane in the Tlhaka powerstation with head approx. 200 m. If the Oxbow hydropower scheme is to be implemented, it should not be calculated with head more than 500 m (the total head is 700 m). This will reduce the output by 28%. This shows that the implementation of the Oxbow project depends on the implementation of the LHWP and the economical calculation have to take into consideration the plans for the LHWP.

A dam in the Tsehlanyane river will raise the water level to 2480 thus creating a reservoir of approx. 100 x 10^6 m^3 which is the same as the mean annual discharge in the catchment area. The water will be led to the powerstation at Tlhaka by a headrace tunnel and a penstock. The dam is very expensive and should be further optimized.

The Oxbow hydropower project will have an output of approx. 55 MW and an energy production of 160–180 GWh depending on the reservoir level in Tsehlanyane valley. The costestimate is approximately 1,000,000,000,– NOK (1986), (333,000,000 M).

More data for the project is found in appendix 3 and 4.

2.3 Quthing project

The project is not in conflict with the LHWP. The scheme includes diverson tunnels in the Quthing catchment area to lake Letseng-La-Letsie which will be the reservoir. The hydropowerstation utilize the water from the reservoir at level 2400 to Quthing river at Ha Lethena, level approx. 1880. The waterway will consist of a penstock, a tunnel or a combination. The installed capacity should be discussed with LEC to get an optimum solution of the development of the energy resources in Quthing and the necessary construction of transmission lines between Quthing and Maseru.

A study carried out by Water Resources Management and Hydro Engineering Department in Austria included the rivers Quanalu, Liphophi and Folestri and a reservoir at Letseng-La-Letsie.

In 1984 the study concluded that the scheme could give a mean annual energy production of 35 GWh with output 15 MW to a costprice of approx. 190 mill NOK. The waterway from Letseng-La-Letsie to the power station was planned to be a penstock.

In this book the Quthing scheme is presented with Likhaelbaneng river in addition to the rivers mentioned in the Austrian scheme. The dam at Letseng-La-Letsie is calculated as a rockfill dam with bitumen core and the headrace is a tunnel and shaft leading the water to an underground power station. The solution depends on the rock. If it is basalt it should be posible. The new calculation is rough and only ment as a pre-feasibility study. NB! The costestimate only covers the construction of the scheme and necessary access roads. The necessary implementation of transmission lines to Maseru is not included.

Regarding hydrologi the report from 1984 gives a mean flow at Letseng-La-Letsie of 0,5 m^3/s which means specific runoff of 11,6 $l/s/km^2$. This is almost equal to the specific runoff in the catchment area of the Oxbow scheme. Since the Austrian report states that there are uncertainties to the hydrological calculations and the difference in mean annual rainfall between Oxbow and Quthing catchments areas is approx. 30%. It is assumed a specific runoff of 8,5 $l/s/km^2$ in this report.

New studies should concentrate on hydrology and economical evaluation on max output. If an underground scheme is possible, then additional cost for raising the output from 15–25 MW is low. Implementation of this project will give a large hydro power station in the south of Lesotho and would be a security to Maseru compared to the Oxbow power station and the power station in the LHWP which are located in the north of Lesotho.

More data in appendix 5 and 6

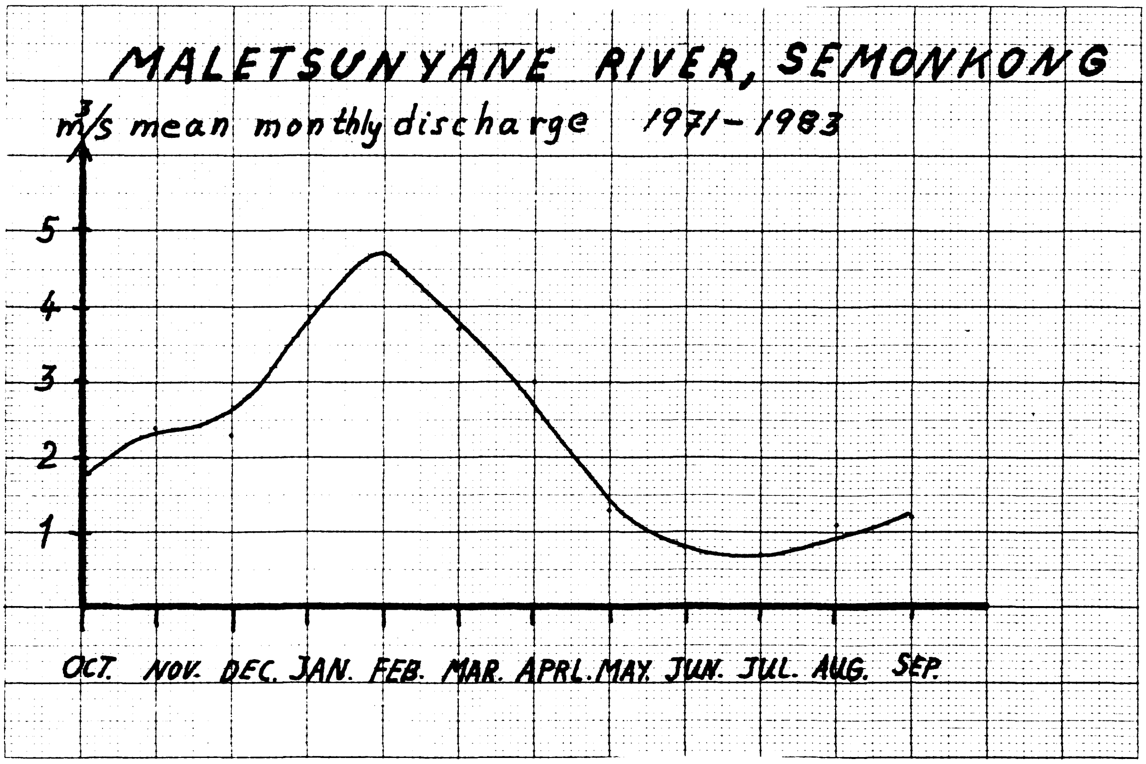
3. SMALL HYDRO

3.1 General

A French consulting firm (SOGRFAH) and a Norwegian consulting firm (NORPLAN) has carried out feasibility studies for several small hydro power plants in Lesotho. The results of these studies are presented with help from WEMMIN.

The report probably does not include data from all pre-feasibility studies of small hydro power plants that has been carried out in Lesotho, and there are still sites to be investigated. So fare sites for small hydro power plants are located near villages where there is an excisting energy demand (Semonkong) or where there is an existing transmission line which makes it cheap to transport the energy to areas where it can be utilized (Mantsonyane). Most small rivers and some large rivers in Lesotho have no gauging station in operation, hence hydrological data is not always available. This lack of data is a disadvantage for studies of small run of the river plants. However, hydrological works carried out for the LWHP and the Oxbow scheme can in some extend be transformed to nearby small rivers. But there is still need for hydrological work in Lesotho.

Small run of the river plants will have to depend entirely on the flow in the river. A fig. giving the yearly average discharge based on monthly mean flow in Maletsunyane river shows that the output from a small scheme will vary a lot throughout the year depending on the max flow through the turbine. Normally there are no uniform consumption of el-energy in rural areas, the load factor is normally between 0,3–0,5, and one will often find that the peak load exceed the possible hydro power output especially during wintertime. A combination with a diesel generator is the most common solution if there are no sites for reservoirs. Reservoirs in Lesotho turns to be expensive and is most likely to be constructed as part of a large hydro power scheme.



Data from Semonkong gauging station 1971-1983

Information from NORPLAN. Drawing T. Jensen

3.2 Sehonghong, Sehlabatebe, Lesobeng

The feasibility studies for this schemes have been carried out by the SOGRFAH Company.

Sehonghong 70 KW, 0.3 GWh/yr, investmentcost NOK 11 x 10^6
Sehlabathebe 100 KW, 0.5 GWh/yr, investmentcost NOK 11 x 10^6
Lesobeng 110 KW, 0.6 GWh/yr, investmentcost NOK 8,2 x 10^6

Because of the variation of energy demand throughout a year, a month ore a day only a small part of the annual production can be used. These small plants are much more expensive than other schemes mentioned in the report and further data is therefore not given in appendix.

3.3 Mokhotlong Hydro Power Scheme

Appendix 7 and 8 give the main data. The Mokhotlong will give an output of 1.5 MW and 7 GWh mean annual production. Investmentcost NOK 32 x 10^6 1984. Data from NORPLAN A/S.

3.4 Motete and Tlokoeng Mini Hydro Power Projects

Appendix 9 to 12 give the main data. Motete can be in conflict with the LWHP. Data from SOGRFAH (France). The construction on Tlokoeng will probably start in 1987, if the financial proposal from France is approved by Lesotho.

3.5 Qacha's Nek Mini Hydro Power Project

Appendix 13 and 14 give the main data.

If connection to the main grid is possible, the scheme can utilize the flow in the river so that the mean annual production rises to approx. 6 GWh. The scheme has been calculated with an output of 500 kW and mean annual production 2.7 GWh. Investmentcost is approx. NOK 19 x 10^6 1984. The calculation is carried out by SOGRFAH. The construction work will probabely start in 1987, if the financial proposal from France is approved by Lesotho.

3.6 Projects in Maletsonyane river

3.6.1 Semonkong

The scheme is under construction and is planned to be commissioned in Dec. 1987. It is situated in Maletsunyane River at Semonkong Falls near the village of Semonkong, which has been designated for development as a rural district centre. It comprises a 1 1/2 m high concrete overflow weir, some 400 m of glassfibre penstock leading to a powerstation in the open equipped with a 180 kW Francis-turbine and a 120 kW diesel generating unit. The station is planned with facilities for the later installation of a second 180 kW turbine operating on 19 m gross head.

The purpose of the project is to provide Semonkong with an electricity supply to replace several separate diesel-powered units which are now privately run, and to provide a community electricity supply at a price level sufficient to stimulate growth of small crafts and community services. Later plans from West-German aid have shown that a woolscouring mill can be built near the powerstation. The energy demand is 100-150 kW and this means that the second 180 kW turbine should be included in the project from the beginning. It also means that there is a need for reservoirs to avoid too much use of diesel generating units during dry-flow periods.

More data in appendix 15 and 18.

3.6.2 Mokhoalapana

This hydro power scheme is totally dependend on a reservoir in the Mokhoalapana river planned to raise the energy production in Semonkong hydro power plant. The necessary investment for the reservoir is very high and it will probably not be implemented unless multi purpuse aspects are taken into consideration.

