Introducing Pumped Storage in Lebanon: Towards a Prospective National Master Plan

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1- Introduction

The Paper gives an overview of the power and energy sector in Lebanon which is currently under radical review for upgrading, modernization and privatization, with particular emphasis on the important role and potentialities of development of the hydropower and of introduction of the pumped-storage for the first time in the country.

Lebanon is typically a mountains' country with a national land of 10,452 km^2 along the Mediterranean Sea with considerable spatial diversity in terms of topography, rainfall and patterns of land use.

There are 17 major perennial rivers in Lebanon and the remarkable seasonality in rainfall – only 80 rainfall days per year – results in a significant stress on available surface water resources; the total average annual runoff is estimated to be 3,094 million m^3.

The present power generation system consists on 8 thermal power plants with nominal capacity of 2,073 MW and on 13 hydropower plants with nominal capacity of 272 MW, all hydro plants were constructed during the sixtees and their share declined to 11.6 % in terms of nominal capacity, there is an urgent need to add 1,000 MW up to year 2012. The burden of the recent fuel prices is expected to cause an annual increase of about 1- 1.5 billion USD on the electricity bill.

No, pumped – storage exists or is planned in Lebanon yet, despite an important development potential and an improvement need for operating control flexibility and reliability of the grid system.

The surface water development potential by direct intake from rivers (11.3%) and by storage facilities by dams and hill lakes (88.7%) amounts to 862 million m^3 per year.

The author identified and studied 9 main potential sites for introducing and promoting the pumped – storage in the country:

- 6 sea-shore schemes along the Mediterranean cliffs,
- 1 inland scheme interrelated with the existing Litani – Aouali complex of Qaraoun Reservoir and its 3 hydropower cascades of installed capacity of 190 MW.
- 1 inland scheme interrelated with a typical river basin having high potential of surface water development by dams,
- 1 inland scheme interrelated with perennial springs and suitable sites for hill lakes.

The characteristics of these schemes are outlined and ranked-up for their pro and Cons key indicators (technical , financial , environmental , ….) towards the initiation and planning of a nation-wide prospective Master Plan of pumped storage, for a target generating capacity of about 1,000 – 1,200 MW and for a base investment needs of about 1.5-1.8 billion USD.

Consequently, BOT'S, EPC, PPP and Carbon Trades perspectives are also outlined.

2- Energy security challenge: need for a global response

- The financial crisis hits the green solutions (e.g. Pumped- Storage)
- The volatility in oil prices is creating great uncertainty
- In an economic downturn, capital is directed to projects that are seen as higher priority than green energy
- The downtime could offer opportunity for looking at what we need going forward via innovation
- The public and private sector should work together and there is needs to be more direction at the national and global level
- Energy security by :
    - Ensuring that supplies and infrastructure are resilient now,
    - Providing enough power growing forward as demand for energy increases,
- A globally co-ordinated response is the only way to tackle this global problem. The challenge for Lebanon is:

    Nation- wide water resources management
    v/s river basin management.

3- Why Pumped Storage For Lebanon?

- A clean renewable energy potential whose time has come now
- A special class of hydroelectric facilities, the value of which is being recognized world wide
- Well – proven , cost –effective and up-to- date technology
- Pumped – storage plants are the " race cars " among power generation facilities : dynamic and rapid reponse capabilities for keeping the electrical grid stable and reliable
- Energy trading by pumped in off-peak hours, using low – tariff thermal energy, and generating in peak times with golden high-tariff (value- added)
- Better accommodation of intermittent power sources : ability to ramp up or down hundreds of mw's in seconds
- Provision of peaking power at competitive cost and improved efficiency
- Improvement of transmission gird stability and flexibility , including modulating gird frequency and phase
- Providing emergency reserves (stand- by hot reserve generating facility).

4- Over View Of The Surface Water Resources In Lebanon (fig . 1)

- Typically Mountain's Country along the Mediterranean Sea (10,452 km^2)
- Considerable Spatial Diversity in Terms of:
  - Topography (0-3,090 m a.s.l)
  - Rainfall (200-1,300 mm/year/region)
  - Patterns of Land Use
- 17 Major Perennial Rivers
- Remarkable Seasonality in Rainfall (only 80 rainfall days / year)
  Resulting in a Significant Stress on Available Surface water Resources
- Total Average Annual Runoff : 3,094 Million m^3
- Surface Water Development Potential:
  - by Direct Intake from Rivers : 11.3%
  - by Storage Facilities by Dams and Hill Lakes : 87.7%
  - TOTAL : 862 MCM/ Year through 27 main dams and about 60 main hill lakes.

