Feasibility Study on Water Resources Development in
Rural Area in
the Kingdom of Morocco
Final Report
Volume III Supporting Report (1)
Basic Study
Supporting Report I
Geology

Tables

Table I2.1 Summary of Geology around and at Respective Dam (1/26)

1, *Neckor*	**River Neckor**		**Zone I**
Province: Al Hoceima	**Cercle**: Al Hoceima		**Commune**: Neckor / Yach Ijarmaouas
Topo-Map (1/50000): AL HOCEIMA	**X**: 644,900	**Y**: 496,035	**Z**: 161
Physiological Condition: Located at the southern end of Rhis-Neckor Plain.			
Geological Province: Rif Oriental, Intrarifaine Zone	**Location**: 25 km SE from Al Hoceima		
General Geology: Generally composed of Flysch Facies of Psammitic Schist and Quartzite. **Geological Structure**: Rhis-Neckor area is tectonically large graben strongly folded and schistose. This area was epi-metamorphosed at the time of Miocene.	**General Stratigraphy**: Triassic: gypsum・mudstone Lias: limestone Dogger: schist・schistose limestone Callovo-oxfordien: sandy mudstone Tithonien: marly limestone Lower Cretaceous: schistose limestone・sandstone・Flysch Cenomano-Turonien: calcareous limestone・ Senonien: calcareous limestone Unconformity at the time Upper Oligocene		
Geology of Reservoir Area: Bedrock is the alternation of Schist, Sandstone and Quartzite. Slope is covered commonly by Talus and Colluvial deposits. River deposits are very thick. Terrace deposits are also developing along both banks of river.			
Geology around Dam Site: Bedrock is the alternation of remarkably folded Quartzite and Psammitic Schist. Quartzite is generally very hard and massive with many quartz veins and iron ore mineral, and microfolded.			
Geomorphology along Dam Axis: RG: approx. 35 , RD: 20～25 , FD: 320m note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed			
Geology along Dam Axis			
Left Abutment	**River Bed**		**Right Abutment**
Zone of weathered rock: Ep = 8 m.	Alluvial deposits: Ep = max. 32 m The interval of schistosity joint is in order of milli-metres, and weathering is observed along those planes.		Thickness (Ep) is: Surface organic soil = 0.2m Talus deposits = max. about 10m Zone of weathered rock = 16m.
note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),			
Remarks of Dam Foundation: Generally bedrock, especially in case of Schist, is weathered much (partly changed into Residual soil)			
Watertightness			
Dam Site	**Reservoir**		
Left Bank: probably better watertightness than Right Bank. River Bed: Deeper than 32m, Lu= 6～9; Shallower portion is more than 50. Right Bank: Deeper than 20m in the middle of slope, and than 16m at the foot, Lu= 1～9; Shallower portion is high permeability.	Basically it seems to be no problem.		
note: Lu; Lugeon Unit			
Stability			
Dam Site	**Reservoir**		
Need to be checked of the stability of Right Bank due to thick Talus deposits.	Basically stable.		
Construction Material			
Earth Material: in the upstream and downstream riverbed of Sub-Dam. Sand & Gravel Material: in the main Neckor riverbed.			

Study Level **APD**

Existing Geotechnical Investigation:

Drilling: Nos.5=162.7m (Dam Site), Nos.3=109m (Sub-Dam)

Test Pit (P) & Trench (T): T: Nos.2 (Both Banks of Sub-Dam), P1: Nos.5 (In the Trench Sub-Dam), P2: Nos.17 (Borrow Area = Earth), P3: Nos.17 (Quarry = Sd & Gr)

Laboratory Tests:

3 samples from P3 (Gradation, Permeability)

P2 samples (Gradation, Atterberg, Compaction, Chemical Analysis, Triaxial, Consolidation, Organic Content, Pinhole, Direct Shear)

Table I2.1 Summary of Geology around and at Respective Dam (2/26)

2, *Tizimellal* **River Mengou (Ouerrha)** **Zone I**

Province: Al Hoceima	**Cercle**: Targuist		**Commune**: Bni Bcher / Sidi Boutmime
Topo-Map (1/50000): TARGUIST	**X**: 592,650	**Y**: 471,950	**Z**: 1,022

Physiological Condition: Located in the very steep Rif mountain range.

Geological Province: Rif Oriental, Intrarifaine Zone	**Location**: Approx. 13 km SW from Targuist
General Geology: Generally characterized by Schist-Quartzitic facies. Schist shows a little different facies locally, that is, the western side is weakly schistose while the eastern side where dam site is located is usually strongly schistose of epi-metamorphosed.	**General Stratigraphy**: Cretaceous: quartzitic schist･siliceous slate
Geological Structure: Generally the area is strongly folded and faults with shear zone are observed at many place.	

Geology of Reservoir Area: Approximately 2/3 of the area is argillaceous and pelitic, remains 1/3 is Schist and Quartzite. River deposits are on river bed, and Terrace deposits are along river course.

Geology around Dam Site: Narrow gorge is open in between Quartzite bars and blackish hard siliceous Slate. Strike is E-W, and dip is 45 N (towards upstream). At least 2 system of fault lines may be inferred.

Geomorphology along Dam Axis: RG: 42 , RD: 35 , FD: approx.20m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
Weathered and loosened rock (Vp=0.5～1.1) Ep = 2～3m, max. 6m, a little cracky rock (Vp=2.0～2.2), Fresh rock (Vp=5.0～5.2). Partly max.3m thickness of brittle sandy layers exist. At some part, depth to Fresh rock is very deep to the extent of depth 30m.	Alluvial deposits (Vp=0.5～0.8): Ep=1～2m. Upper zone of relatively sound rock (Vp = 1.9): Ep = 2～3m Fresh rock (Vp=4.4)	Loosened rock (Vp=0.5～0.7): Ep = about 4 m. Mid hard relatively sound rock (Vp = 2.6): gradually deeper reaching up to 20 m as proceeding to mountain side. Sound rock (Vp = 4.6).

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: The bedrock of the upper portion of Left Bank side is more cracky than that of Right Bank.

Watertightness

Dam Site	Reservoir
Left Bank: Deeper than 30m, permeability is relatively low; Shallower portion, Lu= 10～40, partly more than 50. River Bed: Deeper than few meters, Lu<10; Shallower portion, Lu= 29. Right Bank: Deeper than 30m, Lu is around 5; Shallower portion is around 10.	Generally it shows well--watertightness.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Need to be checked of the slope stability of just upstream and downstream of Left Bank where geomorphologically some sign of ancient slope failures are observed.	The area with steep slope and thick talus deposits has some problem to stability.

Construction Material

BCR Material: (near dam site) River deposits or Quartzite bares; River deposits is not sufficient in both of quantities and qualities. Quartzite shall be used after crush; Quarry＝ 1, Upstream of dam site 2, near dam site. Fine aggregate shall be selected from River deposits or from crusher of Quartzite.
(Purchase Material)＝ approx. 6km from dam site; Upstream of Mrirt river (branch of Mengue river).

Study Level **APD**

Existing Geotechnical Investigation:

Drilling: Nos.8=476m

Seismic Exploration: 1335m

Adit: (Both Banks)

Test Pit (P) & Trench (T): P: Nos.10

Laboratory Tests:

Gradation, Franklin, Los Angels & Deval

Table I2.1 Summary of Geology around and at Respective Dam (3/26)

3, *Ait Badou*	**River Ta'init**		**Zone III**
Province: Azilal	**Cercle**: Azilal		**Commune**: Tannant
Topo-Map (1/50000): TANANT	**X**: 353,400	**Y**: 140,000	**Z**: 750

Physiological Condition: Located near the border of Moyen Atlas and Haut Atlas. Dam site is in the side of Haut Atlas.

Geological Province: Moyen Atlas and Haute Atlas	**Location**: 2 km South of Tanant
General Geology: Generally composed of limestone and marl relatively hard and well--layered. Partly doleritic basalt be observed. Downstream side is ancient to middle Quaternaries, of which upstream side is conglomerate of Vilafransien.	**General Stratigraphy**: Lias (Jurassic): limestone Permo-Triassic～Jurassic: continental limestone～marl Triassic: basalt～dolerite Vilafransian: conglomerate Ancient terrace deposits
Geological Structure: The strata in this area is generally monoclinic towards the coast side. Regionally it is basin structure.	

Geology of Reservoir Area: Composed of the alternation of Limestone and Marly Limestone generally monoclinic towards upstream (N40°E,20°E) with 20 to 70 cm of unit layers' thickness. Travertine and Colluvial deposits exist mainly in the right bank slope.

Geology around Dam Site: Bedrock is the alternation of Platy Limestone and Marly Limestone generally monoclinic towards upstream (N40°E,20°E) with respective layers' thickness 20 to 70 cm.

Geomorphology along Dam Axis: RG: average 20 , RD: average 25 , FD: approx.75m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	**River Bed**	**Right Abutment**
Bedrock outcrops covered by very thin surface soil.	Few meters of silty soil covers the bedrock.	At the foot of abutment, bedrock is covered by travertine and terrace/talus deposits, which are reddish brown silty soil.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: On the top of Right Bank, very porous Limestone and Conglomerate form table-like ground. Bedrock may be pervious.

Watertightness

Dam Site	**Reservoir**
Along bedding planes, some small karsts are observed commonly, and springs in the upstream and downstream exist. As a result, basement rocks in this area seem to be relatively pervious.	There is some possibility that the karsts in the Limestone are connecting from reservoir area to the other.

note: Lu; Lugeon Unit

Stability

Dam Site	**Reservoir**
Basically it seems to be no problem.	Basically stable.

Construction Material

Earth Material: river bed in the reservoir area; light brown clayey soil can be used impermeable material.
Rock Material: Massive Limestone located at the right bank in the downstream.
Sand & Gravel Material: no suitable material.

Study Level **Preliminaire- en cours**

Table I2.1 Summary of Geology around and at Respective Dam (4/26)

4, *Ain Kwachiya* **River Khellata (Yquem)** **Zone II**

Province: Ben Slimane	**Cercle**: S.Y.Zaer		**Commune**: S.Y.Zaer
Topo-Map (1/50000): TEMARA	**X**: 360,200	**Y**: 353,500	**Z**: 163

Physiological Condition: Located at 15 km from the coast line of Atlantic Ocean and in the western end of Moroccan Central Massif.

Geological Province: Western end of Massif Marocain Central	**Location**: Approx. 6 km South of S. Y. Zaer
General Geology: River basin is generally covered by marl, while in the bottom of valley and gorge, Paleozoic (Phyllite, Quartzite, Limestone, Conglomerate, Sandstone, and Volcanics) are commonly exposed. **Geological Structure**: The strata of Upper Devonian-Tournaisien is steeply inclined towards one direction or vertical; folding axis is orienting E‐W. Visean formations outcrop along the axis of syncline. The anticlinal axis exist around El Koudia.	**General Stratigraphy**: (Generally Paleozoic, partly covered by Miocene and Quaternary) Paleozoic: Upper Devonian - Tournaisien: extending some tenth kilometers from Yquem River to Khataouat of the southern area. Zone of Silurian-Devonian: along Cherrat River in the eastern

Geology of Reservoir Area: Bedrock is Psammitic Schist, Micaceous Sandstone, Quartzite, Limestone and Conglomerate of Upper Devonian to Tournaisian. This area is situated geologically in the eastern part of "El Koudia Anticline". Bedding and schistosity is vertical crossing at a right angle to river course (N140°～N180°).

Geology around Dam Site: Bedrock is composed of Quartzite and Schist. Schist is generally dominant, and some layers of Quartzite bar runs obliquely crossing with river course. Schistosity is N80°W, 40°S.

Geomorphology along Dam Axis: RG: 20～30 , RD: 20～30 , FD: approx.50m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
Top layer (Colluvial): Ep=approx. 1～3 m. Very loosened rubble Schist: Ep=2～3 m. Bedrock is basically Schist, however Quartzite bar is found at the upper portion.	Generally covered by gravel tracing silty cohesive soil, thickness of which 3～4 m (max. 5 m). The percentage of gravel is 10 to 30%.	Quartzite bars and Psammitic Schist form bedrock (strikeN0°～30°W, dip 80°～85°E). Top soil is very thin.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Green to olive Schist is usually soft and weak.

Watertightness

Dam Site	Reservoir
Basically Schist consisting of dam site is low permeability except highly weathered portion along ground surface, cracky dark Schist which is oxidized and manganised, and brittle yellowish brown Schist. Quartzite may be considerably pervious however probably well--groutable.	Generally it shows well-watertightness.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Basically it seems to be no problem.	Basically stable.

Construction Material

Earth Material: Deposits in the bottom of valley and weathered residual soil; the former is silty to fine sandy soil, the latter is clayey with rock fragments.
Rock Material: Quartzite outcropping in the downstream; outcrop height 10～20m, volume may be 250,000～500,000m3.
(Purchase Material): Existing Quarry in Temara.

Study Level **APD**

Existing Geotechnical Investigation:

Drilling: Nos.4=127.4m (Dam Axis), Nos.1=40.2m (Spillway)

Test Pit (P) & Trench (T): T: Nos.2 (Both Banks along Axis), P: Nos.3

Laboratory Tests:

Drilling Cores (Specific Gravity and Absorption, Porosity, Super Sonic, Unconfined Compression, Direct Shear)

Table I2.1 Summary of Geology around and at Respective Dam (5/26)

5-1, *N'Fifikh (Downstream)* **River N'Fifkh** **Zone II**

Province: Ben Slimane	**Cercle**: Ben Slimane		**Commune**: Oulad Yahia Louta
Topo-Map (1/50000): BENSLIMANE	**X**: 333,657	**Y**: 331,090	**Z**: 110

Physiological Condition: Located at the most upstream side of the gorge having 300 meters length where is situated in the western end of Moroccan Central plateau.

