TRANSELECTRICA LTD.

KHUDONI HPP (702 MW) HANDBOOK

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1. BRIEF OVERVIEW

a) GENERAL

Khudoni Hydro Power Project is situated in Svaneti Valley on Enguri River in the Caucuses Region of western Georgia just below (4 Kms) Khaishi village, 34 Kms upstream of the existing Enguri River HPP Arch Dam. The distance from Georgia's Capital Tbilisi to the project location is 405 Kms. through an 80 Kms per hour Highway.

The construction of the project was started in 1979 and suspended in 1989 due to the collapse of the Soviet Union and lack of financing. After Georgia's independence the Georgian Government tried to restart the project construction but later decided to allocate it to a private investor instead of relying on state funding. Transelectrica Ltd. (TEL) took over the project in May'2010 for development on Build Own Operate Basis.

b) SCOPE OF THE PROJECT

Construction of Khudoni HPP comprises:

a) 194 m high double curvature concrete arch dam having base width 34.2 m and top width 8.1m;
b) The dam will have two bottom outlets, a small ungated crest spillway and 3 radial spillway gates for silt flushing and passing floods;
c) The power House with an installed capacity of 702 MW (3 X 234) vertical axis Francis Turbines and synchronous Generators will be capable of generating 1500 Million Units of saleable annual energy. The turbines will operate under a maximum gross head of 179.10 meters, minimum head 117 meters and design head of 151 meters;
d) Other main structures of Khudoni HPP are Diversion Tunnel, 3 nos intakes, 3 nos head race tunnels, 3 No pressure shafts, 3 nos Tail race tunnel and out fall structure.

c) PROJECT WORKS ALREADY DONE BEFORE SUSPENSION IN 1989

Approximately 22% of the total work (mainly underground) stands completed before suspension. Brief details as under:

a) Underground Power House Machine Hall and Control room excavated 60% i.e. up to service bay level;
b) Main access tunnel fully excavated;
c) Gate chambers 50% excavated;
d) Diversion Tunnel completed ;
e) Head race tunnels 3 Nos. 50% excavated;
f) Tail Race tunnels 3 nos. fully excavated and partially concreted;
g) Pressure shafts tunnel 3 nos. fully excavated, steel liner to be erected;
h) In addition to above, construction adits, cable cum ventilation gallery, machine hall drainage gallery and 4 nos. dam foundation galleries have also been fully excavated;
i) Part of dam profile excavation has been done and in fact 2 dam concrete block on left bank stand casted.

d) INFRASTRUCTURE

Because of the construction of Enguri HPP, which is not far downstream from Khudoni HPP, most regional infrastructure is already in place. The project site can also be reached via 125 and 225 km long roads from the nearest port (POTI sea port) and international airports at Batumi and Kutaishi. All the construction sites of the project are linked by approach roads which of course would require restoration because of long period of abandonment.

Prior to its suspension, residential, buildings, offices, stores, ware houses and other construction facilities were built in Jvari village and at site. Most of the buildings are made of concrete and steel sheets and are approx. 60% complete. These are now owned by TEL. These however need rehabilitation and balance construction to make them usable.

e) TRANSMISSION LINES

As on today Khudoni has potential access to two high voltage transmission lines. The first has a capacity of 500 KV and passes across Georgia to Russia on one side and to Armenia on the other side. This transmission line is half km from the Khudoni Power Station and can be connected through a Loop-in-Loop-out system. The second one is from Zestaphoni in Georgia connecting AKHALTSIKHA in Turkey with capacity of 500/400 KV. Thus Khudoni HPP has the opportunity to export to Turkey, Russia and central part of Georgia after the 15 years term of existing PPA with GOG (Government of Georgia) expires. Currently the power is to be delivered to Georgian Government at Bus bar and further transmission is Government of Georgia's responsibility.

f) LAND

GOG has acknowledged the Project to be high public necessity and has already transferred 1414 hectares of state land involved in construction of project components. The balance privately owned land plots coming under submergence shall be measured, inventory conducted and registered at National Agency of Public Registry by Project Company with GOG support to obtain relevant rights. In case the project company is unable to do so due to the reasons not attainable to it, GOG within its competence shall ensure issuance of legal act for the purpose of land expropriation procedures.

g) ENVIRONMENTAL & SOCIAL ISSUES

Based on studies carried out in 2006 by environmental consultant team led by BRL-ARS (appointed by World Bank), resettlement of 178 project affected families was envisaged. Subsequently the project company has again done the Environment Studies through CENN (Caucuses Environment NGO Network) in consultation with ERM - A German Company (Environment Resource Management) & also Resettlement Plan through APLR (Association for Protection of Land holder's Rights). The current studies confirm that there are 184 project affected families who need resettlement.

CENN has worked for renowned institutions like World Bank, UNDP, USAID, British Council etc. & ESIA has been prepared on the basis of:

- Georgian law of protection of Environment

- IFC's Stakeholder Engagement(2007) Manual
- Performance requirements of EBRD's Environment & Social Policy(2008)
- International conventions ratified by Georgia
- World Bank Procedures & Guidelines

ESIA Document is ready for uploading in Public Domain. The document was reviewed by Dutch Commission appointed by GOG & their recommendations stand incorporated. The following additional studies suggested by the various experts have been completed & incorporated in the ESIA document.

- Emergency Response Plan;
- Dam Break Analysis;
- Red Species Inventory;
- Cost Benefit Analysis;
- Water & Air Pollution Studies;
- Sedimentation Studies.

Assistance in RAP (part of ESIA) implementation after approval has been tied up with re-plan Canada which is amongst the best in the field.

h) CONSTRUCTION PERMIT DOCUMENTS

Technical documents required for the submission of application for the Construction Permit are ready. These inter-alia include

- Updated project proposals and geo-technical studies;
- Current Topographic maps;
- Seismic studies corroborated by University Professors;
- Preliminary drawings and Dam design;
- Archeological and Cultural Heritage clearances.

i) PPA

The entire amount of electricity generated by Khudoni HPP shall be purchased by GOG through a Guaranteed PPA with ESCO which shall ensure Project Company's rights regarding guaranteed purchase of power during the Initial Operation Period of 15 years. After the initial operation period the project company is entitled to sell power at its discretion and may export electricity in accordance with Georgian Legislation.

Tariff: The tariff for Guaranteed PPA has been set on "take or Pay principles" for initial operation period on reducing basis from 10.50 U.S. Cents initially to 5.00 U.S. Cents in the last year to be in line with diminishing liabilities of the Project Company and increasing pay back. The weighted average annual interest rate of 7.56% on debt financing forms the basis of this tariff. It has been agreed by GoG that electricity purchase price will be updated to reflect changes necessary to compensate any financial impact of actually attracted debt financial terms.

j) PARTICIPATION OF GOG

GOG may acquire up to 20% of fresh equity in the issued and paid up share capital of the Project Company on or before the closure of Financing Agreements of the Project.

k) PROTECTION AGAINST FUTURE CHANGES IN LAW

If Project Company suffers an increase in cost or other finance burden or damages as a result of change of law, GOG shall either agree on the amendments to the agreement (including increase of price in Guaranteed Power Purchase Agreement) or alternative arrangement to put the project company in the same financial position as it would have occupied had there been no change in law.

l) GEOLOGICAL AND GEOTECHNICAL

In 2009, the feasibility study of the Khudoni HPP was redone and updated by using largely Russian data and updated evaluation tools and best practices by a Joint Venture of internationally renowned consultants M/s STUCKY and COLENCO of Switzerland. The study was financed by the World Bank and ratified by a panel of experts appointed by the World Bank.

Further an extensive additional geological and geotechnical program was undertaken by the promoters i.e. TEL in 2012-2013 to corroborate the old Soviet Union data, update correlate and fill in gaps in old data. The Dam designs has been updated using latest available Finite Element Static and Dynamic Analysis on DIANA version 9.4.3 which was not available when the project was started in 1979

The current Conditions of the underground excavations including four galleries in the abutments of the dam provide real in situ information from deep within the foundations. The excavations are largely unsupported, dry and sound indicating good rock quality and tightness of the joints.

m) HYDROLOGY AND POWER STUDIES

Hydrology of the project is well established by way of availability of long term actual; inflows at downstream Enguri Dam and availability of long term data from nearby measuring stations on River Enguri and its tributaries. The hydrological data and reservoir simulation has been used on an in-house program of STUCKY for Energy calculations. The calculations are based on a Monto Carlo algorithm and conclude that approx. 1500 Million Units Energy shall be available for sale in an average year. Envisaged reservoir parameters are as under:

- Length along Enguri River 9.2 Kms
- Surface Area 5.22 Sqkms
- Gross Capacity 364.5 mm^3

n) SEDIMENTATION

Based on the various past studies and current actual study of sediment deposits in Enguri Dam reservoir the sedimentation terms of reservoir has been forecast as 130-150 years. Sedimentation is not a problem for Khudoni HPP as has been demonstrated by the downstream Enguri HPP.