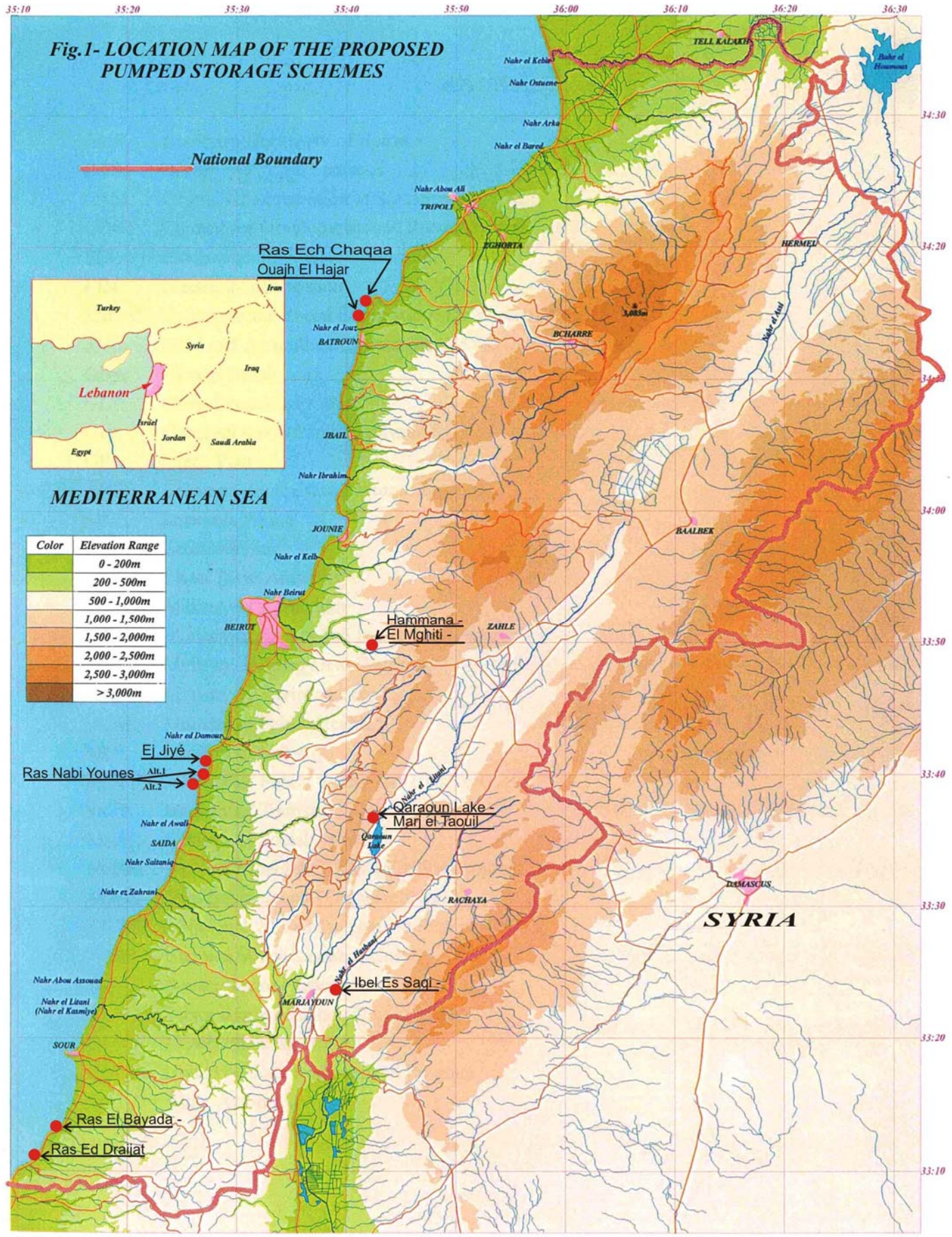


Fig.1- LOCATION MAP OF THE PROPOSED PUMPED STORAGE SCHEMES
National Boundary
Ras Ech Chaqaa
Ouajh El Hajar
Hammana -
El Mghiti -
Ej Jiyé
Ras Nabi Younes
Alt.1
Alt.2
Qaraoun Lake -
Marj el Taouil
Ibel Es Saqi -
Ras El Bayada -
Ras Ed Draijat
MEDITERRANEAN SEA
SYRIA
Lebanon
Turkey
Syria
Iraq
Iran
Israel
Jordan
Saudi Arabia
Egypt
Color
Elevation Range
0 - 200m
200 - 500m
500 - 1,000m
1,000 - 1,500m
1,500 - 2,000m
2,000 - 2,500m
2,500 - 3,000m
> 3,000m
TELL KALAKH
TRIPOLI
EGHORTA
HERMEL
BCHARRE
BATROUN
JBAIL
JOUNIE
BEIRUT
ZAHLE
BAALBEK
SAIDA
RACHAYA
DAMASCUS
MARJAYOUN
SOUR
Nahr el Kebir
Nahr Ostuene
Nahr Arka
Nahr el Bared
Nahr Abou Ali
Nahr el Jouz
Nahr Ibrahim
Nahr el Kelb
Nahr Beirut
Nahr ed Damour
Nahr el Awali
Nahr Saltaniq
Nahr ez Zahrani
Nahr Abou Assouad
Nahr el Litani
(Nahr el Kasmiye)
Nahr el Litani
Nahr el Hasbani
Nahr el Assi
Bahr el Houmous
Qaraoun Lake
35:10
35:20