Data for the hydro power scheme, appendix 16 and 18.

3.6.3 Maletsonyane

This hydro power scheme is dependend on a reservoir in Maletsonyane river planned to raise the energy production in Semonkong hydro power plant. Studies has shown that implementation of a reservoir of 8–10 mill m^3 will raise the firm energy prodution in Semonkong by 0.65 GWh and that the investmentcost might be low enough to make the scheme economically feasible.

Data for the hydro power scheme, appendix 17 and 18.

3.7 Projects in Mantsonyane River

3.7.1 Mantsonyane I Hydro Power Plant

The scheme is under construction and is planned to be commisioned in Dec. 1987. It is located near the village of Mantsonyane in the central highlands of Lesotho (appendix 1) and comprises a rockfill dam with asphaltic core membrane, an unlined tunnel of minimum crossection (ca 9 m^2) with a total length of 655 m and a power station equipped with two Francis–turbines of 1.5 MW and 0.5 MW output respectively. Appendix 19 gives the main data. A map of the project area is found in appendix 24.

The power project is intended to feed the existing 33 kV–line from Maseru to Thaba Teseka which passes through Mantsonyane. The demand for energy and peak power is high compared to the possible production at Mantsonyane. The choice of installed capacity is therefore entirely dependent on the hydrology of the river.

A small reservoir of about 0.6 mill m^3 will allow a 4 days continous supply from the small turbine, which means that short term failure of the Maseru grid can be suitably covered. The large turbine is a peaking unit, running on an average 4–8 hrs per day during weekdays.

3.7.2 Mantsonyane II Hydro Power Project

Implementation of Mantsonyane no II could if the construction starts at the time when Mantsonyane no I is commisioned use the workers, construction camp and equipment from the first project.

The intake for M II is in Mantsonyane river at the confluence of Mantsonyane and Tenane rivers. There are different alternatives for utilizing the rapids between this intake and the headwater for M I. The best solution seems to be to construct a dam at the intake site big enough to enable the construction of a spillway on a saddle separate from the dam (Appendix 21), and to build the power station approx. 5.5 km downstreams in the river. This solution gives a headrace–tunnel of 2.800 m. Access to the power station will cross the Mantsonyane I dam, hence the operation of the two power stations could easily be combined. A feasibility study is carried out by NORPLAN where experience from the construction of M I where used. More data in appendix 20, 21 and 24.

3.7.3 Mantsonyane Power Stations no. III and IV – Reservoirs

The area around the confluence of Mantsonyane and Likomiking rivers are looked upon in order to find more sites for power stations and reservoirs. Appendix 22 and 23 gives an example where the Ha Letuka area in Likomiking river has reservoir possibilities. However, the given example shows that reservoirs in the river are expensive. If a powerstation nr III was built (Likomiking power station – see appendix 22), the implementation of the reservoir would increase the power production in Mantsonyane I, II and Likomiking by approx. 2.5 GWh/year. The cost price is approx. NOK 25 x 10^6. The construction of the reservoirs should be combined with the construction of a powerstation no IV, Appendix 23.

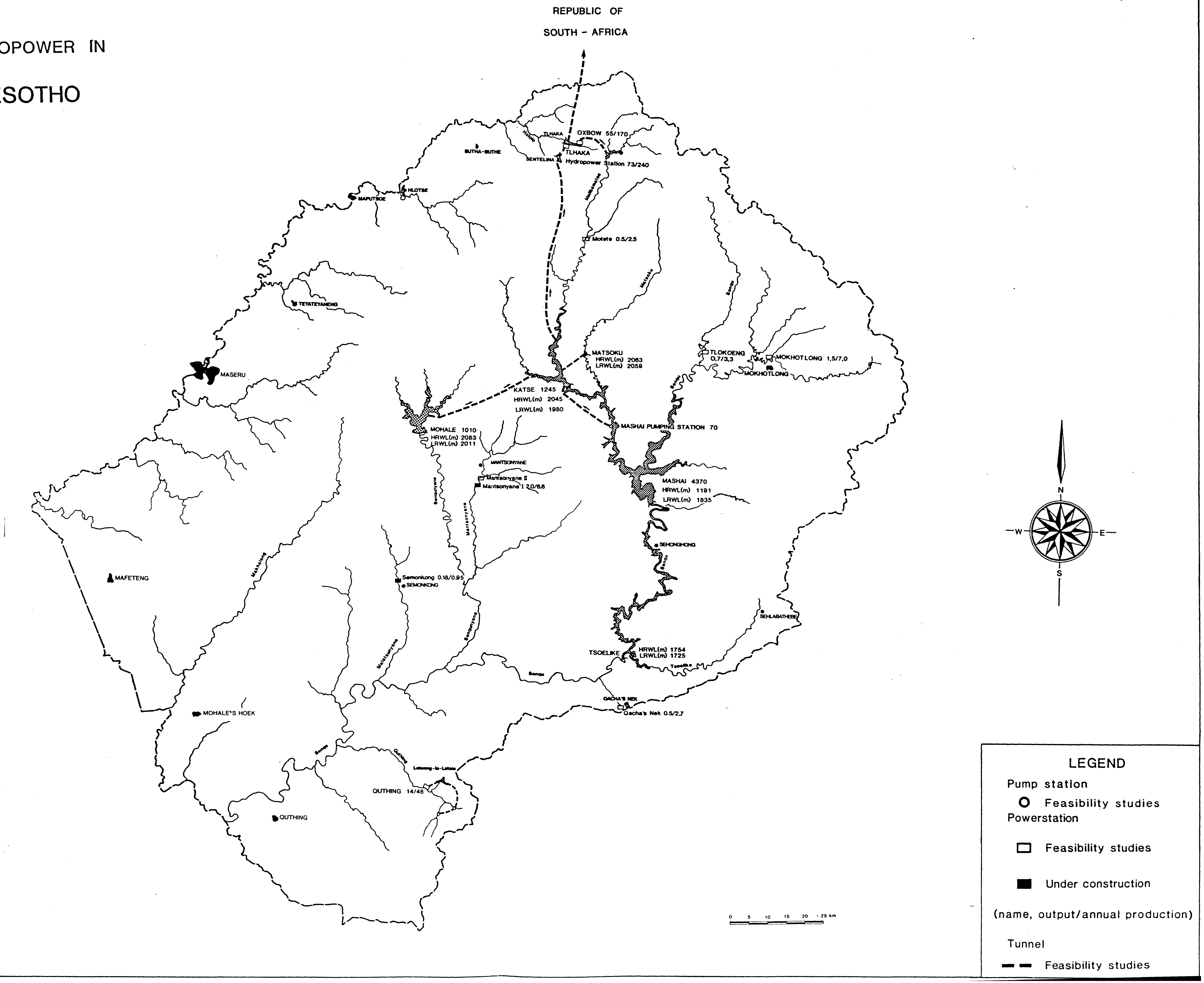
This should be further investigated, but only after the implementation of Mantsonyane II. Then there will probabely be some years measurements from the new gauging station in Mantsonyane, and this will give opportunity for a better calculation of reservoirs and new hydro power stations. The reservoir higher up in the catchment area (shown in map appendix 24) is too expensive due to the required length and height of the dam and access costs.

REFERENCES:

NORPLAN (Norway):	Study of rural electrification and development of minihydropower in Lesotho. Feasibility study report, Oslo, Norway. January 10th 1984.
	Semonkong and Mantsonyane Hydro Power Project, Final Design.
	Feasibility study on Mantsonyane no II SHP, 1986
SOGREAH (France):	Development of small scale hydro-electric Power Plants in Lesotho highlands, Sept. 1982.
Institute of water management, Universität für Bodenkultur, Vienna, Austria.	Feasibility study report on Quthing scheme, August 1984.
Kingdom of Lesotho Ministry of Water, Energy and Mining	Summary report on the Oxbow multipurpose scheme April 1984

The prefeasiblity study for further schemes at Mantsonyane and Semonkong is based on maps (1:50.000), site visits and information given in the study report for Mantsonyane and Semonkong which were carried out by NORPLAN.

HYDROPOWER IN LESOTHO



PHASE	NAME	DAM (RESERVOIR) HEIGHT m	VOLUME $10^6 m^3$	HRWL m	LRWL m	TUNNEL LENGTH km	DIAM. m	DISCH. m^3/s	POWERSTATION/PAMSTATION NAME	OUTPUT MW	ENERGY GWh
I A	Katse	155	1245	2045	1980	48.3	4.05	28	Tlhaka I	73.4	240
	Sentelina	62	3.9	1960	1934	34.3	4.03	28			
	Tlhaka	70	3.9	1773	1768						
I B	Mohale	153	1010	2083	2011	31.5	3.4	9.8	Tlhaka I	36.7	118
II	Mashai	182	4370	1911	1835	105.1	5.0	42	Tlhaka II	166	513
									Mashai-Katse P	70	
	Matsuko	25	–	2063	2059	6.4	3.8	1.6			
III	Tsoelike	155	1100	1754	1725				Tsoelike-Mashai P	12	
									Tlhaka III ?		

<u>Summary cost million Maluti (Norwegian NOK, February 1986):</u>

	Cost	Construction Starts	Completed	
Phase I A	1414.4 (4950 NOK)	1988	1997	(Detailed study will start in 1987)
Phase I B	446.2 (1560 NOK)	1992	2004	
Phase II	1802.6 (6310 NOK)	1995	2012	
Phase III	398.2 (1394 NOK)	2005	2019	

5174p/HH

APPENDIX 3

Project name : OXBOW
Map nr. 2828 DC
Data from WEMMIN

River : Malibamatso
Tsehlanyane
Tlholahatsi

Catchment area / discharge	km^2	m^3/s	$10^6\ m^3/$ year
Tsehlanyane	277	3,3	104

Reservoir (damhight)	area km^2	HRWL (m)	LRWL (m)	$10^6\ m^3$
Tsehlanyane (100m)		2533	2480	100

Waterway : Tunnel L = 10.700 m tunnel boring, diameter 3 m
Penstock L = 2.700 m Ømm 1700

Head	gross head	net head	e : kWh / m^3
		718	1,73

Output / Energy :

q max. m^3/s	r.p.m.	E max. MW	Runoff GWh	mean annual production GWh
2x 4,95	600	54	180	162,4

2 peltonturbines

Costestimate : 1984

Reservoir	NOK	303	10^6kr.
Intake (gate, trashrack etc)		15	"
Tunnel / penstock (incl. civil works) Surge tank		144	"
Powerstation (building)		20	"
Mechanical / Electrical equipment		63	"
Access roads (transport costs etc.)		13	"
Transmission line (incl. civil works)		60	"
Engineering / Administration		59	"
Contigencies		123	"
Total cost	NOK	800	10^6kr.