Geological Province: Western end of Massif Marocain Central	**Location**: Approx. 8 km SW from Ben Slimane
General Geology: Two Groups are extent in the area = "la serie de Fedan Taba" and "la serie des Oulad Bahloul" Fedan Taba: sandy to fine conglomeratic rocks; partly quartzitic and ironic sandstone. Oulad Bahloul: sandy to quartzitic rocks (Ortho-Quartzite, Schistose Mica-Quartz rock, and Quartzitic Sandstone)	**General Stratigraphy**: Upstream side of "la serie de Feddan Taba": Silurian; pelitic schist (serie d'Ain Merseta) Permo-Triassic; saline red mudstone interbedded with thick doleritic basalt
Geological Structure: "la serie du Feddan Taba" has a large symmetric syncline structure, and sometimes faults orienting NE-SW, N-S, and NW-SE change their structure.	

Geology of Reservoir Area: Bedrock of reservoir area is mainly composed of "Oulad Bahloul Group" which is mainly of Marl, Quartzite and Schist, though dam site is of "Fedan Taba". Marl in this area includes usually salt. Slope is covered by Talus and Colluvial deposits, and River deposits are on river bed.

Geology around Dam Site: Bedrock is Quartzite of "Feddan Taba Group" of Ordovician. Tectonic zone may run to the direction NNE-SSW crossing the valley of 300m downstream of dam axis. Others have a system about N60°W direction running along the foot of Right Bank.

Geomorphology along Dam Axis: RG & RD: approx.20～25 , FD: approx.20m, PD: approx.0.2%, Left Bank goes up to the maximum elevation 160m, then forms Saddle with distance approx. 240m from main river bed.

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
Talus: fine grained soil with rock blocks; Ep=2～3m. Bedding of bedrock is not clear. Some Slickensides are commonly observed directing N37 ° W,80 ° W scribing 20°S.	Few meter of clayey to silty colluviums and alluvium cover the bedrock; Ep= 2 ～ 4 m.	Quartzite is layered (bedding E-W,25° S). No soil cover. Along the Faults may be sheared with some meters.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Fault (N60°W,75°～80°SW) along the foot of Right Bank has 7.5m～15m width of yellowish sheared zone (partly laminated).

Watertightness

Dam Site	Reservoir
Quartzite around dam site is relatively low permeability (Lu<10) except weathered portion along the ground surface. However, joints in the shallower portion of Left Bank may probably be open slightly so that permeability may relatively high. Along the Fault and Sheared Zone at the foot of Right Bank, careful study on the leakage is necessary (Lu= 12～17).	Basically it seems to be no problem.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Need to be checked of the stability along the Faults of Right Bank.	Basically the area of Quartzite is no problem. In case the slope of Marl inclined more than 15%, the careful study shall be necessary, especially silty clay-marl of Right Bank side.

Construction Material

Earth Material: sufficient in the reservoir area (weathered material of Mudstone and Marl, Silty deposits in the riverbed)
Rock Material: Quartzite at dam site.
Sand & Gravel Material: no suitable material.
(In between the site of Ben Rouane and Ain Ksob, three areas are set as borrow area).

Study Level **APD**

Existing Geotechnical Investigation:

Drilling: Nos.4=120.2m (Dam Site= RG 2, RD 2)

Test Pit (P) & Trench (T): T: Nos.1 (Left Bank), P: Nos.2 (Right Bank), P: Nos.21 (Borrow Area = Earth)

Table I2.1 Summary of Geology around and at Respective Dam (6/26)

5-2, *N'Fifikh (Upstream)*	**River N'Fifkh**		**Zone II**
Province: Settat	**Cercle**: Ben Slimane		**Commune**: Sk et Tleta des Ziaida / Mellila
Topo-Map (1/50000): AL GARA	**X**: 345,820	**Y**: 311,930	**Z**: 230

Physiological Condition: Located in the hilly area of the massif central marocain. Downstream area is relatively flat or undulated, while upstream area is rather relieved.

Geological Province: Western end of Massif Marocain Central	**Location**: Approx. 20 km South from Ben Slimane
General Geology: Two Groups are extent in the area = "la serie de Fedan Taba" and "la serie des Oulad Bahloul" Fedan Taba: sandy to fine conglomeratic rocks; partly quartzitic and ironic sandstone. Oulad Bahloul: sandy to quartzitic rocks (Orth-Quartzite, schistose mica-quartz rock, and quartzitic Sandstone)	**General Stratigraphy**: Upstream side of "la serie de Feddan Taba": Silurian; pelitic schist (serie d'Ain Merseta) Permo-Triassic; saline red mudstone interbedded with thick doleritic basalt
Geological Structure: "la serie du Feddan Taba" has a large symmetric syncline structure, and sometimes faults orienting NE-SW, N-S, and NW-SE change their structure.	

Geology of Reservoir Area: Bedrock is mainly the alternation of Sandstone and Schist interbedded with Quartzite of "Feddan Taba Group". Terrace deposits are extending relatively widely and River deposits are on river bed.

Geology around Dam Site: Bedrock consists of very folded Quartzite bar, and the alternation of Quartzitic Sandstone and Schistose Slate. Those are belonging to "Feddan Taba" Group.

Geomorphology along Dam Axis: RG: average 30 , RD: 15～25 , FD: approx.60m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
Dam axis is composed of around 10m thickness of right-standing Quartzite which is interbedded by the alternation layers of sandy to quartzitic Sandstone and Schistose Slate. At around 10m upstream of dam axis, fault is inferred.	Alluvial Terrace deposit: along right bank side; composed of fine sand to sandy silt with thickness 2 to 3m. Recent River deposit: sand and gravel	Quartzite bar is gradually inclining gently as proceeding to mountain side and forms the hill ridge.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: At just upstream of Quartzite bar, strata are very folded and deteriorated, and sheared zone may be existing around there.

Watertightness

Dam Site	Reservoir
Quartzite itself along dam axis may be relatively permeable in the shallower portion due to joints probably open. However, it may be not so serious due it to be interbedded between Schist which is seems to be relatively impervious. Along the Fault and Sheared Zone observed at just upstream of Left bank, careful study on the leakage is necessary.	Basically it seems to be no problem.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Left Bank side is relatively steep (average 30°～40°) and the rocks just upstream of dam axis is very folded and deteriorated. Need to be checked the stability around there.	Some area is showing relatively steep slope composed of brittle Schist. Careful study shall be carried out at those area.

Construction Material

Earth Material: Terrace deposits in both banks at dam site and in the reservoir area; Silt～Fine Sand; as impermeable material, property shall be checked.
Sand & Gravel Material: River deposits; volume is insufficient.
Rock Material: Quartzite in right bank.
(In between the site of Ben Rouane and Ain Ksob, three areas are set as borrow area).

Table I2.1 Summary of Geology around and at Respective Dam (7/26)

6, *Tazarane*	**River Malha (Ouergha)**		**Zone I**
Province: Chaouen	**Cercle**: Bab Bered		**Commune**: Mansoura (Tazarane)
Topo-Map (1/50000): TAMOROT	**X**: 540,100	**Y**: 484,000	**Z**: 528

Physiological Condition: Located in the western Rif mountains where is rather gentle hilly mountains comparing to the central and eastern.

Geological Province: Rif Central, Intrarif zone	**Location**: Approx. 37 km NW from Ghafsai
General Geology: Facies of Schist are different respectively at the location in the western and eastern area. Those of western area arre weakly schistose, while of the eastern are remarkable schistose and epi-metamorphosed.	**General Stratigraphy**: Cretaceous: quartzitic schist and pelitic schist
Geological Structure: Generally the area is strongly folded and faults with shear zone are observed at many place.	

Geology of Reservoir Area: Bedrock is Schist of Cretaceous. 1/3 of the area is covered by Alluvial deposits which consist of mainly rock blocs of quartzitic sandstone, sand and gravel partly in clayey soil matrix. Colluvial deposits on slope, which are composed of silty soil and rock fragments of schist, are relatively thick.

Geology around Dam Site: Bedrock is the alternation of Black Schist (phyllitic) and dark gray Psammitic Schist. Schistosity dips towards upstream (N55°W35°NE).

Geomorphology along Dam Axis: RG: 30～40 , RD: 25～30 , FD: approx.22m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
No top soil. A little loose bedrock (Vp=2.9): Ep = around 20 m. Deeper than that depth, Fresh rock exists.	Alluvial deposits: Ep = 1～3 m. Weathered zone (Vp = 1.4～3.0): Ep = 5～8m. Fresh zone (Vp=4.2): normally homogeneous Schist, but sometimes interbedded with thin Quartzite.	Relatively thick argillaceous colluviums covers the slope where thickness is averagely 3～4m. Highly weathered zone (Vp=0.4): Ep= about 1m. A little cracky zone (Vp= 2.5) and Fresh zone (Vp= 4.5) are undelying. Depth to Fresh zone is around 40 m. Schistosity is N75°W 25°N. Some sandy rocks may exist in the upper portion

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Generally bedrock is loose at any outcrops and depth to Fresh rock may be commonly deep.

Watertightness

Dam Site	Reservoir
High permeability zones (Lu>10) exist up to 20 m in Left Bank, up to 12 m at River Bed, and up to 27 m depth in Right Bank. Deeper than those depth, Lu < 10.	Generally bedrock is well-watertightness due that it consists of Schist.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Weathered zone of both banks seems to be relatively deep. Furthermore upper abutment of Right Bank may be composed of Sandstone weathered and sometimes changed into Residual soils underlain by Schist. Their stability shall be carefully checked.	Need to be checked of the slope stability of just upstream of both banks where geomorphologically some sign of ancient slope failures are observed.

Construction Material

(Near dam site)
Earth Material: at upper portion and the just upstream slope of right bank.
Sand & Gravel Material: Deposits in the valley bottom in the reservoir area.
(Purchase Material): Jbel Tizirene, Nakhla dam Quarry, Chraft Limestone Quarry, Jorf Al Malha, Oued Martil

Study Level **APD**

Existing Geotechnical Investigation:

Drilling: Nos.11=565m

Seismic Exploration: 2220m

Adit: (Both Banks)

Test Pit (P) & Trench (T): T: Nos.1 (Right Bank), P: Nos.10 (Right Bank)

Table I2.1 Summary of Geology around and at Respective Dam (8/26)

7, *Amezmiz* **River Anougal=Amezmiz (N'Fis)** **Zone III**

Province: El Haouz	**Cercle**: Amezmiz		**Commune**: Anougal
Topo-Map (1/50000): AZEGOUR	**X**: 226,500	**Y**: 65,400	**Z**: 1,302

Physiological Condition: Located in the northern side of Haut Atlas Occidental where is formed usually by steep mountain ranges.

Geological Province: Haute Atlas occidental	**Location**: Approx. 12 km South of Amezmiz
General Geology: Basement rocks of Haute Atlas Occidental are of Precambrian, folded Paleozoic, and Hercynian Granite. While, Haut Atlas Central is composed of mainly thick marine Limestone of Lower to Middle Jurassic, and partly Triassic in the anticlinal area. Paleozoic distributes only in the anticlinal zone exceptionally.	**General Stratigraphy**: Paleozoic: a series of Schist, schistose calcareous sandstone, volcanics. Cretaceous in the western: red marly rocks and sandstone of Azegour Laguna deposits.
Geological Structure: Atlas Fault orienting WSW-ENE extends around the area. This fault is the reverse fault overthrusting towards the north accompanied by many fractured zone. Haute Atlas mountains ride on this plane and rifted up suddenly. Paleozoic is generally folded with approximately N-S orienting axis, and Granite dyke accompanied by many ore minerals intruded into these formations.	

Geology of Reservoir Area: Slope of left bank side is Cretaceous area where red color fine Conglomerate, Sandstone, and Shale exist with gentle bedding dip. While, slope of right bank side is of Schist of Paleozoic intruded by Micro-Granite where schistosity is N-S,35°～40°E..
River deposits is relatively thick.

Geology around Dam Site: Bedrock is folded Schist of Cambrian and Ordovician, and red Mudstone, Sandstone and Conglomerate of Cretaceous to Tertiary. Micro-Granite intruded at Hercynian orogenic era is also existing.

Geomorphology along Dam Axis: RG: 35 (upper part 16), RD: 40～45 (upper part 20), FD: approx.35m, Left Bank forms the saddle.

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
Composed of Schist intruded by Micro-Granite dyke. In the upper portion and saddle area, Mudstone, calcareous Sandstone, and fine Conglomerate lie unconformably on Schist strata.	Covered by River deposits composed mainly of sand and gravel of Quartzite, Schist, and Granite. Ep may around 10m at maximum.	Composed of Schist and Micro-Granite dyke. Mudstone, calcareous Sandstone, and fine Conglomerate lie unconformably on Schist.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Around the contact between Schist and Micro-Granite, some fractures and cracks are developed.

Watertightness

Dam Site	Reservoir
Schist is considerable basically to be impermeable. However, it may be some permeable along the contact with Micro-Granite where some fractures may develop along the contact.	Generally bedrock of Schist may have the well-watertightness.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Schistosity in the area is usually dipped towards bank sides so that slope along dam axis may be stable. However the stability of loose rocks lying on Schist at Right Bank shall be checked.	In the upstream area of Left Bank, relatively thick talus deposits may cover the slope. The stability in this area shall be checked.

Construction Material

Three Areas are planed as the followings
Zone I: in the reservoir area.
Zone II: the downstream of dam axis
Zone III: at the foot of bridge 12km away from dam site

Study Level **APD**

Existing Geotechnical Investigation:

Drilling: Nos.8=440.8m (RD 3, OD 2, RG 2, Sub-Dam 1)

Test Pit (P) & Trench (T): T: Nos.1, P1: Nos.5 (Dam Axis: RDup 2, RDdown 2, Sub-Dam 1), P2: Nos.31 (Borrow Area: Zone I Nos.12, Zone II Nos.8, Zone III Nos.11)

Laboratory Tests:

Drilling Cores (Specific Gravity, Super Sonic, Deformation Coef., Unconfined Compression)
P2 samples (Atterberg, Gradation, Hydrometer, Sand Equivalent, Los Angels & Deval)

Table I2.1 Summary of Geology around and at Respective Dam (9/26)

8, *Boulaouane* River Seksawa Zone III

Province: Chichaoua	**Cercle**: Imi-N-Tanout (Sidi Bou Othmane)		**Commune**: Sidi Ghanem / Dourane
Topo-Map (1/50000): IMI-N-TANOUT	**X**: 176,000	**Y**: 70,000	**Z**: 754

Physiological Condition: Located in the northern periphery of Haut Atlas Occidental. Dam site is at the most narrow point in the valley.