35:30
35:40
35:50
36:00
36:10
36:20
36:30
34:30
34:20
34:00
33:50
33:40
33:30
33:20
33:10

5- Existing Power Generation Plants In Lebanon

Type	Company / status	River / turbines	Plant Number (N)	Nominal Capacity (MW)
Hydro-Power	EDL[1]/ Semi-Public	Damour	1	13.2
	KADISHA / Semi-Public	Abou Ali	4	21.3
	LRA[2] / Semi-Public	Litani / Aouali	3	190.0
	NAHR EL BARED/ Private	El Bared	2	17.2
	SPHE / Private	Ibrahim	3	30.1
	TOTAL		13	271.8
Thermal - Power	EDL/ Semi-Public	Fuel Steam Gas Combined Cycle	 3 1 2 2	 997.7 65.0 140.0 870.0
	TOTAL		8	2,072.7
GRAND TOTAL			21	2,344.5

1- Electricite du Liban 2- Litani River Authority

6- Recent Repartition of the Annual Production and Import of Energy in Lebanon (Fig. 2)

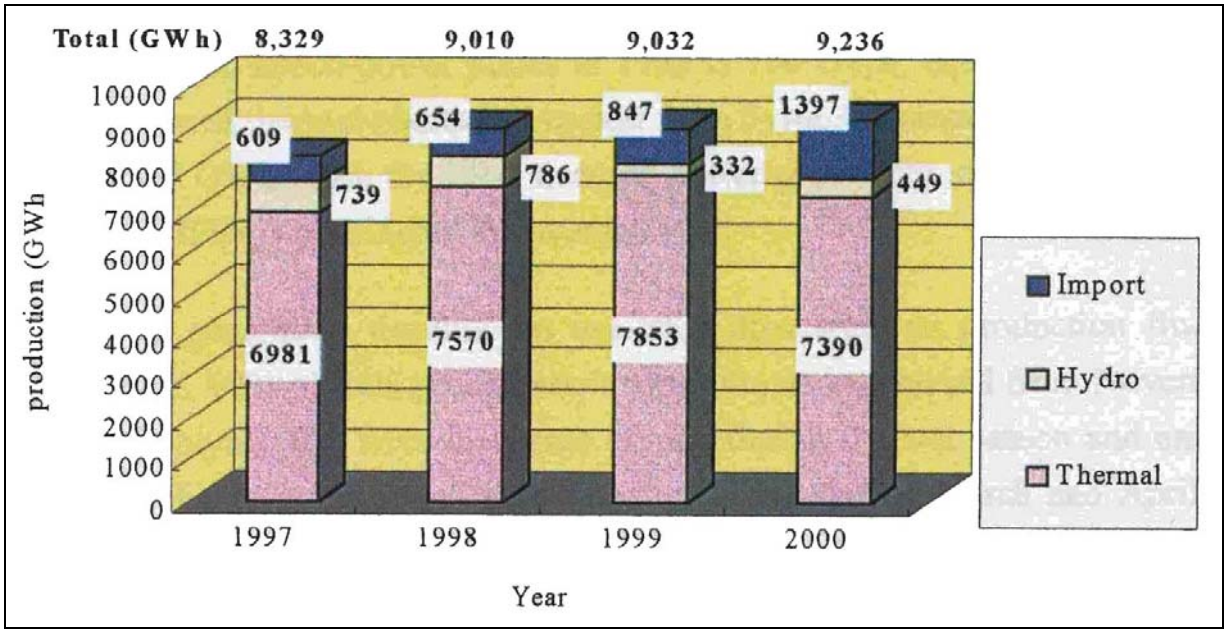


Fig .2. Recent Repartition of the Annual Production and Import of Energy in Lebanon

7- Present public electricity tariffs in Lebanon and assumed pumped – storage costs