o) CONSTRUCTION MATERIALS

Suitable aggregates are available near the location of Khudoni HPP. Cement is available locally in factories around Tbilisi (capital of Georgia). The fly ash and steel will have to be imported from Ukraine or Unye (UNYE) in Turkey via sea route.

p) COST ESTIMATES AND FINANCIALS

- Estimate cost of completing balance works is 961.70 Million USD inclusive of IDC and Financing charges. The Debt to Equity ratio has been proposed as 70:30. The cost of completed works has been estimated as
  - i. Historical approach based on actual Soviet Union records before suspension
    183.039 Million USD
  - ii. Volumes as Built on current prices
    171.87 Million USD
  - iii. KPMG has evaluated enterprise value of KHPP and determined that it is very sensitive to discounting rates and varies from 142.462 to 238.035 Million USD on WACC varying from 13.3% to 12.3%. So a middle value can be adopted for the time being.
- Considering the Guaranteed Power Purchase Agreement prices for first 15 years and projected export prices thereafter the other financial parameters come out as under:

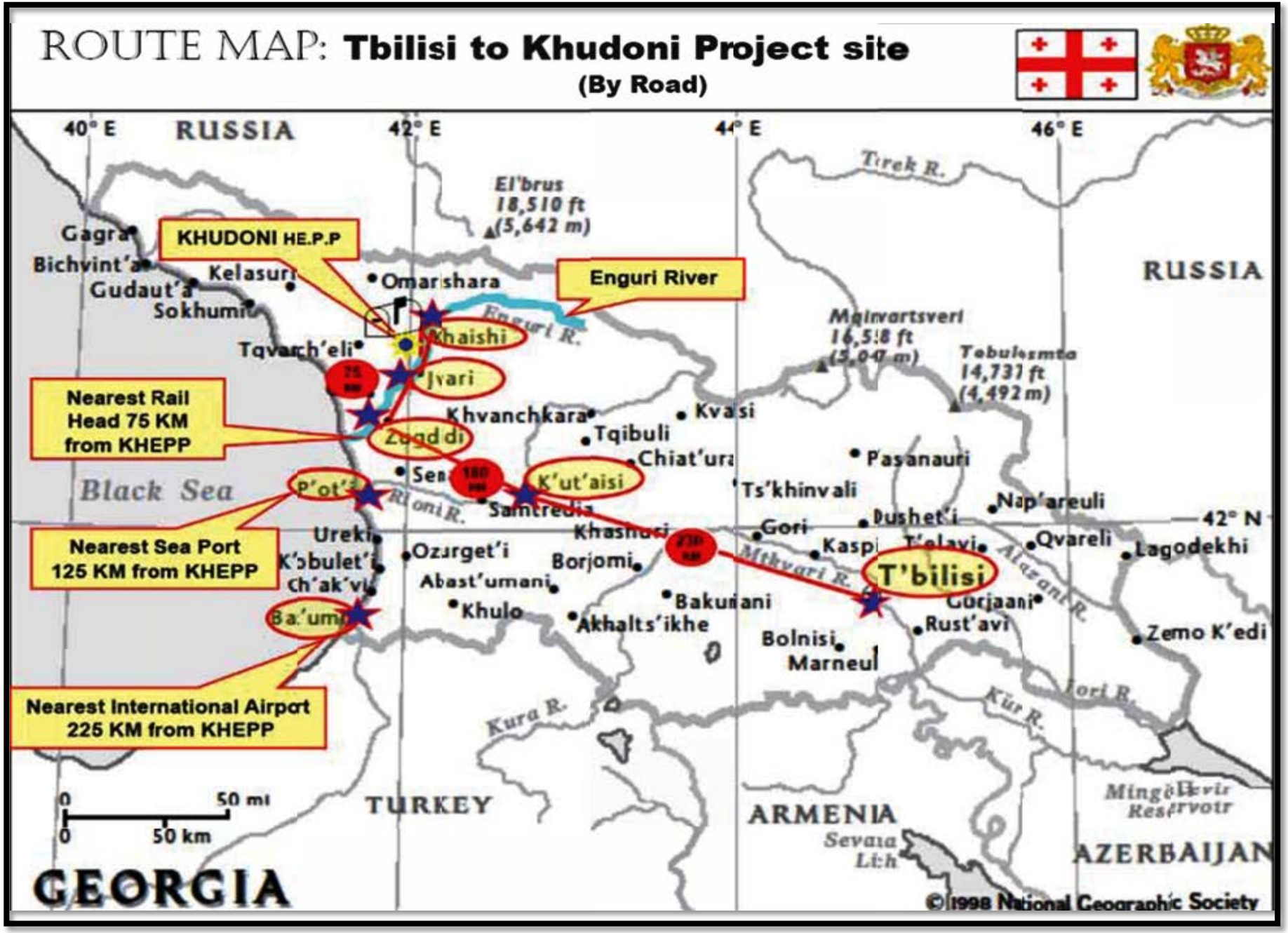
i.	Minimum DSCR	1.12
ii.	Average DSCR	1.51
iii.	Project IRR (Pre Tax)	13.63%
iv.	Equity IRR	15.27%
v.	Payback Period	14.11 years (including 6 years of estimated construction period)

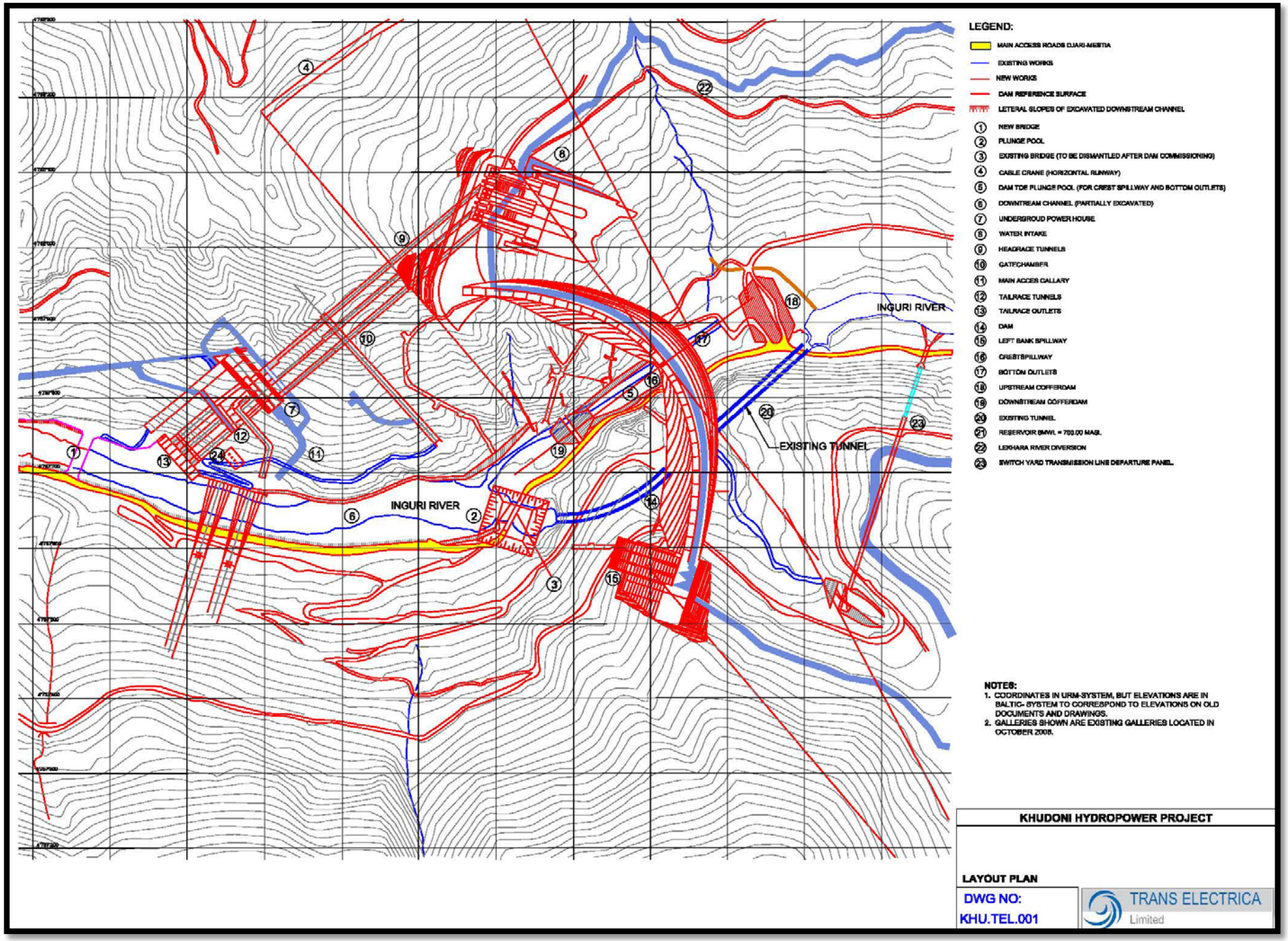
q) RISKS

Design, construction, HM and E&M Equipment operation and legal/Political/Institutional risks can be managed by using 2 independent Engineers (Owner's and Contractor's) POE, choice of reputed suppliers and contractors, well trained O&M staff, planned maintenance, using FIDIC contracts and insurances.

r) TIME FOR COMPLETION

Time for completion has been estimated at 72 months. This shorter time frame is possible due to large underground excavation already done eliminating geological surprises and availability of good infrastructure. The critical path is the construction of Dam.


