European Bank for Reconstruction and Development

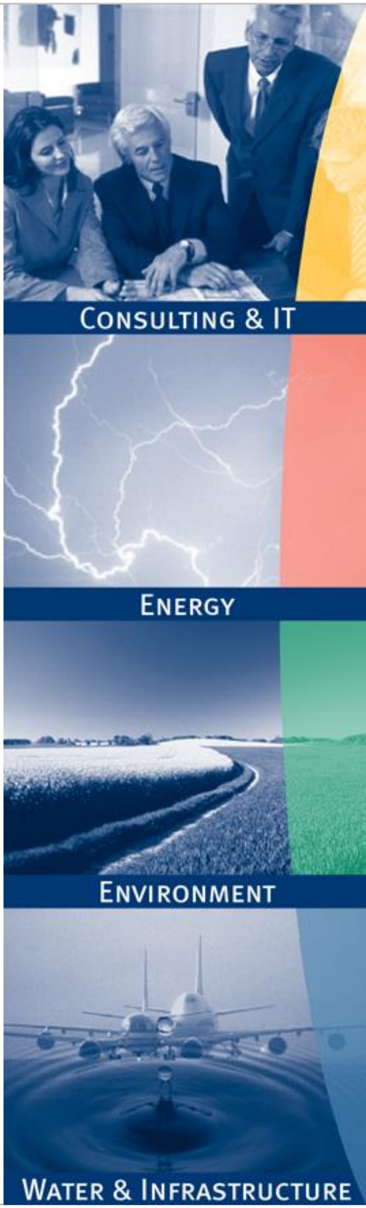
FICHTNER

Planning and Engineering

Case Study Loriberd HPP

Training Workshop “EBRD: Financing Small Hydropower Plants in Ukraine”

Kiev, 05.10.2011



FICHTNER

Program

- Due Diligence of a Small Hydropower Plant,
  Case Study Las Pizarras HPP, Peru
- Economical Optimization of Installed Capacity of a Small Hydropower Plant
  Case Study Gegharot SHPP, Armenia
- Chances and Risks from Pre-Feasibility Study to Operation
- Questions and Discussions

Planning and Engineering

Planning

- Hydropower is using natural head of river reaches, structures are build in nature. Therefore, natural site conditions have to be considered accordingly.
- Each hydropower plant is unique, there is no standardization (except for mini and micro hydropower market segment with total capacity < 5 MW)
- Site conditions are:
  - Topography → Head
  - Hydrology → Flow
  - Sediments
  - Geology
  - Seismicity
  - Social and Ecological conditions

Site Conditions

- Topography: Survey works on ground are necessary for entire structures, impact on bill of quantities
- Hydrology: long term recording of nearby gauging stations are useful, at least 15 years, correlation with other stations possible, various software packages, measurements on site sometimes necessary, hydrological risk remains
- Sediments: sediment laden flow important for project layout, sedimentation of daily storages or storages, differentiation in impacts depending on head of plant, consideration of sediment trap for reduction of abrasion effects on turbines, etc., measurements on site recommended, sediment risk remains
- Regional understanding of geology important for entire project, site investigations with drillings and laboratory tests important for design of foundations and underground conditions.

Planning and Engineering

Optimization

- During a study various layout alternatives shall be identified, developed and assessed in terms of power and energy output and corresponding costs. The aim is to determine the most economical layout causing minor environmental and social impacts
- Various structures shall be optimized during the stage of feasibility study (storage, tunnel diameter, penstock diameter, number and size of units, etc.)
- The design discharge shall be optimized in order to maximize the Net present value of the project, this very much depends on the tariff structure for power and energy generation

Engineering

- The depth of engineering depends on the level of the study, the physical contingencies decrease with detail of the study from about 30% to about 5%.
  - Reconnaissance Level
  - Due Diligence
  - Pre-Feasibility Level
  - Feasibility Level
  - Tender Design
  - Detailed Design
- Ideally a project goes through all development stages