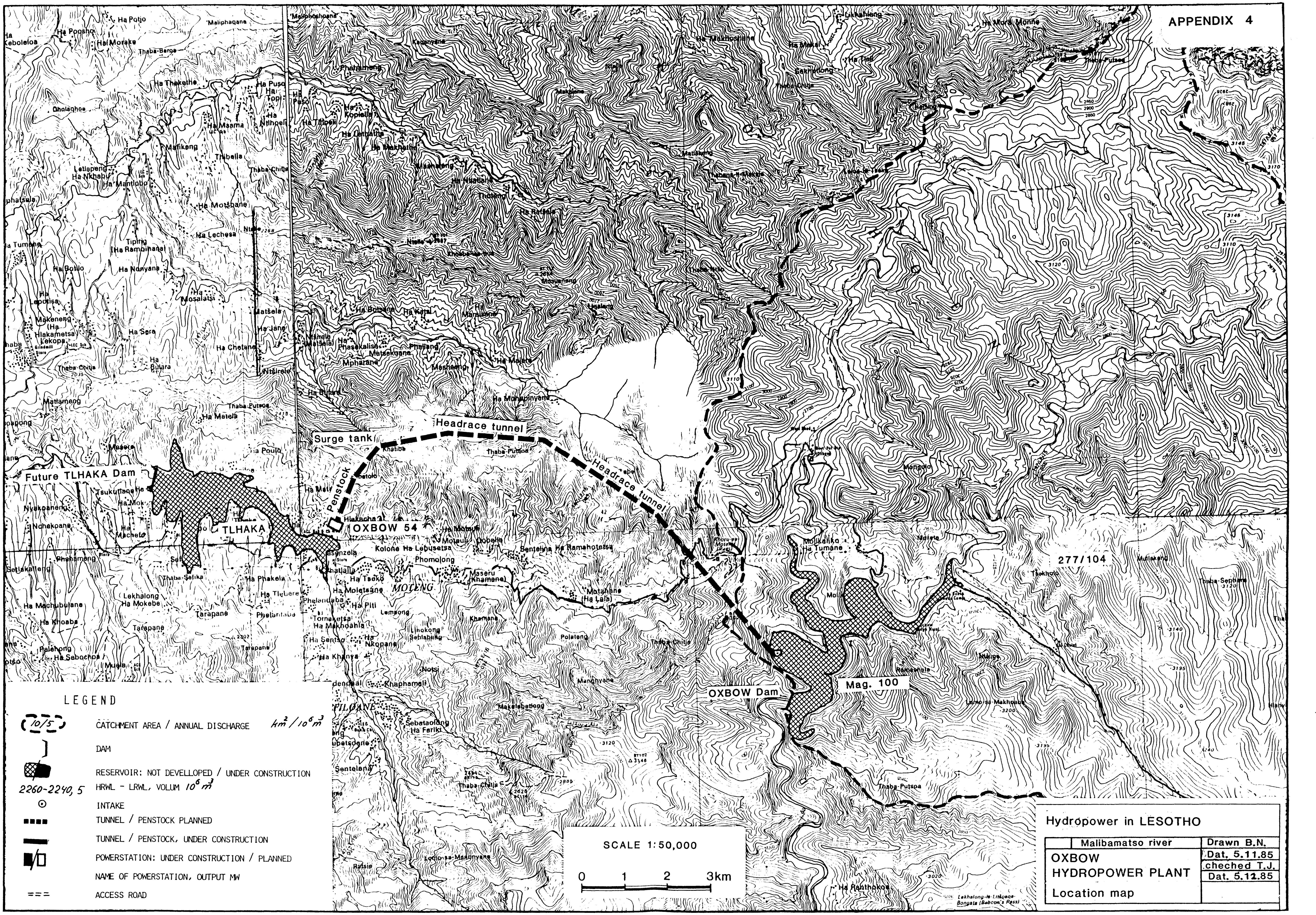
cost / kw : NOK 14.800 kr/kW

cost / kwh : NOK 5,0 kr/kWh (investment)

Comments :

40 year depreciaton time including operation and maintenance cost give an average cost of 0,45 kr/kwh if the internal rate of Return is 7%

APPENDIX 4


Headrace tunnel
Surge tank
Headrace tunnel
Penstock
OXBOW 54
Future TLHAKA Dam
TLHAKA
MOTENG
277/104
OXBOW Dam
Mag. 100
LEGEND
10/5 CATCHMENT AREA / ANNUAL DISCHARGE km²/10⁶m³
DAM
RESERVOIR: NOT DEVELLOPED / UNDER CONSTRUCTION
2260-2240, 5 HRWL - LRWL, VOLUM 10⁶ m³
INTAKE
TUNNEL / PENSTOCK PLANNED
TUNNEL / PENSTOCK, UNDER CONSTRUCTION
POWERSTATION: UNDER CONSTRUCTION / PLANNED
NAME OF POWERSTATION, OUTPUT MW
ACCESS ROAD
SCALE 1:50,000
0 1 2 3km
Hydropower in LESOTHO
Malibamatso river
Drawn B.N.
Dat. 5.11.85
OXBOW
HYDROPOWER PLANT
cheched T.J.
Dat. 5.12.85
Location map

APPENDIX 5

Project name : QUTHING River : QUTHING

Map nr. 3028 AC, AD

Catchment area / discharge	km^2	m^3/s	10^6 m^3/ year
Letseng-la-Letsie	42,4	0,36	11,3
Liphophi	4,8	0,04	1,4
Quanatu	53,5	0,46	14,5
Likhaebaneng	41,6	0,35	11,1

Reservoir (damhight)	area km^2	HRWL (m)	LRWL (m)	10^6 m^3
Letseng-la-Letsie	0,5 → 6,0	2420	2393	87

Waterway : Tunnel L = (5,5 + 5) km diversion, 3 km Headrace cross section : min.

Penstock L = ~ 750 m Ømm 1100

Shaft L = ~ 750 m cross section ~ $4 m^2$

Tunnel L = ~ 300 m Tailrace min cross section

Head	gross head	net head	e : kWh / m^3
Letseng-la-Letsie – Quthing 1885	525	517	1,250

Output / Energy :

	q max. m^3/s	r.p.m.	E max. MW	Runoff GWh	mean annual production GWh
1) I	3,0		13,5	48	46
II	5,5		25,0	48	46

Costestimate : 1.1.86

Reservoir + intake in Likhaebaneng, Qanatu, Liphophi	NOK	53	10^6kr.
Intake (gate, trashrack etc)		2	
Tunnel / penstock (incl. civil works)		150	"
Powerstation (building) including access tunnel		10	"
Mechanical / Electrical equipment		33	"
Access roads (transport costs etc.)		13	"
Transmission line (incl. civil works) (local)(diesel)		4	"
Engineering / Administration		15	"
Contingencies		15	

Total cost NOK 295 10^6kr.

cost / kw : NOK 21.850 kr/kW (1M ~ 3,0 NOK 1.09.86)
(1 US$ ~ 7,5 NOK –"–)

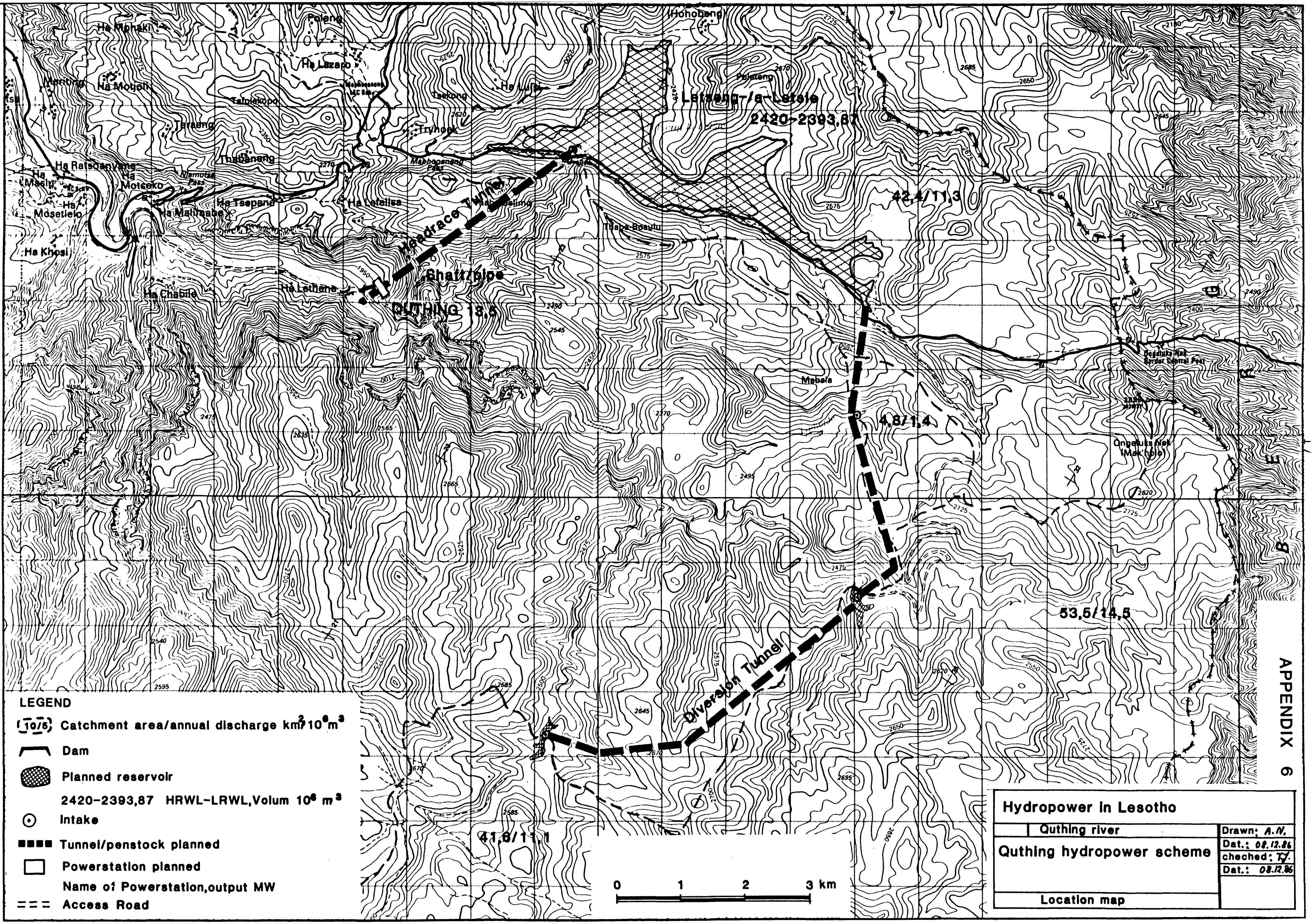
cost / kwh : NOK 6,40 kr/kWh 40 year/7%+M+O : NOK 0,55 kr/kWh

1) Comments : Installed capacity should be chosen in close cooperation with LEC. 13,5 MW (Pelton turbine) used here for economical calculation. Step up transformer 33 kV.