ROUTE MAP: Tbilisi to Khudoni Project site
(By Road)
KHUDONI HE.P.P
Enguri River
Nearest Rail Head 75 KM from KHEPP
Nearest Sea Port 125 KM from KHEPP
Nearest International Airport 225 KM from KHEPP
T'bilisi
RUSSIA
TURKEY
ARMENIA
AZERBAIJAN
GEORGIA
Black Sea
Kura R.
Enguri R.
Tirek R.
El'brus 18,510 ft (5,642 m)
Mqinvartsveri 16,518 ft (5,047 m)
Tebulosmta 14,737 ft (4,492 m)
Gagra
Bichvint'a
Gudaut'a
Sokhumi
Kelasuri
Omarishara
Khaishi
Tqvarch'eli
Jvari
Zugdidi
Khvanchkara
Tqibuli
Kvasi
Chiat'ura
Pasanauri
Ts'khinvali
K'ut'aisi
Samtredia
Ureki
K'obulet'i
Ch'ak'vi
Ozurget'i
Abast'umani
Khulo
Borjomi
Khashuri
Gori
Kaspi
T'elavi
Bakuriani
Akhalts'ikhe
Rust'avi
Bolnisi
Marneuli
Nap'areuli
Dushet'i
Qvareli
Lagodekhi
Gurjaani
Zemo K'edi
42° N
40° E
42° E
44° E
46° E
0 50 mi
0 50 km
© 1998 National Geographic Society


LEGEND:
MAIN ACCESS ROADS DJARI-MESTIA
EXISTING WORKS
NEW WORKS
DAM REFERENCE SURFACE
LETERAL SLOPES OF EXCAVATED DOWNSTREAM CHANNEL
1 NEW BRIDGE
2 PLUNGE POOL
3 EXISTING BRIDGE (TO BE DISMANTLED AFTER DAM COMMISSIONING)
4 CABLE CRANE (HORIZONTAL RUNWAY)
5 DAM TOE PLUNGE POOL (FOR CREST SPILLWAY AND BOTTOM OUTLETS)
6 DOWNTREAM CHANNEL (PARTIALLY EXCAVATED)
7 UNDERGROUD POWER HOUSE
8 WATER INTAKE
9 HEADRACE TUNNELS
10 GATECHAMBER
11 MAIN ACCES GALLARY
12 TAILRACE TUNNELS
13 TAILRACE OUTLETS
14 DAM
15 LEFT BANK SPILLWAY
16 CRESTSPILLWAY
17 BOTTON OUTLETS
18 UPSTREAM COFFERDAM
19 DOWNSTREAM COFFERDAM
20 EXISTING TUNNEL
21 RESERVOIR (MWL = 700.00 MASL
22 LEKHARA RIVER DIVERSION
23 SWITCH YARD TRANSMISSION LINE DEPARTURE PANEL
INGURI RIVER
INGURI RIVER
EXISTING TUNNEL
NOTES:
1. COORDINATES IN URM-SYSTEM, BUT ELEVATIONS ARE IN BALTIC- SYSTEM TO CORRESPOND TO ELEVATIONS ON OLD DOCUMENTS AND DRAWINGS.
2. GALLERIES SHOWN ARE EXISTING GALLERIES LOCATED IN OCTOBER 2008.
KHUDONI HYDROPOWER PROJECT
LAYOUT PLAN
DWG NO:
KHU.TEL.001
TRANS ELECTRICA
Limited

2. GENERAL

a) Proposal for Khudoni Construction was approved on 31st August 1978 by United Ministry of Energy of Soviet Union & Construction of Infrastructure was started in 1979. Arch Dam proposal was approved in 1984. The Construction of Project continued up to 1989 & 25% was completed before further construction was terminated.

b) In 2005, World Bank approved a grant of U.S 5 Million $ for feasibility, EIA & RAP Studies.

c) A study on Energy balance of Power Sector of Georgia was conducted in 2006 by SEEC (South East Europe Consultant) which concluded that Hydro Power is more feasible solution than gas based for Georgia even in low water conditions.

d) In 2006, Govt. of Georgia commissioned a strategic Environment study to address Georgia's Power needs & Prioritize candidate power projects. The study found that Khudoni HPP is the most attractive scenario.

e) In 2009, a feasibility study was carried out by Swiss consultant Stucky & Colenco which was funded by the World Bank. The Studies utilized largely Russian geological & other data& concluded that then existing Khudoni concept was suitable for 200m High Arch Dam. The Project & Arch dams were also endorsed by a World Bank Panel of Experts (PoE).

f) Additional Geological & Geotechnical studies were recommended by the consultant & endorsed by PoE to update arch dam design to current best practice & obtain more accurate cost estimates. However Govt. of Georgia (GoG) terminated further studies because project was taken over by Trans Electrica Ltd. (TEL) in May 2010 for development on Build Own Operate Basis.

g) TEL Submitted a proposal to GoG in December 2010 containing DPR; Draft Implementation Agreement (IA) & Power Purchase Agreement (PPA).

h) TEL Signed IA with GoG on a Build Operate Own Basis during May 2011. IA provided reserving winter power for use in Georgia & for balance months the same can be exported. Both IA & PPA have been revised in 2015 to accommodate current status of project & a guaranteed full year generation PPA with GoG at predetermined tariff.

i) From September 2012 to February 2013, a new campaign of geological geotechnical investigations has been carried out as had been earlier recommended by the World Bank PoE in 2009. PoE had following experts:

   Dr. Harald Kreuzer, Dam Expert (Switzerland)
   Mr. William Moler, Engineering Geology Expert (USA)
   Dr. Juan Valdes, Hydrology Expert (USA)

j) A Detailed Updated topographical Survey of the Project Site has been undertaken by TEL & used in the review & updating Dam Designs.

k) New Geological & Geotechnical data has been obtained that fills the various gaps in the previous geological model which was mainly reliant on Russian Data.

l) The Geology of the Dam site & Geo-mechanical properties of main lithological units have been confirmed & updated.

m) On the left bank spillway area, the thickness of the overburden, top of rock & variations in rock quality have been fully identified & may be used in finalizing the design of spillway.

n) The reservoir simulation & power studies have been updated to take into account the influence of Nenskra Reservoir. In summary Nenskra regulation will increase winter firm energy by +24.5% & overall firm energy by +4%.

o) An updated ESIA study has been carried out by CENN (Caucuses Environment Network) in association with ERM (Environment Resource Management) – a German Company. The updated version has also incorporated recommendations & comments of a Dutch Commission appointed by GoG for the purpose. Canadian company replan has also been roped in.

In Conclusion, the new data complemented the geology already established by the Soviet Union & reconfirmed in 2009 studies & concluded that the site is feasible for a double arch dam. Dam foundation & abutment analysis have been performed & confirm that potential wedges are stable even if conservative assumptions are considered. These studies have also reduced the concrete volume of dam from earlier 2,273,000 m^3 to 2,084,000 m^3 (reduction of 8.3 %.)

3. SALIENT FEATURES

a) Project Location

i.	Country	Georgia
ii.	River	Enguri (213 Km long)
iii.	Vicinity	Khaishi Village (Western Georgia) 405 km from Tbilisi & 70 km from nearest rail head Zugdidi. The nearest sea port of Poti is only 125 km away.