Comparison of Design Stages

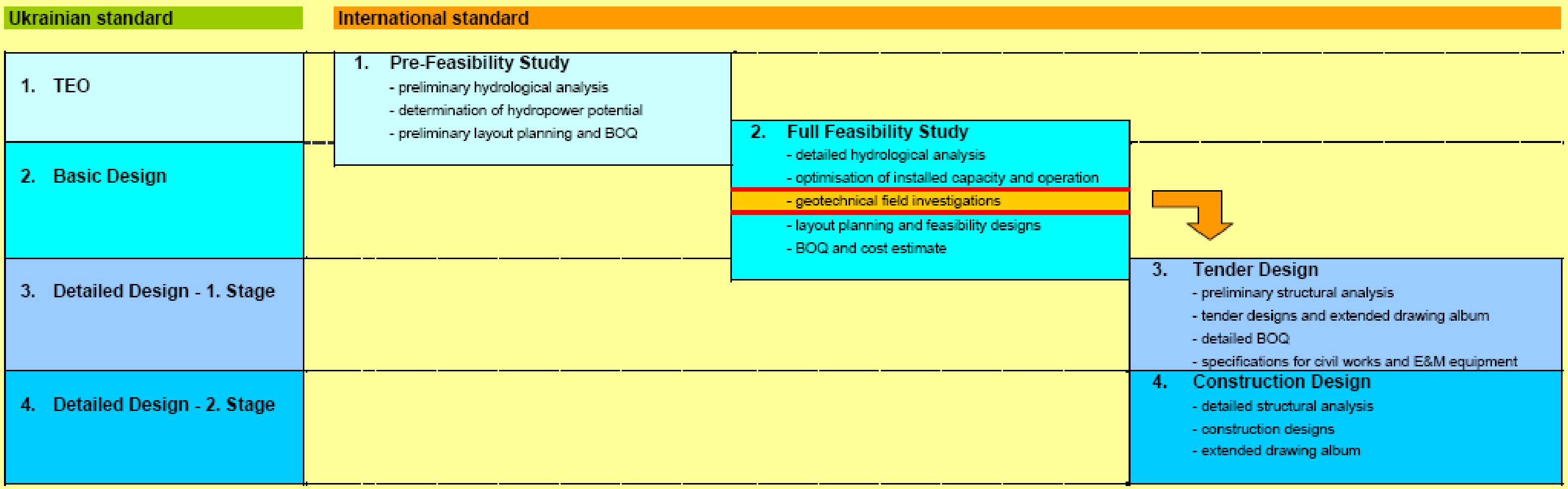


Figure 1: Design stages for hydropower planning

CASE STUDY LORIBERD HPP

Outline Loriberd HPP

Background

Review and Analysis of Original Scheme

Environemental Impact Assessment

Layout Alternatives

Optimization of Design

Availability of Water

Power and Energy Potential

Project Quantities and Costs

Project Implementation

Tashir SHPP

Economic Analysis

Financial Analysis

Summary and Conclusion

Background

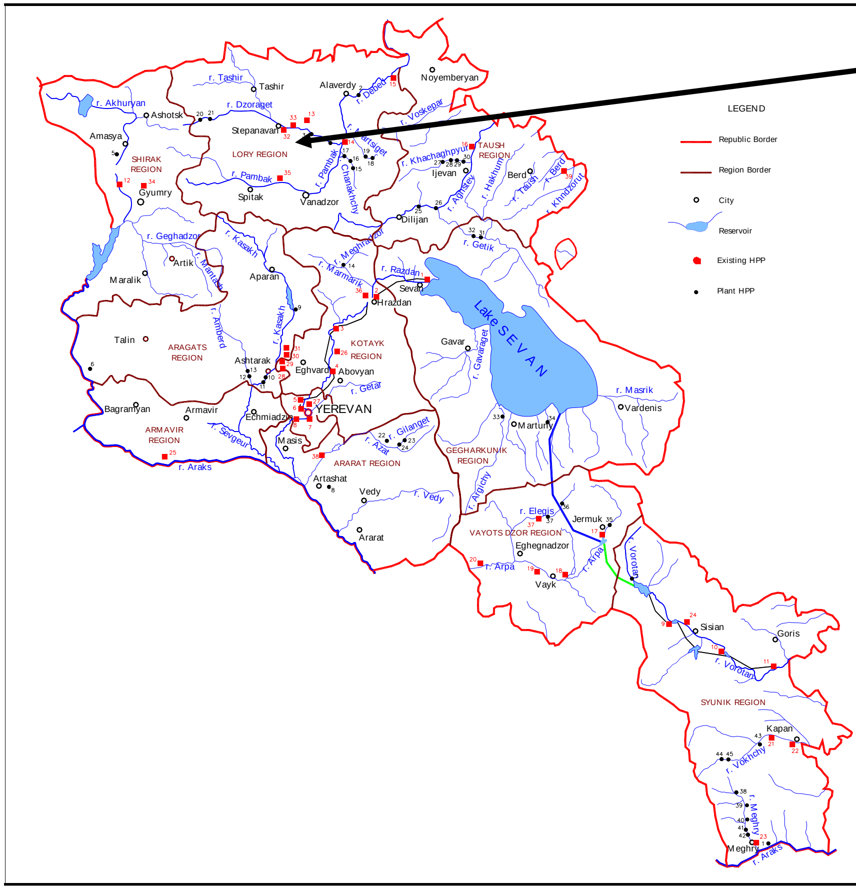
Planning since 1960‘s:

Concentrated Fall Development with large multipurpose dam

Loriberd Cascade Project with 3 separate HPP‘s

Last update in 1992

EU-TACIS:



Loriberd HPP

Background

Cascade Project:

Loriberd SHPP

- (1.8 MW, 6.8 GWh, ca. 9 MUS$)

Loriberd HPP I

- (8.8 MW, 29.8 GWh, ca. 70 MUS$)

Loriberd HPP II

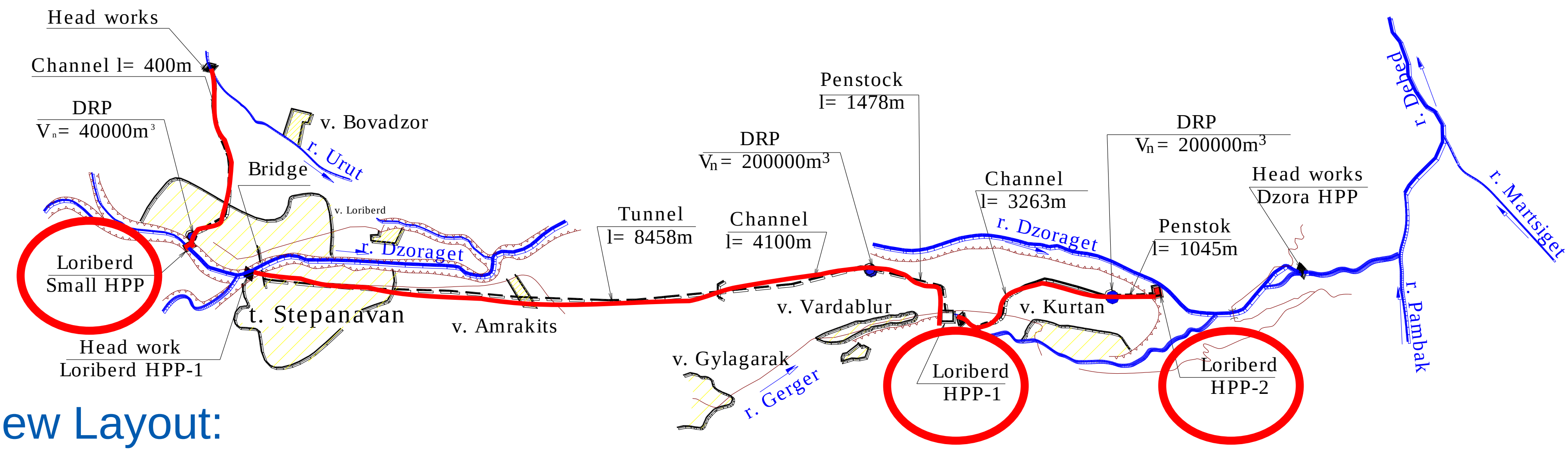
- (51 MW, 180 GWh, ca. 70 MUS$)

Total of the Installed Capacity

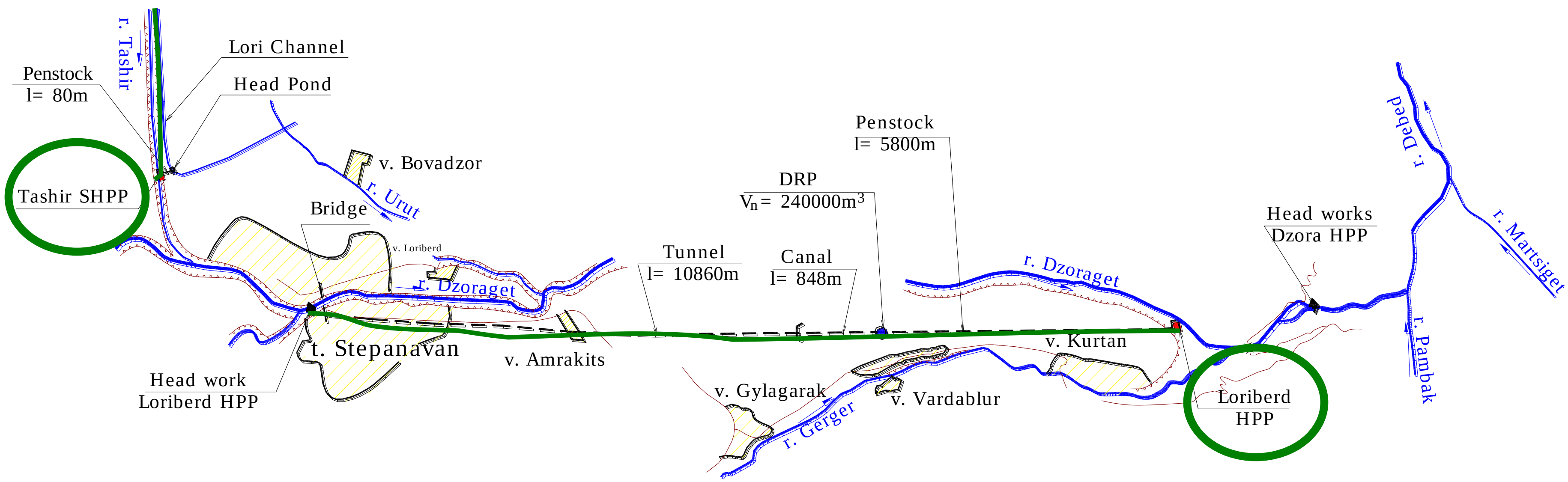
Power	66.6 MW
Energy	216.6 GWh
Invest. Costs	149 MUS$