33 kV Transmission line to Mohales Hoek not included.

NB! Additional cost for 25 MW approximately 25.10^6 NOK.

APPENDIX 6


Hydropower in Lesotho
Quthing river
Quthing hydropower scheme
Location map
Drawn: A.N.
Dat.: 08.12.86
cheched: T.
Dat.: 08.12.86
LEGEND
Catchment area/annual discharge km²/10⁶m³
Dam
Planned reservoir
2420-2393,87 HRWL-LRWL,Volum 10⁶ m³
Intake
Tunnel/penstock planned
Powerstation planned
Name of Powerstation,output MW
Access Road
0 1 2 3 km
Letseng-/a-Letsie
2420-2393,87
Headrace Tunnel
Shaft/pipe
QUTHING 18,5
Diversion Tunnel
42,4/11,3
4,8/1,4
53,5/14,5
41,6/11,1
Ha Lethena
Ha Chabile
Ha Khosi
Ha Lefalisa
Ha Tsepane
Ha Matlinabe
Thabaneng
Ha Ratsoanyane
Ha Motseko
Ha Mosetlelo
Ha Masiu
Ha Motoli
Ha Lazaro
Ha Mphaki
Polang
Tsekong
Tryhoek
Teraeng
Ha Lulu
Polateng
Thaba-Bosulu
Mabala
Ongeluks Nek (Mak'holo)
Ongeluks Nek Border Control Post

Project name : MOKOTLONG   River : Mokotlong

Map nr.

Data from NORPLAN

Catchment area / discharge	km^2	m^3/s	$10^6\ m^3/$ year
Mokotlong 2070	870	5,5	173

Reservoir (damhight)	area km^2	HRWL (m)	LRWL (m)	$10^6\ m^3$
Dam (18m)		2093	2088	1,1

Waterway : Tunnel L = 2400 m   min cross section (~ $9m^2$)

Penstock L = 30 m   Ømm 1200

Head	gross head	net head	e : kWh / m^3
2093-2038	55	54	0,129

Output / Energy :

q max. m^3/s	r.p.m.	E max. MW	Runoff GWh	mean annual production GWh
3,5		1,5	22,2	7,0

Costestimate : 1984

Reservoir	NOK	10,0	10^6kr.
Intake (gate, trashrack etc) } Tunnel / penstock (incl. civil works) }		9,0	
Powerstation (building)		0,8	
Mechanical / Electrical equipment		7,7	
Access roads (transport costs etc.)		0,8	
Transmission line (incl. civil works)		0,2	
Engineering / Administration		1,1	
Contigencies		2,4	
Total cost	NOK	32	10^6kr.

cost / kw : NOK 21.300 kr/kW

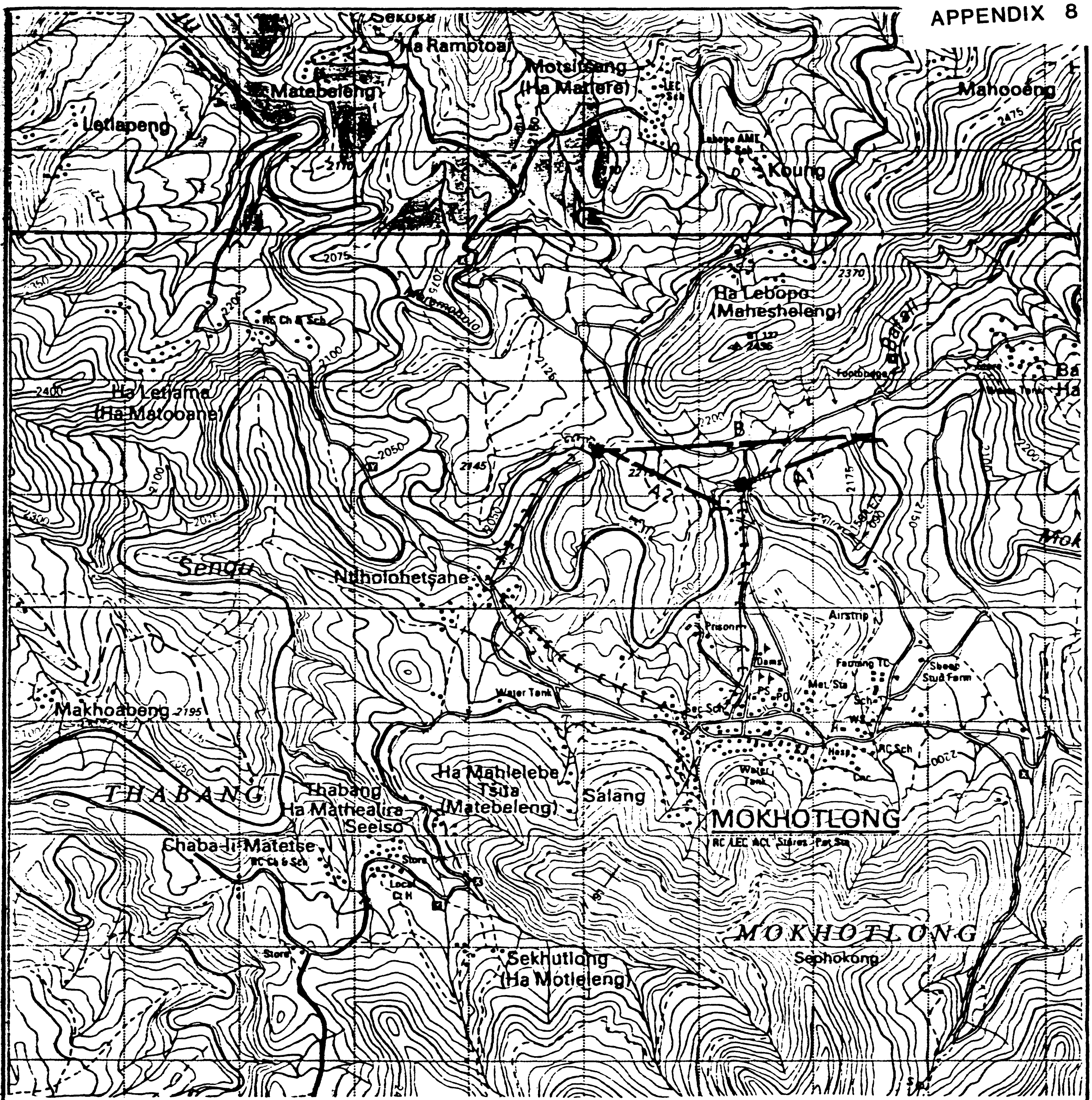
cost / kwh : NOK 4,6 kr/kWh

(Depreciation time 40 yrs and internal rate of return = 7%
Energycost ~ 0,43 kr/kwh)[1]

Comments :

- Energy cost 0,43 kr/kwh includes operation and maintenance cost in 40 year. [1] Only true if the scheme is connected to the main grid.
- The Poli hali dam (Highland Water Project) is likely to create a reservoir up to elevation 2050. Alt. A1 gives a solution; half the energy and 2/3 of the cost of Alt. B.

APPENDIX 8



LEGEND:

TUNNEL	ACCESS ROAD
PIPELINE	DAM
TRANSMISSION LINE	POWER STATION

GOVERNMENT OF LESOTHO
MINISTRY OF WATER,ENERGY AND MINING

MOKHOTLONG MINI HYDROPOWER PROJECT

LOCATION MAP

NORPLAN A/S

Main Office
Bygdøy Alle 5, Oslo 2, Norway
Tel + 47 02 56 56 90
Telex 19361 Nplan N

Hafslund

Reg. no.

Scale

Drawn

Checked

Apprd

Date

Replacem. for

Drawing no

A71-17

File no.

Start

Place

Project name : MOTETE River : Motete

Map nr.

Data from SOGRFAH

Catchment area / discharge	km^2	m^3/s	10^6 m^3/ year
Motete	261	2,7	85

Reservoir (damhight)	area km^2	HRWL (m)	LRWL (m)	10^6 m^3
		2080	2077	0,04

Waterway : Tunnel L = 440 m min cross section

Penstock L = 115 m Ømm 900

Head	gross head	net head	e : kWh / m^3
2080-2046	34	33	0,079

Output / Energy :

q max. m^3/s	r.p.m.	E max. MW	Runoff GWh	mean annual production GWh
2,0		0,55	6,7	2,5
(0,7+1,3)		(0,2+0,35)		

Costestimate : 1982

Reservoir	NOK x		10^6kr.
Intake (gate, trashrack etc)	x		
Tunnel / penstock (incl. civil works)	x		
Powerstation (building)	x		
Mechanical / Electrical equipment		5,5	"
Access roads (transport costs etc.)	x		
Transmission line (incl. civil works)		1,2	"
Engineering / Administration			
Contigencies			
Σx		8,0	"

Total cost NOK 14,7 10^6kr.