b) Hydrology

i.	Design Discharge	510 cumecs
ii.	Flood Discharge	2500 cumecs

c) Reservoir

i.	Capacity	364.5 million Cum (at normal FSL)
ii.	Live Storage	223 million Cum
iii.	Catchment Area	2780 Sq.km
iv.	F R L	700.00 m
v.	M D L	630.00 m

d) Arch Dam

i.	Height	194 m
ii.	Length at Crest Level	718 m (550 m Dam + 168 m spillway gravity block)
iii.	Top Width	8.1 m (at crest level)
iv.	Base Width	34.2 m (at the lowest base point)

e) Underground Power Station

i.	Machine Hall	Size 99 m(L) X 21 m(W) X 49 m(H) **(60% Excavated)**
ii.	Transformer Hall	Size 82.24 m(L) X 16 m(W) X 22 m(H)
iii.	Control Room	Size 36.7 m(L) X 12 m(W) X 11 m(H) **(50% Excavated)**

f) Gate chambers: Size 10 m (W) x 58 m (L) x 25 m H)***(Partially excavated)***

g) Construction Tunnels

i.	Main Access tunnel (MAT) to Machine Hall Cavern	10 m x 10 m, horseshoe, length-130m ***(Excavation complete)***
ii.	Diversion tunnel	10 m x 9 m horseshoe, length – 437.84 m. ***(Complete and in operation)***

iii.	Lekhera diversion tunnel	3.30 m X 3.30 m diameter, Horseshoe shaped, Length – 240 m
iv.	Intake Tunnels	3 Nos. each 6.0 m diameter, circular & of Length – 57.46 m
v.	Head Race Tunnels	3 Nos. each 6.0 m diameter, circular & of Lengths – 240 m, 260 m & 280 m. (50 % Excavated & concreted U/s of Gate Chamber to a length of about 120m)
vi.	Tail Race Tunnels	3 Nos. each 8 m diameter, circular & of Length 145 m. (Excavation complete & Partially Concreted)
vii.	Outfall Structure	3Nos. Gated area having opening size – 8 m X 8 m
viii.	Pressure Shaft tunnels	3 Nos. each of 6.0 m diameter, circular & of Length 156 m. (Excavation complete, steel liner to be erected)

h) Gates

i.	Spillway	3 Nos. each of Size 9 m X 12 m
ii.	Intake (Stop Logs)	3 Nos. each of Size 5.75 m X 18.6 m
iii.	Tail Race Gates(Stop Logs)	3 Nos. each of size 8.60 X 11.00 m
iv.	Bottom Outlet (Radial Gates)	2 Nos. each of Size 2.75 m X 3.50 m
v.	Bonnet Wheel Chamber (Gate Chamber)	3 Nos. each of size 4.00 m X 6.00 m
vi.	Butterfly Valve	3 Nos. diameter 4.96 m each

i) Turbines

i.	Number	3 Nos.
ii.	Type	Vertical Axis Francis Turbines
iii.	Speed	187.5 RPM

j) Generators

i.	Number	3 Nos.
ii.	Capacity	234 MW each

k) Power Output

a)	Annual Saleable Energy (at Bus Bar)	1500.00 GWH

4. KEY PROJECT CONSULTANTS & THEIR SCOPE

Consultants	Scope
Stucky Limited, Switzerland	• Detailed Geotechnical Investigation report • Dam design and energy model of the project • Updating feasibility report for the project • Updating the BOQ
Caucauses Environment NGO Network (CENN), Georgia & Environment Resource Management(ERM), Germany	• Environment and Social Impact Assessment Study for the Project • Environment and Social Action Plan • Environment and Social Monitoring Plan
Association for Protection of Landowner's Rights, Georgia	• Resettlement Action Plan(RAP) • Assessment of compensation to be provided to Project Affected families • Monitoring and Evaluation Mechanism for implementation of RAP
Poyry PLC, UK	• Overview of Turkish power market • Turkish electricity market forecast(wholesale tariffs, demand- supply) • Brief comparative overview of power markets in Southern Russia
Hydrodynamics LLC, Georgia	• Dam Break Analysis to recommend safety levels in the design • Inundation maps for Disaster Management Plan.
Hydro-diagnostics Ltd.	• Forecasting the Khudoni Hydropower reservoir sedimentation.
Schinelli Consulting, Italy and Ilia State University, Georgia	• Seismic Refraction Surveys
Well3 Ltd, Georgia	• Drillings
Piramida Ltd, Georgia	• Grouting Tests
Geo-Engineering , Georgia	• Laboratory Testing

5. COST ESTIMATES

Rates Applied

a) Cement – 100 $/t
b) Aggregate – 12.5 $/m3
c) Reinforcement – 1.4 $/Kg
d) Excavation
   i. Underground – 80 $/$m^3$.
   ii. Rock open – 18 $/$m^3$.
   iii. Soil Open – 5 $/$m^3$.
e) Formwork
   i. Surface – 15 $/$m^3$.
   ii. Underground – 38.40 $/$m^3$.
f) Drilling for Rock Bolts – 100 $/m.
g) Rock Bolts – 1.7 $/Kg.

S.No.	DESCRIPTION	ESTIMATED COST (BALANCE WORKS) (In USD)
1.	Preparation Works	2,232,500
2.	Dam	302,619,830
3.	Power House	21,078,195
4.	Power Water Way	59,121,163
5.	M & E	180,487,500
6.	Misc.	7,701,034
7.	Site Installations	50,859,218
8.	Transport	4,839,762
9.	Contingencies	37,648,963
10.	Social & Environment	61,500,000
11.	Investigations	2,200,000
12.	Detailed Designs, Supervision, Admn.	33,329,408
13.	Contingencies (Land, Invest, Design)	7,926,470
	TOTAL	777,544,043

6. FINANCIALS

Sl.No.	Project Capital Cost	Completed Works Upfront
1.	Hard Cost	919.89 M USD
2.	Soft Cost (IDC 164 t F.C 20)	184.28 M USD
	Total	1104.17 M USD
3.	Equity 30%	331.25 M USD
4.	Debt 70%	777.92 M USD
5.	Depreciation	
6.	Bldg & Civil Works	5% SLM
7.	M & E Works	8% SLM
8.	Max. Dep	90%
9.	O & M Expdt.	1% of Project Cost
10.	Escalation O & M	2%
11.	First Year Revenue	157.48 M USD
12.	Tariff	5yrs 10.50 USC/Unit
		3yrs 10.30
		2yrs 9.80
		1yr 9.50
		1yr 6.00
		3yrs 5.00
		Average 8.51
13.	Min. DSCR	0.87
14.	Average DSCR	1.30
15.	Project IRR (Pre Tax)	12.35%
16.	Project IRR (Post Tax)	11.40%
17.	Equity IRR	16.17%
18.	Payback	17.11 yrs (Including Construction period)

Sl.No.	Project Capital Cost	Completed Works Post Completion
1.	Hard Cost	777.42 M USD
2.	Soft Cost (IDC 164 t F.C 20)	184.28 M USD
	Total	961.70 M USD
3.	Equity 30%	288.51 M USD
4.	Debt 70%	673.19 M USD
5.	Depreciation	
6.	Bldg & Civil Works	5% SLM
7.	M & E Works	8% SLM
8.	Max. Dep	90%
9.	O & M Expdt.	1% of Project Cost
10.	Escalation O & M	2%
11.	First Year Revenue	157.48 M USD
12.	Tariff	5yrs 10.50 USC/Unit
		3yrs 10.30
		2yrs 9.80
		1yr 9.50
		1yr 6.00
		3yrs 5.00
		Average 8.51
13.	Min. DSCR	1.12
14.	Average DSCR	1.51
15.	Project IRR (Pre Tax)	13.63%
16.	Project IRR (Post Tax)	12.61%
17.	Equity IRR	15.27%
18.	Payback	14.11 yrs (Including Construction Period)

7. EVALUATION OF EXISTING WORKS

a) Historical Approach: - Historical records maintained for expenditure show that up to 1989 (Before Suspension) an Aggregate 112.32 Million Rubbles was planned against which 110.265 Million Rubbles was Spent.

Official Exchange Rate during 1983-85, 1 Rubble = 1.66 USD.
So, Historical Expenditure in USD = 110.265 x 1.66
= 183.039 Million USD.