7-1 Present EDL tariffs (Base Rate Excluding Vat and Taxes)

- Residential : 35-200 LBP/KWH Ξ 2.3 –13.3 USÇent/KWH
- Small industry : 115 LBP/KWH Ξ 7.7 USÇent/KWH
- Agriculture : 115 LBP/KWH Ξ 7.7 USÇent/KWH
- Public Facility : 140 LBP/KWH Ξ 9.3 USÇent/KWH

7-2 Assumed pumped – storage costs (base rate excluding vat and taxes)

- Off – Peak Pumped : 75 LBP/ KWH Ξ 5.0 USÇent/KWH
- Peak Generating : 200 LBP/ KWH Ξ 13.3 USÇent/KWH

8- Typical pumped storage scheme of Qaraoun Lake- Marj et Taouil :project features (Fig . 3)

8-1- Hydrology and Reservoirs Data

	Upper Reservoir	Lower Reservoir
Catchment's Area (km^2)	1.13	1,545
Reservoir Max surface Area (km^2)	0.26	12.6
High Water Level (m a.s.l.)	1678	862
Average Water Level (m a.s.l.)	1655	835
Low Water Level (m a.s.l.)	1630	820
Dam Height (m)	50	63
Effective Depth (m)	48	42
Gross Storage (10^6 m^3)	1.6	220
Active Storage (10^6 m^3)	1.4	160
Average River Discharge (m^3/s)	( )	9.34

8-2- Plant Data

Installed Capacity (MW)
- Pumping Mode : 560
- Generating Mode : 388

Max.Pumping Discharge (m^3/s) : 48
Max.Generating Discharge (m^3/s) : 64
Force Mains:
4*DN 2,200mm (ml) :2,940
Steel , PN 80-60-40 bars
Rated Net Head (m):
- Pumping Mode : 838
- Generating Mode : 776

N° of Units (N) : 4
Reversible Pump-Turbines,
FRANCIS, 2- Stages

8-3- Base Development Cost (million usd)

Upper Reservoir	:16
Access Roads	: 5
Force Mains	: 33
Head Race, Tail Race, Shafts' Structures and Water Hammer Protection	:15
HPP	:446
Hv Transmission Lines and Transformers' Stations	:18
Expropriations and Rights-Of- way	:4
Full Engineering Services	: 28
TOTAL	565

8-4- Operation indicators

Daily Max : Off-Peak Pumping Hours	: 8
Daily Max : Peak Generating Hours	: 6
Average Annual Operation Days	: 300
Annual Pumping Consumption (GWH)	:1,334
Annual Generation Production (GWH)	: 713
Annual Pumping Cost (Million USD)	: 67
Annual Generation Sales (Million USD)	:95
Annual Gross Profit (Million USD)	:28
Capital Cost Recovery Period/ Estimated Pay Back Period (year)	:20