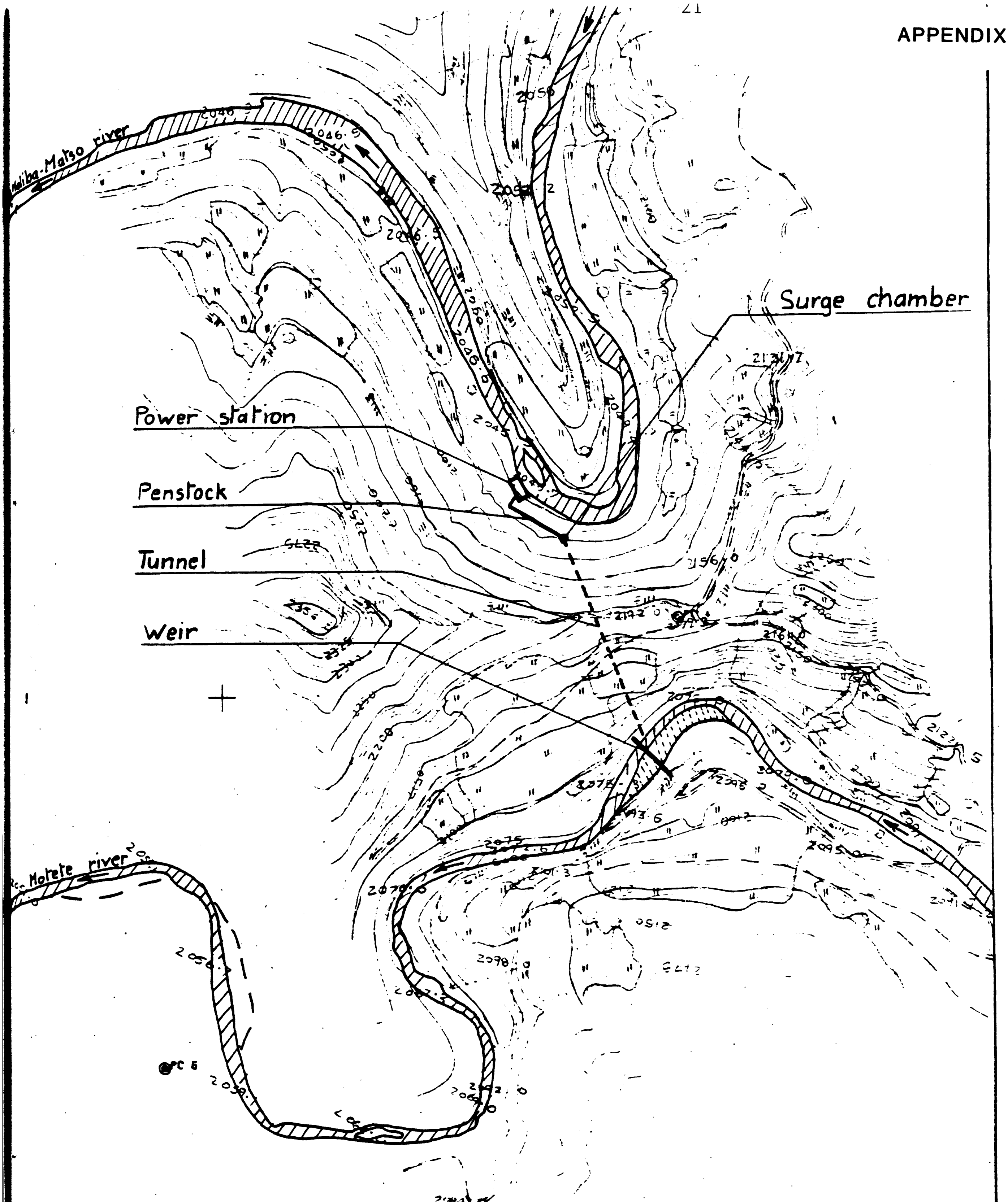
~NOK 18 10^6kr 1984

cost / kw : NOK 32.700 kr/kW 1984

cost / kwh : NOK 7,2 kr/kWh -"- [40 year, 7% + O+M): 0,7 kr/kwh][1]

Comments :

1) Only true if the powerstation is connected to the main grid



GOVERNMENT OF LESOTO MINISTRY OF WATER ENERGY AND MINING	DEVELOPMENT OF SMALL SCALE HYDRO-ELECTRIC POWER PLANTS IN LESOTO HIGHLANDS	
MOTETE GENERAL LAYOUT		
SOGREAH	AUGUST 1982	Plate nr 2 - 01 34 0343 R2

Project name : TLOKOENG River : Kubelu

Map nr.

Data from SOGRFAH

Catchment area / discharge	km^2	m^3/s	10^6 m^3/ year
TLOKOENG	852	5,0	160

Reservoir (damhight)	area km^2	HRWL (m)	LRWL (m)	10^6 m^3
Intake, weir	–	2025	2023	0,05

Waterway : Tunnel L = 170 m min cross section

Penstock L = 240 m Ømm 800 (in tunnel)1)

Head	gross head	net head	e : kWh / m^3
	49	47,5	0,130

Output / Energy :

q max. m^3/s	r.p.m.	E max. MW	Runoff GWh	mean annual production GWh
1,75 (0,6 + 1,15)		710 (81+658)	18,0	3,5

Costestimate : 1982

		10^6kr.	
Reservoir--	NOK x		
Intake (gate, trashrack etc) ----------------------------	x		
Tunnel / penstock (incl. civil works)-------------------	x		
Powerstation (building)-------------------------------	x		
Mechanical / Electrical equipment-----------------------		6,8	"
Access roads (transport costs etc.)-------------------	x		
Transmission line (incl. civil works) ------------------			
Engineering / Administration ----------------		1,1	"
Contigencies --	x	5,4	"
Σx -----			

Total cost NOK 13,3 x 10^6kr.

NOK 16 x 10^6kr 1984

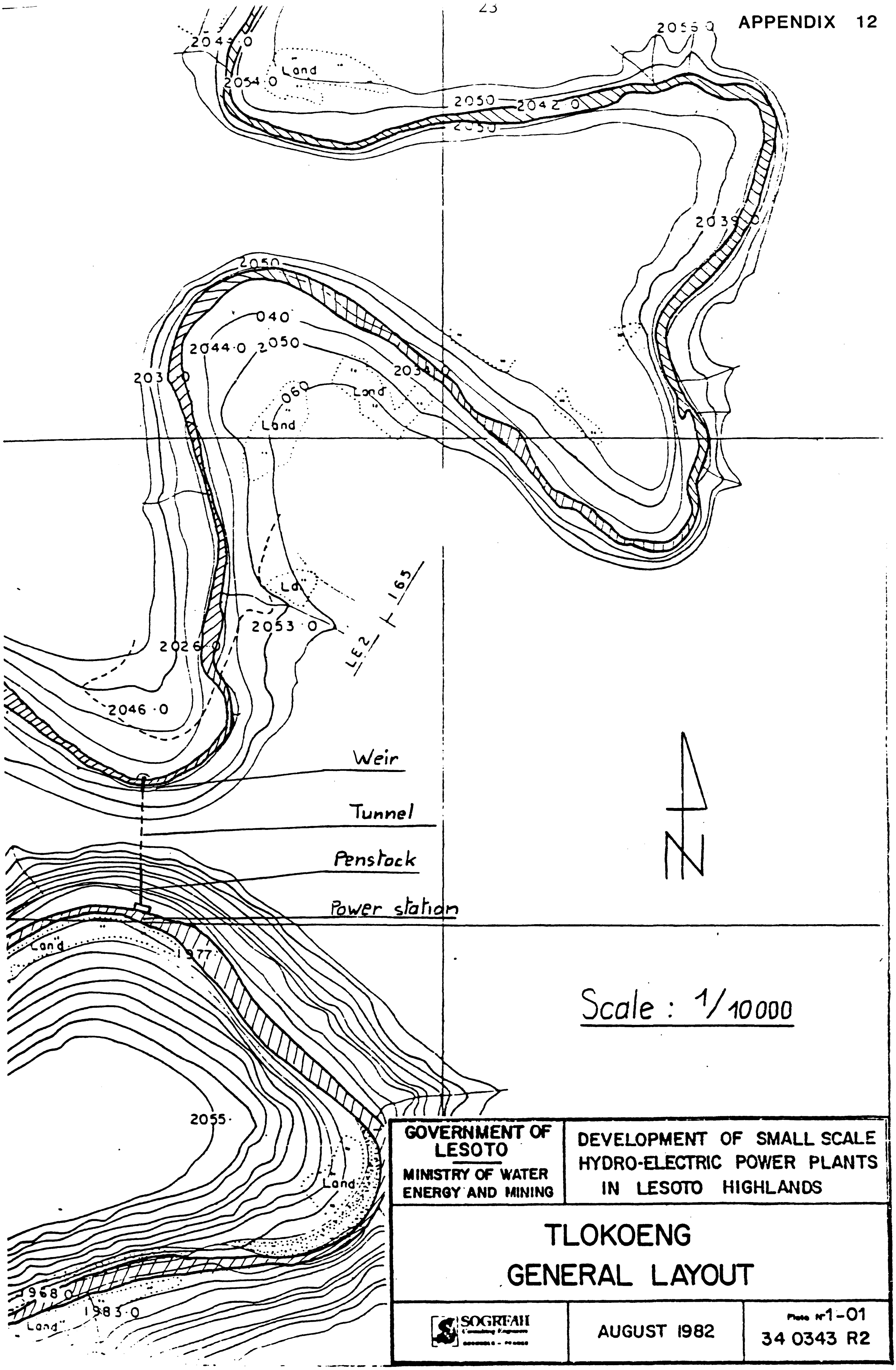
cost / kw : NOK 22.500 kr/kW 1984

cost / kwh : NOK 4,6 kr/kWh –"– [40year, 7% + O+M): 0,45kr/kwh]2)

Comments :

1) Allows a permanent pedestrain access to the Powerstation from the upstream access via the tunnel in any river flood conditions.

2) Only true if the scheme is connected to the main grid.



Scale : 1/10000

GOVERNMENT OF LESOTO MINISTRY OF WATER ENERGY AND MINING	DEVELOPMENT OF SMALL SCALE HYDRO-ELECTRIC POWER PLANTS IN LESOTO HIGHLANDS	
TLOKOENG GENERAL LAYOUT		
SOGREAH	AUGUST 1982	Plate Nº 1-01 34 0343 R2

Project name : QACHA'S NEK River : Tsoelike

Map nr.