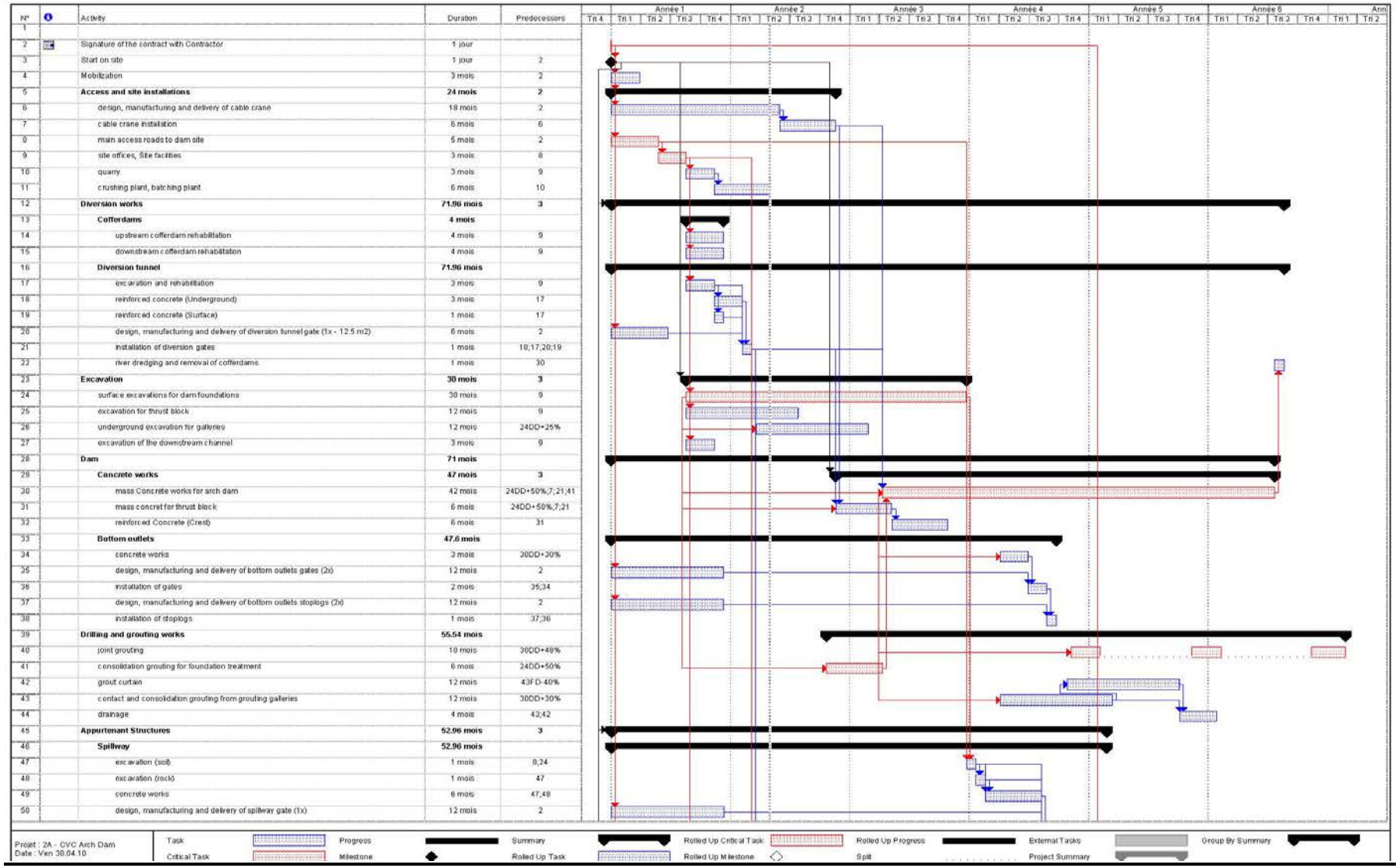
b) Volumes as Built & Present Rates: -
Accessible excavations were surveyed in 2007, volumes determined. Inaccessible Volumes were worked out from Construction Drawings. Based on this approach the evaluation comes as 181.87 Million USD. After deduction of 10 Million USD for Restoration.
The Current Evaluation comes to 171.87 Million USD.

c) KPMG evaluated enterprise value of KHPP & determined that it is very sensitive discounting rate & terminal growth. It Varies as under

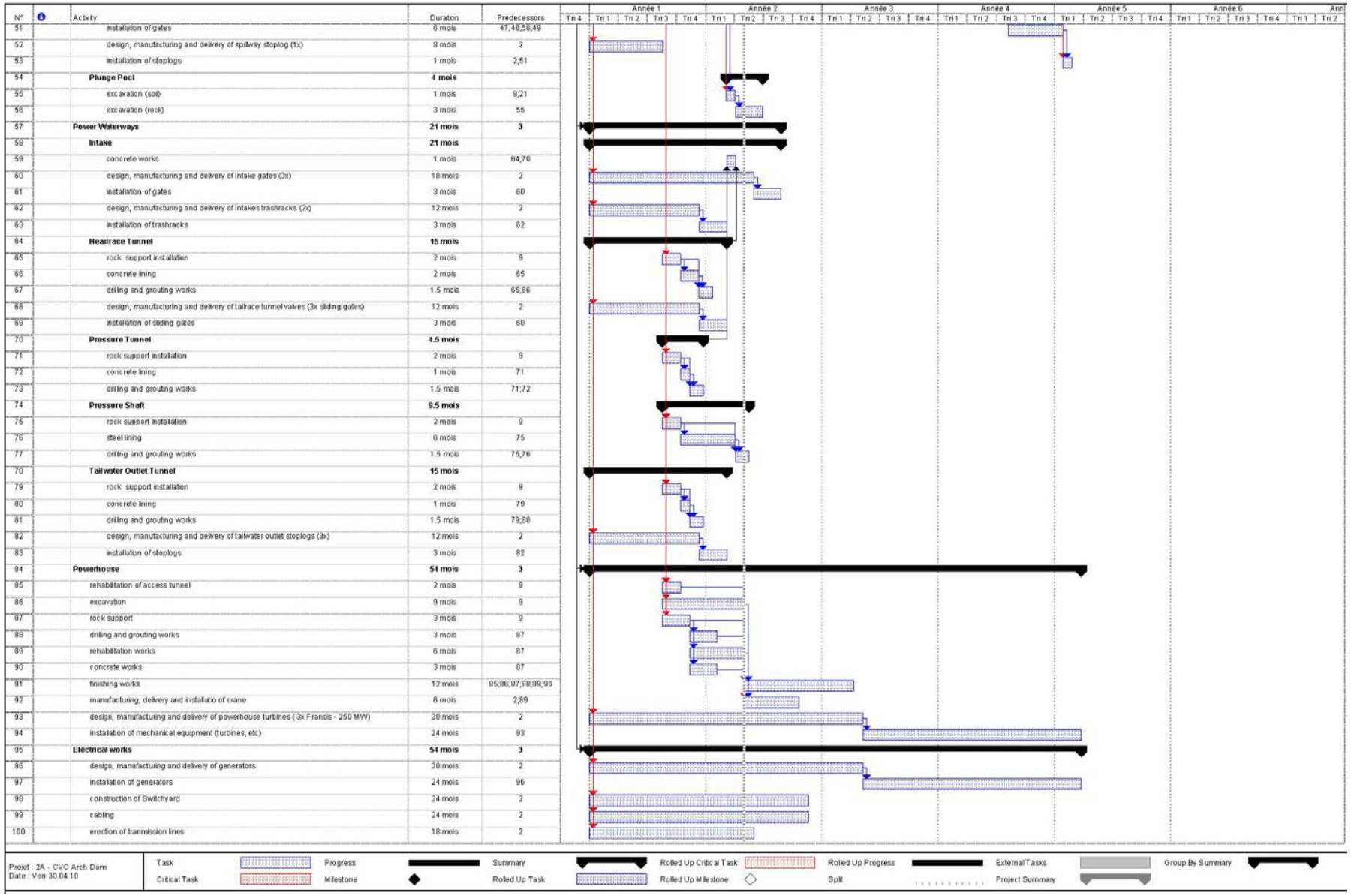
Cost of WACC	EVALUATION
13.3%	142.462 Million USD
12.8%	187.406 Million USD
12.3%	238.035 Million USD

Adopting Middle Figure 187.406 Million USD
It would be seen that current evaluation fairly matches by all the three approaches.

8. CONSTRUCTION SCHEDULE



N°	Activity	Duration	Predecessors
1			
2	Signature of the contract with Contractor	1 jour	
3	Start on site	1 jour	2
4	Mobilization	3 mois	2
5	**Access and site installations**	**24 mois**	**2**
6	design, manufacturing and delivery of cable crane	18 mois	2
7	cable crane installation	6 mois	6
8	main access roads to dam site	5 mois	2
9	site offices, Site facilities	3 mois	8
10	quarry	3 mois	9
11	crushing plant, batching plant	6 mois	10
12	**Diversion works**	**71.96 mois**	**3**
13	**Cofferdams**	**4 mois**	
14	upstream cofferdam rehabilitation	4 mois	9
15	downstream cofferdam rehabilitation	4 mois	9
16	**Diversion tunnel**	**71.96 mois**	
17	excavation and rehabilitation	3 mois	9
18	reinforced concrete (Underground)	3 mois	17
19	reinforced concrete (Surface)	1 mois	17
20	design, manufacturing and delivery of diversion tunnel gate (1x - 12.5 m2)	6 mois	2
21	installation of diversion gates	1 mois	18;17;20;19
22	river dredging and removal of cofferdams	1 mois	30
23	**Excavation**	**30 mois**	**3**
24	surface excavations for dam foundations	30 mois	9
25	excavation for thrust block	12 mois	9
26	underground excavation for galleries	12 mois	24DD+25%
27	excavation of the downstream channel	3 mois	9
28	**Dam**	**71 mois**	
29	**Concrete works**	**47 mois**	**3**
30	mass Concrete works for arch dam	42 mois	24DD+50%;7;21;41
31	mass concret for thrust block	6 mois	24DD+50%;7;21
32	reinforced Concrete (Crest)	6 mois	31
33	**Bottom outlets**	**47.6 mois**	
34	concrete works	3 mois	30DD+30%
35	design, manufacturing and delivery of bottom outlets gates (2x)	12 mois	2
36	installation of gates	2 mois	35;34
37	design, manufacturing and delivery of bottom outlets stoplogs (2x)	12 mois	2
38	installation of stoplogs	1 mois	37;36
39	**Drilling and grouting works**	**55.54 mois**	
40	joint grouting	10 mois	30DD+48%
41	consolidation grouting for foundation treatment	6 mois	24DD+50%
42	grout curtain	12 mois	43FD-40%
43	contact and consolidation grouting from grouting galleries	12 mois	30DD+30%
44	drainage	4 mois	43;42
45	**Appurtenant Structures**	**52.96 mois**	**3**
46	**Spillway**	**52.96 mois**	
47	excavation (soil)	1 mois	8;24
48	excavation (rock)	1 mois	47
49	concrete works	6 mois	47;48
50	design, manufacturing and delivery of spillway gate (1x)	12 mois	2