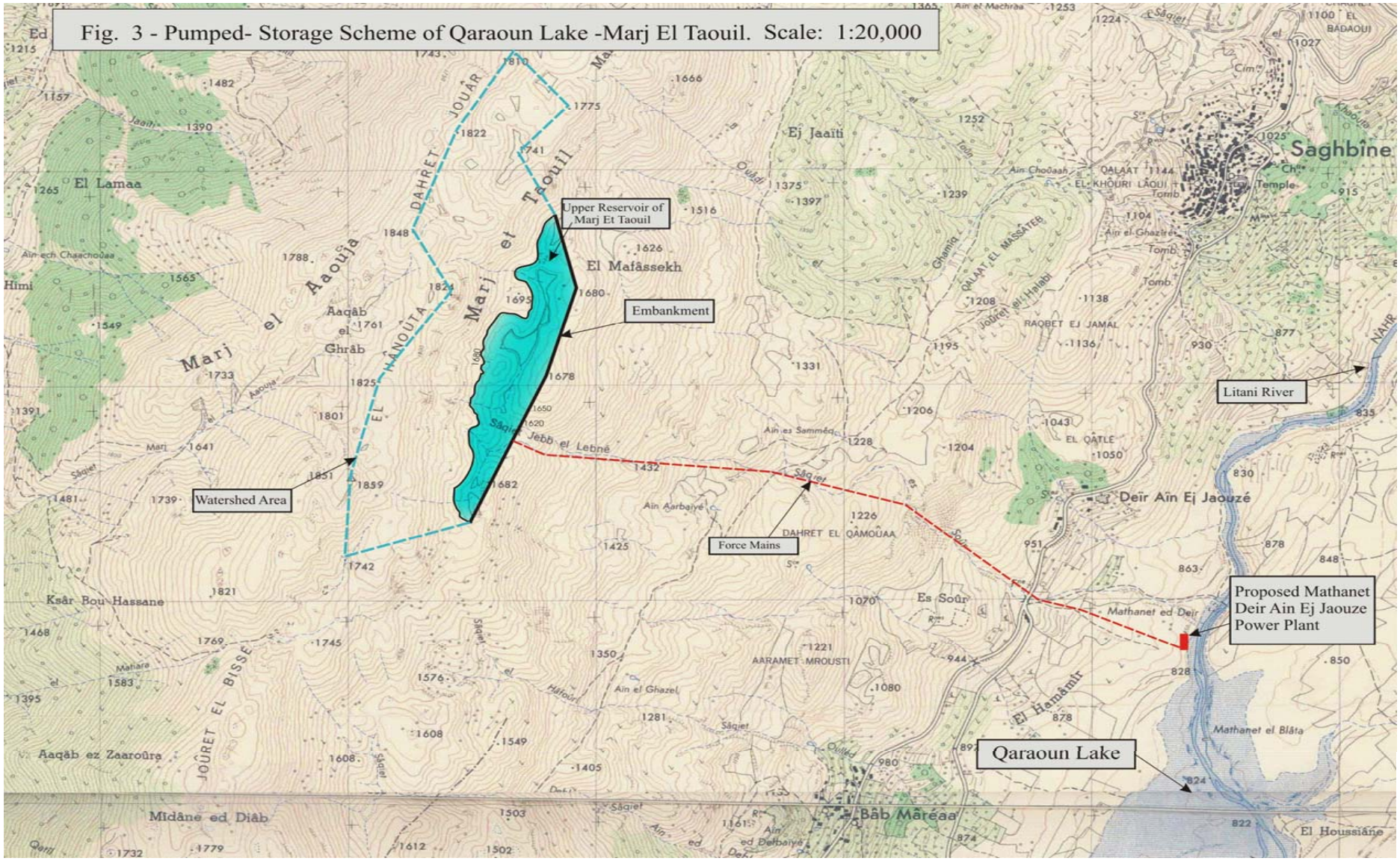


Fig. 3 - Pumped- Storage Scheme of Qaraoun Lake -Marj El Taouil. Scale: 1:20,000
Upper Reservoir of Marj Et Taouil
Embankment
Watershed Area
Force Mains
Litani River
Proposed Mathanet Deir Ain Ej Jaouze Power Plant
Qaraoun Lake
Saghbîne
El Lamaa
El Mafâssekh
Ej Jaaïti
Deïr Aïn Ej Jaouzé
Es Soûr
Ksâr Bou Hassane
Aaqâb ez Zaaroûra
Mîdâne ed Diâb
Bâb Mâreaa
El Houssiâne
El Hamâmir
Marj el Aaoûja
Marj et Taouil
DAHRET JOUÂR
EL HÂNOÛTA
JOÛRET EL BISSÉ
DAHRET EL QÂMOÛAA
AARAMET MROUSTI
Mathanet ed Deir
Mathanet el Blâta
Jebb el Lebné
Ain es Sammâq
Ain Aarbaïyé
Ain el Ghazel
Ain ed Delbaïyé
RAQBET EJ JAMAL
QALAAT EL MASSATEB
EL QATLE
Ain ech Chaachoûaa
Ain el Machraa
Ain Choûaah
Aaqâb el Ghrâb
Ouâdi
Ghamiq
Joûret el Hjalabi
Mahara
Hâfoûr
Ouâdi
Sâqiet

9- Different other Typical Pumped Storage schemEs

9.1- Inland / River Basin Dam (fig. 4)

9.2- Inland/ Perennial Spring- Hill Lake (fig.5)

9.3- Sea Shore / Coastal Cliffs (fig.6)