Review of Original Scheme

Old Layout:



New Layout:



Review of Original Scheme

Loriberd HPP I:

increase of discharge by 1 m^3/s for Loriberd HPP II

add. 15 GWh for add. 14.5 MUS$

Gargar SHPP

Loriberd SHPP:

complex flow diversion (Tashir & Urut Rivers)

bulk of energy of Tashir River

use of Loriberd Irrigation Canal as headrace canal

reduction of costs from 9 MUS$ to 1 MUS$

reduction of energy from 6.8 GWh to 3.9 GWh

Environmental Impact Assessment

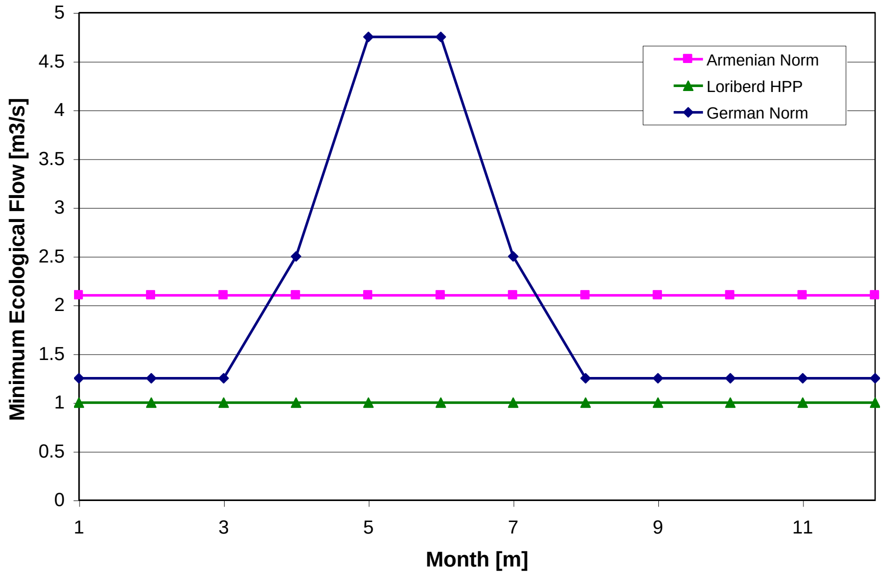
Main Environmental Impacts

Physical:
- excavation and dump of material
- dust, noise by construction works

Biological:
- temp. use of farm land (680 farmers)
- wildlife mostly in woods

Minimum Ecological Flow:

Magnitude



Economic Evaluation
- Investment WWTP: appr. 2000 TUS$
- loss of benefits appr. 12000 TUS$ (24 GWh/a)

Socio-Economics:
- no resettlement
- perm. loss of part of land (25 farmers)
- temp. loss of part of income (appr. 680 farmers, R/S of Lori Plateau)

Mitigation Measures acc. to WCD Guidelines

Layout Alternatives

Four Basic Layouts Loriberd HPP

Run-of-River

Results of Analysis

	Old Design	Free-flow Tunnel	Pressure Tunnel	Penstock in two sta-ges	Penstock in one stage
Installed Capacity [MW]	66.6	52.5	53.8	49.4	48.8
Mean Annual Energy Producti-on [GWh]	216.6	208.2	212.8	193.1	203.7
Spec. Investment Costs [TUS$/MW]	2237	1614	2121	2410	2414
Ranking	3	1	2	4	5