N°	Activity	Duration	Predecessors
51	installation of gates	6 mois	47,48,50,49
52	design, manufacturing and delivery of spillway stoplog (1x)	9 mois	2
53	installation of stoplogs	1 mois	2,51
54	**Plunge Pool**	**4 mois**	
55	excavation (soil)	1 mois	9,21
56	excavation (rock)	3 mois	55
57	**Power Waterways**	**21 mois**	**3**
58	**Intake**	**21 mois**	
59	concrete works	1 mois	64,70
60	design, manufacturing and delivery of intake gates (3x)	18 mois	2
61	installation of gates	3 mois	60
62	design, manufacturing and delivery of intakes trashracks (3x)	12 mois	2
63	installation of trashracks	3 mois	62
64	**Headrace Tunnel**	**15 mois**	
65	rock support installation	2 mois	9
66	concrete lining	2 mois	65
67	drilling and grouting works	1.5 mois	65,66
68	design, manufacturing and delivery of tailrace tunnel valves (3x sliding gates)	12 mois	2
69	installation of sliding gates	3 mois	68
70	**Pressure Tunnel**	**4.5 mois**	
71	rock support installation	2 mois	9
72	concrete lining	1 mois	71
73	drilling and grouting works	1.5 mois	71,72
74	**Pressure Shaft**	**9.5 mois**	
75	rock support installation	2 mois	9
76	steel lining	6 mois	75
77	drilling and grouting works	1.5 mois	75,76
78	**Tailwater Outlet Tunnel**	**15 mois**	
79	rock support installation	2 mois	9
80	concrete lining	1 mois	79
81	drilling and grouting works	1.5 mois	79,80
82	design, manufacturing and delivery of tailwater outlet stoplogs (3x)	12 mois	2
83	installation of stoplogs	3 mois	82
84	**Powerhouse**	**54 mois**	**3**
85	rehabilitation of access tunnel	2 mois	9
86	excavation	9 mois	9
87	rock support	3 mois	9
88	drilling and grouting works	3 mois	87
89	rehabilitation works	6 mois	87
90	concrete works	3 mois	87
91	finishing works	12 mois	85,86,87,88,89,90
92	manufacturing, delivery and installatio of crane	6 mois	2,89
93	design, manufacturing and delivery of powerhouse turbines (3x Francis - 250 MW)	30 mois	2
94	installation of mechanical equipment (turbines, etc)	24 mois	93
95	**Electrical works**	**54 mois**	**3**
96	design, manufacturing and delivery of generators	30 mois	2
97	installation of generators	24 mois	96
98	construction of Switchyard	24 mois	2
99	cabling	24 mois	2
100	erection of tranmission lines	18 mois	2

9. PRODUCTION RATES

CVC Average 50,000 m^3/month; Peak 120,000 m^3/month. Grouting Rate 20 liters/minute. Drilling Rate 15m/day for coring & 30m/day for secondary non-cored holes. Grouting & Drilling ca. 900 m/month. Excavation ca. 45000 m^3/month. Turbines Generator Installation 8 months per unit. Delay in Dam construction to allow the bottom outlets ca. 5 months.

Excavation between 1000 m^3 to 2000 m^3 per day depending on nature of soil & type of excavation (Overground, Underground). Critical Path is Dam Concreting. Completion time is 72 months. Availability of Batch plant 12 months and cable crane 27 months after start of works.

10. SEISMOTECTONICS

It has been concluded that works should take into account the following design parameters.

- Maximum Credible Earthquake (MCE)
- Operating Basis Earthquake (OBE)

is in the line with recommendations of international commission on large dams (ICOLD).

The following values have been adopted.
MCE – Magnitude 9.0

Design Seismic Level	Annual Probability of Exceedence	Peak Ground Horizontal Acceleration (g)	Peak Ground Vertical Acceleration (g)
MCE	1/10000	0.36	0.24
OBE	1/475	0.16	0.10

Damping 10%

11. HYDROLOGY

a) Relevant records of discharges in the Enguri River are available from 1933 (Khaishi Metrological Stn.)
b) High flows are experienced from April to September
c) Flood Discharge of 2500 m3/sec should be adopted for design of permanent works (Gumbel & log pearson methods)
d) Diversion Works should be designed for 1000 m3/sec
e) Catchment Area 2780 sq.km
f) Average Annual Discharge - 127 m3/sec. 75% Exceedence is 88.5%.
g) Peak Discharge 1% Exceedence is 1544 m^3/sec
5% Exceedence is 875 m^3/sec
h) Probable Maximum Flood (PMF) - 4000 m3/sec
i) Minimum Average Annual Discharge - 75% Exceedence 24.2 m3/sec
j) Contribution: - Enguri River 69%
Nenskra 25%
Tkheishi 6%
k) Annual Inflow 3959 Mm3; Specific Run Off – l/s/Km2 45
l) Annual Precipitation - 1421 mm; Winter Season - 662mm; Summer Season - 759mm
m) Snow Cover - December to March; Average 62 Days
n) Frost Free Days – 232
o) Air Temperature – Mean 10.6˚C, Max. 41˚C, Min. -22˚C
p) Average Relative Air Humidity 76%
q) Water Temperature varies between 0.5˚C TO 11˚C
r) 90% Dependable year is 1988-89. However Selection of 90% Dependable year is a function of installed capacity & it would be appropriate to use the average year inflows for energy calculations; as Khudoni HPP is storage Dam
s) Minimum Flow Release. Q347 (Exceeding 347 Days) is 21.5 m^3/sec. So MFR is 4.5 m^3/sec

Note: - For Q_{347} MER must be 2.5 m^3/sec for first 10 m^3/sec & for each 1 m^3/sec more, 150 l/s is added.

For Q_{347} of 60 m^3/sec & more MER must be 10 m^3/sec.

12. RESERVOIR

a) Length
- Along Enguri River 9.2 Kms
- Along Nenskra River 3.8 Kms
- Along Tkheishi River 2 Kms

Total length of the Reservoir Periphery is 36 Kms.

b) Capacity – 364.5 Mm^3 ($282.36_{Enguri\ River}$ + $42.7_{Tkheishi\ River}$ + $39.44_{Nenskra\ River}$)
- Live Capacity – 223 Mm3
- Dead Storage – 141.5 Mm3
- FRL – 700m; MDL – 630 m

c) Water Surface Area – 5.22 sq. km

d) Average Width – 580 m
Maximum Width – 800 m

e) Average Depth – 88 m
Maximum Depth – 177 m

13. SEDIMENTATION

a) Catchment Area Khudoni 2810 sq.km
b) Enguri River provides 94% of sedimentation; Nenskra = 6%; Tkheishi Negligible
c) Main part of reservoir becomes silted up with Enguri Sedimentation. Nenskra & Tkheishi with their sediment load which is quite small. So only lower portion of 282.4 Mm3 gets silted up & upper 82.1 Mm3 sediments will practically not accumulate.
d) According to Tbilisi Hydro project report 1982; not less than 70% of reservoir bank line passes over bare rocks; so negligible contribution. About 25% of bank line represents segments of Quaternary loose material & 5% landslides.
e) Possible silt accumulation will reach bottom outlets in 40-50 years
f) Sedimentation term of main reservoir (284.4 Mm3) is approx. 130-150 years
g) In early stages of operation (first 10 years) intensity of river bed increase is about 1 to 1.5 m per year which shall be decrease to 0.5 m per year & for 5.5 kms distance will merge with natural river bed

Estimated Sedimentation Life: -

Hydro project (1982)	YUEPG (1989)	SAKTSKAL Project
150 Years	**185 Years**	**130 Years**

h) In 2001 – 2004 the instrumental measurement carried out by RDF & in 2010 by HYDROSPHERE LTD. Have determined average annual rate of sedimentation is 1.8 Mm3 in Enguri Reservoir
i) In 2012 – 2013 the environmental protection eco – counter made instrumental measurements & determined Turbidity as low water period 115 gm/m3 & density floods 1220 gm/m3
j) All the estimates include likes drift accumulation

14. POWER & RESERVOIR SIMULATION

Average Inflows to Khudoni = 127 m^3/sec
Average Inflows to Nenskra = 26 m^3/sec i.e. 20% of Total

- October to March – Winter Period
- April to September – Summer Period
- Primary Energy is the total Energy that can be provided at least 95% of Winter & Summer Periods; balance is secondary.
- Machine Efficiency has been considered constant
- For Energy Calculations an In house program of Stucky has been used. The calculation is based on a Monte-Carlo Algorithm
- Global Efficiency has been taken as 0.85
- The Model Simulates 100 Years of Operation.
- Manning – Strickler Formula has been used to calculate Head Loss
- Design Discharge – 3 X 170.29 m3/sec
- Design Head – 151.90 m
- Gross Head – 179.10 m