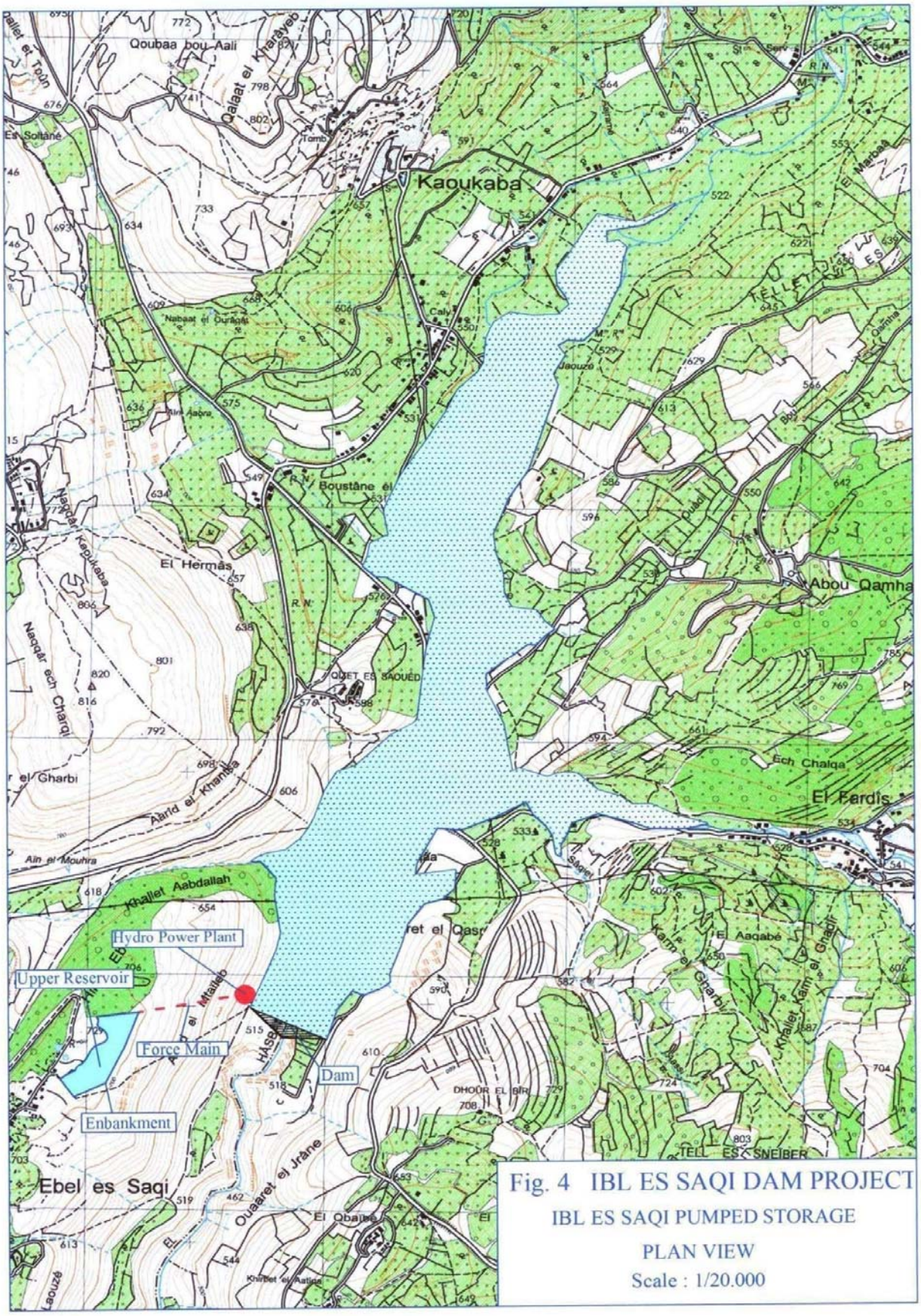