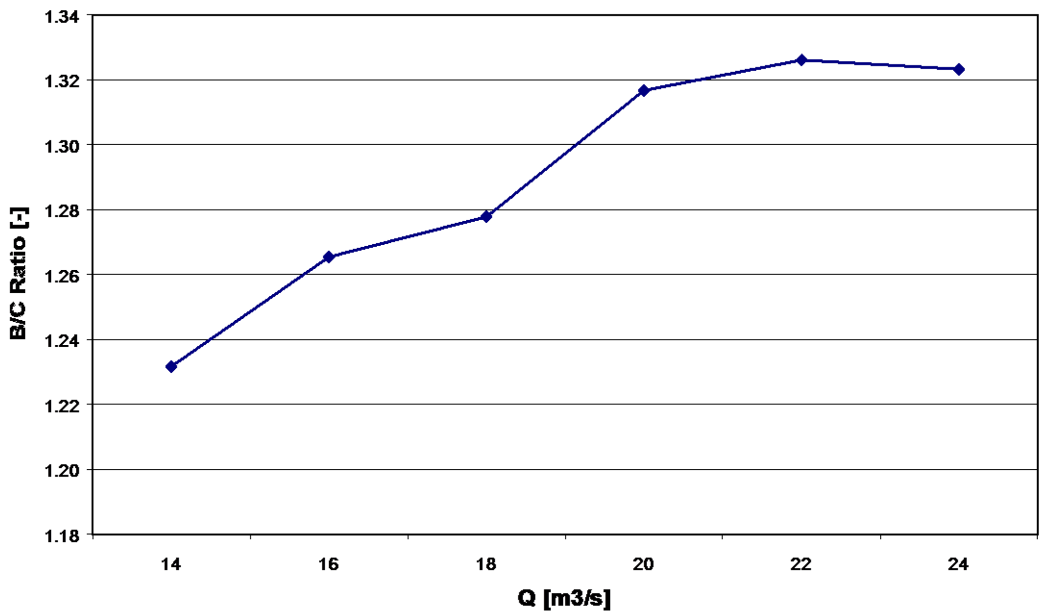
Optimization of Design

Free - Flow Tunnel using Pondage Capacity for Peaking

Design Discharge

Alternative: Gas Turbine Plant - 75 MW

value of energy and capacity output



Dzoraget HPP and Gargar River downstream

Optimization of Design

Peaking Characteristics

- 3 hours continous operation

Design

Weir with gates for flushing of sediments

Sandtrap

- Cost of none implementation:

  2578 TUS$ (O&M)
  \+ 11214 TUS$ (23 GWh energy loss)
  13792 TUS$

- Cost of implementation: 4500 TUS$

Shift of daily storage pond

Economic penstock diameter

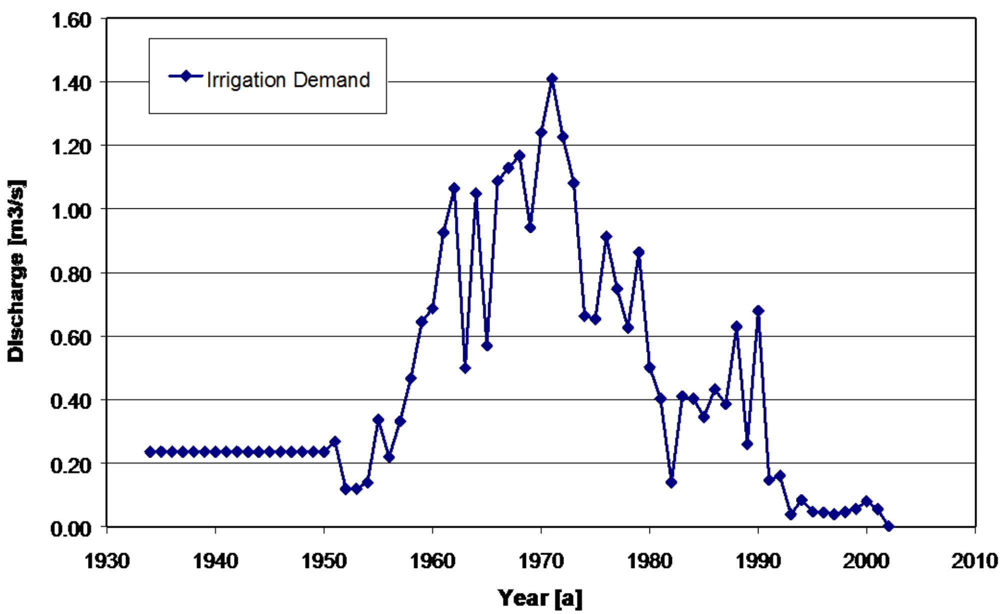
Shift of powerhouse location

Availability of Water

Irrigation

Lori & Kirov Canals

- Future demand based on actual capacities of canals
- Avoiding pumping for irrigation