Geological Province: Haut Atlas occidental

Location: 2 km upstream from Boulaouane village

General Geology: Almost 90% of river basin is made of Paleozoic. The remaining 10% is of Jura-Cretaceous consisting of reddish Muddy Sandstone, and Cretaceous of Marly Limestone. The area of Jura-Cretaceous is eroded, depressed and deposited. The oldest formation is the basement complex of Caledonian-Hercynian in the Haut Atlas mountains, and the newest is the deposit after Hercynian in the Essaouiria-Haouz Synclinal area.

Geological Structure: Paleozoic Schist are folded with orienting NNW-SSE axis. Jurassic to Cretaceous in the reservoir area dip towards the downstream (towards NW) and get under Tertiary area. Dip of strata is gradually going to be steep as proceeding towards the downstream; Their dip around the southern area of reservoir is 25°～30° towards the downstream. Faults of the northern Atlas boundary is dominantly orienting NE-SW, and dipping 45°～60° towards the mountain side.

General Stratigraphy:
Jura - Cretaceous: red argillaceous sandstone
Cretaceous: marly limestone
Alluvium: mainly limestone gravel and fine grain soils deposited mainly in the valley of Jura -Cretaceous area.
Post-Hercynian deposits is in the Essaouiria-Haouz Synclinal area.

Geology of Reservoir Area: Schist and schistose Sandstone of Middle Cambrian to Ordovician outcrop from 2 km upstream of dam site partly including Sandstone and Conglomerate of Devonian in the Thrust.
Jurassic, which is continental, unconformably lies obliquely on Paleozoic.
Cretaceous: from lower to upper; Conglomerate and Sandstone with some purple color (Ep= 2～6m), Dolomite and Dolomitic Limestone (Ep= 5～8m), continental red Conglomerate, Sandstone and Marl (Ep= 10～20m) and lagoonal Limestone and Marl interbedded Gypsum and Anhydrite or other Evaporite (Ep= 50～80m).

Geology around Dam Site: Bedrock is of Mesozoic and Cenozoic extending in the northern front of Atlas: Marly Limestone of Cenomanien, the alteration of green to red Marl and Anhydrite, Limestone bar of Turonien, and the alternation of Marly Limestone and green to red Marl. As proceeding to the downward of slope, unconsolidated deposits are gradually becoming thick.

Geomorphology along Dam Axis: RG & RD: 22～27 , FD: approx.70m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
In the lower portion, anticline makes strata be reverse, where its axis is dipping downstream. Bedding is N40°～N55° crossing at a right angle to river course. 2 fault systems can be observed as: N70°～N80°, 60°～75° ; N150°～N160°, 45°～65° SW. Sheared zones repeat in the interval of about 5～8m respectively.	River deposits are relatively thick, which are mainly composed of sand and gravel. The percentage of gravel along the river course is 70 ～ 80%, and gradually reducing as proceeding to the foot of slope. Maximum size of gravel is around 30cm, the average is pebble size (3 to 4 cm). Terrace deposits are also extending widely.	At the foot of slope, few meters of Talus deposit exists, and loosely cemented by lime partly. Bedrock is right-standing Limestone and sandy/muddy Limestone of which bedding is crossing at a right angle to river course.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Joints of bedrock is commonly open, and some karsts are observed.

Watertightness

Dam Site	Reservoir
Some karsts are commonly observed along the bedding planes of Limestone and sandy/muddy Limestone. Moreover joint planes, direction of which is usually same as river flowing course, are usually somewhat open as far as outcrops at dam site is concerning. Leakage is considerable at this site.	Schistose rocks in the reservoir area may generally be impermeable. Limestone and Evaporite may have some problem with regard to leakage so that their distribution shall be checked.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Basically it seems to be no problem.	In the area of Jurassic and Cretaceous, land is eroded relatively well-and steep slope is commonly developing. Those slope shall be checked.

Construction Material

Sand & Gravel Material: River deposits of Seksawa river; 2.25km upstream from dam site; Terrace deposits in the upstream and downstream of dam site, surface area is approx. 200000m2
Earth Material: Irik reddish silt; 14km NE from dam site
Rock Material: Limestone bare at dam site.

Study Level **Preliminaire**

Existing Geotechnical Investigation:

Drilling: On Going

Table I2.1 Summary of Geology around and at Respective Dam (10/26)

9, *Taskourt*	**River Assif el Ma**		**Zone III**
Province: Chichaoua	**Cercle**: Imi-N-Tanout		**Commune**: Adassil
Topo-Map (1/50000): AZEGOUR	**X**: 207,000	**Y**: 69,000	**Z**: 942

Physiological Condition: Located in the northern side of Haut Atlas occidental ranging steep mountains.

Geological Province: Haut Atlas occidental	**Location**: Approx. 15 km South of Akimakh
General Geology: Mainly composed of Schist, Sandstone, and Quartzite of Paleozoic; Limestone of Jura - Cretaceous; and sedimentary rocks of Eocene	**General Stratigraphy**: Paleozoic: schist, sandstone, and quartzite Jura-Cretaceous: limestone Eocene: sedimentary rocks
Geological Structure: In the river basin, main system of faults mainly orienting NE - SW and sub-system orienting NW-SE exist a lot.	

Geology of Reservoir Area: Bedrock is composed mainly of Quartz - Micaceous Schist and Pelitic Schist with many sheared and fractured zone. In the upstream and higher portion of slope, Limestone of Mesozoic forms cliffs and gorges. River deposits exist very thick.

Geology around Dam Site: Bedrock is composed of Sandstone or Psammitic Schist and Pelitic Schist of Ordovician. Sandy rock is usually siliceous or quartzitic and Pelitic rock is sometimes phyllitic. Many Faults and Sheared zones are observed in this area.

Geomorphology along Dam Axis: RG: 85～90 overhung, RD: approx.30～35 , FD: 70～90m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
Mainly hard slightly folded Sandy rock forms right-standing cliff. Portions around joints are usually cracky but closed.	Large volume of sand & gravel deposit is on the river bed as river deposits. They seems to be very thick. Some big faults may be inferred on the bottom of valley.	Few meters of Talus deposits cover the slope. Bedrock consists of the alternation of Psammitic Schist and black Pelitic Schist.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: River deposits seems to be very thick and joints in the Left Bank dips towards river side.

Watertightness

Dam Site	Reservoir
Faults and Sheared zone inferred along river bed are seemed to be permeable. Along joints of the Left Bank is attached muddy material which may be the sign of water effluent from inside. Furthermore, Schist in this area is somewhat weathered and altered. Then as a result, careful study on leakage is necessary at this site.	Generally the basement composed of Schist may have the well-watertightness.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Some joint planes of Left Bank dip towards river side. Their stability shall be checked.	Some area has very steep slope and Schist is sometimes weathered and deteriorated deeply. Slope stability in those area shall be checked.

Construction Material

Sand & Gravel Material: River deposits; enough volume
Rock Material: Bed rock of left bank at dam axis.
Earth Material: no suitable material; Talus deposits on the right bank slope; volume is not sufficient.

Study Level **Preliminaire- en cours**

Table I2.1 Summary of Geology around and at Respective Dam (11/26)

10, *Timkit* **River Assif N'Ifer (Todrha)** **Zone V**

Province: Er Rachidia	**Cercle**: Tinjdad		**Commune**: Aghbalou-N'Kerdous (Timkit)
Topo-Map (1/50000): TAGHLA	**X**: 507,250	**Y**: 515,450	**Z**: 1,214

Physiological Condition: Located in the gorge torrential flowing Jbel Tadount Serdoun and Bouchenndi constituting the Southern Haute Atlas limit flowing into Tinjidad plain.

Geological Province: Southern limit of Haut-Atlas Central	**Location**: 35 km along the road to Aghbalou N'Kerdous from the junction of the route N32
General Geology: Carboniferous Formations extend in Tisdafine Mountains in the south. In the northern Mountains including the gorge having dam axis, Limestone-Dolomite of Lower to Middle Lias dipping 40°～50° towards upstream extend, and Middle Jurassic and Cretaceous and some blocs of Eocene Formations is in between them. These are forming Synclinal structures covered sometimes by Ancient Quaternary of Conglomerate etc. and new deposits.	**General Stratigraphy**: Carboniferous: schist and sandstone Lower to Middle Lias: limestone and dolomite Upper Lias: marl, red mudstone, limestone and gypsum. Middle Jurassic: marl Cretaceous: marl, argillaceous rocks, red sandstone, marly limestone, conglomerate. Eocene: sandy to muddy limestone, red sandstone.
Geological Structure: Haut-Atlas folding mountains orienting dominantly WSW-ENE～SW-NE is composed mainly of Jurassic. Synclinal area forming usually the depression is of Mudstone or Marl of Middle Jurassic to Cretaceous, and anticlinal area is of Limestone and/or Dolomite of Lower Jurassic (Lias) unsymmetrically limited the one side by fault extending long. The foundation of JICA axis studied in 1988 is mineralized by iron and manganese, and porous.	

Geology of Reservoir Area: Composed mainly of the thin alternation of Dolomitic Limestone partly interbedded with many thin layers of Marl of Lower Lias. Bedding is very regularly dipping towards the upstream and left bank side with 30°～35°.

Geology around Dam Site: Bedrock is Limestone and/or Dolomite (Ep of unit layer: 0.5～1.0m) of Lower Jurassic rarely interbedded with Marl. In the downstream side, black to dark Limestone layers with iron-manganese ore mineral underlie changing gradually into Siltstone and finally greenish Siltstone. In the upstream side, Marl is very few. Bedding is dipping to upstream and a little to Left Bank side with 30°～50°.

Geomorphology along Dam Axis: RG: 45 , RD: 20～30 , FD: approx.22m, PD: 4.2%

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
Composed of Limestone. Middle part of abutment is somewhat weathered and changed into brown color. Partly karsts are developed.	River bed is covered by relatively thick (probably around 10 meters) River deposits. It is composed of sand and gravel (maximum grain size 20cm, medium size 5～10cm) with 1～2m size large rock block.	On the top, very thick Limestone layer underlain by relatively thin layers of Limestone or Dolomite dips towards river side. A lot of karsts are observed along the bedding plane.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Karsts are observed in this area, especially in some special strata.

Watertightness

Dam Site	Reservoir
Limestone and Dolomite at dam site develop many karsts variably from small to big size. Especially those karsts are observed well-in some special formations. Leakage is considerable so that careful study will be necessary.	Both Banks of reservoir area are composed of mainly Limestone and Dolomite where many karsts develops usually. Leakage is considerable so that careful study will be necessary.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Basically it seems to be no problem.	Basically stable.

Construction Material

Sand & Gravel Material: River deposits
Rock Material: Limestone bare
Earth Material: in the reservoir area

Study Level **APD**

Existing Geotechnical Investigation:

Drilling: Nos.3=115.7m JICA(B1,2,3), Nos.8=465.5m (JICA Axis 3,Upstream Axis 5 in 1992)

Seismic Exploration: (6 lines) at JICA Site

Test Pit (P) & Trench (T): P: Nos.22

Laboratory Tests:

Gradation, Atterberg, Water Content, Density, Form Coef., Los Angels & Deval, Chemical Analysis, Alkali Reaction)

Table I2.1 Summary of Geology around and at Respective Dam (12/26)

11, *Tadighoust* **River Rheris** **Zone V**

Province: Er Rachidia	**Cercle**: Tadighost		**Commune**: Tadighost
Topo-Map (1/50000): TADIGHOUST	**X**: 541,709	**Y**: 139,720	**Z**: 1,108

Physiological Condition: Located at just upstream of the Rheris basin. The gradient of river around the site is average 0.3%.

Geological Province: Southern periphery of Haut-Atlas Central	**Location**: Approx. 20 km North of Goulmima
General Geology: Composed of mainly Mesozoic. Likewise, Tertiary and Quaternary are also extending. Precambrian and Paleozoic can be also observed as the butonic (Fenster). Middle Jurassic is called <Couches rouges>, and Cretaceous lye on it concordantly.	**General Stratigraphy**: Mid Cambrian: conglomerate, sandstone, limestone, and quartzitic sandstone. Ordovician: sandy mudstone. Silurian: shale, and limestone. Triassic: red colored detritic rocks and evaporite. Lias - Mid Jurassic: Carbonaceous rock; ammonite bearing limestone and marl. Mid Jurassic 《Couches rouges》 formation: mostly red colored evaporite. Cretaceous: beige color marl, gypsum, and limestone; gypsumeous marl, siltstone interbedded conglomerate lens; calcareous dolomite; phonolite. Paleocene: fine sandstone, red mudstone, and gypsum Eocene: limestone and marl.
Geological Structure: Strata in this area dip towards the north striking E－W. Faults existing in Haut Atlas mountains orient generally E－W. The big Fault of South Atlas deforms the Mesozoic and forms the depression covered by new deposits. These faults is considered generally overthrusting towards the south from the evidence of the Jurassic lies on the Cretaceous and Cenozoic in the south.	

Geology of Reservoir Area: Composed mainly of the following Mesozoic formations: Silt-Sandstone formation; interbedded with Conglomerate lenses and Marl, Limestone-Dolomite formation; interbedded with Marl, Limestone formation; and Limestone and Phonolite. Eocene to Miocene composed of Marl, Limestone and Mudstone is also existing. Partly Paleozoic and Precambrian outcrops as Fenster.