Data from SOGRFAH

Catchment area / discharge	km^2	m^3/s	$10^6\ m^3$/ year
	750	4,5	142

Reservoir (damhight)	area km^2	HRWL (m)	LRWL (m)	$10^6\ m^3$
				0,006

Waterway : Tunnel L = 530 m min cross section

Penstock L = 90m Ømm 900

Head	gross head	net head	e : kWh / m^3
		33	0,079

Output / Energy :

q max. m^3/s	r.p.m.	E max. MW	Runoff GWh	mean annual production GWh
1,8		0,50	11,2	2,7
(1,2+0,6)		(0,17+0,33)		

Costestimate : 1982

	NOK	10^6kr.
Reservoir	×	
Intake (gate, trashrack etc)	×	
Tunnel / penstock (incl. civil works)	×	
Powerstation (building)	×	
Mechanical / Electrical equipment		7,4
Access roads (transport costs etc.)	×	
Transmission line (incl. civil works)		
Engineering / Administration		1,4
Contigencies		
Σ ×		6,6

Total cost NOK 15,4 × 10^6kr.

NOK 19 × 10^6kr 1984

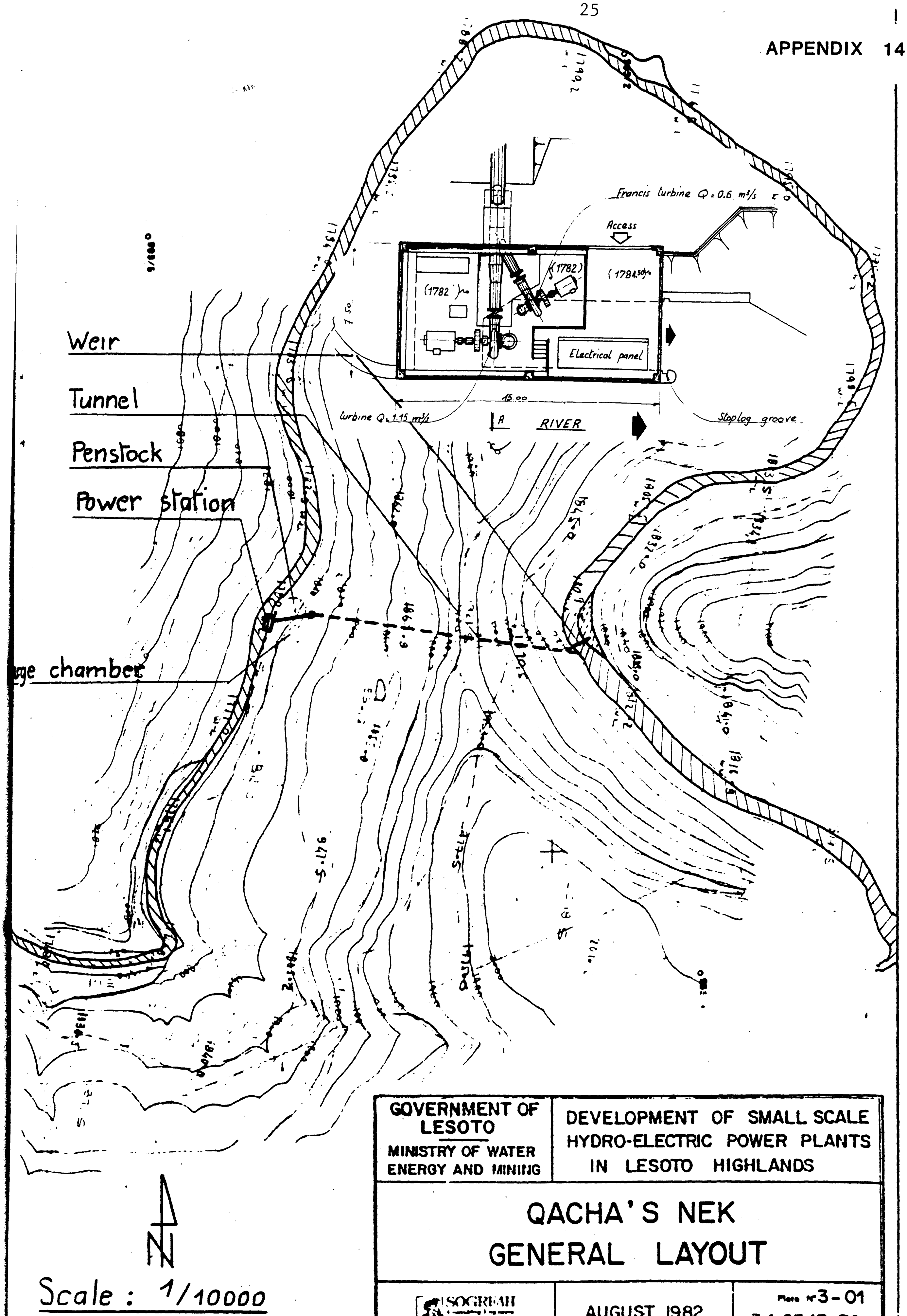
cost / kw : NOK 38.000 kr/kW

cost / kwh : NOK 7,03 kr/kWh [40year, 7% + O+M ⊃: 0,65kr/kwh] 1)

Comments :

1) Only true if the scheme is connected to the main grid.

APPENDIX 14



GOVERNMENT OF LESOTO MINISTRY OF WATER ENERGY AND MINING	DEVELOPMENT OF SMALL SCALE HYDRO-ELECTRIC POWER PLANTS IN LESOTO HIGHLANDS	
QACHA'S NEK GENERAL LAYOUT		
SOGREAH	AUGUST 1982	Plate n°3-01 34 0343 R2

APPENDIX 15

Project name : SEMONKONG River : Maletsunyane
Map nr. 2928 CC (54)
Data from NORPLAN

Catchment area / discharge	km^2	m^3/s	$10^6\ m^3$/ year
Semonkong	231	2,4	75,6

Reservoir (damhight)	area km^2	HRWL (m)	LRWL (m)	$10^6\ m^3$
Intake		101,5	101,1	0.25

Waterway : Tunnel L = cross section
Penstock L = 412 m Ømm 1000 - 1200 Glassfibre

Head	gross head	net head	e : kWh / m^3
Semonkong falls	19.5	~ 18	0.043

Output / Energy :

q max. m^3/s	r.p.m.	E max. MW	Runoff GWh	mean annual production GWh
1.2	750	0,18	3.2	0,95

Costestimate : 1983

Reservoir--NOK		10^6kr.
Intake (gate, trashrack etc) --------------------------	1,0	-"-
Tunnel / penstock (incl. civil works)----------------	1,3	-"-
Powerstation (building)-----------------------------	0,7	-"-
Mechanical / Electrical equipment---------------------	3,3	-"-
Access roads (transport costs etc.)-----------------	0,5	-"-
Transmission line (incl. civil works) ----------------	0,3	-"-
Engineering / Administration ----------------	1,2	-"-
Contingencies--------------------------------------	0.8	-"-

Total cost NOK 9.1 10^6kr.

cost / kw : NOK 50.555 kr/kW

cost / kwh : NOK 9.6 kr/kWh 40 year/7%+M+O : NOK 0,87 kr/kWh

Comments :
Only 0,72 GWh/yr can be sold (40yr/7% ~ NOK 1,15 kr/kwh), however the project is compared to the alternative of the construction of a 33 kV transmission line connecting Semonkong to the Maseru grid. The internal rate of return is found to be 7½ %.

Project name : MOKHOALAPANA River : Mokoholapana

Map nr. 2927 DD (53)

Data : T.Jensen

Catchment area / discharge	km^2	m^3/s	10^6 m^3/ year
Mokhoalapana	32	0,35	11

Reservoir (damhight)	area km^2	HRWL (m)	LRWL (m)	10^6 m^3
Mokhoalapana	0,85	2400	23815	~ 9

Waterway : Tunnel L = 700 m min cross section

Penstock L = 25 m Ømm 1200

Head	gross head	net head	e : kWh / m^3
2400-2345	55	49	0.117

Output / Energy :

q max. m^3/s	r.p.m.	E max. MW	Runoff GWh	mean annual production GWh
1.5		0.6	1,3	1.3

Costestimate : 1983

Reservoir (incl. access road)	NOK ~ 35	10^6kr.
Intake (gate, trashrack etc)	0,9	-"-
Tunnel / penstock (incl. civil works)	3,0	-"-
Powerstation (building)	0,8	-"-
Mechanical / Electrical equipment	3,0	-"-
Access roads (transport costs etc.)	1,5	-"-
Transmission line (incl. civil works)	0,7	-"-
Engineering / Administration	2,0	-"-
Contingencies	1,2	-"-
Total cost	NOK 13.1	10^6kr.

cost / kw : NOK 21.830 kr/kW

cost / kwh : NOK 10,0 kr/kWh 40 year/7%+M+O : NOK 0,9 kr/kWh

Comments :

Implementation of the scheme is only possible if Mokhoalapana reservoir is constructed to raise the energy production in Semonkong hydropower plant.

Project name : MALETSUNYANE River : Maletsunyane
Map nr. 2928 CA (44), 2928 CC (54)
Data : T. Jensen

Catchment area / discharge	km^2	m^3/s	10^6 m^3/ year
Maletsunyane	105	1,09	35

Reservoir (damhight)	area km^2	HRWL (m)	LRWL (m)	10^6 m^3
Maletsunyane	~ 1,3	2265	2250	~ 7,5

Waterway : Tunnel L = 600 m min cross section
Penstock L = 25 m Ømm ~ 1200

Head	gross head	net head	e : kWh / m^3
22[illegible] - ct 2235	25	24	0,057

Output / Energy :

q max. m^3/s	r.p.m.	E max. MW	Runoff GWh	mean annual production GWh
1,25		0,25	2.0	1.6
(max. head 25m		(0.32)		

Costestimate : 1983

Reservoir---	NOK	25	10^6kr.
Intake (gate, trashrack etc) ---------------------------		0.9	-"-
Tunnel / penstock (incl. civil works)-----------------		2.8	-"-
Powerstation (building)-----------------------------		0.7	-"-
Mechanical / Electrical equipment---------------------		3.5	-"-
Access roads (transport costs etc.)-----------------		1.0	-"-
Transmission line (incl. civil works) ----------------		0.5	-"-
Engineering / Administration -----------------		2.0	-"-
Contingencies--------------------------------------		1.0	-"-