Availability of Water

Potable water supply

Cities/Villages

- Future demand based on actual population development
  2003-2008: -1.0%
  2008-2013: +0.5%
  2013-2023: +1.0%
- KfW-Study Lori-Shirak:
  use of Kamenka spring (250 l/s) in future

Potable Water Demand

Demand	Year			
Town/Village	2003	2008	2013	2023
Stepanavan City	0.115	0.111	0.114	0.125
Stepanavan Villages	0.184	0.177	0.182	0.201
Tashir City	0.065	0.062	0.064	0.070
Tashir Villages	0.191	0.183	0.188	0.207
Alaverdi	0.117	0.113	0.116	0.128
Alaverdi Villages	0.040	0.038	0.039	0.043
Subsum	**0.712**	**0.684**	**0.633**	**0.774**
Vanadzor (KfW)	1.069	0.814	0.274	0.303
Total Sum	**1.781**	**1.498**	**0.907**	**1.077**

Availability of Water

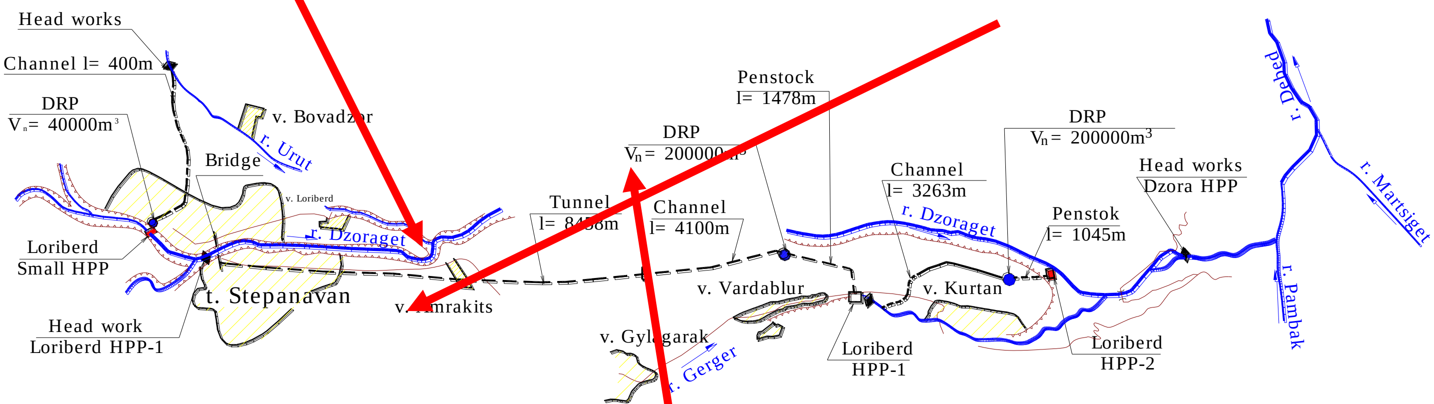
Existing Small Hydropower Plants

Amrakits SHPP I

- Power generation shall be stopped after 2011
- Compensation foreseen: 2011 - 2016

Amrakits SHPP II

- Reduced power generation from 5 GWh to 0.7 GWh
- Compensation foreseen: 2011 - 2016



Agarak SHPP

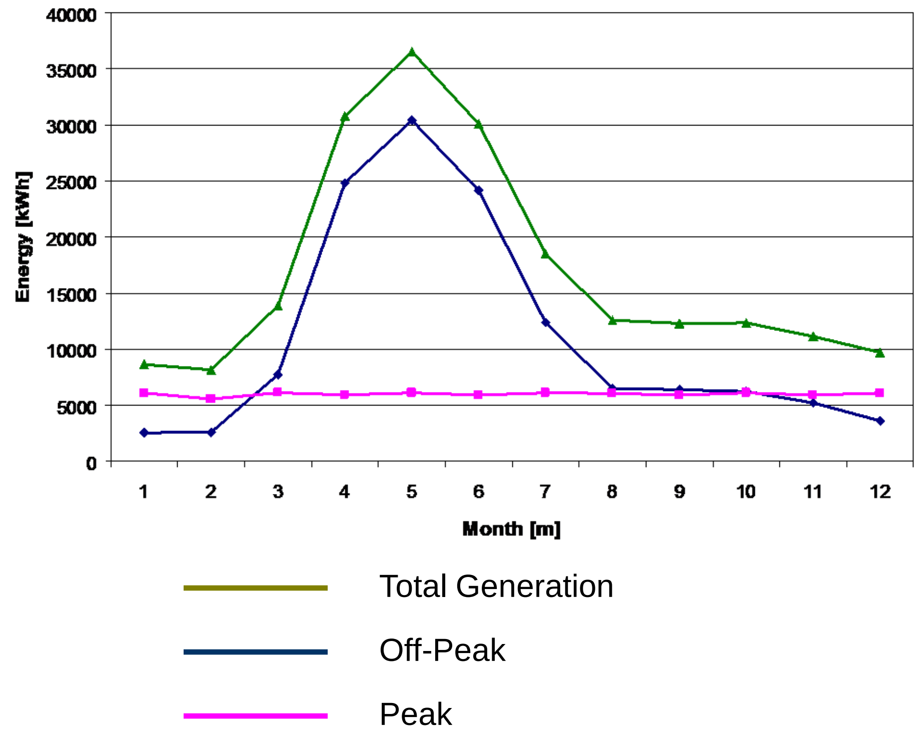
- Reduced power generation from 1.7 GWh to 0.7 GWh
- Compensation foreseen: 2011 - 2016