Geology around Dam Site: Bedrock is Marl of Lower Cretaceous and Limestone of Turonien.

Geomorphology along Dam Axis: RG: 17 , RD: 27 , FD: approx.170m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
At the foot of abutment, Talus deposits exist relatively thick consisting of large rock blocs. In the middle portion, wide terrace forms flatland (width about 50m) but no sediments are on it. Bedrock is mainly fossilferous Limestone alternating with Marl.	Few meters of Alluvial deposits in thickness are on the river bed. Those are composed of sand and gravel relatively homogeneous showing medium grain size 5～8 cm. In the right bank side, alluvial terrace composed of silty soil approximately 2 m in thickness distributes.	Bedrock forms right-standing cliff and Talus deposits accumulat at the foot. On the top, very thick Limestone (Ep= 5～10m) lies on the alternation of Marl and layered Limestone.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Karsts are rarely observed, however vertical joints are existing a lot in Limestone layers which are usually open.

Watertightness

Dam Site	Reservoir
Karst is not developed so much in Limestone at dam site and Marl is basically impermeable. Though open joints are observed in the layer of Limestone, leakage may not be so significant. Since river deposits are thick, its treatment may be important.	Due to Marly rocks in the reservoir area, leakage from reservoir is not so significant.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Basically it seems to be no problem.	Basically stable.

Construction Material

Sand & Gravel Material: River deposits; Terrace deposits around dam site
Rock Material: Limestone around dam site and 5km NW from dam site
Earth Material: no suitable material

Study Level **Preliminaire**

Table I2.1 Summary of Geology around and at Respective Dam (13/26)

12, *Tiouzzaguine*	**River Guir**		**Zone V**
Province: Er Rachidia	**Cercle**: Gourrama		**Commune**: Gourrama (Tiouzaguine)
Topo-Map (1/50000): GOURRAMA	**X**: 618,071	**Y**: 206,923	**Z**: 1,525
Physiological Condition: Located in the Haut Atlas Calcaire torrentially flowed by the river flowing into the depression of Mougueur. Three tributaries confluent just before the dam site.			
Geological Province: Eastern side of Haute Atlas calcaire		**Location**: Approx. 2 km NE from Tiouzzaguine village	
General Geology: Generally composed of Limestone or marly Limestone. Basalt is also existing widely. **Geological Structure**: Reservoir area is around the axis of syncline, and anticline exists at the upper portion of left bank side slope. River course runs parallel to the syncline axis flowing around the foot of limestone hills locating at the eastern end of syncline structure. This syncline structure is closed in the north side (upstream).		**General Stratigraphy**: Triassic: basalt and reddish mudstone Sinemurien: massive limestone Lotharingien - Pliensbachien: black limestone interbedded with marl Toarcien: ammonite bearing limestone, marly limestone Ancient Quaternary: travertine Quaternary: terrace deposits, alluviums and colluviums	
Geology of Reservoir Area: Composed of Basalt and red Mudstone of Triassic, massive Limestone of Sinemurien, black Limestone interbedded with Marl of Lotharingien - Pliensbachien, and ammonite bearing Limestone and marly Limestone of Toarcien. Travertine, Terrace deposits are also extending in the area. River deposits are on river bed.			
Geology around Dam Site: Limestone strata form very narrow gorges, while, the area of Basalt and red Mudstone of Triassic is relatively gently sloping. Travertine extends from the upstream to the downstream partly underlain by Eboulis or Conglomerate. Basalt lies under Limestone.			
Geomorphology along Dam Axis: RG: approx.75 , RD: approx.50 , FD: approx.30m note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed			
Geology along Dam Axis			
Left Abutment	**River Bed**		**Right Abutment**
Limestone exists as a shape of "langue" towards river side dipping 75°～80°. Basalts are outcropped at the foot of Limestone cliff covered by Talus deposits.	River Deposit: Ep= approx. 15m; sand and gravel underlain by Limestone. Right bank side is composed of Travertine.		Travertine exists relatively thick forming terrace which is usually loose and porous. The height of Travertine cliff reach 27 m.
note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),			
Remarks of Dam Foundation: Some faults are inferred on the right abutment and at the foot of left abutment where is usually fractured. Travertine is very porous.			
Watertightness			
Dam Site		**Reservoir**	
Limestone itself at dam site is massive. However, the things that travertine is existing is the matter. There is a possibility that some karsts may develop somewhere. Marl lain under Limestone is basically impermeable.		In the Limestone layers continuing from dam site, many karsts and travertine are observed. Then, Leakage from reservoir may also be considered to some extent. To prohibit from leakage, it shall be checked about the existence some impermeable formation and their distribution. It shall be also checked about the permeability of Basalt.	
note: Lu; Lugeon Unit			
Stability			
Dam Site		**Reservoir**	
The stability of the slope near faults shall be checked.		The stability of the slope near faults shall be checked.	
Construction Material			
Earth Material: Terrace deposits around dam site; muddy soil Sand & Gravel deposits: River deposits Rock Material: Limestone around dam site			

Study Level **APS**

Existing Geotechnical Investigation:

Drilling: Nos.9=576m (Dam Site=RD 5, OD 3, RG 1)

Seismic Exploration: (RD 6 lines, OD 2 lines, RG 3 lines)

Adit: (Both Banks)

Test Pit (P) & Trench (T): T: Nos.1 (Terrace Silt), P1: Nos.2 (Terrace Silt), P2: Nos.10 (River deposits)

Laboratory Tests:

P1 samples (Gradation = Sieve & Hydrometer, Atterberg)

P2 samples (Sieve in situ, Hydrometer, Atterberg, Sand Equivalent, Specific Gravity, Form Coef., Los Angels & Deval, Chemical Analysis, Alkali Reaction)

Table I2.1 Summary of Geology around and at Respective Dam (14/26)

13, *Kheng Grou* **River Kheng Grou** **Zone V**

Province: Figuig	**Cercle**: Beni Tajjit		**Commune**: Bni Tajjit (Ksar Morhel)
Topo-Map (1/50000): QSAR MOUGHAL	**X**: 716,000	**Y**: 194,000	**Z**: 980

Physiological Condition: Located in the gorge situated in the eastern end of Jbel Bou Dahar. Eastern side is Tamlelt plain, North-Eastern side is Hauts Plateaux, North-Western side is Plis Marginaux, and Southern side is Sillon Sud Atlasique.

Geological Province: Eastern end of Haute Atlas calcaire	**Location**: Approx. 42 km East of Beni Tajjit
General Geology: Mainly composed of Limestone. In the western area, an atoll of Lias surrounds Schist and Quartzite (Sebbab Kebir) of Paleozoic. These area has lead and zinc blend mines.	**General Stratigraphy**: Paleozoic: schist and quartzite Sinemurien: limestone Lotharingien: limestone Domerien - Carixien: limestone interbedded with marl Toarcien: marl and marly limestone Aalenobajocien: limestone Quaternary
Geological Structure: The formations observed in the gorge exist as the large anticlinal structure. Around the anticlinal axis, fractured zones develop, and formations are dislocated by faults. The northern side of anticline dips steeply and dislocated by faults etc, while the southern side is nearly horizontal dipping 10°～ 15° towards South until the effluent of gorge.	

Geology of Reservoir Area: Bedrock in the gorge is Limestone of Lotharingien and Sinemurien. Upstream is the large valley composed also of mainly Limestone covered by silt and marly soil.

Geology around Dam Site: Bedrock is Limestone of Mesozoic where bedding is almost horizontal. Some faults orienting generally E－W limit the extension of rock. Mainly following three systems of Faults are recognized where are normally well-developing in eastern side of Bou Dahar Massif. F1 ：N100°, 70°～85°S F2 ：N90°, vertical F3 ：crossing at a right angle to river course N90°～N100°

Geomorphology along Dam Axis: RG: approx.55 , RD: approx.70 , FD: approx.75m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
Composed of hard and massive Limestone. Fault is inferred in the middle of slope. Thickness of unit layer is in order of 10 cm.	River deposits (Ep= about 15m) cover Limestone bedrock. Those are mainly sand and gravel of which maximum grain size is 10 cm, and medium size is 3～5 cm.	Composed of Limestone almost horizontal (dipping 5 ° ～ 10 ° downstream side). They are relatively fresh and massive.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Partly very big karsts are developed sometimes reaching their size 20m x 6m.

Watertightness

Dam Site	Reservoir
Though Limestone at dam site is hard and massive, partly large karsts are observed. Then careful study on leakage is necessary.	The Limestone forming gorge of Kheng Grou river develops sometimes karst erosion. Since many springs exist in the downstream area, leakage from reservoir may be considerable.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Since both banks are steep, the discontinuity in the rock is important to the stability. Their distribution and structure shall be carefully checked.	Basically stable.

Construction Material

Sand & Gravel Material: River deposits; in the downstream of which river width is 200～250m; also in the upstream.
Rock Material: Limestone around dam site
Earth Material: High Level Terrace deposits in the left bank; the Deposits along Ksar Moghel (right bank)

Study Level **Preliminaire**

Existing Geotechnical Investigation:

Drilling: Nos.4=230m (Dam Site=RD 1, OD 2, RG 1)

Test Pit (P) & Trench (T): P: Nos.20 (River deposits), P: Nos.4 (RG Terrace, Gr.), P: Nos.3 (RD Terrace to River, Silt)

Table I2.1 Summary of Geology around and at Respective Dam (15/26)

14, *Adarouch*	**River Tigrigra**		**Zone I**
Province: Ifrane	**Cercle**: Azrou		**Commune**: Sidi el Makhfi (Tigriga)
Topo-Map (1/50000): BOU CHBER	**X**: 489,800	**Y**: 316,350	**Z**: 830,50

Physiological Condition: Located at the eastern end of Moroccan Central Massif near the border of Moyen Atlas Casse.

Geological Province: North-Eastern Massif Central Hercynian

Location: Approx. 35 km West of Azrou

General Geology: Namurienne formations are in Benghanem-M'taoutoult. Dam site is located just on the bedrock of Namuriennes of Fourhal Synclinorium Benghanem-M'taoutoult extending in the limestone mountain range of Chougrane and Agourai. They are Turbiditic but their re-sedimentaries (Olistostrome) can not be found out. They are generally continuing to Flysh deposits of Viseo-Namuriens. South-ward of this area, the southern side of Grou river is composed of Stephano-Autumien Formations.

Geological Structure: Central Morocco Massif is a Hercynian orogenic area extending from the Atlantic to Moyen Atlas and Gharb/Saiss plains to Phosphates plateau forming 5 folding zones bounded by faults orienting NE-SW.
The bedding and schistosity around dam site is striking NE-SW crossing at a right angle to Tigrigra river course. Dam site is founded on Namuriennes formations forming "Fourhal synclinorium Benghanem-M'taoutoult". They are folded orienting their axis NE inclining steeply towards NW to SE or vertical. These formations intruded sometimes by Granite. The biggest one is Ment Granite.

General Stratigraphy:
Namuriennes: at least 800m thick alternation of sandstone and mudstone interbedded with around 1m thick coarse sandstone or fine conglomerate lenses; fossilferous, green to black, sometime slumping. Sometime some tenth centimeter thick of limestone breccia is interbedded.
Viseo-Namuriens: Flysch deposits.
Stephano-Autumien: Agourai synclinorium limestone intruded by granite dyke.

Geology of Reservoir Area: Bedrock is Turbiditic formation of Namurian of which bedding and schistosity (NE-SW) is crossing at a right angle to river course. Geological structure in this area is called "Benghanem-M'taoutoult of Fourhal Synclinorium". They are basically Flysh deposits between Chougrane and Agourai Limestone Massif. These are sometimes intruded by Granite.

Geology around Dam Site: Bedrock is Sandstone, Schist, and Conglomerate of Carboniferous. Sandstone and Conglomerate is the main strata around dam site and right-standing Conglomerate Bar forms the gorge of dam axis. Dam site is situating on the big folding called "Fourhal Synclinorium" composed of Flysh of Viseo-Namuriens, which are sometimes intruded by Granite.

Geomorphology along Dam Axis: RG: 23～25 , RD: 13～15 , FD: approx.40m
note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
Bedrock condition is relatively good. Partly covered by thin top soil. Highly weathered zone: Ep= about 5 m; gradually going to be sound rock as deeper. Faults cross obliquely, of which displacement is about 130m towards the right along bedding strike.	Alluvial deposits: very thin (Ep= 0.5 m) Bedrock of weathered zone : Ep= 1～2 m. Discontinuous sandy Terrace deposits exist narrow and long.	Bedding is dipping towards W= mountain side (more than 75°). Weathered zone reaches up to around 18 m: Highly weathered zone Ep= 5～8m.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Joints parallel to dam axis are very frequent. Faults is clearly displacing the formation. Weathering is remarkable in the sandy part.

Watertightness

Dam Site	Reservoir
Up to 20-25m in the strata of Sandstone and Conglomerate, permeability is high. In the Pelitic Schist it is basically low.	Need to be checked permeability of Conglomerate layers and Fault lines.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Some faults are observed in the left bank, their stability have to be checked.	The slope in the upstream is very steep (max. 5V/1H). Then their stability shall be checked.

Construction Material

Sand & Gravel Material: River deposits around dam site; enough volume
Earth Material: Terrace deposits; clay - silt

Study Level **APD**

Existing Geotechnical Investigation:
Drilling: Nos.6=339m

Laboratory Tests:
Drilling Cores (Specific Gravity, Unconfined Compression, Direct Shear)

Table I2.1 Summary of Geology around and at Respective Dam (16/26)

15, *Sidi Omar* **River Tanoubart** **Zone II**

Province: Khemisset	**Cercle**: Maaziz		**Commune**: Ait Ikkou / Tedders
Topo-Map (1/50000): SEBT AIT IKKOU	**X**: 425,100	**Y**: 336,100	**Z**: 263

Physiological Condition: Located in the center of Moroccan Central Massif. Catchment area is long hilly mountain ranges and plateaus covered relatively with rich vegetation.