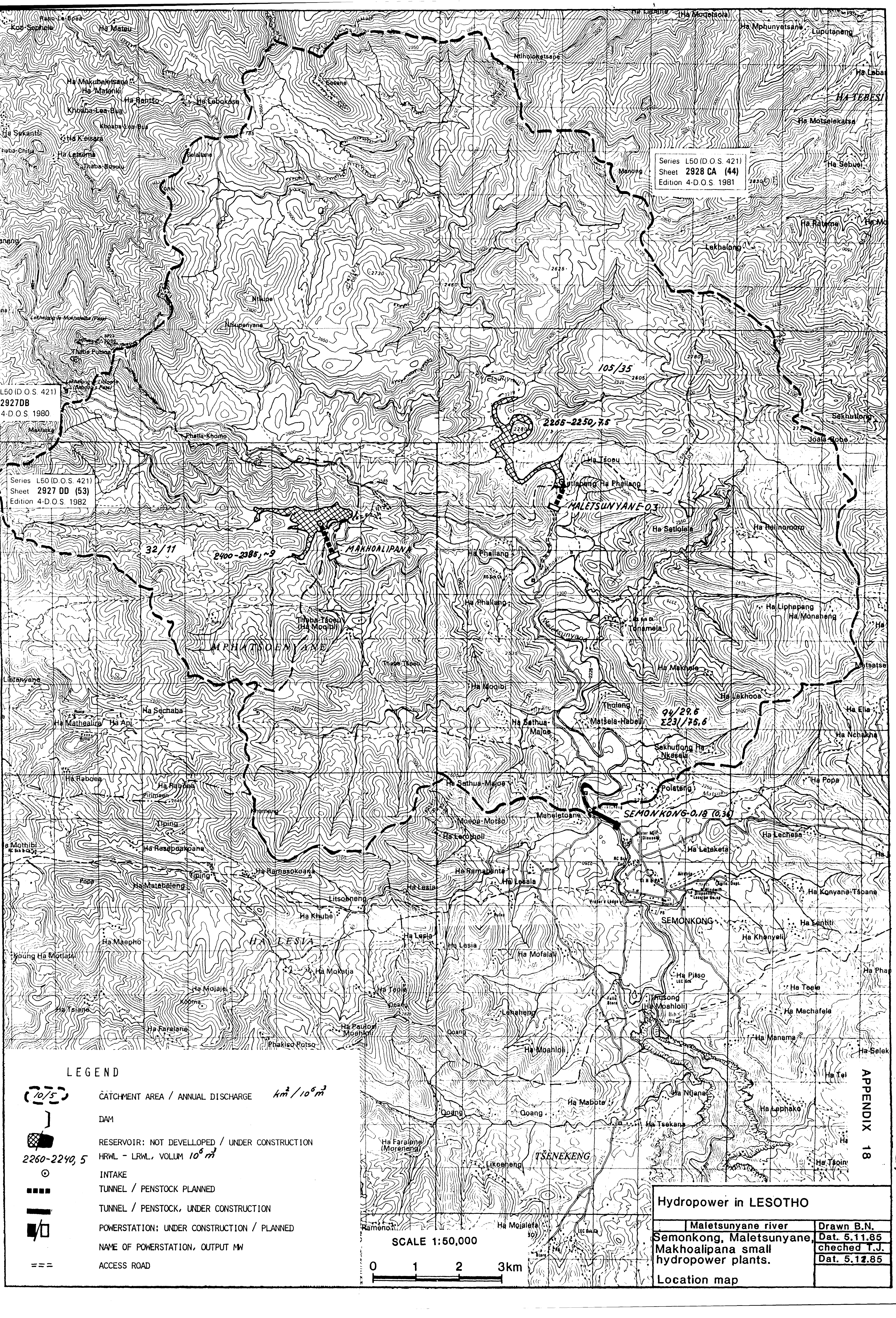
Total cost	NOK	12.4	10^6kr.

cost / kw : NOK 41.300 kr/kW

cost / kwh : NOK 7.8 kr/kWh 40 year/7%+M+O : NOK 0,71 kr/kWh

Comments :

Implementation of the scheme is only possible if the reservoir is constructed to raise the energyproduction in Semonkong hydropower plant.



LEGEND

10/5	CATCHMENT AREA / ANNUAL DISCHARGE $km^2/10^6 m^3$
	DAM
	RESERVOIR: NOT DEVELLOPED / UNDER CONSTRUCTION
2260-2240, 5	HRWL - LRWL, VOLUM $10^6 m^3$
	INTAKE
	TUNNEL / PENSTOCK PLANNED
	TUNNEL / PENSTOCK, UNDER CONSTRUCTION
	POWERSTATION: UNDER CONSTRUCTION / PLANNED
	NAME OF POWERSTATION, OUTPUT MW
	ACCESS ROAD

SCALE 1:50,000

0 1 2 3km

Hydropower in LESOTHO	
Maletsunyane river	Drawn B.N.
Semonkong, Maletsunyane, Makhoalipana small hydropower plants.	Dat. 5.11.85
	cheched T.J.
Location map	Dat. 5.12.85

APPENDIX 18

Project name : MANTSONYANE River : Mantsonyane

Map nr. 2928AC (34), 2928AD (35)
2928CA (44), 2928CB (45)

Data : NORPLAN

Catchment area / discharge	km^2	m^3/s	$10^6\ m^3$/ year
Mantsonyane	567	4,5	142

Reservoir (damhight)	area km^2	HRWL (m)	LRWL (m)	$10^6\ m^3$
Rockfill dam	0,34	2025	2020	~ 0,6

Waterway : Tunnel L = 655 m min cross section (~ $9 m^2$)

Penstock L = 20m Ømm 1400
-"- 700

Head	gross head	net head	e : kWh / m^3
	38,5	~ 38	0.090

Output / Energy :

q max. m^3/s	r.p.m.	E max. MW	Runoff GWh	mean annual production GWh
1: 4,5	500	1,5	12.7	6.7
2: 1,5	750	0,5		

Costestimate : 1984

Reservoir--	NOK	7.2	10^6kr.
Intake (gate, trashrack etc) --------------------------		0,7	-"-
Tunnel / penstock (incl. civil works)------------------		2,8	-"-
Powerstation (building)------------------------------		0.9	-"-
Mechanical / Electrical equipment----------------------		7.7	-"-
Access roads (transport costs etc.)------------------		3.0	-"-
Transmission line (incl. civil works) -----------------		1.0	-"-
Engineering / Administration ----------------		2.4	-"-
Contingencies---		2.6	-"-

Total cost NOK 28.3 10^6kr.

cost / kw : NOK 14.150 kr/kW

cost / kwh : NOK 4.3 kr/kWh 40 year/7%+M+O : NOK 0,4 kr/kWh

Comments :

Project name : MANTSONYANE II River : Mantsonyane

Map nr. 2928AC(34), 2928AD(35)
2928CA(44), 2928CB(45)

Catchment area / discharge	km^2	m^3/s	10^6 m^3/ year
Mantsonyane	504	4,0	126
Lipelaneng	53	0,4	13
	557	4,4	139

Reservoir (damhight)	area km^2	HRWL (m)	LRWL (m)	10^6 m^3
Rockfill dam (38m) ($220.000 m^3$)		2100	2075	7,0

Waterway : Tunnel L = 2800 m min cross section ($\approx 9m^2$)
Penstock L = 30m Ømm 1400
-"- 700

Head	gross head	net head	e : kWh / m^3
2095-2025	mean: 70 max: 75	mean 69 max 74	0,164 0,176

Output / Energy :

q max. m^3/s	r.p.m.	E max. MW	Runoff GWh	mean annual production GWh
1: 4,5		2,8	mean: 22,9 head	17,5
2: 1,5		0,95	max (24,5) head	
Two turbines				

Costestimate : 1.1.86

Reservoir (Spillway separate, included)	NOK 39,0	10^6kr.
Intake (gate, trashrack etc) (includs Lipelaneng)	5,0	"
Tunnel / penstock (incl. civil works)	16.0	"
Powerstation (building) (penstock, tailrace)	5,0	"
Mechanical / Electrical equipment	13,0	"
Access roads (transport costs etc.) 1 bridge, 2 fords	4,0	"
Transmission line (incl. civil works)	0,5	"
Engineering / Administration	8,0	"
Contingencies	14,5	"

Total cost NOK 105 10^6kr.

cost / kw : NOK 17.500 kr/kW

cost / kwh : NOK 6,0 kr/kWh 40 year/7%+M+O : NOK 0,55 kr/kWh

Comments : Implementation of Mantsonyane II will probably result in a discussion on the transmission line between Thaba-Tseka and Roma. If it is a need for a second 33 kV line to day, the implementation on M II will make the construction of a new line more interesting. The peak capacity of M I is 2 MW. Implementation on M II will increase the peaking capacity by 2 MW to 4 MW for both plants.