Power and Energy Potential

Final Technical Data

Storage Plant

- Design Discharge: 25 m3/s
- Gross Head: 341 m
- Net Head: 302.53 m
- Installed capacity: 65.3 MW
- Peaking time: 3 h continuosly
- Peak energy: 71.4 GWh
- Off-peak energy: 131.5 GWh
- Total energy: 202.9 GWh
- Plant factor: 35%



Run-of-River Plant

- Design Discharge: 20 m3/s
- Net Head: 311.75 m
- Installed capacity: 54.3 MW
- Energy: 210.1 GWh
- Plant factor: 44%

Project Quantities and Costs Loriberd HPP

Exchange Rate:		LOCAL	FOREIGN	TOTAL
550	DRAM = 1 US$, Price Index July 2004			
ITEM	**DESCRIPTION**	[TUS$]	[TUS$]	[TUS$]
I	**Environment Mitigation Costs**	600	150	750
II	**Preliminary and General**	1,745	436	2,181
III	**Civil Works**	34,394	8,598	42,992
	Subtotal I - III	**36,739**	**9,185**	**45,923**
IV	**Hydraulic Steel Structures**	3,794	15,176	18,970
V	**Hydromechanical Equipment**	1,758	7,034	8,792
VI	**Electrical Equipment**	2,544	10,176	12,720
VII	**Transmission Line**	864	216	1,080
	Subtotal I-VII	**45,699**	**41,786**	**87,485**
VIII	**Physical Contingencies**			
5	% of Preliminary Works	87	22	109
5	% of Civil Works	1,720	430	2,150
5	% of Hydraulic Steel Structures	190	759	948
5	% of Hydromechanical Equipment	88	352	440
5	% of Electrical Equipment	127	509	636
5	% of Transmission Line	43	11	54
	Subtotal VIII	**2,255**	**2,082**	**4,337**
IX	**Engineering & Supervision**			
7.5	% of Invest. Cost (Subtotal I-VII)	1,968	4,593	6,561
X	**Client's Cost**			
1.5	% of Invest. Cost (Subtotal I-VII)	394	919	1,312
XI	**Miscelleneous**			
	Compensation SHPP's, Model Test, WWTP Step.	2,846		2,846
XII	**Total Base Cost**	53,162	49,380	102,542
XIII	**Duties**			
10	% on Imported Goods	3,423		3,423
XIV	**Total Project Cost**	**56,585**	**49,380**	**105,965**

Project Implementation

Time Schedule

Activity	2005				2006				2007				2008				2009				2010			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Preconstruction	■	■	■	■	■	■	■																	
Construction									■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Civil Works									■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Headworks									■	■	■	■												
Tunnel										■	■	■	■	■	■	■	■	■	■	■	■	■		
Daily Regulation Pond													■	■	■	■								
Penstock/Pressure Shaft																■	■	■	■	■	■			
Powerhouse																	■	■	■	■				
Hydromechanical Equipment													■	■	■	■	■	■	■	■	■	■		
Electrical Equipment													■	■	■	■	■	■	■	■	■	■		
Testing and Commissioing																						■	■	■
Tashir SHPP																			■	■	■			■

Tunnel:

- drilling and blasting: 29 months
- use of TBM: 20 months, Cost Reduction of appr. 25% (7-8 MUS$)

Tashir SHPP:

- no construction works during irrigation period

Commissioning end of 2010

Tashir SHPP

Project Layout

Existing structures: headworks - headrace canal (Lori Irrigation Canal)