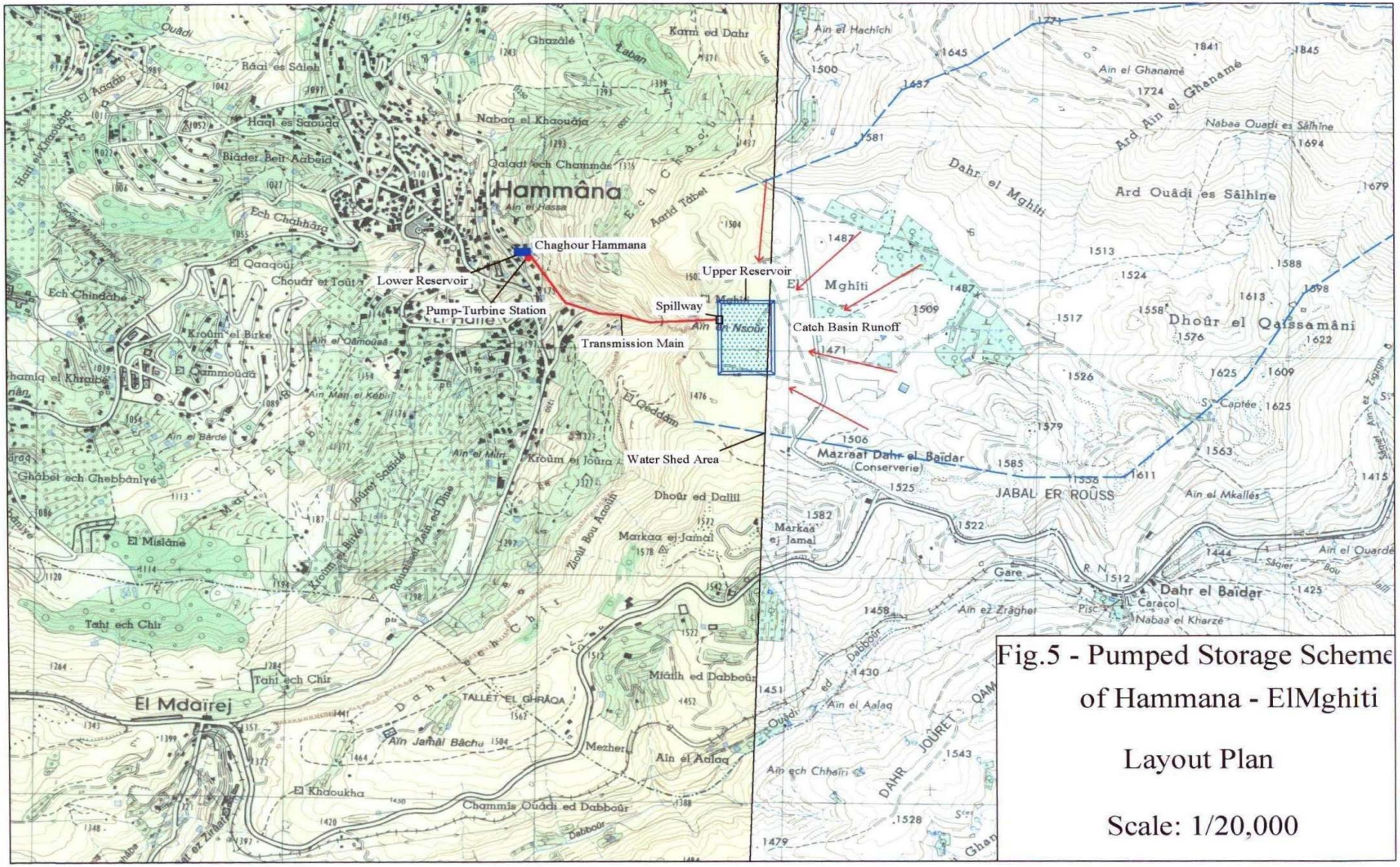