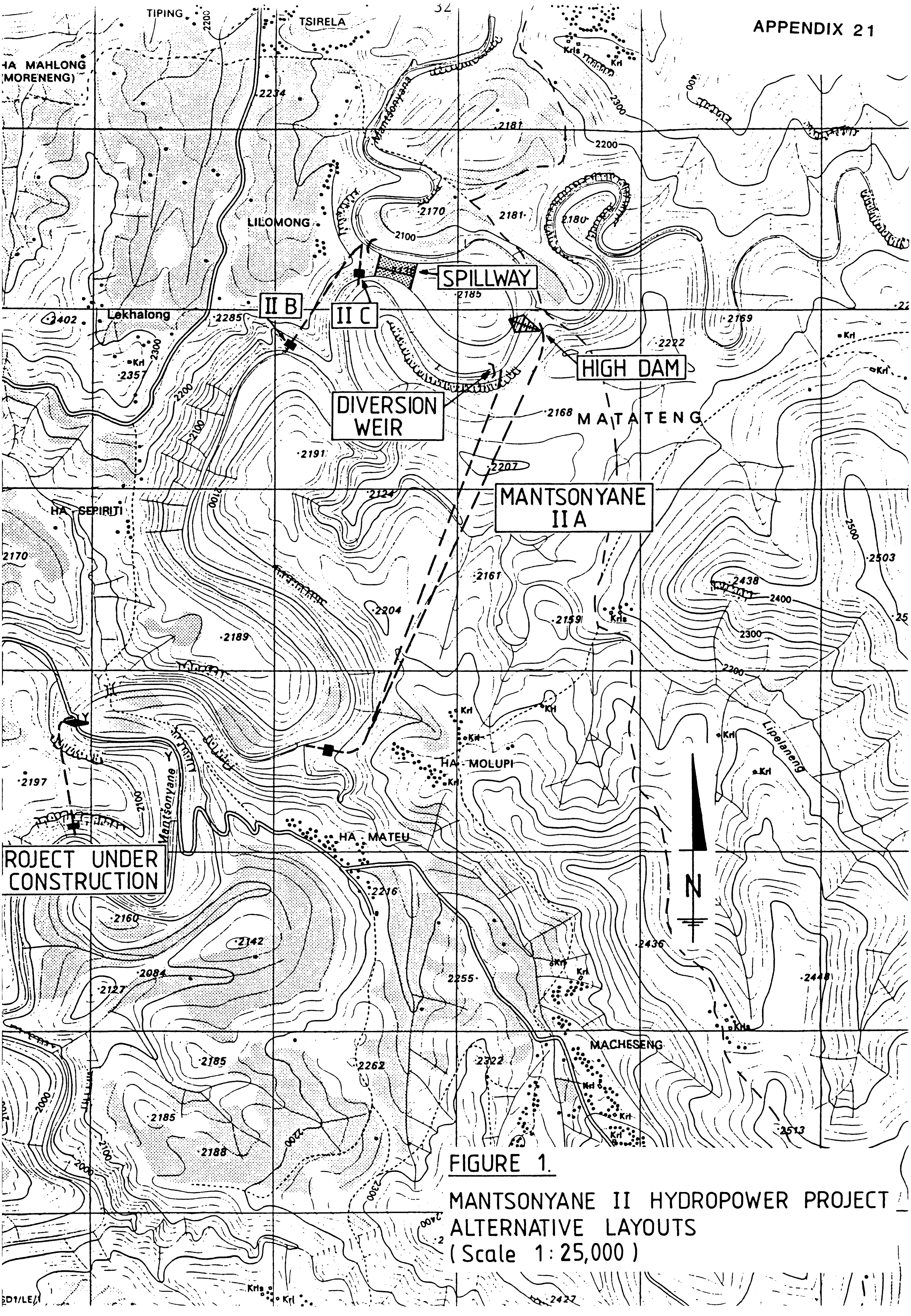


FIGURE 1.

MANTSONYANE II HYDROPOWER PROJECT_
ALTERNATIVE LAYOUTS
(Scale 1: 25,000)

APPENDIX 22

Project name : LIKOMIKING River : Likomiking
Map nr. 2928 AD (35), 2928 CB (45)
Data : T. Jensen

Catchment area / discharge	km^2	m^3/s	10^6 m^3/ year
Likomiking ct.2200	~155	1,2	3,9

Reservoir (damhight)	area km^2	HRWL (m)	LRWL (m)	10^6 m^3
Ha Letuga	0,3	2260	2240	~5.0

Waterway : Tunnel L = 750m min cross section (~9m²)
Penstock L = 20m Ømm 800

Head	gross head	net head	e : kWh / m^3
Likomiking 2210 Mantsonyane 2165	45	44,5	0.105

Output / Energy :

q max. m^3/s	r.p.m.	E max. MW	Runoff GWh	mean annual production GWh
1.6		0.6	4.1	2.9 1)

Costestimate : 1984

Reservoir Ha Letuga part	NOK	8,5	x 10^6kr.
Intake (gate, trashrack etc) incl. dam		1,7	-"-
Tunnel / penstock (incl. civil works)		3.0	-"-
Powerstation (building)		0,8	-"-
Mechanical / Electrical equipment		2.5	-"-
Access roads (transport costs etc.)		0,8	-"-
Transmission line (incl. civil works)		0.2	-"-
Engineering / Administration		1.3	-"-
Contingencies		1.2	-"-

Total cost NOK 20.0 x 10^6kr.

cost / kw : NOK 33.300 kr/kW

cost / kwh : NOK 6.9 kr/kWh 40 year/7%+M+O : NOK 0,63 kr/kWh

Comments :

1) Energy production without reservoir Ha Letuka : 2.1 GWh. Total cost 11.5x10^6kr, 6.900 kr/kW, 0,5 kr/kwh

Project name : *HA-LETUGA* River : *Likomiking*

Map nr. *2928 AD (35), 2928 CB (45)*

Data : T. Jensen

Catchment area / discharge	km^2	m^3/s	10^6 m^3/ year
Ha Letuga	*~ 145*	*1,1*	*35*

Reservoir (damhight)	area km^2	HRWL (m)	LRWL (m)	10^6 m^3
Ha Letuga	*0,3*	*2260*	*2240*	*~ 5,0*

Waterway : Tunnel L = *450m* *min* cross section

Penstock L = *20m* Ømm *800*

Head	gross head	net head	e : kWh / m^3
		32	*0.076*

Output / Energy :

q max. m^3/s	r.p.m.	E max. MW	Runoff GWh	mean annual production GWh
1,6		*0,45*	*2.7*	*2.0*

Costestimate : *1984*

Ha Letuga			
Reservoir	NOK	*25*	10^6kr. *1)*
Intake (gate, trashrack etc)		*0,9*	*-"-*
Tunnel / penstock (incl. civil works)		*2.0*	*-"-*
Powerstation (building)		*0,7*	*-"-*
Mechanical / Electrical equipment		*2.3*	*-"-*
Access roads (transport costs etc.)		*0.3*	*-"-*
Transmission line (incl. civil works)		*0.0*	*-"-*
Engineering / Administration		*1.3*	*-"-*
Contingencies		*1.0*	*-"-*
Total cost	NOK	*8.5*	10^6kr. *2)*

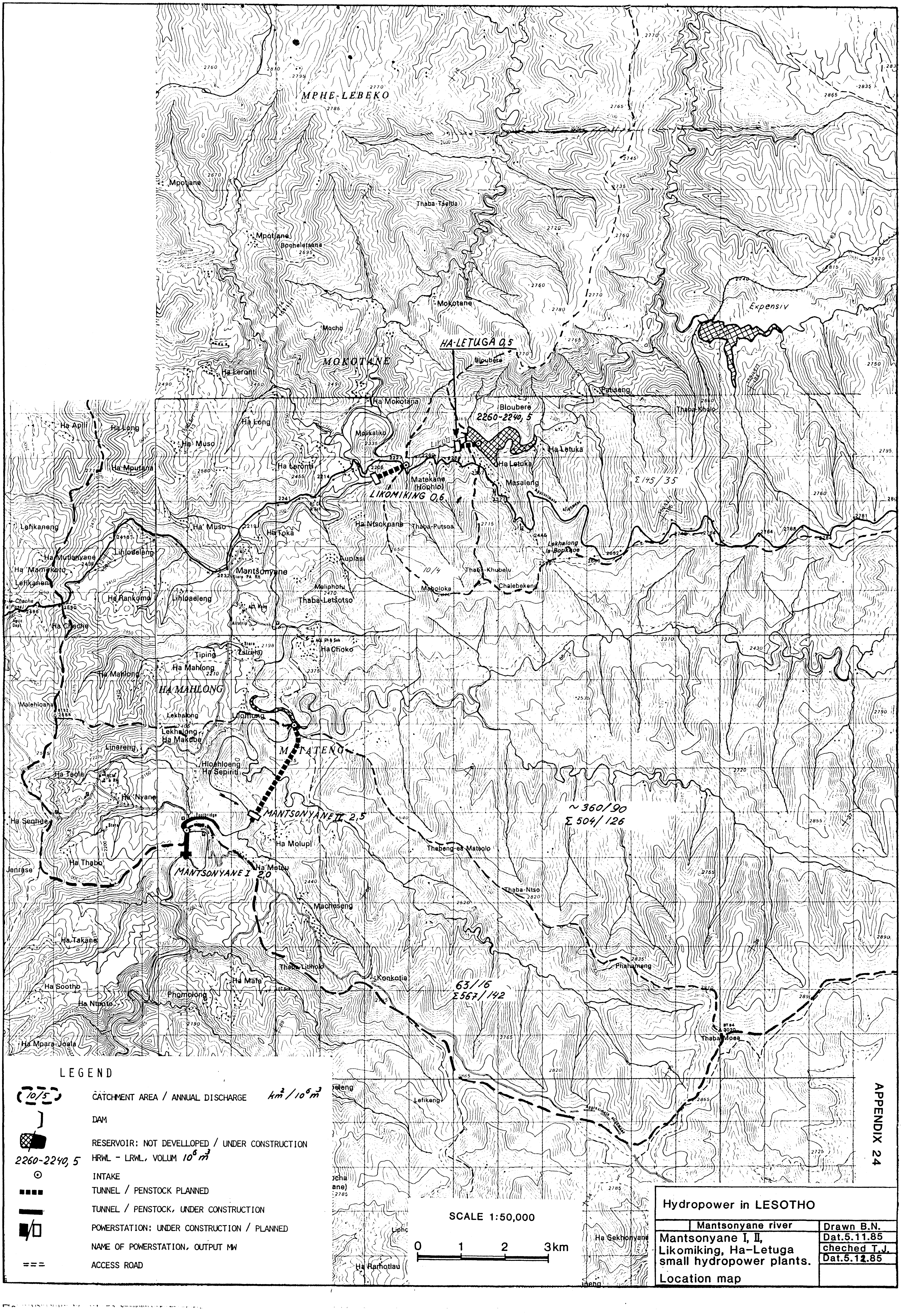
cost / kw : NOK *18.900* kr/kW

cost / kwh : NOK *4.3* kr/kWh 40 year/7%+M+O : NOK *0,4* kr/kWh

Comments :

1) includes access roads, energy consumption, environmental aspects

2) The hydropower scheme is entirely depending on the implementation of the dam.


APPENDIX 24
MPHE-LEBEKO
MOKOTANE
HA-LETUGA 0,5
2260-2240, 5
LIKOMIKING 0,6
Σ 145/35
10/4
HA MAHLONG
MATATENG
MANTSONYANE II 2,5
MANTSONYANE I 2,0
~360/90
Σ 504/126
63/16
Σ 567/142
Expensiv
LEGEND
10/5 CATCHMENT AREA / ANNUAL DISCHARGE $km^2/10^6 m^3$
DAM
RESERVOIR: NOT DEVELLOPED / UNDER CONSTRUCTION
2260-2240, 5 HRWL - LRWL, VOLUM $10^6 m^3$
INTAKE
TUNNEL / PENSTOCK PLANNED
TUNNEL / PENSTOCK, UNDER CONSTRUCTION
POWERSTATION: UNDER CONSTRUCTION / PLANNED
NAME OF POWERSTATION, OUTPUT MW
ACCESS ROAD
SCALE 1:50,000
0 1 2 3km
Hydropower in LESOTHO
Mantsonyane river
Mantsonyane I, II, Likomiking, Ha-Letuga small hydropower plants.
Location map
Drawn B.N.
Dat.5.11.85
cheched T.J.
Dat.5.12.85