Geological Province: North-Western Maroc Central Septentrional	**Location**: Approx. 36 km South of Khemisset
General Geology: Paleozoic, Triassic, Jurassic and Mio-Pliocene～Quaternary extend in the surrounding area. These are composed of both Sedimentaries and Igneous.	**General Stratigraphy**: Ordovician, Silurian and Devonian Carboniferous: turbiditic; greywacke or the alternation of conglomerate/mudstone or orthquartzite/mudstone. Permian: volcanic rocks; andesite, rhyolite, liparite, trachyte; conglomerate, fine conglomerate, reddish sandstone and mudstone. Triassic: silty evaporite, reddish mudstone (lower unit) - basalt and merange of reddish mudstone (upper unit)
Geological Structure: Folding axes orient mainly NE-SW, and schistosity is fitting to that dipping SE.. Joint system is parallel to or at a right angle to schistosity. Generally formations are compacted by reverse faults. The system of normal faults: N70°-125°,40°-75°N, N30-70,40-80NE The system of strike-slip faults: N30°-55°, 85°-90°E, N10°-160°, 50°-90°W	

Geology of Reservoir Area: Bedrock is Schist interbedded with Sandstone of Paleozoic. They are sometimes overlain by Conglomerate, fine Conglomerate, Sandstone and red Mudstone. Colluvial deposits develop rarely.

Geology around Dam Site: Bedrock is the alternation of Schistose Sandstone and Slate (partly Schist) of Namurian and Visean. The thickness of each layers is: Sandstone = approx. 5m, Slate = approx. 10m.

Geomorphology along Dam Axis: RG: 35 , RD: 50～60 , FD: approx.70m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
Composed of red-color, relatively homogeneous, partly sheared alternation of Sandstone and Slate. Top soil cover is thin. Geological structure is relatively simple, namely monoclinic (bedding N30E,60W).	Alluvial deposits cover the bedrock. Those are composed of sand to silt with some cobble and gravel of schist, sandstone, and limestone. Fault may be inferred on river bed.	Top soil: Ep= around 1 m. Bedrock is the alternation of Sandstone and Slate (bedding N30°E,50°W) at just downstream of dam axis, while phyllitic Schist (schistosity N30°E,90°) exists at dam axis. Fault and sheared zone exist at just upstream following very folded schistose rocks.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Left Bank side is composed of yellowish deteriorated Schist continuing to sheared zone at just upstream. Sheared zone may be crossing at river bed.

Watertightness

Dam Site	Reservoir
Some parts are very fractured and faults are observed especially in Right Bank side so that leakage may be considerable around these portions.	Basically it seems to be no problem.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Right bank is composed of folded Schist relatively weathered & deteriorated and partly sheared. Their stability shall be carefully checked.	Upstream slope of dam axis on Right Bank is covered by relatively thick talus deposits which are very erodable. These talus deposits are derived from weathered Conglomerate which exists on the upper slope of Right Bank. Their stability shall be checked.

Construction Material

Earth Material: reddish clay in the reservoir area; Colluvial deposits on the right bank slope just upstream side
Sand & Gravel Material: Tanoubart River deposits; volume is not sufficient
Rock Material: Sandstone-Quartzite bares; Cretaceous formation at 2km downstream from dam axis

Study Level **Preliminaire**

Existing Geotechnical Investigation:

Drilling: On Going

Table I2.1 Summary of Geology around and at Respective Dam (17/26)

16, *Tiouine*	**River Iriri**		**Zone IV**
Province: Ouarzazate	**Cercle**: Ouarzazate		**Commune**: Ait Zinab (Tiouine)
Topo-Map (1/50000): TIKIRT	**X**: 323,543	**Y**: 438,513	**Z**: 1,273
Physiological Condition: Located at the western end of Ouarzazate Basin forming "Sillon Sud Atlasique" between Haut Atlas and Anti Atlas.			
Geological Province: Anti-Atlas occidental		**Location**: Approx. 20 km South of Ait Ben Hadou	
General Geology: The depression of the basin around Tiouine was formed by tectonic movement orienting N-E where is filled by detritus derived from Volcanics. Basement rocks are of Precambrian. Dip of these formations is 10°NE.		**General Stratigraphy**: Precambrian: igneous rocks (pyroclastics, lava, and tuff) Tertiary: conglomerate, sandstone Quaternary: coarse deposits.	
Geological Structure: The big faults forming the boundary is the group orienting NNE～NE being parallel to each unit, and ENE～ESE traversing each unit. The former forms "le horst de Tiouine (Tiouine horst)".			
Geology of Reservoir Area: Bedrock is Rhyolitic to Andesitic rock of Precambrian and Conglomerate and Sandstone of Cenozoic. Precambrian rock is very massive (no bedding) and very hard. Cenozoic rock is relatively loose and porous and so many piping hole can be observed.			
Geology around Dam Site: Bedrock is Ryolite of Precambrian. The area is usually composed of "Series of Volcanics or Volcano-Detritus of Ouarzazate" which is massive (no bedding), homogeneous, and hard. Conglomerate fills the valley of the Precambrian which is usually dipping to 15°～20°E.. Volcanic Breccia is observed in the downstream.			
Geomorphology along Dam Axis: RG: 70～80 , RD: 40～70 , FD: approx.65m note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed			
Geology along Dam Axis			
Left Abutment	**River Bed**		**Right Abutment**
Composed of very hard Rhyolite forming very high right-standing cliff which is usually mineralized by mangano-iron ore.	Very thin River deposits cover the bedrock. Their grain size is widely distributing from sand to boulder. Some salt-gypsum powder can be observed along the water course.		Composed of Rhyolite same as Left Bank. However as being apart from the dam axis, it becomes somewhat andesitic with some faults and sheared zones.
note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),			
Remarks of Dam Foundation: Around dam site, some groups of Fault having the direction E-W, NW-SE, and NE-SW exist. The biggest one is called as "caissees de failles (the Fault box)" with some variety of scale having sometimes 5～6m to 10～15m Mylonite in width.			
Watertightness			
Dam Site		**Reservoir**	
Along Faults and fractured zone, permeability may be relatively high but it may be groutable.		In the Left Bank side of reservoir area very porous and cavitiferous Conglomerate and loose Sandstone are observed. These are very permeable. Their distribution shall be checked.	
note: Lu; Lugeon Unit			
Stability			
Dam Site		**Reservoir**	
The stability along Faults shall be checked.		In the reservoir area, loose and porous Sandstone and Conglomerate are existing. Their stability shall be checked.	
Construction Material			
Sand & Gravel Material: Iriri River deposits; Terrace deposits, heterogeneous (sands～boulder) Rock Material: Rhyolite around dam site; Conglomerate in the reservoir area Earth Material: no suitable material			

Study Level **Preliminaire**

Table I2.1 Summary of Geology around and at Respective Dam (18/26)

17, *Azghar*	**River Zloul (Sebou)**		**Zone I**
Province: Sefrou	**Cercle**: Ribat Al Kheir		**Commune**: Ribat Al Kheir (Betha)
Topo-Map (1/50000): RIBAT AL KHAYR	**X**: 598,800	**Y**: 357,000	**Z**: 824

Physiological Condition: Zloul river is the most upstream tributary of Sebou river. Catchment area is long and narrow hills and plateau covered by rather rich vegetation.

Geological Province: Moyen Atlassique Plisse	**Location**: Approx. 10 km East of Ribat Al Khayr
General Geology: Bedrock is mainly composed of Schist interbedded with Calcareous Sandstone of Jurassic. Colluvial deposits is relatively few.	**General Stratigraphy**: Jurassic: Schist interbedded with calcareous sandstone Colluvial deposits is relatively few.
Geological Structure: Though the strata around dam site form monoclinic dipping gently towards left bank and downstream side, their regional structure is folded by repeated synclines and anticlines with gentle angle.	

Geology of Reservoir Area: Bedrock is mainly composed of Schist interbedded with Calcareous Sandstone of Jurassic. Colluvial deposits is relatively few.

Geology around Dam Site: Bedrock is the alternation of Black Limestone and Marly or Muddy Limestone or Calcareous Slate of Lower to Middle Jurassic. Along Zloul river, they are usually monoclinic, however regionally synclinal directing their axis SW-NE..

Geomorphology along Dam Axis: RG: approx.45 , RD: approx.20 , FD: approx.150m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
Bedrock is monoclinic dipping gently towards the downstream and left bank (bedding N50°W,10°S). They are very sound usually, though having weathered zone up to the depth approximately 2.5m. Joint planes are regularly developed in 2 systems, one is parallel to river course, and another is parallel to dam axis in the interval of 30～50cm. The thickness of unit layers is 20～30cm.	River bed is mainly formed by bedrock covered with very thin sand and gravel. In the right bank side, Alluvial terrace is widely extending consisting of sand & gravel and cobble with thickness around 1.5m along river bed, and as separating from river bed it becomes sand and silt dominants with some subangular rock fragment.	Bed rock is same as Left Bank with very gentle slope formed by bedding plane of Limestone.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Generally the foundation is very sound rocks of the alternation of Limestone and calcareous Slate. Bedrock in the valley has rather dominance of slate portion. Karsts can not be observed.

Watertightness

Dam Site	Reservoir
Basement rocks along dam axis is considered that the leakage problem may be little.	Basically it seems to be no problem.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Left Bank side is very steep. Their stability is necessary to be checked.	Basically stable.

Construction Material

Earth Material: reddish clay in the reservoir area or downstream side
Sand & Gravel Material: River deposits of Zloul river and Quarya river (approx. 1km far from dam site)= sand is dominant
Rock Material: Limestone

Study Level **Preliminaire**

Existing Geotechnical Investigation:

Drilling: On Going

Table I2.1 Summary of Geology around and at Respective Dam (19/26)

18, *Boukarkour* **River Zamrine** **Zone II**

Province: Settat	**Cercle**: Ben Ahmed		**Commune**: Mgarto (El Gara)
Topo-Map (1/50000): MGARTO	**X**: 341,350	**Y**: 291,000	**Z**: 288

Physiological Condition: Located at the ravine of approx. 260m length in the south-western side of Moroccan Central Massif.

Geological Province: South-Western Massif Marocain Central	**Location**: Approx. 1 km downstream of the bridge passing the Zamrine river
General Geology: Central Morocco Massif is mainly composed of Devonian and Hercynian Formations of Carboniferous. As proceeding to West, they are covered by Chaouia and "Plateau des Phosphates". Carboniferous in this area is Visean.	**General Stratigraphy**: Viseen (Carboniferous): Upper portion = mainly muddy sandstone, limestone, and quartzite; Middle Upper = schist interbedded limestone reef or lens; Middle Lower = sandstone, and quartzite. Tournaisien: schist and quartzite Quaternary: red mud, pebble
Geological Structure: Central Morocco Massif is commonly cut by the fault system orienting mainly NE-SW, E-W and N-S. Around dam site, NE-SW orienting faults exist in the upstream and the downstream and dislocating the formation. These faults run crossing along river course and on right bank. The fault system orienting WNW-ESE is also observed.	

Geology of Reservoir Area: Bedrock is mainly Schist sometimes interbedded with Quartzite of Visean. Bedding is N85°～100°,30°～40°N. Two group of fault orienting NE-SW and N-S limit the bedrock. Terrace deposits composed mainly of sand and gravel are extending in the upstream. Colluvial deposits are relatively few.

Geology around Dam Site: Bedrock is very hard sandy Quartzite bars with much iron ore mineral of Visean. Their thickness of unit layer is usually in the order of meters. They are slightly folded and their strike and dip changes delicately from N85～N100 ,30～40 N (dipping to the downstream side).

Geomorphology along Dam Axis: RG: 57 , RD: 47 , FD: approx.50m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
No top soil. Composed of very hard, layered Quartzite interbedded with thin Psammitic Schist. Quartzite is sandy and laminated by sand-size iron ore minerals. Bedding is monoclinic along dam axis dipping towards the downstream (N80°E,35°N).	River deposits composed of sand and gravel covers bedrock. At the foot of both banks Talus and Colluvial deposits exist.	No top soil. Bedrock is same as Left Bank. Some formation dislocated by Fault orienting NE-SW can be observed forming the saddle behind the Right Bank.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Joints observed in Quartzite are grouped into: N20°, vertical N55°,58°S and N154°, 71°SW. Fault may exist from upstream side of Left Bank to the downstream side of Right Bank.

Watertightness

Dam Site	Reservoir
Left Bank: Deeper than 18 m, Lu<2; Shallower portion, Lu= 3～4. River Bed: Generally Lu<1. Right Bank: Deeper than 9 m, Lu= 2～3; Shallower portion, Lu= 9～10.	Since the reservoir area is mainly composed of Schist interbedded with thin quartzitic sandstone, the watertightness seems to be good.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Basically it seems to be no problem.	The area where the slope gradient is more than 30% shall be checked about the slope stability.

Construction Material

Earth Material: soil in the reservoir area
Rock Material: Quartzite bar around dam site or at access road (BenSlimane→dam site).
Sand & Gravel Material: no suitable material

Study Level **APD**

Existing Geotechnical Investigation:

Drilling: Nos 5=176m (Dam Site= RD・OD・RG each 1, Up- and Downstream each1)

Table I2.1 Summary of Geology around and at Respective Dam (20/26)

19, *Aoulai*	**River Aoulai (Ouergha)**		**Zone I**
Province: Taounate	**Cercle**: Ghafsai		**Commune**: R?tba
Topo-Map (1/50000): TAMOROT	**X**: 542,150	**Y**: 467,850	**Z**: 290

Physiological Condition: Topography in the upstream side is composed of hills having relatively gentle slope, however changed suddenly into ravine at dam site, and again into wide valley.