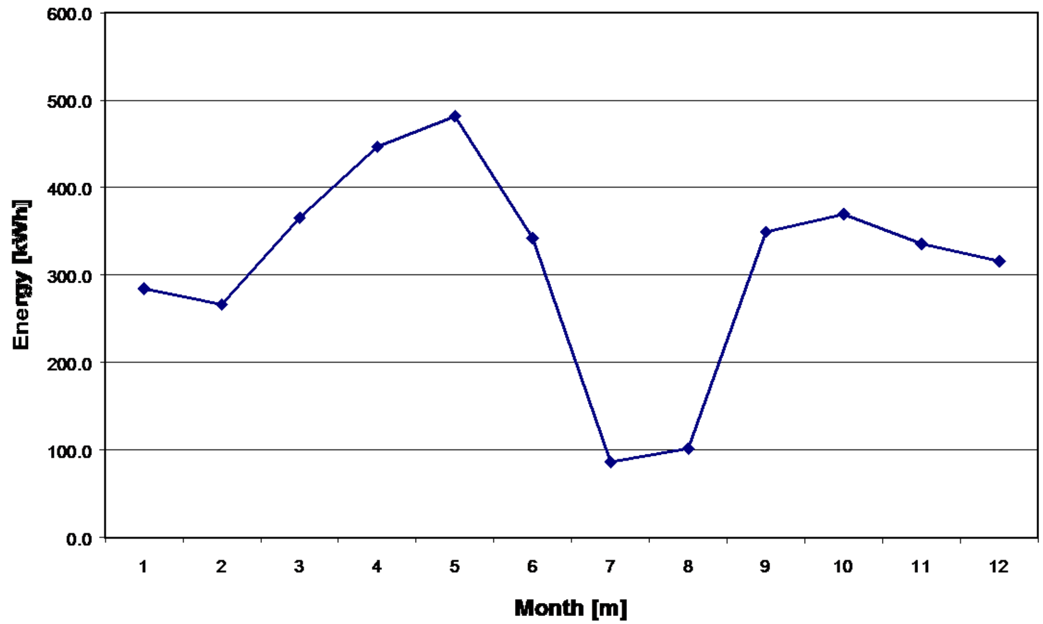
New structures: headpond - penstock - powerhouse - tailrace

Energy Potential

P = 700 kW

E = 3.9 GWh

- reduced energy during irrigation
- appr. 31 GWh at Loriberd HPP gained through Tashir flows



Important Issues

Compensation of Agarak SHPP

Investment Costs = 1000 TUS$

Possible interference with downstream water spring (distance 300 m)

Financial Analysis

Dynamic Production Cost

Assumptions	Peaking	RoR
• Investment Cost [MUS$]	107.01	99.32
• incl. Price Conting. [MUS$]	111.33	103.33
• Financing Requirements incl. Fees and IDC [MUS$]	124.3	115.2
• O&M Cost [% of direct cost]	2%	2%
• Net Energy Production [GWh] (Internal Consump. 1%,TL 2%)	200.7	205.9
• Lifetime Civil Works [a]	50	50
• Lifetime Equipment [a]	25	25

Results (Single Tariff)

Discount Rate	5%	8%	10%	12%
DPC Peaking	4.8	6.6	7.8	9.2
DPC RoR	4.4	5.9	7.1	8.3

Sensitivity Analysis for Peaking Case

HPP (without Tashir SHPP)	5.6	7.6	9.1	10.8
HPP (without water of SHPPs)	6.0	8.2	9.8	11.5

⇨ Project has to be implemented with Tashir SHPP and with water of existing SHPPs

Financial Analysis

Internal Rate of Return

Tariff [c/kWh]	4.5	6.0	8.0	10.0
IRR Peaking (without peaking tariff)	4.3%	7.1%	10.3%	13.1%
IRR Peaking (double of base tariff)	7.2%	10.4%	14.1%	17.4%
IRR RoR	5.3%	8.2%	11.5%	14.5%

Financing assumptions:

- debt/equity ratio 80/20
- interest rate 6.5%
- repayment period 10 years, grace period during construction
- CO_2-avoidance costs not included

Energy demand shows necessity of peaking capacity. Adjustment of tariff is required.

Private investor would expect appr. 20% return on equity

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Summary and Conclusion

Loriberd Hydropower Development

Project technical feasible

Most economic new hydropower project in Armenia / Caucasus Region

Basic figures: 66.0 MW 206.8 GWh 124.3 MUS$

Investment Costs comparable to similar projects in international context

Financial Analysis

DPC comparable to new thermal peaking plants

Peaking Operation Recommended

Role of Project

Important renewable energy project for Armenian energy sector

Contribution to reduced import dependency

Contribution to closure of Medzamor NPP