Winter Energy	Firm = 164	Secondary = 96	Total = 260
Summer Energy	Firm = 878	Secondary = 374	Total = 1252
Total	**1042**	**469**	**1512**

15. GEOLOGY & SOIL MECHANICS

a) The Site Investigations done during Soviet Era inter alia included
- Large no. of bore holes (Logs of 22 boreholes found & translated into English)
- Investigations Adits (Logs of 30 Adits found & translated into English)
- Geophysical Exploration
- Seismic Profile in Adits
- Pits & Trenches
- Water Pressure & Grouting tests

b) A New Site Investigations program was undertaken in 2012-13 which comprised: -
- 28 No. Vertical & Inclined boreholes
- 1891 meters of underground & surface seismic surveys
- 140 m down the hole seismic surveys
- Dialtometer tests in selected bore holes
- Grouting tests in 8 no. bore holes to determine GIN
- Lab test to determine the Mechanical Properties of DAM Foundation Rock, Direct Shear, Elastic Modulus, Brazilian Tensile Strength Test
- Lugeon Tests & Water pressure tests as per Old Russian pattern to determine co-relation between the two.

c) Of note is the fact that substantial excavations including underground has been carried out at Khudoni Site in the past. Underground Excavation are unsupported other than occasional spot bolt. The conditions of underground excavations are good measure of quality of rock mass & can be considered representative of overall foundation conditions. Groundwater Observed was insignificant & excavations can be classified Dry; confirming the tightness of the joints.

d) Four Galleries in abutment of the dam have also been located which provide real in situ information from deep within foundation of the dam. As a result it can be confirmed that good co-relation exists between the past investigations & actual field conditions.

e) Main Targets of New Investigations were: -
- Determine Quality, Strength, and Deformation & Permeability characteristics of rock mass on which dam will be founded.
- Characterize Fault 5.
- Determine nature & orientation of main faults.
- Define top of rock on upper part of left abutment above EL 660 & determine rock quality on which gravity block will be founded.
- Determine top of rock & permeability in Intake area Shales.

f) Main Conclusions are as below: -

- The Geology of Dam site & Geo-mechanical properties of the main lithological units have been confirmed & updated.
- Left Bank abutment thickness of overburden & variation in rock quality has been fully identified & can be used in spillway design.
- The contact (earlier identified as fault 19) is considered to be sedimentary contact & not a fault as previously proposed.
- The Thickness of Fault 5 varies from 0.5 m to 5.0 m.

16. ROCK – MECHANICS PROPERTIES

a) From 2012 -13
- 126 Samples were tested.
- 89 Uniaxial Compression Tests.
- 101 Brazilian Tensile Strength Tests.
- 40 Direct Shear Tests on joints.

b) Properties of main interests are Bulk Density, Uniaxial Compressive Strength, Elastic Modulus, Tensile Strength

c) Mean Uniaxial compressive strength: -
- Density Varies from 2.61 t/m3 to 2.69 t/m3.
- Mean σc varies from 9 MPa to 182 MPa.
- Modulus of Elasticity mean varies from 5 to 36 GPa

d) Mean Tensile Strength Varies from 1.1 to 12.1 MPa. Sample in vicinity of Fault 5 represent very low values.

e) Direct Shear Tests: -
- Unit B TUFF/BRECCIA.
- C-Peak Mean 0.48 MPa.
- Q Peak 30˚
- Unit C Porphyry C-Peak mean 0.45; Q Peak 29˚.

f) Measured Wave Velocities;
3.5 To 4 km/s – 5-10 GPa;
4.0 km/s – 10 GPa; 10 GPa;

For <1.5 km/s; Edf 1.0 GPa.
1.5 -2.5 km/s; Edf 1.0 to 2.5 GPa.
2.5 -3.5 km/s; Edf 2.5 to 5.0 GPa.

g) In the Valley floor 15 GPa is attained between 10-15 m depth.

h) In the Area of Fault 5; Dynamic E-Modulus is 2.4 GPa.

i) Overall Selected Estimation of Rock Mass Modulus

LOCATION	LEFT BANK			RIGHT BANK		
	Upper Porphyries	Fault 5	Middle	Lower TUFF	Middle TUFF	Upper Breccia
Selected Em (GPa)	8	<1	6	10	6	6

j) Recommended Design Values for Intact Rock (Faults Excluded).

Unit	σ_c (Mpa)	E (GPa)	σ_t (Mpa)
B: TUFF/TUFF BRECCIA	62	53	9
C: Porphyry	62	36	8

k) Recommended Design Shear Strength Values for Joints Cohesion 0.45 MPa; Friction Angle 30˚.

17. CONSTRUCTION MATERIALS

a) Estimated Quantities: -

S.No.	Description	Cement(Tonne)	Aggregate(Cum)
1.	Dam Spillway, Diversion Tunnel, Bottom Outlets	421,800	3,060,000
2.	Underground Works (Intakes, HRT, PS, PH, TRT)	27,200	92,400
	Total	**449,000**	**3,152,400**

b) Assumptions: -

S.No.	Description	Quantity
1.	CVC Mass Dam Concrete	180 Kg of Cementations Material
2.	Aggregates	1.3 Cum/Cum of Concrete
3.	Shotcrete Mix cement	500 Kg/Cum
4.	Steel	70 Kg/Cum of Concrete
5.	Grout Intake	120 Kg/m

c) Sources: -

- Cobbles, Gravel, Sand bed material of river Enguri at Jvari, 7 Kms D/s of Enguri Dam.
- Detritus of Porphyrites & Diabase Materials near Khaishi, 2Km U/s of Khudoni Dam where left Tributary Tkheishi River joins river Enguri Alkali Aggregate Reaction is not significant.

d) Estimated Qty: - Alluvium in Lower Quarry 3,810,000 M.

e) Cement: - Rustavi 50 Kms; East of Tbilisi, Georgia.
Kaspi 50 Kms; West of Tbilisi, Georgia.

f) UNYE: - (Turkey) 200 Kms from Batumi Port.

g) FLY ASH POZZOLONA: - Ukraine from Poti Port (20 to 30%).

18. DESIGN & OPTIMIZATION

DAM

a) Based on 2012-13 Additional Investigations: -

- Bottom Elevations can be raised from 501.5 to 510 m. At this Depth the rock mass Quality is Suitable for Foundation of an Arch Dam.
- This change induces a reduction of Maximum Height of Dam to 194 meter.
- The total length of left bank spillway gravity block increases from 70 m to 168 m to ensure the water tightness of the Reservoir.
- Shape of Spillway Ogee Chute modified from H:V equal to 1.0:0.8 to actual 0.9:1.0.
- Total Concrete Volume reduces from 2,273,000 to 2,084,000 m^3 with a 8.3% reduction.

b) Design Mass Concrete properties of Dam

Static				**Dynamic**		
Modulus of Elasticity (GPa)	**Poisson's Ratio** -	**Unit Weight KN/ m^3**	**Coefficient of Thermal Expansion**	**Modulus of Elasticity (GPa)**	**Poisson's Ratio** -	**Damping Ratio %**
E	ν	KN/ m^3 γ	ac	Ed	ν	ε
31	0.20	23.5	1 X 10^{-5}	38	0.20	5% (OBC) 10% (MCE)

c) 180 Days Instantaneous Modulus.

d) Sustained Modulus of Elasticity has been used as 60% to 70% of Instantaneous one i.e. 22 GPa to account for Creep effects.

19. DESIGN MECHANICAL PROPERTIES OF ROCK FOUNDATION

S.No.	Zone Rock Type	Static Modulus of Deformation (GPa)	Poisson's Ratio	Dynamic Modulus of Deformation (GPa)	Unit Weight KN/ m^3
1.	PORPHYRES	8.00	0.25	10.00	27
2.	TECTONIC FAULT	0.50	0.35	0.63	19
3.	TUFF/TUFF BRECCIA	6.00	0.25	7.50	27
4.	TUFF BRECCIA	10.00	0.25	10.25	27
5.	TUFF	5.00	0.25	7.50	27
6.	TUFF BRECCIA	6.00	0.25	7.50	27

- **STATIC DESIGN LOADS**

i. Self-Weight Loading

ii. Hydrostatic Loading: - Hydrostatic Pressure on U/s face of Dam considering water level in reservoir. Wt. of water, ϒ=10KN/m3; MWL=630 m; FSL=700 m; PMF=703.7m.

iii. Silt loading: - It is applied as pressure normal to U/s face of Dam. The Max. Height of silt is assumed to reach invert level of bottom outlet at 570 m.a.s.l.

iv. Thermal loading: - Due to difference between temperature fields in the Dam body at the time of joint grouting (closure temperature) & at a given time during operation.

v. Earthquake Loading: -

Design Seismic Level	Annual Probability of Exceedence	Horizontal Acceleration (g)	Vertical Acceleration
MCE	1/10,000	0.36	0.24
OBE	1/475	0.16	0.10

vi. Hydrodynamic Loading: - Due to interaction between Dam & Water in reservoir in case of strong ground motions.