Geological Province: Rif Occidental, Intrarifaine zone	**Location**: Approx. 20 km North of Ghafsai
General Geology: Generally homogeneous and same scale of Cretaceous Flysh extend in this area and lye under soft Ultrarifaines Nappe. Upper Cretaceous is in the age of Cenomanien - Turonien and Senonien, and partly Numidienne mass of Nappe is scattering.	**General Stratigraphy**: Upper Cretaceous: Cenomanien - Turonien and Senonien Flysh; schist, marl, marly limestone Ultrarif Nappe partly Numidienne: sandstone, mudstone
Geological Structure: Generally the area is strongly folded and faults with shear zone are observed at many place.	

Geology of Reservoir Area: Bedrock is Schist interbedded with black Limestone of around 10cm in thickness. Unconsolidated deposits such as Terrace deposits, Colluvial deposits, and River deposits are very limited.

Geology around Dam Site: Bedrock is Schist interbedded with Black Limestone layers of Cretaceous. They are normally homogeneous.

Geomorphology along Dam Axis: RG: 17 (11～30), RD: 30 , FD: 100m, Right Bank forms the saddle of relative height 40m (El. 330m) from main river bed.

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
Top soil is derived from Residual soil of Schist with some rock fragments. Schist is completely weathered and lost its rock structure. Black Limestone outcrops in the middle of slope having many lime veins (bedding averagely N120°, 25°).	Alluvial and Terrace deposits cover the bedrock. Alluvial deposits: River deposits (Sand and Gravel) and Alluvial Terrace deposits (Silty soil) Terrace deposits: composed generally of rounded gravel and cobbles diameter in the order of centimetric to decimetric in a silty matrix.	In the upstream side, fresh rock washed by river water outcrops showing the dip 30° towards N averagely (schistosity N10°,30°～40°N). In the center of dam site, fresh bedrock is covered by overburden of 3m in thickness. In the downstream, 400m length of Terrace deposits are extending.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: From Left Bank to River Bed, bedrock is very highly weathered forming very weak foundation.

Watertightness

Dam Site	Reservoir
Permeability seems to be low due to argillaceous rocks. However, the existing of unconsolidated material may be carefully treated. Leakage from the foundation of saddle dam shall be carefully checked.	Basically it seems to be no problem.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Foundation is generally weathered very much and loose. Their stability shall be checked.	Schist in this area is generally weathered and loosened deeply and sometimes forms steep slope. Their stability shall be checked.

Construction Material

Earth Material: Colluvial deposits on the slope= volume is not sufficient; Terrace deposits (silty portion)
Rock Material: Black Limestone outcropping at middle slope
Sand & Gravel Material: River deposits and Terrace deposits

Study Level **Preliminaire**

Existing Geotechnical Investigation:

Drilling: Nos 16=690m (Dam Site 13 Sub-Dam 3)
Seismic Exploration: (10 lines), Resistivity (5 lines)
Adit: (Both Banks 50m)
Test Pit (P) & Trench (T): T: Nos.1 (Right Bank), P: Nos.19

Laboratory Tests:

(Gradation, Atterberg, Metilen Blue, Sand Equivalent, Los Angels & Deval, Franklin, Alkali Reaction)

Table I2.1 Summary of Geology around and at Respective Dam (21/26)

20, *Sidi Abbou*	**River Lebene**		**Zone I**
Province: Taounate	**Cercle**: Ain Aicha		**Commune**: Beni Frassene
Topo-Map (1/50000): TISSA	**X**: 585,000	**Y**: 424,700	**Z**: 250

Physiological Condition: Located in the southern Rif region where is usually composed of gentle hills and plateaus, sometimes of very rocky hills of limestone.

Geological Province: The border of Prerif and Mesorif	**Location**: Approx. 30 km WSW from Ain Aicha
General Geology: Southward is Prerif distributing Ouazzane Nappe and Upper Cretaceous. Northward is Mesorif and partly Triassic is distributing.	**General Stratigraphy**: Ouazzane Nappe Triassic Upper Cretaceous: marl Lower to Middle Cretaceous: limestone bars Miocene: marl
Geological Structure: Basement rocks form island arc curving towards South, however the orientation around dam site is nearly E-W. In the south, Intrarif Nappe forms many hills.	

Geology of Reservoir Area: Bedrock is composed mainly of Marl interbedded with Limestone. River deposits and Alluvial terrace deposits are widely extending in the reservoir area.

Geology around Dam Site: Bedrock is slightly crystallized Limestone sometimes forming Limy Conglomerate and Limy Sandstone of Jurassic to Cretaceous. They are normally massive and bedding is unclear.

Geomorphology along Dam Axis: RG: 60～80 , RD: 45～90 , FD: 5～10m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
Left Bank is overhung. In the upper portion, rocks are weathered then joints are open and filled with muddy materials. While, lower portion is very fresh, hard, and closed joints relatively.	Gravel or sometimes sands fill the depression of bedrock in a small scale. Maximum grain size of river deposits is 20 cm, while the rock block has 2 m size. Bedrock is fresh, very hard and their joints are closed well.	Joints are dipping towards river side with gradient 50 °～70 °. In the downstream side, very big karsts exists developing along the Joint or Fault orienting N10°W40°W.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: The portion along some discontinuity in the Limestone develops very large karsts.

Watertightness

Dam Site	Reservoir
Though Limestone at dam site is hard and massive, partly large karsts are observed. Then careful study on leakage is necessary.	Both Banks of reservoir area continuing from dam site are composed of Limestone where some large karsts develop specially in some area. For leakage control, their distribution must be carefully studied.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Basically it seems to be no problem.	Basically stable.

Construction Material

Rock Material: Limestone around dam site
Sand & Gravel Material: River deposit in the reservoir area
Earth Material: Top soil distributing on the bedrock of Marl in the reservoir area and in the downstream side

Study Level **Preliminaire- en cours**

Table I2.1 Summary of Geology around and at Respective Dam (22/26)

21, *Sidi el Mokhi*	**River Amzez (Ouerrha)**		**Zone I**
Province: Taounate	**Cercle**: Sidi Mokhi		**Commune**: Sidi Mokhi / Timezgana (Galaz)
Topo-Map (1/50000): RHAFSAI	**X**: 558,450	**Y**: 448,300	**Z**: 257
Physiological Condition: Located in the southern side of Rif region.			
Geological Province: Northern side of river basin is Mesorif, and the southern side is Prerif.	**Location**: Very near Galaz village		
General Geology: Homogeneous rock facies of Intrarif zone, which are folded and overthrusted by the mass of Triassic to Pliocene to the mountain peak ward.	**General Stratigraphy**: Lias to Middle Cretaceous: marly limestone interbedded with Flysh. Upper Cretaceous: marl Lower Eocene: massive limestone or flint-like rocks Upper Eocene: merange Oligocene and Lower to Middle Miocene: schist, sandstone and conglomerate		
Geological Structure: Generally the area is strongly folded and faults with shear zone are observed at many place.			
Geology of Reservoir Area: Bedrock is of Marl, calcareous Slate and Limestone. Terrace deposits and Colluvial deposits are extending.			
Geology around Dam Site: Bedrock is composed of layered black Limestone and calcareous Slate of Lias to middle Cretaceous. Bedding is N60°E,35°S dipping to the downstream. Some faults may exist crossing at a right angle to the river coarse across just upstream of dam axis.			
Geomorphology along Dam Axis: RG: 30 , RD: 15 , FD: 35m note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed			

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
2～5 meters of Colluvial deposits covers bedrock. Bedrock is massive, medium hard, and closely jointed black Limestone and calcareous Slate. Bedding is delicately changing due to small folding. The thickness of weathered zone is 1～2m.	River deposits cover the bedrock. Their thickness is 2～5m.	Bedrock is same as Left Bank.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Some faults are inferred at just upstream of dam axis crossing at a right angle to river course.

Watertightness

Dam Site	Reservoir
Partly natural hole along bedding plane can be observed, then careful study on leakage is necessary.	Since the reservoir area is mainly composed of Marl, the watertightness is considered good.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
At just upstream side of Left Bank, large slope failure is observed. Stability along inferred fault located at just upstream of dam axis shall be checked.	It is necessary to be checked about the slakability of Marl.

Construction Material

Earth Material: located at 3km from dam site
Rock Material: Limestone around dam site
Sand & Gravel Material: River deposits, volume is not sufficient

Study Level **Preliminaire**

Existing Geotechnical Investigation:

Test Pit (P) & Trench (T): P: Nos.3

Table I2.1 Summary of Geology around and at Respective Dam (23/26)

22, *N'Ouantz*	**River N'Ouantz**		**Zone III**
Province: Beni Mellal	**Cercle**: El Ksiba		**Commune**: Tizi N'zly (Aghbala)
Topo-Map (1/50000): AGHBALA	**X**: 471,530	**Y**: 206,600	**Z**: 219
Physiological Condition: Located at the border of Moyen Atlas and Haut Atlas. Dam site is just in the side of Haut Atlas.			
Geological Province: The border of Moyen Atlas and Haut Atlas Central	**Location**: Approx. 4 km NW from Rhafsai		
General Geology: It is characterized by large subsidence in the time of Jurassic and Eo-Cretaceous followed by the deposits of through continental or sub-continental.	**General Stratigraphy**: Jurassic and Eo-Cretaceous: reddish detritic deposits.		
Geological Structure: Around dam site, the strata is monoclinic dipping gently towards the downstream and left bank side. However regionally observing, it is in the large folded zone orienting its axis E-W, and overfolding and nearly vertical strata can be observed in the upstream. Dolerite intruded somewhere. The large fault orienting ENE-WSW exists, and some discontinuous lines orienting N-S develops well.			
Geology of Reservoir Area: Bedrock is Silty Sandstone which is covered by Alluvial deposits and Colluvial deposits.			
Geology around Dam Site: Bedrock is the alternation of red Mudstone and Sandstone of Jurassic of which the thickness of unit layer is in the decimetric order.			
Geomorphology along Dam Axis: RG: average 20 , RD: average 21 , FD: 50 m note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed			
Geology along Dam Axis			
Left Abutment	**River Bed**		**Right Abutment**
Colluvial deposits are very thin distributing locally. Bedrock is rhythmically alternating and monoclinic. Mudstone is dominant.	Alluvial deposits cover bedrock. They consist mainly of silt of 1.5～2.0m in thickness. Terrace deposits also develop at both bank sides composed of sand and gravel with silt.		Few meters of Alluvium composed of sand and gravel with some rock bloc covers bedrock. Bedrock is same as Left Bank.
note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),			
Remarks of Dam Foundation: The overburden of Right Bank is thick, and bedrock is composed of mainly Mudstone which is not so hard enough.			
Watertightness			
Dam Site	**Reservoir**		
Permeability seems to be low due to mainly composed of argillaceous to pelitic rocks. However, in case Limestone is existing, careful consideration shall be necessary.	Basically it seems to be no problem. However, if porous Limestone exists somewhere, leakage may happen. Then their distribution shall be checked carefully.		
note: Lu; Lugeon Unit			
Stability			
Dam Site	**Reservoir**		
Basically it seems to be no problem.	Basically stable.		
Construction Material			
Earth Material: cohesive soils being sediment on the valley bottom; enough volume Rock Material: Limestone around the site Sand & Gravel Material: no suitable material			

Study Level **APD**

Existing Geotechnical Investigation:

Test Pit (P) & Trench (T): P: Nos.5

Table I2.1 Summary of Geology around and at Respective Dam (24/26)

23, *Igui N'Ouaqqa* **River Aguerd (Nokheil)** **Zone IV**

Province: Taroudant	**Cercle**: Old Berhil	**Commune**: Ida ou Gailal / Talgjount (Agoumadane)	
Topo-Map (1/50000): IGLI	**X**: 187,000	**Y**: 418,000	**Z**: 717

Physiological Condition: Located in the southern slope of Haut Atlas Occidental.

Geological Province: Southern slope of Haut Atlas Occidental

Location: 50 km NE of Taroudant

General Geology: The area of Haut Atlas Occidental is composed of Precambrian basement and Paleozoic folded in the time of Hercynian Orogeny and intruded by Granite. In the Atlantic Ocean side, Haut Atlas Occidental calcaire exist and is separated into two by Argana Triassic gorge which are generally composed of Upper Jurassic to Lower Cretaceous followed by Upper Cretaceous to Eocene.

Geological Structure: Dam site is located at the northern end of anticlinal fault. The central area of the fault has a basement of Paleozoic composed of transgressional limestone, sandstone and mudstone interbedded gypsum. Atlas Fault (WSW - ENE) is generally reverse type overthrusting dominantly to North. The contact of South Atlasic border and Cretaceous can be described as South Atlas Line orienting NE-SW and EW.

General Stratigraphy:
Paleozoic basement: Tichka Granite dome surrounded by calcareous area.
Lower Cretaceous: mudstone, marly limestone.
Turonien: dolomitic limestone bar, thin limestone and flint.
Upper Cretaceous: mainly marl, marly limestone
Maestrichian: sandstone
Pliocene to Quaternary: reddish mud and gravel, lagoonal limestone and conglomerate

Geology of Reservoir Area: Bedrock is mainly Marl interbedded with Limestone of Cretaceous which is characterized by yellowish to reddish color. Fine conglomerate, Sandstone, and Mudstone is also existing. Bedding of Cretaceous formations is dipping towards the upstream around 25°. Terrace deposits are existing widely.

Geology around Dam Site: Dam site is situated in the gorge of Limestone Bars interbedded with Marl of Cretaceous. Bedding is N75°～90°,20°～25°N dipping towards the upstream.

Geomorphology along Dam Axis: RG: 70～90 , RD: 70～90 , FD: approx. 20m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
No top soil. Composed of many type of Limestone, Marl and mudstone. Mudstone is usually layered very thin, while unit layer of Limestone and Marl is 40～100cm thickness, sometimes reaching 1～2m. Many karsts develop along bedding plane and in some layers. Rock blocs are accumulated at the foot of cliff.	Some meters of River deposits cover bedrock probably sometimes reaching to 10 m thickness. It is composed of rock blocs, sand and gravel of so many type of rocks such as quartzite, schist, or granitic.	No top soil. Bedrock is same as Left Bank. Limestone bars are dominant and karsts are also observed at many place.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Karsts are observed at many place. Moreover, 2 groups of fault (one is vertical orienting N160°～180° and parallel to water course, and another is dipping steep orienting N100°～130°) are existing and joints along them are open, some are sheared.