Fig. 4 IBL ES SAQI DAM PROJECT

IBL ES SAQI PUMPED STORAGE

PLAN VIEW

Scale : 1/20.000


Hammâna
Chaghour Hammana
Lower Reservoir
Upper Reservoir
Pump-Turbine Station
Spillway
Transmission Main
Catch Basin Runoff
Water Shed Area
El Mghiti
Dhoûr el Qaïssamâni
JABAL ER ROÛSS
Mazraat Dahr el Baïdar
(Conserverie)
Dahr el Baïdar
El Mdaïrej
Ard Ouâdi es Sâlhine
Ard Ain el Ghanamé
Dahr el Mghiti
Fig.5 - Pumped Storage Scheme of Hammana - ElMghiti
Layout Plan
Scale: 1/20,000

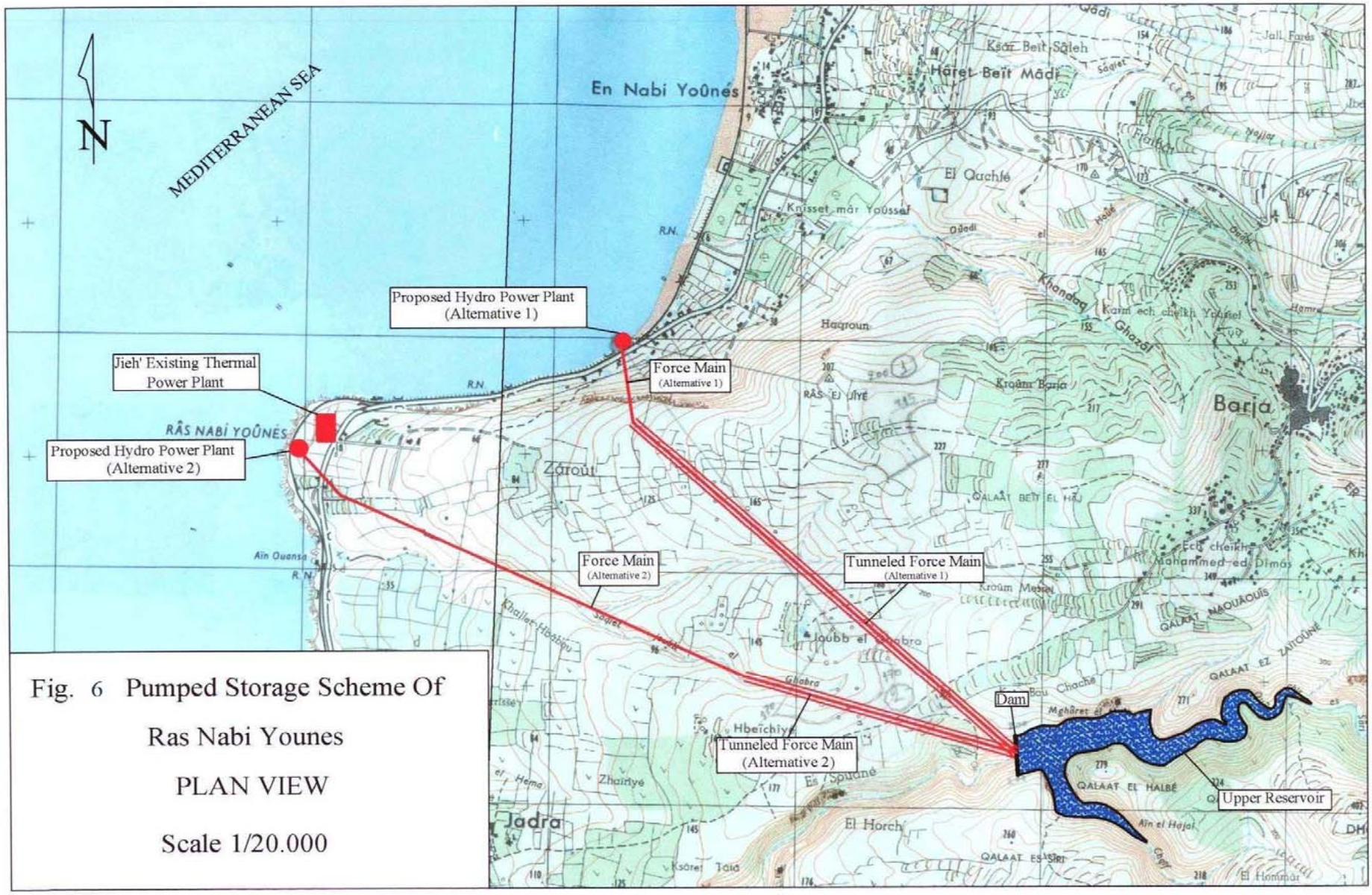


Fig. 6 Pumped Storage Scheme Of Ras Nabi Younes PLAN VIEW Scale 1/20.000

10- Lebanon's Pumped Storage Master Plan: Data of Identified Typical Potential Projects

Category Type	Project		Generating Capacity (MW)	Expected Annual Peak Generation (GWH)	Base Investment Cost (Million USD)	Estimated Pay Back Period (Year)	Rank
I-Inland / Qaraoun Lake / Litani River	Qaraoun Lake–Marj Et Taouil		388	713	565	20	2
II- Inland / River Basin Dam	Hasbani River-Ibl Es Saqi Dam		21	37	34	31	4
III-Inland/ Perennial Spring – Hill Lake	Hammana- El Mghiti		12	9	31	35	5
IV- Sea Shore / Coastal Cliffs	Ras Ech Chaqaa		30	54	50	37	5
	Ouajh El Hajar		33	60	52	16	1
	Ej Jiye		225	405	344	16	1
	Ras Nabi Younes	Alt.1*	234	421	348	18	1
		Alt.2	221	398	351	23	3
	Ras El Bayada		90	163	135	18	1
	Ras Ed Draijat		140	252	219	20	2
TOTAL			1,173	2,114	1,778	16-37	( )

*proposed

11- Prospective Master Plan of Pumped Storage

	Period 2010-2015	Period 2016-2022	Total
Target Capacity in the Generating Mode(mw)	613	560	1,173
N° of Plants (n)	2	7	9
Base Investment Needs (Million usd)	909	869	1,778
Preparation of The Master Plan (Million usd)	5	4 (up date)	9

12- Financial Engineering Tools and Packages

- Paris-3 Funds and Soft Loans
- Loi- Programme for 10 Years
- PPP : Private Public Partnership :
- Partial Incorporation and Privatization of Electricité du Liban EDL In Conformity With Regulation Law Nº 462/2002
- Bot , Boot , ….
- EPC (Engineering , Procurement , Construction)
- Carbon Trades (Kyoto Protocol)
  Flexible Mechanisms to Develop Joint Implementation Projects between Lebanon and the EU Countries, in Particular.

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