- **DESIGN LOAD COMBINATIONS**

i. SU (Static Usual)

ii. SUN (Static Unusual)

iii. DUN (Dynamic Unusual) OBE Condition

iv. DE (Dynamic Extreme) MCE Condition

- **FACTORS OF SAFETY**
  i. Usual load combinations F.S 2.0
  ii. Unusual load combinations F.S 1.3
  iii. Extreme load combinations F.S 1.1

- **T-T Tension Zone; T-C Tension Compression Zone; C-C Compression Zone**

- **EXCAVATIONS OUTSIDE DAM**
  i. Should have slope V:H as 5:1 with a berm width varying between 5 to 7.5 m. Vertical Heights between berms should not be greater than 15 m.
  ii. In alluvial deposits V:H as 1:2 is acceptable.
  iii. Dam arch shall penetrate into rock minimum 10 to 20 meters depending on rock quality from both the left & right abutment sides.

- **BASIC SHAPE OPTIMIZATION**
  The Main objective is to achieve a limited tensile stress (less than +1.0 MPa).

- Contraction Joints is fixed at spacing 18 m in the arch directions towards the abutments.

20. MODELLING OF DAM FOUNDATION – RESERVOIR DOMAINS

Having prepared the Dam model, finite element static & dynamic analysis has been carried out. Six Dam shape variants were considered before final dam shape was arrived.

- Finite Element model has been made with DIANA Version 9.4.3

Mesh Set	Elements	Nodes
Foundations	3200	16133
Dam	1616	8968
Reservoir	2000	10246

- Dynamic Apparent tensile strength of concrete has been estimated at about 5.5 MPa.
- The Maximum compressive upstream stress is 10.0 MPa & occurs at the Dam Crest to the left of the crown section.
- The maximum tensile stress on downstream face is 3.0 MPa & occurs at ¾ of Dam height to the left of crown section. This is less than the apparent dynamic tensile strength of concrete.
- At the point of max. compressive & tensile stresses occurring in Dam; concrete of higher grades i.e. M30 can be used locally.

21. SPILLWAY DESIGN CRITERIA

a) Designed Flood 2500 m3/sec.
b) Design Conditions: - Routed Flood. Water level at Normal; Power house out of service; all spillway devices in operation; No use of Bottom Outlets. Remaining Freeboard is sufficient to avoid wave topping.
c) Verification Conditions: - Routed PMF; Water level at Normal Level; Bottom Outlets may be used only in case of failure of a spillway device; limited overtopping may be accepted for concrete Dams.
d) N-1 Conditions: - Routed Q 10,000 flood; Water level at Normal Water Level; Power House out of service; one spillway device of highest capacity out of service; Limited overtopping may be accepted.
e) Large sizes of dam crest spillway gates are not suitable on account of unfavorable seismic loads, construction interference; energy dissipation at dam toe. So ungated crest spillway Q is 150 – 200 m^3/sec; Gated spillway on left abutment (3 bays size 9X12 m).

22. INTAKES

a) Inclination of runways for stop logs & trash racks - (1H:0.58V) 30˚C.
b) Size of trash rack - 10 W X 22L
c) Operating level platform - +703m
d) Lift gantry crane capacity - 200T
e) Intake gate sill level - 615 m
f) Entry - bell mouth
g) Length of each intake tunnel - 57.46 m; 6 m Dia.

h) Spacing - 3 Nos @ 30 m each

23. GATE CHAMBERS

a) 3 Nos. bonnet wheel gate (4 X 6 m)
b) Span – 4 m
c) Height – 6 m
d) Static head – 117.19 m

24. PRESSURE SHAFTS

a) 3 Nos. @ 19.5 m c/c finished dia. 6 m
b) Length - 156 m
c) Inclination 55˚C
d) Average thickness of plate 25 mm (10 mm to 40 mm)

25. POWER HOUSE

a) Envisaged size 99 m (L) X 23.6 m (B) X 49 m (H) is O.K.
b) Present excavation completed up to +530 m to be lowered to 502 m.
c) M.A.T – 130 m Long
d) Power house drainage gallery = Level 503.00 m; Length 280 m; Excavated 4.15 m Dia.
e) Draft tube drainage gallery = Level 494.47 m; Size 2.0 m X 2.5 m;
f) Negative pressure inside draft tube 11 meters.
g) Crown level PH – 552.08 m
h) Crane beam top = 540.40 m
i) Machine floor hall = 523.00 m
j) Generator floor level = 517.50 m
k) Turbine floor level = 512.00 m
l) MIV floor level = 502.00 m.
m) Draft tube pit bottom = 494.50 m
n) EOT 2 X 250 T
o) Draft tube length 22m; dia 7.2 to 3.6 m; elbow type

26. TRT

a) 3 nos; finished dia 8 m; length 145 m.

27. OUTFALL

a) 3 units independent each; stop log 8 m X 8m; gantry crane 50 T capacity.
b) Sill level gates – 519.30 m
c) Operation platform – 530 m.

d) Max. TWL – 522.30 m.

28. HRT

a) 3 nos @19.5 m c/c diameter 6 m; Length 240 m; 260 m; 280 m respectively are O.K.

29. BOTTOM OUTLETS

a) 2 Nos; equipped with U/s stop log gate (roller type); a D/s maintenance gate (sliding type) & D/s service gate (radial Type).

30. DIVERSION TUNNEL

a) Existing Capacity 1000 m3/sec. O.K.
b) New Outlet to be constructed in existing tunnel.
c) The existing tunnel to be repaired & rehabilitated including Inlet portal in low flow season.
d) C/o Upstream Coffer Dam.
e) Dredging of D/s river channel to be done in parallel for proper hydraulic operation of diversion systems & also to excavate spillway plunge pool & tail race channel (with clear benefits for power generation & scheme operation).

31. BUTTERFLY VALVES

a) 3Nos; Dia 4.96 m; Static Head 196 m; Max. Transient Head 267 m.

32. TRASH RACKS

a) Area – 778.32 m^2.
b) Spacing – 60-80 mm.
c) Inclination – 30˚
d) Head – 90 Meters.

33. TAIL RACE GATES

a) 3Nos; Span 8.60 m
b) Height – 5.5(11.00) m
c) Head on Sill – 28.20 m
d) Gantry Crane – 50 T.

34. ELECTRO-MECHANICAL

a) FRL – 700 m.
b) Average Operate Level – 659.8 m.

c) Minimum Operating Level – 630 m.
d) Max. TWL = 522.3 m.
e) Min. TWL = 519.5 m.
f) Design Head = 151.90 m.
g) Max. Net Head = 174.90 m.
h) Min. Net Head = 117.60 m.
i) Static Head = 180.50 m.
j) Turbine Power (Shaft) = 238.77 MW.
k) Live Reservoir Capacity = 223 Million m3 (from 630 – 700 m).
l) Turbine
   - Type: - Francis Turbine Vertical Shaft.
   - Rated Discharge: - 170.29 m^3/sec.
   - Efficiency: -94%.
   - Synchronous Speed: -166.67 rpm.
   - Adopted Synchronous Speed to take advantage of water level in Draft Tube: - 187.50 m.
   - C/L of Distributor: - 508 m.
   - C/L of MIV: - 508 m.
   - Bottom of Draft Tube: - 496.5 m.
   - Runner 13% Cr & 4% Ni; Stainless steel with HVOF Coating.

35. GENERATORS

a) Rated Speed: - 187.50 rpm.
b) Rated Capacity: - 260 MVA.
c) Power Factor: - 0.9.
d) Terminal Voltage: - 15.75 KV.
e) Rated Frequency: - 50 Hz.
f) No. of Poles: - 32
g) GD2: - 17,275 Tm2.
h) App. Rotor Weight: - 466 Tonne.
i) Insulation: - F-Type
j) Generator Ventilation system would be recirculation type with Air (the primary coolant) cooled by water.

36. TRANSFORMERS

a) Ten Nos Single Phase 15.75/500KV.

37. RISK ANALYSIS

a) Design Risks: - Use 2 Separate Engineers(Construction + Owner's, second opinions & POE)
b) Geological & Geotechnical: - Good geological & geotechnical surveys & interpretation, selection of reputed engineers & contractors.

c) Hydrological Risks: - This Risk is well managed, long series of data available.
d) Construction Risks: - Choice of good reputed contractors, suppliers, supervision by reputed owner's engineers.
e) Dam Failure: - Good Design, Good Construction, Regular Monitoring by independent expert, Good Instrumentation, Well trained O & M Team, Well defined chain of command.
f) HM & EM: Equipment Risks: - Good Quality equipment well adapted to O & M, Good T.O.R & Contracts, and Supervision.
g) Energy Delivery Risks: - Good Construction, Need to have reserve additional equipment such as transformers, insurance etc. Good Maintenance.
h) Operation risks: - Well Trained Staff, Maintenance planned in advance. Spares must be available.
i) Legal, Political & Institutional Risks: - Use FIDIC Contracts, Insurance (Political), Risk Guarantee, Stakeholders participation & NGO influence must be taken in to consideration at all stages of Project Development.