Watertightness

Dam Site	Reservoir
So many caves, cavities, and holes are observed due to karsts. Leakage is the most considerable in this area.	Limestone existing in Both Banks continuing from dam site may have many karsts so that leakage may probably happen.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Basically it seems to be no problem.	Basically stable.

Construction Material

Sand & Gravel Material: River deposits of Faregh river (the downstream zone of Aguerd river: 15km downstream from dam site)
Rock Material: Limestone around dam site
Earth Material: no suitable material

Study Level **APD**

Existing Geotechnical Investigation:

Drilling: Nos. 7=442.5m (Dam Site= RD 3, OD 2, RG 2)

Adit: (Right Bank 60m)

Laboratory Tests:

Drilling Cores (Specific Gravity & Absorption, Super Sonic, Form Coef., Unconfined Compression)
River deposits (Gradation, Sieve in situ, Sand Equivalent, Los Angels)

Table I2.1 Summary of Geology around and at Respective Dam (25/26)

24, *Amont Abdelmoumen*	**River Issene**		**Zone IV**
Province: Taroudant	**Cercle**: Argana		**Commune**: Argana (Aoia Tazouent)
Topo-Map (1/50000): ARGHANA	**X**: 145,400	**Y**: 427,000	**Z**: 780

Physiological Condition: Located at the upstream of Large Abdelmoumen Dam on the river forming Argana Triassic gorge orienting NE-SW in the Haut Atlas Occidental.

Geological Province: Western side of Haut Atlas Occidental	**Location**: 4 to 5 km upstream from Argana
General Geology: Triassic detritic deposits, which is continental along ancient depression area, extending along the gorge. In the right bank side, Basalt sheets are also observed.	**General Stratigraphy**: Permo-Triassic: continental deposits Basalt dyke.
Geological Structure: Dam site is located in the Arghana Triassic Gorge. The strata is monoclinic dipping towards the downstream. Some faults orienting E-W～NE-SW can be observed.	

Geology of Reservoir Area: Bedrock is almost same as dam site.

Geology around Dam Site: Bedrock is the alternation of Sandstone, Mudstone, and Conglomerate of Triassic. Sandstone and Conglomerate are medium hard, while Mudstone is relatively soft. Some joints in Conglomerate are open. Some Mudstone layers have slumping structure.

Geomorphology along Dam Axis: RG: 35～40 , RD: 30～35 , FD: approx.100m

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
No top soil. The thickness of Conglomerate is more than 5m, while unit layer of Sandstone and mudstone is 0.5～1.5m. Bedding is monoclinic (N20°E,20°W) dipping towards the downstream. Any folding cannot be observed. One very clear big fault is observed where formations are displaced more than 5m.	River deposit is relatively few and bedrock outcrops to and fro. Deposits are almost of rock blocs and cobbles. Sands and silts are very few.	No top soil. Bedrock is same as Left Bank. One fault is observed displacing formation 2～3m. Sheared zone is very small. In the lower portion of abutment, the ancient slope failure exists.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: In Conglomerate layer, some open joints are observed.

Watertightness

Dam Site	Reservoir
In Conglomerate layers, bedding planes are sometimes open, and layer itself is a little porous resulting highly permeable. To avoid leakage, the distribution of Conglomerate shall be carefully studied.	Though the Conglomerate layers in the area may be permeable, its distribution is limited in the reservoir. Then leakage from reservoir may not be so significant.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
One relatively large slope failure is observed at Right Bank. It is not so old. Its stability shall be carefully checked.	Some clear fault lineaments are observed in the area. The slope stability along these lineaments shall be carefully checked.

Construction Material

Sand & Gravel Material: River deposits; enough volume
Rock Material: Sandstone and Conglomerate around dam site; not enough strength
Earth Material: the soils distributing around the river from right to reservoir area

Study Level **Preliminaire- en cours**

Table I2.1 Summary of Geology around and at Respective Dam (26/26)

25, *Sidi Abdella* **River Ouaar (Souss)** **Zone IV**

Province: Taroudant	**Cercle**: Tamaloukt		**Commune**: Ait Iga (Ouarhenchoucht)
Topo-Map (1/50000): TAMALOUKT	**X**: 171,700	**Y**: 408,600	**Z**: 478

Physiological Condition: Located in the southern slope of Haut Atlas Occidental.

Geological Province: Southern slope of Haut Atlas Occidental	**Location**: Approx. 22 km from Ahad Imoulass Souk located on the Taroundant - Tamaloukt road
General Geology: In the central part, Schist of Cambro-ordovicien forms the basement. Around anticline, Cretaceous distribute. The strike and dip around dam site is N75° -90° (parallel to dam axis),25°～35° to the downstream.	**General Stratigraphy**: Lower Cretaceous to Turonien (Upper Cretaceous): limestone, fine conglomerate, sandstone and mudstone. Cambro-ordovicien: shale interbedded with sandstone
Geological Structure: South Atlas Fault (WSW-ENE) is reverse type overthrusting dominantly to North partly with secondal shear zone. The contact of South Atlasic border and Cretaceous can be described as South Atlas Line orienting NE-SW and EW. Cretaceous is uniformly folded and dislocated vertically by the faults orienting E-W which influences also to Paleozoic.	

Geology of Reservoir Area: Right bank slope is generally gentle, while left bank slope is steep. Cretaceous rock is extending in the reservoir area characterized red color composed of generally brittle and high erodibility of Shale, Sandstone and Fine Conglomerate, partly interbedded with Limestone Bar sometimes suffered karst erosion. Bedding is dipping towards the downstream around 30° and schistosity is N80°,30°～35°. Terrace deposits extend mainly along right bank side. River deposits are relatively few.

Geology around Dam Site: Bedrock is mainly Shale interbedded with few Sandstone layer of Paleozoic. Doleritic dyke intrudes obliquely crossing river course. Limestone and Marl of Mesozoic lye on the Paleozoic, which are very suffered by karst erosion. Bedding of Paleozoic is N30W,20E..

Geomorphology along Dam Axis: RG: 40～60 , RD: 30～90 , FD: 15m, PD: average 2.7%

note: RG; Slope Angle of Left Bank (°), RD; Slope Angle of Right Abutment (°), FD; Width of Valley Bottom, PD; Inclination of River Bed

Geology along Dam Axis

Left Abutment	River Bed	Right Abutment
Bedrock is Shale intruded by Doleritic dyke overlain by Dolomitic Limestone interbedded with red detritics (fine Conglomerate, Sandstone, and Mudstone) where thickness of unit layer is in the order of centimetric to decimetric. Limestone is sometimes suffered karst erosion.	Bedrock is covered by Alluvial deposit of few meters thickness. They are composed of rock blocs and cobbles, and sandy layers. Maximum grain size is around 1m, medium size is 20～30cm.	10～20m thickness of Talus deposits accumulate at the foot underlain by Terrace deposits where thickness is 10～15m. Bedrock is Shale partly schistose and interbedded with few Sandstone. Shale is generally very brittle and weak. Very karsit-erosioned Limestone forms right-standing cliff.

note: Ep; Thickness, Vp; Seismic Transversal Velocity in (km/sec),

Remarks of Dam Foundation: Paleozoic bedrock is generally very brittle and weak. Furthermore Mesozoic Limestone is very suffered by karst erosion.

Watertightness

Dam Site	Reservoir
Left Bank: Generally permeability is low; averagely Lu= 1～2. River Bed: Deeper than 20 m, Lu= 3～9; Shallower portion, Lu= 10～28 Right Bank: Upper abutment is composed of highly karst erosioned Limestone so that leakage may be highly considerable.	In the case karst erosioned Limestone exists in the reservoir area, leakage may be happen so that their distribution may be carefully checked.

note: Lu; Lugeon Unit

Stability

Dam Site	Reservoir
Both Banks are right-standing and Talus deposits is existing at those foot. Their stability shall be checked.	Left Bank in the reservoir area is steep. Their stability shall be checked.

Construction Material

Sand & Gravel Material: River deposits around dam site; Terrace deposits in the right bank side of dam site
Rock Material: Limestone around dam site
Earth Material: Talus deposits exists at the foot of right bank lain by Terrace deposits; many rock fragments are included and clay percentage is low
(Purchase Material): Earth Material; approx. 12 km downstream from dam site. 4 location
Sand & Gravel Material: 2 location; 1, 6km downstream from dam axis, River deposits of Ouaar river; 2, 30km from dam site, river deposits of Souss river

Study Level **APD**

Existing Geotechnical Investigation:

Drilling: Nos.8 (Downstream Site=RD3,OD2,RG3) Nos.9 (Upstream Site =RD・OD・RG each3)= 492.2m

Test Pit (P) & Trench (T): T: Nos.1 (Right Bank), P1: Nos.6 (Upstream Site; RD Nos.4, RG Nos.2), P2: Nos.15 (Borrow Area = Earth)

Laboratory Tests:

Drilling Cores (Density, Super Sonic, Form Coef., Unconfined Compression)
P2 samples (Gradation, Atterberg, Density, Compaction, Direct Shear, Odometer, Permeability)

Table I5.1 Existing Material Data for Respective Dam Construction (1/9)

1 Neckor

-Coarse Aggregate-				
Dam Axis Zone				
Alluvium				
<Granularity>				
>2mm	68.0 %			
0.08-2mm	19.3 %			
<0.08mm	12.7 %			
<Permeability>				
W_{opt}:	6.7 %			
D_{max}:	2.2 t/m^3			
k:	$1.10*10^{-3}$-$1.89*10^{-7}$cm/s			
Emprunt Zone				
Limon				
Locality	Upstream Side		Downstream Side	
<Density>				
γ :	1.61-1.78 t/m^3		1.56-1.57 t/m^3	
<Natural Water Content>				
W:	16-21 %		22-23 %	
<Granularity>				
>2mm	7-41 %		1 %	
0.08-2mm	15-22 %		2-5 %	
<0.08mm	41-74 %		94-97 %	
<Atterberg's Limit>				
W_L:	37-47 %		48-52 %	
Ip:	18-22		24-26	
<Procter Test>				
ρ d_{max}:	1.85 t/m^3		1.76 t/m^3	
W_{opt}:	15 %		20 %	
<Confined Compressive Strength>				
After Procter's Test				
TUU				
C:	0.3 MPa		- MPa	
φ:	6 °		- °	
TCD				
C':	0.0 MPa		- MPa	
φ':	11 °		- °	
TCU+U				
CCU:	0.0 MPa		0.0 MPa	
C':	0.0 MPa		0.1 MPa	
φCu:	12		17	
φ':	15		29	
β :	-		0.4	
<Compressibility and Permeability>	Upstream Side		Downstream Side	
	W_{opt}	W_{opt}+2%	W_{opt}	W_{opt}+2%
W	12-16 %	12.5-16 %	16 %	18 %
$\gamma_{(Wet)}$:	2.12-2.26 t/m^3	2.16-2.26 t/m^3	2.17 t/m^3	2.21 t/m^3
$\gamma_{(Dry)}$:	1.86-1.98 t/m^3	1.86-1.98 t/m^3	1.87 t/m^3	1.87 t/m^3
σ_c:	64-196 MPa	79-108 MPa	294 MPa	157 MPa
I_c:	0.053-0.078	0.078-0.1	0.065	0.08
σ_g:	15-118 MPa	15-118 MPa	167 MPa	34 MPa
I_g:	0.015-0.042	0.015-0.031	0.051	0.035
K:	$7*10^{-8}$-$2.10*10^{-9}$ cm/s	$2.4*10^{-7}$-$7*10^{-9}$ cm/s	$1.2\text{-}4.8*10^{-8}$ cm/s	$3.3*10^{-8}$-$6*10^{-9}$ cm/s
Cv:	$1*10^{-3}$-$2.65*10^{-4}$ cm^2/s	$1.1*10^{-3}$-$7*10^{-5}$ cm^2/s	$5\text{-}5.7*10^{-4}$ cm^2/s	$2.6\text{-}4.45*10^{-4}$ cm^2/s
<Chemical Composition>	Total	Upstream Site	Downstream Site	
$CaCO_3$	3.9 %			
$MgCO_3$	4.3 %			
Silica-Alumina	79.6 %			
$CaSO_4$, H_2O	0.2 %			
H_2O	3.6 %			
Organic Material	0.7 %	0.6 %	0.34 %	
Reliquat	0.1 %			
Oxidized Ferite	7.8 %			
Alluvium				
<Granularity>	Upstream Site	Downstream Site		
>0.08mm	4-7 %	3-6 %		
0.08-2mm	16-23 %	15-25 %		
2mm<	71-79 %	72-81 %		
<Sand Equivalnet>				
Es	28-44	37-43		
<Procter Test>				
ρ d_{max}:	2.091-2.258 t/m^3			
W_{opt}:	5.0-6.5 %			
<Direct Shearing Test>				
TEST TYPE: CNCR				
W_{opt}:	8 %			
ρ d_{max}:	2.15 t/m^3			
CU:	0.03 MPa			
φ:	44 °			

2 Tizi Mellal

-Rock Material-	
<Density>	Sandstone/Quartzite
γ :	2.6 t/m^3
<Porosity>	
n:	1.8 %
<Unconfined Compressive Strength>	
$q_{U(Dry)}$:	58.0 MPa
$q_{U(Wet)}$:	54.0 MPa
<Franklin's Test>	
Is:	7.2 MPa
<Longitudinal and Transverse Wave Velocity>	
V_l:	3750-6230 m/s
(V_l: Quartzite)	6000 m/s
Vt:	2420-3900 m/s
<Dynamic Young's Modulus>	
E_{dyn}:	64 GPa
-Fine/Coarse Aggregate-	
Alluvium	
<Granularity>	
>2mm	75< %
<2mm	<20 %
<Atterberg's Limit>	
W_L:	29-39 %
Ip:	<12
<Franklin's Test>	
Is:	4-8 MPa
<Deval Test>	
(25/50mm)	
$R_{(Dry)}$:	13.0 %
$R_{(Wet)}$:	9.0 %
<Los Angeles Test>	
R:	24 %

4 Ain Kwachiya

-Rock Material-		
	Fresh Schist	Altered Schist
<Density>		
Dry:	2.65 t/m^3	2.36 t/m^3
Wet:	2.74 t/m^3	2.72 t/m^3
<Water Content>		
w:	1.2 %	5.6 %
<Porosity>		
n:	3 %	13 %
<Unconfined Compressive Strength>		
$q_{u(Dry)}$:	6.4 Mpa	6.0 Mpa
$q_{u(Wet)}$:	0.7 Mpa	2.4 Mpa
<Direct Shearing Test>		
C':	0.2 MPa	0.0 MPa
ϕ':	23 °	41 °
<Longitudinal and Transverse Wave Velocity>		
V_l:	3679 m/s	2751 m/s
Vt:	2127 m/s	1599 m/s
<Dynamic Young's Modulus>		
E_{dyn}:	2593 GPa	2885 GPa
<Poisson's Ratio>		
ν :	0.35	0.16

Table I5.1 Existing Material Data for Respective Dam Construction (3/9)

6 Tazarane

-Rock Material-		
<Density>		
γ :	2.6	t/m^3
<Porosity>		
n:	4.0	%
<Franklin Test>		
Is: Schist	2.1	Mpa
<Unconfined Compressive Strength>		
q_U: Schist	45	MPa
-Fine/Coarse Aggregate-		
<Granularity>		
>125mm	37	%
63-125mm	10	%
>63mm	47	%
>20mm	54	%
>2mm	75	%
0.08-2mm	18	%
<0.08mm	7	%
<Atterberg's Limit>		
W_L:	30-39	%
Ip:	16	
<Deval Test>		
(25/50mm)		
$R_{(Dry)}$:	8	%
$R_{(Wet)}$:	3	%
<Los Angeles Test>		
R:	26	%

Table I5.1 Existing Material Data for Respective Dam Construction (4/9)

7 Amezmiz

-Rock Material-			
<Density>	Schist/Micro Granite		
$\gamma_{(Dry)}$:	2.7 t/m^3		
<Porosity>	Schist/Micro Granite		
n:	2.5 %		
<Unconfined Compressive Strength>	Schist	Micro Granite	
$q_{U(Dry)}$:	22.5±7.1 MPa	101.5±15.0 MPa	
$q_{U(Wet)}$:	19.9±6.6 MPa	- -	
<Longitudinal and Transverse Wave Velocity>	Schist/Micro Granite		
V_l:	3854 m/s		
Vt:	2256 m/s		
-Coarse Aggregate-			
Alluvium	Zone 1	Zone 2	Zone 3
<Granularity>			
<.08mm	1-9 %	3-10 %	1-9 %
<2mm	14-29 %	17-28 %	9-31 %
<5mm	24-40 %	25-38 %	15-38 %
>2mm	71-86 %	72-83 %	69-91 %
>63mm	18-45 %	18-40 %	30-58 %
>80mm	12-41 %	14-36 %	26-55 %
<Sand Equivalnet>			
Es:	68±13.8	67±17.7	50±17.5
<Atterberg's Limit>			
Ip	<12	<11	<14
<Rock Type>			
Schist: 5/25mm	85 %	80 %	85 %
Schist: 25/63mm	54 %	66 %	52 %
Basalt: 5/25mm	6 %	10 %	7 %
Basalt: 25/63mm	20 %	25 %	32 %
Quartzite: 5/25mm	7 %	3 %	5 %
Quartzite: 25/63mm	18 %	- %	16 %
Granodiorite: 5/25mm	2 %	7 %	3 %
Granodiorite: 25/63mm	8 %	9 %	- %
<Deval Test>			
R:Dry	6.8 %	10.0 %	16.5 %
R:Wet	3.9 %	5.2 %	5.8 %
<Los Angeles Test>			
R: 25/50mm	53 %	50 %	42 %
R: 16/31.5mm	34 %	32 %	27 %
R: 6.3/10mm	28 %	27 %	22 %
<Deval Test>			
$R_{(Dry)}$:	7 %	10 %	16 %
$R_{(Wet)}$:	4 %	5 %	6 %

10 Timkit

-Fine Aggregate-		
<Bulk Density>	Sandstone/Quartzite	
$\gamma_{(Dry)}$:	18.8	t/m^3
$\gamma_{(Wet)}$:	19.9	t/m^3
<Water Content>	Sandstone/Quartzite	
w:	6	%
<Granularity>	Sandstone/Quartzite	
>2mm	3	%
0.08-2mm	13	%
<0.08mm	84	%
<0.002mm	13	%
<Attergerg's Limit>	Sandstone/Quartzite	
W_L:	41	%
W_P:	20	%
Ip:	22	

-Coarse Aggregate-				
<Bulk Density>	Zone A		Zone B	
$\gamma_{(Dry)}$:	2.67	t/m^3	2.67	t/m^3
<Granularity>	Zone A		Zone B	
>2mm	81	%	87	%
0.08-2mm	17	%	9	%
<0.08mm	2	%	5	%
<0.002mm	0	%	1	%
<Sand Equivalnet>	Zone A		Zone B	
Es:	71		20	
<Attergerg's Limit>				
W_L:	25	%		
W_P:	18	%		
Ip:	8			
<Deval Test>				
$R_{(Dry)}$:	14.9	%		
$R_{(Wet)}$:	7.5	%		
<Los Angeles Test>				
R	24.1	%		
<Chemical Composition>				
$CaCO_3$	59.0	%		
$MgCO_3$	13.7	%		
Silica-Alumina	25.0	%		
SO_3^-	0.03-0.13	%		
NaCl	<0.02	%		
$CaSO_4$, H_2O	0.3	%		
<Alcali-Reaction>				
Dissolved Silica	68.3	mmol/l		
Reduction of Alcaline	4.9	mmol/l		

Table I5.1 Existing Material Data for Respective Dam Construction (6/9)

12 Tiouzzaguine

-Fine/Coarse Aggregate-	
Alluvium	
<Density>	
γ :	2.6 t/m^3
<Granularity>	
>20mm	52.1 %
>2mm	82.4 %
0.08-2mm	14.0 %
<0.08mm	3.6 %
0.08-0.002mm	2.6 %
<0.002mm	1.0 %
<Sand Equivalnet>	
Es	62.4
<Deval Test>	
(25/50mm)	
$R_{(Dry)}$:	22.8 %
$R_{(Wet)}$:	5.4 %
<Los Angeles Test>	
R:	24.1 %
<Alcali-Reaction>	
	No-Reaction
Terrace Deposits	
<Granularity>	
>20mm	0-51 %
>2mm	5-65 %
0.08-2mm	35-30 %
<0.08mm	5-60 %
0.08-0.002mm	4-48 %
<0.002mm	1-12 %
<Atterberg's Limit>	
Ip	NP, 7.9
<Sand Equivalnet>	
Es	7.7, 58.7

14 Adarouch

-Rock Material-			
<Density>	Fine Sandstone	Pelite and Schist	Conglomerate
γ :	2.6 t/m^3	2.6 t/m^3	2.6 t/m^3
<Longitudinal and Transverse Wave Velocity>	Fine Sandstone	Pelite and Schist	Conglomerate
V_l:	4026 m/s	3559 m/s	2857 m/s
Vt:	2776 m/s	2254 m/s	2254 m/s
<Unconfined Compressive Strength>	Fine Sandstone	Pelite and Schist	Conglomerate
$q_{U:}$	47.0 MPa	22.9 MPa	9.9 MPa
<Residual Cohesion>			
Cr	0.03 MPa	0.00 MPa	-
<Residual Friction Angle>			
φr	25.5 °	22.8 °	-
<Cohesion>			
C	0.08 MPa	0.04 MPa	-
<Residual Friction Angle>			
φ	23.8 °	23.8 °	-

Table I5.1 Existing Material Data for Respective Dam Construction (7/9)

19 Aoulai

-Rock Material-						
<Franklin Test>	Sandstone	Pelite	Schist	Limestone	Granite	Quartzite
Is:	3.5 Mpa	3.0 Mpa	3.0 Mpa	2.2 Mpa	4.4 Mpa	7.5 Mpa
-Fine/Coarse Aggregate-						
Alluvium						
<Granularity>						
>20mm	#### %					
<5mm	#### %					
>2mm	#### %					
0.08-2mm	#### %					
<0.08mm	8.0 %					
<Atterberg's Limit>						
W_L:	#### %					
W_P:	#### %					
Ip:	####					
<Sand Equivalnet>						
Es:	####					
<Deval Test>						
$R_{(Dry)}$:	7.8 %					
$R_{(Wet)}$:	2.9 %					
<Los Angeles Test>						
R:	#### %					
<Alcali-Reaction>						
	No-Reaction					

Table I5.1 Existing Material Data for Respective Dam Construction (8/9)

23 Igui N'Ouaqqa

-Rock Material-				
	Unit A'	Unit A	Unit B	Gypsum
	Calcareous Sandstone with Marl	Limestone Bar	Sandstone with Argilite and Marl	
<Density>				
γ :	2.3 t/m^3	2.4 t/m^3	2.3 t/m^3	2 t/m^3
<Porosity>				
n:	20.0 %	11.3 %	18.5 %	13 %
<Unconfined Compressive Strength>				
$q_{U(Dry)}$:	10.7 MPa	22.5 MPa	30.0 MPa	18.8 MPa
$E_{(Dry)}$:	10.0 GPa	26.5 GPa	15.0 GPa	19.0 GPa
$q_{U(Wet)}$:	-	17.6 MPa	-	10.3 MPa
$E_{(Dry)}$:	-	29.0 GPa	-	13.5 Gpa
<Longitudinal and Transverse Wave Velocity>				
$V_{l(Dry)}$:	3581 m/s	4383 m/s	4714 m/s	4,560 m/s
$Vt_{(Dry)}$:	2483 m/s	2398 m/s	2750 m/s	2,933 m/s
$V_{l(Wet)}$:	-	3976 m/s	-	4,161 m/s
$Vt_{(Wet)}$:	-	2308 m/s	-	2,525 m/s
<Dynamic Young's Modulus>				
$E_{dyn(Dry)}$:	28 GPa	47 GPa	42 GPa	39 GPa
$E_{dyn(wet)}$:		46 GPa		33 GPa

-Coarse Aggregate-	
Oued Faregh	
<Granularity>	
>63mm	19 %
>20mm	48 %
>2mm	73 %
<80 μm	5 %
<Sand Equivalnet>	
Es:	66
<Micoro-Deval Test>	
$R_{(Wet)}$:	13 %
<Los Angeles Test>	
R	17 %
Oued Souss	
<Granularity>	
Sand: 5/16mm	40±11 %
Gravel: 5/16mm	12±3.7 %
Gravel: 16/25mm	10±2.8 %
Gravel: 25/63mm	25±5.3 %
Gravel: >80mm	9±4.2 %
<Micoro-Deval Test>	
$R_{(Wet)}$:	7 %
<Los Angeles Test>	
R	15 %

Table I5.1 Existing Material Data for Respective Dam Construction (9/9)

25 Sidi Abdellah

-Rock Material-				
<Density>				
$\gamma_{(Dry)}$:	2.59±0.07 t/m^3			
<Porosity>				
n:	3.8±2.65 %			
<Longitudinal/Transverse Wave Velocity>				
V_l:	3181-5355 m/s			
Vt:	2122-3385 m/s			
<Unconfined Compressive Strength>	Limestone		Sandstone	
$q_{U(Dry)}$:	30±13 MPa		32±17 MPa	
$q_{U(Wet)}$:	31±5 MPa		26±2 MPa	
-Aggregate-				
	Terrace, Right Bank		Talus, Right Bank	
	(Finer)	(Coaser)	(Finer)	(Coaser)
<Natural Water Content>				
W:	3 %	3.3 %	15.1 %	1.7 %
<Bulk Density>				
$\gamma_{(Dry)}$:	1.57 t/m^3	- t/m^3	1.76 t/m^3	- t/m^3
$\gamma_{(Wet)}$:	1.52 t/m^3	- t/m^3	2.02 t/m^3	- t/m^3
<Granularity>				
>20mm:	1 %	68 %	1 %	4 %
>2mm:	10 %	90 %	5 %	64 %
<0.08mm:	49 %	4 %	87 %	21 %
<Atterberg's Limit>				
W_L:	- %	(23) %	33 %	23 %
Ip:	N.P.	N.P., 8	17	10
-Fine Aggregate-				
<Direct Shearing Test>				
C':	20.1 kPa			
ϕ':	24.8 °			
<Proctor Test>				
$\gamma_{d\ max}$:	1.93 t/m^3			
W_{opt}:	12.0 %			
<Oedometric Test>				
lg:	0.006			
lc:	0.069			
c:	1.5			
g:	1.70 Pa			
<Permeability Test>				
k:	6.1*10^{-7}-8.2*10^{-9} cm/s			
	Zone 1	Zone 2	Zone 3	Zone 4
<Natural Water Content>				
W:	5.2 %	6.0 %	5.1 %	5.9 %
<Bulk Density>				
γ :	1.64 t/m^3	1.60 t/m^3	1.72 t/m^3	1.81 t/m^3
<Granularity>				
>20mm:	17 %	5 %	0 %	0 %
>2mm:	26 %	16 %	10 %	7 %
<0.08mm:	43 %	57 %	54 %	55 %
<Atterberg's Limit>				
W_L:	(24.0) %	34.5 %	22.5 %	22.0 %
Ip:	(9.4)	9.3	8.5	8.3